UK Pesticides Policy –
A policy paradigm in transition?

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Declaration

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Abstract

This research has established that a dominant 'pesticide policy paradigm' emerged in the UK in the mid 20th century which is now challenged and under pressure. The research proposes that another 'ecological pest management paradigm' appears to be emerging, but its development is held back by under-investment and powerful commitments to the current pesticide policy paradigm.

In the main, pesticides are researched and studied within the confines of natural science. The cross disciplinary nature of the present research has involved a wider analysis of pesticide policy from a scientific, social and political perspective. Pesticide policy and practice has been analysed using existing research data, grey literature and semi-structured interviews with 47 senior pesticide policy stakeholders from across the food and agrichemical sectors. The interviews were conducted to test the theoretical framework proposed.

After the Second World War significant crop yield increases were achieved, partly through the intensive use of synthetic pesticides, as an established part of conventional agriculture. Although successful at controlling pests, synthetic pesticides have also had unintended side effects on human health and the environment, which are reviewed. In response to rising evidence of harm, critical stakeholders have asserted the primacy of protecting human health and the environment.

The research identified 'productive stakeholders' who are locked into the technology, and 'critical stakeholders' with fundamental concerns about the need for pesticides, who champion a more precautionary approach. The interviews suggest 'societal failure' for pesticides, which is not dispelled by government and productive stakeholder assurances.

Biologically based alternatives are emerging as one response to the unintentional side effects of synthetic pesticides. However these bio-pesticide products are considered under the same regulatory requirements as synthetic pesticides. Thus, the high cost of regulatory development is impeding their development, and though widely considered safer than synthetic pesticides, this is currently difficult to prove. Bio-pesticides are thus subsumed in the same paradigm as synthetic pesticides, where as they could be seen as part of a more sustainable and holistic ecological pest management paradigm.

Abbreviations

ACP	Advisory Committee on Pesticides
ADAS	Agricultural Development and Advisory Service
AFS	Assured Food Standards
AI	Active ingredient (pesticide)
APS	Assured Produce Scheme
BAA	British Agrochemicals Association (for runner of the CPA)
BASF	German pesticide manufacturer
BASIS	British Agrochemical Supply Industry Scheme
BCA	Bio-control agent
BMA	British Medical Association
BP	Bio-pesticides
BSE	Bovine spongiform encephalopathy
CAP	Common Agricultural Policy (EU)
CFS/ME	Chronic Fatigue Syndrome/Myalgic Encephalomylelitis
COPR	Control of Pesticide Regulations
CPA	Crop Protection Association
DDE	Dichlorodiphenylethane (breakdown product of DDT)
DDT	Dichlorodiphenyltrichloroethane (pesticide)
DEFRA	Department for Environment, Food and Rural Affairs
DETR	Department of Environment, Transport and the Regions
DG SANCO	European Commission, Directorate for Health and Consumer Affairs
EA	Environment Agency
ECPA	European Crop Protection Agency
EEC	European Economic Community
EFSA	European Food Safety Agency
EU	European Union
EUREP GAP	European Retailers Good Agricultural Practice
FEPA	Food and Environmental Protection Act (1985)
FMD	Foot and Mouth Disease
FSA	Food Standards Agency
GATT	General Agreements of Tariffs and Trade
GMB	General and Municipal Boilermakers Union
HSE	Health and Safety Executive
IBMA	International Biocontrol Manufacturer Association
ICI	Imperial Chemical Industries (former pesticide manufacturer, now part of Syngenta)
IARC	International Agency for Research on Cancer
ICM	Integrated Crop Management
IFM	Integrated Farm Management
IPM	Integrated Pest Management
KEMI	Swedish Chemicals Inspectorate
LEAF	Linking Environment and Farming
M&S	Marks and Spencer
MEP	Member of the European Parliament

MP	Member of Parliament
MPL	Maximum Permissible Level
MAF	Ministry of Agriculture and Fisheries (UK Ministry until 1951)
MAFF	Ministry of Agriculture, Fisheries and Food (UK Ministry from 1951 to 2000)
MRL	Maximum Residue Limit (of pesticide residues in food)
NCC	Nature Conservancy Council
NFU	National Farmers Union
NGO	Non-Governmental Organisation
NHL	Non-Hodgkin's lymphoma
NPS	National Pesticides Scheme
OECD	Organisation for Economic Co-operation and Development
OED	Oxford English Dictionary
OP	Organophosphate (pesticide group)
PAN	Pesticide Action Network
PIAP	Pesticide Incidents Appraisal Panel
Ppb	Parts per billion
Ppp	Plant protection product (EU technical name for pesticide active ingredients under Directive 91/414
PRC	Pesticide Residues Committee
PSD	Pesticide Safety Directorate
PSPS	Pesticide Safety Precaution Scheme
PURE	Pesticide Use Reduction Policy in Europe
RCEP	Royal Commission on Environmental Pollution
REACH	EU Registration, Evaluation and Authorisation of Chemicals
RSPB	Royal Society for the Protection of Birds
SAIF	Safer Alternatives Innovation Forum
SSC	Scientific Sub Committee (of the ACP)
TGWU	Transport and General Workers Union
UKASTA	UK Agricultural Supply Trades Association
UNISON	Public Service Union
VI	Voluntary Initiative
VPC	Veterinary Products Committee
WHO	World Health Organisation
WTO	World Trade Organisation
WWF	World Wide Fund for Nature

1. Introduction

Albert Einstein was once asked why it was more difficult to make an agreement not to use the atomic bomb than it was to make the bomb itself. He said: 'The answer is simple – politics is more difficult than physics' (Charlesworth, 1970: 146).

1.1. The research problem

This chapter introduces the thesis for the present research which examines the developments of practice and policy in the field of agricultural pest control and the use of pesticides in the UK. It sets out the problems that have been researched. The Chapter contains an overview of the research topic and a summary of the content and context of each of the subsequent chapters.

Modern synthetic pesticides were developed in the years during and following world war two in response to heightened threats to food security and for the maintenance of both military and civilian public health. These new chemicals were attractive to farmers because they were more effective than any other measures at reducing crop losses caused by pests and diseases. Thousands of pesticide products subsequently emerged to control the wide range of agricultural pests – especially insects, weeds, fungi and rodents[1]. Fossil-fuel based synthetic inputs, such as pesticides and fertilisers, were an important part of conventional intensive agriculture that made farming increasingly profitable. A strong link developed between the selection of high-yielding crop varieties and the rapid increase in the implementation and use of pesticides in conventional agriculture (Rosenzweig et al., 2000).

The UK food chain became dependent on a pesticides industry that oversaw the development, supply and distribution network for pesticides. This industry was dominated by multi-national UK, European and US based chemical companies. The pesticide market increased dramatically from 1945 onwards and by 2007, global sales stood at US$ 33,390 million (Crop Life, 2008). Today pesticides represent the dominant method of pest management. In the decades after 1945 crop yields increased in line with increasing dependence on pesticides, assisted first by the UK government and later by the European

1. A more detailed definition and explanation of the term 'pesticide' is given in the historical analysis of pesticides in Chapter Four.

Union based production subsidies. As the pesticide market grew so did the interdependent network of actors developing, supplying, using and regulating pesticides.

The food supply chain has become heavily reliant on pesticides as an integral part of intensive agriculture. The defence of this process, defending the use of pesticides per se, has become a very important part of defending conventional agriculture and the food supply chain. Without the one, you cannot have the other.

The widespread use of pesticides increased crop yields, but also produced side effects. The following section outlines some key examples of adverse affects on human health, wildlife and the environment.

Adverse effects on human health have been studied. At the global level, a number of international reports have estimated the acute poisoning effects of pesticides globally (WHO, 1990, ILO, 2005). Many serious cases have occurred in developing countries, although exact figures are not known. One estimate calculated that 25 million developing country agricultural workers are poisoned each year (Jeyaratnum, 1990). One group of problematic pesticides described by Kamanyire and Karalliedde (2003: 69) as "the ubiquitous organophosphates" provide what they consider "a continuing health hazard in agriculture".

The acute effects of pesticides are also apparent in countries such as the US and the UK, and pesticide poisoning is acknowledged as being commonly under-reported (Alarcon et al., 2005).

A range of studies have shown a link between chronic exposure to pesticides and adverse human health effects (Alavanja et al., 2004, Colborn, 2004, Alarcon et al., 2005, Alavanja and Bonner, 2005, Colosio et al., 2005, Acerini and Hughes, 2006, Colborn, 2006, Provost, 2007, Dick et al., 2007). Alavanja et al. (2004: 179), who have reviewed epidemiological data, conclude: "evidence clearly suggests that at current exposures pesticides adversely affect human health." Furthermore, Dick et al. (2007) have found evidence of an increased risk of Parkinson's disease after exposure to pesticides . The International Agency for the Research on Cancer (IARC) concluded that non-arsenical insecticides are probably carcinogenic to humans, based on its assessment of limited data largely from epidemiological studies (IARC, 1991). There are problems that have emerged in recent years such as endocrine disrupting chemicals of which some pesticides are implicated in adverse effects on humans and wildlife (Colborn, 2006).

Pesticides are deliberately released into the environment and can have widespread impacts on wildlife (Fournier-Chambrillon et al., 2004, Brakes and Smith, 2005, Berny, 2007, Devine and Furlong, 2007) and cause environmental pollution (Tiktak et al., 2004, Fox et al., 2007). Pesticide residues in UK (and EU) drinking water have to be removed through expensive filtration techniques. Residues are regularly found in food. Figures vary, but a recent UK report showed that about 30% of food consumed in the UK contains detectable residues and about 1% is above the maximum residue level (PRC, 2007).

Whilst there is scientific evidence that pesticides do cause harm, there are also concerns about uncertainties in assessing the problem posed by pesticides. For example, Alavanja and Bonner (2005: 700) have recently stated: "The potential for human carcinogenicity of almost all pesticides currently on the market has been poorly evaluated and is inadequately understood". Similarly the problems of assessing the impacts of pesticides on wildlife has been outlined by Colborn (2006: 10): "It is impossible to determine the cumulative risk posed to wildlife and humans as the result of releasing vast amounts of pesticide mixtures into the environment." The difficulties are underlined by a veterinary toxicologist: "Pesticides are used under very different circumstances, on diverse crops and under variable climatic conditions. It is therefore impossible to foresee all the different circumstances and to calculate the risk for wildlife species during pre-market approval of a product" (Berny, 2007: 94).

In recent years there has been recognition by regulators that there are areas of risk analysis for pesticides that are problematic. There are no international agreed methods to establish whether pesticides are endocrine distruptors. There remain uncertainties around the effects of mixtures of pesticides (and other chemicals) and the implications for such exposure. In 1999 the chairman of the UK Pesticide Residue Committee considered that "little is known about the toxicological interactions between pesticides" and recognised that there is consumer concern about this issue (Committee on Toxicity, 2002: 11). In particular there is concern about the synergistic[2] effects of pesticides. For example, one study has shown that exposure to two pesticide formulations may lead to synergistic neurotoxicity after in vitro study (Axelrad et al., 2002).

The risks posed by pesticides are difficult to quantify: only a small community of industry/government/academic experts understand the mechanisms of pesticide risk

2. A synergistic effect occurs when the toxic effect of two or more substances exceeds the additive effect of the combined substances.

assessment. Their technocratic model of policy making has failed to convince civil society, and some parts of the food supply chain, notably multiple food retailers. This is because the UK has resisted following a pesticide risk analysis process which would include the social, political and cultural contexts of policy making. The technocratic model has been challenged by civil society groups for many years. In the last few years, it has also been challenged by the Royal Commission on Environmental Pollution (RCEP) and some members of the expert Advisory Committee on Pesticides (ACP). The reason the risks of pesticides are being questioned is because of evidence of adverse effects, uncertainty with the science, and also because of the failure of pesticide safety data to meet the increasingly tough regulatory requirements. Another, unrecognised reason is that the key players in the pesticide policy process (government and industry) are failing to tackle the social science issues raised by pesticide use.

The problems caused by pesticides have required a complicated set of responses that have developed over the last seven decades. The following section introduces three perspectives – historical, regulation and governance – from which to examine these changes. There is widespread recognition that pesticides have the potential to cause adverse health and environmental effects (DEFRA/HSE, 2005: 4).

The adverse effects caused by pesticides was brought to the fore and publicised by US scientist Rachel Carson in the early 1960s in her book *Silent Spring* (Carson, 1962). This publication, heavily criticised by the pesticide industry at the time, provided the spur for civil society to pressure governments in the UK and elsewhere to adapt and provide assurances of safety. Yet there is continuing concern about the use of pesticides. A complicated array of concurrent and parallel concerns about the health and environmental effects of pesticides have since the 1950s led to increasingly sceptical views from civil society which have not been reassured by government and food supply chain advocates of pesticide use within conventional agriculture. This has produced a challenge from concerned individuals, scientists, consumer and environmental public interests non-governmental organisations (NGOs) to question the continued use of pesticides.

The response from the UK regulatory to the problems presented by pesticides has been marginally to increase the controls (through regulation) over their use. There are a numbers of ways in which this can be done: pre-market testing and approval, controls during use, monitoring effects which required more data collection from government and the pesticide industry.

Pesticide legislation at the UK and European Union levels have resulted in a decline in the availability of pesticides, that is the number of pesticide authorised for use. In 1993 there were 984 pesticide active ingredients authorised for use in the EU. By 2008 this figure has reduced to 629, a decline of 57% (Nomisma, 2008). Some of this reduction was due to the deletion of obsolete pesticides and some of it was due to removal of pesticides hazardous to human health and the environment. The number of pesticides withdrawn from the pesticide market is greater than the number of new pesticides coming on to the market. The cost of pesticide regulation has increased over the years so much that there are only few crops in the world that can return the expenditure on their research and development.

If this trend continues, eventually there will not be enough pesticides to support the pest management requirements for conventional agriculture in the UK. There are a number of potential responses to this problem. In general terms this has resulted in an evolutionary response in which conventional agriculture continues, and new pesticides replace the obsolete, discarded pesticides, or there are continually extended derogations allowing continued authorisation for the pesticides that remain on the market. There are differences in the way in which food supply chain actors are responding to this problem. Some multiple food retailers, who are also influenced by their customer concerns, have adopted their own progressive company-wide pesticide policies. Previously this responsibility would have been a prerogative of government.

There are a number of responses to the problems posed by synthetic pesticides. One is the development of genetic modification (GM) technology as a replacement for pesticides, as advocated by the pesticide industry. This has not been studied in any detail because it is beyond the scope of the present research. This research is primarily UK-focussed. Currently, there is a virtual a moratorium on GM research in the UK, amidst strong opposition from civil society and multiple food retailers.

The present research evaluates the development and regulation of bio-pesticides[3] in terms of two different approaches.

The first approach involves bio-pesticides as a direct replacement for synthetic pesticides within conventional agriculture. Bio-pesticides represent a wide range of biological based

3. The term 'bio-pesticide' is a generic term to describe biologically based pest control products, derived from or consisting of living organisms. Four sub-groups include: 1) Plant-based chemicals such as garlic and mint oils; 2) Semio-chemicals such as pheromones; 3) Microbials such as viruses and bacteria and fungi; 4) Invertebrate bio-controls such as nematodes and insects. The term 'bio-pesticide' which is defined in UK and EU law excludes the 4th Bio-control agent group.

chemicals and species that are used in agricultural systems to control pesticides. A widely held assumption within the stakeholder groups (supported by the present research) is that these alternatives are safer and more sustainable; but is this true? There are fewer scientific data on the bio-pesticides, although the majority have to go through the same regulatory approval process as synthetic pesticides. This process has developed over decades and has been complicated by an expensive safety regime in order to support pesticide use. This is proving a barrier to the development of bio-pesticides registration in the UK.

In the second approach, bio-pesticides can be used in all types of agriculture including conventional and organic. They could be part of a fundamentally different way of securing pest management within agricultural systems, along with non-chemical methods of pest control. Here control can be attained through crop husbandry, rotation or variety choice in a whole farm approach.

1.2. Chapter summaries

The following section summarises the contents of each of the subsequent chapters of the thesis from Chapters Two to Nine. This includes the literature reviews and analysis, development of a conceptual framework, research methods, analysis of the data collected and concluding discussion.

Chapter Two: Conceptual framework for the research – Paradigms in transition: pesticide to ecological pest management?

In this chapter, starting assumptions for the research are presented through the formation of a conceptual analytical framework for pesticide policy. It establishes the concept of a pesticide policy paradigm in terms of use and policy. The argument is presented that the dominant and mature pesticide paradigm is under threat, but the emergence of an ecological paradigm is fraught with uncertainty.

Chapter Three: Methodological approaches to the research

This Chapter introduces the methodological approaches for the present research. It explains that Chapters three to six examine the development of synthetic pesticides, evidence of adverse effects, and responses to those threats. The chapters provide more than a review of the literature. Data that is analysed and form the basis of the development of a theory for pesticide use. Following chapters presented the findings and analysis of semi-structured stakeholder interviews. This data was triangulated with other relevant documentation and literature. The chapter covers a review of the aims of the study and the research for data collection through interviews with key pesticide stakeholders.

Chapter Four: Historical context: The emergence of the pesticide policy paradigm

This chapter surveys the historical development of modern synthetic pesticides as an integral part of post Second World War intensive agriculture. It is important to examine why synthetic pesticides developed as they did. This chapter describes the chronology of pesticide use and regulation in the UK, acknowledging the increased role of the European Union, and also introduces the conceptual model which the present research is calling a 'pesticide policy paradigm' in which stakeholders developing pesticides did so within the framework of a common set of beliefs. The model is reviewed and developed in more detail in Chapter seven.

Chapter Five: Scientific evidence of adverse effects of pesticides

This chapter identifies the unintentional side effects of the widespread use of modern synthetic pesticides. The evidence is presented in three main sections: the routes of pesticide exposure, human contamination (acute and chronic) and non-target environmental contamination. Four themes have emerged that increase pressure on the use of pesticides. These are: variability, ubiquity, uncertainty and increased risks associated with pesticides.

Chapter Six: Response to the threats posed by pesticides

This chapter reviews a number of responses to the threats posed by pesticides. It discusses a body of criticism which focuses on the health and environmental effects of pesticides, including the emergence of an environmental movement, a regular flow of official independent reports, consensus statements from academic health and environmental professionals, and developments in some elements of the food supply chain.

This criticism has led primarily to the introduction of pesticide legislation which has become more stringent in recent years, and has led to a sharp increase in the time and expense of developing new pesticides for regulatory approval. It has also led to another emerging response to synthetic pesticides. This includes the development of biologically based products as alternatives to pesticides. The chapter explores whether and how these developments can be linked to a wider, farming systems approach, including research for safer alternatives, safer pest management through comparative assessment, and emerging pesticide policy initiatives.

Chapter Seven: Contemporary stakeholders – key actors and relationships

This chapter explores the roles and dynamics of the pesticide debate, and establishes that there are a number of contested views held by the key pesticides stakeholder groups and their policies for the UK. It concludes that there has been a shift from the 'government' to the 'governance' of pesticides through increased enforcement measures from the private sector on the food supply chain.

Chapter Eight: Findings from stakeholder interviews

This chapter presents the results of the interviews carried out with 47 stakeholders. The first section covers the risk analysis processes for pesticides, focussing on the precautionary principle. This allows for uncertainty and social considerations to be included in the pesticide debate. The second section describes the concerns raised by those stakeholders who challenge the pesticide policy paradigm. The third section presents comments about the introduction, development and use of biologically derived alternatives to synthetic pesticides. In particular, there is a detailed examination of the regulatory barriers which restrict bio-pesticides because the legal process treats them in the same way as synthetic pesticide. It compares bio-pesticides with synthetic pesticides and illuminates the difficulties of fitting bio-pesticides into the pesticide regulatory process. This chapter argues that the development of bio-pesticides represents a technical response within intensive agricultural systems, rather than being part of an agricultural philosophy. It also covers the technical, practical and economic obstacles in developing an 'ecological pest management paradigm' and what part bio-pesticides might play in this development. Such a holistic approach would include a process that delivered a range of safer pest management options.

Chapter Nine: Discussion and Conclusions

This chapter forms the final section of the dissertation. It draws on all the other chapters to discuss the research findings in terms of the conceptual framework for the research. It provides answers to the research questions. The present research confirms that the pesticide policy paradigm is under significant pressure. An ecological paradigm is emerging but is being subsumed by the dominant paradigm.

2. Conceptual framework for the present research – Paradigms in transition: pesticide to ecological pest management?

2.1. *Introduction*

This chapter presents the outline for a conceptual framework covering the assessment of pesticide policy for the UK. Such a framework provides a path for the research process which is based on a review of the literature coupled with an assessment of the implications for pesticide policy and the proposition of a theoretical model. This chapter outlines the key starting assumptions for the conceptual framework that structures the subsequent collection and analysis of relevant data.

The first section comprises a literature review of 'paradigms', 'risk analysis' and 'policy networks', all of which are connected to the roles that human activities play within the technological developments of pesticides and pest management. In the second section, a conceptual framework for the research is constructed that draws on the literature and the pre-theoretical pesticide developments presented in Chapter One.

Pesticide use has created problems that can be analysed drawing on models and concepts that are appropriate for the present research. 'Paradigm' is a term that has been used to describe an underlying set of beliefs, from which an area of knowledge is developed. For the present research, the concept of a paradigm is used to represent an underlying belief which has emerged and developed, since world war two, that pesticides are vital for conventional agriculture. This generalised view continues to be supported by an integrated community of 'productive stakeholders' along the food supply chain. This fundamental belief or paradigm view is underpinned by a raft of regulatory and policy initiatives designed to support the continued use of pesticides.

Presently, a dominant 'paradigm' for pesticides is defined and linked to a 'policy network' of stakeholders with a range of different interests, some of which raised fundamental questions about the continued use of pesticides. The present research is calling this a 'pesticide policy paradigm'[4].

4. A more complete definition of a 'pesticide policy paradigm' is presented on Vol. 1, page 60.

A 'paradigm shift' can occur after anomalies have arisen and the policies that support a dominant paradigm have been challenged by a competing paradigm. For pesticides, anomalies cause 'pressure on the paradigm' which can for example arise from the discovery of adverse health and/or environmental impacts of pesticide use. One alternative prospect involves a switch to biologically-based bio-pesticides. The present research examines to what extent these solutions could represent an emerging and contesting paradigm called the 'ecological pest management paradigm', in which the fundamental utility of pesticides is questioned.

The potential problems posed by pesticides are estimated and evaluated through a process of risk analysis. Risk analysis provides an important tool for the stakeholders within a network to defend or challenge a current paradigm, such as that surrounding the use of pesticides.

This chapter reviews the ways in which risk analysis is carried out for pesticides, which takes place through regulatory processes at both the UK and (emerging) EU levels. The chapter acknowledges that there are pressures on the dominant paradigm, for example due to uncertainties in science that are failing to accommodate increasing regulatory demands. The chapter also reviews some risk analysis models that focus on the social, political and economic forces that govern pesticide use. In addition attempts to incorporate these factors into a scientifically dominated process are discussed in terms of the science policy debate.

The governance process for pesticides accepts, in effect, that there are established patterns of rule without an overall ruler. The governance theory of 'policy networks' provides a useful way of examining how pesticides are governed. The manner in which the UK pesticide policy network integrates with the European Union framework is assessed in terms of the concept of multi-level governance, which is a reflection of the complicated structures and competing forces that have developed in recent years. Finally this chapter draws on the concepts reviewed and presents a framework of ideas for the present research. This includes a series of interconnected Tables (2.1-2.5) that summarise the key concepts drawn out within this chapter. They include existing models with their relevance and limitations, combined with the starting assumptions for the present research.

2.1.1. Paradigms

This section reviews the literature on the concept of 'paradigms' and explains the analogous links with pesticide policy and the present research. The various paradigm models and interpretations are reviewed for their relevance and limitations for pesticide policy which results (at the end of the chapter) in the starting assumptions for a paradigm for pesticides within the present research.

The original definition of a paradigm refers to a 'standard reference' or 'model'. A more refined version of the term is defined as a 'scientific paradigm' which was coined by the philosopher of science Thomas Kuhn. He used it to describe how scientists make socially constructed framing assumptions when developing a body of knowledge (Kuhn, 1970). His definition of a 'scientific paradigm' described how scientific communities work within accepted, even unquestioned, ways of defining and assigning categories, framing theories and procedures within disciplines and during particular historical periods.

Within Kuhn's paradigm theory it was important to define what is to be observed and scrutinised; what kind of questions are to be asked, how they are structured, and how the results are interpreted. Within the paradigm there is a set of experiments that are expected to be copied and repeated. Kuhn called this 'normal science'. From this it can be inferred that the aims and conclusions of scientific endeavour can be subjective in their nature.

Kuhn's concept is useful for the present research because pesticides have been produced in standard ways that conform to a set of experiments that are copied and repeated. But there are comparative limitations because a scientific paradigm emerges from a scientific community and for the present research, a paradigm is much richer. A link can nevertheless be made between Kuhn's scientific community and the scientifically-based pesticide community (academic, governmental, and private)[5] that developed in the UK from the 1940s onwards. Here the mode of 'pest management' is a paradigm which includes not just a set of common beliefs but also the relationships between institutions, practices, governments, companies and markets.

Other researchers have drawn on Kuhn's work. Dosi (1982) defined "a 'technological paradigm' as a 'model' and a 'pattern' of solution of *selected* technological problems, based on *selected* principles derived from natural sciences and on selected material technologies." Dosi makes a link between scientific research, and the technological advancements that are progressed over a period of time through a process of problem-solving activity. For his technological paradigm a historical perspective is important as key elements cover the direction of change and what technological paths are followed.

5. The community that developed synthetic pesticides is explained in more detail in Chapter Four.

Dosi defined a paradigm in generalised terms, and its impact has been broad, covering the academic literatures of economics, management, history and sociology (von Tunzelmann et al., 2008). For Kuhn, the scientific paradigm defines the area of activity, and for Dosi 'technological clusters' (such as nuclear and semi-conductor technologies) define the technological paradigm. Dosi (1982) adapted Kuhn's paradigm to incorporate technological development and introduced the term 'technological trajectory' to indicate the strong influence that was required on the directions of technological change. In other words, paradigms place severe constraints on the future directions of technological development (von Tunzelmann et al., 2008). Technological trajectories result from 'generic needs' such as "producing chemical compounds with certain properties" (Dosi, 1982: 152). Here a direct link can be made with pesticides which can be included as a sub-set of this group – that is, chemicals that are discovered and produced with the toxic properties to kill a designated pest (or pests)[6]. Pesticides are produced with this key requirement in mind, with the added and problematic proviso of being benign towards everything else (non-target organisms [including humans] and the wider environment). For the present research, both these factors place severe constraints on the direction of any 'pesticide technological trajectory'. If the former requirement (producing efficacious chemicals) occurs at the expense of the latter requirement (negative side effects) the trajectory may follow an unsustainable path. For the present research, a paradigm has to follow the efficacy and safety [reducing negative side effects] requirements of a generalised pesticide technological trajectory.

Some researchers have used the concepts 'technological paradigm' and 'technological trajectories' specifically in relation to pesticides (Hartnell, 1996, den Hond, 1998, Joly and Lemarié, 2002, Chataway et al., 2004, Tait et al., 2000)[7]. Those authors focussed largely on the agrichemical industry's discovery, development, and marketing of pesticides as solutions to various pest problems within in the conventional agricultural sector.

From the Second World War to the present day, agricultural pest problems have largely been tackled by the market-led demand for relevant synthetic chemistry. According to Hartnell (1996), the development of resistance to specific pesticide products and competitive pressures within the pesticide industry, has led to high levels of expenditure on

6. The term 'pest' includes a wide number of organisms including amongst others, insects, weeds, fungi. See Glossary Vol. 2, page 106 for a more detailed definition.
7. These authors also referred to the term 'agrochemicals' and 'crop protection chemicals' when in fact they were referring to 'pesticides' as defined by the present research. See Glossary page for a more detailed definition.

research and development to market new products. But the development and use of chemical pesticides has, over time, created its own unintended non-target adverse side effects. As Joly and Lemarié (2002: 259) state: "a consensus has emerged on the need to reduce the negative impact of conventional agriculture (high input, high yield) on the environment". Joly and Lemarié (2002) also observed that there is both change and continuity within the pesticide industry. They use the concept of 'technological trajectory' to describe a 'normal' way of solving pesticide problems within the pesticide industry. In order to accommodate these adverse effects, Joly and Lemarié (2002) consider that the pesticide industry has evolved from a 'plant protection' trajectory to an emergent 'crop protection' trajectory. These two terms are used to denote a change for the pesticide industry from a chemical focus to crop focus for pest management. Although this represents constant flux, responding to the adverse effects of pesticides, the change has occurred within 'normal' practice.

Den Hond (1998) studied 'search heuristics' that agrichemical companies follow for pesticide discovery, as products have to be registered prior to marketing. Tait et al. (2000) focussed on the drivers that influence innovation within agrichemical companies by examining the direction and strength of new technological trajectories. These are influenced by the companies themselves, the nature and direction of the regulatory regime, the breadth and depth of company knowledge and commercial considerations such as pesticide product patent protection.

The above articles (Hartnell, 1996, den Hond, 1998, Joly and Lemarié, 2002, Chataway et al., 2004, Tait et al., 2000) describe what could be considered as a 'pesticide technological paradigm'. But they have largely focussed their investigation on the needs and perspectives of the agrichemical industry. Furthermore Chataway et al. (2004) have shown the limitations of some views from the agrochemical industry sector. These researchers have suggested that managers have 'blind spots' with regard to politics and policy and the interplay between the two, which are to some extent reflected in conceptualisations of technical change. Chataway et al. (2004: 1056) concluded that agrichemical company managers "...did not fully recognise the relationship between R&D decisions and policy environments and often seem to be acting in ways that had negative impact on the firms themselves and had dramatic unintended consequences on the rate and direction of innovation in the sector".

The agrichemical-innovation approach has limitations. By comparison, the present research takes a wider policy and regulatory perspective covering all pesticide stakeholders such as regulators, the food supply chain and civil society coupled with their interactions and impacts on the pesticide (agrichemical) industry. Reviewing these characteristics is an important part of the data collected in subsequent chapters.

2.1.2. Paradigm shifts

Kuhn described a 'paradigm shift', whereby a dominant paradigm is successfully challenged by and replaced by another paradigm. Dominant paradigms can be subject to failures, or crises, brought about by divergence between theory and fact or changes in social and/or cultural climates. Once a paradigm is entrenched its theoretical alternatives are strongly resisted. Kuhn considered that a challenge to the entrenched paradigm was usually unsuccessful as the entrenched paradigm is supported by the parameters of 'normal science'. On the other hand, when 'revolutionary science' is successful it leads to fundamental changes to the scientific overview leading to a paradigm shift (Kuhn, 1970).

The negative impacts caused by pesticides can threaten the stability of what might be considered a 'paradigm' for pesticides. These impacts and threats are analogous to what Kuhn referred to as 'anomalies'. The present research argues that the 'technological trajectories' developed by pesticide manufacturers try to ensure that mitigating measures are adopted incrementally to defend the paradigm. Typically this takes the form of extra scientific tests and experimentation on problematic products in the hope that new data re-assures the regulatory process through a risk analysis process. Another more general route is to innovate and develop new areas of technology, such as the development of 'bio-pesticides'[8] or genetic modification (GM).

The research literature is divided on whether the development of GM can be viewed as a technological trajectory within the pesticide policy paradigm, or whether it represents a new paradigm. Tait et al. (2000) consider it possible to see the move to GM technology from chemical based technology as a break in the technological trajectory. A decade ago Hartnell (1996) predicted that the 'application of biotechnology would emerge as the new dominant technological paradigm... although much of the current research is focussed on integration of the chemical and biotechnological approaches'. In other words the status quo then was that the technological trajectory incorporated 'normal' scientific and

8 . The term 'bio-pesticide' is a generic term to describe biologically based pest control products, derived from or consisting of living organisms. Four sub-groups include: 1) Plant-based chemicals such as garlic and mint oils; 2) Semio-chemicals such as pheromones; 3) Microbials such as viruses and bacteria and fungi; 4) Invertebrate bio-controls such as nematodes and insects. The term 'bio-pesticide' which is defined in UK and EU law excludes the 4th Bio-control agent group. For a more detailed review of bio-pesticides, see Sections 6.9-6.10.

technological choices. And according to Chataway et al. (2004) biotechnology provides a very different set of technological options compared with pesticides, but the foundations for such a paradigm are weak and its direction is unclear. The present research considers the status quo has actually been maintained and GM has 'locked' into the same unbroken technological trajectory within the same pesticide policy paradigm[9]. GM technology has been designed to be compatible with pesticide technology and intensive conventional agriculture, although there are differences as GM is regulated under a separate legislation compared with pesticides.

The present research primarily focuses on bio-pesticides as one possible response to the pressure on the pesticide policy paradigm. A key question is whether these changes would represent a fundamental paradigm shift or an incremental incorporation within the same paradigm? Here the literature is more limited than that for GM. Gaugler (1997) considered that bio-pesticides could not be subsumed within the existing dominant paradigm and that an alternative paradigm was required to accommodate them. A new paradigm requires leadership in building a new research base that develops detailed and reliable protocols.

De Buck et al. (2001: 155) have examined the reasons why Dutch arable farmers consider changing to more sustainable practices. They considered that, in theory, integrating ecological goals in the objectives of farm management implies an expectation that 'the adoption of sustainable farming systems to require a paradigm change rather than to represent an adoption and innovation within the same paradigm'.

The barriers to the introduction of alternative technologies have been highlighted by Kemp et al. (1998). They argued that technological change is often but not always locked into dominant technological regimes and suggest a process called 'strategic niche management' as a way of incorporating new technologies that may otherwise struggle to be adopted. For the present research, strategic niche management can be useful in assessing the prospects for the development of bio-pesticides. There have been a number of barriers for the development of bio-pesticides – regulatory, economic and agronomic. One key proposition of present research is that a strategic niche management approach could provide the technological and managerial space for alternative paradigm to develop.

9. For the reasons argued in Chapter Six (see Vol. 1, page 207) GM technology is not covered in detail within the framework of the present research.

Political scientist Peter Hall (1993) has examined the circumstances of UK economic policy change and described under what conditions they may be linked it to a paradigm shift. He focussed on developing a view of institutions that examines the ways they interact and the ways they affect society, from a perspective known as 'neo-institutionalism'. He has used the term 'policy paradigm' to describe a framework for British macro-economic policy. It covered the period 1970-89 and encompassed three orders of policy change that can occur within institutions. The first order involves changes in the setting of policy instruments, and the second includes the replacement of one policy instrument with another. In both cases the state actors carry on autonomously and no institutional change is required. Referring to the Kuhnian hypothesis, Hall calls this a 'normal policy-making' process that adjusts policy without challenging the overall terms of a policy paradigm, in a similar fashion to Kuhn's 'normal science'. The third order encapsulates a significant departure in policy goals, based on a new theoretical and ideological framework or paradigm, and usually involves both the state and non-state actors, or a 'state-structural' response. A paradigm shift occurs when anomalies accumulate, polices fail and the authority of the original policy paradigm is undermined. In the case of pesticides a paradigm shift would require fundamental institutional changes, broader than those of just a scientific community, as described by Kuhn.

The following section reviews some further examples of paradigms that are relevant for the present research. Paradigm shifts have been described in terms of agricultural policy by Coleman et al. (1997). Using three cases studies (Canada, Australia and the US) they drew on Hall's (1993) conclusions, but describe an alternative policy paradigm shift in which there has been a change from a state-assisted to a market-liberal paradigm. This involved changes in agricultural policy from state intervention and production subsides towards a greater emphasis on competitive markets providing the main source of income for commercial farmers. Contrary to Hall's (1993) view, the paradigm shift comes more gradually, and is negotiated between actors, and there is no requirement for a preceding and significant institutional change. It has been argued that the changes examined by Coleman et al. (1997) do not constitute a paradigm shift (Orden, 2000 cited in Moyer and Josling, 2002: 31). Odren argues that a Kuhnian paradigm shift had not occurred because the underlying models for agricultural support had not changed.

Other food and agricultural paradigms have been described by Lang and Heasman (2004). Whilst drawing on features of the scientific communities referred to by Kuhn (1970), they include analogous features such as a 'scientific focus' and the 'role of knowledge' in their paradigms (Lang and Heasman, 2004: 29-32). However they complement these features by drawing on policy frameworks (as did Hall, 1993) and other stakeholder and political features that are also relevant for pesticides. Lang and Heasman (2004) argue that intensive agriculture, or the 'productionist paradigm' is declining, not just because of human health and environmental concerns, but on economic grounds. Its replacement is being contested between a life science biotechnological paradigm and an ecological paradigm, including the holistic model as advocated by organic farming. The productionist paradigm depends upon pesticide use; the adverse health effects now associated with pesticides provide an example of tension within the productionist paradigm.

Lang and Heasman's approach offers a tool to explore prospects for the future and clarify differences and perspectives between stakeholders, both for the wider paradigm and the narrower paradigm for pesticides. The relationships between the citizen, science, technology and innovation are being fought over by adherents of alternative paradigms.

In another context, den Hond et al. (2003) have examined pesticide policies and pest management. They have looked at the question of why pesticides are still used, despite all the concerns they have raised, as well as identifying alternative strategies to overcome the problems of pesticides. Their framework of analysis addresses the complex, dynamic and interactive system of agricultural production between what they describe as three spheres; agricultural production, innovation and socio-economic institutions. Broad lines of analysis can focus on these three spheres. The first sphere includes agricultural production in which crop rotation options are adopted and investments made in the prospect of making a profit. Under conditions of uncertainty farmers take a series of agronomic risks. Pesticides have become an important variable in these decision making processes. Farmers are guided by the pesticide industry, as well as structural characteristics of their business environment of regulation, prices, subsidies, and the dictates of important supply chain players such as multiple food retailers. This sphere is not static, and it interrelates with the second sphere, innovation. Here the problems of pesticide innovation provide a barrier to development. There are also problems for alternatives, such as bio-pesticides, which are, on the whole, promoted by small companies that are not backed by large research and development budgets and well resourced regulatory affairs departments. To complete the framework, the third sphere of socio-economic institutions provides a wider context for the direct relationship between political and economic processes with those of agricultural production and innovation. Production and innovation are restricted by socio-economic institutions. A good example of this is the impact that supermarkets, as socio-economic institutions, have had on agricultural production, through the banning of certain pesticide active ingredients. At the same time these institutions develop in response to internal and external problems of agricultural production and innovation. The development of alternatives therefore depends on how well they are received in the socio-economic institutions.

The term 'pesticide paradigm' has occasionally appeared in the scientific discourse, although it has not been defined in detail (Gaugler, 1997, Altieri et al., 2004, Welsh et al., 2002). The technological paradigm has been used to describe agrichemicals (by which they mean pesticides) but from the perspective of the agrichemical industry. Indeed, Kuhn is said to have used the term paradigm with at least 21 different shades of meaning (Masterman, 1970 cited in Lang and Heasman, 2004). Paradigm shift has also been used when comparing synthetic pesticides with bio-pesticides (Gaugler, 1997). Gaugler considered a paradigm shift is needed and that alternatives to the chemical pesticides paradigm were poorly developed for growers, extension staff and industry. He commented: "This transition [considering an alternative paradigm] will require growers to be better educated about biological control technologies... Extension has developed an immense knowledge base to develop chemical pesticides, but no comparable database exists for any biological agent." Researchers were also criticised for being "absorbed with the chemical paradigm" (Gaugler, 1997: 181). Altieri et al. (2004) used the terms 'ecological engineering' and 'genetic engineering' to argue that there was scope for synergy for two approaches with many points of contrast in terms of principles (ecology versus genetics), maintenance costs, public acceptability, and level of current use. When the term 'paradigm' has occurred, it is often in the title of papers as a headline comment, or it is in the aims/introduction and\or conclusions of technical lectures/debates. Its meaning is usually assumed to refer to the framing assumptions of how chemical pesticides are developed, regulated, sold and used, but this is rarely spelt out. This is intriguing given the importance pesticide plays in conventional agriculture.

The present research has not identified any detailed pesticide paradigm models in the literature. In light of this, the nature of the paradigm for the present research is described at the end of this chapter. It argues that the idea of a 'pesticide policy paradigm' provides a useful model to describe the dominant way of thinking about the use and development of pesticides. The prospect of a paradigm shift provides scope to analyse the exploration of alternatives to pesticides.

2.2. *Risk analysis*

This section assesses the risks associated with pesticides as they are related to the present research. It reviews the literature critical of the formal risk analysis process, and examines the social construction of risk in a technical field heavily reliant on scientific input.

Risk plays an important role in the continued use of pesticides given their potential to cause adverse effects. Its analysis through a regulatory process frames the way pesticides are used and governed. Any definition of a pesticide policy paradigm has to take account of the risk analysis process and its role in the regulation of pesticides. Risk analysis is an overarching term that can vary according to the particular process being examined. In its more comprehensive sense it incorporates a scientifically-based 'risk assessment' component with wider socio-economic and political considerations, known as 'risk management'. The regulatory conclusions of this process are then communicated to wider public through 'risk communication' (see EU risk model outlined in Figure 2.3). There are other narrower examples of risk analysis, such as the UK, in which risk assessment predominates and the risk management role is down-played and/or lost within the regulatory process (UK risk model outlined in Figure 2.2. Figures 2.2 and 2.3 are presented side by side to facilitate comparison).

For the purposes of the present research, risk analysis for pesticides also provides one key way of gauging the extent to which the dominant paradigm is under pressure. The parameters of risk analysis can change depending on whether there is a more or less comprehensive and/or stringent regulatory process.

Formal risk analysis models have developed through regulatory processes and changed and increased in complexity over the last 60 years. As a result there has been a great increase in the requirement for data and also the requirement for the data to be harmonised internationally. Over the same period, a diversity of pesticide risk analysis stakeholders have emerged who challenge the official methodology and conclusions of the national regulator.

The following section reviews the risk literature and its relevance for the present research into UK pesticide policy. Risk provides a way of assessing the likelihood of harm occurring, by measuring the extent of exposure to the hazards of a substance (Davies et al., 2004: 218). In this context, Rodricks (1992: 48) described risk as "...the likelihood, or probability, that the toxic effects of a chemical will be produced in populations of individuals under their actual conditions of exposure. To evaluate the risk of toxic effects occurring for a specific chemical at least three types of information are required": the types of toxicity the chemical can produce; the level or amount of exposure; and the conditions under which the population of people or other organisms are exposed Rodricks (1992: 48).

The historical assessment of pesticides has shown that many challenges for risk analysis have emerged. In the early years of pesticide use, the risk debate was mainly concerned with efficacy motivated by a policy promoting an increase in agricultural production. Knowledge of product safety was limited. Since then the risk analysis process has had to embrace newly discovered hazards caused by pesticides and interpret a mushrooming amount of safety data. There are a number of variable characteristics to consider. Each product has to be assessed separately because of the inherent and unique properties of the respective chemicals. Pesticides are used in a diffuse fashion by a largely unknown number of operators in an unknown number of locations. Those who are exposed to the risk – humans, wildlife and the environment – can vary considerably. Which of the many risks takes precedence? It is impossible to answer this question objectively. The level and length of exposure and the combination of chemicals can vary, and as a result the extent of safety data requirements has increased. Dutch researchers (den Hond et al., 2003) have suggested that pesticide regulation is facing what they call 'regulatory failure', where the regulation of pesticide(s) generates more costs than return from sales of the product(s).

The pesticide industry has to carry out a battery of pre-registration research before pesticides are approved as safe and efficacious by the regulator, for use in the food supply chain. These tests have to be carried out in a pre-ordained way, set out in detailed legislation[10], in order to deliver regulatory consistency. The challenge this places on the risk analysis of pesticide regulation has been defined through a concept described as 'regulatory science' (Irwin et al., 1997). The term 'regulatory science' has been employed in order to distinguish it from 'academic science', as practised in universities and other academic institutions. Academic scientific endeavour is curiosity driven, iterative, reflexive and welcoming of a wide range of views. Learning from mistakes and failed or revised theories is part of the process. The framework encourages open peer-reviewed discussion. There is little room for these activities with the regulatory process where absolute certainty and closure are required. Yes/no absolute-type responses are required – a pesticide is either safe to use or it is not. These are the requirements of regulatory science that governments demand from the pesticide industry. For development and marketing of new pesticides, the

10. As laid out in Annexes for EU Directive 91/414.

commercial realities of multi-million dollar research budgets operate. The commercial sensitivity of company data on pesticides stifles open and transparent debate. External deadlines are of paramount importance. For example, if a pesticide product fails to make the marketplace in time for a particular growing period, the (possibly global) financial returns for a whole agricultural spraying season may be lost.

Further pressures include the different types of regulatory regimes that exist from one country to another, and the fact that regulatory science is undertaken with the aim of aiding policy-making (Irwin and Rothstein, 2003, Irwin et al., 1997, Rothstein et al., 1999, Jasanoff, 1990). In order to deliver successful regulatory outcomes, the process of regulatory science has to be adapted in a way that separates it from academic science, so that all the economic pressures mentioned above can be accommodated. Where error does occur in the generation of safety data, it has to be explained within the risk analysis process.

There are uncertainties to consider when assessing the effects of pesticides that have implications for risk analysis. The main areas are: estimating the inherent toxicity of pesticides to humans and non-target species (which is largely based on animal test data); estimating the likely exposure to pesticides; and data gaps (especially for pesticides that were first approved and registered decades ago). A number of academic studies have noted the difficulty in establishing policy within scientific realms that are characterised by uncertainty (Irwin, 1995, Jasanoff, 1990, Wynne, 1992). For pesticides, the two forms of science – academic and regulatory – are separated by marked economic and cultural and institutional differences. In the case of regulatory science, commercial pressures have important implications for the research process.

2.2.1. Overview of formal risk analysis models

Contemporary risk analysis shows how the regulatory process is burdened by the requirements of 'regulatory science'. Risk analysis refers to the overall way in which pesticides are deemed to be acceptable. The formal approach to risk analysis occurs through a well organised regulatory process at the national (UK), regional (EU) and global levels.

There is great pressure to harmonise risk analysis from the local to global as the major pesticide producers market at an international level. The financial research and development costs are much reduced if there is a universally agreed regulatory framework (known as mutual recognition) both at the regional and international levels. Mutual recognition is not constant however, and there are differences in the risk analysis approach, which is described below. The present research has assessed the UK and the EU risk analysis processes because of the dual regulatory approval procedures at the Member State and EU levels which now operate (see Figure 2.1). The step-by-step process for both systems has been outlined in Figure 2.2 (for the UK) and Figure 2.3 (for the EU)[11]. Both systems demand a high level of technical input and are bureaucratically complicated processes that have increased in intensity over the last 60 years. The UK regulator has developed a pesticide approval process that follows the notion of regulatory science (see above). The pesticide company provides a detailed dossier of about 30,000 pages covering test data. The regulator accepts the dossier and makes a regulatory decision after carrying out a risk analysis.

The following two sections review representations of models from the formal risk analysis processes – the first for the UK model (Figure 2.2) and then the international EU model is presented in Figure 2.3. The EU risk analysis is different from that which operates in the UK, whereby the scientific risk assessment has been separated from the political risk management and risk communication.

Both these regulatory process are discussed in more detail in Chapter Six. They are introduced in the sections below to establish the starting assumptions to focus on the pesticide risk and regulation policies and how they can be accommodated within the science/policy literature and be presented as part of the starting assumptions for the research process.

2.2.2. The UK model

The UK regulatory process for pesticides is reviewed in Section 6.4. This section introduces the UK risk analysis process for pesticides in the UK as it is currently incorporated in regulation[12].

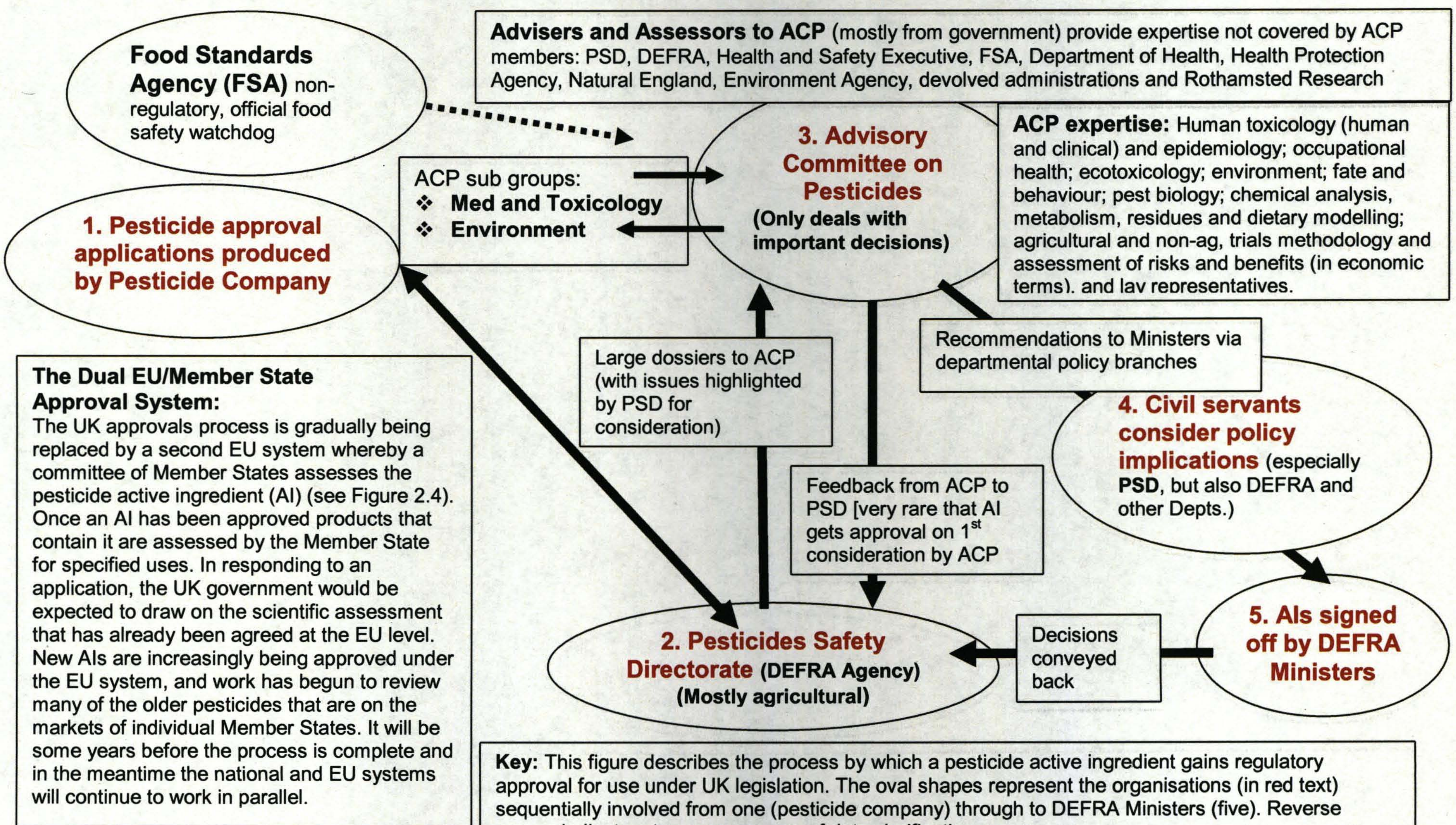
The way in which pesticides are assessed is described in Figure 2.1 (with an outline of the risk analysis model in Figure 2.2). The UK model follows a traditional format in which the science-based risk assessment process dominates. In the UK, this comprises identifying and

11. These figures were also used as an illustration of the UK and EU risk analysis process during stakeholder interviews for the present research (See section 8.2.5).
12. Agricultural pesticides are regulation in the UK under the Pesticides Regulation 1986 and the Plant Protection Products Regulations (2003).

characterising the hazard of the chemical, assessing the exposure to it, and concluding with a risk characterisation. Risk assessment involves an evaluation of toxicological endpoints such as a no-observable adverse-effect level (NOAEL). The process is highly reliant on modelling theoretical exposure assessments, and a monitoring system for products that have been approved by the regulatory process.

In the UK, there is an unclear distinction between risk assessment and risk management with both functions being carried out by the Pesticides Safety Directorate (PSD). Here, processes are, in effect and in general terms, peer-reviewed by the external Advisory Committee on Pesticides (ACP) in the form of advice to Ministers, but the detailed scientific risk assessment of safety dossiers is carried out by PSD. A 2000 review of scientific committees by the UK chief scientific officer included an ACP self-analysis response which acknowledges that it carries out 'final risk assessment' for pesticides and is also responsible for risk management (May, 2000: 14). The ACP subsequently produced a lay guide to pesticide regulation which refers to 'risk management' in the context of the scientific assessment of pesticides (DEFRA/HSE, 2005). There is no mention of policy or any other considerations apart from scientific and technical data.

Figure 2.1: UK pesticide risk analysis approval process



Source*: Author*

This is perhaps why there is also blurring of the risk terminology within the UK regulatory process. A UK perspective is presented in Figure 2.2 by a former chair of the ACP, with annotations from the author. Called 'risk assessment' it incorporates no formal account of the risk management process, although informally it must be occurring. In the UK, the bovine spongiform encephalopathy (BSE) crisis of the 1990s was precipitated by a similar risk assessment-dominated conceptual model that has been described by Van Zwanenberg and Millstone (2005: 15) as a 'technocratic model'. They drew on the discourse between regulators and scientific experts around science and policy-making. Their description of the model draws on the fact that science has a very direct link to regulatory decisions. Van Zwanenberg and Millstone (2005) conclude that UK scientists who offer government regulators expert advice have traditionally maintained the notion of a 'firewall' between science and politics. There are similarities between their technocratic model of risk assessment, and that of the UK pesticides risk model (Figure 2.2) which is highly technocratic.

The technocratic model has been criticised by van Zwanenberg and Millstone (2005) because it fails to acknowledge the social, political and cultural dimensions that need to be included before regulatory decisions are made. Wynne (2002) has recommended that technical advances require social assessment. Pesticide usage is an example of such an advance – there are issues to consider that are not only scientific in nature (Irwin and Rothstein, 2003). The agronomic need for pesticides is inextricably interconnected with the economics of the food supply chain. Judgements such as the 'required burden of proof' as a measure of pesticide safety are political rather than scientific, although the evidence is guided by scientific experts and scientific technique.

Regulatory decisions concerning pesticide safety are still held in secret between government officials, led by the regulator Pesticide Safety Directorate, and members of the expert Advisory Committee on Pesticides. For the last few years, agenda items and minutes of the meetings have been available on the committee website.

The Food Standards Agency (FSA) has reviewed scientific committees coming under its responsibility including the Committee on Carcinogenicity, the Committee on Toxicity and the Scientific Advisory Committee on Nutrition (FSA, 2002). The FSA review however specifically excluded the Advisory Committee on Pesticides (FSA, 2002: 4). This was because the FSA has a 'responsibility' for the above government committees, but only a more limited 'interest' in the ACP. The FSA made 50 recommendations on a wide range of issues. One of the main conclusions was to review openness in relation to the information that the committees are asked to assess, and the handling of potential conflicts of interest.

For the ACP meeting process, stakeholders are kept out of the risk assessment process as far as possible[13]. For the UK, the regulator (in the form of risk assessment civil servants with technical expertise based at PSD) produces a draft risk assessment after submission of safety and efficacy data from the marketing pesticide company. This data is then scrutinised by the committee of experts (the Advisory Committee on Pesticides) who make a recommendation, such as banning the use of a specific pesticide, to government ministers at DEFRA[14]. The final risk management occurs at this stage when the policy and political implications of pesticide approval can occur, through lobbying by any stakeholder to the minister – so long as they have, or can obtain, the ear of the minister. In theory the whole risk analysis process can be 'short circuited' at this stage on political and economic grounds.

13. This includes public interest organisations and members of the food supply chain. If the ACP has specific questions to ask, representatives from companies supporting a pesticide approvals, may be asked specific questions for which specific answers can be supplied.
14. For this research the researcher was permitted to attend a meeting of the Advisory Committee on Pesticides, as an observer and on a confidential basis.

Figure 2.2 UK risk analysis 'technocratic model'

Risk Assessment

↓

Toxic effect + Exposure

↓

Estimate initial risk

↓

Refine risk with new data

↓

Restrict use, make application changes

↓

Establish new pattern of use

↓

Monitor

Source: UK model after: Berry (2004: 340)

Figure 2.3 EU risk analysis 'inverted decisionist model'

Risk assessment	1. Hazard identification 2. Hazard characterisation 3. Exposure assessment 4. Risk characterisation
Risk management	▪ Weighing policy alternatives ▪ Consultation with all interested parties ▪ Promotion of fair trade
Risk communication	▪ To provide information in clear and understandable terms ▪ Fostering public trust and confidence in safe food / health and safety

Risk assessment is carried out by the European Food Safety Agency and risk management/communication is carried out by DG SANCO.

Source: Van Eck (2004)

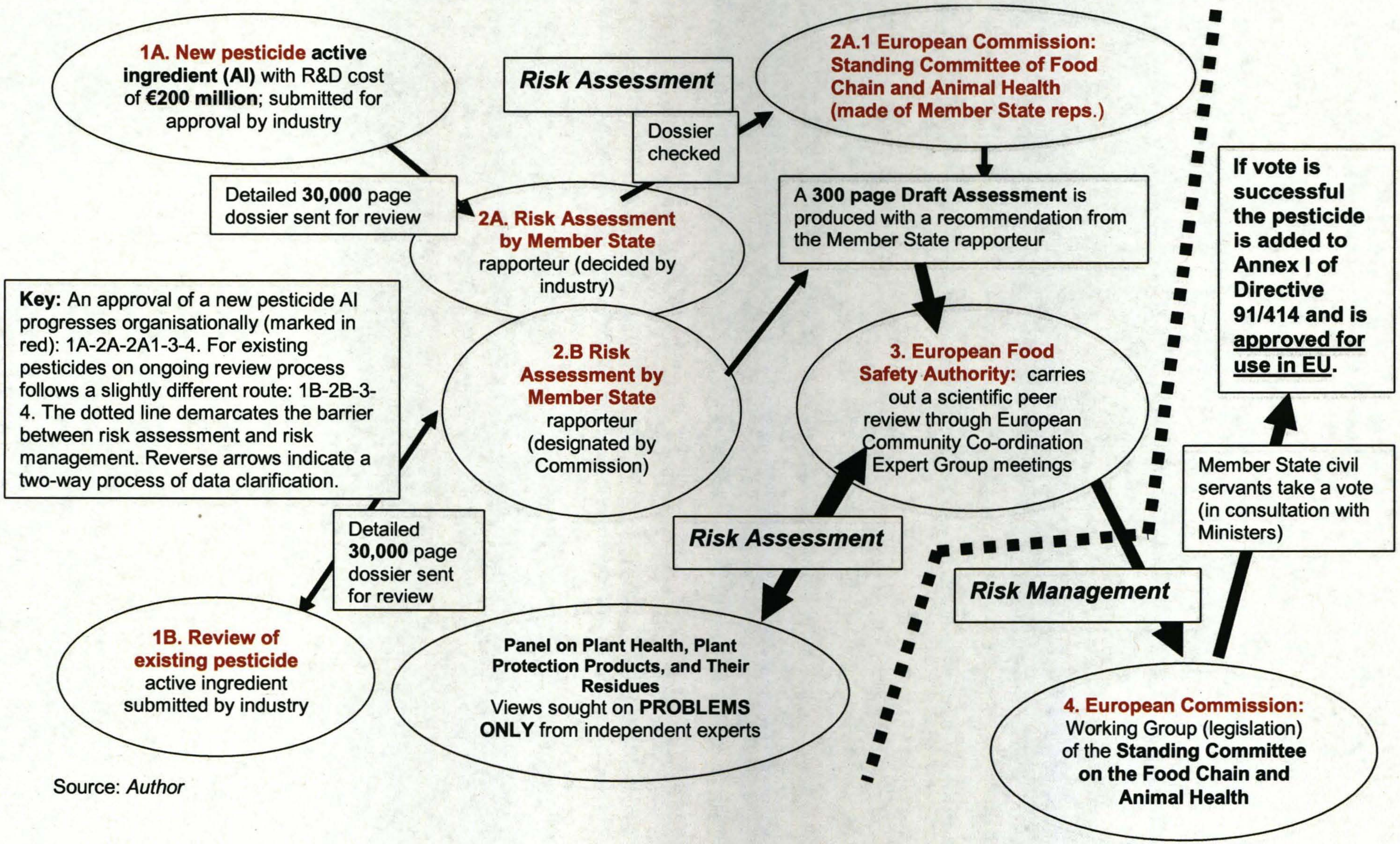
2.2.3. The EU model

At the EU level, agricultural pesticides are regulated under Directive 91/414 (European Commission, 1991), as outlined in Figure 2.4. This figure abridges the process by which a pesticide is approved through the Directive from the research and development by the pesticide industry through to assessment by Member State regulators and the EU.

Within the remit of this legislation, there have been a number of changes in the risk analysis process in recent years. It has made attempts to acknowledge the political element in risk analysis. A representation of the EU risk analysis model is presented in Figure 2.3. In 2001, the European Food Safety Authority (EFSA) was created to carry out technical risk assessments for food safety issues across the food chain, including for pesticides (see Section 7.10). Creating a new agency (EFSA) locates all the scientific assessors outside the regulatory body. The separation was made with the Health and Consumer Protection Directorate General of the European Commission (known as DG SANCO) carrying out risk management and the risk communication (see Figure 2.4). Risk management has been defined internationally through CODEX as "the process distinct from risk assessment, of weighing policy alternatives in consultation with all interested parties, considering risk assessment and other factors relevant for the health protection of consumers and for the promotion of fair trade practices, and if needed, selecting appropriate prevention and control options" (FAO, 1999 cited in Van Eck, 2004: 308-309).

There is another structural difference between the UK system and the EU apart from the institutional separation of risk assessment from risk management. For the UK, a separate regulator has emerged (PSD) which only regulates pesticides. At the EU pesticides are regulated more generically through DG SANCO and EFSA, both of which have regulatory responsibilities for wider food safety issues. The recognition of factors external to the risk assessment, and the political input from all sides is different from the UK model. Van Zwanenberg and Millstone (2005) have also examined a number of conceptual models that have emerged since the UK technocratic model. These include what they have called 'inverted decisionism' and 'revised inverted decisionist' models. For inverted decisionism, scientific assessment feeds into policy making, allowing for the social, political, and cultural contexts to be incorporated before regulatory decisions are made. The 'revised inverted decisionist model' describes the relationship between the technocratic risk assessment process leading to risk management, where again social, political and cultural contexts are included.

Figure 2.4: EU pesticide approval (Directive 91/414) risk analysis process



Source: *Author*

In the case of pesticides, the present research concludes that the EU is ostensibly following an 'inverted decisionist approach' whereby the European Food Standards Agency (EFSA) carries out the technical risk assessment which is intended to be separate from the risk management, carried out by DG SANCO. Here risk management incorporates policy considerations (as outlined above), and contrasts with the UK technocratic model.

Further changes to the EU pesticide regulatory system are ongoing which may have impacts on risk analysis. A new EU Pesticide regulation is being discussed within the European Union (Anon, 2007c). It could have serious impacts on the yields of agricultural crops, although stakeholder views are divided on the subject.

As a replacement for the existing Directive 91/414, various forms of the draft regulation have been debated by the European Commission, European Parliament, European Council, Member States governments and other stakeholders, and a final outcome could be imminent.

The new draft regulation has the potential to remove more pesticide active ingredients from the European market, compared with the current Directive. This would be achieved through the provision of progressive measures such as the adoption of a hazard-based approach 'cut off criteria' and the 'substitution principle' as opposed to a risk assessment approach. Cut off criteria means that certain hazardous chemicals[15] are banned for use, regardless of likely exposure levels to the substance. The substitution principle means that chemical A is banned in preference for chemical B if B has fewer hazardous properties. Risk assessment, on the other hand takes into account exposure and hazard. Risk assessment therefore relies heavily on accurate knowledge of likely exposure, which can be difficult to achieve. One example where exposure is difficult to measure is for endocrine disrupting compounds[16]. McKinlay et al. (2008) conclude that the residential and/or bystander pesticide exposure in rural areas could be grossly under-estimated. This being so, it in turn makes pesticides difficult to regulate.

Crucially, it allows for the continued marketing of potentially hazardous substances, provided the exposure to them is below levels officially deemed to be 'acceptable'. This is why the pesticide policy community is supportive of the risk assessment process which relies on mitigation rather than the cut-off criteria which would prohibit use outright.

15. Such as a chemical that has EU recognition as a 'possible human carcinogen'.
16. For a definition of endocrine disrupting pesticides see Glossary.

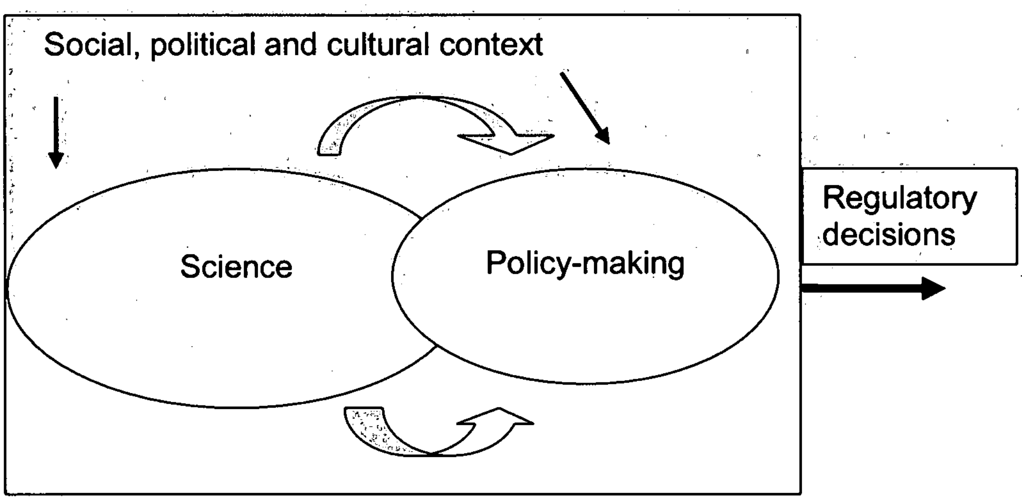
These future developments are likely to present further divergence between the European Commission approach to risk analysis and the UK approach. At the EU level there is greater complexity in the risk analysis and a greater degree of change in the processes. It acts in a more formally transparent manner, and there is greater acknowledgement of interested parties.

2.2.4. Discussion of the formal risk analysis models

Criticisms of the UK and EU risk analysis models have centred on the difficulty of integrating science with policy. One area in which this manifests itself involves the political discourse surrounding the uncertainties presented by scientific analysis in the risk assessment process. One set of attempts to accommodate these problems has been established through the precautionary principle: where the threats are of serious or irreversible damage, lack of full scientific certainty should not be presented as a reason for postponing cost effective measures to prevent environmental degradation (European Commission, 2000). Dealing with the threat in this way is what (Beck, 1992) calls reflexive modernity – where there is a re-organising of the process in which risks are posed by modern technology such as pesticides. Both the UK and the EU pesticides regulatory processes have rhetorically embraced the precautionary principle, but it is politically controversial because of stakeholder conflict between the environment and health view and the economic productionist view. There is also the issue of fundamental need for pesticides, which cannot easily be accommodated by compromise. The precautionary principle is covered in greater detailed later in this chapter (see Section 2.2.5).

Millstone and van Zwanenberg (2002) argued that greater acknowledgment should be made by the regulatory process of competing economic, political and social interests, compared with the scientific risk assessments. Any disparity between experts should be made more transparent. For example expert committees should explain when differences of opinion have occurred and any assumptions and uncertainties should be included in their conclusions. In elaborating this, the following questions need to be asked. What is the range of policy questions to be assessed? What are the criteria by which they should be evaluated? Is the data considered relevant? What are the standards used to produce and interpret data? (van Zwanenberg and Millstone, 2005). In the 1970s, these questions were relevant for the risk assessment of pesticides in the UK (Gillespie et al., 1997), and they are still as relevant today according to the Royal Commission on Environmental Pollution (2005a) who carried out a review of the impact of pesticides on residents and bystanders. For the decisionist models there is a theoretical assumption that science and policy should be separated. Academics have challenged this hypothesis arguing that science and policy need to be more explicitly and effectively interrelated. Van Zwanenberg and Millstone (2005) have developed a 'co-evolutionary model' (Figure 2.5) in which it is important that there are reciprocal links between science and policy. It indicates institutional structures and procedures through which policy making can become both democratically and scientifically legitimate. The FAO/WHO CODEX Alimentarius Commission has embraced the co-evolutionary model introducing the concept of Risk Assessment Policy as part of its risk analysis process, according to Van Zwanenberg and Millstone (2005). Discussion is ongoing at the European Union level about the way in which EFSA and DG SANCO can re-integrate risk assessment and risk management, possibly along co-evolutionary lines (Dreyer and Renn, 2007)[17].

Figure 2.5: Co-evolutionary model



Source: Van Zwanenberg and Millstone (2005: 29)

The present research argues that these models can also apply to pesticides, (See Conceptual Framework section 2.4) where a fixed series of risk assessment/risk management procedures have developed prior to regulatory approval. Furthermore the development of 'risk regulation' is interpreted to reflect the broader political and cultural change where risk is a political weapon used by governments that have to balance the needs and expectations of individuals and the capacity of society to meet these needs. It is also used by the public to blame those who wield power in the state and big corporations for what happens to the rest of us (Hood et al., 2004). The outcome is that regulation of risk itself 'colonises' the regulation of pesticide through the government interface with market or social processes to

17. This report is also referred to in section 2.3, Vol. 1, page 53).

control potentially adverse health consequences (Rothstein et al., 2006). Rothstein et al. (2006) argue that the pressures towards greater coherence, transparency, and accountability of the regulation of what they described as 'societal risks' can create extra risk for the regulating institution by exposing inevitable limitations of regulation because absolute safety cannot be guaranteed. In the case of pesticides this would include the difficulty in dealing with scientific uncertainty and assessing accurate exposure estimates.

2.2.5. The Precautionary Principle

In recent years, the precautionary principle has become an important part of the risk analysis framework for environmental protection and for the security of public health. Its application requires that regulatory action is taken before all relevant scientific information is available. It acknowledges that there are limits and uncertainties in the interpretation of scientific analysis and it provides a basis for policy making and the management of risk (Levidow, 2001; European Commission, 2005). The precautionary principle has become part of European Union law and is enshrined in many international treaties. Although referred to as 'the precautionary principle' there are different definitions and stakeholder interpretations which are reviewed in this section, along with their relevance to pesticide regulation and policy. The terminology of precaution is also discussed, for example, referring to precautionary approaches when regulating pesticides.

The term 'precautionary principle' first appeared in the 1972 Stockholm Environment Conference (O'Riordan and Cameron, 1994) and is linked to the *Vorsorgeprinzip* or foresight principle which developed as part of German environmental policy in the 1970s and 1980s. Literally translated it means 'before' (*Vor),* 'care' (*Sorge)* 'principle' *(Prinzip)* – the principle of taking care before we act (Adams, 2002).

Adams (2002) has further described how the German use of precaution has progressed from a 'precautionary measure' in the early 1980s to a 'precautionary approach' in the late 1980s ending with an adoption of the phrase 'precautionary principle' in the 1990s[18]. The difference in interpretation from 'measure' to 'approach' can be seen as comparing "restricting harmful substances" with "control inputs of harm without restrictions on the use of those inputs" (Adams, 2002: 304). The 'precautionary principle' emerged from these descriptions and was advocated by governments, although it was not clear what the principle meant in practice.

18. The precautionary measure referred to the significant reductions in the use of CFC's through a 1980 EC Council Decision and the precautionary approach was included in the 1987 Ministerial Declaration of the Second International Conference on the Protection of the North Sea (Adams, 2000).

In practice the principle allows for the relevant political actors to bargain with each other on the basis of agreed ground rules. Where they can agree is a matter of negotiation between stakeholders. From this beginning, the precautionary principle has been applied to international agreements covering environmental and risk policy areas such as climate change, biodiversity, genetic modification, chemicals regulation, food safety, public health and trade policy (Sand, 2000).

The most notable international interpretation of the principle is the 1992 Rio Conference on the Environment and Development which recommended:

> *"Where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing cost effective measures to prevent environmental degradation"* (UNCED, 1992).

Since the Rio Conference, the precautionary principle has been consolidated into international environmental law (European Commission, 2000), although its application within multilateral agreements has been controversial. The US in particular has been critical of the principle per se during global negotiations covering the Kyoto Protocol on fossil fuel emissions, and the Cartagena Protocol on Biosafety (Levidow, 2001).

The precautionary principle is now part of EU environment policy and was incorporated in the European Union Maastricht Treaty of 1992. It contained the requirement that preventative action should be taken to prevent environmental damage. The EU policy was also widened to include food safety, consumer protection, trade and research, and technological development. In the UK, commitment to the precautionary principle was first elucidated in a 1990 policy document produced by the government of the day (DOE, 1990). The principle was defined around the relative cost of action. If costs were lower than the costs of not taking any action, the precautionary principle should apply, especially if effects were irreversible; although that interpretation gives no recognition to the challenge of scientific uncertainties, it presumes that risks and costs can be known and accurately estimated. The parameters of risk and grounds for taking action were not however explained in any detail. In later years, the principle was brought to the fore by the BSE debacle (Pennington, 2003), and was required to be adopted according to EU policy.

In the years since 1992, the principle has been reviewed and re-interpreted. The Draft EU Constitution now requires that EU policy should in general terms be "based on the precautionary principle and on the principles that preventative action should be taken" (Bonde, 2007: 136-7).

In 2000 the European Commission provided its most detailed analysis of its interpretation of the principle through a consultation process that culminated in a Commission Communication (European Commission, 2000). The current definition, based on this process, is outlined below:

> *"The precautionary principle may be invoked where urgent measures are needed in the face of a possible danger to human, animal or plant health, or to protect the environment where scientific data do not permit a complete evaluation of the risk. It may not be used as a pretext for protection measures. This principle is applied mainly where there is a danger to public health. For example, it may be used to stop distribution or order withdrawal from the market of products likely to constitute a health hazard"* (European Commission, 2005).

The European Commission also amplified the circumstances in which the precautionary principle may be invoked through 'triggers', 'measures' and 'guidelines'. The factors relating to triggers are the 'dangerous effects' identified by scientific and objective evaluation in which there is uncertainty. The Commission has ruled out the use of arbitrary decision-making when considering invoking the principle. Any decision to act on the precautionary principle must be preceded by an assessment of the risks (European Commission, 2000).

Public interest organisations have lobbied for the precautionary principle and reports have been produced clarifying their position. For example, the public interest network Consumer International has suggested:

> *"The principle should apply in cases when the scientific evidence is not conclusive enough to establish control measures based on a sound and accurate risk assessment but there is a necessity for the purposes of protecting public health, safety or the environment"* (NCC, 2000: 3).

The above consumer version is similar to the European Commission 2005 version, both of which do not include the cost effective provisos of the 1992 Rio version.

In general terms, the principle has been linked to 'precaution as a process' in which there is a multidimensional broadening out of the regulation process, as described by Stirling (2002). Conventional risk assessment takes place within a closed range of specialist perspectives. By including consideration and comparison of a wider range of options, uncertainties, disciplinary contributions and socio-cultural perspectives, the knowledge base for appraisal is extended.

The following section reviews the implications of the precautionary principle on chemical policy and pesticide regulation. The precautionary principle has been defined and recommended by groups of concerned scientists as a way to reduce exposure to environmental pollution caused by pesticides and other chemicals.

The following section reviews the actions of such groups whereby concerned scientists call for the implementation of measures designed to avoid the negative consequences of certain technologies. The Science and Environmental Health Network[19] produced a definition as a conference conclusion that includes health as well as environment (unlike the Rio definition). Known as the Wingspread Statement, it represented a consensus agreed among 32 scientists from different disciplines of health and/or and environmental expertise. It said:

> *"[when] an activity raises threats of harm to the environment or human health, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically."* (Anon, 1998b)

Those attending the conference were concerned that regulation based on risk assessment had failed adequately to protect human health and the environment. The process of risk analysis must be open, democratic and include potentially affected parties, and involve the full range of alternative options. The similar 2001 *Lowell Statement on Science and the Precautionary Principle*[20] set out some elements of a principle (Tickner et al., 2003).

The principle is also supposedly a fundamental part of the EU strategy for a chemicals policy (European Commission, 2001c). If a chemical has properties that may have adverse effects to humans and/or the environment (properties such as persistence, bio-accumulation, carcinogenicity and teratogenicity), and that there is scientific uncertainty about the magnitude of that problem, decision-making must be based on precaution. Under

19. The Network produced the Wingspread Statement on the Precautionary Principle, 23-25 January 1998, signed by 32 health and environmental academics (see also Vol. 1, page 116).
20. Signed by an international group of scientists, legal scholars, medical professionals and others, co-ordinated through the University of Massachusetts Lowell, US, 2001.

this EU policy, the principle will be evoked when a risk assessment is unduly delayed and there is an indication of unacceptable risk, and a chemical of particular concern could be banned during the risk management process.

The final paragraphs of this section refer to the precautionary principle as it relates to the risk analysis and regulation of pesticides. Pesticide regulation, and its failures, as perceived by the public, has been described as the main stimulus for the emergence of the precautionary principle approach to risk regulation in Europe (Tait, 2001b). One of the first applications of the precautionary principle involved EU Drinking Water Directive (80/778EEC) in which the contamination levels of pesticide residues in drinking water were set at very low arbitrary levels[21] (Tait, 2001b).

Although not specifically referred to in the pesticides authorisation Directive 91/414, the word 'precaution' appears 44 times in the Directive, and 'special precautionary measures' appears twice, referring to Acceptable Operator Exposure Levels (AOELs)[22] and re-entry conditions for humans and animals to enter recently sprayed areas (European Commission, 1991).

Since 2001, it has been clear that any revision of the Directive 91/414 would include specific reference to the precautionary principle (European Commission, 2001b). A more recent proposal for Regulation has indicated that the precautionary principle should be applied, where the pesticide industry ensures that pesticides do not adversely affect humans. The proposal also requires that particular attention be a given to the protection of vulnerable groups, including pregnant women, infants and children (European Commission, 2006b).

Specific demands for the application of the precautionary principle have been put forward by pesticide-specific non-governmental organisations such as Pesticide Action Network International (PAN International, 2006). Their briefing paper on the subject requires the regulatory process to take early preventative actions to eliminate harmful pesticides, including those that are persistent, accumulative or highly toxic and those that cause, or are suspected to cause, cancer, reproductive problems, birth defects, developmental and behavioural impacts, and effects on the immune, endocrine, and neurological systems.

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21. 0.1 μg/l (parts per billion) for an individual pesticide residue and 0.5μg/l for the combination of all pesticide residues in any one sample.
22. AOELs are calculated as part of a pesticide operator exposure risk assessment. They are derived from no-effect level from a relevant toxicity study that is divided by an 'uncertainty factor' that takes into account extrapolation from the test animal to humans and variation within species or uncertainty about the no-effect level itself (Hamilton and Crossley, 2004: 163).

There is a call for the substitution of harmful pesticides with less harmful pesticides, including agro-ecological methods, and holistic approaches to control weeds, pests and disease. As with the above proposal from the European Commission (2006b), there is a recommendation that regulations are drafted on the basis of most vulnerable groups, and that there is recognition of the experiences of workers and communities with regard to the adverse effects of pesticides. In line with Irwin's 'citizen science', there is a call for popular participation in the decision-making processes for pesticides.

2.2.6. Diversity of risk analysis

Regulators currently make their decisions whether or not to approve pesticides in the light of risk assessments of the safety of pesticides, where risk is assumed to be a function of the intrinsic hazardous properties of a substance coupled with the likely exposure of an individual or population. Pesticide manufacturers provide a dossier of toxicological and environmental impact evidence, which is assessed by expert panels. Risk assessments are supposed to be founded upon hazard identification, hazard characterisation and exposure assessment. The reliability of the risk assessment is totally dependent upon the quality of these components of the process, the information available and the judgment and values of those involved.

Exposure assessment, central to the process of pesticide risk assessment, is reliant upon models rather than on actual exposure data. The regulatory process attempts to compensate for this through the adoption of 'uncertainty' factors in the case of human health and risk mitigation requirements in the case of environmental protection (RCEP, 2005a).

2.2.7. Broadening of stakeholder involvement in risk analysis

The formal risk analysis process now has to compete with other stakeholders who are increasingly carrying out their own elements of risk analysis – making their own judgements about pesticides. In the UK, independent bodies such as the British Medical Association and the Royal Commission on Environmental Pollution have made their own independent pronouncements about the safety of pesticides that differ from the official view (BMA, 1990, RCEP, 2005a). Public interest groups and multiple food retailers also have their own pesticide policies that make risk analyses based on the hazard criteria of a chemical (Barker, 2003). In these cases, if a chemical is an officially recognised hazard,[23] such as a 'possible human carcinogen', their recommendation is not to use it – regardless of

23. Hazards such as that identified by the International Agency for Research on Cancer, the US Environmental Protection Agency and/ or the European Union.

the level of exposure that there may be. The rationale here is that the exposure is too unpredictable, and that a more precautionary approach is required. It does eliminate most of the risk assessment process beyond the hazard characterisation stage (see Figure 2.2).

More recently, the draft European pesticide regulation includes a hazard based approach to approval of pesticides (EU, 2008) as opposed to the risk assessment approach favoured by the UK PSD (DEFRA/HSE, 2005).

The work of Van Zwanenberg and Millstone has focussed primarily on the relationships between experts and regulators. The present research is also interested in the wider policy involvement in pesticide policy, including civil society. Irwin argues that there should be greater openness and participation in what he calls 'citizen science' (Irwin, 1995). The agrichemical industry and government officials have seen a limited role for public interest NGOs. They defended this position on the grounds that NGOs do not possess the resources to undertake regulatory scientific work, nor were able to develop the very specialised expertise needed to shape debate (Rothstein et al., 1999). Broadening the debate also has relevance for the development of IPM and ecological pest management in that policy discussion shapes their development could be subject to public participation.

Irwin (1995: 170) describes how society might now move on in terms of social and technical responses to specific environmental threats, including pesticides. It is not a question of whether science should be applied but rather which form of science is most appropriate and what should the relationship be to other forms of knowledge and understanding. Others (Wynne and Mayer, 1993 cited in Irwin, 1995) have stressed the uncertainty of knowledge and ignorance in understanding of the environment among the scientists involved in these debates. They call for a greater value to be given to areas of science such as ecology which consider the environment in its broader context, or a 'greener science' as they refer to it.

One way of incorporating green science into pesticide policy is to consider the adoption of safer alternatives which might include bio-pesticide agents. The risk analysis processes for bio-pesticides are in emerging phases both at the UK and EU levels. One sub-group is regulated under the same legislation (Directive 91/414) as synthetic pesticides. There is a very limited literature (academic or regulatory) on the risk analysis of the biologically based alternatives to synthetic pesticides, which presents a potential regulatory barrier for development. In some cases, they are designated by the regulatory processes as demonstrably less hazardous and are considered as candidates for substitution through a comparative risk assessment framework. In other cases, the ecological implications of the release of live organisms into the environment presents a new and challenging element in risk analysis that was not included within chemical pesticide regulations. If bio-pesticides are to be included in an ecological pest management paradigm, these risk analysis questions have first to be addressed.

2.3. Governance and policy networks

A number of interested parties play a part in determining the parameters of risk and what is acceptable to society in terms of pesticide policy. This section examines how the policy process engages the numerous interested parties.

'Policy' refers to the process by which society is governed, and it is an area in which various ideological positions compete for supremacy. From a social science perspective it has been defined as a course of action adopted by a government and is a central concept in both the analysis and practice of the way in which societies are governed (Colebatch, 2002: 1). Henson and Caswell (1999) maintain that policy is the outcome of a complex trade-off between alternative demands that reflect the interests of different groups that might be affected.

Since the 1940s, organisations have come together to network and develop a policy that promotes the use of pesticides (see Section 4.7). Policy analysts describe the exchange of concerns and demands between interest groups and government as a 'policy network' model. A network approach helps explain the different types of relationships between politicians, bureaucrats, group representatives and other participants in which political systems process policy (John, 1998: 78).

Rhodes and Marsh (1992: 182) have described a policy network as: "a cluster or complex of organisations connected to each other by 'resource dependencies' and distinguished from other clusters or complexes by breaks in the structure of the resource dependencies." What distinguishes policy networks from other organisational networks is that the state has an interest in sustaining them. There are four reasons for this, according to Jordan and Richardson (1987) and Smith (1993) as cited in (Hill, 1997). They facilitate a consultative style of government; they reduce policy conflict and make it possible to depoliticise issues; they make policy-making predictable; and they relate well to the departmental organisations of government.

Pesticide policy in the UK has changed considerably since the early use of synthetic pesticides in the 1940s. Analysis of these changes is of relevance to the present research. This can be done by drawing on Rhodes and Marsh (1992) who have defined five different types of policy network along a continuum that ranges from a highly integrated form to a much looser integration. For the present research are the two extreme models, 'policy community' and 'issue network'. Policy communities are characterised by stable relationships of shared beliefs. They have the continuity of a highly restrictive membership and vertical interdependence predicated on shared delivery responsibilities. In particular, this would equate to the regulatory approvals for pesticides. Policy communities are also insulated from other groups, especially the general public. The policy community can be of value to the policy analysts' tool kit because it helps to understand how policy discourse is framed (Grant, 2005). The term 'policy community' would closely equate with the pesticide policy environment in the 1940s, where a small group with common interests (farming, pesticide industry, government and academic experts) were brought together by the state to develop and use pesticides – the 'pesticide policy community' which in effect supports a pesticide policy paradigm. This community was also isolated from outside pressure, particularly the general public which largely held an uncritical view of pesticides.

Since the 1960s the pesticide policy community has been challenged by policy positions from civil society public interest groups that were, in essence, fundamentally critical of the pesticide policy paradigm. The pesticide policy community then became subsumed by what (Rhodes and Marsh, 1992) termed an 'issue network'. This is characterised by a large and diverse number of members with a limited degree of interdependence. There are fluctuating levels of contacts, less agreement among the members and unequal echelons of power.

The terminology in this field is confused. The literature sometimes defines 'policy network' as an over-arching term including policy communities and issues networks (John, 1998: 205). Elsewhere, a policy network is synonymous with 'issue networks' (Hill, 1997: 72). For the present research however, the Rhodes' definition of the term 'policy network' is used in the conceptual framework. The less integrated pesticide issue network still includes the regulatory process of the old policy community. It has been joined by a non-regulatory element, such as public interest groups.

For the pesticide regulator, this transition meant less direct governmental control for wider pesticide policy. One example of this is the Voluntary Initiative,[24] which is organised and run by the pesticide industry rather than by the UK government. The present research argues this process reflects the evolution of what Majone (1993) describes as a 'regulatory state', in which a new policy style is emerging, where the government's role as a regulator advances while its role as a direct employer may decline through bureaucratic downsizing and privatising. Other researchers have described the regulatory state as 'steering rather than rowing' (Osborne and Gaebler, 1992: 35 cited in Moran, 2002: 414). Moran concludes that this is done in order to reduce the likelihood of catastrophic strategic decisions by the 'pilot on the bridge' and to "improve the work carried out by the crew" (Moran, 2002: 415). For pesticides the 'crew' along the food supply chain is having to elaborate a multiplicity of policy initiatives emanating from the pesticide industry, food retailers, and other agents apart from, and in addition to, the main UK regulator PSD.

The Rhodes and Marsh (1992) model for analysing policy networks assumes that three key variables determine the type of policy network:

- The relative **stability** of a network's membership
- The network's relative **insularity**
- The strength of **resource dependencies**

Stability refers to whether the same actors of the network dominate decision-making, or whether its membership is in a state of flux, and/or issue-dependent. For insularity, the question is, if outsiders are excluded, is there access for actors with different objectives? Resource dependency is determined by the extent to which members of the network depend on each other for valued resources such as money, expertise and legitimacy or whether most actors are self-sufficient?

For the pesticide policy network, the third variable is particularly important. There are no direct resource implications for civil society organisations because they do not use pesticides on a professional basis. They also have fundamental concerns about the pesticide policy paradigm with which they have to engage. On the other hand, the pesticide industry and the regulatory bodies all have powerful resource dependency.

24. An attempt by the pesticide industry to reduce the environmental side effects of pesticides (see Vol. 1, page 240,).

As with many other areas of policy the regulation of pesticides is increasingly being addressed at the European level. The evaluation and authorisation system of pesticide active ingredients in the UK, and the other Member States, is gradually being taken over by the European Union through the adoption of Directive (91/414).

A recent series of stakeholder meetings on EU governance and food safety highlighted the difficulties surrounding the interplay between actors involved in the risk analysis process. The shaping of interactions between political decision-makers, scientific experts, and corporate and civil society actors throughout the governance process presents a major challenge. The problems include balancing the involvement of different actors around a complex array of food safety issues with high levels of scientific uncertainty (Dreyer and Renn, 2007). At their conclusion, these meetings identified the following as drivers to the debate around governance:

- Interaction of risk assessment and risk management
- Scientific uncertainty
- Societal concerns and stakeholders' engagement in food safety and governance
- Transparency and accountability.

In a wider context, but still relevant to pesticide policy, public policy analysts Coen and Thatcher (2008) have examined the European networks for a wide range of industries. They conclude that the newly created European agencies have been given a wide range of tasks and broad membership, but enjoy few formal powers or resources. They are highly dependent on the European Commission and face rivals (in the form of other relevant national regulatory agencies) for the task of co-ordinating European regulators. Thus, in institutional terms, the spread of network governance has in fact been limited (Coen and Thatcher, 2008). There are also complexities with the dual regulatory role involving the EU institutions and the Member States. This means it is important to examine the workings of the EU as a whole, in order to place the particular development of pesticide policy into a wider theoretical perspective. The European Union is however a complicated operation that is not easy to explain theoretically. This is accentuated by the fact that when the pesticide authorisation Directive 91/414 was negotiated there were only 12 Member States. Now there are now 27 Member States, many of which have to make sure their pesticide regulatory processes have caught up with the original 12 members. Even though the EU is recognised as the most successful example of institutionalised international policy co-ordination, there is at the same time little agreement among academic scholars to explain its development. European integration was described by the theorist Stanley Hoffman as 'complex and messy' (Hoffman, 1983: 21). During its 50 year history there have been many academic theoretical models which have, in their own way, helped to explain the operation of EU decision-making policy.

Multi-level governance theory emerged during the 1990s (Marks et al., 1996). The model asserts that Member States no longer monopolise European level policy-making, or the aggregation of domestic interests. Decision-making competencies are shared by the policy actors at different. That is to say, supranational institutions, and in particular the European Commission, the European Court of Justice, and the Parliament, have independent influence in policy-making that cannot simply be derived from their role as agents of Member States. Furthermore, under multi-level governance, states do not monopolise links between domestic and European actors; there are a variety of transnational associations that are made at different levels. Complex interrelationships in domestic politics do not stop at the member state level, but extend to the European level. Here, multi-level governance as discussed by Marks et al. (1996) has relevance for pesticide policy. A wider European Regulatory Network (ERN) governance has developed involving a decision-making process for pesticides which is shared between the EU and member state regulators, although the framework agenda is set at the EU level. It involves the complexity of the UK (Member State) regulation processes, the European Commission, European Parliament (for overall policy and law making only), and the European Council. The creation of the European Food Safety Authority further complicated the process by taking on the technical role for pesticide risk assessment whilst the political risk management responsibility remained with the European Commission (what van Zwanenberg and Millstone (2005) call 'inverted decisionism').

The term policy network has also been used in vague terms to explain the more detailed workings of the European Union, as opposed to neofunctionalism (Hass, 1992, Lindberg, 1963) and liberal intergovernmentalism (Hoffman, 1983, Moravcsik, 1993). It does not cover the 'big history-making' decisions, such as treaty establishment or reform, debated between the member governments, through the powerful European Council. Network analysis is considered helpful in explaining the day-to-day detailed negotiation that goes on (Peterson, 1995). In this context, a policy network has been described as "a cluster of actors, each of which has an interest or stake in a given EU policy sector and the capacity to help determine policy successes or failures" (Peterson and Bomberg, 1999). Policy networks operating in the EU usually include all the institutional players and a range of other stakeholders. European integration, new technologies, cultural changes and global interdependence have led to the creation of a huge range of European (and international) networks. Some have been supported by Community funding for a number of years (European Commission, 2001a). Institutional actors come from the relevant Commission Directorate(s), the Council (which has its own secretariat operating on behalf of member governments) and the Parliament. Often the views vary between, and sometimes within, these various branches. Others include lobby representatives from commercial sectors, public interest groups, research centres, local authorities, consumer and health perspectives, technical and academic experts, unions, and national officials.

Policy network analysis and multi-level governance are important concepts to use for the regulation, policy and control of pesticides. Pesticide policy in the UK has been transformed, moving from control by the nation state, such as the UK, to governance through the European Union. These concepts help explain why the pesticide network networks has become more diverse both vertically and horizontally. Vertically, the chain of command controlling pesticide regulation and risk analysis has diversified, encompassing the UK and EU systems. Horizontally, new non-state actors have joined the network with a range of diverse fundamental views about pesticides.

2.4. Conceptual framework: Changing from a pesticides policy paradigm to an ecological pest management paradigm?

This section collates and summarises the starting assumptions for the present research, locating the particular research proposition within the broader context of theory from the academic literature. As a result of literature research and analysis of theoretical work the proposition of this thesis is that the current dominant 'pesticide policy paradigm' is being seriously challenged. At the same time the impacts of the dominant paradigm act as a constraint on the emerging ecological pest management paradigm. The framework has been divided into four interlinked components. The first defines what is meant by a pesticide policy paradigm. The second addresses risk analysis. The third addresses policy networks and governance. The fourth examines the paradigm shifts. Elements of the risk assessment implications have been incorporated into the paradigm and policy network concepts. Each component is complemented with a table that summarises the main concepts on which the present research draws and from which reference has been made elsewhere in the text. For each concept, relevance and limitations (if relevant) are listed followed by assumptions that are subsequently derived.

2.4.1. Understanding of a pesticide policy paradigm for the present research

The use of synthetic pesticides provides the dominant method of pest management within conventional agricultural production. The present research puts forward the term 'pesticide policy paradigm' as a concept to describe a mode of pest management that is actively driven and maintained by its own integrated community. The paradigm which emerged during the 1940s is referred to in the present research as a 'pesticide policy paradigm'. Although there are loose references to a 'pesticide paradigm' in the literature, the term 'policy' has been specifically added to denote the importance that the pesticide policy community has in supporting pesticide use and on the development and trajectory of the paradigm. The trajectory denotes the fact that the paradigm has had to change incrementally over the decades since the 1940s in order to respond to the hazardous nature that pesticides present to human health and the environment.

Kuhn's scientific paradigm related to a set of beliefs and a way of working within scientific communities. For the present research, the concept relates to a broader community of largely commercial institutions, practices, companies and markets interested in sustaining this dominant method of pest control. This community also had a common set of beliefs that relied on scientific research devoted to the development of synthetic pesticides, to be carried out and utilised in certain standardised series of ways. Instead of 'scientific communities' a paradigm for the present research relies on a 'pesticide policy community' that shares the same beliefs and preconceptions that support the premise that synthetic pesticides are an indispensible part of conventional agriculture – hence the 'pesticide policy community'.

For pesticides, the present research is suggesting that the policy community encompasses pesticide manufacturers that provide pest management solutions based on synthetic chemistry. A chemical is developed to control a pest species, or group species within the framework of conventional agriculture. For the agricultural context this means the provision of a range of products, typically 10-20 for any one crop. Assessing the risk posed by pesticides requires the development of a risk analysis process within the private (manufacturing sector) and the public regulatory process.

Synthetic pesticides developed during and immediately after the Second World War were more effective than any other existing pest management options, and became the dominant technology of the time. The technological paradigm could be useful here because it took the scientific paradigm of Kuhn and applied it to technological development. The starting assumptions of the present research are that synthetic pesticides represent a 'locked in' technology and are vital for the continuance of intensive agriculture. The lock-in has occurred for the pesticide policy because this technology presents risk (health and environmental) as well as benefits (economic) to the food supply chain that relies on conventional agriculture. Today the pesticide policy paradigm is still dominant, but has had to develop and change in order to deal with the adverse effects or risks. As a result what might be considered as a 'pesticide technological trajectory' [analogous to Dosi (1982)] developed to sustain the continued use of pesticides. In order to follow this path, an integrated group of actors is required that broadly have the same set of beliefs. Within the paradigm there is demand from the supporting 'policy community' to produce, as near as possible, the 'perfect pesticide' – that presents zero risk. For these actors, it is important that the products are efficacious and safe. Defining how these products are safe and effective is at the crux of pesticide use, and could equate to the 'normal science for pesticides'. Normal science represents the tests and procedures by which efficacy and safety are demonstrated. Efficacy means that pesticides attain their intended consequence – to control pests in a way that does not cause economic injury. From the farmer through the supply chain to the customer, there has to be trust and confidence that the pesticide products are safe. In order to resolve this, a battery of pre-market tests has to be carried out in consistent fashion. In order to defend the continuation of the policy paradigm, a set of rules (voluntary at first) had to be established and maintained by the policy community. Any contradiction of the processes of normal science within this process would result in a threat to the paradigm itself which would in turn threaten the development of conventional agriculture.

As per Kuhn's discussion, paradigms gain acceptance because they are more successful than their competitors. But they never explain all the facts with which they are confronted. In the same way, the pesticide policy paradigm is not always successful (e.g. in presenting zero risk, or avoiding scientific or policy controversy). Concerns about adverse occupational health threats, environmental pollution and risk to bystanders and residents have consistently been raised by civil society since the early 1960s. In response, the government, the pesticide industry, agricultural workers and food retailers have repeatedly had to re-assess the hazards posed by pesticides and act through a range of regulatory measures, in order to reduce the risk of adverse outcomes. This has led, on the one hand, to the creation of a relatively large regulatory agency in the UK (of around 180 scientific, policy and support staff) (PSD, 2008b), and, on the other, to a diminishing number of multinational companies with the financial resources to research and maintain the development of chemical pesticides. Both the UK government and the pesticide industry have relied on assurances of the safety of pesticides provided by scientific expert opinion. It is important to capture and describe these changes in order to understand and explain how they have evolved.

The present research hypothesizes that a 'pesticide policy paradigm' institutionalises the continued governance of synthetic pesticides in the UK (and internationally) as summarised in Table 2.1. The rationale for this conceptual framework is based on a review of relevant social science literature combined with a review of the historical and technical development of synthetic pesticides. It explains why the word 'paradigm', as discussed in the previous section, has relevance for pesticide policy. Furthermore, Table 2.2 which highlights the starting assumptions for a pesticide policy. The features and requirements for such a paradigm have been postulated from the text.

Table 2.1: Overview of paradigms for pesticide policy

Paradigm models and related terms...	Relevance for the present research...	Divergence/limitations for the present use...	Starting assumptions for pesticide policy paradigm...
Scientific paradigm[1] • Normal Science	• Shared set of beliefs • standard ways of working • a set of experiments to be repeated • Never does explain all the facts with which it can be confronted	• Limited to scientific communities	• A pesticide policy community includes a group wider than a scientific community including the food supply chain, regulators
Technological paradigm[2] • Technological clusters • Technological trajectories	• Selected technological problems based on selected principles based on natural science. • Trajectories develop path-dependent 'lock-in' where past activities have implications that have lingered decades into the future. • Trajectories take into account change over time. • Researchers have used agrichemicals (pesticides) as a subjective example of technological paradigm and trajectories.	• Tends to be analysed from the technological perspective only • Does not take into account food supply chain factors, governance and regulation	• There is a perceived need for chemical technology in which problems (pests) require the synthesis of a chemical for solution • The pesticide policy paradigm follows a technological trajectory to signify changes over time
Technological paradigms (specifically relating to pesticides)[3,4,5,6,7,8]	• Technological paradigm has been used to describe agrichemical (ie pesticides) innovation • Pesticides represent one of the technological clusters that follow particular pesticide technological trajectories	• Tends to be analysed from the perspective of agrichemical innovation which has followed a GM path • Does not take into account food supply chain factors, governance and regulation	• These assessments provide useful examples and insights into the processes of pesticide development
Policy paradigm[9] • Normal policy-making	• Recognises that institutions have an important role in the development of a paradigm. • Normal policy- means that policy changes occur within existing institutions.	• Does not take into account policy network in which some stakeholders criticise the fundamental paradigm.	• Policy community defends the pesticide policy paradigm

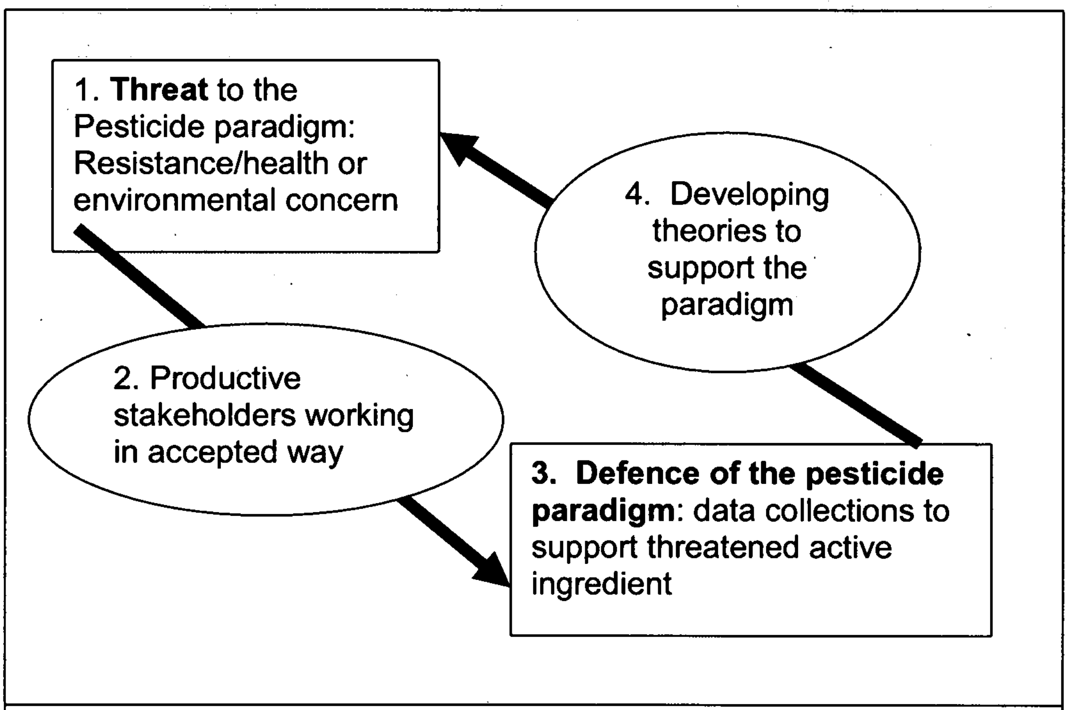
Sources for Table 2.1: Kuhn, (1970); 2. Dosi, (1982); 3. Hartmell (1996); 4. den Hond (1998); 5. Joly and Lemairé (2002); 6. Chataway et al. (2004); 7. Tait et al. (2000); 8. de Buck et al. (2001); 9. Hall, (1993).

The 1940s dominant views of pesticide manufacturers, users and regulators were encapsulated by DDT which was seen as a 'miracle cure', and a 'safer alternative' to what went before. Today, DDT is banned in most countries of the world. The remaining uses are restricted to public health malaria control programmes in a few African countries. Problems with resistance and with undesirable health and environmental effects are now widely recognised – but in the 1940s they were not. The emphasis was focussed around the individual chemical active ingredient, and its development for pest control as part of a process that was aspiring towards greater efficacy and security of food production. The chemical products were easy to use, delivered quick results and were economical to use. They were produced by a chemical industry that had the finances to research and develop new pesticide products. A protocol for pesticide analysis developed in order to provide scientific data on which to justify the continued used of the chemical products.

It is also important to include the stakeholders as an active part of the make-up of the pesticide policy paradigm. The present research proposes that there is a group of stakeholders who maintain the paradigm, the conditions of which are in a constant state of flux, but within the confines of 'normal science for pesticides'. One could consider that the paradigm is flexible and those stakeholders maintaining it have to respond to the pressures put upon it, in order that the paradigm can be defended and sustained (as outlined in Figure 2.4, Vol. 1, page 39). Therefore the term 'pesticide policy paradigm' has been put forward to denote what was originally a small and strong policy community that worked to support an emerging pesticide policy. Derived from 'policy paradigm' as outlined by Hall (1993) (see Section 2.2.1), the phrase acknowledges that the paradigm is highly reliant on an integrated group of stakeholders (policy community) who work according to common interests – use and development of pesticides. Its members act within a framework of common ideas – the paradigm – and can be described as 'productive stakeholders'. From the 1940s, it could be argued that these stakeholders have been part of the pesticide policy community with an active interest in the production and use of pesticides. Productive stakeholders included the conventional farming industry, the pesticide industry, the government regulator and, to a large extent, expert advice.

In this way a 'scientific paradigm' as outlined by Kuhn (1970) was developed in order to continue the development and use of pesticides as a vital component of conventional farming. In this sense it can be seen that without the paradigm, the dominant form of agriculture would be threatened and also the security of food supply that ensues. For a productive stakeholder, the protection of the paradigm is paramount, if it is challenged. This is why the paradigm framework can as it were 'afford to lose' a limited number of individual active ingredients (through a regulatory ban), as long as these measures do not completely undermine the paradigm *per se.* If an institution/individual supports intensive conventional agriculture then one has to support the pesticide policy paradigm. Each time there is a threat to the pesticide policy paradigm because of a health or environmental factor, it leads to a defence which takes the form of the generation of more data and/or more regulation or policy instruments, as outlined diagrammatically in Figure 2.6. This Figure shows the response to one threat; say, for example, the discovery that a group of pesticides causes a high hazard to honey bees. Here the productive stakeholders would work to mitigate the problem (eg restriction in product application) that supports the paradigm. However, this would solve the particular problem, until another threat occurs – such as high levels of a pesticide occurring as residues in food. To solve this problem, the same process in Figure 2.6 could occur again. In this way it might be seen that a repetitious cycle of 'threats and defence' occurs over time relating to a whole host of health and environmental problems for pesticides that might occur. In these cases the productive stakeholders of the policy community have had to adapt to new challenges presented by the risks of pesticides.

Figure 2.6: Threats and defence for a 'Pesticide policy paradigm'



Key: This figure describes the way in which pesticide characteristics (in square boxes) interact with the paradigm characteristics (in the oval boxes) to protect the pesticide paradigm. It is suggested that the arrows indicate a 'response flow' between a threat (box No.1) that leads science-based productive stakeholders (oval box 2) to defend of the paradigm (box 3.) who then develop theories to stop the problem occurring again (oval box 4).

There are also important geographical components to the paradigm. The focus of the present research is UK/EU based, and embraces one of the main countries in which the paradigm developed. But at the same time, it grew globally with the development of a multi-national pesticide industry headquartered in countries such as France, Germany, Japan, UK and US.

It is suggested that the paradigm grew internationally because the chemical industry was able to develop and market pesticides that controlled pests in almost every country across the globe. It could be suggested that, in order to defend the paradigm, international and regional standards would be mutually agreed within the wider pesticide policy community to allow globally compatible trade in agriculture goods. The implications for pesticide residues in food link international pesticide agreements, through FAO/WHO, to the wider network of food and commodity trade.

2.4.2. Generalised features of a pesticide policy paradigm?

The boundaries of a paradigm for pesticides are difficult to describe, as pesticides are by their nature, a means to an end. They are a key ingredient, or input, into conventional agriculture to agricultural production. But for most (apart from those who make or sell pesticides), food is the end product rather than pesticides. For the purposes of the present research, the boundaries of the paradigm are assumed to be broad and represent all the actions and activities around the discovery, development and use of pesticides in agricultural production. This includes the research and development by pesticide companies, pesticide regulation and use through the food supply chain. It also includes the social, environmental and economic constraints and opportunities of the pesticide policy network. The action and activities also relate to the adverse effects of pesticides as well as their activity as pest control agents.

Threats to the continued use of pesticides are considered to put pressure on the paradigm. It is important to clarify what this means for the present research. Pressure occurs when there is a challenge to normal pesticide science or normal policy. This can take the form of scientific research data which question the safety or efficacy of a pesticide (or group of pesticides). A few examples are cited here, with more details provided throughout Chapter Four. Attempts will be made by one or more members of the pesticide policy community[25] to accommodate the scientific data with one of four outcomes:

25. This may come from the scientific community, pesticide industry, or regulatory sector.

1) The data may be rejected as not significant in which case no further action will be taken.

2) The data may be accepted; whereby action such as the banning of a single problematic pesticide will occur. This would constitute a normal policy response which is accommodated within the paradigm.

3) The data may be accepted; but in circumstances in which a normal policy response cannot occur, in which case the problem is 'parked' for future resolution. This could include the lack of consensus around a safety testing protocol such as endocrine disruption.

4) The data may be of fundamental concern, all pesticides are unsafe. This scenario is considered by the pesticide policy community as very serious and is avoided at all costs. The loss of the paradigm would result in significant changes to agricultural practice away from conventional agriculture – a revolutionary shift in pest management practices coupled with change in general agricultural practice.

Step one would count as an evolutionary change or normal activity. But the incremental shifts and cumulative effects of a series of incidents analogous to step 1), combined with the consequences of not dealing with step 2), will eventually lead to step three. For example, if more pesticide products are coming off the market than those going on, eventually the paradigm will fail. Pressure on the paradigm relates to the relative accumulation of data covered by step one and step two.

Table 2.2 Starting assumptions for a pesticide policy paradigm

Features	Requirements
Shared set of beliefs	Integrated pesticide community (regulatory and supply chain) willing to provide political support
Need for synthetic chemical technology in conventional agriculture	Integrate pesticide community with the economic capacity to discover pesticides, to register them with the regulatory, and marketing them with wider social acceptance
Needs guarantees of health and environmental safety	Requires a regulatory process and national pesticide policy
Needs guarantees of economic return	Requires efficacious products regulatory process and commercial acceptability). Patents and confidentiality are important economic factors
Geographical location	A global market for sales to provide a high return on R&D
Change over time	Unintentional effects require monitoring and handling resulting in increasing legislation
Links with sustainability	Need to demonstrate low impacts
Links outside the paradigm	Pesticides are a means to an end

Note: It is important to know what happens when the features are challenged.

Table 2.3 summaries the research starting assumptions for the UK pesticide policy network in which stakeholders maintain and/or challenge the pesticide policy paradigm. The Rhodes and Marsh (1992) typology in which policy networks are used generically is useful. For the present research, there is just one pesticide network, but its constituents have changed considerably over the decades since world war two. This means that the terminology used here to describe the pesticide policy network, over time, has changed too. Over these periods there are different terms to describe the network, and its constituents.

This change is related to the suggestion that the pesticide policy paradigm has also changed and adapted over the same period. This is because there have been a number of threats to the paradigm which have been defended by the 'productive stakeholders'. These include technical constraints on pesticides such as the development of resistance by pests. The consideration is that agricultural policies which previously supported production have diminished. At the same time, 'critical stakeholders' (as opposed to productive stakeholders) have emerged who have to varying degrees attacked or challenged the pesticide policy paradigm because of incremental concerns about the health and environmental effects of pesticides. The present research argues that a restricted policy community of productive stakeholders emerged from the 1940s to support the use of pesticides. It developed into an 'issue network' comprised a lose collection of actors and organisations. The newcomers include organised civil society, public interest groups, and organised sectors of the scientific community. There have also been critical reports from independent bodies such as the Royal Commission on Environmental Pollution, who enter the issue network, and who have a type of role similar to an external audit. The argument is made that for the present research, these pesticide critics place extra pressure on the paradigm, and are largely located outside the pesticide policy paradigm. In an extra twist, there have also been critiques from within the food supply chain in the form of food retailers. All of the above mentioned components place additional pressure on the pesticide policy paradigm. The present research also requires a term to describe the critical stakeholders who have joined the contested political territory of the issue network along side the productive stakeholders and their unreconstructed policy community. They are called the 'critical group' (rather than a network) because they tend to act independently maintaining their own political positions.

Table 2.3: Policy network for pesticides

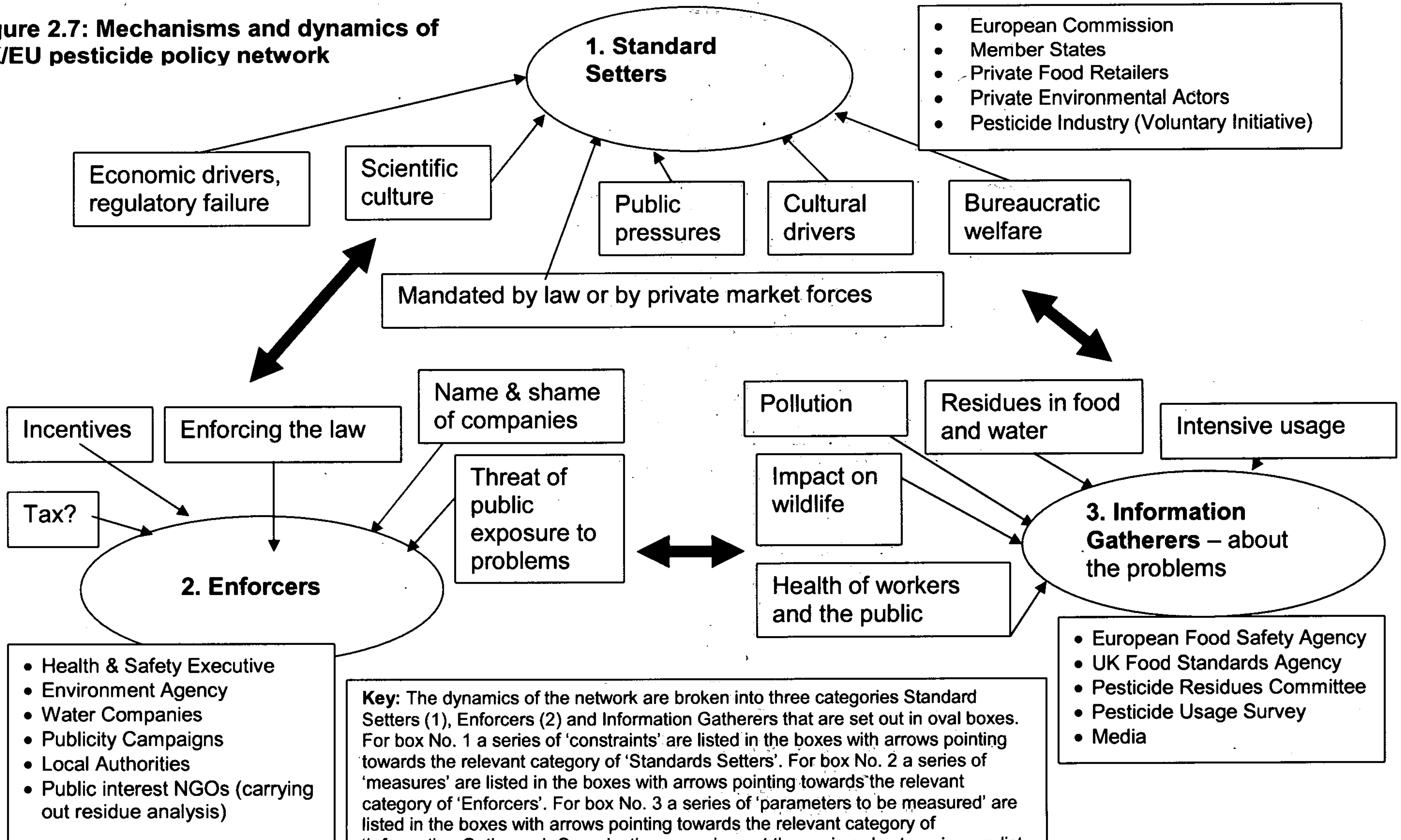
Models and related terms...	Relevance for the present research...	Divergence/limitations for the present use...	Starting assumptions for Pesticide Policy Network...
Policy networks[1]	• Representation of the relationship between interested parties and the government who have a resource dependency	• Is a generic term which needs a subjective definition in the case of pesticides	• A pesticide policy network describes the current UK stakeholder group for pesticides
Policy community[2]	• A policy community represents a group of stakeholders who have a common set of views around one particular policy area such as a pesticide policy paradigm • Contains a highly restrictive membership in which there is shared decision-making	• Such a group no longer represents the totality of the pesticide policy network for the UK	• Such a group was represented by the pesticide policy paradigm in the first few decades post world war two. • The policy community defended the paradigm in an integrated and coordinated fashion
Issue network[3]	• Is a less integrated group of stakeholders, compared with policy stakeholders, which includes members who are critical of common set of beliefs • Represents the current diversity within the network and the more policy-consultation	• Does not specifically prescribe that an issue network contains the two groups outlined in starting assumptions (see right)	• The less integrated pesticide policy network includes the original policy community (of productive stakeholders) that has been joined by an independent 'critical group' of stakeholders
Regulatory state[4]	• Reflects on the notion that the UK government no longer has a command and control function in many regulatory areas	• Is a generic term which needs a subjective definition in the case of pesticides	• Initiatives carried out by the pesticide industry and multiple retailer supermarkets have indicated that the private sector is taking on a partial regulatory role for some aspects of pesticide policy.
Multi-level governance[5]	• The membership of the EU has meant that governmental regulatory roles have to be negotiated between UK and other member states and within the European Union	• Needs to address global assessment of pesticides (eg CODEX)	• Pesticides are regulated through the EU and UK allowing for policy network to be explained in vague terms

Source: 1. Rhodes and Marsh (1992); 2. Grant (2005); 3 Rhodes and Marsh (1992); 4. Majone (1993); 5. Marks et al. (1996).

The stakeholder groups outlined in Figure 2.7 are put forward as the current UK/EU pesticide policy network, from a UK perspective. The figure has been constructed from the current research to help understand where the power lies, and how the various stakeholders interact[26]. It includes a wide array of stakeholders with a range of different interests – a loosely integrated policy network. Figure 2.7 helps identify the stakeholders in terms of the categories of 'standard setters', 'enforcers' and 'information gatherers'. Standard setters can be seen as establishing the criteria by which pesticides are considered acceptable to use or not. Traditionally this has been restricted to the government, but others listed in Figure 2.7 can have a contemporary role to play. Enforcers make sure that the policy and regulations for pesticides are adhered to. A number of organisations are also presented in this category and there is a range of influencing measures presented. For example, the prospect of a pesticide tax may influence purchasing option for operators and therefore their application behaviour. The threat of publishing data about residues in food sold by retailers may have the enforcement effect of changing pesticide use behaviour through the food supply chain. Finally information gatherers collect and collate data that can have implications for enforcement (such as when legal limits are exceeded) and for standard setters (when assessing the significance and acceptability of data gained). This process is useful because the roles of the stakeholders have changed and/or emerged over time. Critical stakeholders may have enforcer and information gatherer roles that run parallel to (and possibly contrary to) that of the regulator. Some multiple food retailers also have new roles as enforcers because of their company pesticide policies. These 'command and control' functions, traditionally carried out by government involve all other players to some degree. For pesticide regulation at the UK level, network governance has been limited, however, as responsibility remains with the government department (MAFF/DEFRA) rather than with the independent regulatory agency (the Food Standards Agency). The lines between risk assessment and risk management are merged, as are the roles between the regulator/ministers, and the expert committee (Advisory Committee on Pesticides). It is clear that there are more than organisation has a role standard setter, enforcer and information gather. This presents the potential for conflict and pressure if the organisations have different perspectives in their category role. These differences could be presented for standard setters because of the measures listed in Figure 2.6. The wider pesticide policy network can and does bring pressure to bear on the current pesticide policy paradigm. Figure 2.8 includes 'standard setters', which highlights the regulatory burden on pesticide producers.

26. These characteristics were developed after personal communication with Dr Henry Rothstein, Centre for Analysis of Risk and Regulation, London School of Economics and Political Science (2005).

Figure 2.7: Mechanisms and dynamics of UK/EU pesticide policy network



Key: The dynamics of the network are broken into three categories Standard Setters (1), Enforcers (2) and Information Gatherers that are set out in oval boxes. For box No. 1 a series of 'constraints' are listed in the boxes with arrows pointing towards the relevant category of 'Standards Setters'. For box No. 2 a series of 'measures' are listed in the boxes with arrows pointing towards the relevant category of 'Enforcers'. For box No. 3 a series of 'parameters to be measured' are listed in the boxes with arrows pointing towards the relevant category of 'Information Gatherers'. Organisations carrying out the assigned categories are list in the boxes with bullet points. The reversible arrows indicate that there are organisational inter-relationships between the three categories.

Source: Author, in discussion with Henry Rothstein, 2005

This burden has created a scientific culture in which the risk assessment element of the risk analysis process is under pressure to deliver acceptability, rather than failure, because of the economic drivers (see Table 2.4). So much research time and development money is spent in the search for new pesticides that regulatory non-approval at a late stage of product development is financially costly for the company registering the pesticide. The pressures of 'regulatory science' and 'resource dependency' come into force here. By default natural science actually has 'double-edge' implications for pesticide regulation. On the one hand it provides legitimacy for the pesticide industry through the regulatory process and assists the detailed active ingredient based safety dossiers to prove acceptability; but on the other it presents liability by casting doubts in quantifying the risks associated with pesticide use, as shown in Chapter Four.

The bureaucratic welfare of the regulatory agency, the Pesticide Safety Directorate (PSD), is partly dependent on pesticide approval fees from the pesticide marketing companies (as outlined in the Standard Setters category in Figure 2.7). PSD's financial interest is dependent on a continual stream of new products from the pesticide industry that it has been set up to monitor and regulate. This resource dependency could place extra pressure on the productive stakeholder element of the pesticide policy paradigm because of the perception of conflicts of interest from critical stakeholders.

The risks posed by pesticides are difficult to quantify. Only a small policy community of industry/government/academic experts understand the mechanisms of pesticide risk analysis. But their technocratic model of risk analysis has failed to convince civil society and some elements of the food chain (food retailers) that their analysis is sufficiently comprehensive. The present research maintains that this is because the UK has resisted following a decisionist or co-evolutionary model of pesticide registration which includes the social, political and cultural aspects of risk analysis. The technocratic model has been challenged by civil society groups for many years. In the last few years, some of its defects have also been challenged by the Royal Commission on Environmental Pollution and even by some members of the expert Advisory Committee on Pesticides. Those challenges added to pressure on the pesticide policy paradigm. The present research proposes that the reason why the risk from pesticides is causing concern is because of uncertainty with the science, and the failure of 'regulatory science' to accommodate the increasingly tough regulatory requirements of the dominant pesticide paradigm. Another reason, which is under-acknowledged, is that the key players in the pesticide policy process (government and industry) have not fully appreciated the social issues raised by pesticide use as outlined in this thesis.

Table 2.4: Overview of risk analysis for pesticides

Models and related terms...	Relevance for the present research...	Divergence/limitations for the present use...	Starting assumptions for divergent risk analysis...
Regulatory science[1]	Demonstrates the pressure regulatory science places on the research and development of pesticides (and other pre-tested substances) compared with academic science.	• Limited to regulatory process and does not encompass wider policy discourse	• Conceptualises and provides a link to one of the key pressures on the pesticide policy paradigm • Over time, relative increase in adherence to regulatory science places corresponding increases to paradigm
Regulatory failure for pesticides[2]	• The increasing burden of 'regulatory science' ultimately lead to regulatory failure of substances that have increasing health and environmental testing requirements on top on of efficacy testing	• There are also external costs of pesticides which place addition burdens on the pesticide policy paradigm	• There are examples in which individual pesticide active ingredients have been taken off the market because the cost of regulating them
Technocratic model[3]	• Describes the way in which science based risk assessment approach dominates a risk analysis-regulatory framework	• Is limited to the risk assessment of science/policy debate whereas present research is also interested in wider pesticide network	• Close correlation between the way that this model characterises the traditional way in which pesticides have been regulated in the UK
Inverted Decisionist model[4]	• Describes the way in which risk assessment and risk management should be separated within a framework	• Only addresses risk analysis decisions, and not wider policy discussion	• Close correlation between the way that this model characterises the traditional way in which pesticides have been regulated in the EU
Societal risks[5]	• Societal risks exposed the limitations of the regulation of risk inherent in the uncertainty with the science compared with the high expectations of the wider society		• The uncertainties in estimating pesticide exposure scenarios, and sceptical view from the general public and NGOs lead to the prospect of 'societal failure' for pesticides
Precautionary principle[6]	• Allows action prior to availability of full scientific knowledge • For uncertainty, hazard cut-off criteria and sound judgement to be incorporated into the regulatory process	• Various definitions and interpretations exist • Differing subjective views according to stakeholder views	• Allows for the establishment of hazard trigger values for pesticides on which precautionary principle can be invoked

Sources: 1. Irwin et al. (1997); 2. Den Hond (2003); 3. Van Zwanenberg and Millstone (2005); 4. Van Zwanenberg and Millstone (2005); 5. Rothstein et al. (2006); 6. Many authors, especially UNEP and EC.

Public interest groups do not have direct commercial interest and dependence on pesticides and therefore have nothing to lose by advocating restriction on the use of pesticides. They are however in a difficult position because they are observers, and have to convince others in the network to do what they say. In order to have influence and take the opportunity to raise concerns, they have to some extent joined the network. Within the public interest NGOs it is moot point what level of discussion there is with the pesticide industry, if any. Traditionally public pressure groups see some degree of risk of pesticides in terms of absolute hazards to be avoided rather than accepting exposure to hazards that can be risk mitigated. Pesticide use is still subject to a raft of UK and EU regulations, but multiple food retailers are adopting their own additional measures to reduce environmental pollution and pesticide residues in food, although they are still reliant on a food supply chain that largely relies on pesticide use. This represents further evidence of the widening of the policy network from a relatively restricted policy community to a more open policy network (comprising of a policy community of productive stakeholders and an issue network of critical stakeholders) along the lines of Rhodes and Marsh (1992). The market power of the food retailers has meant that their supply chain growers and suppliers have had to comply. This move could have important implications. These new critics are 'productive stakeholders' who it could be argued have added extra pressure to the pesticides policy paradigm by changing the dynamics of the network.

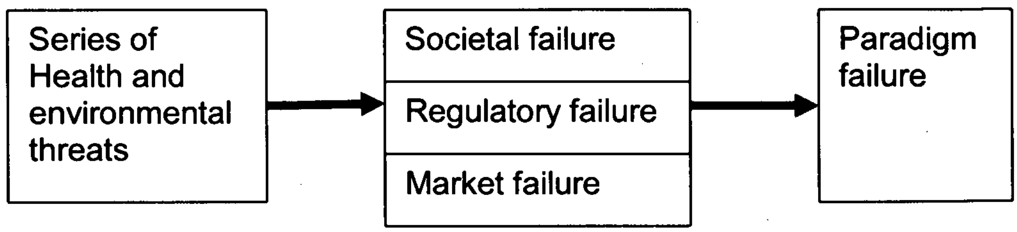
The pesticide policy paradigm operates at a national, regional and global level. For the European Union (EU) the situation is different from the UK. The impact of the spread of policy network and governance has been to weaken and dissipate power among the regulatory institutions. The regulatory outcome of this has been an increase in the restriction of pesticide active ingredients, a longer period for approval assessment, and longer periods of deliberation before new regulation and policy measures come into force.

There is an important inter-relationship between regulation and approval of pesticides on the one hand, and pesticide policy on the other. The present research framework agrees with the van Zwanenberg and Millstone notion of a 'co-evolutionary' model for pesticide regulation – that is the science and policy need to be explicitly and effectively inter-related. The present research suggests that there is a different approach to pesticide risk analysis in the UK compared with the EU (see Sections 2.2.2-3).

Enforcement has traditionally been a function of government through its role in implementing regulations and policy. However the shift towards pesticide governance is reflected in the incentives that the private sector can offer through voluntary market-led measures. Naming and shaming tactics (e.g. naming food retailer outfits that sell food items contaminated with illegal pesticide residues) used by civil society groups and accessed via the media can have lasting impacts on pesticide reduction policies. For 'information gatherers' (see Figure 2.7) the diagram reflects the diverse range of monitoring that is required to ensure that non-point source pollution (referring to widespread pollution originating from many sources) is reduced to an acceptable level. In all cases the level of monitoring is limited by the size of budgets available, and therefore baseline data on the residue levels of pesticides in food and the environment is difficult to establish.

The following section focuses on the idea that the pesticide policy paradigm is threatened with ultimate failure (see Figure 2.8). Growing concerns about the health and environmental effects of pesticides have led to increasingly sceptical views from civil society that have not been reassured by government and food chain stakeholders supplying food sourced from conventional agriculture. This has produced a societal challenge to the paradigm which the present research is calling 'societal failure'. This is a threat to the basic beliefs that support the pesticide policy paradigm. This, in turn, threatens trust both in the processes and in the outcome of the paradigm, which makes it increasingly difficult for scientific advisors to inform and allay that lack of trust and belief. The societal failure is not in itself catastrophic for the paradigm, but the response from the food chain supporters of the paradigm is to increase the regulatory burden which will eventually lead to 'regulatory failure' for the pesticide policy paradigm – when the cost of regulating pesticides exceeds the long-term financial return to the company from sales. The few remaining companies that have the resources to register a pesticide have had to develop large regulatory affairs departments that specialise in product approval. In the UK a large regulatory agency has been constructed to oversee the registration applications, which relies partly on contributions from the pesticide industry to fund its work. But the number of new active ingredients entering the market, and in effect the pesticide policy paradigm, is fewer than the number being banned and taken off the UK/EU market. The consequences of regulatory failure in turn lead to wider 'market failure' for the pesticide paradigm as a whole as the number of companies with resources to develop new pesticides dwindles to nought. At this point, when the all three failures have occurred, the research proposes that pesticide paradigm has failed, as illustrated in Figure 2.8). Working against this are the productive stakeholders, the old 'policy community' elements of the pesticide policy network, who remain supportive of the pesticide policy paradigm and assist in its resilience.

Figure 2.8: The processes that threaten pesticide policy paradigm



Key: The process that can lead to the failure of the paradigm flows from left to right as indicated by the arrows. Societal failure (which includes many factors) leads regulators to increase the regulatory burden (costs and technical) which precipitates market failure in which the cost of regulation exceeds the financial return from pesticides sales.

Source: Author

2.4.3. Paradigm shift

The present research is examining two paradigms, the dominant pesticide policy paradigm and the prospects of an emergent ecological pest management paradigm as summarised in Table 2.5. Technologies such as GM are part of the pesticide paradigm, because they have so far been mainly designed by the pesticide industry as complementary to their pesticide interests. The pesticide policy community has acknowledged them as such. The ecological pest management paradigm on the other hand requires fundamental shifts in the institutions of the pesticide policy community in terms of research and operational deployment throughout the food supply chain.

One way in which some parts of the food supply industry has responded to the threat to the paradigm is to develop and market biological-based replacements. These products are regulated according to the same pesticide policy paradigm, and are in many ways treated in the same ways as synthetic pesticides. This regulatory path has had its challenges, as outlined in Chapter Five. The route taken by the UK regulator (Pesticide Safety Directorate) was to make 'first order' changes, as outlined by Hall (1993) (see Section 2.2.1) and provide a bio-pesticide approval scheme modelled on the more developed synthetic pesticides approval scheme. The state response has been to work within the current paradigm, and reject a radical policy paradigm shift. In this 'first order' response, fundamental institutional changes are not introduced.

Conditions justifying a paradigm shift from synthetic pesticides to an ecological paradigm are extant. The hypothesis of the present research is that a 'third order' policy paradigm shift, as described by Hall (1993), would be required for bio-pesticide approvals so that those products can safely be incorporated into an ecological approach to pest management. The 'third order' approach would entail a radical shift in policy. To achieve it would require fundamental institutional changes throughout the food chain, and across government departments.

A switch away from conventional agriculture would be required given these would have to be global because of the global food supply chain. Although the regulatory risk analysis could take place in a co-evolutionary model, this model would have to exist in a paradigm which has shifted from a pesticides policy paradigm to an ecological pest management paradigm. This is different from the Van Zwaneberg and Millstone (2005) situation in which they discuss risk models within the same paradigm. For them the paradigm is a constant, examining risk analysis of an unintentional consequence (BSE) within an intensive agricultural production system.

The problem with the PSD approach is that synthetic pesticides are replaced with bio-pesticide on a product-by-product basis. This fails to take into account the different ecological impacts of biologically derived products. It also has a bearing on their sustainability status because they can be used in a range of agricultural systems (from very intensive to the least intensive forms of farming). The change from a product substitution approach to a more ecological pest management framework would require major institutional changes for the regulatory, the advisory and the food supply chain sectors in order to deliver ecological pest management. For this sort of paradigm shift there needs to be a change to normal policy making. Given the entrenched position of the pesticide policy paradigm, the prospects of a shift would first require a fundamental political change to such policy making. Additionally, ecological pest management would encourage wider stakeholder input into the pesticide policy network, including critical stakeholders, as described by Irwin (1995) as 'citizen science'.

Table 2.5: Overview of prospects of a Shift to Ecological Pest Management Paradigm

Models and related terms...	Relevance for the present research...	Divergence/limitations for the present use...	Starting assumptions for Divergent Risk Analysis...
Paradigm shift[1]	• Anomalies undermine the basic set of principles	• Limited to scientific communities and scientific research	• Provides basis for a community with a different set of beliefs
Alternative paradigm for bio-pesticides[2]	• Called for a new alternative paradigm for bio-pesticides because alternatives had been poorly developed with the pesticides policy paradigm	• Limited to bio-pesticides – excludes non-chemical forms of pest management	• Shows how the development of bio-pesticides have been stifled by synthetic pesticides – the dominant paradigm
Strategic niche management[3]	• Barriers to alternative technologies are prevented because current technological regimes are locked in • Niche management provides spaces for new technologies to be developed	• Limited to bio-pesticides – excludes non-chemical forms of pest management	• Provides a link to the specific barriers that places extra constraints on the development of bio-pesticides: legal, economic and agronomic
Citizens science[4]	• Describes how society might move in terms of societal response to technological responses and health & environmental threats	• Covers wider policy areas • Difficulty engaging wider society on risk posed by pesticides	• Has the potential to incorporate wider societal views in pesticide regulation
Greener Science[5]	• Greater value is given to areas of science such as ecology which consider the environment in its broader context	• Need to focus on pest management	• Would work well with
Third order policy paradigm[6]	• Encapsulates a significant departure in policy goals based on a new theoretical framework	• Not previously applied to pesticides	• Fundamental change in policy structure is required for shift to occur
Sustainable farming systems require paradigm change[7]	• Integrated in the goals and objectives of farm management to adopt sustainable farming systems would require a paradigm shift, rather than working within the existing system	• Controversial view: many within conventional food supply chain consider to be farming sustainably	• Recognises that 'sustainable farming' is contested territory
Ecological Engineering[8]	• The terms 'ecological engineering' and 'genetic engineering' are two approaches with many points of contrast in terms of principles (ecology versus genetics), maintenance costs, public acceptability, and level of current use.	•	•

Sources: 1. Kuhn (1970); 2. Gaulger (1997); 3. Kemp et al. (1998); 4. Irwin (1995) 5. Wynne and Mayer (1993); 6. Hall (1993); 7. De Buck et al. (2001); 8. Altieri et al. (2004) adapted from Mitsch and Jørgensen (2004).

2.5. Conclusions

This chapter has drawn together some of the social determinants that frame pesticide policy and governance. In conjunction with the literature reviews a conceptual framework for this current research is presented. The concept of 'paradigm' links in with the way in which pesticide policy has developed. Called the 'pesticide policy paradigm', it exists to justify and manage the continued use of pesticides within conventional agricultural systems. The institutional and personal agents within the pesticide policy network that play an active and institutionalised role in the process are named by the present research as 'productive stakeholders'. They support and defend the paradigm because of the perceived economic rewards from pesticide usage and they are locked into a mutually reinforcing resource dependency within the pesticide policy network. Technical constraints and the growth of critical stakeholders have increased pressure on the paradigm. This group of critics has challenged the ideas and beliefs of the paradigm, because of their fundamental concerns about the sustainability of pesticides, and their desire for an ecological response to pest management. The complexity of the network is reinforced by the multi-level governance of pesticide policy (see Figure 2.8). The command and control elements of the network have changed, as new policy enforcers (multiple food retailers) have emerged in the private sector. As former and solely 'productive stakeholders', their emerging criticism places a new pressure on the paradigm. They now have a dual role as both productive and critical stakeholders. Many of their growers and suppliers still rely on pesticide use, but there is an acknowledgment that there are serious problems with the paradigm, including over reliance on the technocratic model. The technocratic nature of pesticide regulation is highlighted and compared with a co-evolutionary model that incorporates science with policy in a way that includes both democratic and scientific legitimacy. For pesticide policy this includes an ecological pest management approach in which the unsustainable nature of pesticides is addressed in a way that fundamentally challenges the pesticide policy paradigm.

The present research suggests that the pesticide policy paradigm has produced a series of failures which, acting together may prove catastrophic for the paradigm. Firstly, societal failure has threatened the beliefs that support the paradigm that has eventually led to regulatory failure, where the cost of regulating pesticides exceeds the financial return to the company. Eventually the consequences of regulatory failure could lead to market failure, where the cost of regulating pesticides across all companies could prove excessive. At this point the paradigm could fail.

The present research further suggests that a 'third order' paradigm shift will be essential to provide a viable ecological pest management paradigm. Elements of an ecological pest management paradigm are already emerging, but they are still constrained by a failing pesticide policy paradigm.

The findings in subsequent chapters provide for a more thorough testing of the framework from which research conclusions can be drawn.

Revised questions from the conceptual framework:

- Is a paradigm useful in describing pesticide policy and developments?
- Is it meaningful to talk about a pesticide policy paradigm?
- Conflicts between paradigm and policy network – what happens when shared beliefs are criticised – the roles and risks and who manages them and how?
- Paradigm shift: revolution or evolution?

3. Methodological approaches to the research process

3.1. Introduction

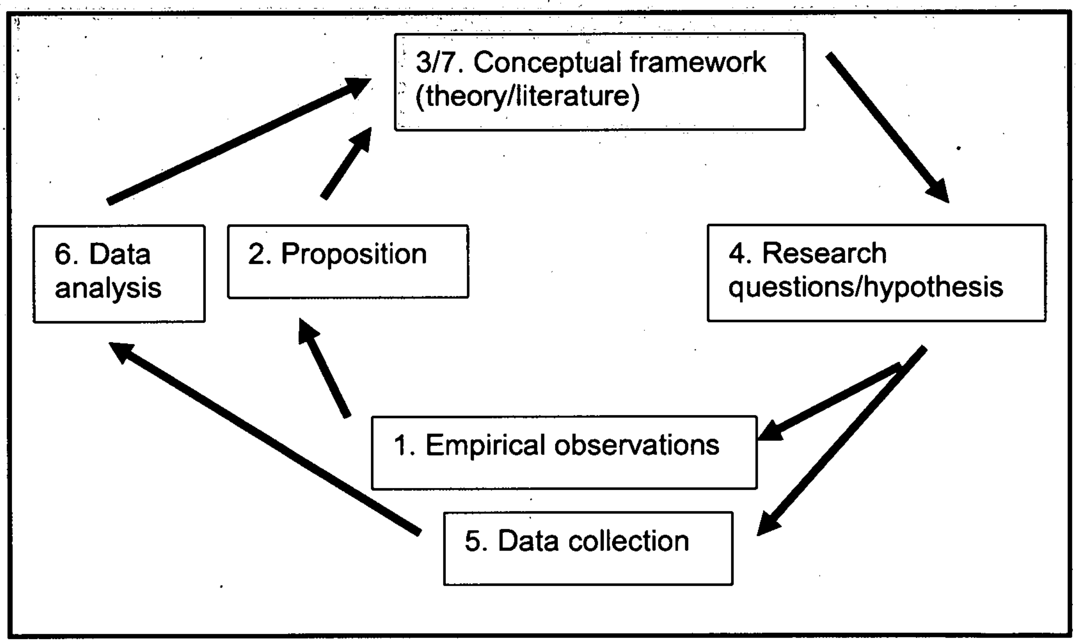
In this Chapter the research process has been summarised and explained. This includes the aims, the analytical framework, the methodology, the research questions and hypotheses, the programme of data collection used, and the resulting conclusions.

The research described in this thesis has been carried out within the disciplines of social science. The research methods of social science differ from those of natural science. In the latter, all the relevant variables are controlled, except the one which is the subject of the research. Hypotheses in social science cannot normally be tested in this way. It is difficult to isolate one component of human activity from all the other interactions of day-to-day life. Social science seeks to understand and analyse the inter-relationships within society. It is multidisciplinary in its approach, drawing on a range of disciples including sociology, the natural sciences, psychology, anthropology, economics, political science, geography and history. Social scientists have at their disposal a range of methods for gathering evidence – the collection of qualitative and quantitative data, including the use of questionnaires and interviews, and the systematic study of human behaviour. It is worth noting that a number of terms are used throughout this thesis that are particular to one specific discipline or another. Please refer to the Glossary (Vol. 2, page 106) for explanations of such terms.

This chapter presents an overview of the methods of data collection for the present research. The upcoming Chapters 4-6 have been reviewed, analysed and concluded from the social science and natural science literatures as they relate to pesticide use, policy and regulation. The boundaries of the data collection are established from the conceptual framework as outlined in the previous chapter. Another important element of data collection included carrying out stakeholder interviews among the pesticide policy network as identified as part of the present research. This section outlines why qualitative analysis of semi-structured elite stakeholder interviews was chosen as a major research method, together with a triangulated assessment using a variety of other forms of data collection. Other forms of interview technique are discussed and examined for their suitability for this research.

The following sections present a methodological outline for research. Rudestam and Newton (2001: 5-8) describe the phases of the research process in terms of a **'Research Wheel'** (see Figure 3.1). As part of the research process, a further complementary diagram (Figure 3.2) was constructed by the author specifically as a guide for the present research. The circular nature of both diagrams indicates that the research process is not linear, but is an iterative cycle of steps that are revisited over time. The following text outlines how this process applies to the present research on pesticide policy. The bold phrases (with following numbers) relate to the sequences of research as outlined in Figure 3.1. The methodological approach for the present research is described at this stage of the thesis because the academic theory is built up from the research as an on-going process – starting with a cross disciplinary review of the natural science and social science literatures, on which the conceptual framework is based, and then tested and amended according to the results of the research findings.

Figure 3.1: Research wheel

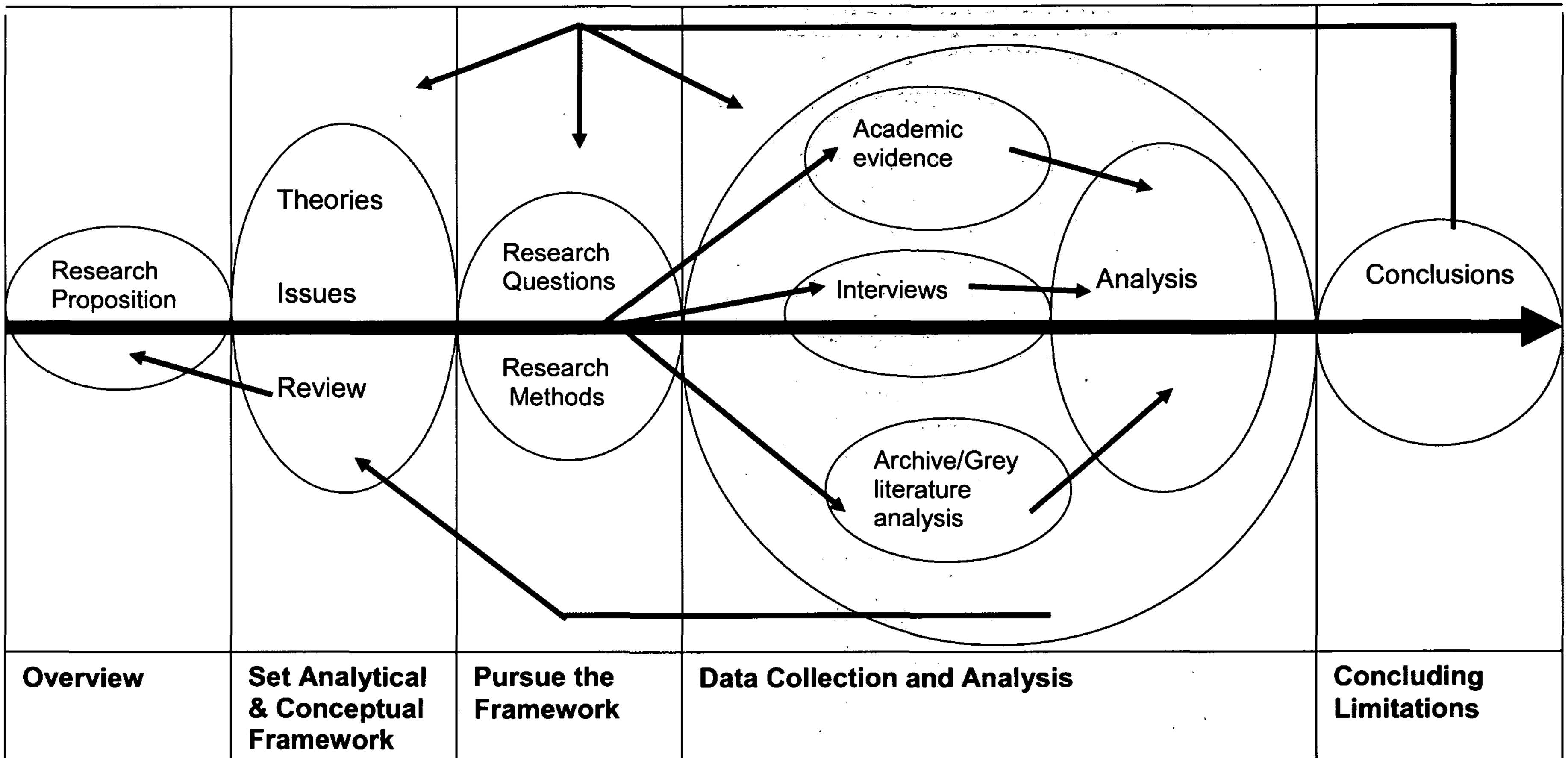


Source: Rudestam and Newton (2001)

3.1.1. Area of research: Social, economic, political, policy and scientific contexts of pesticide use

A common starting point for social science research is a thorough examination of a subject area through **empirical observation (1)**. For this thesis, the area of study is pesticide policy.

Figure 3.2: PhD process for the present research



Key: The thick arrow in the middle of the figure indicates the general direction of research during the PhD. The smaller arrows represent the more diffuse reflection carried out at certain stages, such as the return to the conceptual framework during analysis, the review of the framework and data collection and analysis when concluding the research.

Source: Author

Pesticides are normally studied in the context of the natural sciences of chemistry, biology and physics. They are developed and, to an extent, measured in this context, but there is need for a broad context to be taken into consideration. Pesticides are used in a wider public, social, political, economic and global environment, presenting a range of risks as well as benefits. There are many different views on appropriate policy and a level of regulation, all taken within the framework of the economic imperatives of the food supply chain. This is why the quotation from Einstein (Vol. 1, see page 11) is relevant. Physical entities are easier to measure in isolation, compared with the processes that justify and allow their development and use.

Pesticide use interconnects the public, social, economic and environmental spheres, and the technical sphere in which they are used to control pests. In order to understand this milieu it is important to identify the key components and explain them in an interconnected and logical manner. This is difficult. No one can be an expert in everything which is why, as a society, we struggle to understand the full impact of pesticides.

Pesticides are often studied and conclusions reached in a compartmental manner. This may concern the impact of a single active ingredient, on a single pest species, of a single crop, in one location. Or a pesticide may be studied in terms of a particular adverse health effect, or a specific environmental effect. These specific investigations are important. Equally important is an examination of the effects of the generality of pesticides.

Adverse health and environmental side effects of synthetic pesticides have led to the development of alternative products as a way of reducing the need for synthetic pesticide use. These can take the form of replacement biologically based products, often referred to as bio-pesticides. The other routes taken have involved changing the farming system. One example seeks to reduce the impacts of pesticides through a systemic approach known as integrated farming that reduces, but does not eliminate, the use of synthetic inputs such as pesticides. Another option, organic farming takes an approach which seeks to eliminate the use of pesticides altogether through a holistic whole farming approach in which the farming process reduces pest and disease problems.

Research Proposition: The pesticide policy paradigm is under threat, and an ecological pest management paradigm is emerging as an alternative

Returning to the process, the present research has selected a topic from a wide array of potential topics around pesticide policy and related areas and has formulated a **proposition (2)**. The proposition of the present research is that in the efforts of post-World War II agriculture to increase yields through pest control, a dominant 'pesticide policy paradigm' has emerged, supported by a closely knit 'policy community' of individuals with a shared framework of goals and beliefs supporting the use of synthetic pesticides. The present research has put forward the term 'pesticide policy paradigm' to denote the particular driving role played by this community with its common policy to defend and support the continued use of pesticides. For a variety of reasons, including an increased understanding of unintended adverse effects and an evolving approach to risk analysis, this paradigm is now under serious threat. The policy community which supported it has had to expand to incorporate critics of pesticide use – forming a wider 'pesticide policy network'. The dominant paradigm is now challenged by an alternative 'ecological pest management' paradigm, but this is constrained by the entrenched status and complex procedures of the pesticide policy paradigm.

The development and use of pesticides has increased over the past 60 years as part of an intensive industrial system of agriculture that was linked to UK and European Union production support. Pesticides can be effective in controlling pests, but can also have adverse side effects on human health, wildlife and the environment.

Pesticides are an indispensable component of conventional agriculture. At the same time, the availability of pesticide products on the UK/EU market is in chronic decline for a range of reasons. The regulatory requirements have also increased significantly over the last fifty years. Health and environmental concerns have come to the fore. Most modern pesticides are fossil-fuel based, and are therefore a limited resource. There is little data on this issue in the public domain. The production of pesticides is energy-intensive and adds to the overall greenhouse gases produced by intensive farming (Bellarby et al., 2008). Furthermore, many pests have developed resistance to some of the pesticides which is an increasing problem. In addition, there are now only four chemical companies in the world that have sufficient pre-market research and development budgets to develop new pesticides.

One response to the decline in the availability of synthetic pesticides has been the development of biologically-based bio-pesticides. They are perceived to have fewer impacts on the environment and human health, compared with synthetic pesticides. The bio-pesticides market is comparatively small. Most of the companies involved are very small commercial enterprises employing a handful of people, compared with the large numbers of staff of multi-national pesticide companies. Market projections are that the bio-pesticide market will increase at a faster rate that the synthetic pesticide market. Will bio-pesticides remain part of a niche market, or will they become mainstream? The efficacy of bio-pesticides has been questioned. At the start of this research (2004) very few bio-pesticides were registered for use in the UK. This was because bio-pesticides are regulated through the same UK and EU legislation and regulatory processes as synthetic pesticides. This involves complicated and expensive registration costs that the small bio-pesticide companies cannot afford. Do bio-pesticides need the same regulatory approach? Are the same multi-million dollar research and development requirements needed? Finally, is the use of bio-pesticides alone inherently more sustainable, or should they be linked to the sustainability of farming methods, such as organic farming and integrated crop management?

Pesticide policy and regulation are increasingly being co-ordinated through the European Union, although the UK regulator, the Pesticide Safety Directorate (PSD), is still an important EU Member State player. UK government pesticide policy is challenged by sections of the civil society. Expert advice on pesticides is increasingly equivocal. Consumers decreasingly trust government assurances over safety levels, which have led these multiple food retailers to develop their own pesticide policies that are more progressive than the current government position. The discourse on the risk analysis of pesticides is similarly contentious. The fundamental challenge to pesticides is whether we need pesticides at all.

The post Second World War UK pesticide policy comprised a productive network whose members who had a coherent and consistent view that was generally in support of pesticides. The group of stakeholders has since grown to include critics of pesticide. The bio-pesticide policy network is small, weak and emergent – it has only been in existence in the UK for a few years. How well does this emerging network fit in with sustainable agriculture, and will it attract criticism in the same way that pesticides have done?

3.2. Analytical framework

Next it is established that the proposition exists within a **conceptual or theoretical framework (3)**. It is the role of the researcher to clarify the relationship between a particular proposition and the broader context of theory and previous research. A conceptual framework, which is a less developed form of a theory, consists of statements that link abstract concepts (for example motivation and role) to empirical data. Theories and conceptual frameworks are constructed that describe abstract phenomena that occur under similar conditions.

The framework presented in Chapter Two guides the data collection and analysis and helps establish what counts as relevant data.

The academic literature covering the social and political analysis of pesticides is limited. The first task here is to establish the academic terrain where little else otherwise exists. The second is to establish where the analysis of the social impact of pesticides relates to academic theories and hypotheses – notably in this case in the fields of risk analysis and policy networks. The first process follows an inductive format in which theory is derived from the evidence, and the second is deductive, where the theories are tested, and developed according to the new data examined.

3.3. Research Questions

The researcher moves from the larger context of theory to generate specific **research questions (4)** that are the formal statement of the researcher's intent. The proposition of the present research that **the synthetic pesticide policy paradigm is under threat and that an alternative ecological pest management paradigm is emerging in its place.** This generates three key research questions:

1. **Is the concept of a paradigm useful in describing pesticide policy and development?**

2. **What impact does pressure on the pesticide policy paradigm have on the governance of pesticides?**

3. **What are the prospects for a paradigm shift from a pesticide to ecological pest management?**

3.4. Data collection and analysis through the use of qualitative research

The **data collection (5)** is an important part of empirical observation, (initiating another cycle of the research wheel) which leads to **data analysis (6)**. The method of data collection in this research has been carried out using a qualitative research process. Qualitative research is a widely used method of analysis used by social scientists. It includes a greater emphasis on description and discovery than on the hypothesis-testing and verification of quantitative research. Qualitative research methods, are useful in the

"...generation of categories for understanding human phenomena and the investigation of the interpretation of meaning that people give to events they experienced" (Polkinghorne, 1991). There is a wide range of qualitative research methods each of which starts with different premises and different aims. The essential elements of qualitative research have been described as the choice of appropriate methods and theories; perspectives of the participants and their diversity, reflexivity of the researcher and the research; and variety of approaches and methods (Flick, 2002). Denzin and Lincoln maintain that qualitative research involves the studied use and collection of a variety of empirical material, including – case studies, personal experience, introspection, life-story, interview, and cultural texts. Accordingly, qualitative researchers deploy a wide range of interconnected interpretive practices. Each of these practices makes the world visible in a different way (Denzin and Lincoln, 2000: 4-5).

3.4.1. Relevance of qualitative research to pesticides

There is a significant volume of natural science literature on the use and impacts of pesticides. Much of the literature includes classic scientific experimentation within a rigid regime of aims, methods, results, conclusions and discussion. Great emphasis is placed on the precision of methodology that often involves quantitative analysis. This data is important. But it needs to be placed in its social, economic and political context. There are thousands of published studies on the health and environmental effects of pesticides, but there is a much smaller literature covering the social science research on pesticide policy and related issues. In this thesis, reference will be made to all of these sectors as the contestation of this research is that they are all of equal importance, even if they are represented disproportionately. Qualitative research is relevant to this research because it allows the research questions to be examined in greater detail. It will, for example, help with the questions: why is pesticide policy polarised and a contested field, and why given the same set of empirical data do stakeholders come to different political conclusions? Natural science cannot answer these questions, whereas qualitative social science research methods possibly can, as they incorporate the social dynamics of a technical issue. It is important to remember that opinions and perceptions matter, because they frame the ways in which people operate.

3.5. A range of methods for gathering the data for analysis

The research process has been based on a number of data collection methods that are incorporated into the qualitative research approach.

1. Data collection was carried out among the academic literatures, archive documentation, and the assessment of grey literatures (especially those produced by relevant organisations). Chapters Four to Six include a number of academic literature reviews with analysis and conclusions. Although as individual studies, the research conclusions they convey are not new when collected together across many different research disciplines, the concluding comments linked together do provide a unique perspective. This is a broader assessment than, for example, a review and analysis of the literature in which the combined results of several studies address a set of related research hypotheses.

2. The findings from semi-structured in-depth interviews are presented in Chapter Eight. They were carried out with 47 key informants who have a range of views concerning pesticide policy. The methodology for the interviews is introduced below and background to the interview questions is also presented.

3. Attendance of the researcher at pesticides meetings as an observer. For example this included attending a meeting of the Advisory Committee on Pesticides in 2007 and a European Commission stakeholder meeting of minor uses of pesticides in 2006. Notes were taken of the meeting for background information.

4. Prior to embarking on this research, the researcher had many years of experience working for a pesticide non-governmental organisation in the civil society sector. Before that he had experience working for a pesticide industrial concern. In addition he has two degrees in pest management and environmental science. The researcher was a former policy actor involved in the UK/EU pesticide political debate. It is important to note that in the relevant research, the correct protocols have been adhered to in an objective manner. But it is clear that the researcher's previous pesticide stakeholder involvements have framed the way in which the present research has been carried out.

3.6. *Interviewing as a method of data collection*

Using an interview technique is recognised as the most common method of collecting data for qualitative research (Bryman, 2004: 319, Hopf et al., 2004: 203, Punch, 2003). The interview, as an analytical technique, has been described as "one of the most common and powerful ways in which we try to understand our fellow human beings" (Fontana et al., 2003: 61). The use of interviewing has become so widespread that social science researchers have said that we live in an "interview society" (Fontana et al., 2003: 62).

Using the interviewing process is important for the present research because it allows for the examination of the social and political context in which pesticides are used. Pesticides are part a technological advancement that provides the direct benefit of increased food production, but they also pose risks that are difficult to quantify. How they are evaluated is based on science but they are used in a social, economic and political world. In order to understand this process, it is important to hear directly from those involved in the process to provide insights which scientific reports and articles cannot articulate.

There are a wide range of interview techniques currently applied in social science research. The most common involves individual face-to-face verbal exchange with the researcher. For practical and financial reasons, it may be easier and/or cheaper to interview over the phone. Other interview types include face-to-face group interviews in which the researcher may or may not be present. Researchers can also interview by using questionnaires (mailed, emailed or by carrying out telephone surveys). Interviews can be structured, semi-structured or unstructured. The reasons for carrying them out can vary: it could be for market research, political polling intentions, therapeutic reasons, or academic analysis. The length of interview time can vary from a few minutes over the phone to multiple sessions that may span days covering partial life history events. Here all the possible responses are familiar, and the only goal is to count the number of responses falling into each category of response (Leech, 2002). These sorts of approaches may suit large-scale public opinion surveys, but such tactics may yield limited results when dealing with key-informant/stakeholder interviews. This can occur if the specific questions fail adequately to answer the research questions. On the other hand, there may be questions that have been framed in the wrong way, or they may omit an important response choice. In these surveys, reliable data may be obtained, but it may lack content validity (Leech, 2002).

3.6.1. Semi-structured interviews

Semi-structured interviews are the most generally used form of interviewing for policy-makers and the decision-making process (Burnham et al., 2004). This form of interview takes a middle ground between structured and unstructured interviews, in which the researcher has a list of questions or fairly specific topics to be covered. Researchers have referred to this as an 'interview guide', which allows the interviewee some leeway in how to reply to the key questions. Some recommend that questions do not have to follow the same sequence, and additional questions can be asked, as the interviewer picks up on the answers to initial questions (Bryman, 2004). Here, the advantages of conversational flow and depth of response outweigh benefits consistent ordering On the other hand, other researchers prefer to keep to a consistent order of questioning (Aberbach and Rockman, 2002).

For the present research semi-structured interviews were chosen as the method of data collection. Structured interviews were discounted because it was considered that the likely interviewee responses would be too restrictive. The present research wanted to encourage detailed replies to interview questions in order that interviewees could explain and discuss complicated issues in which a certain amount of deviation was encouraged. Given the differences of opinion among pesticide policy network stakeholders, it was anticipated that a wide range of responses would be likely. The stakeholders had a range of experience and knowledge areas, and the interviewer need the flexibility to accommodate this difference in the responses to questions. Unstructured questioning was also rejected because it would give too much leeway to the interviewee in their responses, and would have presented difficulties in the consistency of findings analysis.

Within the framework of qualitative analysis, semi-structured interviewing was a major method of data collection for this research. This section outlines why this technique was used and how it was applied in practice.

Semi-structured interviews provide a flexible approach which allows the interviewee to give detailed responses that deliver greater depth in their answers. It also facilitates the examination of important contested parameters that may influence the interested parties in different ways. Comparisons can be made between responses both within and between interview groups and sub groups. The broad scope of a semi-structured interview permits the analysis of perceptions and framing assumptions around technical subjects, such as pesticide policy. The interview process for this research follows the semi-structured format as outlined in a number of social science texts (Bryman, 2004, Flick, 2002, Rudestam and Newton, 2001).

It is important for the interviewees to be free to develop their own arguments that would be more constrained during structured interviews. One of the main facets of semi-structured interviewing is the open-ended nature of questions, as opposed to the close-ended questioning adopted in structured, questionnaire-type interviews.

When interviewing those stakeholders with pesticide policy expertise, it was anticipated that responses would be difficult to predict because of the variability of response from one interviewee to another. This may be because of different perspectives, areas of interest, responsibility, or expertise within the stakeholder group. But for this group, adopting the technique of unstructured interviews would allow too much leeway. It would provide responses that would not be comparable with input from the other interviewees. It could also allow the interviewee to take over the interview agenda. The interviewee might digress to such an extent that would not help in addressing the core objective of the research questions. If interviewees did have particular areas which they wanted to discuss at greater length, the interviewer could offer the option to discuss the points on or off the record at the end of the interview. This has the advantage of providing a greater richness of response for the research, whilst not interfering directly with the requirements of the semi-structured interviewing process.

3.7. Interviews with stakeholders

Once the interview method was decided, the researcher had to plan and prepare for the interview phase of the research. For this, the researcher had to follow a pre-existing procedural format and gain ethical approval from the Research Degrees Committee at City University. In practical terms this meant the researcher was required to provide a draft interview consent form and explanatory statement to the University authorities, so that they are content that prospective interviewees understand the nature and conditions of the research being carried out.

A total of 47 interviews were carried out largely between March and September 2006 (see Table 3.1). The first two interviews were pilot interviews. Carrying out this process was very useful and helped to fine-tune the interview methodology. Occasionally the literature may throw up contradictory interview advice. If so, the pilot stage is the best time to find out which method best suits the current research. For example, Leech (2002) recommends the interviewer summarises, in more than one sentence, what the interviewee has just said, before moving onto the next issue. However, Ritchie and Lewis (2003) disagree: they say summarising what people say is rarely helpful because it is difficult to capture the full meaning of a response in a short summary, and attempts may seem glib and patronising to the interviewee (Ritchie and Lewis, 2003: 158). In this research, experience from experimentation in the pilot interviews demonstrated the latter advice to be more relevant. It proved difficult if not impossible to summarise lengthy answers in one sentence. Answers to questions often required the addition of caveats and qualifying comments in order to explain a multifaceted issue such as pesticide policy. In this context, it is difficult to avoid the impression that the interviewer is putting forward his own interpretative view.

This exercise was also useful because it mapped the stakeholder group conceptually. Mainly it is based on practice in the UK; many elements relate to the multi-level governance of pesticides as seen for example where the regulation box includes EU regulators as well as the UK.

A list of organisations was identified and subgroups were established based around the agricultural use of pesticides. From that, a list of 60 prospective interviewees was drawn up, making sure that all the above sub-groups were represented in roughly equal numbers. The exception to this was the Advisory Committee on Pesticides, for which a disproportionately large number were interviewed. This is because the committee is made up of experts from a range of different disciplines, with sometimes differing views. From these criteria potential interviewees were selected on the basis that they fitted into one of the groups or sub-groups listed. Often the interviewees' role was singular and clear, but others have a range of expertise. For example one interviewee may be a member of the ACP, but also a toxicologist, or union nominee, or have an expertise in agronomy.

Interviewees were usually recruited by email, with the consent form and explanatory statement attached explaining the research in more detail. They all had a professional interest in the subject matter to be discussed covering chemical pesticides, biocides and pest management policy and regulation. The interview did not gather personal, medical or other sensitive data about individuals. The researcher explained to each interviewee that the interview would be on a confidential basis, and that any quotes would be published in an anonymous fashion.

The term and 'pesticide policy paradigm' is used widely throughout the present research. It was not used during the interviews because it is not a familiar term, and had not been defined in detail prior to the present research. The present research suggests that the continuation of the 'Pesticide policy paradigm' is highly reliant on a policy community of integrated productive stakeholders to support and justify the pesticide paradigm against the concerns of critical stakeholders. The paradigm also reflects the political nature of current pesticide policy.

3.7.1. Was interview saturation reached?

Saturation occurs when the interview has no additional information to contribute to address the research questions. It is likely that for this research saturation was not reached, because of lack of resources and chiefly time limitations. Areas not covered sufficiently included:

intergovernmental organisations (excluding the EU); small-scale food retailers; producer suppliers; pesticide distributors; generic pesticide manufacturers (without research and development facilities).

Table 3.1: Interviewees by sector and sub group

Groups	Sub-groups	Interviewee code
Production	Synthetic pesticide manufacturer	26; 40; 41
	Bio-pesticides/ alternatives industry	07; 21; 38
Research and advisory role		05; 09; 15
Control	Regulator (UK/EU)	22; 23; 25; 28; 39; 42; 46
	Expert advice (ACP/EFSA)	02; 03; 04; 13; 24; 33; 35; 36; 44
	Government Ministers (former at time of interview)	19; 45
Food producers	Farmers, growers and suppliers	14; 16; 17*; 18; 32
Food manufacturers		20; 29
Food distributors	Retailers	06; 08; 31; 37
Civil society	Public interest groups	10; 11; 12; 30; 34; 43; 47
	Media	01; 27

Notes: * This interviewee is an organic farmer and advocate.

3.7.2. Interview guide

There is limited academic methodology literature specifically designed for interviewing experts in what researchers call 'elite interviews'. This would apply to the pesticide stakeholder group interviewed for this research (Burnham et al., 2004). Much of the literature is designed for interviewing members of the public, in one form or another. Where methodology does exist, one of the key recommendations is to produce an 'interview guide' as an aid for the use of the interviewer during the interview. (Bryman, 2004: 324). The interview process is aided by the interview guide, as it orientates the interviews and helps to prevent discussion of topics that are not relevant to the study. It is less specific than a structured interview schedule, usually consisting of a brief list of the main areas to be covered, or it could just include a list of issues to be addressed (Burnham et al., 2004).

3.7.3. Constructing an interview guide

As part of the interview process, for this research, an interview guide was produced in which six key questions were included. For more background, see Table 3.2. It is important that the guide allows the interviewer to ascertain the ways in which the interviewees view their social world and that there is flexibility in the conduct of the interviews. The guide was constructed so that the answers would provide what is needed to help answer the research questions. This requires finding out what the interviewees saw, from their perspective, as key issues in relation to each of the research topic areas.

It has been recommended that easier questions should be asked first, in order to put the interviewee at ease, and allow them to get into their flow, before moving onto the more sensitive questions. The more challenging questions should be asked in the middle, or possibly towards the end of the interview; but not at the last minute, when the quality of discussion may have tailed off, at which time it might be undesirable for the interviewee to impart important matters of relevance to the research questions (Leech, 2002).

3.7.4. Background to interview guide questions

This section describes the interview guide questions, followed by a brief rationale.
The first question covered the experience of the interviewee (see Table 3.2). It was designed to put the interviewee at ease by giving the historical context and background which located them within the stakeholder network.

The second question asked about the interviewees' views on the need for pesticides, and how they are regulated. This is what Leech (2002) refers to as a 'grand tour' question that allows the interviewee to develop their own position within the debate. It provides them with the opportunity to describe something they know well. It was expected that this question would allow interviewees to cover the historical implications of pesticide use, the risk assessment processes, the robustness or otherwise of the regulatory process.

The third question addresses the challenges of the pesticide debate and allows interviewees them to address issues in greater depth. It represents another grand tour question that presents the interviewee with the opportunity to help elucidate a challenging area.

The fourth question asked the interviewee to discuss a recent policy position that they had been involved with, which allowed for their perspective to be placed on the issue.

The fifth question asked the interviewees about pesticides and the role of precautionary principle. It is what Leech (2002) calls an 'example question' which has similarities with a grand tour question, but is more specific. It relates specifically to one of the research questions that highlights a particularly contested concept which stakeholders interpret differently. The question specifically invited comments by asking: "What is the role of the precautionary principle for the control of pesticides?" (See Table 3.2.). This question was asked because it provides stakeholder feedback on an aspect of the risk analysis debate that is controversial and subject to contention between members of the pesticide policy network. A number of interviewees made critical references to the principle unprompted, which is an indication of the importance they place on it.

The sixth question enquired where pesticide policy is developing, in relation to bio-pesticide alternatives. This question provided the opportunity, with prompt, for interviewees to provide a comparison between synthetic pesticides and bio-pesticides. For the final question, the interviewees were shown two diagrams and asked to give comments. The first diagram showed the approval process for the UK (see Figure 2.1); and the second showed that for the EU (see Figure 2.4). Pesticides are regulated a dual system as outlined in these Annexes and they both start with the development of a pesticide by the marketing company. As part of the interview process, free comment was invited on such aspects as policy input, technical debate and how and when wider stakeholder input should occur.

Table 3.2: Interview questions

Interview questions	Interview data used in findings chapters
1. Can you characterise the need for pesticides[27]	Chapter 8.2. Pesticide debate/policy
2) bio-pesticides?[28]	Chapter 8.3 Bio-pesticides
3. What difficulties/challenges have you encountered around the pesticide policy debate?	Chapter 8.2 Pesticide debate/policy
4. Can you explain your professional/group involvement with pesticides by talking me through a recent policy position you have developed?	Chapter 8.2. Pesticide debate/policy
5. What is the role of the precautionary principle?	Chapter 8.1. Risk analysis
6. Where is pesticide policy developing in your view?[29]	Chapter 8.1. Risk analysis

Key: The left hand column presents the interview questions. The right hand column represents a further stage of data analysis in which responses to the questions were allocated to one of three research findings chapters that relate to the research questions and conceptual frame work.

27. Originally this question was: What is required for a pesticide approval? It produced predictable responses, and therefore was change to a more fundamental question.
28. If the interviewee had an expertise/knowledge of biopesticides, comments were requested on these products.
29. This question was made with reference to the risk analysis of UK and EU pesticide approval processes

3.7.5. Factors to consider when interviewing

There are a number of factors to consider when carrying out interviews. Rapport with the interviewee is important because, without it, questions can fall flat and engender brief and uninformative answers. Rapport involves making the interviewees relaxed and convincing them that the interviewer is professional, interested in their views and is generally knowledgeable, but less knowledgeable than the interviewee on the particular subject area of the interview. In addition, many of the interviewees were representing an organisation's point of view, which meant they had to be conscious of adhering to the official line. It may be that a detailed question involved a response for which there was a general organisational answer, but when asked to go into detail, some element of personal interpretation was required and sometimes there may not be a fully mapped out official line to follow. This would add pressure to the interviewees. Certainly, after the first few pilot interviews the interviewer had more 'interview experience' and familiarity with the specific interview questions, than the interviewee. On the other hand, interviewees were experts in their field and many were used to doing interviews with the media, other academics, or commercial researchers.

According to Bryman (2004), questions do not have to follow the same sequence, and additional questions can be asked, as the interviewer picks up on the answers to initial questions. On the other hand, Aberbach and Rockman (2002) prefer to keep to a consistent order of questioning, argue that the advantages of conservational flow and depth of response outweighs the benefits of consistent ordering. After carrying out two pilot interviews, this research opted to allow different ordering of questions. In some cases, the interviewer pre-empted questions by answering them as part of answers to previous questions. In other cases some questions were more relevant to certain interviewees, depending on their particular area of expertise.

All the interviews were conducted by the researcher and audio recorded with the permission of the interviewee. In one case, the interview was recorded by the interviewer taking detailed notes, which were written up as soon as possible after the interview. All other interviews were transcribed verbatim, 33 by the researcher, and the other 14 by a volunteer. There was regular consultation between the researcher and transcribing volunteer to check that transcription techniques were compatible. The interview length ranged from 34 minutes to 131 minutes. Some of the interviews were shorter because the interviewee had a busy work schedule; in other cases, interviewees had less to say on one or more of the subjects covered in the interview.

3.7.6. Advantages of transcribing interviews verbatim

As one of the interviews (No. 12) was written up non-verbatim, comparison could be made methodologically with the other interviews written up verbatim. Many of the interviewees gave detailed responses to questions and prompts raised. Had the researcher relied on making detailed notes during interviews, it might have over-simplified responses, possibly leading to too much of the researcher's emphasis in his summaries. Recording the interview meant that the researcher did not have to carry out the double task of making accurate notes of what was said, and thinking about the next question or prompts to ask the interviewee as the interview developed, given the semi-structured nature of the interview. Had the researcher been carrying out closed-end questionnaire-type questions, detailed notes may have sufficed because the questions would be in sequence, in a written format and available on cue, freeing the researcher to concentrate on taking notes of what was said during the interview? The interviewees in this research had different levels of knowledge about areas covered in the interviews. Some interviewees were more practically-based, and had less experience, and therefore less to say in areas of pesticide policy. This meant that the interviewer had to adapt the interview to the type of interviewee interviewed. If time is available, the effect of transcribing has the effect akin to listening to the interview in 'slow motion' which allows the interviewer/researcher to know the data, and develop a detailed perception of what is being said, without other distractions. In the field of pesticide policy, there are a number of contested views and perceptions. Their verbatim analysis does greater justice to the interviewee, and there can be no misunderstandings about what the interviewee actually said. In other areas, there are often a range of comments that may have subtle differences in emphasis, which require accurate analysis of what was said. Many interviewees gave equivocal answers to questions "pesticides are safe but..." which are sometimes detailed and convoluted, and which benefit from verbatim analysis. The advantage of verbatim audio and a written report is that the researcher can revisit the interview as many times as necessary, both listening to the interview again in audio, and/or reading the transcript. For this research, the interviewer read each of the interview-transcripts at least three times. Another advantage is that the emphasis given by the interviewee is recorded and available for analysis after the interview.

3.7.7. Disadvantages of transcribing interviews verbatim

The disadvantage of transcribing interviews verbatim is that it is very time-consuming, a fact which should not be under estimated. It took about 8 hours to transcribe 20 minutes of interview time, out of a total of 44 hours of interview time transcribed. In total, each interview took about one week to set up, carry out, transcribe and analyse. In planning the research programme, the researcher had to account for this long time factor, and not embark on transcription unless adequate time and resources were available. Also, if the transcriber(s) was not the same person as the researcher(s) recognition should be made of the fact that the researcher would have less familiarity with the data than when the main transcriber is also the researcher. Voice recognition technology is available but was not at the disposal of the researcher. This technology may save time, but the processes of re-listening to the interview, as part of the transcribing process, has additional benefits in that it immerses the researcher in the interview data. The area of pesticide policy is diverse and there are many different types of interested parties and they even differ within sub-groups. The researcher estimates that there could have been 70 interviews before saturation might have been reached. There is a danger that verbatim interviews provide an overbearing amount of irrelevant information, and the key points from an interview are lost in the detail.

3.7.8. Interview analysis

The whole of each interview was transcribed verbatim. Occasional exceptions to this were made if the interviewee digressed into an area that was not relevant to one of the research questions, or area of research interest. Often, the researcher's words were summarised and truncated in the transcript, especially in relation to the last question about risk analysis, in which the researcher explained the UK and EU pesticide approval processes diagrams in a similar manner for all the interviews. The researcher considered each of the answers. The data were analysed and coded, in order to allocate each response to one of the six key question areas (see left hand column of Table 3.2). This was done because the questions and the sequence of questioning were not always from one through to six. Also in depth answers often meant that interviewees would answer more than one question at a time. The coding process identified common issues within the responses to the six question areas.

The interview transcripts were all then read a second time in more detail in order to assess what the interviewee had said in relation to the six questions. Each time the interviewee said something of relevance to the research questions, the comment was transcribed into a separate document, using the six questions as main headings. Sometimes the interviewee would say something that encapsulated a key point in one or two sentences, which were then used verbatim. Often the interviewee's phrase would need transcribing into a précis. Great care was made to ensure that the meaning of what the interviewee was saying was not lost. Once the interviews had been coded, all the quotes were extracted and cut-out and re-read. Sub themes emerged from what the interviewees had said, and were presented in summary form. At this stage no analysis was made or conclusions drawn. It was important first to codify exactly what was being said by the interviewees themselves. Once this was established the responses were then drawn against the research questions in order to elucidate the research hypotheses. The findings were then presented in the following chapter(s) in relation to three main areas of interest for the research questions: the risk analysis of pesticides; the pesticide policy network and the debate around the pesticide policy paradigm, and finally the prospects for development of bio-pesticides and their link to an alternative ecological pest management paradigm.

3.7.9. Summary of research analysis

The results are presented in detail in the following sections. The analysis of the interview data was carried out a number of steps. The interviews were scanned to check that the questions refer to one of the six questions asked during the interview. The interviews were re-read to code the comments made by the interviewees that relate to the research questions. The comments were then transcribed onto an analysis documents, according to the six identified themes. The comments were then re-read and coded according to themes that emerged. A 50 page Working Document was written linking together common areas of discussion. This includes sub-themes for each question.

The Findings Chapter Eight was written on the basis of the results from the findings from the Working Document that were then analysis in terms of risk analysis; pesticide debate/policy network; and the prospects for bio-pesticides. The headings and sub-headings covered by the interviewees are listed in Tables 8.1-4,6. A summary of interview data was presented in the table format. The analysis was carried out in this fashion to see if any indicative patterns emerged within the seven stakeholders sub-groups identified. It also gave the possibility of highlighted a diversity of views, where they existed. For these tables a relative interpretation is given. This can only be done for key issues because there is enough comparable data across the stakeholder groups. Interviewing stakeholders was the most relevant form of data collection for carrying out analysis of interviewee sub-groups because consistent data on this range of subjects could not be compared in another way. At the same time it gave the stakeholders the opportunity to put their views forward in a detailed and nuanced way that would not have been possible if for example questionnaires were used as an alternative form of data collection.

3.8. Integration of interviews with other research data

The rationale for the data collection and analysis in the following chapters are framed by the starting assumptions in the conceptual framework presented in Chapter Two. The establishment of a 'pesticide policy paradigm' is presented from the historical data and analysis in Chapter Four. The diverse effects caused by pesticides are catalogued in Chapter Five which highlight the complexities in risk analysis for pesticides. Chapters Six and Seven explore the pesticide policy network in relation to how and why the paradigm is either supported/defended or challenged. The interview findings (Chapter Eight) were compared and verified with other forms of data collection, such as a review of archive documentation, and the assessment of grey literature (especially that produced by stakeholder organisations). Triangulation is used to indicate that more than one method is applied to verify the results data. Focussing in on a phenomenon by using multiple research strategies selected because their respective strengths and weaknesses complement one another (McIntyre, 2005: 123-125).

In a polarised area such as pesticide policy, it is important to use multiple methods and tap into different sources of data. Here the researcher was not looking for a simple coherent synthesis of the data that might be required from the analysis of a questionnaire. For this research, the decision was taken to have interviews as the main method of data collection, triangulated with documentation (peer reviewed and grey literature), attendance of stakeholder meetings, and the experience of the research in pesticide policy.

The question needs to be raised: Should these techniques be used in this research? For example, the use of interviews in qualitative research is important, but it has been criticised for being unrepresentative and atypical. Its findings can be impressionistic, piecemeal, and even idiosyncratic, (Devine, 1995 cited in Burnham et al., 2004: 218). They may be true for the present research, where the intention was to cover all sub groups within the policy networks, and there was an intention to capture the diversity of responses: but inevitably it will be piecemeal to an extent. (This was backed up by the findings of the interview data for this research.) In addition, the function of the interviews is that they make a major contribution to triangulation with the other forms of data collection, listed above. It is not, for example, to gain information, which has been gained from sources elsewhere (e.g. grey literature on organisation websites). Reliance on a number of methods can be carried out through triangulation, which has been defined as a technique of focussing in on a phenomenon by using multiple research strategies selected because their respective strengths and weaknesses complement one another (McIntyre, 2005: 123-125). In a polarised debate on such a subject as pesticide policy, it is important to use multiple methods and tap into different sources of data. Here the researcher was not looking for a simple comprehensive synthesis of the data that might be yielded by the analysis of a questionnaire.

For this research, the decision was taken to use interviews as a major method of data collection, triangulated with documentation (peer reviewed and grey literature), and attendance at stakeholder meetings. The research is also informed by the 20 years of experience of the researcher who has applied pesticides on a professional basis, carried out policy research, and worked as an advocate in pesticide orientated civil society organisations in the UK, at the EU level, and in south-east Asia.

It is important to note that care had to be taken when interpreting comments made during the interviews. There can be potential problems taking all comments at face value and it was anticipated that some interviewees would be likely to contradict each other. This was addressed by making sure interviewees backed what they said with evidence and/or interviewees could be asked to put themselves in the position of the opposing views. Other views could be substantiated with triangulated evidence from other methods of data collection (via literature and reports etc. if available). Contradictory statements in interviews were also presented during the analysis of interview data through the production of Tables 8.1-4,6 that included views from all the various stakeholder groups.

3.9. *Arriving at research conclusions*

Finally generalisations are drawn from the data collected and analysed and referred back in order to test and refine the **conceptual framework (7)**, which then leads to the implications for subsequent research. The pathway towards the research conclusions involves both a linear and retrospective process (see Figures 3.1 and 3.2). This final chapter opens with a brief outline of the conclusions so far, in terms of the significance of what has been achieved. The following text makes clear the implications of the findings of the research questions. There is then an explanation of how the research findings add to the field knowledge, and the implications for other theories relating to the area of interest. Any limitations for the research are highlighted, and are linked to further research that is suggested by these findings.

4. Historical context: The emergence of the pesticide policy paradigm

"The excellent DDT powder which has been fully experimented with and found to yield astonishing results... " **Sir Winston Churchill, FRS, Prime Minister, 1944.**

"It is obvious enough that DDT is a two-edged sword. " **Sir Vincent Wigglesworth, FRS, Director of the Agricultural Research Council Unit of Insect Physiology, 1945.**

4.1. Introduction

In this chapter the historical development of pesticides used in the UK is reviewed. It describes how the ways and means of pesticide use became the dominant post-war method of pest and disease management.

The early modern synthetic pesticides were developed over a remarkably short period of time. They represented an urgently required technical response to the necessities of World War Two, in which the mantra was – the total destruction of the enemy is paramount. The pesticides were very effective in controlling pests that caused human disease and/or agricultural pests. Little forward planning was given to the sustainability of their long term use.

Post-war, the military-based pesticide technology was transferred opportunistically to peacetime purposes. In particular, the greater efficacy of synthetic pesticides helped secure the UK agricultural policy objective in which security of food production predominated. The key stakeholders with an active role in governing the development of synthetic pesticides included government, scientific research and advice agencies, the farming industry, and the agricultural supply industry. As an integral part of intensive agricultural production, pesticides helped to increase food production. The initial 'pesticide policy community' driving this was small and strong. It focussed on efficacy, and firmly believed in the economic need for pesticides. There was little internal criticism or wider disagreement within the stakeholder group, and these drivers led to the rapid research and development of new pesticide products and an increasingly widespread uptake and usage by farmers.

The pesticide policy community existed within a 'pesticide policy paradigm' in which all the stakeholders have a common interest in maintaining the success of the paradigm. The establishment and existence of a paradigm and its links to the policy community are important elements of the conceptual framework for the present research. However, monitoring the progress of the pesticide paradigm is also an important process of the research narrative because the starting assumption is that the paradigm is in flux whilst operating within the constraints of normal science for pesticides. This chapter covers the period before the development of what the present research is calling a pesticide policy paradigm in which 'critical stakeholders' joined the pesticide policy network.

The internal harmony within the paradigm produced a series of predominantly voluntary agreements for the control of pesticides. In this situation, regulation was an extra financial burden that was deemed unnecessary because all parties agreed on the course of actions being taken. By the mid 1950s, an expert committee was established[30] to assess the risks posed by pesticides. Initially it addressed the acute dangers to human health (such as occupational and residues in food) and wildlife. There was little consideration of the chronic effects on human health or the environment.

This section concludes with a review of pesticide usage. In the years after the Second World War, the sales of synthetic pesticide increased dramatically. This was linked to wider agricultural subsidies that supported increases in agricultural production. The pesticide market today is not increasing at the rate it was in the 1960s, but synthetic pesticides still dominate the pest control sector as an intrinsic part of intensive conventional agriculture. Agricultural policies are moving away from production towards environmental stewardship, but this had the effect of decreasing pesticide usage.

4.2. Background: defining pesticides

Pesticides are chemicals designed to kill or control pests. The definition of a pesticide is therefore dependent on the definition of a pest. The Oxford English Dictionary (OED) defines a pest as "the bubonic plague, a person or thing which is destructive, noxious or troublesome, or any animal, especially insect that attacks agricultural crops, livestock or stored goods. It is also a plant that is an invasive weed" (Anon, 2007b).

30. Originally called the Working Party on Precautionary Measures against Toxic Chemicals used in Agriculture

In the context of the present research a pest is defined as "any living organism which is considered by the user of the word to be destructive, noxious or troublesome". It should be noted that the critical clause in the definition is "which is considered by the user". Unfortunately the listener may consider differently. As the Roman philosopher Lucretius said: "One man's meat is another man's poison". This conflict creates some fundamental difficulties in any societal dialogue.

Pests have been most prevalent in agriculture posing a threat to crops and livestock. They are also important in the spread of human disease, such as malaria which is transmitted through Anopheles mosquitoes that act as disease vectors. Pests, such as weeds, insects and rodents, are found in household/garden and urban settings. In practical terms this means there are large numbers of pest species around the world. For example, there are an estimated 30,000 species of weeds, and 10,000 species of plant-eating insects (Crop Life, 2007a). Therefore the definition of a pest in theory embraces an enormous number of species. In particular pests pose threats to global food production and also to human health through the spread of diseases that have the potential to reach plague proportions. In these cases there is little doubt about their status. But pests are defined variously and subjectively, by individuals, or by a sector of society, or by agreement collectively within society as a whole. To whomsoever and for whatsoever reason an organism is deemed to be a pest, it is a pest. Pests are pests not because of what they are, but because they compete with human activity and livelihoods. They threaten health and economic security. Pests are not wanted, and most people would prefer not to think about them. They can deliver wide scale death and misery, as in the case with malaria and locust plagues; or they may compete with and challenge economic trade, and agricultural activity. They may be a mild irritant – something people find aesthetically displeasing, like a garden weed to be controlled for cosmetic reasons. Or it may be that a weed that grows alongside a railway track poses a threat to safe transportation. In these cases the pest status is decided by the individual or a sector within society, either of which scenarios may be contested by others.

The dominant method of controlling pests has involved the use of chemicals, or more specifically synthetically manufactured pesticides. The term pesticide relates to a broad group of chemicals designed to kill the diverse groups of pests, as described above. The variety of pesticides mirrors the diversity of pest and reasons for controlling them – health, economic and cosmetic. There are many legal and technical definitions of pesticides. One authoritative version is provided by the International Union of Pure and Applied Chemistry (IUPAC) (Stephenson et al., 2006).

Pesticides are a broad class of bioactive compounds important for food and crop production and for human health. The development, production, use and regulation of pesticides encompass a very wide range of disciplines including synthetic chemistry, chemistry of formulations and residues, biological and environmental fate, soil and plant science, toxicology, ecotoxicology, and risk assessment.

Historically pesticides have included natural chemicals found in the environment, either simple chemicals such as sulphur or extracts from plant-based material that showed pesticidal properties. The main component of modern pesticide is a chemical active ingredient that is designed by the manufacturer to cause a toxic effect against the intended pest. The active ingredient is marketed in a formulation which contains inert ingredients that assist in the application of the product. Formulations may contain one or more active ingredient (up to four), and multiple formulations may be applied in multiple form known as a 'tank mix'. Once formulations are applied, active ingredient residues can remain in the environment for days, weeks, months, or years. They can also interact with other pesticidal or non-pesticidal residues.

Modern synthetic pesticides are produced by a large, and often multinational, chemical industry. In 2006, they included 1,524 separate active ingredients produced over the last 60 years[31] (Tomlin, 2006). These basic building blocks form the basis of many thousands of product formulations used around the world.

Today, pesticide active ingredients are subject to widely varying national regulations. Pesticides are divided into different sub-groups according to the groups of pests they attack, or to their chemical composition, or to the location in which they are applied. In terms of the groups of pests they attack, there are four main categories: insecticides, fungicides, herbicides and rodenticides. Other categories include nematicides, molluscicides, and acaricides (Alderton et al., 2006). The complexity of pesticides is confirmed by the IUPAC Glossary of Terms which includes over 500 terms related to pesticide use, often used by practitioners in relation to the chemistry, mode of action, regulation, and use of pesticides (Stephenson et al., 2006). The permutations of pesticide uses are further increased by the number of pest-crop combinations.

The synthetic pesticide provides a quick, simple and convenient answer to a nasty noxious and threatening problem – the pest. As a pest develops, a solution, usually chemical, is

31. The Pesticide Manual (Tomlin, 2006) lists 881 globally available pesticides, plus 643 superseded pesticides totalling 1,524 pesticide active ingredients developed over the last 60 years.

found. This single pest-chemical approach is piecemeal and disjointed, and the wider consequences are not always taken into account. Removing or reducing the abundance of one pest provides opportunities for others. It does not cure the problem, but just addresses the symptoms. Certain types of human activity may increase the likelihood of pests developing.

Synthetic pesticides are not the only answer to reducing pests. There are bio-rational pesticides which include biologically derived chemicals and biological agents (microbial organisms and invertebrates) that act by controlling pest species. There is also a range of non-chemical methods of pest control that can be used individually or as a multi-integrated approach that can incorporate methods of husbandry, cultural techniques and improved harvesting, storage, transport and distribution. There are systems which try to prevent pest pressure rather than curing it. For example, in theory, organic farming is predicated on the presumption that the methods of operation in themselves reduce pests and disease, reducing the need for chemical intervention in the first place.

Pesticide is a generic term. There are a number of different words that are embraced by the term. For example, 'plant protection product' is the legal word for a pesticide active ingredient defined in the EU Directive 91/414 (European Commission, 1991) (which legalises pesticides) and covers pesticides used mostly in agriculture. The Crop Protection Association, which represents the agro-chemical industry, refers to pesticides as 'crop protection chemicals'. Pesticide used in the home and commercial buildings are called 'biocides' according to EU Directive 98/8 (which also legalises pesticides). Pesticides used to control ectoparasites on domestic animals, such as sheep dips, are known as 'veterinary medicines', under the UK Medicines Act. It is possible for the same chemical active ingredient to be in one or more of these groups. For example, the pesticide cypermethrin can be a plant protection product, a crop protection product, a biocide and/or a veterinary medicine.

For simplicity and clarity, in the present thesis, the term pesticide will refer to the agricultural use of any synthetic chemical designed to kill any pest, unless otherwise stated. The phrase synthetic pesticide is sometimes used in the text to make it clear that the pesticide is not naturally derived.

4.3. *Early historical examples of chemical control*

The application of chemicals used as a form of pesticide goes back to ancient times. There are reports which indicate that poisonous plants were used in India 4,000 years ago to control pests; and that the Egyptians also used plants as sources of insecticidal compounds (Thacker, 2002: 5). There are a number of references to plagues of locusts, and other pests in the Old Testament, although it does not say whether anything was used to control them. Around 1,000 BC, the Greek poet Homer referred to the use of sulphur as a fumigant (Wilson, 2003). Writing in *Historia naturalis* in the 1st Century AD, the Roman naturalist Pliny the Elder recommended the use of arsenic as an insecticide, and suggested soda and olive oil for treatment on legumes (Lang, 1993). Later in 970 AD the Arab scholar Abu Mansur described over 450 plant products with toxicological and/or pharmacological properties (Thacker, 2002: 5). By the 16th Century the Chinese were applying arsenic compounds as insecticides (Cremlyn, 1978: 3). Between these early developments and the 16th Century, there are few references in historical literature to further developments in chemical pest control. The situation gradually changed during the European agricultural revolutions of the 17th/18th Centuries when new agricultural systems led to increasing pressures from pests and disease that farmers considered needed controlling. The exploration of the New World and the development of trade routes with Asia included with them a movement of food and crops. As an unintended consequence, pests, especially rodents and insects, were transported too, often to locations that allowed them to multiply unchecked by their natural predators or diseases. The global exploration also led to the discovery that some cultures were already using extracts from plants as a method of pest control. Examples included nicotine (from the tobacco plant *Nicotiana tobacum*) discovered in North America during the late 1500s, and used in Europe as an insecticide; pyrethrum (from *Chrysanthenum cinerariaefolium*) used from the 1800s for fly control in public health and agriculture; and derris (from *Derris chinensis*) which was discovered in the mid 1890s being used in East Asia to poison and catch fish, and which has been more widely applied as an insecticide (Thacker, 2002: 7-11). By the mid 19th Century systematic scientific methods began to be applied to agricultural production. Technological developments in agricultural equipment were coupled with the introduction of new inorganic chemical pesticides. For example, the French inventor Victor Vermorel designed and marketed one of the commercial crop sprayers in 1880 (Thacker, 2002: 8). Arsenic-based chemicals applied included copper arsenate and lead arsenate. Calcium arsenate became available, along with a number of formulations based on sodium, mercury, copper and tin. Some of them were quite successful at controlling pests, although the hazards to operators were great as they had high mammalian toxicities (Cremlyn, 1978: 5, Thacker, 2002: 8). By the early 1920s, the extensive application of arsenical insecticides caused widespread public dismay because treated fruits and vegetables were sometimes shown to contain poisonous residues (Cremlyn, 1978: 5). Many of the early chemicals were by-products discovered accidentally during experiments with arsenic-based dye manufacturing involving chemicals such as Paris Green (Montague, 2000: 335).

4.4. Introduction of synthetic pesticides during World War Two

The modern era for synthetic pesticides based on organic chemistry began in a limited way during the 1930s. It was initially driven by the safety concerns over the broad-spectrum toxicity of the existing arsenic-based pesticides. This led to the development of such pesticides as the alkyl thiocyanate insecticides and the fungicide group dithiocarbamates for the control of pathogenic fungi on fruit and potatoes. The Second World War was an important driver for the development of synthetic chemical pesticides. In this context, government scientists and civil servants were heavily and actively involved in what the present research has called a pesticide policy paradigm.

4.4.1. The need to control vector-borne diseases

The research and development of synthetic pesticides was important at this time because they were considered to have enormous potential benefits in helping with the war effort. Writing in the 1930s, Zinsser had attempted to show that, throughout history, insect-borne diseases (such as typhus) in wars had always killed more people than that of the military exchanges, even including the mass slaughter of the first world war (Zinsser, 1934). In the early 1940s, government scientists realised the important potential for pesticides to control insect vectors, such as lice (which carried typhus) and the mosquito (which carried malaria micro-organism), in order to protect troops stationed in hot tropical regions.

4.4.2. Link between synthetic pesticides and agriculture

The original objectives were to find chemicals to control vectors of disease, rather than to control agricultural insect pests. Nevertheless, the impetus for the agricultural research followed on from these close links with government-controlled military uses. Many chemicals and technologies were developed with government support, which were intended for use primarily in the theatre of warfare. They provided a firm basis for adaptation and adoption to civilian uses by pesticide companies, especially for use as pest management tools in UK-based agriculture. The development of this sector received the backing of the government who provided the foundation for research and development within a regime of self regulation. At this time the government can be seen to have backed the notion of a pesticide policy paradigm and were actively part of the 'policy community', thus creating stability for the paradigm. They did this because of a severe threat to UK food security: it was vital to maintain and increase local food supply with the use of effective synthetic chemical pesticides, because imports were so badly affected by shipping losses caused by German submarine activity, particularly in the North Atlantic Ocean.

4.4.3. Biologically-based pesticide supply disrupted by war

Not only was UK food in short supply, but the import and existing trade in biologically-based pesticides was severely curtailed. The natural insecticide pyrethrum was extracted from a chrysanthemum plant which, before the war, had been imported mainly from Japan, (King, 2006: 125), and Kenya, (Mellanby, 1992: 18). The Japanese sources became unavailable to the UK as soon as Japan entered the war. Pyrethrum from Kenya was in short supply because imports were threatened by attacks on shipping. Even if limited supplies could be delivered to the UK, there was a wartime need for increases in the production of pyrethrum. This could only be met by an increase in the planting of the chrysanthemum, which would take a number of seasons (years) to deliver. This option was too slow for the immediate and extra needs of wartime deployment. Synthetic alternatives on the other hand could potentially be manufactured much more quickly, so long as the production factories were in place. Rotenone, another natural insecticide, came from the derris plant that grew in what is now Indonesia and Malaysia. Again, supply was halted when Japan occupied South-East Asia in 1941-42. According to Wigglesworth (1945: 107), (an authority on insect physiology) supplies of pyrethrum were diverted towards military uses, and uses in the agricultural and other civil purposes were restricted. He adds that: "...supplies were hopelessly inadequate to meet rising demands – skyrocketing from month to month – and desperate efforts were made to find a sufficient substitute". It was this shortfall in the availability of naturally-based pesticides that drove the British government to oversee the development of new synthetic pesticides to meet military demands. According to Alexander King, an official at the Ministry of Supply: "We therefore decided, immediately we heard about the lack of insecticides, to set up a research programme into the mosquito and the louse" (King, 2006: 125). Wigglesworth (1945: 107) agreed with this sentiment by concluding: "It is against this background of anxiety that [the insecticide] DDT appeared". It was therefore the urgent war-time need for pest control in public health, rather than its use in the agricultural sector, which provided the initial spur for the development of synthetic pesticides in the UK. At the time there was little external verification or detailed risk analysis of possible adverse effects concerning these technical innovations.

The development of the organochlorine insecticide dichlorodiphenyltrichoroethane (DDT) originated with support from the Ministry of Supply (which co-ordinated the supply of equipment to the armed forces), and not the Ministry of Agriculture. At this time the link between government, the armed forces and industry was strong. This was exemplified by the position of Sir Andrew Duncan, a captain of industry who was brought into government as Minister of Supply during 1940-41, and then again throughout 1942-45. As a Director of Imperial Chemical Industries he was closely involved in a company that would become a major post-war manufacturer of pesticides. This presented a potential conflict of interest for someone simultaneously and intimately involved in both chemical production and regulation. Such an inconsistency was allowed to happen in those days because of the overriding wartime prerogative.

4.4.4. Suitability of synthetic pesticides during war

Of all the synthetic pesticides developed during the war, the most notable was DDT. Its insecticidal properties were described in 1939 by the Swiss chemist Paul Muller working for JR Geigy (now part of the pesticide company Syngenta), a Basel based company which until then produced dyes and tanning products. DDT was found to be toxic to a range of insects, and had relatively low acute toxicity to humans. The scientific analysis that demonstrated environmental persistence and chronic adverse effects did not emerge until many years later. Indeed DDT was seen at this time as a 'safer alternative', the other synthetic alternatives being largely arsenic-based. This exemplified the mindset of the day which helped foster a set of beliefs within the policy community and create conditions favourable for the development of the pesticide policy paradigm.

In Switzerland, DDT was used in agriculture from August 1941 onwards as a dust and wettable powder. It proved effective against the Colorado beetle (*Leptinostra decemineata*) that attacked potato crops. As Switzerland was a neutral country during the Second World War, the technology being developed was available to German, British, and US authorities through publications in international journals, although it was only the British and US who, independently, saw the significance of the technology (Mellanby, 1992). Tests in the US on Gesarol, the trade name for the agricultural uses of DDT, were "so spectacular that the Surgeon-General's Office and the Office of Scientific Research and Development became very interested" (West and Campbell, 1950: 6).

4.4.5. The active role of the state in developing pesticides for war science

From the outset, DDT was politically important and the British government considered it on a par with the development of radar technology. In 1943 the Prime Minister sent round a government memorandum requesting that: "all Ministries concerned should urge DDT production at the utmost of their resources" (West and Campbell, 1950: 6).

According to King (2006: 125), at the Ministry of Supply, the technical details of DDT were intercepted by a British censor in a letter sent from the Geigy Company in Basel to its offices in Manchester (and New York and Frankfurt). From these details, the Ministry of Supply produced a sample of DDT and sent it to a London University for toxicological testing, where it was "passed as fit for use by humans". Government officials then went to the Geigy Company in Manchester, told them about their own discovery, and ordered them to produce one tonne of DDT in one month. This was duly done, and DDT found its first operational use within three months of the censored letter reaching King's desk (King, 2006: 126). The risk analysis process for DDT was carried out in haste and bore no resemblance to the process today. Little was known about the hazards of DDT at that time (Rudd, 1966: 28). Mellanby, who worked on DDT during the war, later commented in the 1990s: "It is salutary to realise that with the constraints which operate today, and which delay the marketing of any new pesticide, DDT would probably not have been available for general use until 1949 (Mellanby, 1992: 11). The same process today takes about 11 years and costs of €200 million (ECPA, 2007); and it would not receive approval today anyway because of the tighter health and environmental regulatory standards. Had the development of DDT been delayed until 1949, Mellanby considers millions of people throughout the world would have died of typhus and malaria, and food supplies in several countries would have been at risk (Mellanby, 1981: 119). In March 1944 the Prime Minister Winston Churchill requested urgent action, as outlined in a minute sent to Andrew Duncan, Minister of Supply: "I am told that the demand for the new insecticide DDT is urgent and increasing. Pray let me know what output is to be expected, whether this is completely adequate, and, if not, whether anything can de done to expand and accelerate it… Please try and get a move on on a large scale" (Churchill, 1951: 530). This shows that government was the instigating force behind the development of a paradigm for pesticides, an active participant in the pesticide policy community.

By September 1944, Churchill's request had borne fruit and the high regard in which this new synthetic pesticide was held was made public in a BBC broadcast by an enthusiastic Prime Minister: " The excellent DDT powder which has been fully experimented with and found to yield astonishing results will henceforth be used on a great scale by the British forces in Burma and by the American and Australian forces in the Pacific and India" (West and Campbell, 1950: 11).

The government support for DDT (and pesticides in general) was reflected in wider policy terms, linking the pesticide policy paradigm to conventional agriculture. According to McMichael (1996), the state often took a very active role in promoting increases in productivity in industry and agriculture, while also stressing the need for economic efficiency. One example of this occurred in October 1939 when the British government promised to buy the whole crop at fixed prices, and mandated the production of specific crops with compulsory cropping orders (Smith, 1990).

4.4.6. Instituting scientific advice for governmental approval

Despite the rapid development of DDT, the Government had recognised the need to seek scientific advice on the use of pesticides, with the establishment in 1944 of the first government-appointed chemicals' approval scheme. As part of the drive to increase food production, the Ministry of Agriculture and Fisheries (MAF) wanted to provide pesticide advice through its fledgling advisory service. At the time it was thought that government officials were not able to advise on the use of proprietary products unless they had gone through some sort of official approval and testing procedure, or peer review. In 1944, the Ministry proposed setting up an Advisory Committee which would take the responsibility for approving products. It was called the Scheme for the Approval of Proprietary Products for the Control of Plant Pests and Diseases, and was operated by MAF's Plant Pathology Laboratory at Harpenden. The first products submitted were lead arsenate, lime sulphur, miscible tar oil winter washes, stock emulsion tar oil winter washes, and organomercury seed dressings (Montague, 2000: 348). At this time, DDT was not used in agriculture because of its very limited availability, and its use was restricted to militarily authorised public health uses. Although the development of DDT, and other pesticides, was carried out within the background of limited risk analysis processes, there was nevertheless a fledgling recognition that pesticides were hazardous, which meant that scientific reassurance was required for pesticide approval.

4.5. Post-war boom in synthetic pesticides

In the aftermath of the Second World War, agricultural production levels increased in line with the British government's support for food commodities. Synthetic pesticides were an important technical component of what was becoming known as conventional farming, and usage levels increased in line with agricultural production output. This resulted in economic benefits for the agronomic and food industry sectors and led to the production of a cheap industrially dependent food supply (Oerke et al., 1994). The newly emerging pesticide technology provided excellent export prospects for the British chemical industry.

4.5.1. Synthetic pesticides supersede natural pesticides

DDT became widely used for the control of numerous agricultural pests, and led on to experimentation with a number of other synthetic pesticides. The beginnings of a modern 'chemical age' gave rise to a diverse array of new chemical pesticide products. This included the organochlorine and organophosphate groups of insecticides and the phenoxy herbicides (2,4,5-T and 2,4-D). In 1944 there were 63 pesticide approved products which expanded to 532 by 1960, and 810 by 1976 (Sly, 1977). After the Second World War the drive to expand local UK food production, as a food security policy, continued and brought significant opportunities for the rapidly expanding pesticide industry. Other organochlorine insecticides were developed at this time such as the cyclodienes aldrin and dieldrin, and the isomers of hexachlorocyclohexane (HCH) including lindane (Thacker, 2002: 60-61).

The organophosphate insecticides were discovered as a result of research carried out during the Second World War on chemical warfare agents in Nazi concentration camps. Post-war, this technology attracted the interest of the American intelligence services, and the technological advances of OPs were passed on the US pesticide industry, for use in the agricultural sector. One of the first (OP) insecticides to be developed for agricultural use was parathion (Gunther and Jeppson, 1960).

These new synthetic pesticides out-competed and replaced natural pesticides, such as rotenone, in the post war agrichemical marketplace. The naturally-based pesticides never re-captured their pre-war market pre-eminence. The new synthetic pesticides had a longer shelf life, ease of application, and quick-acting pest control results that gave them a competitive economic advantage over the traditional biologically-derived chemicals. In 1939 for example, the US imported 4,000,000 pounds (1,818,182 kg) of plant roots containing rotenone. When production started again after the war, imports had increased to 10,400,000 pounds (4,727,273 kg). But by 1952 the market had decreased to 3,600,000 pounds (1,636,363 kg), losing out to the new organophosphate alternatives (Gunther and Jeppson, 1960). A closely related group of insecticides, the carbamates, were first discovered by the Swiss company Geigy in 1947, although the most widely used carbaryl was not introduced until the mid 1950s (Cremlyn, 1978: 6). The inaugural International

Congress on Crop Protection, held in London in 1949 (Montague, 2000: 349), was the prelude to a period of rapid expansion in Britain's pesticide industry. It was supported by a government-backed drive to increase domestic food production and help deliver post-war food security. Scientists were reportedly confident that organic chemistry could produce a range of synthetic chemical armoury to control weeds, pests and diseases, particularly in the agricultural sector.

4.6. The development of pesticide governance

The following section reviews how the dramatic increase in post-war use of synthetic pesticides was governed in the UK. The post-war Labour government was intent on overseeing an increase in agricultural efficiency. This was clearly exemplified by the establishment of the National Advisory Service (the precursor of the Agricultural Development and Advisory Service). Launched on 1 October 1946, the service consisted of 1,300-1,400 highly trained technical officers providing advice to improve agronomic techniques, including pest management. This service was free of charge to farmers (Williams, 1965: 159). This gave a clear signal that government was going to drive UK agricultural policy, one important component of which was the assessment of effective chemical pesticide control. This provides further evidence of support for the pesticide policy paradigm.

The levels of pesticide use were delivering significant improvements for pest control. Fewer losses from pests and diseases helped support an increase in agricultural production. But with the benefits came associated safety risks. Several agricultural workers had been killed using dinitro herbicides during the 1940s (Bidstrup, 1950). In 1949 an official committee on Health, Welfare and Safety in Non-industrial Employment recommended that employers should provide protective clothing when 'poisonous sprays' were being used (Mellanby, 1992). A review of organophosphate insecticides by researchers at the Medical Research Council cautioned that these chemicals were "effective chemicals but extremely dangerous to man unless handled with extraordinary care". The researchers were concerned these products were used by operators of variable experience before their toxicity had been studied adequately. They concluded: "We know little about the acute toxicity of some of these substances, and almost nothing about the long-term effects of repeated small doses" (Bidstrup, 1950: 548). In 1951, the Working Party on Precautionary Measures against Toxic Chemicals used in Agriculture recommended that arrangements for the notification of new products should be required. This would include providing information on the toxicity to workers and also the implications of consuming pesticide residues in food (van Zwanenberg, 1995). During the mid 1950s a series of working parties chaired by Professor Zuckerman, a key scientific adviser to the UK government, produced a number of reports on the dangers of pesticides to humans and on the levels of residues in food. In 1952 the subject of danger to wildlife was added to the remit of the working party, largely as a result of submissions from the Nature Conservancy, the official government body concerned with conservation. At the time, there was very little information on environmental effects available for the experts to examine.

4.6.1. The voluntary control of pesticide use

In 1957, a non-statutory Pesticides Safety Precautions Scheme (PSPS) was formally agreed between the government departments and the pesticide association (the Association of British Insecticide Manufacturers (a precursor of the Crop Protection Association). PSPS was run by the Ministry of Agriculture, Fisheries and Food (MAFF) and included the input of scientific expert advisers. It was a voluntary arrangement – a 'gentleman's agreement' between pesticide manufacturers and the government, whereby the industry agreed only to sell to suppliers products that had been officially cleared for use. A limited number of specified, more acutely toxic pesticides, came under the poisons lists established under the Poisons Act 1972, including aldicarb, carbofuran and endosulfan. For the majority of pesticides, PSPS operated on the non-statutory basis that only pesticides approved by a government-appointed independent expert review body, [by then called the Advisory Committee on Pesticides (ACP)] would be available for sale and use (Rothstein et al., 1999). It covered pesticides used in agriculture, forestry, home and gardens, and food storage in Britain. The scheme was extended to cover Northern Ireland in 1970. Starting in 1975, the scheme was extended to cover all non-agricultural uses of pesticides. The aim of PSPS was to safeguard humans (occupational, bystander and consumer), domestic and farm animals (including beneficial insects). The scheme requested (not required) manufacturers, distributors and importers of new pesticides or new uses of pesticides to undertake to seek prior official agreement and to submit test data relevant to the safety of their products to independent expert scrutiny. As DDT, was already in widespread usage by 1957, it was exempt from the PSPS scheme. In the 1950s-60s, the ACP included representatives from government departments, experts from within government and more independent scientists with scientific expertise in the disciplines concerned (biology, medical science, toxicology and pharmacology). At this time, the ACP had a Scientific Sub-Committee (SSC) comprised of scientific and medical experts who were appointed solely for their specialised knowledge. The SSC was concerned only with the scientific assessment of pesticides. A distinction was however made for the ACP parent committee where 'other factors' could be taken into account. This meant that the ACP must at times have made what were effectively value judgements, balancing the risk against the benefits (RCEP, 1979). Finally the ACP's advice was passed to Ministers, who were ultimately responsible for granting clearances (under the non-statutory arrangements). Although in practice the decision to approve a pesticide was left to the recommendation of the ACP, and the implementation by the regulator, final responsibility remained with the Minister, who could intervene at anytime.

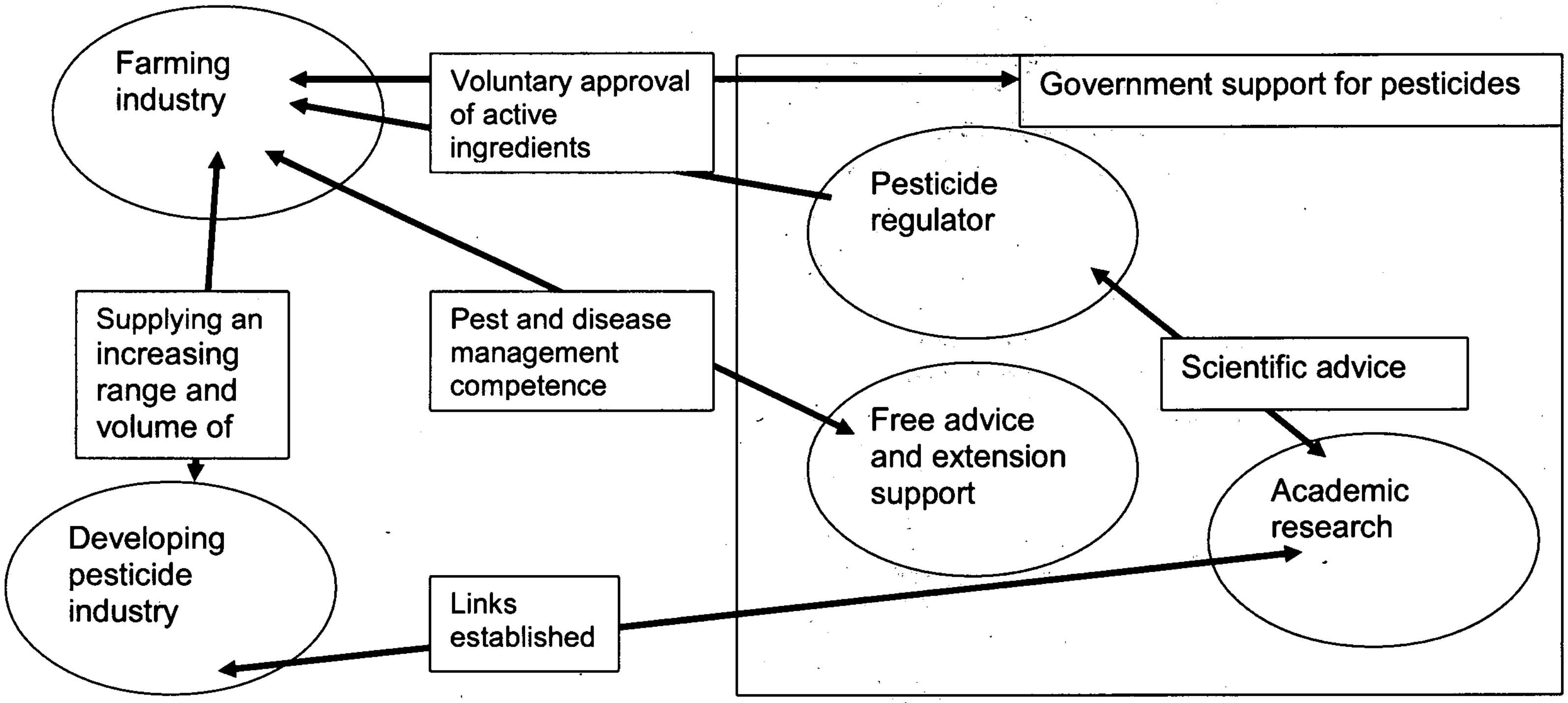
4.7. Pesticide policy paradigm development during the 1940-50s

The above section has described the conditions in which the pesticide policy paradigm developed in the UK during the 1940s (see also Table 4.1). The technological advances that led to this outcome included the establishment of a pesticide process which could comprehensively deliver pest and disease management for a range of diverse agricultural crops and other situations that are vulnerable to attack. Individual pesticide formulations could not just appear at random in an uncoordinated fashion, they had to be marshalled by a co-ordinated by group of inter-related organisations and entities in order to be effective. To deliver this outcome a pesticide policy network emerged and involved the farming industry, agricultural supply sector, government and scientific experts.

The concept of a 'pesticide policy paradigm', as outlined in Chapter Two is linked to the data collected and analysed from the present chapter. It also shows how the pesticide technological trajectory developed over time and was maintained by productive stakeholders to defend the paradigm. This section shows that a historical analysis is important implications for subsequent paradigms that have developed since. In this context a paradigm relates to the pesticide policy and the way in which it developed in a particular mutually accepted manner in order to continue the use of pesticides.

At this stage there were a number of factors that characterised the pesticide policy community as outlined in Figure 4.1. This figure is a simplified expression of the inter-locked relationships between the stakeholders (farming, pesticide industry, government and expert advice). It was small and internally strong and restricted to government, academic experts, the pesticide industry and the agricultural sector (and other pesticide users). There were important political drivers for development, and little public opposition to pesticides. A range of public research, support and advice was offered to the farming sector in support of the new synthetic pesticides. They were cheap to develop, effective at killing pests, easy to use. Policy stakeholders focussed on control and efficacy rather than any potential adverse effects. Little consideration was given to the long term sustainability of pesticides, during the Second World War. These included potential adverse effects such as environmental persistence and the chronic effects of exposure to pesticides. There is little evidence that the health implications of low-long exposure to pesticides through water air and food were anticipated. The acute and hazardous effects of pesticides were nevertheless apparent. The government realised that scientific expertise would be required to support a potentially hazardous technology in which chemicals were deliberately released into the environment in order to achieve their intended effects of pest control. The stakeholders are characterised by a lack of critical external input from civil society. The decision making process was couched in secrecy both in terms of the pesticide industry and government. Government officials were heavily involved in the development of pesticides and in control of the process. Although firmly in control, the government nevertheless constructed a voluntary system of pesticide approval. The farming sector was supported by the government through free pest management advice and a network of advisors set up to provide wider agronomic support. In terms of the prognosis for pesticides, many scientists were confident that synthetic chemistry would comprehensively support the agronomic pest control needs of the country. Again, it is worth noting the emphasis was on developing efficacious pest control and there was little awareness concerning the health of workers and impacts on wildlife/environmental fate.

Figure 4.1: Development of a 'pesticide policy community' during the 1940s



Key: This diagram shows the common ground between the dominant pesticide stakeholders. The background emphasis promoted an increase in agricultural efficiency, output production and input subsidies. Commercial and government secrecy; official backing of a voluntary professional sector largely trusted and believed in by wider-society. There was little dissention among the stakeholders and initial concerns about the health of workers and impacts on wildlife, and there was little concern from wider society outside the pesticide stakeholder group. The arrows in the diagram represent the role from one stakeholder to another with an explanation of the role in the overlapping square box. The mutually beneficial two-way and essentially harmonious relationship between organisations is indicated by the double-headed arrows. , The knowledge emphasis was on efficacy data, rather than human and environmental safety.

Source: Author

Table 4.1:
Components of an emerging pesticide policy paradigm – 1940s

1.	**War, food security** and **increased production** were key drivers for pesticide development and factors for the development of the paradigm
2.	Policy controlled at the **national level** by central government in an era of **secrecy** through **'gentleman's agreement'** in which productive stakeholders work within a mutually reinforcing policy community
3.	Government support for pesticide-related research and **free** point-of-delivery **agronomic advice** on pest and disease management
4.	Development of a food supply economy that was **dependent on pesticides**
5.	Growth of **marketable pesticides** with powerful effects, long shelf life, quick results, are easy-to-use and effective against many pests in diverse locations
6.	Establishment of a small, closed, strong, professional and mutually reinforcing group of policy stakeholders governed by **liberal voluntary agreements**
7.	Emphasis on research and development of **active ingredient** safety and efficacy on crops with high potential for economic return
8.	**Scant** consideration for long term **sustainability** of pesticides including little questioning of adverse health & environmental effects and pest resistance
9.	**Policy segmented** by industry sectors and government departments
10.	Requires a **pro-pesticide defence** of the policy, including scientific 'peer review'
11.	Opportunities for post-war development of a **global pesticide industry** (supplied by UK companies)

4.8. *Historical review of the changes in pesticides usage levels*

This section examines the rise in pesticide usage over the last 60 years, and addresses the reasons why these trends occurred. It shows that, under the developing paradigm, conditions were rife for the rapid expansion in pesticide production, sales and usage levels. Pesticide usage data is important because it allows for the impact of pesticides to be monitored. It shows trends in usage patterns over time and it shows which pesticides are likely to be distributed more widely in the environment.

When pesticides come onto the market, it is not always clear which ones are going to be market leaders. It may be that the pesticide company expands its market by registering the pesticide in many countries and on different crops and against a wider range of pests. In this case, a pesticide can have increased unintentional global adverse effects, simply because it has become a market leader in a large number of countries. It is also desirable that accurate and detailed monitoring is carried out at the active ingredient level so that if adverse effects are observed they can be linked to individual chemicals. A number of human health studies monitoring the effects of pesticides have lacked accurate pesticide data, because the location and chemical name (of both the formulation and active ingredient) is not available. For example, a number of retrospective case control studies researching adverse health outcomes are unable to establish the specific pesticide(s) to which individual people have been exposed (Dick et al., 2007). Mostly data are provided by the national pesticide industry organisation and includes crude sales figures in money terms or in terms of volumes according to main pesticide groups (insecticides, fungicides, herbicides etc).

The data provided in the following section provides an indication of trends from which conclusions can be drawn about the intensity of usage. However there is poor data for examining the adverse effects of pesticides (exposure to humans and wildlife and/or environmental contamination) which leads to difficulties with exposure assessment, and therefore risk analysis for pesticides.

4.8.1. The development of a global pesticide industry

In the 60 years since 1945, synthetic pesticide use has increased dramatically up to the present day. In tonnage terms, agricultural pesticide production levels have now reached 2.56 million tonnes per year. (Pretty, 2005: 3). For the year 2005, the market value of pesticides increased 1.5% in US dollar terms to reach US$31,190 billion (Crop Life, 2007b).

From the mid 1940s, to the mid 1960s, the use of DDT increased dramatically becoming the most widely used pesticide in the world (Rudd, 1966: 61). Today it is still probably the only pesticide with which the general public are familiar. In 1944, a few thousand kilos were available, and by the mid 1960s, total annually production had reached an estimated quarter of a billion pounds (about 110 million kg)[32]. Writing at the time Professor Rudd[33] commented on DDT saying: "no other synthetic chemical has had such an impact on the world's population" (Rudd, 1966: 61).

There were economic advantages to be gained from the use of DDT. It was relatively cheap to manufacture, compared with later pesticides, because it had incurred very few research and development costs to assess its potential adverse health and environmental impacts.

For pesticides as a group, the highest annual growth rates were during the 1960s when they were at 12% throughout the decade. (Pretty, 2005: 3). Rosenzweig et al. (2000: 18) have described the way in which pesticides were linked to the economic benefits of higher yielding crop varieties as: "The adoption of high-yielding varieties during the 1960s was associated with a dramatic increase in pesticide use". As the yields increased the economic incentive to continue applying pesticide technology locked these chemicals into becoming the dominant form of pest control in conventional agriculture.

In more recent decades sales in pesticides continued to grow, but at lower annual rates of increase in sales, compared with the 1960s. The increases were on average 2% per annum during the 1980s, and 0.6% during the 1990s (Pretty and Hine, 2005). During the 2000s, rates of increase fluctuated between plus and minus figures. For example, in 2005, in real terms the market value declined 2.5%, due to adverse weather effects resulting in a reduction in product usages. Similar factors depressed the market in 2003, whilst overall conditions in 2004 were more favourable, and there was an increase of 4.7% (Crop Life, 2007b).

During the 1970-80s there was a big expansion in the global trade in pesticides providing opportunities for British, other European and North America pesticide companies. For example, in the UK, pesticide exports increased (at constant prices) from £33 million in

32. This assumes the author was referring to an American billion (10^9)
33. Professor of Zoology, University of California, US.

1972 to £211 million in 1980 (Bull, 1982: 191). Many of these exports were to developing countries in which pesticides were used in very hazardous circumstances (Bull, 1982).

Pesticides are used at a global level because the companies developing them operate on a global basis. Many in the food supply chain also operate at a global level. Key players such as multiple food retailers have to supply produce lines 52 weeks of the year. This means that they are dealing with farmers, growers and suppliers that rely on pesticides as part of the farming systems that they operate. It is in the interest of those global international stakeholders that standards are harmonised in order to help facilitate international trade. However national governments do not always come to consistent regulatory decisions. For example, the herbicide paraquat may be legal to use in one country, and illegal in another. This can have potential implications for countries importing food produce especially if it contains residues of a pesticide that is legally available to be used in the country where the food was produced, but illegal (to be used and as a residue in food) in the counties to which the food was imported. To overcome these potential restrictions to trade, the Organisation for Economic Co-operation and Development (OECD) has a programme of joint co-operation that was set up to help the international harmonisation of safety data requirements. In addition, the joint World Health Organisation/Food and Agriculture Codex Committee of Scientific Experts on Pesticide Residues harmonises internationally acceptable residue standards. When monitoring for pesticide residues in food, for example, a wide range of parameters has to be measured. These include: Environmental fate (food and drinking water), pesticide metabolism in crops and livestock, effects of food processing on residues, toxicological assessments, diets and modelling for dietary exposure, chronic intake, acute intake (Hamilton and Crossley, 2004). The important elements for the evaluation of risk is the use of 'suitable scientific principles' and to 'ensure necessary consistency' in risk analysis (Hamilton and Crossley, 2004: 306).

4.8.2. Pesticides and related technologies

Pesticides were very much interlinked within a package of technological developments that led to an increase in agricultural productivity. The most important linked technological developments responsible for these substantial increases were the use of hybrid seeds, more efficient use of fertilisers, the use of more machinery, and the development of disease control in plants and livestock.

Some crops, such as the cereals used for animal feed, required greater use of pesticides, so levels can change according to changing crop patterns. For example, the profitability of cereal growing in the UK was high in the mid-1970s as a result of the UK joining the EU and because of low world stocks of grain. This profitability allowed the expansion of pesticide application, which had not previously been cost effective for weed control. The introduction of chemical fertilisers and herbicides in the late 1940s had reduced the need for rotation. However, the resulting minimal tillage and over reliance on herbicides induced increased levels of grass weed species and herbicide resistance in blackgrass, creating a continuing demand for new chemical controls. In addition, high fertiliser applications, particularly on weak-strawed varieties, created a demand for plant growth regulators to prevent lodging (stem breakage) and ensure quality at harvest (Thomas and Wardman, 1999).

When pesticide-based agricultural systems are adopted, yields and returns become dependent on agrichemical inputs despite the high costs of these inputs. This imposes an 'economic barrier' to switching to other systems, or away from pesticide use. Once a pest control strategy is adopted it then becomes the dominant strategy as has been the case with pesticides (Wilson and Tisdell, 2001) (see Section 7.4, Vol. 1, page 232).

4.8.3. Links between pesticides and agricultural subsidies

Pesticide use has also been linked to agricultural subsidy, and the wider support for agriculture. In general terms subsidies can encourage wasteful use of materials, energy, natural resources and also encourage over production (Lingard, 2002). Other research has linked their adoption to the cause of adverse environmental effects (Pretty et al., 2005).

Internationally, there are examples of where subsidies can often stimulate greater use of chemical inputs. Rice farmers in Japan, Taiwan and Korea have been reported to use just over half of all insecticide applied to rice worldwide, and yet only produce 2% of the worlds crops. The reasons for this inconsistency are due to large government price support making it profitable to increase insecticide use even when the resulting production gains are small (Vorley and Keeney, 1998). Although it cannot be argued that subsidies were put forward in order to sustain a pesticide policy paradigm, one unintended consequence was that it did. The cereals produced were 'pesticide-hungry' and provided a return on sales that helped maintain a pesticide industry that could sustain the high research and development budgets required to innovate new pesticide products. According to Thomas and Wardman (1999) changes in CAP and the General Agreement on Tariffs and Trade (GATT) have influenced the profitability of pesticide use, as directly affecting the areas of individual crops grown. In a climate of price supports and subsidies for production-orientated technology, farmers were encouraged to purchase the products of industrial suppliers – feeds, grains, machinery, fertilisers and pesticides. This system produced an expanding market for the agro-industrial firms (Marsden and Whatmore, 1994: 117).

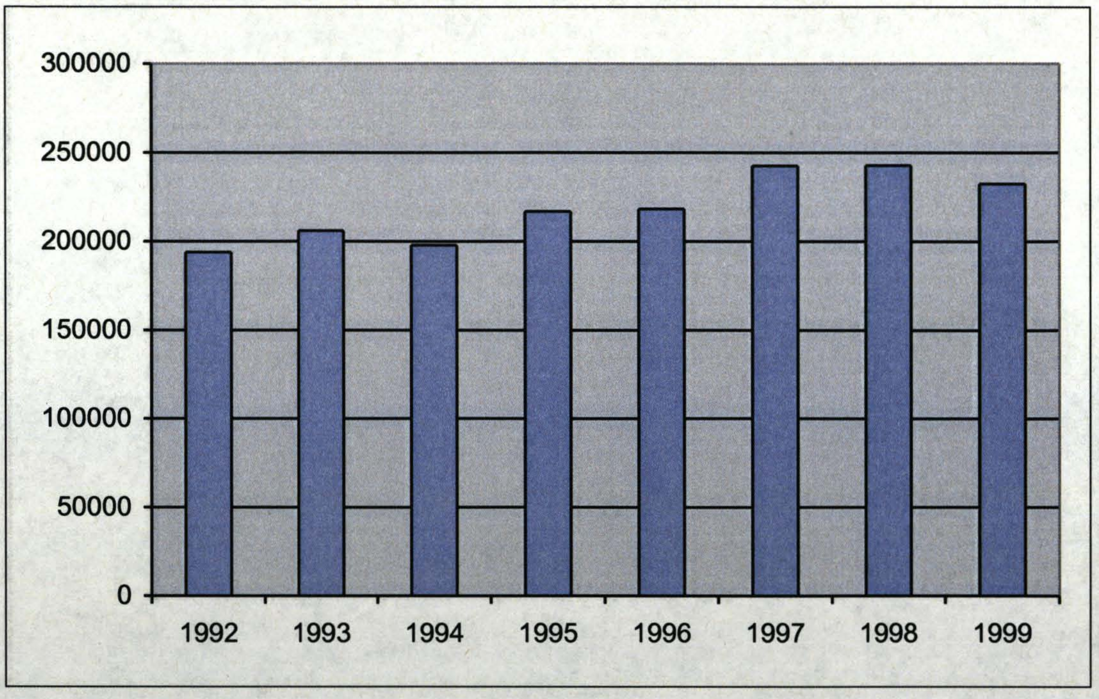
4.8.4. European pesticide usage

Over the 30 years up to the end of the 1990s, changes in international trade arrangements such as the Common Agricultural Policy (CAP) and the General Agreement of Tariffs and Trade (GATT) influenced the profitability of pesticide use, and directly affected the areas of individual crops grown.

The main source of information for pesticide usage in the European Union is the EU organisation Eurostat, that relies on data supplied by the agricultural pesticide industry trade association the European Crop Protection Agency (ECPA). The total amount of plant protection products (pesticides) increased between 1992 and 1998. A slight decline was reported for 1999 and it is not clear yet whether this represents a downward trend or not (see Figure 4.2). The data provided only comprises pesticides supplied by ECPA, which is largely restricted to the agricultural sectors. This includes the largest area of usage, but by no means provides a comprehensive overview of the total use of pesticides. Even for agriculture, some commonly used pesticides are not included in the usage figures, such as molluscicides and pesticides applied post harvest. The data also excludes biocides (non-agricultural pesticides), or veterinary medicines (such as sheep dips) used in agriculture, and human medicines used as pesticides (such as head lice treatment).

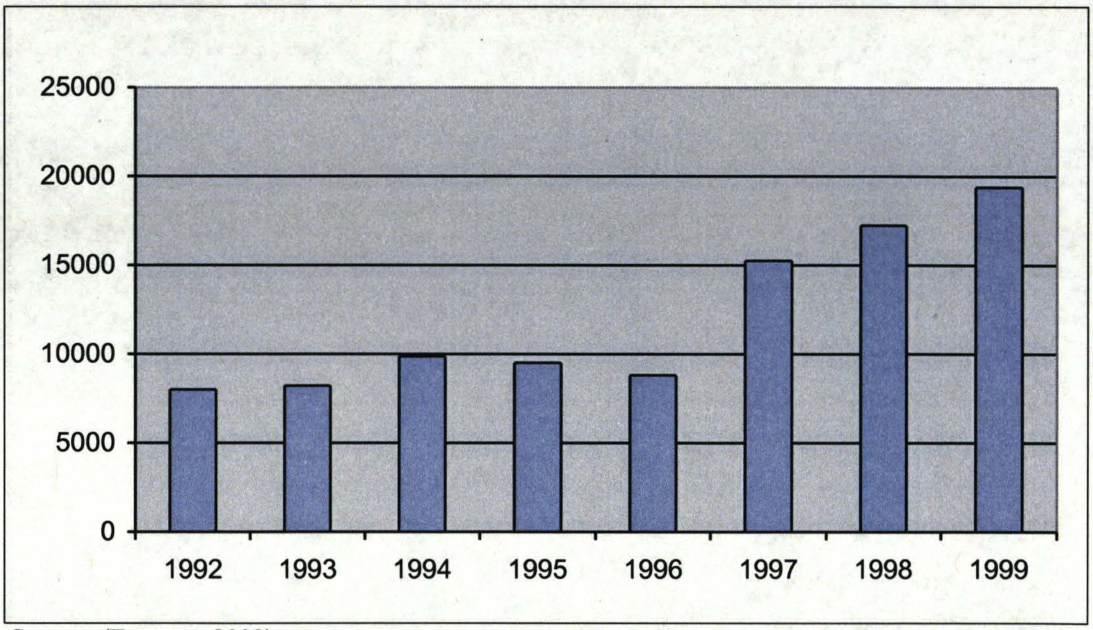
The period of increase in pesticide use (1992-1998) coincided with the introduction of the CAP reforms of 1992. They were set out by the EU Council of Ministers that marked the beginning of an agricultural environmental policy. The two main aspects of the policy were to reduce the link between subsidies and increased food production, coupled with a reduction in agriculturally produced pollution, known as decoupling. For crops, this meant the reduction in the use of fertiliser and pesticides (Gardner, 1996: 113). The reforms were clearly backed by the UK. In 1993, a senior civil servant said: "the quality of food and quality of the environment were more important than quantity for ministers" (Jordan et al., 1994: 506). This signal showed that a policy change for the UK government meant a shift away from simply supporting the quantity of agricultural output. Their instigator role as active members of the pesticide policy community had come to an end by this time, although its support for the pesticide policy paradigm was not diminished.

Figure 4.2: Volume of pesticides (ppp) used in the EU (tonnes of AI)



Source: (Eurostat, 2002)
Note: 'ppp' refers to the EU term for pesticides which is 'plant protection product'
AI = active ingredient

Figure 4.3: Volume of insecticides (ppp) used in the EU (tonnes of AI)



Source: (Eurostat, 2002)

CAP reform has been a long drawn out process, which is set to carry on at least until 2013 (EU, 2003). The pesticide usage data (see Figure 4.2) shows the CAP reform has had little impact on reducing the overall use of pesticides, or any impact on reducing insecticide levels (see Figure 4.3). The same situation occurred in the UK for volume of pesticides used (see Figure 4.4) and insecticides used (see Figure 4.5). Reducing the use of herbicides and fungicides in the arable sector (cereals, maize and sugar beet) would have only marginal effect on the total volume of pesticides used, which is dominated by bulky products such as sulphur and copper compounds. The use of fungicides and insecticides were least affected by CAP reform as the bulk of these products is used on speciality crops not subjected to CAP regulations (Eurostat, 2002: 11). Overall, insecticides were a relatively small proportion of pesticides used (8% of the total) but it has increased the most rapidly of all the pesticide sectors, again since the 1992 CAP 'reform'. Although the direction of EU policy changed in 1992, up until 1999, there had been little direct impact on the use of pesticides. Clearly it takes time for such policy measures to take effect.

4.8.5. UK pesticides usage

The industry lobby organisation, the Crop Protection Association, which represents the major manufacturers, estimated that pesticide sales were £388.88 million for the year 2006[34]. Agriculture and horticulture accounted for 84.7% of this market, with 10.9% representing home and garden use, of which the remaining 4.4% included the industrial, amenity and forestry sectors. Usually these sales figures are amalgamated into major pesticide groups (insecticides, herbicides, fungicides, rodenticides, miscellaneous others). The European Union data agency Eurostat provides figures provide data on overall usage of pesticides (Figure 4.4) and insecticides (Figure 4.5). Both figures show upwards trends towards the end of the 1990s. Another way in which pesticide use is measured is through Central Science Laboratory. The results from these surveys are presented in two ways: according to weight of pesticide active ingredient applied; in terms of area of active ingredient applied. In recent years the tonnage of pesticide use has decreased whereas the area applied has increased. In the case of arable crops, excluding set-aside[35], between 1992 and 2002, there was a 25% increase in the area treated, but a 2% decrease in the weight of pesticide applied. This reflects both the move to products containing newer molecules "intrinsically more active at lower levels" and the use of reduced pesticides application rates[36] by farmers and growers. In particular the use of organochlorine and

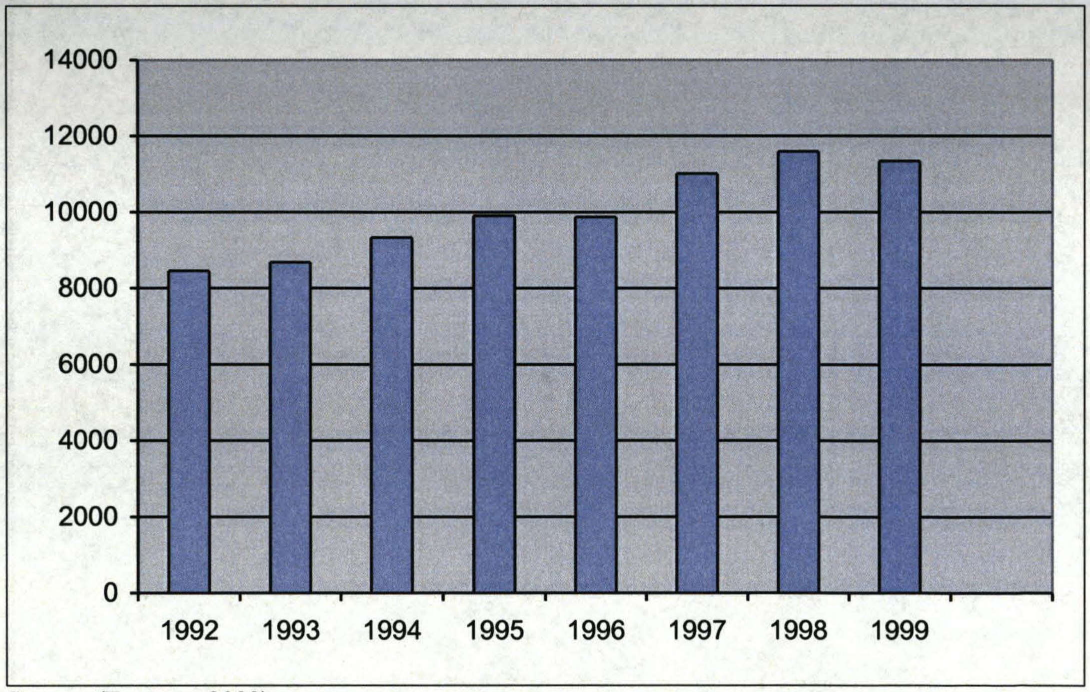
34. www.cropprotection.org.uk
35. The phrase 'set aside' is an EU term that refers to land taken out of farming production. It was developed as part of the 1992 CAP reforms, and attempted to tackle over production in cereals.
36. The volume application rate is the amount of formulation applied per hectare (ha). Rates can vary from less than 5 litres per ha to greater than 600l /ha (www.dropdata.org).

organophosphate insecticides, both used at relatively high rates, have decreased by 83% and 75% respectively. In contrast the use of pyrethroids, which are used at lower rates, increased by 44% (Garthwaite et al., 2003).

4.8.6. Limitations of usage/sales monitoring

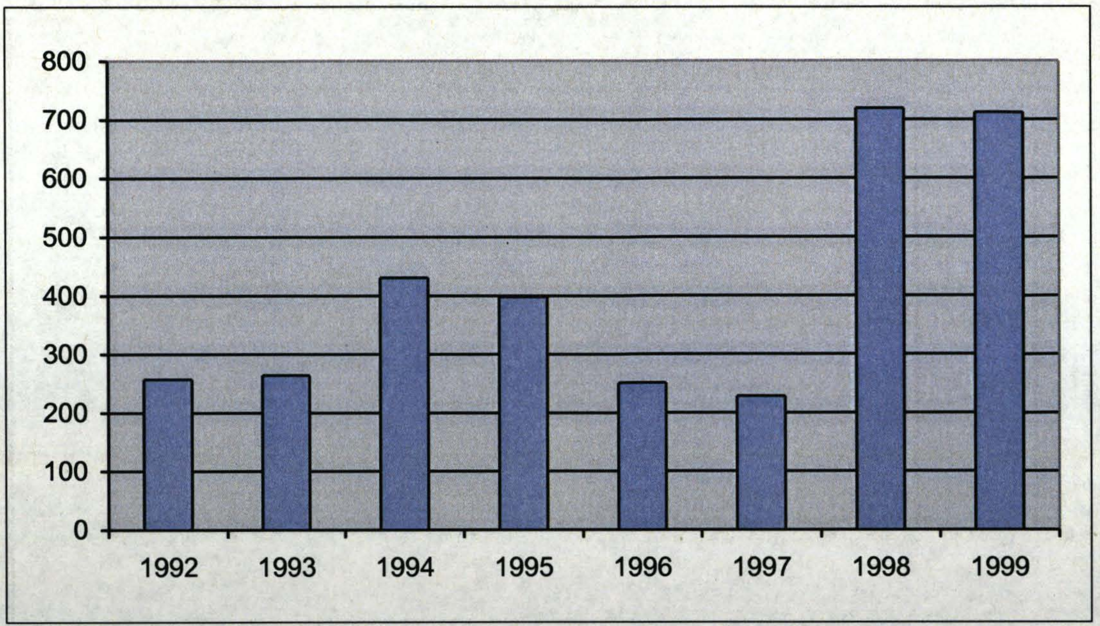
Very often the use levels of individual active ingredients are not known. But there is a complex array of factors that relate to pesticide usage which bear no relationship to agronomic policy or agronomic need for pest management intervention. Abiotic factors can be important, including temperature, rainfall, and humidity. A warm, wet summer can lead to an increase in pesticide usage. For all these reasons, the implications of fluctuations in headline volume of pesticides have to be treated with caution (Eurostat, 2002). Measuring pesticide use in terms of active ingredient over time provides a much more accurate estimate of the risks to human health and the environment.

Figure 4.4: Volume of pesticides (ppp) used in the UK (tonnes of AI)



Source: (Eurostat, 2002)

Figure 4.5: Volume of insecticides (ppp) used in the UK (tonnes of AI)



Source: (Eurostat, 2002)

4.9. Conclusions

The use of synthetic pesticides was developed during the Second World War under a fledgling chemical industry that was actively supported by the UK government policy and scientific expertise. The restrictions on global trade meant that imports of naturally-based bio-pesticides to control insect pest were limited and government civil servants decided to develop synthetic alternatives as quickly as possible as a vital wartime public health measure to control insect disease vectors. By today's standards the development, regulation and use of pesticides was not carried out according to any sort of sustainability principles. There was overconfidence on the part of scientists. They had thought that synthetic chemistry would solve all pest and disease problem. Little consideration was given to any debate (internal and/or public) of these decisions, including the long-term health and environmental sustainability implications of such decisions. The organochlorine insecticide DDT was seen as a 'safer alternative' in the 1940s because it replaced arsenical chemicals which were known to have acute mammalian toxicities. The persistence of DDT and chronic adverse effects were not immediately apparent. The impacts of DDT are still being widely studied today.

Post war the pesticide technologies developed by the UK, US and German wartime governments were transferred opportunistically to the emerging agrichemical industries to help increase agricultural production and improve the security of food supply. This was in line with government policies that backed agricultural subsidies. The use of hazardous pesticides posed risks that had to have safety verification assessed by scientific expertise.

The group of stakeholders developing, regulating and using pesticides did so with common actions. The result was a conventional agricultural system that became reliant on the use of synthetic pesticides and fertilisers. These inputs became locked into the farming process. The present research argues that these actions can be described in the terms of a 'pesticide policy paradigm'. A set of common ideas and beliefs was developed by the pesticide stakeholders and designed to supply synthetic pesticides. The government and pesticide industry had their own in-house scientific experts, and both private and public funds supported an academic expertise outside their direct control. It was important that these scientists developed their research in a common way in order to develop safety and efficacy testing that produce pesticide formulations that could be regulated, marketed and used in a mutually acceptable manner. A chain of interactions was required that meant each stakeholder group was depend on all the others. No one group could develop, regulate and use pesticides on their own (although the UK government was close to this 'command and control' state of affairs during the Second World War. The pesticide paradigm model is described in greater detail in Chapter Seven where it is discussed in light of a literature analysis from the preceding chapters.

The final section of this chapter reviews pesticide use from the 1940s to the 2000s. The economic power of synthetic pesticides was strong. It easily out-paced the pre-war naturally based pesticides, and during the 1950s, developed into a significant global business dominated by the US, UK, Switzerland, Germany and France. The pesticide increases in the global pesticide market have flattened off in recent decades, although they still dominate the pest control sector. Production subsidies such as the European Common Agricultural Policy (CAP) did help develop the pesticide industry. Reform of CAP, moving away from production subsidies, has had a limited impact on pesticide sales, perhaps marking the high level of dependability synthetic pesticides have for conventional agriculture.

5. Scientific evidence of the adverse effects of pesticides

5.1. Introduction

The previous chapter has reviewed the impact of synthetic pesticides since their introduction from the 1930s onwards. This chapter examines the health and environmental impacts that have been recorded in the scientific literature as a result of exposure to synthetic pesticides. These impacts occurred following approval and regulation of the individual active ingredient. The registering company was responsible for producing safety and efficacy data, and the regulatory processes deemed the chemical to be acceptable for use, according to the best available knowledge of the day.

The chapter identifies risks associated with the use of pesticides in the form of undesirable side effects. A literature review was carried out by using Pub Med (US Library of Medicine and the National Institutes of Health) with the search words 'pesticide' and 'adverse effects'. Emphasis was placed on identifying any increased risk associated with exposure to an active ingredient, pesticide sub-group, or pesticides as a whole group. The reports cited relate largely to environmental and public health work carried out by research establishments and published in the academic literature.

The research data quoted are largely located in Europe and North America. The focus of this study is on UK pesticide policy as it relates to the European Union. The search could have been restricted to data from the UK. This was not done because of the lack of UK data. If the study of pesticide impacts had been restricted to the UK, there would be little data. Of the studies cited in this chapter, few relate exclusively to the UK. Including the wider geographical range of studies allows a better statistical perspective.

Although pesticides are developed and registered as individual active ingredients and formulations, once they have been released onto the market it is very difficult to monitor them as an individual active ingredient. The impact of the exposure to these chemicals is monitored and regulated by a pesticide (as opposed to an active ingredient) regulator. This is reflected in the general public and media perception, which may consider pesticides in ad hoc and irregular fashion. Active ingredients are produced for specific pest control functions in technologically exact terms. Once they are released into the environment, it is unfortunately more difficult to study the impact of pesticides in the same way. They are used under diffuse and general terms that are difficult to monitor in such a way that absolute safety can be demonstrated. Pesticide use can vary over location and time. Chemical 'x' may be banned in country 'a' and used in country 'b'. Or chemical 'z' was in country 'c' from 1950 until 1990. It is impossible to disentangle what active ingredients constitute pesticides exposure; but the research requires an overall assessment of pesticides.

5.2. Routes of exposure

Pesticides are designed to be toxic to the intended pest. In theory they should be directly toxic only to the intended pest(s). In practice this is not the norm, and in some cases, much of the pesticide formulation misses the pest and is released into the environment to form what is called 'non-point source pollution'. Point source pollution on the other hand can also be caused by the inappropriate disposal of pesticide concentrate (for example, directly to watercourses). A schematic model of pesticide exposure has been constructed as part of the present research (see Figure 5.1). The diagram provides an overview of the routes of exposure through two cycles – one active ingredient/pest control-based and the other pesticides/pollution-based. The arrows and boxes represent the sequence of events from when the active ingredient(s) enter the cycle, that is, when they are developed by the pesticide industry. Their legal use is subject to regulatory control and to political control through policies, such as the UK national strategy. Once they are approved they are used by a range of users and released into the environment to control the pest(s). Here the cycle splits into two.

For the 'unintentional use route' the model assumes the formulation is effective, and controls the pest(s). If it is not effective, it will eventually leave the market place. If it is effective, crops are protected from pests and disease, the private sector, in this case the agriculture and food industry, receives its economic reward and the ingredient continues in the market place. Political approval is re-affirmed, which continues to drive the cycle onwards.

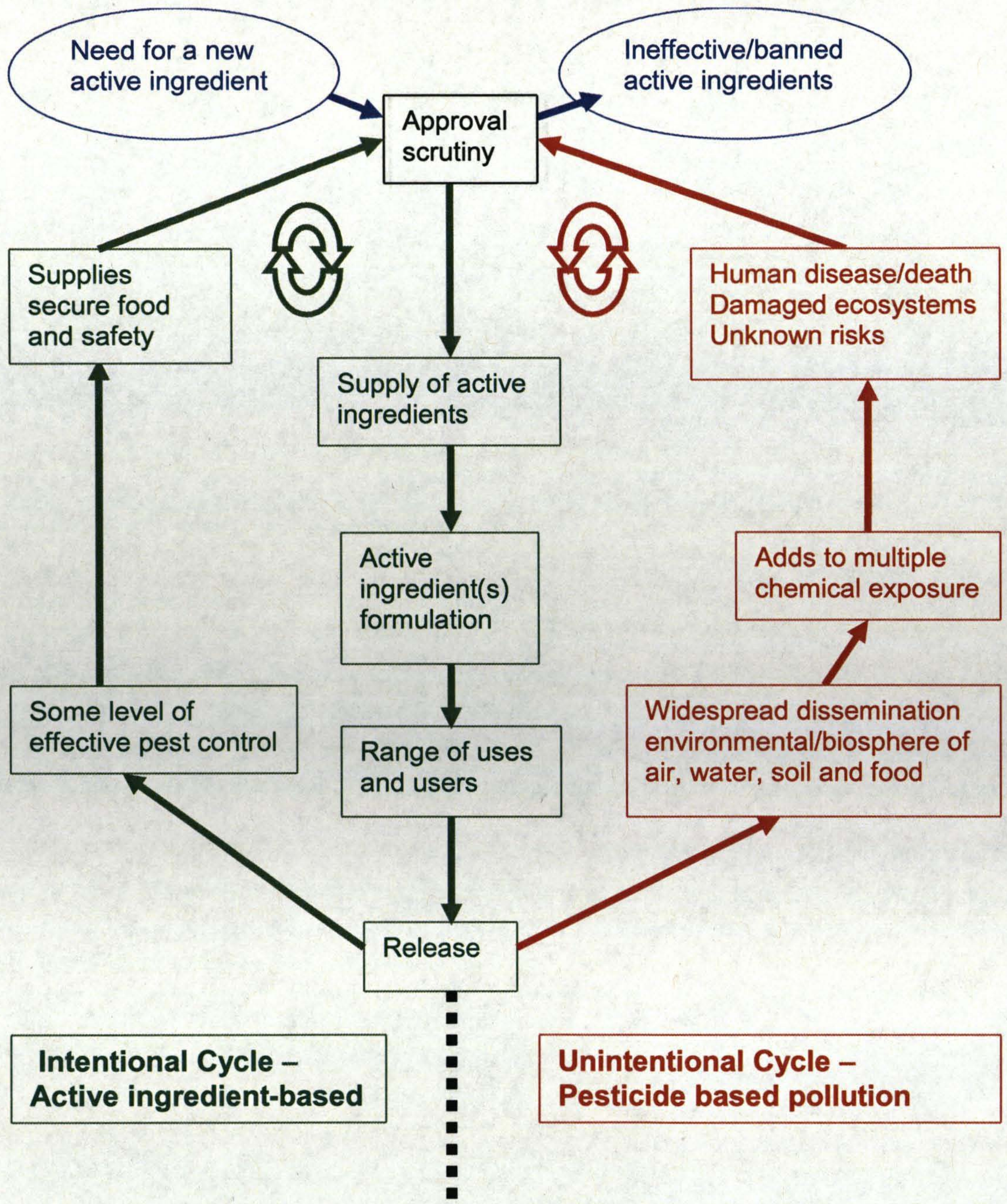
The second cycle describes the unintentional impact that pesticides have collectively. They add to other chemicals in the environment and can potentially have a range of adverse effects. Political pressures determine which active ingredient(s) are to be banned, and which continue to receive approval, driving the pesticide cycle onwards. If political control leads to a ban on the chemical active ingredient, it leaves the cycle. Where active ingredients are banned, the cycle is depleted and they have to be replenished by new actives. The unintended cycle is repeated many times, each time a new pesticide is produced incrementally building up more pressure on the pesticide policy paradigm.

Once a pesticide has been released into the environment, there is a cascade of consequences from the various media, routes and location where pesticide contamination can occur, as indicated in Figure 5.2. Sometimes pesticides are released into relatively closed systems and the environmental dissemination is limited. Such cases include pesticides used in conjunction with pheromone traps. But this is rare. In most cases most of the pesticide formulation released into the environment misses the intended target. In some cases, less than 1% applied to a crop reaches the pest (Dhaliwal et al., 2004). The rest contaminates soil, water, air, food, feed forage, wildlife and humans. The remainder of this section reviews each of these areas and summarizes what is currently known.

The unwanted exposure to pesticides is an inevitable part of the intended use of the active ingredient as agreed prior to marketing by the manufacturer, on the one hand, and the regulator who deems the use to be acceptably safe and on the other. When, post approval and registration, pesticides are used there is a need to consider the impact of exposure on non-target organisms, including humans and wildlife, within the wider environment. The variable adverse health effects from a diffuse range of uses are illustrated in Figure 5.3. In terms of the environment, it is impossible to guarantee that there will be no impacts on non-target organisms. Each time pesticides are used, some of the product fails to reach the target and can enter the atmosphere and/or it can enter the soil directly, or through plant foliage. Excess product can run off into surface water or through the soil into ground water and has the potential to contaminate wildlife, domestic animals and humans. Pesticides can be transported long distances across national boundaries, and be deposited diffusely thousands of miles from their point of application.

Importantly, the model in Figure 5.1 provides an overview of both intentional and unintentional effects of pesticides. An ideal pesticide would be one for which the unintentional effect side of the cycle does not exist. Anything else represents a state where risks (some of which are difficult to measure) have to be accepted through the political control mechanism. It is that acceptance that is contested by the different stakeholders. Whilst the cycle can accept the banning of active ingredient(s), the cycles are maintained.

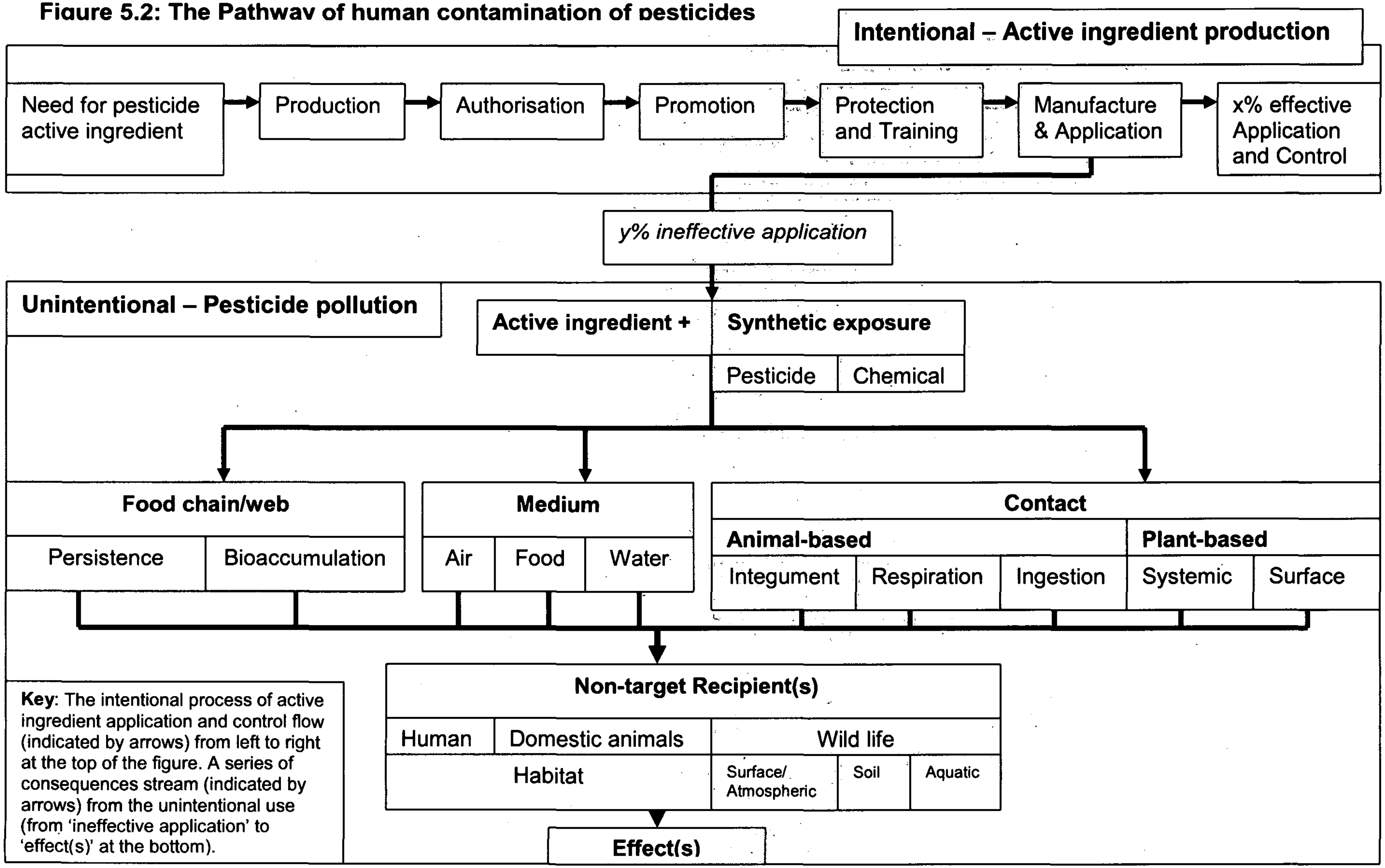
Figure 5.1: The intentional and unintentional pesticide cycles



Key: The diagram provides an overview of the routes of exposure through two cycles – one intentional/pest control-based and the other pesticides/pollution-based. The arrows and boxes represent the sequence of events from when the active ingredient(s) enter the cycle, that is, when they are developed by the pesticide industry. The blue boxes represent the supply and limitation of active ingredients. The green boxes characterise the intentional use of pesticides, and the red boxes symbolise the unintentional adverse effects. The dotted line at the bottom of the Figure represents the divide between the intended and unintended effects of pesticide application. The red and green double arrows (below 'Approval scrutiny') represent the fact that many active ingredients enter and circulate within the pesticide cycles at any one time.

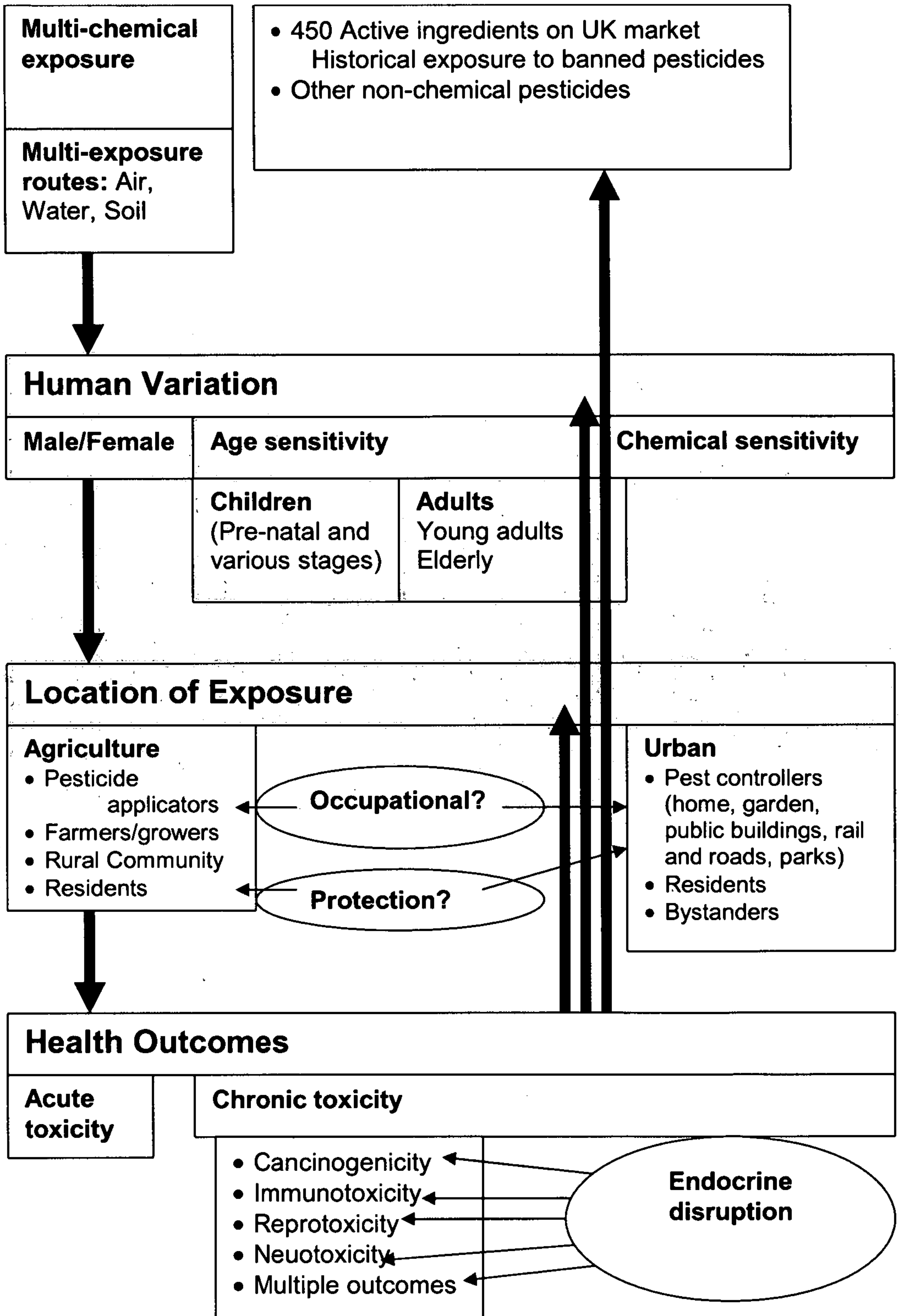
Source: Author

Fiaure 5.2: The Pathwav of human contamination of pesticides



Source: Author

Figure 5.3: Pesticide exposure variants



Key: This Figure represents a multifactor circular and iterative pathway in which health outcomes may occur. The arrows represent a process in which a variety of factors starting with a variation of chemical exposure through a range of mediums against a variable human susceptibility in a range of locations may occur, resulting a range of possible health outcomes.

Source: Author

5.2.1. Atmospheric contamination

There is a body of research that has revealed the presence of pesticides in a range of environmental media, including air, soil, water, atmosphere and living organisms. Residues have been detected going back to the 1960s.

Pesticides may undergo long-range airborne transportation and be deposited considerable distances from their area of application, including remote areas such as the Artic and Antarctica. For example, DDT was first detected in Antarctic penguins in the mid 1960s (Sladen et al., 1966). Pesticides have been found in air, rain, cloud water, fog and snow. The levels and behaviour of pesticides in the atmosphere are complex and depend on a number of variables including volatility, photostability, how they were applied, level of overall use, and the nature of area treated (such as soils and leaf structure), and the ability to which aerosols are created during application. Pesticides that are resistant to hydrolysis (breakdown by water) and photolysis (breakdown by light), such as the organochlorine insecticides, can be transported great distances (Unsworth et al., 1999). More recent research in Antarctica has concluded that melting glaciers are a probable source of DDT exposure of the marine ecosystem (Geisz et al., 2008).

During and after pesticide application a substantial amount of the formulation may be transported through the air over varying distances. The rate of pesticide diffusion can vary considerably during application, and after application where the properties of the pesticide, soils, crops, and environmental conditions are important (van den Berg et al., 1999). In Europe, a total of 80 pesticides have been found in rain, and 30 in the air, with the highest concentrations being found in fog. Those most commonly detected are the insecticide lindane and the herbicide atrazine. Phenoxy acid herbicides (such as 2,4-D) and organophosphate insecticides have been also found (van Dijk and Guicherit, 1999). In a Belgian study that analyzed the results of four years' monitoring, a number of pesticides were detected: endosulfan, lindane, dichlorvos, atrazine, diuron, DNOC, glyphosate, AMPA and isoproturon. The researchers also found that higher residue levels corresponded with local spraying operations (Quaghebeur et al., 2004). Dutch analysis carried out between September 1999 and the end of 2001 revealed that 50 different pesticides were detected in precipitation and air samples. Some of the pesticides found included a number of pesticides that are no longer approved for use in the Netherlands such as atrazine, DNOC, and trifluralin. The concentration and deposition of pesticides shows a large variation across the country linked to agricultural practice throughout the year. The concentrations of 17 different pesticides exceeded the surrogate Maximum Permissible Level (MPL)[37] in precipitation, and 22 exceeded the standard for drinking water (0.1 ppb). The pesticides dichlorvos and chlorothalonil were observed above the MPL in more than 20% of the samples, and DNOC exceeded the 100 ngl^{-1} (ppb)levels at all stations. In addition residues of atrazine found could have been related to emissions from outside the Netherlands (Duyzer, 2003).

5.2.2. Drift

Pesticide drift is the airborne component of application that falls outside the intended target area. Pesticide residues have been detected up to 3 miles (4.8 km) from the area of pesticide application (Lee et al., 2002). Reports indicate that a significant percentage of some pesticides disappear from the target area and are present in the atmosphere; in some cases pesticides were found to volatilize and could still be detected days after application. In one US study, where the herbicide trifluralin was used on soybean, seasonal volatilization losses were 25.9% of the originally applied herbicide. Of the total losses, about half was lost during the first 9 days, and 90% in 35 days. Combined seasonal losses by other pathways (excluding volatilization) were almost 2.5 times greater than aerial losses (White, 1977). Levels of pesticide residue can vary and there is a great deal of uncertainty in estimating dispersion (Duyzer, 2003).

There is increasing public health concern regarding potential residential exposures to agricultural pesticides and there is limited understanding about the potential for such exposures (Lee et al., 2002). Many researchers have described models to represent the behavior of spray drift, but no one model provides a complete understanding of the subject (Unsworth et al., 1999). There are many published drift models and databases from various countries, notably Germany, the Netherlands, and the UK. In the US the Environmental Protection Agency has teamed up with 32 manufacturers to form the Spray Drift Task Force in an attempt to develop a single drift estimate database (Unsworth et al., 1999). There are also likely to be considerable variations in occupational, residential and bystander exposure to spray drift because of the range of factors and conditions, such as spray composition and concentration, nozzle design and operation, meteorological conditions, field topography, crop foliage and buffer zones (RCEP, 2005a: 53).

37. In the absence of a quality standard for precipitation, the author decided that observed levels were compared to the maximum permissible level in surface water (MPL) for the Netherlands.

5.2.3. Water

Pesticides are regularly detected in the aquatic environment in ground and surface water[38]. Groundwater contamination is reported in the scientific literature as an increasing and long term threat to the quality of drinking water (Tiktak et al., 2004, Lapworth and Gooddy, 2006, Stuart et al., 2006, Gooddy et al., 2007). European public health/environment researchers such as Tiktak et al. (2004) have concluded that contamination of groundwater is an important side-effect of the use of pesticide plant protection products in modern agriculture. This is of concern because the use of pesticides that potentially contaminate groundwater is banned at both the European level (EU Directive 91/414) and at the Member State level (Tiktak et al., 2004).

Until the 1980s, the likelihood of groundwater contamination from synthetic organic chemicals (including pesticides) was largely ignored because it was assumed that the soil profile would always serve as an efficient purifying filter. However reports in the mid 1980s raised both public and regulatory/governmental concern about the potential threat to drinking water (Aharonson et al., 1987). Residue analysis carried out at the end of the 1980s detected over 70 pesticides in groundwater (Ritter, 1990). Understanding the mechanisms of pesticides leaching to groundwater has been a challenge because of the range of issues involved. There are mobility and transformation factors (microbial and chemical reactions) in the root, sub-soil and saturation zones that determine the amount of pesticide reaching the groundwater. Other factors include the soil-subsoil-groundwater structure, depth of groundwater, macropore flow (through cracks in the soil) and rainfall and water management practices (Aharonson et al., 1987). A US review of pesticides in groundwater (1992-96) documented residue analysis for 90 pesticide compounds (pesticides and breakdown products). The results revealed that mixtures of pesticide residues regularly occur in groundwater. One or more residue was found at 48% of sites tested; and at 70% of sites where pesticides were detected, two or more compounds were found. Pesticides were regularly detected in shallow groundwater that was beneath agricultural land (in 60.4% of sites), and also in urban areas (48.5%). The latter was an important finding, because urban areas were thereafter also recognized as a potential source of pesticide contamination (Kolpin et al., 2000).

38. Groundwater is found below the surface of the ground in soil pores and the fractures of rock formations. Surface water, as opposed to groundwater, collects on the ground as a result of precipitation and flows into streams, rivers, lakes or wetlands. Both water sources are extracted as a source of drinking water. They are also used in agriculture and as a raw material source for a range of industrial sectors.

Pesticides contamination in groundwater is an increasing problem that poses a significant long-term threat to water quality. Testing was carried out following the detection of elevated residue levels of the herbicide diuron in a southeast England aquifer. Between 2003 and 2004, diuron was found in 90% of groundwater samples analyzed, and in 60% of these samples, metabolites of diuron were more prevalent than the parent compound. Long-term monitoring (1989-2005) has demonstrated that aquifer pollution by atrazine, simazine, and more recently diuron, coincides with periods when groundwater levels are high. The researchers suggest that diuron contamination is coming from urban and industrial development (see also surface water below) (Lapworth and Gooddy, 2006).

An assessment of monitoring from both the UK and the US tested the importance of site (land use, soil and aquifer) and chemical factors (such as solubility in water) and between and within year variations in controlling groundwater contamination. Results from the two countries showed that both chemical and site factors have a statistically significant influence on groundwater (Worrall et al., 2002). A study in the UK concluded that groundwater is more at risk when there is a combination of leachable compounds, vulnerable soils, shallow groundwater and high product usage (Garratt and Kennedy, 2006). The latest monitoring in the UK has found that the herbicides atrazine and simazine most frequently exceed the drinking water levels, although most samples were below this limit (Environment Agency, 2007). Further research shows that groundwater close to agricultural land continues to be vulnerable to pesticide contamination and needs constant monitoring (Haarstad and Ludvigsen, 2007).

There are fewer reports on the quality of surface water. A German study concluded that almost all surface water tested contains pesticides in highly varying concentrations, and is an import source of groundwater contamination (Mathys, 1994). The latest figures for 2005 provided by the UK Environment Agency show that almost 8% of samples contained pesticide concentrations above the drinking water limit, a significant increase on previous years (Environment Agency, 2007). The most commonly found pesticides are mobile and persistent herbicides (diuron, isoproturon, mecoprop, MCPA, 2,4-D, chlorotoluron, simazine, dichlorprop, atrazine). It is difficult to identify the source of this diffuse pollution. Not all of it comes from agricultural sources. Diuron, the most commonly found pesticide in 2005, is now only used in the amenity sector largely for controlling urban weeds (Environment Agency, 2007). A German study found 'remarkable' contamination of rivers with the herbicide diuron caused by municipal waste water (Mathys, 1994: 338). Persistence of pesticides in the environment remains an import factor to consider. River systems in the Hesse region of Germany were monitored for the herbicide terbutryn between September 2003 and September 2006. During this time there was no trend towards declining residue levels, despite the implementation of ban on the use of terbutryn in July 2003 (Quednow and Püttmann, 2007).

One study has been carried out specifically to show how climate change may impact the fate and transport of pesticides in surface and groundwater. The main climate drivers for change are thought to be seasonal changes in rainfall and intensity and increased temperatures. As with many factors in relation to climate change, the effect on pesticide fate and transport is likely to be very variable and difficult to predict (Bloomfield et al., 2006).

5.2.4. Soil

Healthy soils contain a wide array of invertebrate and microbial biodiversity on which agricultural crop and livestock productivity is based. Pesticide contamination can have an impact on soil quality by reducing soil fertility and affecting the viability of soil organisms (Kookana et al., 1998, Fox et al., 2007). Soils are also an important medium through which diffuse pesticide pollution can leach into surface and groundwater. There is a need to improve the understanding of the fate of pesticides in soil in order to reduce their environmental impact. Research carried out between the late 1980s and the early 1990s showed that pesticides could move rapidly through the macropores in soils into ditches and drains and thus could potentially contaminate surface waters (Jones et al., 2000).

The extent to which pesticides are susceptible to transport through soil and contribute to non-point source pollution is dependent on biodegradation and sorption, which have an impact on the pesticides' longevity and mobility on the soil (Kookana et al., 1998). A strong sorption property that minimizes pesticides losses to drain flow is, in most cases, indicated by a high K_{oc}[39] value (Jones et al., 2000). Pesticides enter soils by direct application, or as a result of spraying onto foliage, in which the pesticides are translocated by the plant to the soil, or other surfaces and through spray drift. The fate of pesticides in soil depends on the chemical properties, environmental conditions, biota and sediment characteristics. Again the extent of pesticide degradation varies considerably, from minor alterations to complete mineralization to carbon dioxide, ammonia, water and inorganic salts (Hamilton and Crossley, 2004: 41).

39. *Koc* is the organic carbon binding constant that provides a way of predicting the mobility of a chemical in an ecosystem by determining its potential to binding to organic material such as humus. Mobile chemicals have *Koc* values of less than 500.

Most studies show that pesticide biodegradation rates decline with soil depth, although there are exceptions to the rule. Within the topsoil there can be significant within-field spatial variability in pesticide degradation rates, associated with variation in soil properties controlling the degradation process. Current models dealing with the environmental fate of pesticides take no account of this variability. Research from Rodríguez -Cruz et al. (2006) demonstrates that pesticide fate in soils shows considerable three dimensional variability, and an accurate assessment of risk associated with pesticide use will need to take this into account (Rodríguez-Cruz et al., 2006). Results from a Pan-European study show that the predicted leaching concentration increases with precipitation and irrigation and decreases with increasing organic matter content (Tiktak et al., 2004).

5.2.5. Human contamination

Humans are exposed to pesticides via inhalation, ingestion and dermal exposure. The circumstances in which people are directly exposed to pesticides is through occupational and residential exposure to pesticides as result of use in agriculture, urban pest control or during pesticide manufacture. A recent UK study raised concerns that the exposure of people resident in or visiting rural areas could have been grossly underestimated (McKinlay et al., 2008). A 2002 report by the UK Committee on Toxicity (COT) concluded that exposure data for humans is limited. There is limited data in relation to residues in food, but this is targeted where residues are most likely to occur. Data on exposure from sources other than food and water seem to be extremely scanty, or non-existent, the COT report found (Committee on Toxicity, 2002).

Members of the public may be exposed as residents or bystanders to commercial pesticide use, to non-commercial home and garden use, through atmospheric contamination and by the consumption of food and drinking water. The term 'bystander' is used widely in debates about human exposure to pesticides. It has been seen as failing to recognise the permanency of residents and the degree of their exposure to pesticides (RCEP, 2005a: 5). Spray drift can also affect whole communities. Families, especially children, can be affected through 'carry-home exposures' by parents occupationally exposed to pesticides. Parental exposure during their child's gestation or even preconception may also be important. Residential exposure can lead to adverse health effects for those living near to agricultural activity where pesticide spraying occurs (Aschengraui et al., 1996, Bell et al., 2001, Lee et al., 2002, Alarcon et al., 2005). Pesticides are also used to clear weeds in public parks, highways, pavements and railway tracks. They are also used in domestic (home and gardens) and other urban settings such as the kitchens and other areas of hotels, bar, cafes and restaurants predominately to control insects and rodents. There are differences in vulnerability among the population, for example, those with susceptibilities to environmental chemicals, or during development stages from the foetus through childhood, young adulthood, and the elderly. And although some harmful effects of pesticide exposure are well known, we are still discovering other short term and long term health effects (Arcury and Quandt, 2003). The following sections show what effects have been reported in the literature.

5.2.6. Residues in food and water

Since 1980, the EU Drinking Water Directive (updated in 1998) has meant that UK drinking water must not contain any single pesticide residue above 0.1 (parts per billion) ppb, and 0.5 ppb for the total pesticides, defined as the sum of all individual pesticides detected in the monitoring procedure (European Commission, 1998b). In order to achieve this, water supply companies have to filter drinking water with activated carbon in order to comply with the EU Directive. This so-called end of pipe solution is recognized as the only way of protecting drinking water (Mathys, 1994). As a result of the Drinking Water Directive, levels of pesticide residue are very low, much lower than in food, for example.

The importance placed on the significance of pesticide residues in food is acknowledged in the literature (Shaw, 2000, Hamilton and Crossley, 2004). Pesticide residues provide no nutritional value and yet potentially pose a risk to health.

There are few scientific peer reviewed journal studies in the literature on the occurrence of pesticide residues in food. Most research refers to advances and debate in methodological sampling techniques. Residue data is regularly released by the UK and EU regulators that have been generated by internationally accredited laboratory analysis of food. The European Commission publishes an annual report on pesticide surveillance in 26 European countries. For the year 2004, a total of 60,450 samples were analysed for 677 different pesticides (European Commission, 2006a). About 92% of the samples were fresh fruit, vegetables and cereals; and 8% were processed products. Residues were detected in 39.7% of samples. In 4.7% of all samples, residues were found above the maximum residue limit. The most frequently detected pesticides were diphenylamine, the maneb group, cyprodinil, tolyfluanid, the benomyl group, iprodione and fenhexamid. Strawberries, apples and lettuce had the highest percentage of samples with residues. Data from the acute exposure revealed that exceedences of the acceptable safety limit 'acute reference dose' (ARD) occurred in some samples, in particular for residues of oxydemeton-methyl in apples and lettuce (European Commission, 2006a).

The UK regulator Pesticide Safety Directorate (PSD) contributes to pesticide surveillance through the Pesticides Residue Committee (PRC) and the publication of quarterly monitoring results. PRC data from 2006 shows 3,562 samples were analysed and residues were found in 33.1% of samples. Of the total, 1.7% samples were above the MRL. For each category of food the number of pesticides tested for varied: fruit and vegetables 129, starchy food and grains 43, and animal products 13 (PRC, 2007). The occurrence of residues in food is similar to that reported by Shaw (2004), an ex-chair of the PRC, who said that about 30% of food consumed in the UK contains detectable residues and that 1% is about or above the MRL. The latest PRC report confirms that the frequency of food contamination is 'remarkably stable' (PRC, 2007). In addition to regulatory surveillance, there is some monitoring carried out by the food supply industry, especially major food retailers, but much of this data is considered commercially sensitive and little of it reaches the public domain. Two examples where such data is however released include J Sainsbury (Sainsbury, 2005) and Marks and Spencer (M&S, 2008). Public interest groups also carry out ad hoc analysis, such as Greenpeace Germany (Krautter, 2007). This activity has generated much media publicity in Germany, and many responses from local food retailers.

One area of public interest is the comparison of pesticide content between organic and conventionally produced food. It may be generally assumed that organic produce contains fewer residues compared with conventional food, but there are in fact very few studies that have made any comparisons. One such exception included research carried out by public health researchers from Washington state in the US who assessed dietary exposure to organophosphate (OP) pesticide residues through biological monitoring among pre-school children. Children were classified as having consumed organic or conventional diets based on the analysis of diary data, and in addition, their exposure to residential pesticide use was also assessed. The researchers collected 24-hr urine samples from 18 children with organic diets and 21 children with conventional diets and tested for OP metabolites. The median total dimethyl metabolite concentration was about six times higher for children with conventional diets. The dose estimates suggest that consumption of organic fruits, vegetables and juice can reduce children's exposure levels from above to below the US Environmental Protection Agency's guidelines. The researchers conclude that consumption of organic produce appears to provide a relatively simple way for parents to reduce their children's exposure to OP pesticides (Curl et al., 2003).

A study in the US carried out a comprehensive analysis comparing pesticide residue levels in organic, integrated pest management (IPM) and conventional food, based on three US testing programmes (Baker et al., 2002). One of the programmes from the US Department of Agriculture showed 73% of conventionally grown produce contained at least one pesticide residue compared with 23% for organic; and that multiple residues were found in 46% of conventionally grown crops, and only 7% of organic samples. From an array of data, the researchers concluded that organically grown foods contain fewer pesticide residues than conventional or IPM grown foods, and that residues when present are lower in organic foods. Although the levels of residues are lower, synthetic residues still occur. The researchers put forward some reasons as to why this may occur. Many residues do not violate organic standards which recognise that small amounts of residues from sources beyond farmers' control are inevitable. In addition, mislabelling of organic produce does occur and samples from wilful fraud or inadvertent lapses will be detected in the supply chain from time to time. Other positive residue samples seem to have occurred because post harvest contamination of organically grown samples (Baker et al., 2002).

Pesticide residue limits for conventionally grown food are set by a joint Food and Agricultural Organisation (FAO)/World Health Organisation (WHO) international body[40] that sets thresholds for acceptable exposures which includes the acceptable daily intake (ADI), measured in mg/kg body weight, for each pesticide active ingredient over a lifetime without ill effect. The legal limit for pesticide residues in food, to which farmers and retailers are required to comply under UK and EU law, is the maximum residue level (MRL). ADIs and MRLs were developed for individual pesticides from the early 1960s (Pennycook et al., 2004).

Since the late 1990s, a new set of acceptable residue limits has had to be initiated, after routine monitoring found uncharacteristic and inexplicably wide variations of pesticide residues taken from a variety of different vegetable samples. The work, carried out by scientists at the Pesticide Safety Directorate (PSD), initially found a wide variability between organophosphate (triazophos) residue levels in samples of individual carrot roots. This variability had not been picked up before because vegetables were analysed in bulk samples (of about 1kg) and an average residue level was calculated (Hamey and Harris, 1999, Harris, 2000). Variability (defined as the highest residue level found in any one crop item divided by the level found in a composite sample from the same batch) in carrots could differ by up to 25 times. The researchers found that a similar phenomenon occurred

40. National regulators set international pesticide residue standards through the Joint FAO/WHO Meeting on the Pesticide Residues (JMPR) for agricultural pesticides.

with other crops including apples, peaches, and celery, and that variability in one batch of plums was up to 34 times the mean value. The researchers were at a loss to explain how this variation occurred.

In terms of health implications, there were two problems. As nerve poisons, OP compounds have the potential to produce a toxicological effect after a single dose. It was clear that the conventional risk assessment might not be adequate in view of the higher level residues found. ADIs are long-term assessments which relate to a life time of exposure. Researchers also had to ask whether sampling procedures were sufficient to deal with variability. It meant that: "Conventional deterministic methods used in consumer assessments were likely to give gross over-estimates of short term exposure because of the assumptions employed" (Harris, 2000: 491). This presents a problem when estimates were derived from worst-case scenarios from these more variable results. In other words, if the exposure was calculated according to higher residues levels, the ADI's would be exceeded. A whole new set of additional safety limits has had to be developed in order to make sure that limits are not exceeded. As a result, the international regulatory community has had to add an additional hurdle to the formal consumer risk assessment process with the introduction of the short-term intake acute reference doses (ARfD) for acute health risk assessments for agricultural pesticides (Hamilton et al., 2004, Solecki et al., 2005). Haematotoxicity, immunotoxicity, neurotoxicity, liver and kidney toxicity, endocrine effects as well as developmental effects are taken into account as acute toxic alerts, relevant for regulatory purposes (Solecki et al., 2005).

5.3. *Health impacts from exposure to pesticides*

The following section reviews the acute and chronic human health impacts from exposure to pesticides. The mechanisms of acute poisoning by pesticides are well understood compared with the chronic effects. Many of the chronic impacts have only recently been identified as such, decades after the introduction of synthetic pesticides.

5.3.1. Acute toxicity

Estimates of acute toxicity measure the adverse health effects occurring within a short period of time after exposure to a single dose of the pesticide. The greatest concern for human health is associated with exposure to insecticides. For example, organophosphate insecticides are associated with acute health problems such as nausea, dizziness, vomiting, headaches, abdominal pain, and skin and eye problems (Ecobichon, 1996) cited in (McCauley et al., 2006). Acute poisoning is a matter for serious concern in developing countries, where extremely hazardous pesticides are used with little or no protective equipment (Murphy et al., 1999). Acute toxicity can occur as a result of occupational exposure, accidental spillage, or as a result of suicide or homicide. The true extent of the problem is not known (Litchfield, 2005, Bertolote et al., 2006, Thundiyil et al., 2008); and there are documented concerns that acute pesticide poisoning may go unreported, especially among farmers with poor access to medical care (Moses et al., 1993). There is little information on pesticide residue levels in food, water and the environment from developing countries. In many parts of the world it is very difficult to carry out regular residue analysis in foods (Dinham, 1993: 55).

During the early years of pesticides use no accurate or reliable figures were available on the global scale of pesticides poisoning. From the 1970s onwards the World Health Organisation (WHO) has periodically indicated the scale of the problem by providing estimates based on extrapolated data. In 1972, a WHO Expert Committee on Insecticides calculated that there were about 500,000 cases of accidental acute pesticide poisoning annually of which 1% were fatal. The estimate was reached by constructing a model based on available statistics using conservative assumptions (WHO, 1973). In 1981, Bull used these WHO estimates to calculate that the global annual pesticide poisoning rate was 750,000 people with 13,800 deaths (Bull, 1982: 38). This figure increased during the 1980s, and extra WHO data from the early 1990s suggested there were three million cases of severe pesticide poisoning cases every year, and 20,000 deaths from occupational exposure (WHO, 1990). These are likely to be under estimates because they are based only on confirmed hospital registries (Kishi, 2005: 25). In another estimate, Jeyeratnum calculated that 3% of agricultural workers in developing countries, totalling 25 million people, suffer from pesticide poisoning every year (Jeyaratnum, 1990). A further 2005 estimate by the International Labour Organisation estimated that pesticides annually cause some 70,000 acute and long-term poisoning cases leading to death and a much larger number of acute and long-term non-fatal illnesses (ILO, 2005).

The pesticides that cause the biggest acute health problems are the organophosphate and carbamate nerve poison insecticides. There is little evidence that poisonings have diminished in recent years (Kishi, 2005: 25). In 1998, work carried out by van der Hoek et al. (1998) in Sri Lanka resulted in a call for the enforcement of legislation to restrict the availability of the most hazardous pesticides, and the promotion of alternative non-chemical methods of pest control.

A significant number of deaths are caused by deliberate ingestion of toxic pesticides. Further Sri Lankan-based research shows that regulatory control of highly toxic pesticides provides important health benefits, in terms of lower numbers of deaths from suicide. However, despite the positive effect of these bans, many deaths from pesticide self poisoning still occur after ingestion of agricultural pesticides classified only as moderately poisonous. (Van der Hoek and Konradsen, 2006).

In developed countries there have been reports of acute poisoning, although not to the same extent as that of developing countries. A US governmental state-wide review has concluded that pesticide poisoning is commonly under-diagnosed illness (Reigart and Roberts, 1999: 2). Another US study reported that pesticide exposure has caused acute illness among school employees and students as a result of pesticide use in schools. The study also raised concern about repeated pesticide applications on school grounds because of low level exposures to pesticides at schools (Alarcon et al., 2005). According to data from the California's mandatory pesticide poisoning reporting system there is estimated to be 10,000-20,000 cases of farm worker poisoning every year in the US. (Blondell, 1997) cited in (Reigart and Roberts, 1999). The last two studies also acknowledge that pesticide poisoning is a commonly under-reported in the United States. Pesticide poisoning can often resemble other conditions such as acute upper respiratory tract illness, conjunctivitis, or gastrointestinal illness (Alarcon et al., 2005).

In the mid 1990s the US Poison Centers produced data on the commonest pesticides implicated in illness out of 22,433 cases reported to the Centres. The top seven pesticide categories included organophosphates, pyrethrins/pyrethroids, hyperchlorite disinfectants, carbamates, organochlorines, phenoxy herbicides and anticoagulant rodenticides. The relative frequency of cases generally reflects how widely a product is used. For example, the disinfectants occur in the top ten because they are far more common in the home and workplace compared with other pesticides. Most pesticide-related diseases have clinical presentations that are similar to common medical conditions and display non-specific symptoms and physical signs. Knowledge of a patient's exposure to occupational and environmental factors is important for diagnostic, treatment and public health requirements. There are multi-locations, sources of exposure so it is important to take into account the work, home and community environment (Reigart and Roberts, 1999).

According to voluntary reporting to the Health and Safety Executive (HSE), some 100-200 incidents occur each year, of which few are substantiated. However other HSE research indicates significant under-reporting. One survey of 2,000 pesticide users found that 5%

reported at least one symptom in the past year and about which they had consulted a doctor. A further 10% had been affected (mostly by headaches), but had not consulted a doctor. As some 105,000 farmers hold pesticide certificates in Britain this suggests that at least 5,250 farmers suffer sufficient symptoms to consult a general practitioner each year, and a further 10,500 area adversely affected to a lesser degree (Pretty et al., 2000).

5.4. Chronic exposure

Chronic effects of pesticides result from low-level long-term exposure or higher dose short-term exposure leading to adverse health outcomes. The range of outcomes includes cancer, neurological and reproductive defects, respiratory and skin disorders and immune system defects (Kishi, 2005). It is more difficult to prove cause and effect for chronic exposure to pesticide chronically compared with acute intoxication. This is because chronic exposure can occur over many years; involve low levels of a number of pesticides, other chemicals and agents that can cause similar adverse health outcomes; and it is also more difficult to monitor the health effects because pesticide usage data is often not recorded. In a few cases there are some examples where specific active ingredients are associated with an increased risk of adverse health outcomes. The following sections review studies carried out by researchers in cancer institutes and environmental health/medical departments that have been reported in the academic literature. Most have been carried out in developed countries where there is relatively more data and better research facilities compared with developing countries. In particular several references are made to the US Agricultural Health Study, the biggest study on occupational and related exposure to pesticides used in agriculture. It covers multiple research areas, and includes health assessment data from 90,000 farmers and their spouses in Iowa and North Carolina.

5.4.1. Respiratory effects

A review of the literature (Hoppin et al., 2002) acknowledges that farmers represent a high-risk group for occupational asthma and other respiratory diseases. Animals, grains and dusts are the primary respiratory hazard, although a sparse literature suggests a role for pesticides. The organophosphate insecticides may contribute to respiratory symptoms, and carbamate insecticide was associated with self-reported asthma. Insecticide application to livestock, the mixing and applying of pesticides by grain farmers, fungicide use, and the fumigants (methyl bromide and sulphur dioxide) were all linked to respiratory effects. Most of these studies have identified associations only with pesticides as a whole, or groups of pesticides, with the exception of paraquat.

As part of their own research, the Hoppin et al. (2002) study, part of the US Agricultural Health Study (AHS), found associations with specific active ingredients. In this research, a total of 20,468 pesticide applicators in the AHS were assessed for any association between individual pesticides and respiratory wheeze[41]. Elevated odds ratios (OR) were found for paraquat, three organophosphates (parathion, malathion and chlorpyrifos) and a thiocarbamate fungicide EPTC (S-ethyl-dipropylthiocarbamate). Although the ORs were relatively small, the associations did suggest an independent role for specific pesticides and respiratory symptoms of farmers. Further analysis of the AHS has shown that the insecticides DDT, lindane and aldicarb were positively associated with farmer's lung[42]. Until this research was carried out, pesticides had been an unexplored factor for this condition (Hoppin et al., 2007a). Few investigations have considered any link between pesticides and increased risks in chronic bronchitis. Hoppin et al. (2007b) in another AHS analysis have found 11 pesticides were significantly associated with chronic bronchitis.

5.4.2. Immune system responses

Studies have shown pesticides alter the immune system in experimental animals. Exposure to immunotoxic chemicals may result in increased immune response that may then lead to allergic response or autoimmunity (the failure of an organism to recognise constituent parts as 'self'). Immuno-suppression may increase cancer susceptibility and risk of infections (see also 5.4.3, below). A review of the literature by Colosio et al, (2005) concludes that there is convincing laboratory evidence of the capacity for a number of different pesticides to affect the immune system, including: aminocarb, dieldrin, carbaryl, dithiocarbamates, lindane, permethrin, and pyrethroids. There are relatively few studies that have assessed the impact of pesticides on human health, partly because research methodology is difficult to design and implement (Repetto and Baliga, 1996). The situation was similar ten years later when Colosio et al. (2005: S326) explained that the available data are sparse and that contradictory results have been obtained. Also, they say that existing studies examining immunotoxic risk were limited because of poor exposure data, differing research approaches, and a difficulty in providing a predictive significance to the slight changes often observed. "One of the most critical aspects of the immunotoxicity studies is the difficulty in distinguishing between 'adaptive/non adverse and 'adverse' effects". Nevertheless Colosio et al. (2005) conclude that there is concordant evidence of immuno-suppressive effect for pentachlorophenol, hexachlorobenzene and mancozeb. Immune

41. Wheeze is a whistling sound produced in the respiratory airways. Wheezing is common in people with lung disease, and the most common cause of recurrent wheeze is asthma.
42. Farmer's Lung, or extrinsic allergic alveolitis, is an allergic disease usually caused by breathing dust from mouldy hay.

suppression from pesticide exposure may also play a role in the development of some cancers. As a group, farmers have higher than average risk of developing Hodgkin's lymphoma, melanoma, multiple myeloma, and leukaemia, all of which are cancers of the immune system (Repetto and Baliga, 1996) (see also below).

5.4.3. Cancer

Cancer is the term used to describe a large heterogeneous group of diseases characterised by abnormal cell division. The resulting new tissues (neoplasms) expand within the parent organ. Malignant neoplasms also invade the tissues of the parent organ impairing or destroying its normal function. The malignant character of cancer is greatly increased by its tendency to metastasize – a process whereby viable tumour fragments spread via lymphatic and blood channels to produce widespread new foci of cancer. Cancer is a leading cause of death and metastases are a major cause of death from cancer.

From a total of 58 million deaths worldwide in 2005, cancer accounted for 7.6 million (13%) of all deaths (WHO, 2006). The overall incidence of cancer, especially in the developed world, has been increasing steadily for many years. Since 1990, incidence has risen by 19% worldwide, and cancer rates set to increase by 50% between 2003 and the year 2020, according to a World Health Organisation report (Stewart and Kleihues, 2003). It has been estimated there could be up to 15 million new cases per year, unless further preventative measures are established. In part this increase is inevitable due to increasing human longevity (Frankish, 2003). The development of cancer is also linked to both genetic predisposition and environmental contamination, with environmental and lifestyle factors accounting for an estimated 75% of most cancers (Czene et al., 2002) cited in (Sharpe and Irvine, 2004). There are many environmental factors which predispose to the development of cancer including tobacco, alcohol, occupational exposure (e.g. asbestos), environmental pollution and diet. One important and relatively recently recognised factor is exposure to pesticides (Jaga and Dharmani, 2005).

A test for carcinogenicity is one of a battery of pre-market approval tests to which pesticide active ingredients are subjected. There are over 160 potential pesticide carcinogens that have been designated as such by one of three governmental or intergovernmental agencies – the International Agency for Research on Cancer (IARC), the US Environmental Protection Agency and the European Union (PAN UK, 2005). Toxicologists agree that some pesticides prove positive for carcinogenicity in test systems. Pesticides may be genotoxic or non-genotoxic. If they are genotoxic carcinogens, the UK policy is that quantitative risk estimates are not relied upon, and the recommendation is to eliminate exposure or reduce exposure so that they are as low as possible (IGHRC, 2002). Unfortunately there is uncertainty surrounding studies of pesticide exposure and genotoxic damage, including the reliability of exposure assessment, the power of studies, the suitability of control groups and the protocols for determining genotoxicity (Bull et al., 2006). Non-genotoxic carcinogens are considered to be 'threshold dependent' and therefore acceptable for use, so long as recommended exposure thresholds are not exceeded. Many pesticides are considered carcinogenic as a result of testing in animals. But they can act through several species-specific mechanisms and their role in humans in less clear (Zahm et al., 1997). According to Aaron Blair of the US National Cancer Institute, no chemical class of pesticides can be considered problem free. Carcinogenicity has been associated with insecticides, (organochlorines, organophosphates, carbamates and pyrethrins), herbicides and fungicides (Lang, 1993). There are still challenges in assessing pesticides and cancer. According to Occupational and Environmental Epidemiologists at the National Cancer Institute (NCI), the potential for human carcinogenicity of almost all pesticides currently on the market has been poorly evaluated and is inadequately understood (Alavanja and Bonner, 2005).

In recent years, a number of research studies have examined the incidence of cancer following occupational exposure to pesticides, supplementary to the data gathered by the pesticide manufacturers as part of the regulatory protocol required for pesticides approval. They are one way of gaining information concerning the chronic effects of pesticides. By definition, this has to be post-approval, for use in any one country (unless there is widespread illegal manufacture and use). Epidemiological studies indicate that, despite pre-market animal testing, current exposures to pesticides are associated with significant chronic risks to humans (Alavanja et al., 2004, McCauley et al., 2006, Beard et al., 2003). A review of genotoxicity and human biomonitoring literature has been carried out by the Italian Cancer Research Institute. Experimental data has revealed that various agrichemical ingredients possess mutagenic properties including mutations, chromosomal alterations or DNA damage. It reported that studies have focussed on cytogenic end-points that evaluate the potential genotoxicity of pesticides used by manufacturing workers, pesticide applicators, floriculturists and farm workers. A positive association between occupational exposure to complex mixtures of pesticides and the presence of chromosomal aberrations, sister-chromatid exchanges and micronuclei has been detected in the majority of studies reviewed. The majority of studies indicated some dose-dependent effects, with increasing duration or intensity of exposure (Bolognesi, 2003).

There have been many studies carried out on pesticides and cancer and it is a keen area for research internationally among public health departments (a PubMed search for 'pesticides' and 'cancer' revealed 4130 studies in the public domain [12.09.07]). There have also been a number of academic reviews in the general terms of 'pesticides and cancer' published in recent years. Another review looked at research on a number of cancers linked with exposure to particular pesticides or groups of pesticides, including malignant lymphoma, leukaemia, multiple myeloma, testicular cancer, cancer of the gastro-intestinal tract, lung cancer and brain cancer (Moses, 1989). A recent review of the environmental influences in carcinogensis concludes that chemical contaminants, particularly synthetic pesticides, could be major factors for cancer development including breast, testicular, and prostate cancers (Michigan State University, 2000).

A number of studies have shown that overall levels of cancer in the agricultural community are low, but there are some individual cancers that are elevated for farmers. Lymphomas, leukemias, multiple myeloma and malignacies of connective tissue have been reported as possibility associated with pesticides (Axelson, 1987). The US Agricultural Health Study found a low overall rate of cancer. In some specific cancer types, the risk was elevated including multiple myeloma and cancers of the lip, gall bladder, ovary, prostate and thyroid (Blair et al., 2005).

5.4.4. Specific cancers

There have been a number of studies that have linked pesticide use with specific cancer outcomes. A meta-analysis of 22 epidemiological studies published between 1995 and 2001 assessed the risk of prostate cancer in pesticide related occupations. There was a significant increase in the risk, calculated as an odds ratio, for pesticide applicators; whereas no significant increase was observed for farmers. The study concluded that occupational exposure to pesticides is a possible factor in developing prostate cancer (Van Maele-Fabry et al., 2006).

There are several studies that have linked the use of organochlorine insecticides with breast cancer (Davis et al., 1993, Høyer et al., 1998, Ibarluzea et al., 2004, Romieu et al., 2000, Teitelbaum et al., 2007). In particular, dieldrin was associated with a significantly increased dose-related risk of breast cancer (adjusted odds ratio 2.05 [95% CI 1.7-3.57][43]) (Høyer et al., 1998); and among menopausal women, the odds ratio for aldrin was 1.55 (CI 1.00-2.40) and for lindane it was 1.76 (CI 1.04-2.98) (Ibarluzea et al., 2004). Research

43. CI = confidence interval (see glossary).

from Mexico also suggests that high levels of exposure to DDE (a breakdown product of DDT) may increase women's risk of breast cancer, particularly among post-menopausal women (Romieu et al., 2000). A more recent US study was the first to show that residential pesticides may be linked to the development breast cancer after finding a 39% increased risk of developing the disease in people exposed (Teitelbaum et al., 2007). Further work at the US Public Health Institute suggested that exposure to *p,p'*-DDT[44] (Anon, 1994) in early life may increase breast cancer risk. Many US women heavily exposed to DDT in childhood have not yet reached 50 years of age, and the public health significance of DDT exposure in early life may be large. These conclusions were based on results that showed high level of serum *p,p'*-DDT predicted a statistically significant 5-fold increased risk of breast cancer among women who were born after 1931. These women were under 14 years old when DDT came into widespread use after 1945. Women who were not exposed to DDT before 14 years of age showed no association between *p,p'*-DDT and breast cancer (Cohn et al., 2007).

A meta-analysis of 33 epidemiological studies of brain cancer in farmers reported a 30% increase in risk associated with the disease (Khuder et al., 1998). A number of individual studies have addressed the link between pesticides and brain cancer. A Massachusetts study found that those living within 2,600 feet (780m) of cranberry cultivation had a twofold increased risk of developing brain cancer and a 6.7 fold increase of developing astrocytoma (a type of brain tumour) (Aschengraui et al., 1996). Another study found significant associations between agricultural pesticide use and gliomas (a type of brain tumour) in a population-based case-control study in eastern Nebraska, US. For the pesticides metribuzin, paraquat, bufencarb, chlorpyrifos and coumaphos, they found significant positive associations (Lee et al., 2005). A large case-control study in the Bordeaux region of France found that a high level of occupational exposure to pesticides might be associated with an excess risk of brain tumours, especially gliomas, but only for high levels of occupational exposure. The paper calls for a better understanding of pesticide exposures in farmers (Provost, 2007). The results are consistent with an earlier Italian study that suggested occupational exposure of farmers to the use of insecticides or fungicides showed a significant increase in relative risk of developing brain glioma (Musicco et al., 1988).

The incidence of non-Hodgkin's lymphoma (NHL), a cancer that develops in the lymphatic system, has increased over the last 40 years. Some of this is linked to pesticide exposure

44. Normally the toxicological and environmental fate data relates to the technical product. Technical grade DDT is a mixture of three isomers principally *p-p'*DDT, with *o,p'*-DDT and *o,o'*-DDT isomers present in lesser amounts.

(Zahm and Blair, 1992, McDuffie et al., 2001, Hardell et al., 2002). A recent review of 25 years of research into the disease and pesticide exposure revealed an association particularly in case control studies. The pesticide groups identified include chlorophenol and phenoxy acetic acid herbicides, organochlorine, organophosphate, and carbamate insecticides and fungicides. Spanish farmers exposed to non-arsenical insecticides were found to have an increased of risk of lymphomas. The risk was clearly observed for crop and livestock farmers. The risk was greatest after exposure to (non-arsenical) pesticides for a period of 9-17 years (Van Balen et al., 2006). A further Swedish study found that previous exposure to certain fungicides and herbicides was significantly associated with an increased risk of NHL (Hardell and Eriksson, 1999). A recent study from the US National Cancer Institute has pooled NHL data from US farmers. A large sample size (3,417) allowed analysis of 47 pesticides, linking some individual active ingredients with increased NHL including the organophosphate insecticides coumaphos, diazinon and fonofos, the insecticides chlordane, dieldrin and copper acetoarsenite and the herbicides atrazine, glyphosate and sodium chlorate. The study also examined combined pesticide exposures. Results indicated an increased NHL incidence by 'number of pesticides used' only for a sub group of what the researchers referred to as 'potentially carcinogen pesticides'. This suggested that specific chemicals, not pesticides, insecticides, or herbicides, as groups, should be examined as potential risk factors for NHL. In conclusion, the researchers recommended that a chemical-specific approach to evaluating pesticides as risk factors for HNL should facilitate interpretation of epidemiological studies for regulatory purposes (De Roos et al., 2003).

The above study looked at exposure to individual pesticides. At the same time there is a contradictory case for considering multiple chemical exposures. Another study has looked at the association between different types of NHL and exposure to pesticides. They reported a 2.6-5.0 fold increase in the incidence of t(14;18)-positive NHL with exposure to animal insecticides, crop insecticides, herbicides and fumigants. There were no observations with the t(14;18) negative HNL (Chiu et al., 2006). Furthermore, researchers in the US have suggested that the risk of NHL among asthmatics with pesticide exposure may be higher than among non-asthmatics with exposure. The odds ratio (OR) among asthmatics was 1.8 (95% CI 1.1-3.2) for the identified group "ever-use of crop insecticides", 2.7 (95% CI 1.0-7.2) for chlordane, 2.4 (95% CI 1.0-5.7) for lindane and 3.7 (95% CI 1.3-10.9) for fonofos. Among non-asthmatics, ORs were 1.1 (95% CI 0.9-1.3), 1.5 (95% CI 1.1-2.2), 1.3 (95% CI 0.97-1.8) and 1.6 (95% CI 1.0-2.4) respectively (Lee et al., 2004). A later study supported this previous finding that the risk of NHL from pesticide exposure may be greater among asthmatics (Lee et al., 2006).

No causality has been proven, although the levelling off of NHL incidence in certain countries may be a result of modified pesticide use patterns (Dreiher and Kordysh, 2006).

5.4.5. Neurological effects

A large number of published studies supports the position that long-term, low-level exposure to organophosphorus esters may cause neurological effects (Jamal et al., 2002). The risk of Parkinson's disease following pesticide exposure is the most studied and established neurological effect.

Parkinson's disease is a nervous disorder which usually occurs in elderly people and is caused by degeneration of cells in the brain which secrete the neurotransmitter dopamine. It results in serious difficulties in controlling the movement of voluntary muscles (Hardie, 1992). Many studies have examined pesticides as a risk factor for Parkinson's disease and Parkinsonism and the possible mechanisms by which pesticides may act. A comprehensive review of pesticides and Parkinson's disease has been carried out by researchers at the Institute for Environment and Health at the University of Leicester (Brown et al., 2006a). They cite in supplementary material a large epidemiological literature including a review of 177 studies of case reports, case series, and incidence, prevalence, mortality and cohort studies (Brown et al., 2006b). In particular the study focussed on 31 case control studies that presented results for exposure to pesticides as an exposure category. The odds ratios were at or above 1.0 for 29 of the studies, of which 12 reported a significant association between pesticide exposure and Parkinson's disease, with odds ratios of 1.6 to 7.0 (the confidence intervals (CIs) are wide, reflecting the small sample sizes). In conclusion, the weight of evidence was considered sufficient to say there is an association between exposure to pesticides and Parkinson's disease. But they could not link any one specific pesticide or any other pollutants (Brown et al., 2006a).

A further study in the US reported 7,864 people exposed to pesticides, including 1,956 farmers, ranchers or fishermen had a 70% higher incidence of Parkinson's disease than those not exposed. The data presented in this study support the hypothesis that exposure to pesticides may increase risk for Parkinson's disease. Again researchers cannot identify specific pesticides (Ascherio, 2006). A Californian study showed that people exposed to pesticides in the home or garden may have a significantly higher risk of Parkinson's disease (Stephenson, 2000).

Recent research, known as the Geo Parkinson's study, has agreed with the majority of other studies that there is an increased risk of developing Parkinson's disease after exposure to pesticides. The researchers carried out a case-control study of 959 cases of Parkinson's disease/Parkinsonism and 1989 controls in Scotland, Italy, Sweden, Romania and Malta. Lifetime occupational and hobby exposure to solvents, pesticides, iron, copper and manganese was recorded from an interview-administered questionnaire. Research identified an increased risk if the statistical figure odds ratio is greater than 1.0. Results showed significant increase odds ratios for Parkinson's disease/Parkinsonism with an exposure-response relationship for pesticides. The odds ratio for low exposure versus no exposure was 1.13 (95% CI 0.82-1.57) and 1.41 (95% CI 1.06-1.88) for high exposure versus no exposure. The researchers concluded that the association of pesticide exposure with Parkinson's disease suggests a causative role (Dick et al., 2007). The significance of this study lies in the relatively large sample size over a wide geographical area. It confirms that pesticide exposure may be a causative and potentially modifiable risk factor.

There are a number of limiting factors for the pesticides and Parkinson's studies. Firstly the diagnosis of the disease can be difficult while the patient it still alive. There is also a range of possible causes including environmental pollutants and genetic predisposition. None of the studies so far has been able to identify any one pesticide active ingredient or sub-group of pesticides, although there are a number of suspects. These include rotenone, paraquat, dithiocarbamates, cylodienes (organochlorine insecticides) and pyrethroids (Brown et al., 2006a). Another problem is the difficulty of modelling for a disease like Parkinson's disease. As Brown et al. (2006a: 162) conclude: "We identified no study that administered pesticides at levels comparable with those encountered by pesticides users, nor were the routes of administration those that would be experienced by pesticides users... As a result it is difficult to interpret the relevance of such studies to humans, although the difficulty in modelling a disease such as Parkinson's disease is acknowledged".

In conclusion, researchers recognise that it is going to be very difficult to identify unequivocally any individual causal factor, given the many possible causes of Parkinson's disease.

5.4.6. Neurobehavioural effects

A research review has shown an association between pesticide exposure and neurological dysfunction and disease (Kamel and Hoppin, 2004, Alavanja et al., 2004). Most assessments have involved organophosphates, but other groups include carbamates, pryrethroids fungicides or fumigants. Although the weight of evidence suggests that pesticide use is associated with increased symptoms in neuro-behavioural performance, there were some inconsistencies. Of critical concern is the accuracy of exposure assessment; and both quantitative and qualitative aspects of exposure differed among the studies. (Kamel and Hoppin, 2004). In the UK, there have been concerns about the long-term exposure to organophosphate sheep dips[45] which may result in damage to the nervous system. In a cross-sectional study the researchers compared neuropsychological performance in 146 sheep farmers exposed to organophosphates sheep dip compared with 143 non-exposed quarry workers. The farmers performed significantly worse than controls. The researchers concluded that repeated exposure to OP-based pesticides appears to be associated with changes in the nervous system. They recommended measures be taken to reduce exposure to OPs as far as possible during agricultural operations (Stephens et al., 1995). Other research has looked at pesticide exposure and the development of mild cognitive dysfunction (MCD) which is a condition indicative of cognitive impairment without dementia. The results showed there may be subtle changes in brain function among people exposed to pesticides (Bosma et al., 2000). Concern has also been expressed that long-term exposure may result in damage to the nervous system (Stephens et al., 1995, Beach et al., 1996). A recent US study has examined whether concurrent genetical vulnerability in an individual prenatally exposed to organophosphate insecticides at critical periods in neurodevelopment could be linked to autism. The researchers assessed 177 Italian and 107 Caucasian American families. They found that concurrent genetic vulnerability to autism and environmental organophosphate exposure may possibly contribute to autism in a group of North Americans (D'Amelio et al., 2005).

5.4.7. Multifactor diseases

Exposure to pesticides has been associated with multifactor diseases including Chronic Fatigue Syndrome/Myalgic Encephalomyelitis (CFS/ME) and Multiple Chemical Sensitivity. MCS is an acquired disorder characterised by recurrent symptoms, referable to multiple organ systems, occurring in response to demonstrable exposure to many chemically unrelated compounds at doses far below those established in the general population to cause harmful effects. No single widely accepted test of physiological function can be shown to correlate with symptoms (Cullen, 1987). Chronic fatigue syndrome (CFS), also known as ME, is a condition with contested terminology. In 2002, a Department of Health report from the CFS/ME Working Group confirmed CFS is a chronic illness. CFS is the preferred medical term, whereas most patients' groups use the term ME.

45. Regulated in the UK as a veterinary medicine.

The Working Group considered the diagnosis CFS inappropriate for some severely affected patients. Another conclusion of the Working Group acknowledged organophosphate compounds as a possible CFS trigger, although a clear causal relationship could not be identified (CFS/ME Working Group, 2002).

The increased use of chemical agents in modern warfare, and the consequent wide exposure of military and civilian populations suggest that these disorders require continued careful scientific study. A survey comprising three controls by British military veterans who had served either in the Gulf war, or in Bosnia, or on active service in 1991 but not deployed in the Gulf war, found that MCS and CFS may account for some of the medically unexplained illness following deployment. The prevalence of MCS in the three cohorts was 1.3% (Gulf), 0.7% (Bosnia) and 0.2% (non-deployed). For CFS the prevalence was 2.1% (Gulf), 0.7% (Bosnia) and 1.8% (non-deployed). MCS was particularly associated with the Gulf deployment and self-reported exposure to pesticides in which the estimated adjusted odds ratio was 12.3 (95% CI 5.1-30.0) compared with non-deployed military (Reid et al., 2001).

A UK study has investigated the hypothesis that repeated exposure to organophosphate pesticides in sheep dip may increase the possibility of developing 'chronic fatigue' (sic). Results from 178 subjects that completed questionnaires provided limited evidence of an association between exposure to organophosphates and CF (Tahmaz et al., 2003).

5.4.8. Reproductive effects

Reproductive toxicity begins with parental exposure to pesticides. Preconceptions, conception, prenatal and postnatal periods all provide special opportunities for adverse reproductive effects such as sterility, and foetal death or toxicity or teratogenicity.
A Spanish study on parental agricultural workers in areas where pesticides are heavily used showed that there was an increase in the risk of foetal death from congenital anomalies. They found the relative risk of foetal death between April and September (the period of greatest pesticide use) was 1.62 (95% CI 1.01-2.60) agricultural workers compared with 0.90 (95% CI 0.64-1.28) for manual workers (Regidor et al., 2004).

Women

Relatively few studies have examined the effect of pesticide exposure on women's reproductive health, compared with those on men (Farr et al., 2004, Hoppin et al., 2008).

Others researchers have looked at the impact of maternal exposure to pesticides on their offspring.

Researchers using data from the US Agricultural Health Study have suggested that certain hormonally active pesticides may affect menstrual cycles in women. They investigated the association between pesticide use and the menstrual function among 3,103 women living on farms in Iowa and North Carolina who were pre-menopausal, not pregnant or breastfeeding, and not taking oral contraceptives. The women completed self-administered questionnaires on pesticide use and reproductive health. The results showed that women who used pesticides had longer menstrual cycles and an increased risk of missed periods with an odds ratio of 1.5 [95% CI 1.2-1.9] compared with women who never used pesticides. The researchers also carried out a literature review to determine which of the 50 pesticides listed in the questionnaire showed evidence of ovarian effects, disruption of oestrous cycles in animal models, or evidence of endocrine disruption. As a result of the review, they listed the herbicide atrazine and the insecticide lindane, and the fungicides mancozeb and maneb as probable hormonally active pesticides and probable oestrous cycle-disrupting pesticides. Other pesticides were classed as possible endocrine disrupters or those for which there is conflicting evidence (Farr et al., 2004). Another study using data from the Agricultural Health Study has examined the association between pesticide use during pregnancy and gestational diabetes mellitus (GDM). It addressed the association between pesticide exposure during the first trimester of the most recent pregnancy and GDM among 11,273 women. Of the 506 who had GDM, women who reported pesticide exposure (mixing or applying pesticides to crops or repairing pesticide equipment) during pregnancy were more likely to report GDM (odds ratio of 2.2 [95% CI 5-5.3]). Risk of GDM was associated with the herbicides (2,4,5-T, 2,4,5-TP, atrazine, or butlylate) and the insecticides (diazinon, phorate, or carbofuran). The study conclusion suggested that activities involving exposure to agricultural pesticides during the first trimester of pregnancy may increase the risk of GDM (Saldana et al., 2007).

A US case-control study of pesticides examined the association between foetal death due to congenital anomalies and maternal residential proximity to pesticides. The odds ratios for all pesticides classes increased when exposure occurred within the same square mile of maternal residence (Bell et al., 2001).

In another preliminary study, women who live near California's agricultural fields sprayed with organochlorine pesticides have a six fold (odds ratio 6.1 [95% CI 2.4-15.3]) increased risk factor in giving birth to children with Autism Spectrum Disorders (ASD). The researchers caution that the sample size is small (including 29 women), but the rate of developing autism was much higher than in many other epidemiological studies assessing pesticide exposure and the development of adverse health outcomes. ASD increased with weight of organochlorine applied and decreased with distance from field sites (Roberts et al., 2007).

Men

Disorders of development and function of the male reproductive tract have been increasing in incidence over the last 30-50 years, such as testicular cancer. There has been a striking drop in semen volume and sperm counts in adult men over the same period. Since these changes are recent and replicated in many different countries, researchers assume they are linked to environmental or lifestyle factors, rather than genetic predisposition (Sharpe and Skakkebaek, 1993).

A number of studies have examined pesticides and effects on the male reproductive system. Glass et al. (1979) studied male pesticides applicators who worked with the nematicide 1,2-dibromopropane (DBCP) and found that they may have suffered testicular toxicity as a result (Glass et al., 1979). A Dutch study has examined the fertilizing ability of 836 couples who sought in-vitro fertilization treatment. It concluded that fertilization rates were significantly reduced for couples with paternal pesticide exposure, possibly because the sperm fertilizing ability was decreased. Because most individuals were exposed to multiple pesticides with various active ingredients, it was impossible for the researchers to draw conclusions as to which chemical may have been responsible for the observed effect (Teilemans et al., 1999). A further US study on exposure to non-persistent insecticides and male reproductive hormones has found that levels of 3,5,6-trichloro-2-pyridinol (TCPY) [a metabolite of the insecticides chlorpyrifos and chlorpyrifos methyl] and 1-naphthol (1N) [a metabolite of carbaryl and naphthalene] were associated with reduced testosterone levels. On a population level these reductions are considered by the researchers to be of potential public health importance because of widespread exposure to these non-persistent insecticides (Meeker et al., 2006). There is limited evidence of an inverse association between pp'-DDE and sperm motility (Hauser et al., 2003). Spanish researchers have analysed levels of 14 organochlorine pesticides in the blood of 220 young males in southern Spain. This is the largest area of intensive glasshouse agriculture in Europe. Detectable levels of *p,p*-DDE were found in 96% of the serum samples. In addition to DDT and its metabolites, other residues found included aldrin, dieldrin, endrin, lindane, methoxychlor, endosulfans and DDT. The results indicate that men of reproductive age in southern Spain have been exposed to organochlorine pesticides, many of which have estrogenic and anti-androgenic properties (Carreño et al., 2007).

5.4.9. Impacts on children

There have been a large number of studies on the impact of pesticides and children in recent years (Zahm and Ward, 1998, Garry, 2004, WHO, 2007). The World Health Organisation report is especially comprehensive. The previous section addressed the impact of pesticide exposure pre-natally. This section examines the post-natal impact, although it is not always easy to make a distinction between the two. For example, exposing boys to the organochlorine insecticide endosulfan is associated with delayed puberty. Did this result from parental exposure or childhood exposure? The researchers remain unclear on the issue (Saiyed et al., 2003).

Children have been recognised as the most vulnerable of the world's population to environmental pollution which can affect their health in quite different ways from adults (WHO, 2007). Research has focussed on pesticides and children in relation to cancer, neurologic/neurobehavioural and endocrine effects (Garry, 2004). There is also evidence that the observed increase in behavioral disorders among children in industrialized countries could be in part related to parental exposure to pesticides (Landrigan, 2001). A US study indicated that children living in agricultural regions represent an important sub-population for public health evaluation, and that their exposure falls within the range of regulatory concern (Fenske et al., 2000). Risks to children are uniformly higher than adults because they have a greater inhalation rate/body weight ratio among other factors (Lee et al., 2002). Not only are children especially vulnerable but they respond differently from adults when exposed to environmental factors. This response may differ according to the different periods of development. For example, their lungs are not fully developed at birth, or even at the age of eight. Lung maturation may be altered by air pollutants that induce acute respiratory effects in childhood which may be the origin of chronic respiratory disease later in life (WHO, 2007).

While research has addressed the impact of environmental chemicals on children's health, usually the focus has been on exposure to a particular polluting chemical or group of chemicals such as pesticides, and the impacts on a specific organ or adverse end-point. There is an absence of 'prospective longitudinal studies' that encapsulate the impacts at key life stages. For example, virtually no studies have included peri-conceptional exposures either alone or in addition to other life stage exposures (WHO, 2007). There have been studies that have looked at parental, paternal and maternal impacts. Results from the US Agricultural Health Study have shown that that parental exposure to pesticides may contribute to childhood cancer risk (Flower et al., 2004). Researchers identified data for 17,357 children of Iowa parents who were pesticide applicators, and have found that the risk of all childhood cancers increased according to a standardized incidence ratio (SIR) of 1.36 (95% CI 1.03-1.79). In another review, case reports or case-control studies include leukaemia, neuroblastoma, Wilm's tumor, soft-tissue sarcoma, Ewing's sarcoma, non-Hodgkin's lymphoma and cancers of the brain, colorectum and testes (Zahm and Ward, 1998). Despite limitations of non-specific pesticide exposure, small numbers exposed, and the potential for recall bias, the researchers note that many of the risks are greater for children compared with adults suggesting that children may be particularly sensitive to the carcinogenic effects of pesticides.

In particular, a number of studies have focused on the risk of childhood leukemia following pesticides exposure. A Canadian study of acute lymphoma compared 491 cases with as many controls. Indoor use of some insecticides and pesticide use in the garden and on interior plants, in particular frequent parental use was associated with an increased risk of up to several fold in magnitude (Infante-Rivard et al., 1999). Results from France from 280 incident cases of acute leukemia and 288 controls suggested that the risk of developing acute leukemia was almost twice as likely in children whose mothers had used insecticides in the home while pregnant and long after the birth (children under the age of 15) (Menegaux et al., 2006). A further French study investigated the role of household exposure to pesticides in the causation of childhood hematopoietic malignancies (including acute leukemia, Hodgkin's lymphoma and Non-Hodgkin's lymphoma). Insecticide use during pregnancy was significantly associated with childhood acute leukemia (OR 2.1 [95% CI 1.7-2.5]), Non Hodgkin's lymphoma (OR 1.8 [95% CI 1.3-2.6]), and mixed-cell Hodgkin's lymphoma (OR 4.1 [95% CI 1.4-11.8]). The findings of this research add to the hypothesis that domestic use of pesticides may play a role in the development of childhood hematopoietic malignancies. These conclusions, coupled with previously consistent studies, lead the researchers to consider that pregnant women should be prevented from using pesticides (Rudant et al., 2007).

A recent US study suggests that household chemical exposure may play a role in the development of acute leukemia in children with Downs syndrome. Positive associations were found between acute lymphoblastic leukemia and maternal exposure to professional pest control (odds ratio (OR) 2.25 [95% CI 1.13-4.49]), to any pesticide (OR 2.18 [CI 1.08-4.39]) and to any chemical (OR 2.72 [CI 1.17-6.35]) (Alderton et al., 2006). Researchers in the US have evaluated the data from a previous study of organophosphate exposure among 109 children in an agricultural community in Washington State; 91 of the children had parents working in agriculture. Organophosphate exposure was estimated from urinary metabolite concentrations and compared with toxicological reference values. For children whose parents worked in agriculture either in orchards or as fieldworkers, 56% of the doses estimated for the spraying season exceeded the US Environmental Protection Agency chronic dietary reference dose (Fenske et al., 2000).

5.4.10. Endocrine disruption

Endocrine disruptors include chemicals that alter the action of hormones in the body. They usually manifest themselves as oestrogen mimics or androgenic antagonists. A number of diffuse pollutants, including organochlorine pesticides and other synthetic chemicals, are endocrine disruptors. In recent years, there has been growing concern and public debate over the potential adverse effects of chemicals that have the potential to alter the normal functioning of the endocrine systems in wildlife and humans (Colborn et al., 1993, Damstra et al., 2002, Birnbaum and Fenton, 2003, Colborn, 2004, Sharpe and Irvine, 2004). The link between human health and endocrine disrupting pollutants remains the subject of debate among the scientific community, and is interpreted differently by regulators internationally. The concern centres on the increased incidence in the hormonally dependent disorders breast cancer and testicular dysgenesis syndrome (comprising low sperm counts, testicular cancer, cryptochidism and hypospadias) (Safe, 2000, Sharpe and Irvine, 2004). In addition, Colborn (2004) researching neurodevelopment and endocrine disruption, has explored the possibility that pesticide contaminants contribute to the prevalence of attention deficit hyperactivity disorder, autism, and associated neurodevelopmental and behavioural problems in developed countries. She also presented associations between exposure to specific chemicals or chemical classes and developmental difficulties in laboratory animals, wildlife and humans.

Sharpe and Irvine (2004) cite a number of examples of reproductive effects caused by environmental chemicals; they describe the research evidence linking human disease and exposure to environmental chemicals as 'sketchy'. They point out that it is difficult to say whether such effects are present or absent making it difficult to establish them, also taking into account mixtures of chemicals. Japanese research found that exposure to endocrine disruptors caused disturbances to the human hormonal system during foetal development, but they acknowledged that they are subtle and difficult to detect and research (Mori, 2001). Interaction between endocrine disrupters and such processes as carcinogenesis, immunological, reproductive and neurodevelopment processes at all ages and in both sexes is highly complex. This process is increased by the natural variation in human beings. Furthermore, there are no validated or standard screens or assays developed to test chemicals for their possible endocrine-disrupting effects (Colburn, 2004). This may explain why there are differences between regulators concerning the interpretation of potential endocrine disrupters and their possible impacts. Some researchers are calling for new models for pesticide assessment (Acerini and Hughes, 2006, Colborn, 2004, Colborn, 2006), because they consider that it may never be possible to link prenatal exposure to a specific chemical with neurodevelopmental damage in humans (Colborn, 2004).

The different approaches taken by regulators can be seen in the different lists of possible endocrine disrupting pesticides established by different international and national regulators. A recent study has identified 127 endocrine disrupting pesticides from research carried out using the UK as a case study. The difficulties in making links between endocrine disruption and pathological disorders are acknowledged. It concludes that the material links between endocrine disrupting pesticide use and specific illnesses or deformities are complicated by the multi-factorial nature of disease. Despite these difficulties, the researchers conclude that a large body of evidence has accumulated linking specific conditions to endocrine disrupting pesticides in humans (and wildlife, see also below) (McKinlay et al., 2008).

5.5. Environmental effects of pesticides: impacts on wildlife

Pesticides are used in a variety of circumstances on a whole range of crops and under a wide range of climatic conditions. Under these conditions it is impossible to predict or calculate the risk for wildlife species during pre-marketing approval of a product (Berny, 2007). Wildlife exposure to post-approval pesticides follows the pathway outlined in Figure 5.2. This not only includes the pollution caused by the 31,000 tonnes of pesticides sprayed onto 64.5 million ha of UK agriculture[46]. But it also includes other areas of usage such as the 175-220 million litres of spent sheep dip produced each year. The effects of such levels of discarded dip alone on the microbial ecology of soil and aquatic systems are still relatively unknown (Boucard et al., 2004). Although regulated under different legislation, and distributed by different industrial concerns, sheep dips include the same chemical active ingredients (such as cypermethrin and chlorfenvinphos) used elsewhere in

46. The area treated refers to the active substance treated area. This is the basic area treated by each active substance multiplied by the number of times the area was treated. For example a field of 3ha is treated 4 times with active X = a treated area with X of 12ha (http://pussstats.scl.gov.uk).

agriculture. This presents wider pollution implications for the combined effects of the same or similar chemicals used in different occupational and/or regulatory sectors.

There have been regular reports of pesticide poisoning of wildlife since the 1950s. For example, a report during 1959-1960 showed that seed treated with the organochlorine insecticide dieldrin almost certainly caused lethal secondary poisoning of 1,300 foxes as well as farm dogs and cats, badgers and carnivorous birds, which had consumed birds which previously fed on the contaminated seed (Mellanby, 1967: 140).

The most common pesticides involved in direct wildlife poisoning are organochlorine, organophosphate and carbamate insecticides and the anticoagulant rodenticides. Other chemicals implicated are mollusicides and herbicides (paraquat, MCPA and bromoxynil) (Berny, 2007). Brakes and Smith (2005) cite seven studies from around the world that have demonstrated exposure of many non-target species to anticoagulants. Use of rodenticides on farms in the UK increased from 74% in 1992 to 89% in 2000. Exposure may be direct (primary), when non-target species eat bait; secondary, when predators eat contaminated prey; even tertiary poisoning can occur further down the food chain (Brakes and Smith, 2005). The more persistent the pesticides are, the more they bio-accumulate at the tertiary and subsequent levels. Poisoning data may be incomplete as it remains difficult to detect all affected animals, since most species live in small groups or individually and have predominately nocturnal activity (Fournier-Chambrillon et al., 2004). Devine and Furlong (2007) conclude that the great majority of insecticide poisoning events on non-target organisms, are likely to go unrecorded – especially if those organisms are considered non-charismatic.

5.5.1. Birds

Bird populations in particular have been affected by many different pesticides. According to Berny (2007), most scientific papers dealing with wildlife poisoning report incidents in birds of prey. The incidence of poisoning goes back many decades. Melanby (1967) cites a number of important studies carried out during the 1960s (Prestt, 1965, Murton and Vizoso, 1963, Moore and Walker, 1964, Moore and Tatton, 1965, Moore, 1965, Lockie and Ratcliffe, 1964). Later work found a relationship between exposure to organochlorine insecticides and population decline in peregrines, sparrowhawks and golden eagles caused by egg-shell thinning. Persistent organochlorine compounds accumulate in the tissue of wild raptors and have been shown experimentally to disturb physiological mechanisms affecting calcium metabolism in birds. The introduction of DDT and lindane during 1946-

48 coincided with the onset of egg-shell thinning, and these chemicals were suspected as initiators of this change (Ratcliffe, 1970). In the US similar effects were noted for loggerhead shrikes (*Lanius vicianus*) with DDE as a possible causative agent (Andersen and Duzan, 1978). Most of the organochlorine pesticides were replaced by organophosphates and carbamates during the 1980s and 1990s. They too have had impacts on bird populations as a result of birds ingesting treated seed (Devine and Furlong, 2007).

Reports since the 1980s have linked the indirect effects of pesticides with impacts on bird populations. Pesticide may kill the non-target invertebrates on which avian populations feed. This has happened in the case of grey partridge chick populations in the UK. Research has shown that the mean brood size and the abundance of insects as food for partridge chicks were significantly higher where small areas of cereal fields were left unsprayed than on sprayed fields (Rands, 1985). This finding was more generally recognized by a report by the Joint Nature Conservation Committee which summarizes the evidence that pesticide use indirectly affects bird populations, particularly through their food supplies (Campbell and Cooke, 1997). Another study said that invertebrate food abundance affected chick conditions for the skylark and the number of fledging chicks for yellowhammers and corn buntings (Boatman et al., 2004).

The wider pesticide aspects of agricultural intensification have continued to lead to a decline in UK farmland birds. For example, decline in the population levels of seed-eating birds have been driven primarily by herbicide use as well as by the switch from spring-sown to autumn-sown cereals, both of which practices have massively reduced the food supply of these birds (Newton, 2004). A more recent French review confirms that non-target birds are affected by acute poisoning. Direct exposure includes accidental poisoning from licensed and illegal poisoning. Field studies indicate that avian mortality occurs frequently after regular intentional use of pesticides in agricultural fields (Berny, 2007).

5.5.2. Small mammals

Non-target small mammals are vulnerable to the effects of anti-coagulant rodenticides because they are attracted to the poisoned bait. In turn these mammals are considered important in the diet of many predatory and scavenging species (Brakes and Smith, 2005). In one study, the carcasses of 40 stoats (*Mustela erminea*) and 10 weasels (*Mustela nivalis*) were collected by estate gamekeepers and analyzed for rodenticides. Residues were found in the livers of 23% of stoats and 30% of weasels. The researchers concluded that stoats and weasels are secondarily exposed to rodenticides mainly by eating non-target species

(McDonald et al., 1998). The same study showed that non-target small mammals provide a route of exposure to rodenticides that will increase in importance as rodenticides are increasingly applied away from farm buildings. As conservation biologists, the researchers express concern that the requirement of purchasers of farm produce for assurance schemes includes prophylactic rodent control. They are further concerned that predators and scavengers (including birds of prey) are exposed to rodenticide-contaminated animals through non-target as well as target species (Brakes and Smith, 2005).

5.5.3. Microbial contamination

A recent systematic review of data in the public domain revealed 970 toxicity endpoint data sets, representing 71 pesticides and 42 soil invertebrate species. Relatively high numbers of pronounced and persistent effects occurred when Lumbricidae (earthworms) and Enchytraeidae (potworms) were exposed to fungicides and when Lumbricidae, Collembola (springtails) and Arachnida (spiders, mites, harvestmen and ticks) were exposed to insecticides (Jänsch et al., 2006). Another recent study has shown *in vivo* evidence that a sub-set of pesticides (methyl parathion, DDT and pentachlorophenol [PCP]) and other environmental contaminants block the chemical processes that allow nitrogen-fixing bacteria to function. Over time, nitrogen levels can be reduced in the soils in the vicinity of the treated plants, subsequently requiring the use of more fertilizer to produce the same yield. Fox et al. (2007) tested this pesticide sub-set on Oregon alfalfa plants that rely on nitrogen-fixing bacteria. Methyl parathion and DDT showed a decrease in yield of approximately 20%; and for PCP, the reduction in crop yield was over 80%. These environmental effects of synthetic chemicals which compromise symbiotic nitrogen fixation led to an increased dependence on synthetic nitrogenous fertilizer, reduced soil fertility and decreasing long-term crop yields (Fox et al., 2007).

5.5.4. Invertebrates

Risk assessment for soil invertebrates (and other wildlife species) now adopts a tiered experimental approach starting with relatively simple single-species tests carried out under (assumed) worst-case exposure conditions in laboratory studies. If these studies indicate an unacceptable level of risk, further testing under more ecologically realistic conditions is carried out (Jänsch et al., 2006).

Non-target arthropods are often severely affected by insecticide use, especially in the short-term. Aquatic invertebrates are particularly vulnerable to pesticides and their decline can have indirect effects on fish populations by destroying their food sources. In the UK, Cypermethrin is a pesticide used in many sheep dip formulations. It has an extremely high toxicity with concentrations as low as 10 ng/L (parts per billion) destroying aquatic life (Virtue and Clayton, 1997).

5.5.5. Wildlife and endocrine disruption

According to a review by Colborn et al. (1993), exposure to endocrine disrupting chemicals in the environment has been associated with abnormal thyroid function in birds, and fish; with decreased fertility in birds, fish and shellfish and mammals; with decreased hatching success in fish, birds and turtles; with demasculation and feminisation of male fish, birds and mammals; with defeminisation and masculinisation of female fish, gastropods, and birds; and with alteration of immune function in birds and mammals. These effects have been observed in the of presence multiple chemical exposures to pesticides and other synthetic chemicals (Colborn et al., 1993). The list includes 35 pesticides (8 herbicides, 8 fungicides, 17 insecticides, and 2 nematicides and 10 industrial chemicals with widespread damage in the environment reported in the literature due to reproductive and endocrine disrupting effects. Recent data (Fox, 2004) have shown that many of the same synthetic and natural environmental chemicals that disrupt endocrine signalling in vertebrates also disrupt the phytoestrogen-NodD receptor signalling in soil bacteria, which is necessary for nitrogen-fixing symbiosis [see also Section 5.2.4 'Soils' above]. Fox (2004) concludes that bacteria-plant symbiosis is an unexpected target of endocrine disruption. Other unexpected non-target species may also be vulnerable to environmental endocrine disruptors.

One of the clearest cases of endocrine disruption involved the marine anti-fouling paint tributyl tin (TBT). Once widely used on boats and ships, it impacts seriously on aquatic invertebrates. Imposex (female growth of male sex organs) and intersex (hermaphroditism) have occurred in dog-whelks (*Nucella lapillus*) after long-term low level exposure to TBT (Bryan et al., 1987).

In another case, a US-wide study has shown that exposure to the herbicide atrazine at levels below or equal to 0.1 parts per billion (ppb) restricted gonadal development (dysgenesis) and testicular hermaphroditism (oogenesis) in leopard frogs (*Rana pipens*). Atrazine is a widely used herbicide in the US and around the world, and contamination has been found in excess of 0.1 ppb in rainwater and even in areas where it is not used (Hayes et al., 2003). Related US research has also found amphibian survival rate is affected at low levels of atrazine (Storrs and Kiesecker, 2004). The researchers investigated ~30 days exposure of amphibians to low levels of pesticide at early and late developmental stages. The four species involved were the spring peeper frogs (*Pseudacris crucifer*), American toads (*Bufo americanus*), green frogs (*Rana clamitans*), and wood frogs (*Rana sylvatica*). The 30 day exposure was considered more realistic than most previously reported studies where they used ~4 days exposure at relatively high concentrations. The amphibians were exposed to 3, 30, 100 parts per billion (ppb). This can be compared with the US Environmental Protection Agency drinking water standard which is 3 ppb. The researchers found counterintuitive patterns in survival rates. Survival was significantly lower for all animals exposed to 3 ppb compared with either 30 or 100 ppb, except for the late stages of *B. americanus* and *R. sylvatica*. In making wider conclusions, the researchers comment that survival patterns highlight the importance of using realistic exposure levels at various developmental stages. This may also be more important for endocrine disruptor compounds that produce greater mortality at lower doses.

5.5.6. Exocrine disruption

Many organisms use pheromone chemicals to lure a mate, or to detect natural enemies and to avoid predators. Non-toxic concentrations of chemicals, including pesticides, can act as 'exocrine disruptors' by interfering with the transfer of chemical information between a signaller and receiver organisms. Similar to endocrine disruptors, these external chemicals from a new type of threats, which could have far-reaching implications for the ecosystem stability, and conservation management, according to aquatic ecologists Lürling and Scheffer (2007). They conclude that the wider issue of info-disruption should be investigated as a matter of priority, as opposed to endocrine disruption.

5.6. Technical and economic challenges

A number of issues have emerged which have reduced the effectiveness of pesticides. These add to the other challenges to the continued use of pesticides. The increasingly serious problem of pesticide resistance has reduced the effectiveness of pesticides. This increases the cost to pesticide industry which has to develop new replacements, and can have serious pest and disease management consequences for farmers and growers who expect to purchase reliable products. The disposal of unwanted pesticide stockpiles is a global problem. This process can be a hazardous operation and a costly exercise, not always paid for by the industry producing the pesticides in the first place. There is also an organised and significant trade in illegal pesticides. Experts have estimated that 5-7% of the pesticides used in Europe are illicit, putting consumers' health and farmers' livelihoods at risk. Finally, the consequence of using pesticides can result in negative external costs that adversely affect unrelated third parties.

An undesirable effect of the intensive use of pesticides is induced resistance in pests, weeds and disease. Resistance can develop in a pest population if some individuals posses genes that provide resistance mechanisms to overcome the toxic properties of the pesticide. Having not succumbed, these individuals pass on the genetic trait and the resistance mechanisms to their offspring, leading to an increasing proportion within the exposed population that can survive subsequent pesticide applications. The first reported case of resistance to pesticides occurred in 1947 when resistance to DDT was found in the house fly (*Musca domestica*) (Sacca, 1947) cited in (Georghiou, 1972). By 1972, more than 225 species had developed resistance to pesticides (Georghiou, 1972). Today there are 540 of insects and spider species resistant to more than 310 pesticide products (Michigan State University, 2000).

The problem of disposal of unwanted or obsolete pesticides has been described by the UN Food and Agricultural Organisation as a 'pesticide waste time bomb' in developing countries. For example, it is estimated that the Ukraine has around 19,500 tonnes of aging chemicals, Macedonia 10,000 tonnes, Poland 15,000 tonnes and Moldova 6,600 tonnes. These hazardous obsolete pesticides are left over from former pest control campaigns. Stockpiles have accumulated because a number of products have been banned for health or environmental reasons, but never removed or disposed of properly (FAO, 2004).

In recent years, the official pesticide industry has had to contend with a growing number of fake and dangerous pesticides reaching the market. To cope with this, an initiative called the European Crop Protection Information Services was launched in 2008 by the European Crop Protection Association (ECPA). The trade in illegal and counterfeit pesticides is linked to the growth in chemicals industry in China, in which products are reaching the European market through the Ukraine. These products are highly dangerous and toxic both to public health and the environment, according to the trade body ECPA (ECPA, 2008). It estimates that fake pesticides represent up to €500 million of a €10bn market. Almost 90% of the fakes come from China, whose pesticide exports nearly doubled between 2000 and 2005 (Bounds, 2008).

Estimates for the external costs of pesticides are almost certainly considerable under-estimates owing to differing risks per product, poor understanding of chronic effects, weak monitoring systems, and misdiagnosis by doctors (Pretty et al., 2000). In the UK, significant costs arise from contamination of drinking water from pesticides at £120 m per year. The money spent would be much higher if the policy goal were complete removal of all residues.

It is very difficult to say exactly how many people in the UK are affected by pesticides each year. According to voluntary reporting to the Health and Safety Executive (HSE), some 100-200 incidents occur each year, of which few are substantiated. However recent HSE research indicates significant under-reporting. One survey of 2,000 pesticide users found that 5% reported at least one symptom in the past year and about which they had consulted a doctor. A further 10% had been affected (mostly by headaches), but had not consulted a doctor. As some 105,000 farmers hold pesticide certificates in Britain this suggests that at least 5,250 farmers suffer sufficient symptoms to consult a general practitioner each year, and a further 10,500 area adversely affected to a lesser degree. This suggests the annual cost borne by farmers and the health system are £1.05 m. Chronic effects of pesticides, are difficult to assess and were therefore not included in the Pretty et al. (2000) study.

Pretty et al. (2000: 18) conclude by saying that "a more fair and efficient use of public resources would be achieved if policy sought more explicitly to internalise the external costs to agriculture. This would imply a redirection of public aid from polluting activities to sustainable practices, with subsidies used to encourage those positive externalities under-provided in the market place, combined with a mix of advisory and institutional mechanisms, regulatory and legal measures, and economic instruments to correct negative externalities".

5.7. Conclusions

This chapter has provided evidence that the pesticide policy paradigm is under such stress from its unintentional effects that the long-term sustainability of pesticide use is called into question. This paradigm is global, and so are the unintentional side-effects. The assessment focuses on the risks of adverse health outcomes and the extent of environmental pollution. Many of the examples of adverse pesticide effects cited are from Europe and the US. It is concluded that these examples can be useful in making judgements about pesticide policy in the UK.

The evidence has been presented in three main sections; the routes of exposure; human contamination; and non-human, non-target, environmental contamination. It contains a number of themes, drawn together below, that have emerged to support the general conclusion that the pesticide policy paradigm is increasingly coming under stress.

A full assessment of the impacts of pesticides embraces a wide number of disciplines because of the complex interactions between the pesticides, their target pests, their unintended victims and the whole of the natural and bio-environment. Figure 5.1 summarises the main interlocking 'intentional' and 'unintentional' effects of the cycles of pesticide use. It reinforces the fact that, while the 'intentional cycle' is focused on individual active ingredients, the 'unintentional cycle' is driven by the sum of all the pesticides in use, past and present, together with their total possible polluting effects.

The model in Figure 5.1 provides an overview of both intentional and unintentional effects of pesticides. An ideal pesticide would be one for which the unintentional effect side of the cycle does not exist. Anything else represents a state where risks (some of which are difficult to measure) have to be accepted through the political control mechanism. It is that acceptance that is contested by the different stakeholders. Whilst the cycle can accept the banning of active ingredient(s), the cycles are maintained

This chapter has focused on the 'unintentional cycle'. The breadth of the subject under review is reflected in the references presented have necessarily been taken from a very wide range of scientific research disciplines, many of which will have had very little contact with each other. These disciplines include agricultural research, human toxicology, human epidemiology, occupational and environmental health, preventative medicine, public health, health policy, rural health, family and community medicine, child health, biostatistics, geology, hydrology, atmospheric environmental epidemiology, biological science, zoology, terrestrial and aquatic ecology, soil science, integrative biology, environmental endocrinology, nanotechnology, animal and plant health, environmental policy. This broad research horizon, compounded by the range of different human agencies involved in their use and regulation, makes a study of the conflicting benefits and disadvantages of pesticides very difficult to present.

Many of the parameters within the pesticide policy paradigm show a high degree of variability. There are a number of variables in terms of how pesticides are dispersed. A summary of the pesticide exposure variants in presented in Figure 5.3. First there is the variable context of the location in which they are used, whether in agriculture or in urban settings for example. The levels and behaviour of pesticides in the atmosphere is complex and highly variable. The rate of pesticide emission can fluctuate considerably during application, and the effective concentration and deposition of pesticides can vary. Understanding the mechanisms of pesticides leaching to groundwater is made difficult by the complexity of issues involved. The fate of pesticides in soils depends on the chemical properties, the meteorological conditions, biota and sediment characteristics. Pesticide degradation varies considerably. Even within the top soil, there can be significant variability from field to field in pesticide degradation rates because of variation in soil properties. All living organisms, from the air they breathe, from the food they eat and from the water they drink are exposed to the potential danger of contamination. In all these media there is the potential for variable exposure. There is also wide variation in the level of pesticide residues which can accumulate in food for reasons which are not well understood.

There is also variation in terms of the possible results of human contamination by pesticides. There is variation between the responses of human beings in relation to their gender, age and genetic susceptibility. The route of contamination and length of exposure also vary. There is the multi-factorial nature of the causation of many diseases that may be mediated by interaction between pesticide toxicity and other pathogenic factors, leading to a number of adverse health progressions such as carcinogenesis, and in disorders of immunological, reproductive, neuro-developmental and neurological processes. The precise mechanism of the toxic action at a cellular and sub-cellular level is variable and often uncertain as with endocrine disruption and genotoxicity. There are even implications across generations where variable adverse outcomes may occur in children whose parents were exposed to pesticides. It is impossible to isolate one variable factor for study and assume all the other factors are constant.

When pesticides are applied, only a small amount actually kills or controls the target pest; the bulk of the product is released into the environment resulting in ubiquitous 'unintentional effects' of application (see Figure 5.1). Pesticide residues appear throughout the environment, in the air, in precipitation, in the surface water, in the groundwater and in the soil. Chemical contamination occurs in the bodies of wildlife, of domestic animals and of humans; and in crops and other plant foods. Often this contamination is in the form of multi-residues. From all of these sources of contamination there is a constant threat. 'Acceptable' levels of pesticides are found regularly to have been exceeded, so that active monitoring has to be carried out as a matter of routine. Pesticide contamination can cross national boundaries. The agents may be applied in one country, only to be monitored in another (where its sale and use may be banned). Furthermore, not only is there the parent compound to consider, but also its potentially toxic breakdown products. For example, in groundwater, metabolite samples can be more abundant than the parent compound.

The species-specific effects of these pesticides have been reviewed. Exposure to pesticides, or pesticide sub-groups, has been linked in humans to an increased risk of malignant brain tumours (astrocytoma and gliomas), of breast and prostate cancer, of non-Hodgkin's lymphoma and of Parkinson's disease. It may also cause immunotoxicity, multifactorial diseases (such as MCS and CFS), a range of problems affecting the male and female reproductive systems problems and cross-generational impairment.

A better understanding and awareness of pesticide exposure risk is urgently needed in order to control the public health impacts of pesticides. There are some examples where elevated health risks are associated with specific active ingredients; but it is much more likely that groups of pesticides, or just pesticides as a generic group, are identified. If one specific active ingredient were to be linked to the increase incidence of, say, Parkinson's disease, its production and use would almost certainly be halted. But this is often not the case. When pesticides as a group are implicated, rather than single active ingredients, experience shows that nothing is likely to happen. To ban all pesticides would threaten the economic and political basis of the 'intentional' side of the pesticide paradigm; banning one active ingredient does not.

Important areas of uncertainty have emerged. There is uncertainty in estimating the dispersal of pesticides in terms of what is used, where it is used and when it is used. There is uncertainty in estimating pesticide drift. The exposure of people resident in rural areas seems likely to have been substantially underestimated. The true extent of pesticide poisoning is not known. At best it has been chronically under-reported. The ability to link human disease and environmental chemicals is difficult, not least because of the multi-factorial nature of most diseases. Often the literature in these areas is limited and tentative in its conclusions. Efforts to reduce these important areas of uncertainty are likely to reduce one of the pressures on the pesticide paradigm.

The increased risks from exposure to pesticides underpin the chapter. The known risks have increased over time, and are still increasing as more data about the impact of pesticides becomes apparent. Indeed many of the studies concerning the risk associated with exposure to pesticides were published, after this PhD research had commenced. New risks have materialized in this time such as recognition that genetic predisposition to autism may be accentuated by environmental chemical contamination. Another examine is the under-researched impact of pesticides as exocrine disruptors. All these problems have emerged as new issues after the original framing of pesticide policy in the 1940s. An analysis of the examples presented in this chapter is summarised in Table 5.1. It lists in a diverse array of unintentional effects from the last 50 years that were not identified before the pesticides concern were approved for use. The conventional pre-approval testing procedures were not designed to detect these outcomes.

These four themes, 'variability', 'ubiquity', 'uncertainty' and 'emerging risk', have emerged as the key components of the 'unintentional' pesticides cycle which are in turn being driven by the 'intentional' pesticide cycle. They are the essence of the health and environmental concerns posed by the 'unintentional' pesticide cycle (see Figures 5.1 and 5.2). The four themes are all difficult to measure scientifically, but the collective evidence shows that there many increased risks associated with the use of pesticides. It has been argued that they constitute a serious challenge to the sustainability of the pesticide policy paradigm. They complement with the historical challenges to the paradigm detailed in Chapter Four.

Table 5.1: Examples of belatedly discovered adverse health and environment effects of pesticides

1.	It was not until the 1960s that pesticides were found to have contaminated the Antarctic and Artic regions due to long range transportation of pollution.
2.	The indirect effects of pesticides on bird populations were not recognised until the 1960s-70s.
3.	From the 1960s to the present day, a range of chronic effects on humans exposed to pesticides has been recognised.
4.	The likelihood of groundwater contamination was largely ignored until the 1980s.
5.	Endocrine disruption and similar scientific ways of studying the impact of pesticides began with the discovery of egg shell thinning in the 1960s, and developed further in the 1990s. More recently, concerns have been raised about the exocrine disrupting effects of pesticides.
6.	In the 2000s, a new set of acceptable level for residues in food has had to be developed in order to satisfy newly elevated concerns over the variability of pesticide residues in food and the uncertainty of increased risks to health.
7.	Implications of multiple chemical sensitivity and the difficulties of more than one factor cause adverse outcomes.
8.	Discovery of chemically induced immuno-suppression in humans, that is, a weaker immune system to fight off disease.
9.	The realisation during the 1990-2000s that parental exposure to pesticides may lead to adverse effects (such as leukaemia) in the children of those exposed.
10.	The life-stage timing of exposure (to the foetus or young child) can have adverse effects at low concentrations
11.	Researchers in the US have found that the risk of non-Hodgkin lymphoma among asthmatics with pesticide exposure may be higher than among non-asthmatics with exposure. Those with one condition and exposure to pesticides have a greater predisposition to a second adverse outcome, presenting difficulties for establishing adverse end-points.

6. Responses to the threats posed by pesticides

6.1. Introduction

The historical challenges and adverse effects of pesticides have led to the emergence of stakeholders who have criticised the use of pesticides. This chapter reviews four groups of stakeholders that have emerged in recent years. The first group represents civil society environmental concern. It is supported by a wide-ranging literature, starting most notably with Rachel Carson's *Silent Spring,* which documented damage that pesticides can inflict on human health and the environment. These concerns have resulted in the formation and development of a global coalition of anti-pesticide organisations.

The second group includes an un-coordinated collection of independent actors who have produced official and authoritative reports, from the 1960s onwards that have raised pesticide policy recommendations, often from a critical standpoint. They are written from a perspective outside that of the productive stakeholders reviewed above. This group does not represent a collective movement, in the same way that public interest organisations have emerged. These reports were individually constituted, but have been collated together for the present research because of their independent approach and critical outcomes.

The third group encompasses health and environmentally based academic researchers, some of whom have organised collective consensus statements which contain clear policy recommendations. It also includes examples of individual or research groups have made ad hoc policy recommendations that have been published as conclusions in articles in the scientific literature.

The final group includes a number of UK-based multiple food retailers, who have initiated their own pesticide policies. This has been driven by consumer concern about pesticide residues in food. The company-wide pesticide policies are more stringent than that required through government regulation and policy. This last group has also been included in the productive group of stakeholders, straddling as they do the food supply chain on the one hand, whilst trying to accommodate the wishes of civil society on the other.

The following section of this Chapter reverts back to the 1960s to examine the ways in which the intervening years have demonstrated how these discoveries have been handled. There is particular focus on the regulator and how there has been a growing reliance on stringent regulatory requirements. This chapter demonstrates that the regulatory response to the discovery of adverse health and environmental effects has been to increase the range and scope of safety data, carried out by the pesticide industry, prior to gaining regulatory approval. The increasing research and development costs of gaining regulatory approval for pesticides have led to consolidation of the pesticide industry. These additional requirements have added to the pressure on the pesticide policy paradigm.

The response from the pesticide industry to the problems posed by pesticides has been to develop genetically modified (GM) organisms (see Section 6.8) as a direct replacement for individual pesticides, and to support integrated crop management (ICM) farming systems (which is defined below). GM technology has not been studied to any great extend in the present research. This is because the geographical scope of the present research is largely confined to the UK. There has been very little experimentation and commercial adoption of GM in the UK in recent years, because of civil society and multiple food retailer rejection of this emerging technology.

Another response to these problems, which has been a key focus for the present research, is the development and use of biologically-based alternatives. This chapter catalogues what alternatives are available, and the prospects for their development which traditionally has been limited. Product-based biological alternatives to synthetic pesticides are emerging. Although considered as alternatives to pesticides, many of them are in fact registered and regulated in the same way as pesticides. As a result, their uptake and marketing is constrained by the legislation that was originally developed for synthetic pesticides. These constraints became apparent because of the health and environmental problems that emerged from the use of synthetic pesticides. They had to deal with the acquisition of more safety data and the adoption of an array of constraints that may not be appropriate for bio-pesticides.

Bio-pesticides can be used in both conventional farming, such as integrated crop management and organic farming (which discourages use of chemical pesticides). The regulatory mechanism of 'comparative risk assessment' is described in which the approval of safer alternatives is supported. This could, in theory, include substituting a more hazardous synthetic pesticide in favour of less hazardous bio-pesticide.

6.2. *Pesticide critics*

The fact that pesticides presented the potential for unintended consequences was first recognised by Wigglesworth in the mid 1940s (see Section 4.4.3), although such early warnings were largely neglected. It was not until the 1960s that stakeholders emerged who have been increasingly and strategically critical of the use of pesticides. The acknowledgement and extent of the health and environmental effects of pesticides have been chronicled and categorised in the following section. It examines a number of areas in which the pesticide paradigm has been criticised: the creation of an environmental movement; official independent reports; consensus statements from academics; and multiple food retailer concerns, centred on pesticide residues in food.

The first section includes an independent collection of reports and books that have catalogued environmental and health concerns; and the campaigning organisations that this concern has spawned.

6.2.1. The emergence of an environmental movement

From the 1960s onwards there has been a long history of reports that have identified the excessive use and adverse effects of pesticides, as reviewed in this section. Civil society concern about these pesticide problems was one of the main causes which led to the subsequent creation of the wider environmental movement from the 1970s onwards (Lear, 1997).

The first major criticism of pesticides stemmed form of the publication of *Silent Spring* written by Rachel Carson in 1962. This seminal book documented the long-term effects of pesticides on wildlife of the widespread use of pesticides (Carson, 1962). It articulated, for the first time, a dawning belief that there were adverse side effects from the widespread use of pesticides (Cremlyn, 1978: 16). Pesticides were being routinely applied as an insurance against pests, regardless of whether the pests were present or not. Rachel Carson (1962) drew on data from the US and UK about the indiscriminate use of pesticides and the resulting impacts on wildlife. At the time, it caused a furious response from those who supported pesticide use. Until then criticism concerning the pesticide use and government policy on pesticides had been piecemeal and un-coordinated. According to Jasanoff, (1990: 123) *Silent Spring* not only launched a new social movement, but helped locate pesticides at the very heart of environmental politics. Rachel Carson managed to put across a technical message in such a way that was understandable to the lay person. She was a staff scientist working for the US Fish and Wildlife Service who had access to the many departmental scientific reports that were being produced. Rachel Carson was able to analyse this data and challenge the prominence of the commonly used insecticide DDT, and also raise concerns over pesticides that had a much higher acute toxicity. These included other organochlorine insecticides (aldrin and dieldrin) and the emerging organophosphate group of insecticides. She challenged the objectivity of industry sponsored scientists and advocated changes in government policy (Lear, 1997).

The difference Rachel Carson made was that her publication in effect challenged the 'pesticide paradigm', although she did not call for the complete banning of all pesticides. She set in motion a critical movement that still exists and has become organised through environmental and consumer civil movements world-wide. A number of environmental, consumer, international development and trade unions organised campaigns against the use of hazardous pesticides.

Since Silent Spring, a comprehensive collection of related and complementary reports and books have been written. They have emanated from a wide range of organisations within public interest NGOs or academia. These books largely focussed on the 'unintentional cycle' of pesticides as their central theme. This equates to the right-hand cycle of the Figure 5.1 (Vol. 1, page 133), whereas her pro-pesticide critics were focussed on the left-hand cycle or 'intentional cycle'. Previous publications had primarily had a pest control and agronomic remit, which may or may not have referred subsequently to the unintended consequences of pesticides. They also commented on the increasing development of resistance pesticides and their limitations in controlling pests. Some of the post-Silent Spring Carson literature is reviewed below, starting in chronological order.

During the 1960/70s, three academics produced well researched publications criticising pesticide use (Rudd, 1966, Mellanby, 1967, Van Den Bosch, 1978). In what was described as 'a sequel to Silent Spring', Rudd (1966), looked at the failure to consider the consequences of the release of pesticides into biological and ecological systems. Mellanby (1967) explained the extent to which pesticide (and other agricultural pollution) had reached such significant proportions. He called for a switch to alternative biological control techniques in which natural predators are manipulated to control agricultural pest populations. Van Den Bosch, (1978) described how research into alternatives to pesticides had been repressed during the 1960s/70s. A subsequent publication by Mellanby (1981), maintained the view-point that contemporary intensive farming methods were having deleterious effects on the biodiversity of British wildlife. This data and related reports (see Section 4.5) led to pressure from conservationists to phase out the use of organochlorine insecticides. At the time farmers opposed these recommendations because the chemicals they were using were cheap and effective.

Two US-based researchers, Weir and Schapiro (1981), focussed on a concept they called a 'circle of poison' whereby hazardous US-made pesticides were exported to developing countries, used on local export crops, and then imported back into the US in the form of pesticide residues in food. They reported that some of exported pesticides were banned for use in the US and then imported into the US in food that subsequently contained illegal pesticide residues. About the same time, an Oxfam publication A growing problem: pesticides and the Third World poor was published highlighting the hazardous of using pesticides in developing countries (Bull, 1982). It showed that pesticides were being sold with the promise of high yields, but they also threatened the health and environment of the rural poor. It estimated that 13,800 workers, mostly in developing countries, were being killed per year from occupational exposure to pesticides.

A 1982 campaign by the National Union of Agricultural Workers to ban the herbicide 2,4,5-T has been analysed Cook and Kaufman (1982). They explained how the UK government had avoided taking regulatory action against a chemical that the union argued had caused workers serious adverse health effects. Dudley (1987), examined the extent to which pesticides are damaging to the environment and threatening wildlife. Gipps (1987) found that viable safer alternatives were available for 12 of the most hazardous pesticides used in global agriculture. Watterson (1988), presented a review of a growing body of evidence to suggest that there were risks from the widespread use of pesticides. Studies linked pesticide to health problems such as leukaemia and cancer. Pesticide users, such as farmers were at risk, and yet pesticide use still continued on a broad-scale fashion.

Conway and Pretty (1991) investigated a range of pollution problems caused by global conventional agricultural systems. In the case of pesticides, they catalogued contamination of rainwater, surface and groundwater that caused harm to wildlife and exceeded standards for drinking water.

Hurst et al. (1991) assessed the controls governing the use of chemicals in the UK, Europe and the US. They looked at what information should be made available in the public domain and what action manufacturers, governments and farmers should take to protect occupational health. Lang and Clutterbuck (1991), identified the most hazardous pesticides and provided advice to consumers about how to avoid them. They suggested that UK food should be labelled with 'P numbers' so that consumers could be aware which pesticide active ingredients had been used during the preparation of their food. Robbins (1991: 164), investigated UK pesticide use and regulation and concluded that "Consumers should have more involvement in decisions on the safety and regulation of pesticides". He also concluded that supermarkets were more cautious guardians of the publics' safety than the UK government. Another publication produced by Watterson (1991) identified the hazards of pesticides for consumers. It addressed the occupational and environmental health questions raised by the global use of many dangerous chemicals.

Beaumont (1993), questioned whether the use of pesticides is sustainable and argued for a pesticide reduction policy in order to reduce the risks to human health and the environment. This would require the development of an agricultural system that had a reduced dependence on chemical inputs.

According to Dinham (1993), the primary victims of the global trade in pesticides are the poor who live in developing countries. This book documented the specific impacts of pesticide products, suggesting that the full scale of the global pesticide problem has never been acknowledged. It also surveyed attempts by governments to control pesticide hazards through the Prior Informed Consent procedure that had been set up by the Food and Agriculture Organisation. This is a mechanism that requires the regulatory status of an exported pesticide to be provided to the imported country before pesticides have been exported to the importing country.

From an academic perspective, Irwin (1995) examined the health debate between scientific experts and union representatives concerning the use of the herbicide 2,4,5-T, as outlined by Cook and Kaufman (1982) (see above Vol. 1, page 181). Irwin argued that the statements of scientists are increasingly open to question, and coined the term 'citizen science' that provides a route through the fraught relationship between science, the public and the environment.

During the 1990s continuing analysis of the long-term low-level chronic effects of pesticides were investigated. Using evidence from wildlife studies, laboratory experiments and human data, Colborn et al. (1996) traced birth defects, sexual abnormalities, and reproductive failures in wildlife linked to synthetic chemicals (including pesticides) that mimic natural hormones, otherwise known as endocrine disruption. She asserted that humans may also be affected by similar exposure scenarios. Evidence was presented showing that male sperm counts have dropped by as much as 50% in recent decades, and women have suffered a rise in hormone-related cancers. Following a similar theme, Steingraber (1997) wrote about the growing body of evidence linking cancer to environmental contamination. She traced the entire web of connections between human bodies and the 'ecological world' in which people eat, drink, breathe and work.

In his book, Hough (1998), explored the international controls over pesticide use. Many areas, such as the overuse and misuse of pesticides and the control of health and environmental effects remain unregulated. In contrast, international trade and control of pesticide residues in food are regulated, respectively, through the Rotterdam Convention47 and the WHO/FAO Codex committee on pesticide residues48. In another international report, Jacobs and Dinham (2003) investigated the experiences of rural women in developing countries. Their work examined the differential effects pesticides can have on men and women. Pretty et al. (2005) focussed identifying the hidden costs arising from the widespread use of pesticides. They also addressed scenarios for phasing out hazardous pesticides.

Many of these critiques struck a chord with consumers and wider society and helped foster a public consciousness that was critical of pesticide use. It also led to the creation of public interest organisations that focussed on environmental matters, worker rights, community issues, and perspectives in developing country. This research helped to explain why and how pesticide pollution had assumed significant proportions. As the pesticide industry had sought a global market, the reviews highlighted acute problems in developing countries where the worst effects of pesticides were noticed. They catalogued the failure to consider the consequences of releasing toxic chemicals into biological and ecological systems. As far back as the 1970s, there was concern about the suppression of research into alternatives to pesticides. All the critiques had strong conclusions that followed a number of strands. They called for a significant reduction in the use of pesticides and advocated the uptake of safer alternatives. Another route taken by the critiques was to offer advice direct to the consumer, covering information in the public domain about the pesticide active ingredients and residues in food.

These reports were published in conjunction with the creation of civil society groups who have formed to campaign against the hazardous use of pesticides. They are characterised by the fact that their primary concern is the health and environmental aspects of pesticide use.

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47. The Rotterdam Convention promotes shared responsibility and cooperative effects among countries in the international trade of hazardous chemicals (including certain pesticides) in order to protect human health and the environment.
48. The World Health Organisation and Food and Agriculture Organisation committee of experts sets international standards for the pesticide maximum residue limits in food.

Publications written by the above mentioned authors Carson (1962), Bull (1982), Weir and Schapiro (1981) were, amongst others, directly inspirational in the establishment of the Pesticide Action Network (PAN) in the early 1980s. At the same time there were a series of accidental incidents that heightened concern. Earlier, in 1984 Union Carbide's pesticide plant in Bhopal, India, leaked a gas (methyl isocyanate) causing 2,000 deaths and critical illness in thousands of others (many of whom subsequently died) (Sambhavana Trust, 2005). An explosion in 1986 at the Sandoz chemical plant on the banks of the Rhine in Switzerland released large quantities of organophosphate and mercury-based chemicals (including pesticides) into the river contaminating the water of five countries and killing millions of fish (BBC, 1986).

Capturing the health and environmental concerns, a Friends of the Earth (FOE) pesticide campaign in the mid 1980s had, as its main goal, the imposition of statutory controls for the approval and use of pesticides in the UK. Friends of the Earth (FOE) in London established a high-profile campaign in the mid 1980s to highlight the lack of comprehensive pesticides regulation. FOE had found examples of breaches of the voluntary scheme that included the sale of DDT. In 1985, two members of the government-run voluntary scheme were found to have sold DDT in the Vale of Evesham, after the insecticide had had its approval status withdrawn (in 1984) because of environmental concerns (FOE, 2001). The regulator, the Ministry of Agriculture, Fisheries, Food, did not at that time have any legal powers to ban DDT.

From the 1990s, FOE's campaign concerns centred around pesticide residues in food, the banning of specific active ingredients of concern, especially those with high toxicity or persistence in the environment. During this period public interest groups heightened their involvement in the pesticide policy debate and started calling for greater control over the use of pesticides. Campaigns were launched against specific pesticides that evidence has shown presented hazardous to the people who used them and/or to the environment in which they were applied (Irwin, 1995). The agenda of these groups was framed around the consequences of pesticides, rather than controlling pests that presented a threat to agricultural production and the food supply chain.

The global network Pesticide Action Network (PAN) was formed in 1982 after a group of individuals and environmental organisations met to discuss their concerns about the health and environmental effects of pesticides. They came together at a meeting in Penang, Malaysia organised by the International Organisation of Consumers Unions and Sahabat Alam Malaysia (Friends of the Earth Malaysia) and formed an international network with contacts based in the organisation now known as PAN UK. A major recommendation to reduce the most hazardous pesticides was exemplified by PAN's 'Dirty Dozen campaign' that began in the early 1980s, and called for the world-wide elimination of the most hazardous pesticides. The advantage of forming a single issue group was that limited resources could be devoted to covering a technically complex issue such as that posed by pesticides.

There have also been a number of individuals who, as victims of pesticide exposure have set up campaigns that have been critical of pesticide use. Operating during the 1980s, 90s, and 2000s, they included Enfys Chapman who set up the Pesticide Exposure Group of Sufferers, Elizabeth Sigmund who established the Organophosphate Information Network and Georgina Down who runs the UK Pesticide Campaign. They have run campaigns in an uncompromising manner. The position of the UK Pesticide Campaign is one of campaigning to highlight the government's failure to protect rural residents and communities from exposure to pesticides. In November 2008, Ms Downs won a legal challenge against the Department for Environment, Food and Rural Affairs at the High Court over pesticides. The Judgment said: "The alleged inadequacies of the model and the approach to authorisation and conditions of use [of pesticides] have been scientifically justified. The claimant [Ms Downs] has produced cogent arguments and evidence to indicate that the approach does not adequately protect residents and so is in breach of the Directive [91/414] (Downs v Secretary of State DEFRA, 2008: para 39).

6.2.2. Critical reports from authoritative independent bodies

As early as 1945, scientists such as (Wigglesworth, 1945: 112) had warned of the possibility of environmental dangers arising from the use of pesticides. He described DDT as "like a blunderbuss discharging shot in a manner so haphazard that friend and foe alike are killed". The technical experts knew as early as 1945 that pesticides like DDT properties that were described as 'a double edge sword' (Wigglesworth, 1945: 113) that is they provided effective pest control, but had the potential to produce adverse side effects. According to the government advisory body, Nature Conservancy, there were reports going back to 1952 of the death of birds and mammals on farm land linked to pesticide use. In the UK this resulted in numerous letters appearing in the newspapers. Questions were raised in parliament on the issue.

Since the 1950s, there have been a number of official reports that have raised concerns about the health and environmental effects of pesticides. These include written reports by

MPs in the House of Commons, successive reports from the Royal Commission on Environmental Pollution, and the British Medical Association (BMA) (House of Commons, 1961, RCEP, 1979, House of Commons, 1987, BMA, 1990, RCEP, 2005a). These reports were drafted by authoritative officials and professionals who are outside the strict confines of the governmental regulatory pesticide process.

A first example of external criticism came in 1961 when a House of Commons Select Committee of MPs examined the impact of toxic chemical pesticides (dieldrin, aldrin and heptachlor) on wildlife, including birds. The committee concluded that "sufficient scientific and circumstantial evidence was presented to prove the responsibility of these exceedingly toxic chemicals for most of the recent mortality of wild life" (House of Commons, 1961: xxiii). There was concern for birds of prey (hawks, kestrels and owls), and a range of seed-eating birds (pheasants, partridges, rooks, pigeons, finches and sparrows). The Committee recommended an immediate ban on seed dressings containing dieldrin, aldrin and heptachlor, or chemicals of comparable toxicity. The House of Commons report was blunt in its conclusions, with the MPs recalling: "the most alarming evidence of serious mortality among wildlife... due to the use of toxic chemicals" (House of Commons, 1961: xx). A witness from the Nature Conservancy Council (NCC) stated that the use of these chemicals was "quite probably the biggest risk to wildlife and game that has ever occurred in the country" (House of Commons, 1961: xx). The poisoning had occurred because the birds were consuming cereal seed that had been treated with lethal levels of an insecticide/fungicide that had been applied as a seed dressing (House of Commons, 1961). Later in 1962, the Advisory Committee on Pesticides recommended that seed dressing with aldrin and dieldrin no longer be used in spring-sown corn. Because this was a voluntary restriction, bird kills still occurred. It was not therefore until a later agreement that the use of these chemicals as seed dressings was completed halted (Mellanby, 1981: 119-120).

In 1979, the Royal Commission Report on Environment Pollution (RCEP) investigated the environmental impacts of pesticides. The report recognised the environmental threats posed by organochlorine pesticides. In evidence presented, the Nature Conservancy Council (NCC) linked the occurrence of egg-shell thinning in birds of prey with pesticide usage and, as a result, recommended a reduction in usage.

A 1990 BMA report suggested there were possibilities that cancer, nervous and allergic diseases and reproductive problems were linked to pesticide exposure, but that they were difficult to prove. This meant that the BMA could not say whether many pesticides in common use were harmful or not in day to day use. The report called call for more data to clarify the situation (British Medical Association, 1990). The BMA was also concerned that there was a lack of central strategy governing the use of pesticides, and that there was a need for a national pesticide policy for the UK. Such a policy would have to include a timetable for the reduction in pesticide use. It would need to allow better access to information on new research and existing data so that informed bodies and individuals could make more informed decisions.

A later Royal Commission on Environment Pollution (RCEP) report on the impact of pesticides on bystanders and residents was critical of the UK government and the Advisory Committee on Pesticides (RCEP, 2005a). It concluded that there is significant uncertainty in the scientific evidence available about whether pesticide spraying can cause ill health. The report notes: "it is plausible that there could be a link between resident and bystander exposure and chronic ill health... The existing uncertainties indicate the urgent need for research to investigate the size and nature of the problem and underlying mechanisms that link pesticide spraying to ill health" (RCEP, 2005a: 108). It recommended "that the current approach for assessing resident and bystander exposure should with some urgency be replaced by a computational model which is probabilistic, looks at a wider range of possible exposure routes and more robustly reflects worst-case outcomes" (RCEP, 2005b: 109). The RCEP report was also critical of the governance of pesticides. It recommended that the responsibility for pesticides policy should be separate from that for the approval of pesticides (RCEP, 2005a: 112). Both the ACP and DEFRA produced lengthy responses to the RCEP report, which accepted some conclusions and recommendations, and contested others (ACP, 2005, DEFRA, 2005). Indeed the ACP report acknowledged that there were also different views expressed among members of the ACP. In conclusion, the Royal Commission and the BMA were advocating a more precautionary approach compared with the UK government's pesticide policy.

6.2.3. Academic health and environmentally based critics

Professionals with health and environmental backgrounds have raised concerns about pesticide use and called for a reduction in their use. In recent years there have been a number of declarations produced which have been signed by groups of academics working in similar fields. This section reviews five named statements that have been produced calling for changes to pesticide policy and/or regulatory action.

In 1998 the *Wingspread Statement on the Precautionary Principle* was signed by 32 health and environmental academics. It called for action to be taken to reduce chemical exposure even if cause and effect relationships are not fully established (Anon, 1998b) (see also Vol. 1, page 46).

Another declaration, the *Lowell Statement on Science and the Precautionary Principle*, was signed by an international group of scientists, legal scholars, medical professionals and others, co-ordinated through the University of Massachusetts Lowell, US. It also set out principles on the precautionary principle (Tickner et al., 2003) (see also Vol. 1, page 46).

The *Prague Declaration on Endocrine Disruption* contains the signatories of over 100 scientists from around the world (Anon, 2005). They were concerned about the risks to human and wildlife health posed by chemicals, including some pesticides that interfere with hormonal systems – endocrine disrupters (see Sections 5.4.10 and 5.5.5 for more details on endocrine disruptors). The declaration concludes that the existing safety assessment for chemicals is ill-equipped to deal with endocrine disruptors. Testing does not take account of simultaneous exposure to many chemicals and may lead to serious underestimation of risk.

In 2007 a group of public health academics released the *Faroes Statement*, in which they raised concerns about the human health impacts of environmental exposure to chemicals, including pesticides. Their expertise included environmental chemistry, developmental biology, epidemiology, nutrition, and paediatrics. In particular they were concerned about critical times of exposure by chemicals to the human foetus and the child. At these life-stage periods there is heightened susceptibility to a wide range of health effects. In conclusion they challenged the old toxicological view developed by Paracelsus (in the Sixteenth century) that the 'dose makes the poison'. They refer to an alternative proposition that: 'timing makes the poison'. The researchers recommended that this different finding deserves wider recognition in order to protect the foetus and child against what they called 'preventable hazards' (Grandjean et al., 2007).

Another 2007 declaration, the *Scientific Consensus Statement on Environmental Agents Associated with Neurodevelopment Disorders,* was signed by 55 North American scientists and health professionals. It incorporated concerns about a range of chemicals, including pesticides. Specifically these scientists noted that environmental contamination is associated with learning difficulties, autism spectrum disorder, attention deficit disorder, intellectual disabilities and developmental delays. They called for the elimination of children's exposures to these pollutants by implementing health-based policies requiring safer alternatives. Their arguments were underpinned by projected economic saving resulting from the adoption of these policies. They suggest there would be billions of dollars saved by cutting the health costs of childhood disabilities (Gilbert, 2007).

Concerns and recommendations similar to the statements above are reported ad hoc in scientific peer-reviewed articles produced by individual scientific researchers. For example, Davis et al. (1998) called for 'prudent precautionary principles' because of concerns about breast cancer and environmental contamination. They suggested that reducing exposure to avoidable or modifiable risk factors should receive high priority from the public and private sectors. More recently, McKinlay et al. (2008) recommended a more precautionary approach to the use of endocrine disrupting pesticides.

Newby and Howard (2006) have concluded that there is increasing evidence that environmental contaminants (especially persistent organic pollutants) are involved in the development of cancer, particularly during prenatal, childhood and adolescence. They recommend: "An overall exposure reduction of bioaccumulative, persistent, carcinogenic, and/or endocrine disrupting chemicals should be planned. This should be based on the precautionary principle… Action will have to be taken in the absence of absolute scientific certainty" Newby and Howard (2006: 46).

These researchers are characterised by being primarily focussed on possible adverse health effects of pesticides, rather than having a professional preconceived agronomic need for pesticides. In many cases they are calling for a more precautionary approach to the use of pesticides, and a focus towards health-based polices. It is also important to note that many such scientific papers increasingly call for wider health policy recommendations and addition to the specific research conclusions and discussions.

6.2.4. Multiple food retailers

The final group in this section includes some of the multiple food retailers who have taken an increasingly critical view of pesticides in recent years. They tried to influence their market share by encouraging more sustainable food and farming techniques among their grower supply base (van der Grijp et al., 2003).

Since 2000, some UK-based food retailers have developed their own pesticide policies that reflect their customers concerns about pesticide residues in food. This reflects a wider trend in which the private sector is taking over the responsibility for policing and regulating pesticide use in the food supply sector in order to reduce pesticide risks (van der Grijp, 2008).

This particularly includes the UK retailers the Co-op, Marks and Spencer and J Sainsbury. This is a new departure for them as their previous practice was to follow the government lead and leave supply chain issues them. This meant that they now take a heightened interest in pesticide supply, use and development. According to a Co-op opinion survey, consumers were increasingly worried about health scares, which had created an atmosphere of mistrust (Co-op, 2001).

Marks and Spencer were also acting on the concern of their customers. Feed back from their customer surveys were telling M&S: "consumers believe pesticide residues have no place being in food." In explaining their rationale behind pesticides and risk, Marks and Spencer are not so interested in a prospective report that might contain: "800 pages of scientific studies which say a pesticide is safe". If significant stakeholders are concerned about specific pesticides, based on the precautionary principle, Marks and Spencer may decide to act and ban their suppliers from using those pesticides (Buffin et al., 2001). Whilst still relying heavily on a food supply chain that produces food through conventional farming methods, they have liaised with public interest organisations, and decided to take a more precautionary approach to the pesticides they allow their supplier to use.

These retailers have used their power within the food supply chain to remove the use of specific hazardous pesticide active ingredients from their supply base, and to encourage aspirational goals around zero residues in their customers' food. See Chapter Seven for more details of retailer pesticide policies (see Vol. 1, pages 235-248).

6.3. *Pressure for pesticides legislation*

The pressure from the historical challenges and adverse effects of pesticide has led to the development of public interest NGO organisations that recognised the hazardous nature of pesticides and who wish to see a significant reduction in their use. The UK regulator has responded to these problems by gradually and belatedly increasing the controls over pesticide use, first on a voluntary basis, and later through UK and the EU legislation. The following section goes back to examine how these pressures, combined with the environmental obligations of joining the European Community, led the introduction and development of pesticide regulation in the UK.

From the Second World War onwards, it was clear that the use of hazardous pesticides presented potential risks to the operators, to food treated with pesticides, and to wildlife. The government needed the assistance of experts to advise on these matters. The Zuckerman committee examined all these areas during the 1950s (see Section 4.6, Vol. 1, pages 114-115). During this time the risks were assessed by the existing pesticide policy community – the regulators, experts and the pesticide industry as listed in Figure 4.1 Vol. 1, page 118.

From the 1960s onwards this situation changed. It also became clear to other interested parties (outside the policy community) that pesticides had potential adverse effects, in addition to the pest control benefits. The response of the regulator was to restrict the use of individual pesticides, or groups of pesticides. In particular there were restrictions on the use of organochlorine insecticides which occurred over a long period from the 1960s to late 2000s.

In 1962 the US ecologist Rachel Carson documented the impact of pesticides in her book *Silent Spring* (Carson, 1962) (see Vol. 1, page 179). This was not the first time concerns were raised, as noted in Section 5.2.2), but the publication of her research nevertheless had an epoch-making impact and marked the beginning of the end of the chemical pesticide age. Written in an authoritative but popular fashion, it had a widespread appeal to the general public, and had an impact on those who govern and use and manufacture pesticides that is still evident today

Silent Spring was all the more shocking because Rachel Carson criticised synthetic pesticides which represented a modern technology that only 20 years earlier had been seen as a safer alternative that could comprehensively solve all pest problems. Not only did the politicians, civil servants and farmers in the UK adopt the same ground rules, they also had a common view of world agricultural policy. For example, it was accepted that agricultural production would expand whatever the cost. Anyone who questioned this set of beliefs was heavily criticised (Lear, 1997, Van Den Bosch, 1978). Her work helped establish an environmental movement and civil society campaigns have expanded and are currently thriving (see Vol. 1, page 179). But as Montague (2000: 354) agrees, the impact of the book was profound, and the public's view of agricultural chemicals was changed for ever.

The risks posed by pesticides also provoked a longstanding debate between the pesticide policy stakeholders of government, industry and scientific experts as to whether pesticides should be subjected to legislative control.

In its First Report, the Royal Commission on Environmental Pollution (RCEP) supported a recommendation, previously made by the Advisory Committee on Pesticides (ACP) in 1967, that a mandatory pesticide scheme replace the then existing voluntary arrangement. The ACP had made this recommendation partly because of a 'loophole' in which it was possible to market a pesticide which had not been cleared as safe under the voluntary Pesticide Safety Precaution Scheme (PSPS) without any impediment in law, and partly because of its concern about the need to restrict the use of persistent organochlorine pesticides. A 'Pesticides Bill' was subsequently drafted, with pesticide industry support (RCEP, 1979), but later in 1972, the then Agriculture Minister James Prior announced that because PSPS was working "so effectively to ensure the safe use of pesticides" there was no need to change. After taking advice from the Royal Commission, the Minister decided that the principle of introducing legislation should not be ruled out as: "an ultimate sanction against to control those substances which, when misused, can harm – and in its [the RCEP's] view have harmed – the environment" (House of Commons, 1972).

The impact of European policy on pesticides began after the UK joined the European Economic Community (EEC) in 1973. There was pressure from European partners to introduce national pesticide regulation because the UK was one of the few European countries not to have a statutory scheme for the approval and registration of pesticides (Rothstein et al., 1999) (see also Section 5.5). During the 1970s, however, UK government policy continued to resist the introduction of pesticide legislation.

As the PSPS scheme was voluntary it was important that the relationship between the pesticide industry and government departments remained on co-operative terms. There is no evidence that poor relations ever existed, and indeed the fact that good relations prevailed was put forward as a reason for not introducing statutory measures. It does nevertheless leave the two parties open to the suggestion of collusion. Indeed, if the amicable relationship had broken down, it was clear to all that statutory measures would have had to have been adopted (RCEP, 1979).

In the late 1970s, the Ministry of Agriculture, Fisheries and Food used the threat of enacting legislation to persuade the agricultural supply organisation [UK Agricultural Supply Trades Association (UKASTA)] and the pesticides lobby group [British Agrochemical Association (BAA)] to introduce improved self regulation. As a result, the British Agrochemical Supply Industry Scheme (BASIS) was launched in 1978. The scheme was voluntary, and there was a gentleman's agreement that the supply industry would not sell products that were not PSPS (government) approved.

By 1979 the ACP had changed its position and no longer supported a mandatory scheme, possibly because of the decline in the use of organochlorine pesticides, one of the committee's major environmental concerns. By this time the committee considered that a mandatory system would be inflexible, costly, and time consuming, and that it would tie up additional toxicological expertise and require a considerable increase in the number of civil servants required to operate it. Similar concerns were expressed by the BAA, despite the fact that many of their company members had had to operate in emerging regulatory regimes elsewhere in Europe. At this time, they acted more as a national lobby organisation, rather than at the European level of today, which is necessary because of the enactment of European Directives and Regulations. BAA's main concern was that, if a new 'Pesticide Bill' was passed, 'political', as opposed to 'scientific', considerations might predominate. They considered a resulting Act from such a Bill would include considerable extra expenses in staff time for pesticide companies and government, with, in their view, no compensating gains in safety or efficiency. When assessing the implications of such legislation, the Royal Commission on Environmental Pollution (RCEP) recommended a half-way measure suggesting that ministers should take reserve powers to make regulations for the control of pesticides, as they see fit (RCEP, 1979). An opportunity to be progressive and forward thinking had been lost.

By 1981, the period of high prices and a protected market for the sale of British pesticides was over. Farmers were starting to buy cheaper identical products from European countries, completely by-passing the UK supply network. The UK pesticides market was seen by the industry to be facing 'meltdown'. The industry had been told by MAFF that existing systems would be able to protect the market. But they were wrong. Imports could not be banned because pesticides were not labelled as toxic or harmful. Schemes carefully constructed to avoid restrictive legislation fell into the trap of contravening EEC rules on free trade. Also UK suppliers could not source from European countries because they were not PSPS approved, and the UK supply industry had agreed to use the PSPS scheme exclusively (Montague, 2000: 362).

6.4. Regulation of pesticides in the UK

As a result of the European pressure, and NGO campaigning, the UK government finally replaced the voluntary PSPS scheme with the 1985 Food and Environment Protection Act

[FEPA] (1985) and introduced enabling legislation with the Control of Pesticides Regulations (COPR) (1986) (Rothstein et al., 1999). This legislation aimed to protect the health of human beings, creatures and plants; to safeguard the environment; to secure safe, effective, and humane methods of controlling pests; and to make information on pesticides available to the public. The UK legislation was later followed by European Directives and Regulations as outlined in Section 5.5.

Public interest groups may still have had concerns about the control of pesticides, but the regulatory control had increased substantially. A pesticide could not now be advertised, sold or used unless it had been given formal approval under the authority of FEPA. Government ministers at the Ministry of Agriculture, Fisheries and Farming now acted on the advice of the Advisory Committee on Pesticides, whose terms of reference had been specifically laid out under FEPA. FEPA also gave ministers the power to set maximum residue limits for food, and to issue Codes of Practice for conditions of pesticide use (DEFRA/HSE, 2005).

The Control of Pesticides Regulations (COPR) provided the mechanism for the implementation of the aims of FEPA. Under FEPA, the term pesticide includes insecticides, herbicides, fungicides, soil sterilants, wood preservatives, antifouling paints and surface biocides. A more comprehensive definition can be found in Regulation 3 of COPR (HMSO, 1997). Pesticides excluded from the FEPA/COPR definition include veterinary products used to control internal and external parasites of domestic and companion animals (such as sheep dips), and human medicines such as head lice treatments. Both the latter types of pesticides are also covered by the Medicines Act 1968, with the Veterinary Medicines Agency taking the lead role for veterinary medicines and the Department of Health for human medicines.

Since 1985, pesticide regulation and enforcement has involved a number of government offices in an increasingly complex way. Six government departments shared responsibility for pesticides – MAFF (taking the lead), Department of Employment (for the Health and Safety Executive), Department of Environment, Department of Health, The Scottish Office, and the Northern Ireland Office. Currently, responsibility for the approval of pesticides rests with the Pesticides Safety Directorate (PSD) (an executive agency of the Department for Environment, Food and Rural Affairs [DEFRA]), the Department for Transport and Local Regions (for the Health and Safety Executive Agency), the Department of Health, the Scottish Executive Environment and Rural Affairs Department, the National Assembly of Wales, and the Department of Agriculture and Rural Development in Northern Ireland (who publish their own regulations). In addition, the Food Standards Agency has oversight on all matters relating to the safety of food (DEFRA/HSE, 2005).

PSD, established in mid1980s, is the lead agency for pesticides and has now become an institution employing around 200 scientific, policy and support staff headed by a Chief Executive and three Directors. Income provided to run such a large institution comes partly from the pesticide companies in the form of registration fees, with the rest coming from central government. PSD accounts in 2000/2001 showed that the total income of £11.21 million was derived from a levy on pesticide approvals of £4.98 million, £1.34 million for fees for approval from the European Union, and £4.89 million coming from DEFRA for policy advice.

Over the last 20 years there has been a great increase in the regulatory mechanisms that have led to a total of 45 Acts, Regulations, and Codes of Practice relating to pesticides in the UK. Figure 6.1 illustrates the relationships between the stakeholders for pesticides approval as established under FEPA. The entry point for pesticide approval is the pesticide industry. The process is dependent on marketing companies carrying out the research and development to bring new products onto the market, or for their older products to be reviewed so that their safety profile matches more modern requirements.

An important element in FEPA was the statutory status given to the Advisory Committee on Pesticides. Since 1985 it has had statutory powers as a body set up by Ministers under section 16(7) of the Food and Environment Protection Act 1985 to advice on all matters relating to the control of pesticides. The Committee is also specifically established by a specific control order[49]. This provides advice on active ingredients/formulations to pesticide manufacturers and marketing companies seeking UK approval. The committee receives dossiers based on pesticide industry data that are written by PSD. The ACP then makes formal recommendations to DEFRA Ministers, based on what they have received from PSD. It is very difficult for Ministers to challenge the committee's decision, although they are occasionally given a range of options, rather than more direct advice, which given its technical nature, is difficult to countermand.

The ACP has a number of sub-committees (Environmental Panel and the Medical and Toxicology Panel), and sometimes takes advice and comment from other committees such as the Committee on Toxicity, and the Committee on Carcinogenicity. For example, the

49. The Control of Pesticides (Advisory Committee on Pesticides) Order 1985, SI No 1985/1516.

Committee on Carcinogenicity has recently advised that occupational exposure to pesticides may cause prostate cancer (Meikle, 2005).

The ACP has to take its expertise from a wide range of sources that include different disciplines of human health and environmental fate. The main categories of expertise are: Human toxicology (human and clinical) and epidemiology; occupational health; ecotoxicology; environment; fate and behaviour; pest biology; chemical analysis, metabolism, residues and dietary modelling, trials methodology and assessment of risks and benefits (in economic terms), and lay representatives. In addition, the committee's chair has the option to call in extra expertise if it is felt necessary.

6.4.1. The creation of the Food Standards Agency and pesticide policy

The Food Standards Agency is a government department, independent regulator and a consumer protection body. It was established in 2000 in the wake of the BSE crisis to be a food safety regulator independent from government Ministers at the Ministry of Agriculture Fisheries and Food (MAFF) (Millstone and van Zwanenberg, 2002). Unlike other food safety issues, the role of pesticide regulator remained at MAFF. The main architect of the FSA, Professor James had recommended that pesticide regulation transfer to PSD (James, 1997), but MAFF ministers overrode this proposal when they published the government's proposals for the establishment of the Food Standards Agency (Anon, 1998a). James (1997) had suggested that the FSA take over the safety evaluation of pesticides from PSD (an executive agency of MAFF). He suggested that PSD would still licence pesticides, but only evaluate efficacy and the technical side of approval. Responsibly for monitoring pesticide use and for policy on pesticide use would transfer to the FSA. This suggestion raised concerns across government and doubts were expressed about the practicality of implementing his proposals. The food safety evaluation for pesticides was considered by government to be an integrated process involving the consumers, operators, bystanders, and the environment. Pesticide safety was also inextricably linked to efficacy, and it was felt that separating these two arrangements would compromise safety (Anon, 1998a: 21). The regulatory web that PSD had created could not easily be disentangled, unlike all the other food safety issues for which FSA was to have responsibility. In the end, the FSA ended up with a so-called 'watchdog' role for pesticide regulation, specifically in relation to residues (including residues from veterinary medicines) in food. The proposed functions for pesticides (as well as veterinary medicines and BSE) was limited to "providing advice, guidance, and information; and carrying out research and surveillance" (Anon, 1998a: 9). The FSA had these responsibilities for all other food safety issues plus the more important roles of regulation, policy formulation, standard setting and enforcement[50].

6.4.2. Overview of the UK regulatory system

The outline of pesticide approval is presented diagrammatically in Figure 6.1 (UK Pesticide Approval). Compared with the 1940s, it is a complicated arrangement that has evolved in way that has reacted to s number of hazards that he been identified. This has been described by Tait (2001a) as a reactive/preventative system.

One of the first main challenges of the regulatory system was organochlorine insecticides. After they had been shown to accumulate in the food chain, and threaten wildlife there was a regulatory shift to organophosphates (Tait, 2001b). For example, the debate around DDT was disputed for many years. In the UK it was not banned until the mid 1980s and yet data was available on environmental persistence and damage to wildlife. Only after a hazard has been identified conclusively does the regulatory system react to prevent future prospective products from giving rise to the same problems. Once the risks had been officially recognised, any future chemical which showed similar properties was eliminated from the R&D schedules of the pesticide companies at an early stage of development. Thus the regulatory system evolved in a reactive manner to control the impacts of new chemicals. During the 1970s, there was a shift to organophosphorous insecticides which presented a greater threat to the health of spray operators. The further shift to pyrethroid insecticides reduced the problem of environmental persistence and they were less hazardous to operators, but were particularly to aquatic invertebrates and can lead to indirect effects on fish populations (Tait, 2001b). The main characteristics of a reactive/preventive system have been described by Tait and Levidow (1992):

- A statistically convincing standard of proof is demanded before any claimed or suspected hazard is given official credence;

- The industry and/or products are controlled by a system set up in response to such scientifically proven impacts;

50. The FSA took over the additional responsibilities for all food safety areas including: formulating policy, drafting secondary legislation, negotiating in EU and internationally, standard setting, and monitoring/enforcement for all other safety issues including: pathogens in live animals, animal feed, food hygiene, meat and milk hygiene, food-borne illness, novel foods and processes, food additives, chemical contaminants, radiological safety, food intolerance, food emergencies, food standards [including labelling] and nutrition) (Anon, 1998a: 9).

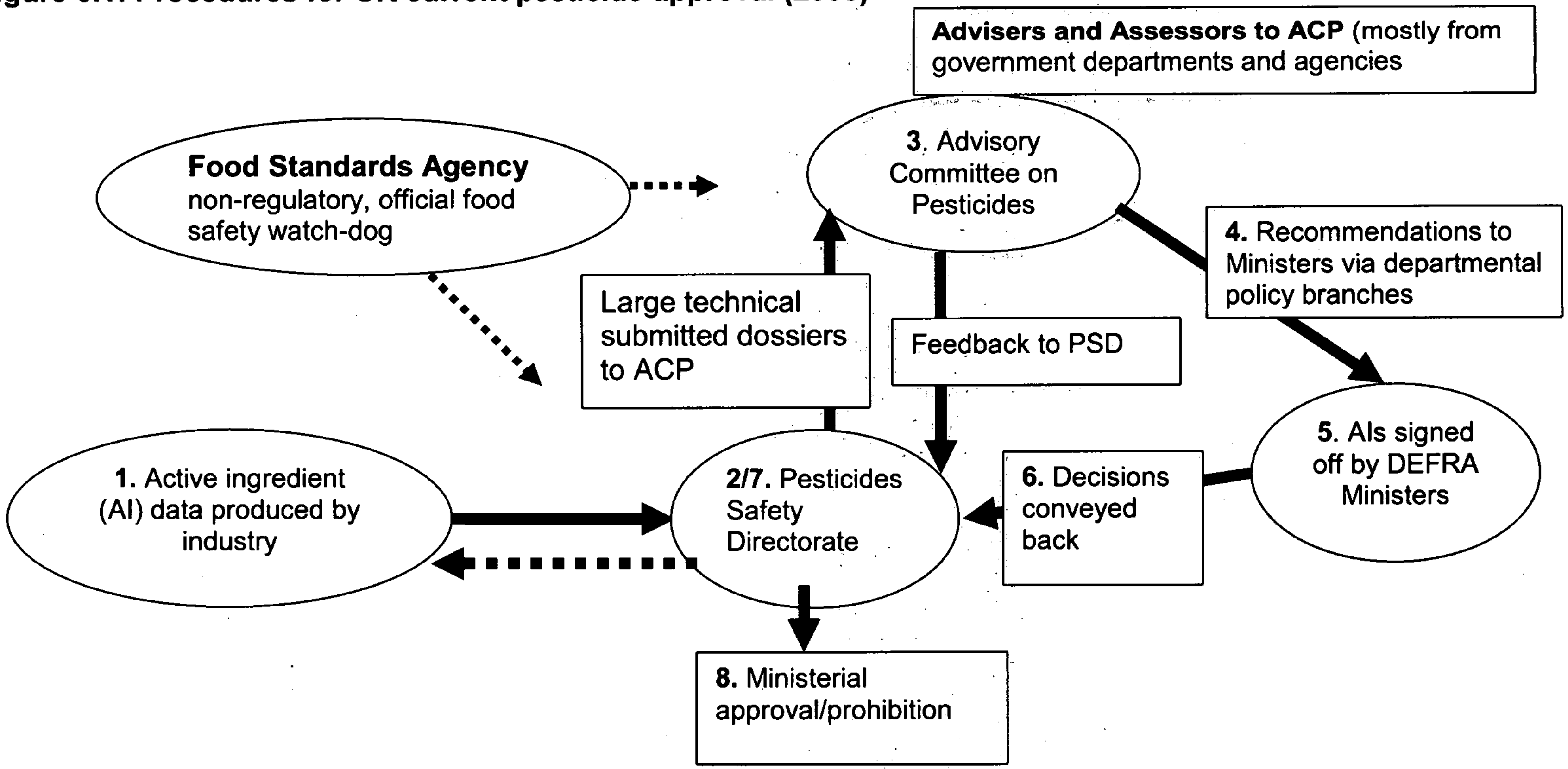
- New products and processes are screened to make sure that they do not give risk to any similar hazards;

- The regulatory system is built up slowly in a piecemeal fashion as new generations of product or processes exhibit different hazards;

- Decisions about the need for regulation and the level of regulation required are based on an analysis of relevant costs and benefits.

The potential for pesticides to have one or two adverse effects, from a range of human and/or environmental acute or chronic effects complicates the regulatory process for pesticides. Given the range of chemicals regulated as pesticides and the complexity of their potential interactions it is not easy to demonstrate that this evolutionary approach to pesticide regulation is leading to safer pesticides (Tait, 2001b).

Figure 6.1: Procedures for UK current pesticide approval (2008)



Key: This diagram shows the process by which pesticide safety is assessed in the UK under the Control of Pesticides Regulations. The numbers show the sequence of events over time, and the arrows represent the direction in which the production, examination and interpretation of data flows from organisation to another. The FSA arrows are dotted to denote its watch-dog, rather than regulatory role, specifically with regard to pesticide governance. The dotted arrows reciprocating between PSD and industry recognise the inter-dependence required between these two bodies. The complicated technical dossiers submitted by industry often require technical clarification from PSD.

Source: Author

6.5. *The role of environmental policy and the integration of EU and UK control of pesticides*

This section reviews the involvement of the European Union in pesticide regulation, making links to wider environmental policy.

The UK pesticide regulatory process is gradually being replaced by a complementary European Union system in which new active ingredients are approved at the European level. There is also a review process which is re-assessing older pesticides that have been on sale in individual Member States. It will be some years before the process is complete and in the meantime the national and EU systems will continue to work in parallel.

The involvement of the EU in the regulation and approval of pesticides in the UK, and other Member States, can be linked to an increasingly dominant EU environmental policy. This became evident in the years after the UK joined the EU in 1973 (McCormick, 2001). British officials massively underestimated the wider European wish for a common set of environmental rules for the EU (Jordan, 2004: 205). Indeed according to Sbragia (2000: 296), the British negotiators did not realise how binding EU Directives actually were on Member States. She cites the Drinking Water Directive (1980) as an early measure precautionary measure (see also Vol. 1, page 46) which, once passed, was to able withstand the 'winds of controversy' over the decades since and is still in force today.

Another driver for EU environmental action was economic. The European Commission wanted to move into the environmental sector because some Member States were adopting their own environmental legislation which could act as trade barriers. The Commission quickly took on the role of embracing environmental legislation for its own sake (Sbragia, 2000: 296).

The transnational nature of pollution was also a factor in the EU's increasing role in environmental policy. In 1986 there was a large spillage of organophosphate and organo-mercury chemicals (including pesticides) which caused international concern along the river Rhine (see Vol. 1, page 184). With such shared natural features, such as rivers, seas and air, it became clear that solutions to these environmental problems had to be addressed at the European level (Bomberg, 1998: 34).

As a result of such events, environmental policy has, over the years since, assumed a much more important role for the EU (Haigh, 1999, O'Neil, 2000). The subsequent environmental legislative advances owe much to the political support of the 'green states' Denmark, the Netherlands and particularly Germany. By externalising their regulatory regimes, the high regulation states were able to protect their economic competitiveness (Sbragia et al., 1996).

This regime existed for pesticides in which some member states, led by Germany, were developing legislation under their own national legal framework. German pesticide companies therefore had to support the regulatory costs of local pesticide legislation regardless of what happened at the European level. This put them at a competitive disadvantage with respect to other EU pesticide companies (such as those in the UK) where similar legislation had been successfully resisted and circumvented, with the introduction of FEPA (1985) (see Vol. 1, page 193). But there was also pressure to act at the EU level. In order to compete across the EU there was a strong lobby for EU-wide mutually recognised harmonised standards that would allow free trade within the EU.

After many years of negotiation among member states, Directive 91/414 covering the authorisation of agricultural[51] pesticides (European Commission, 1991). EU Directives have to be transposed into national law, which allows some flexibility to member governments, but within the limits set by the European Court of Justice. They are binding in terms of the results to be achieved, but the choice of form and methods are left to member states. They are more appropriate for general measures, where some flexibility is required because of existing member state procedures, as is often the case with environmental matters including pesticides. The approval of pesticide active ingredients lies within the European Community, although the responsibility for product authorization remains with the national Member States. Annex I of the Directive requires that a positive list of pesticide active ingredients be developed at the European Commission level whereby pesticides meet the detailed requirements set out in Directive 91/414 (European Commission, 1991).

The Directive specifically makes a provision for a system of mutual recognition, so that when an active substance is listed on Annex I of the Directive, all Member States are obliged to allow the same active ingredient to be used in their own country. The mutual recognition position has been challenged in recent years by the Swedish government over the approval of the herbicide paraquat. In October 2003, a majority of European Union

51. Directive 91/414 does also include a minority of non-agricultural pesticides, such as herbicides used by local authorities in urban and highway situations.

Member States (excluding Sweden) voted paraquat onto Annex 1 of Directive 91/414 (European Commission, 2003b), which meant it could in theory be used anywhere in the Europe Union, including Sweden. In February 2004, the Swedish government decided to challenge the European Union. In 2007 the European Court of Justice ruled in favour of the Swedish government, which over turned the European position (EC Court of Justice, 2007). As a result of the finding, the UK took the regulatory decision to suspend the approval for using paraquat as of 12 September 2007 (PSD, 2007). The decision is important because it upheld the view of one member state against the view of the European Commission. It also had the impact of altering the actions of another member state (the UK). The member state is no long in sole charge of which pesticides are approved for use in their own country.

As the Directive 91/414 has been in force for over 10 years, it is due for amendment, but there are a number of political developments that have stalled the process (Smeets 2003). The Commission is proposing to establish a centralised body to co-ordinate the registration process at the product level. This might provide an easier vehicle for applicants to obtain mutual recognition of approval within the European Union. Mutual recognition, if operated effectively has the potential to provide benefits to growers and will reduce the amount of work required by Member State regulators. Until now mutual recognition has generally been of limited success because of the relatively small number of pesticides approved under Directive 91/414, and as a result of a reluctance by industry to request that Member States apply it (Smeets, 2003).

6.6. *Higher development requirements and costs for pesticides*

Since the 1960s the risks associated with pesticides have become more apparent and have led to a gradual increase in the regulatory systems to control the use of pesticides. This has manifested itself in the significant increase in safety data requirements, or 'regulatory hurdles' for pesticide approval since the 1950s (see Table 6.1). In the 1950s, very basic toxicity data were required from one test species from which the hazard implications were extrapolated to humans. These limited requirements were a consequence of the voluntary controls in place at the time. By the 1980s the number of species tested increased to two, and some chronic assessment. This coincided with the introduction of national UK pesticides regulation through the 1985 Food and Environment Protection Act (see Vol. 1, page 193).

By 1990s, the testing regime had broadened, and for the first time the potential environmental effects were required. The EU Directive 91/414 (see Section 6.5) was implemented into UK national legislation which put a further increase in the safety data required for pesticide approval. By the 2000s the number of different tests had increased to 24 from the 1950s figure of two. The present requirements are broken down into four areas: basic toxicity data, environmental fate, human toxicity, and ecotoxicity. The pesticide manufacturer must demonstrate that the pesticide is safe and does not pose an unacceptable risk to users, consumers and the environment. What constitutes an unacceptable risk is a vitally important question that is at the crux of the European regulatory system. The data requirements relating to the active substances and their pesticide products are extensive (European Commission, 1991), as are the related internationally agreed OECD Guidelines for Testing Chemicals (OECD, 2004). The specific safety testing requirements for the EU are laid out in Annexes II and III of Directive 91/414. They relate to six discrete areas of the risk assessment, namely physical and chemical properties, environmental fate and behaviour, ecotoxicity, mammalian toxicity, residues and efficacy (European Commission, 1991). Exposure data only appears in Table 6.1 in the last section, covering the 2000s[52]. This has meant that new pesticides coming onto market have had more pre-market safety tests than previous pesticides had had. Pesticides already on the market had to be re-reviewed according to set deadlines, and the pesticide marketing companies had to spend extra research resources to provide new safety data in order to satisfy the more contemporary safety demanded by EU regulators. In essence this meant that pesticides first regulated in the 1940s/50s/60/70s had safety data gaps that needed filling according to more modern requirements. The impact of these changes has led to a consolidation of the pesticide industry and a reduction in the number of pesticides on the EU market.

52. Risk is a function of hazard and exposure (see Vol. 1, page 183,).

Table 6.1: History of regulatory safety data requirements for pesticides

Decade	Data requirements
1950s	1. Rat feeding test 2. Rat acute toxicity
1980s	1. Rat feeding test 2. Rat acute toxicity 3. Dog feeding test 4. Dog acute toxicity 5. Teratogenic effects 6. Metabolic studies
1990s	1. Rat and dog acute and chronic tests 2. Bird acute toxicity 3. Bird 5 day dietary toxicity 4. Bird sub-chronic and reproductive toxicity 5. Fish acute toxicity test 6. Fish life cycle toxicity test 7. Fish early-life stage toxicity test 8. Fish 28-day chronic toxicity (juveniles) 9. Fish bio-concentration toxicity tests 10. Aquatic invertebrates acute toxicity test 11. Algal growth rate toxicity test 12. Midge larvae acute or chronic toxicity 13. Bees acute oral and contact toxicity 14. Bee brood feeding tests 15. Arthropods residual exposure tests 16. Earthworm acute toxicity tests
2000s	**A) Experimental data** 1. Rat feeding test 2. Rat acute toxicity (oral, dermal and inhalation) 3. Dietary intake assessments 4. Exposure to operators 5. Other workers and bystanders **B) Environmental fate and behaviour** 6. Exposure to non-target species in soil and water 7. Contamination of drinking water supplies and groundwater 8. Effects on, or residues in following crops by estimation of half-life 9. Metabolite testing 10. Mobility in soil [Koc value]) **C) Human toxicity** 11. Sub-acute and chronic toxicity assessing 12. Carcinogenicity 13. Genotoxicity 14. Developmental toxicity 15. Two successive generational toxicity 16. Skin and eye irritability 17. Allergenicity 18. Further tests may be required to understand nervous, immune or endocrine effects **D) Ecotoxicity for non-target organisms** 19. Birds 20. Wild animals 21. Fish 22. Aquatic invertebrates and plants 23. Insects (including bees) 24. Other non-target arthropods, earthworms and soil micro-organisms

Source: 1950s; 80s and 90s: *(Thacker, 2002: 15)*; 2000s: *(DEFRA/HSE, 2005)*.

The cost of generating this extra safety data (identified in Table 6.1) has had an impact on the pesticide company research and development (R&D) budgets (see Table 6.2). In 1956 R&D costs for developing a pesticide were £0.5 million, by 1989 the figure had risen to £20 million, and by 2000 the amount was £140 million (CPA, 2005a). Since the early developments of the synthetic pesticide industry, the regulatory framework in which they operate is constantly changing. More requirements are demanded by the regulators – answers to the questions that were not previously asked. By the 2000s, pesticide regulation had become a very complicated business. For example, some 200 studies and 50,000 pages of data are reviewed by UK regulators during the evaluation of a new pesticide (Popple et al., 2003).

Another way of assessing the impact of increasing regulation is to calculate the economic gain from the R&D investment. The pesticide industry is concerned the returns on R&D are decreasing. In 1971, for every R&D dollar invested, just over seven dollars was returned fifteen years later in sales. In contrast, just four dollars was returned in 1995, from a dollar invested in 1980. And an industry prediction made in 2003 doubted that the level of growth in pesticides from then onwards would be supported by the overall investment in R&D made by industry in the preceding 10 years. (Pragnell et al., 2003: 11).

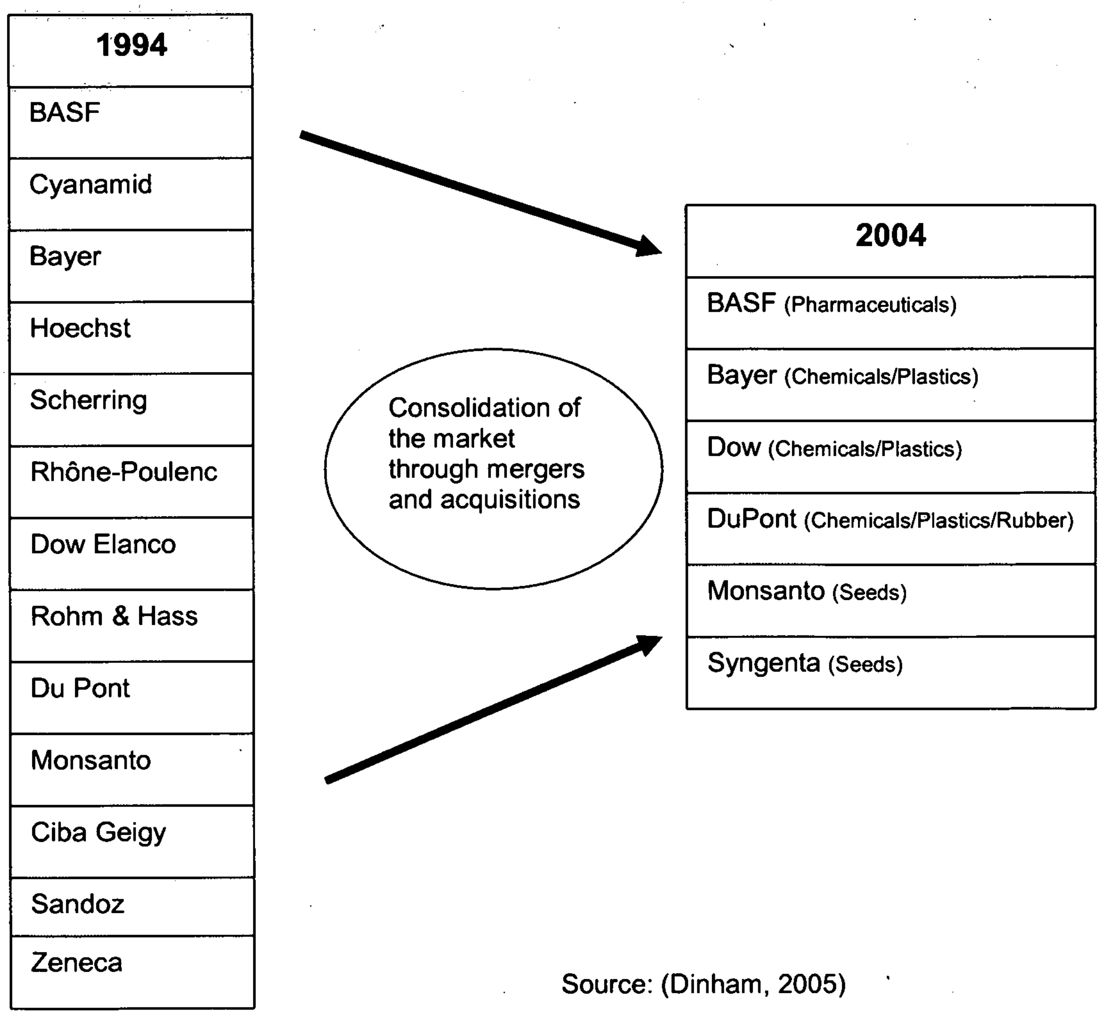
The increased regulatory requirements have had their impacts on the composition of the pesticide industry. In 1994 the majority (90%) of the global pesticide market is dominated by 12 research and development companies (see Figure 6.2). By 2004, the number of companies had dropped to six. The consolidation came about because of mergers and acquisitions. At the same time, there has also been an increased in the manufacture of generic pesticides. These chemicals are produced by companies who do not carry out research and development into their own products or develop new products.

Table 6.2: Rates of discovery and costs of gaining regulatory approval for new pesticides

Year	Rate of discovery	Cost in £M
1956	1 in 1,800	0.5
1964	1 in 3,600	1.5
1970	1 in 7,400	NA
1972	1 in 10,000	NA
1977	1 in 12,000	10
1987	1 in 16,000	10-15
1989	1 in 20,000	20
1996	1 in 30,000	30-45
1998	1 in 50,000	50-60
2000	1 in 140,000	140

Source: Figures for the years 1956-98 refer only to insecticides and include the rate of discovery per chemicals screened (at not developed as products); and cost (£ million) of research and development. N/A = figures not available. (Thacker, 2002: 15); with 2000 figures (referring to pesticide): (ECPA, 2007).

Figure 6.2: Consolidation of the pesticide industry



Source: (Dinham, 2005)

6.7. *Consequences of the increased regulation of pesticides*

As a result of the more stringent regulatory process, the number of pesticides on the EU market has decreased in recent years. It has had the effect of reducing the number of existing pesticides on the market and reduced the capacity of the pesticide industry to bring new products through the regulatory processes (Nomisma, 2008).

The period after the Directive 91/414 had past marked as slow progress towards the review of older active ingredients. As of July 1993, there were 984 pesticide active ingredients approved for use across the European Union marketplace, but these all had to be review under the terms of the Directive (see Table 6.3). Many of these pesticides are now banned for use across the EU. For example in July 2003, 320 pesticide active ingredients were withdrawn from the EU market because of a safety review (European Commission, 2002). Some of the 320 pesticides were obsolete or considered to have limited market potential but 78 were considered to be hazardous by government and industrial sources (Buffin et al., 2003). By 2004, regulatory judgments have been made on 67 pesticides (out of a total of 984), 40 of which were added to Annex 1, considered safer to carry on using. The remaining 27 were excluded from the Annex I and were not considered acceptable because the additional safety data had not been provided. At that time there were a further 110 new pesticides that have been submitted for approval, of which 10 have been accepted for use, and 2 rejected from Annex I (European Commission, 2004). More recent data shows that 629 pesticides (57%) of the pesticides on the market in 1993 can no longer be authorised for use in the EU (Nomisma, 2008).

Table 6.3: Regulatory status of EU pesticide active ingredients

	Decision Pending	Included in Annex I	Out of Annex I	Not supported	**Total**
Existing Pesticides for review	489	27	40	428	**984**
New Pesticides	98	10	2		**110**
Total	**587**	**37**	**42**		**1094**

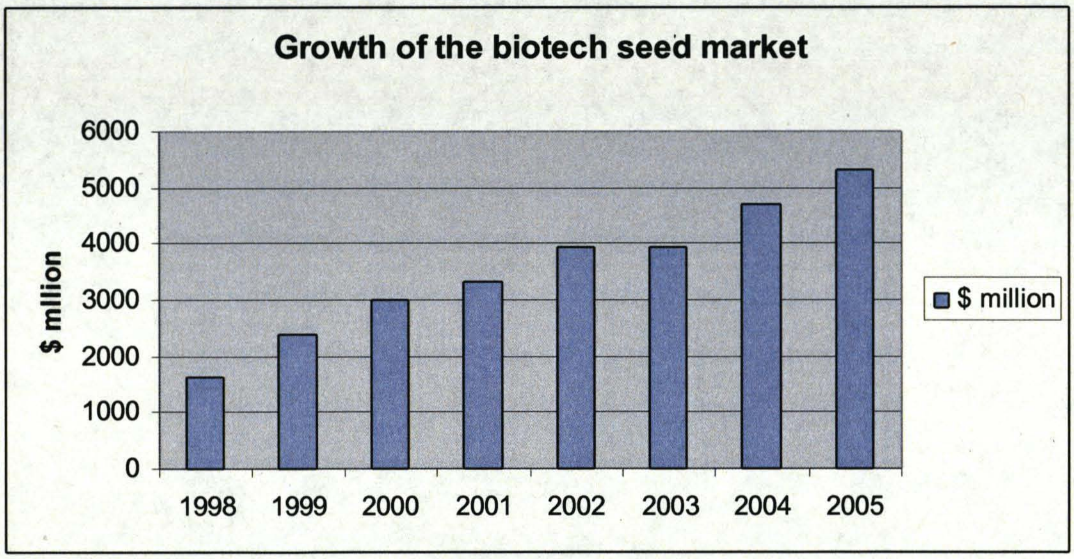
Source: (European Commission, 2004)

6.8. *Pesticide industry investment in GM technology*

According to the pesticide industry sales have flattened off in recent years. The change in pesticide usage levels has been put down to the declining returns on research and development and the impact of biotechnology (see Figure 6.3) (Pragnell et al., 2003: 9). The response of some pesticides companies to has been to develop seed bio-technology and genetic modification (GM) technology. This included introducing genetically engineered pest control properties into susceptible crops.

Industry investment has delivered substantial developments in agricultural seed biotechnology, as a delivery vehicle for the new genetically modified pest control traits. Despite consumer resistance in Europe, the biotechnology industry considers that it has made an enormous impact on agriculture in a relatively short period of time. The global biotech seeds market has increased rapidly in recent years. It has been described by an industry spokesman as: "the fastest agricultural revolution ever" (Pragnell et al., 2003: 11). However for the present study, GM technology has not been studied to any great degree. This is because there has been no commercial growing of GM crops in UK, and very limited commercialisation in the rest of Europe. Genetically modified maize is licensed to be grown in the EU in a limited way, and there has been some research into the effects on European butterflies (Lang and Vojtech, 2006). There have been few recent studies in the UK during the period of the present study. For example, during 2006 there were no field trials with GM crops in the UK (Anon, 2007d).

Figure 6.3: Global biotech market



Source: (Phillips McDougall, 2006 cited in (Crop Life, 2007a).

6.9. Bio-rational approaches towards pest management and the role of bio-pesticides

6.9.1. Introduction

This section reviews the development of biologically based pest management techniques as alternatives to the adverse effects presented by synthetic pesticides. This is an altogether different response to from that of the previous section in which pesticide use was defended through an increasingly stringent regulatory process. It reviews a group of products known as bio-pesticides which on the one hand are direct replacements for synthetic pesticides that can be used in all types of farming systems.

Calls for the development of safer alternatives to pesticides are not new. In the early 1960s the side effects of pesticides were becoming of concern to ecologists and naturalists, and there were recommendations for alternative biological methods of pest control (George, 1961). In more recent years calls for safer alternatives have come from a number of environmental NGOs (Harvey, 2004), and there is evidence that shows that these approaches are ones that some food retailers are developing as part of their support for alternatives to pesticides (Barker, 2003, Buffin et al., 2001). The question is whether bio-pesticides are safer alternatives to synthetic pesticides. This issue is addressed in the findings from stakeholder interviews (Chapter Eight).

Bio-pesticides can be used as direct replacements for synthetic pesticides and still used within a conventional agricultural framework. In this sense they would still be used within the pesticide policy paradigm. On the other hand they can be used as part of an ecological or holistic approach to pesticide management. This would result in a more fundamental approach as replacements for synthetic pesticides – a paradigm shift.

The definitions of biologically based pest control are presented in the next section. They are somewhat contradictory in nature because the UK and EU legal term for most (but not all) products is 'bio-pesticide', and the companies prefer the term 'bio-control agent'. These pest control options are products which can be used individually in their own right, or collectively as part of a pest management package. In the latter case biologically derived products can be used as part of a bio-rational approach that relates to a range of techniques (including non-chemical and non-biological) used in an ecological manner.

There is no recognised definition of a bio-rational approach. For the purposes of the present research, it has been defined as a way of pest management that works with natural processes to control pests in a fashion that minimises risks to human health and the environment. There are other similar definitions in the literature, in relation to bio-rational approaches, although it is a moot point whether the term includes products derived from natural sources (Schuster and Stansly, 2005).

Within a bio-rational approach there are products that have been developed that can directly replace synthetic pesticides, or used in an integrated way with a range of chemical and non-chemical methods that complement each other to form the equivalent pest control that would otherwise be conferred by a single synthetic pesticide. These alternatives to man-made pesticides are referred to, by the industry developing them as bio-pesticides.

6.9.2. A review of bio-pesticides

Bio-pesticides have pest control properties that are biologically derived. This includes biologically based chemicals (including plant-derived chemical extracts and semiochemicals) and biological control organisms (including microbials and invertebrates). The pheromones and botanical plant extracts are both versions of non-synthetic chemical pesticides. The other two represent biological controls and include the microbial group (such as bacteria, viruses and fungi) and invertebrate group (predatory and parasitoids nematodes, insects and mites). The first three bio-pesticide groups (pheromones, botanicals and microbials) are defined under the EU Directive 91/414 and therefore registered in member states under the same regulatory process as synthetic pesticides (see Figure 6.4 Vol. 1, page 212). This figure illustrates in a combined ways the UK and EU procedures for the registration and approval of bio-pesticides (plant-derived chemical extracts; semiochemicals; microbials) operate as if they were synthetic pesticides. This means that in theory they are subject to the same reactive regulatory process that has incrementally become more stringent because of the adverse effects belatedly discovered.

In the UK non-native invertebrate biological controls are scrutinised through a lighter regulatory process that involves fewer data requirements. This compares with the much tougher requirements for the other bio-pesticides mentioned above, that are regulated under the EU Directive 91/414. The non-native invertebrate biological controls are approved and regulated under different legislation. They can be released as part of a pest management programme after recommendation from the Advisory Committee on Releases to the Environment (ACRE) and are regulated through a different sector within DEFRA that is separate from PSD. The different regulatory approaches for the bio-pesticides and the invertebrate bio-control agents are illustrated in Figure 6.4. The use of native invertebrate biological controls, on the other hand, is not subject to any regulatory scrutiny.

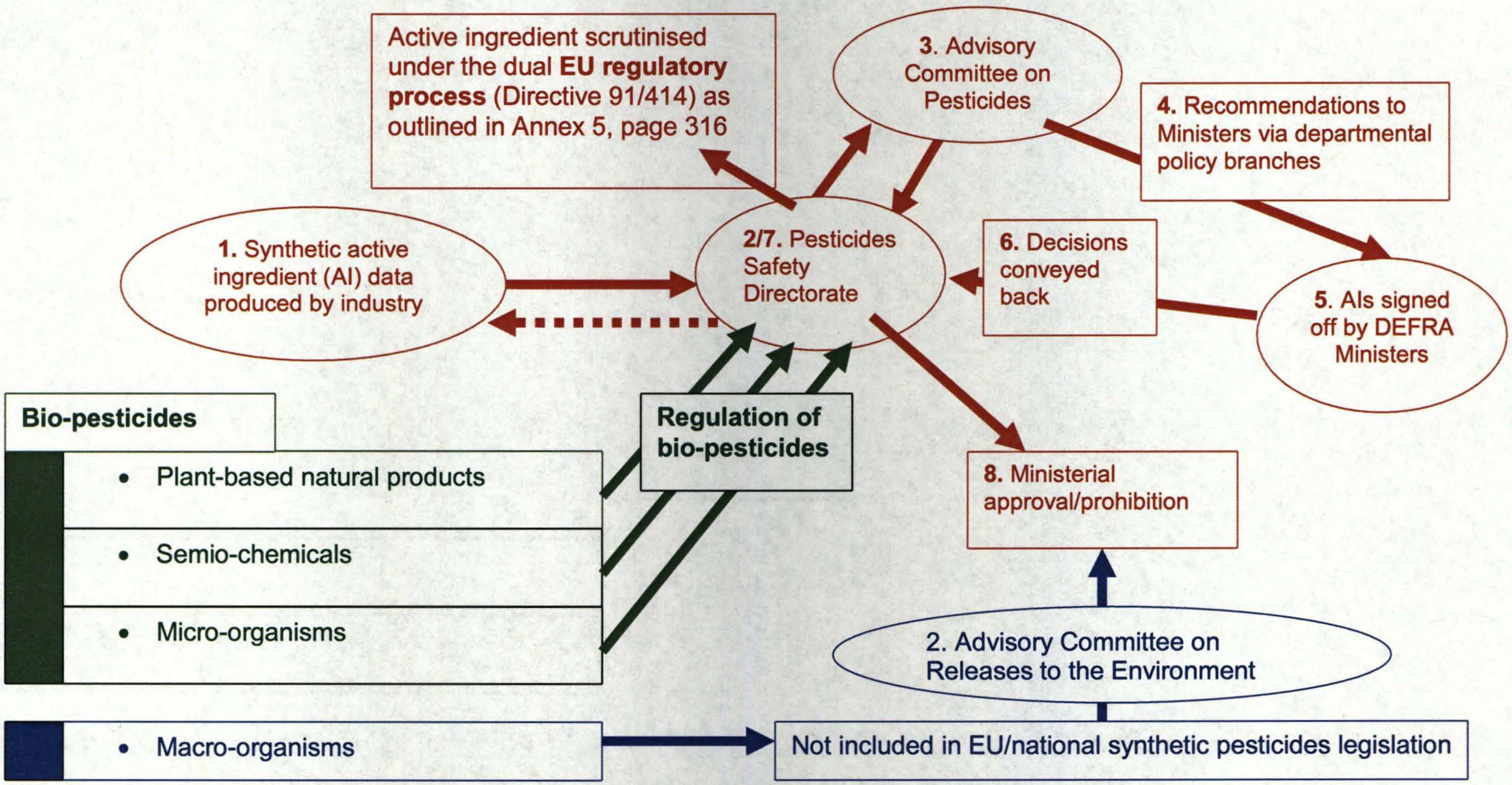
The market for bio-pesticides is small but is increasing at a time when the synthetic pesticides market has flattened. The following section will assess whether the use of bio-pesticides produces lower risks compared with synthetic pesticides. This assessment is carried out with an acknowledgement that levels of efficacy may vary between powerful synthetic pesticides and lower-impact bio-pesticides. It is important that both need to demonstrate some level of efficacy. But the possible lower efficacy of a bio-pesticide could be off-set by the wider societal/environmental benefits presented by such a reduced risk option.

'Bio-pesticides' is the term used by the UK regulator (Pesticide Safety Directorate [PSD]) to describe 'pesticides that are biologically derived'. An important part of the present research includes an analysis of the regulation of bio-pesticides through the same UK and EU legislation as for synthetic pesticides through Directive 91/414. The default term for the present research will therefore be 'bio-pesticides'. Invertebrate or macro bio-pesticides will be discussed separately because of the different legislation that covers them.

Some authorities include genes introduced through genetic modification as bio-pesticides (Copping, 2004). The present research has followed the EU and PSD definitions of a bio-pesticide and bio-pesticide plant protection production, which exclude gene transfer and transgenic crops in their definitions.

Many bio-pesticides are approved for use in organic farming as well as conventional farming. Many of the chemicals, despite being plant-based, are synthetically manufactured by the pesticide companies for the purpose of crop protection. In some cases the products are available in the 'naturally occurring form' from synthetic manufacture. For example, clove oil, found in a wide range of plants, including laurel, is predominately comprised of the chemical 4-allyl-2-methoxyphenol, and lesser amounts of acetyl 4-allyl-2-methoxyphenol. The 4-allyl-2-methoxyphenol is manufactured and available for use in agriculture, although use in organic farming is restricted to the naturally occurring material (Copping, 2004: 175). The following text provides an outline of the three main bio-pesticide groups (micro-organisms, natural products and semio-chemicals) and the macro-organism bio-pesticides.

Figure 6.4: UK and EU registration processes for bio-pesticides



Key: The red boxes refer to the UK/EU regulatory process for synthetic pesticides, (see also Figures 2.9 [for the UK] and 2.10. [for the EU]). The green boxes represent bio-control agents legally classified as bio-pesticides, which are regulated under Directive 91/414. The blue box represents an additional class of bio control agent not classed as bio-pesticides and therefore subject to subject legislation.

Source: Author

6.9.3. Natural products

Natural products include a range of plant extracts. Some examples are unprocessed representing a cluster of substances, whilst other examples are highly refined chemicals containing a single active ingredient. The risk associated with plant extracts may vary between low and very high risk. Internationally there are 58 natural products on the market. These include on the one hand garlic oil, which is considered not to be hazardous, and accepted for use in organic farming; and on the other, rotentone and nicotine, which are potentially hazardous to human health (Copping, 2004).

6.9.4. Semiochemicals

Semiochemicals (SCs) are chemicals produced by plants, animals and other organisms, and synthetic analogues of such substances that produce a behavioural or physical response in individuals of the same or other species. They include pheromones (producing an intra-species effect) and allelochemicals (inter-species effect), and, in pest management terms, usually relate to modifying behaviour in arthropods.

SCs are inherently different from synthetic pesticides in that they have a target (species) specific mode of action within natural processes and are derived from the natural environment. Unlike synthetic pesticides, they are not designed to be toxic. They are generally effective at very low application rates in the field, often comparable to levels found naturally. However, they are often volatile and usually dissipate widely in the environment.

6.9.5. Micro-organisms

Microbial pesticides include viruses, bacteria and fungi. They are used against arthropod pests, most prominent of which are insects. The potential for microbial control was established during the late 19th/early 20th Century, but their potential was not fully developed, and interest has been re-established over the last 20 years (Taborsky, 1992). In order to be effective on a large-scale, they normally have to be mass-produced. There are 112 different micro-organisms sold and in at least one country world-wide (Copping, 2004). There are 7 registered for use in the EU, and 7 (not all the same) in the UK. The Organisation for Economic Co-operation and Development (OECD) has produced an evaluation of microbials used in pest control. It concluded that many microbials "have the capacity to produce potentially toxic metabolites that can present a dietary risk to consumers if residues… are found in food" (OECD, 2008: 53).

Bacteria

The most widespread microbial insecticide is Bacillus thuringiensis (Bt) and its subspecies. In the late 1990s, they accounted for 90% of the global microbial bio-control agent market (WHO, 1999a). They are derived from the spore-forming rod shaped *Bacillus* genus that produces a spore and crystalline toxin that the pests must eat in order to have a lethal effect. Products of a single *Bacillus* species may be effective against an entire order of insects or they may be effective against one species or a few species. For example *Bacillus thuringiensis* var. *kurstaki* kills the caterpillar stage of a wide range of Lepidopteron pests. On the other hand, a product formulated from *Bacillus thuringiensis* var. aizawi exclusively controls the wax moth caterpillar (Weinzierl et al., 2005). A 1999 World Health Organisation review concluded that *Bacillus thuringiensis* is unlikely to pose any hazard to human or other vertebrates or to the great majority of non-target invertebrates (WHO, 1999a).

Viruses

The virus pathogens Baculoviruses are used to control Lepidoptera larvae and Hymenoptera (sawfly) larvae. Like Bt they are stomach poisons, and death of the pest occurs after 3 to 10 days. The pest host range is narrow, usually restricted to a single species or genus. This has environmental benefits, but does restrict market size, which has restricted its use compared with that of Bt. Viruses must be produced in live insect hosts, which makes them expensive and time consuming to use. In 2002, an Organisation for Economic Co-operation and Development (OECD) consensus document came to a generic conclusion that no adverse effect on human health has been observed in safety tests of more than 51 entomopathogenic viruses (OECD, 2002). A review of the literature has shown that there is little further information, beyond regulatory data, available on the safety of viruses used in pest control, but it is likely that uncertainty in this area has the potential for considerable wider public disquiet.

6.9.6. Invertebrates

Macro or invertebrate bio-pesticides include a wide range of insect, arachnid and nematode organisms used to prey on and control mostly glasshouse pests. They are often used as a part of an integrated pest management programme. They can often be susceptible to the same chemicals that are used to control invertebrate pests. Careful use and selection of pesticides is therefore required. In the UK and the EU they are not classed as pesticides, unlike the other bio-pesticides discussed above, under the relevant legislation. The potential harmful effects on non-indigenous species introduced for biological control are of particular concern. There are few documented instances of damage to non-target organisms or the environment from these species, but this does not mean bio-control is safe (Simberloff and Stiling, 1996).

6.9.7. Safety of bio-pesticides

It is widely assumed that bio-pesticides have less environmental impact compared with synthetic pesticides, and that they are less harmful to human health. For example, a regulatory view is that biopesticides are usually less toxic than conventional pesticides (US EPA, 2008). The first thing to establish is that, as a group, these products have very different properties (as is the case for synthetic pesticides). It is therefore very difficult to generalise. The one thing they have in common is that they are not chemicals of synthetic origin. But they include naturally based chemicals on the one hand, and microbial and microbial species, on the other. For synthetic pesticides, the chemicals are designed and constructed in the laboratory from basic elements. Bio-pesticides are extracted from the complexities of their natural state. In many cases there is very little academic literature, on safety and efficacy. There are a number of papers on Bt, but often they are linked to its use with GM technology.

6.9.8. Bio-pesticide market

There is little information in the public domain about the sales of bio-pesticides. This is partly because of the commercially sensitive nature of the data, but also because usage levels are low compared to the synthetic pesticides industry. Although more than 1,000 different products are available through more than 350 manufacturers in the world, the use of bio-pesticides is still limited. Traditionally the bacterium *Bacillus thuringensis* (Bt) has dominated the biopesticide market. Global Biopesticide sales accounted for about $160 million in 2000, of which over 90% was due to the sales of Bt products (Jarvis, 2001). In 2003, global sales amounted to US$588 million, which is about 2% of the total plant protection market, most of which includes synthetic pesticides; and by the end of 2008, the market is expected to reach US$ 973 million (Gullion, 2007).

As noted in chapter two, the use of bio-pesticides is not new, but the extent of its use was severely curtailed after the development of the more economically competitive synthetic pesticides, post world war two. Poor development of the bio-pesticides market has been blamed on poor quality control and an inappropriate model for bio-control agent manufacture, distribution and sales model which is otherwise successful for chemical control. The pesticide policy paradigm includes the adoption and development of chemicals with a long shelf life, stability under a wide range of storage conditions, broad-spectrum in terms of pest-attack range. These chemical-based pest control attributes apply in opposite measure to bio-pesticides and are inappropriate for their development (Dent and Waage, 2000). And it is recognised that these products currently available in the UK cannot even offer realistic substitutes for synthetic pesticides currently being withdrawn under the EU pesticide review programme (ACP, 2003a). According to Hynes and Boyetchko (2006), the literature is abundant with studies screening for micro-organisms with attributes of biopesticidal activity, however very few of the authors have considered formulating the micro-organisms with commercial applications in mind. The authors recommend that multi-disciplinary teams are required to optimise bio-pesticide yield, efficacy, storage stability and delivery for this technology to evolve and meet today's pest control and agricultural demands.

According to Jarvis (2001) the market is largely driven by consumer, retailer, and government pressure to minimise the use of chemical pesticides. Key areas of commercial potential include organic farming; integrated pest management; resistance management programmes; and high value speciality crops, where the development of conventional pesticides is discouraged by the cost of registration. This is important because synthetic pesticides are normally approved for use on specific crops for which expensive crop residue data has to be generated. Factors that limit the growth of the market include the fragmented nature of the industry; low levels of interest in the agrichemical industry; high production costs; difficulties in formulation and application; and a lack of commercial awareness on the part of the manufacturers.

6.9.9. Research for safer alternatives

There is a chronic shortfall of funding for research into, and development of pest control. Historically funding has come from large multi-national synthetic pesticide manufactures that allocate multi-million pound budgets for the development of a single pesticide active ingredient which may go on to support anything from one to half a dozen or so related pesticide formulated products. Today it costs a pesticide marketing company £140 million to commercialise a single active ingredient. From its beginnings in a company test tube to achievement of full regulatory approval, pesticide approval can take nine or more years. So in financial terms it is imperative that the company receives a positive regulatory approval for its active ingredient, especially the closer the chemical is to commercialisation.

The biopesticide industry is dominated by small to medium sized companies that are often small 'start-up' enterprises based on a single new technology of commercial potential. Many are linked to academic institutions which may not be driven by a demand for new market opportunities. Failure rates are relatively high, due to the difficulties of bringing to market a novel pest control agent, marketing and distribution difficulties, and a lack of awareness of the market potential for new products. The larger biopesticide companies are those that have survived the initial start-up problems and have gone on to grow, often through mergers and acquisitions. Few of the leading global pesticide companies have biopesticide division of their own, and many of the investments that were made in the biopesticide divisions in the 1980s have divested in recent years. The major exception to this is in Japan, where several large pesticide companies have recently invested (Jarvis, 2001).

6.9.10. Why focus on bio-pesticides?

Over the past 50 years, the market for agricultural crop protection has been dominated by synthetic pesticides. The main reason for focussing on bio-pesticides is because they are potentially safer alternatives to synthetic pesticides and can help reduce pesticide residues in food and present an environmentally-friendly profile (Buffin et al., 2003). The market has been slow to provide bio-pesticides despite political support for such options. This is because the companies developing these products face a high cost of market development, relative to their sales turnover, and regulation costs for what are often very small private enterprises. There are also concerns from farmers and growers about the efficacy and costs-effectiveness of bio-pesticides, within a very price-competitive crop production and food supply industry.

There have been efforts to research and address these issues, through dialogue and discussion with the pesticide/bio-control agent stakeholders. To some extent this has included non-governmental organisations but they have limited capacity to become involved in and offer views on the need and safety of these products. A 2003 report produced by public interest organisations raised concerns about the use of hazardous pesticides on sale in the UK and EU marketplaces, and recommended the development of safer alternatives (Buffin et al., 2003). It cited a number of barriers for the development of these products. These include regulatory barriers, an un-coordinated research and development strategy, insufficient funding, and a lack of near-market research opportunities.

Despite the above mentioned study, there has been no engagement with wider civil society or gauging of public opinion concerning bio-pesticides. This contrasts with public opinion on synthetic pesticides. Responses have, when prompted, been consistently negative towards the chemicals, especially in relation to pesticide residues in food. Given this level of concern, it is particularly important that anything that replaces them is given a wider debate in order for lessons of previous mistakes to be adapted and incorporated into future policy directions.

6.9.11. The challenges of registering bio-pesticides

Bio-pesticides (plant-derived chemical extracts; semiochemicals; microbials) are considered and approved through the same regulatory process as for that of synthetic pesticides (see Figure 6.4). This has presented a difficult challenge for registration in the UK and the EU. One example has been that of garlic *(Allium sativum)* a plant-extract bio-pesticide that has been put forward as an insect deterrent. It was presented to the Pesticide Safety Directorate and the Advisory Committee on Pesticides for consideration against the cabbage root fly in various Brassica vegetable crops including swede and cabbage (ACP, 2003b). Although lower in efficacy, it was seen as a politically desirable alternative to the more hazardous organophosphate insecticides chlorpyriphos and chlorfenvinphos (Buffin, 2004). Chlorpyriphos is a suspected endocrine disrupter (PAN UK, 2005). In the UK the organophosphate chlorfenvinphos insecticide had its approval extended for use on vegetable pests including cabbage root fly, while garlic granules remained unapproved although they offer an alternative (Anon, 2002) which may have a lower risk to human health and the environment. The comparison here is whether a food grade material (garlic extract) is used instead of a toxic nerve poison. Garlic is considered safe because it is a food supplement and widely used in cooking. It is therefore not considered hazardous (Copping, 2004). However little information is in the public domain to prove garlic is safe, in the same way that would be expected for an acutely toxic synthetic pesticide. The main safeguard is that it has been used for hundreds of years as a food ingredient and as an insect deterrent.

The Advisory Committee on Pesticides (ACP) first examined a formulation containing 45% garlic juice for the intention of reducing cabbage root fly damage in various Brassica crops including swede and cabbage. The ACP recommended that garlic should not receive approval because further data were required to complete a risk assessment, while efficacy data indicated a variable response (ACP, 2002b). Whilst the risk assessment data were subsequently accepted by the committee, at five later meetings application for garlic was refused on grounds of efficacy. The last such examination was in 2007 when it was put forward as a nematicide on carrots and parsnips (ACP, 2007).

6.9.12. A bio-pesticides scheme for the UK

During the period of the present research, the UK regulator (Pesticide Safety Directorate [PSD]) launched a scheme specifically aimed at helping small businesses gain market approval for pesticides. This included a reduction in registration fees and a more practical approach to the risk analysis of bio-pesticides. (For more details on the scheme see Section 8.5) Pesticide registration systems throughout the world largely rely on methods of analyzing the risk of each pesticide independently of other options. Users have no means of knowing which chemical or product carries the least risk to health or the environment. The scope for including non-chemical approaches is not considered.

At present pesticide approval is based on a consideration of the hazards of the active ingredient and an assessment of the risk of harm of the product in use, both to human health and the environment. In the UK, this process occurs on a product-by-product basis with no consideration given to the relative merits of competing chemical pesticides or of other products or active ingredients, including biological control that may be used to control the same pest, disease or weed.

6.10. The relationship between bio-pesticides and farming approaches

Organic farming is a holistic system which avoids, or largely excludes the use of synthetic pesticides (Browne et al., 2000). Since organic farming rejects the use of synthetic pesticides, it could be argued that it should be excluded from this overview of pesticide regulation. However, organic farming does allow the use of some natural chemical pest control options, and the non-routine use of some veterinary medicine anthelmintics (synthetic pesticides used to control internal parasites of farm animals). The protagonists of organic farming consider chemical pesticide use only as a last resort (Soil Association, 2006). A recent Soil Association report calculate that pesticides used in organic farming amounts to 10 tonnes per year (compared with 31,000 tonnes applied to UK farmland as a whole) (Soil Association, 2007). Organic protagonists, such as the Soil Association, do not defend the pesticide paradigm although they permit some very limited chemical use. Organic farming is also relevant to the pesticide debate because it is seen by organic protagonists and some stakeholders as an important way of reducing pesticide use, as part of a national pesticide reduction programme. Discussions at many conventional stakeholder meetings often ignore the role organic farming could play in reducing pesticide use. For many years organic farming was seen as a niche sector, but it is a fast developing niche market. A paper presented at a Food and Agriculture Organisation conference in 2007 concluded that organic agriculture has the potential to secure a global food supply; just as conventional agriculture has today, but with reduced environmental impact. The shift would depend heavily on political will, and the allocation of resources towards a greater integration within national agricultural policies (FAO, 2007).

The conventional response to the pesticide problem has been to reduce the risks associated with pesticides rather than to replace them altogether. One practical way of achieving this has been the development of integrated pest management (IPM). Although first developed in the 1950s, the concept of IPM expanded during the 1970s after environmental health and production problems associated with the dependence on large-scale use of pesticides became evident.

A broad definition of IPM has been adopted by the Food and Agriculture Organisation Panel of Experts: "Integrated pest control is a pest management system that, in the context of associated environmental and population dynamics of the pest species, utilizes all suitable techniques and methods in as compatible a manner as possible and maintains pest populations at levels below those causing economic injury" (FAO, 1967).

Following some large-scale US and developing country successes with IPM, based on biological control systems, sustained profitability and pesticide reduction has meant IPM has become a more important part of pest management. However, the IPM term is disputed by stakeholders and it has come to have different meanings, so much so that some 70 definitions now exist (Koul et al., 2004). Much of the difference surrounds the level of chemical pesticide control permitted under IPM. Some ecologically-based IPM concepts address the issue of reducing or even eliminating pesticide use, but many IPM techniques are based on economic thresholds for pesticide application that do not explicitly consider either environmental or human health impacts (Kishi, 2005: 36). There are also a number of related 'IPM terms' such as integrated control, integrated production, and integrated farming which have developed. In the UK the pesticide/food/retail industry, is heavily involved in developing 'Integrated Crop Management' (ICM) which calls for an improved pesticide use, and specifically rules out any reduction in the levels of pesticides use. However, a survey of 1163 respondents from nine UK arable and horticulture sectors revealed that only 40% of arable farmers had heard of IPM and 30% of those growing field vegetables had heard of integrated crop management (Bradshaw et al., 1996). Despite the efforts of many governments, wider IPM/ICM is carried out on only 3% of EU farmland.

Some reasons for limited uptake of integrated approaches may include poor farmer understanding and confusion about the concept or lack of incentives to change practice (Williamson and Buffin, 2005: 213). Since the beginning of the 1990s, organic farming has increased rapidly in almost all European Countries. Growth has however slowed down in recent years. Nevertheless, in the across Europe there are 6.5 million ha are under organic management from around 167,000 farms. In three EU countries (Liechtenstein, Austria and Switzerland) the organic area (as a percentage of the total agricultural area) is above 10%; and in an additional seven countries (Finland, Sweden, Italy, Czech Republic, Denmark, Portugal and Estonia) the figure is above 5% (Willer and Yussefi, 2006).

6.11. Links between bio-pesticides and an ecological pest management paradigm

Bio-pesticides can be used as a replacement for synthetic pesticides or they can be part of an integrated or holistic approach to pest management. The present research has examined whether this total replacement would amount to a fundamental shift towards an ecological approach to pest management. This would involve major institutional changes to the way in which the process was governed by the regulator and how the replacement of pesticides would be implemented through the food supply chain. It would mean that an ecological pest management approach would embrace a bio-rational approach which has been defined as a way of pest management that works with natural processes to control pests in a fashion that minimises risks to human health and the environment. Such an approach would also have to include a mechanism that allowed for the comparative assessment, making sure that the pest management solutions adopted are the safest options available. (see below). This would require an agronomic advice service that currently does not exist in the UK.

6.11.1. Ecological management by substituting more hazardous products for safer alternatives through a process of comparative assessment

One way of developing a more ecological approach to pest management is to adopt the substitution principle in which more hazardous products are removed and replaced with safer alternatives. Comparative assessment represents the processes by which substitution occurs in practice taking into account risks to human health, wildlife and the environment (ACP, 2001a).

Comparative assessment can part of a regulatory requirement or it can be part of a voluntary practice as adopted by end-users. At the regulatory level comparative assessment is included in the EU Biocides Directive (European Commission, 1998a)[53] and the EU Registration, Evaluation, and Authorization of Chemicals (REACH) (see Vol. 1, page 223).

There has been a debate among stakeholders about the regulatory adoption of substitution/comparative assessment for pesticides at the UK level (ACP, 2001a).

For pesticides, the scope for comparative assessment depends on there being an overlap between similar uses of different products or active substances. This is not necessarily always the case. The situation can be made more complex where resistance management is necessary or where products have specific fields of use (for example during stages of crop growth, or where crops are grown on different soil types). Choosing the safest approach is complicated by differential risks. A product or substance may pose a lower risk to human health, but a higher risk to the environment. Often, the health effects are considered in isolation of the environmental effects (or vice versa). For example in the UK, two multi-stakeholder groups, (the Pesticide Forum and the Voluntary Initiatives to reduce the environmental impacts of pesticides) only focus on environmental issues.

Where pest, disease or weed control can be achieved by non-chemical methods, for example by crop husbandry, rotation or variety choice, this non-chemical method could be included in a broader comparative assessment. The approach could prioritize methods that are significantly less risky and cost effective. On what basis could the substitution of chemical by non-chemical methods be considered?

The European Union has included the principle of comparative assessment in the form of chemical substitution in the Non-agricultural Biocides Directive (98/8) (European Commission, 1998a), but there was no reference to it in the Agricultural Pesticides Directive (91/414) (European Commission, 1991). In reviewing the operation of this Directive, the Council has called on the Commission to examine the scope for substitution and comparative assessment. During the late 2000s, a new EU Regulation has been drafted to replace the old Directive (91/414) (EU, 2008). This new legislation is likely to be finalized during 2009 and the current draft has the provision to include comparative assessment for plant protection (pesticide) products earmarking them as 'candidates for substitution' (EU, 2008: 48).

53. The Biocides Directive includes non-agricultural pesticides used predominantly for urban pest control.

In the Biocides Directive, comparative assessment will be applied to active substances, with the proviso that substitution can only occur within the same product type. If the same approach were to be applied to the comparative assessment of pesticides, it would ignore product formulation, rate of application, crop and site of use. The comparison would be based on intrinsic hazard rather than risk. Some believe that comparative assessment and substitution could only operate at the level of products, targets and uses.

Comparative assessment may be complex to implement, but it is crucial for developing safer methods of pest management. It forms the cornerstone of precaution in practice. Although there may be conflicting priorities in balancing the concerns of human health or the environment, comparative assessment will force regulators to make qualified and transparent judgments which will help provide a practical approach to risk management with widespread public support. Public interest NGOs consider comparative assessment could be a mandatory part of the pesticide approvals process. It has the support of a diverse range of stake-holders, and although it may place a greater burden on regulators and on the agrichemical industry, it will stimulate the research and commercial development of least risky solutions to pest management problems. On the other hand the pesticide industry and some sections of the farming lobby want comparative assessment to remain instituted at a voluntary level.

There is a parallel regulatory process that is assessing non-pesticide chemicals through the EU REACH process (European Commission, 2003a). Registration, Evaluation, and Authorization of Chemicals (REACH) will simplify the complex system for approving new chemicals. Substitution is a key component of REACH, and there are some surprising similarities between completely different substitution cases, although the specific effect and the relative importance of each of the influence factors (economic, technical, communication/social, risk management, regulatory) varies from case to case. At the policy level, there is a 'waiting game' going on. European regulators for pesticides are waiting to see how their REACH colleagues develop substitution in practical terms; and vice versa, the REACH regulators want to see how their pesticide colleagues move the same process onwards.

The rationalisation of EU chemicals regulation came about (as with pesticides) because of the need to create a single market with common standards that allows the free circulation of products between member states. However the need for a better regulatory system was not the only driving force behind the perceived need for a new regulatory framework for chemicals. During the 1970s and 1980s there were widespread stories about 'cancer-causing chemicals' and about the degree of ignorance of the possible adverse effects of chemicals on human health and the environment. In response, an informal EU Environment Council, held during the UK Presidency in 1998, discussed the EU chemicals regulatory system, which eventually led to the REACH process (Rogers, 2004).

6.12. Conclusions

This Chapter describes the responses to the adverse effects of pesticides as demonstrated by a series of pesticides civil society and other critics. One response has been the development of pesticide regulation as means of defending the continued use of pesticides. The other involves the use of bio-pesticides as an alternative to synthetic pesticides.

Health and environmental side-effects from the use of pesticides emerged incrementally from the 1950s onwards. A complicated array of measures was developed to accommodate the increase in pesticide use. These included research and development supported by academic and governmental institutions linked with expertise in the private sectors of agricultural supply (including pesticide manufacturers, farming and the food industry). In order to develop pesticides for use in agriculture, a 'pesticide policy paradigm' emerged in which this dominant and secretive technical group came together with common methods of working and within accepted ways of defining categories (see Section 2.4.1). It was important for the present research to carry out an historical assessment because the pesticide policy parameters of the paradigm are in a constant state of flux, requiring defence and development from within.

Views that were critical of pesticide use emerged after the publication of *Silent Spring* in 1962. It represented a key moment for the pesticide paradigm, which heralded the beginning of the end of the chemical age for pest control. These views were external to the pesticide policy community whose interests were predicated by the need for pesticides within a conventional farming system. Since the early 1960s there has been an increasing range of criticism which has led to some actors, such as those supporting organic farming, rejecting the pesticide paradigm. The public interest groups have nothing to gain from bargaining within those stakeholders who support pesticide use. They can more easily maintain their theoretical position compared with other stakeholders who are mutually reliant on the cooperation of others within the network. On the other hand, in not using pesticide themselves, public interest groups have to persuade others the merits of their policy suggestions. In order to achieve this public interest organisations have to enter the debate. This can either be through direct negotiations, or through third parties such as the media. One clear example is the pesticide marketing company which needs the co-operation of the regulatory and scientific committees; otherwise their products do not reach the market.

The first response to the risks posed by pesticides, led by the UK government, was to control through voluntary arrangements that had the backing of scientific experts and the pesticide industry. The introduction of pesticide regulation was resisted by these stakeholders because of the extra expense of regulatory control for both the government and industry. The effect of joining the European Union, and the public interest NGO concerns about pesticides, eventually led to pesticides legislation, first at the UK level through FEPA (1985), and then at the EU level via Directive 91/414. The UK pesticide industry accepted regulation per se, but were more concerned about political consequences of such an action. The result today is a system of pesticide regulation that is producing regulatory failure. For the few companies that can still afford the research and development costs of developing new synthetic pesticides, the likely sales returns are becoming increasingly challenging.

The development of bio-pesticides has been reviewed in this chapter. They represent an alternative to synthetic pesticides. At present they occupy a limited market, but are important for in the horticultural sector. The market sector is growing faster than the synthetic pesticide market, albeit from a small market base. The drivers for this development are political as bio-pesticides are seen as more sustainable compared with synthetic pesticides. Elements of the food supply chain are interested in these alternatives because they offer the prospect of lower residue levels in food, a consumer requirement that they are keen to oblige.

The barriers for bio-pesticides centre on the relatively lower efficacy compared with more power synthetic chemicals. They have not been as closely researched in safety terms, and for innovation and commercial development. A summary of the key issues are presented below:

- Lack of public or private money to fund safer alternatives
- Bio-pesticide manufacturers are often small enterprises and have little funds for development and registration of products
- Links between chemical pesticides/bio-pesticides and integrated farming

Many of the companies developing bio-pesticides are small enterprises that do not have the marketing and research facilities that multinational chemical companies have at their disposal. The prospects for bio-pesticides to replace synthetic pesticides on a like-for-like basis are limited.

There are also opportunities to include bio-pesticides in farming systems organic and integrated farm management. In the case of IFM bio-pesticides allow for the comparative assessment where they are available. For organic farming there are opportunities for the use of bio-pesticides. The conditions for an ecological pest management paradigm are emerging but may take some time to implement unless there is a political will, and a willingness throughout the food supply chain to take these option for pest management. The current dominant belief is that synthetic pesticides are paramount, and this view is preventing they development of any fundamental change. This will be examined further in the interview chapter (eight).

7. Diversity of stakeholders within the pesticide policy paradigm – key actors and relationships

This section reviews the pesticide stakeholders and policies for the UK. The first section puts the pesticide policy stakeholders into their historical perspective. It draws on data from previous chapters in order to present a historical perspective of pesticide policy for the UK.

In addition to the regulation of pesticides, policy initiatives can have important impacts on pesticide use which can reduce or increase the pressure on the pesticide policy paradigm. Immediate post Second World War UK government policies were very supportive of pesticide, which reduced pressure on the paradigm. Other more recent policies put forward by public interest organisations add pressure to the paradigm. It is in this context that the following section presents the stakeholders and their policy perspectives. It starts with the pesticide regulators, and stakeholders within the food supply chain. It presents the civil society public interest NGO positions and finally reviews pesticide policies as a whole. There are a number of policies operated by different UK stakeholders which conflict with one another, for example from the pesticide industry and civil society. There are also differences between government and pesticide retailers. There are many pesticide policies that operate at the national level that are developed by different stakeholders. There are also many different pesticide networks that operate at different geographical levels. The present research focuses mainly on a network of UK pesticide stakeholder groups which are presented in this chapter. Pesticides are also subject to governance at the EU and global levels as well As such, there are networks which operate at these levels, which are a relevant to the UK.

7.1. Introduction

The composition of the early pesticide stakeholder network in the 1960s-70s, was similar to the pesticide policy community that originated in the 1940s. It included: government support for pesticides; a pesticide industry that could meet the regulatory demands for pesticide registration; scientific advice and research facilities from public and private sources that could provide technical advice; and a farming community willing to use the emerging technology. The friendly, voluntary 'gentleman's agreement' suited all concerned and occurred because of mutual dependency within this community. They all relied on the development, production and use of pesticides as part of conventional agriculture.

There have been many changes to the pesticide paradigm since the 1940s. The simple and strong pesticide policy network that developed in the 1940s has become complicated and weakened. The first stakeholders involved in pesticide governance operated a closed system between the government/research, industry, and the farming community. They were still operating within a 1940s paradigm, into the 1960s, constantly having to catch up with pressure for pesticide regulation and policies that reduced the use of pesticides. Expert scientific advice was helping to support the pesticide paradigm, but other independent research was highlighting problems associated with pesticide use. A more questioning civil society and scientific community resulted in a less quiescent media mirroring concerns about the health and environmental consequences of pesticides. This new political input meant that the debate became less technocratic in nature that is moving away from maintaining a 'firewall' between science and policy.

Pressure for legislation emerged from the realisation that environmental and health problems could result from pesticide use. From the 1960/70s onwards, lobbying from stakeholders external to the UK pesticide policy community pressured for legislation. This included civil society campaigns against the use of certain pesticide active ingredients as well as pesticide legislation. After the UK had joined the EEC in 1973, national policy became subject the more progressive European environmental policies.

During the 1970s the pesticide industry and government considered the cost of introducing pesticide legislation to be too onerous. Setting up a department to approve and regulate pesticides would be expensive. Pesticide legislation was first recommended in 1967 by the expert Advisory Committee on Pesticides, but it was not implemented until 18 years later. The pesticide industry instead argued for better self regulation. The government agreed with industry, and whilst friendly relations existed between the stakeholders, it was felt there was no need for regulation – but the prospect remained as a threat that could be enacted if necessary. The pesticide policy community had become heavily inter-dependent on mutual good will and internal agreement. The pesticide industry needed official approval from the government in order that their potentially hazardous pesticide active ingredients could be formulated and sold to the agricultural community for use on farms. At the same time, farmers had become economically dependent on pesticides as an integral element of their conventional farming system.

By the mid-1980s, civil society NGOs had set up organisations that were calling for pesticide regulation. At the same time the consequences of joining the European Union meant there was an increased likelihood of EU-wide pesticide regulation that would have to be implemented in the UK. National regulations in Germany put the German pesticide industry at a competitive disadvantage. As a result there was pressure from Germany for other industries (notably in France and the UK) to accrue the same regulatory costs through a 'level playing field'. Legislation came in the UK in the form of the 1985 Food and Environmental Protection Act as a way of protecting the UK pesticide industry from European imports.

7.2. *The UK Regulator*

The Pesticides Safety Directorate (an executive agency of DEFRA) was established on 1 April 1993 and is the lead agency for agricultural pesticides regulation and policy in the UK (Wells, 1998). It has responsibility for registering and monitoring pesticides[54].

PSD regulators attend all official EU meetings to discuss agricultural pesticide policy and co-ordinate the official UK position, in consultation with Ministers. PSD plays a pivotal role in channelling the UK 'pesticide position' to the European Community, where policy and regulatory measures are increasingly being set. There are a number of government departments and agencies that are officially consulted on matters of pesticide policy and regulation.

PSD provides the secretariat for the Pesticides Forum, which has a wide stakeholder membership[55]. The Forum addresses the environmental impacts of pesticides, (it was originally set up by the Department of Environment in the mid 1990s). The Health and Safety Executive (HSE), regulates non-agricultural pesticides known through the European legislation as 'biocides' (European Commission, 1998a). The HSE is also responsible for monitoring the occupational and bystander health impacts of agricultural pesticides regulated under Directive 91/414. The Veterinary Medicines Directorate regulates veterinary medicine pesticides covered by the Medicine Act 1968. The Department of Health, is the lead agency for pesticides that come under the Medicines Act 1968, because they are used as human medicines, for example, as treatment against head lice. It has also produced a guide for medical practitioners on pesticide poisoning (DoH, 1997).

PSD has the responsibility for overseeing the UK National Pesticide Strategy. It is heavily reliant on stakeholder involvement and consultation with farmers, the pesticide industry and other non-governmental organisations. There are five action plans (water, biodiversity, amenity, amateur, and health). The UK strategy came about because new EU legislation on

54. After 01.04.08 PSD became an executive agency within the Health and Safety Executive.
55. http://www.pesticides.gov.uk/pesticides_forum_home.asp

the sustainable use of pesticides is likely to produce 'national action plans' on pesticides. According to PSD, the drivers are said to include the publics' concern over the health effects of pesticides including the cocktail effect and bystander exposure. Consumer sensitivity about pesticide residue levels in food led to action by supermarkets and the Food Standards Agency (Williams, 2003).

The Food Standards Agency (FSA) was not given responsibility for pesticide regulation (from PSD) when it was formed in 2000. It has a 'watchdog' role for pesticide regulation, most specifically in relation to pesticide residues in food (including residues from veterinary medicines) (see also Section 5.4.1). The FSA has a small fraction of the number officials employed on pesticides issues, compared with the PSD. In recent years, the FSA has made a number of direct efforts to gauge the general public and NGO perceptions of pesticide issues.

The Environment Agency (EA) monitors aquatic pesticide pollution, and provides the government with policy advice. EA regulators are also involved in stakeholder discussion and environmental perspective input into the Voluntary Initiative and Pesticide Forum. English Nature provides official advice to the government on biodiversity/wildlife issues. There is also participation in the Voluntary Initiative and Pesticide Forum. Both the Environment Agency and English Nature maintain good links with environmental public interest groups. Treasury officials attend Voluntary Initiative meetings and are keeping a watching brief in relation to whether there will be a pesticides tax or not.

7.2.1. Post approval monitoring – health, environment, food quality and water

After pesticides are approved for use, the regulatory process requires continued monitoring of pesticides. Pesticides are considered safe, according to the best knowledge available on the day. If significant problems are identified, the active ingredient(s) are reviewed, and their use is restricted. Sometimes this only comes to light after approval. The main agencies carrying out post approval monitoring are listed below. They all have to report to the ACP on a routine basis.

The Health and Safety Executive (HSE) Pesticide Incidents Appraisal Panel (PIAP) aims to consider all incidents investigated by HSE or local authority inspectors in which the use of pesticides may have affected a person's health. The Panel receives detailed information about each incident, including a report of the field investigations carried out by the HSE's Field Operations Directorate or the local authority together with the results of any medical investigations and the known or suspected adverse effects of the chemical involved. A report of the incidents considered by PIAP is published annually, and is available from HSE Books. These reports are presented to the ACP to check whether further action is considered necessary. In addition, the findings in relation to specific pesticides are taken into account when they are reviewed. Epidemiological studies of pesticides are regularly published in the scientific literature, and to ensure that this information is given proper consideration, a system for reviewing the published literature has been established.

Residues in food are monitored by the Pesticide Residues Committee (PRC) at the national level. Testing is also carried out by local authorities, as well as at the national level. It is coordinated under the PRC. UK surveillance also feeds into a European Union monitoring scheme. The PRC is an independent committee set up under the Control of Pesticides Regulations, and its secretariat is located at PSD.

Pesticides that are used as veterinary medicines are surveyed by the Veterinary Products Committee which feeds back information to the Veterinary Medicines Directorate. The VPC assess residue analysis of organochlorine and organophosphate residues in meat in addition to veterinary medicine pesticides. The use of organophosphate (nerve poison) sheep dips (regulated as veterinary products) has been particularly controversial because of alleged health effects recorded by some farm operators who dip sheep against ectoparasites.

Pesticide residues in public drinking water supplies are kept at a very low level because of the EU Drinking Water Directive which, since 1980, has set the legal limit at the then limit of detection. As a result drinking water is filtered using activated carbon, and most detectable residues are removed. Analysis of residues is coordinated by the Drinking Water Inspectorate. The Environment Agency monitors the natural aquatic environment for pesticides (where relatively high levels can be found) for both non-point source and point source pollution. The Wildlife Incident Investigation Service, based at PSD, mainly focuses on deliberate poisoning. It meets on a regular basis with stakeholders. The Pesticide Usage Survey, based at the Central Science Laboratory in York, interviews a proportion of farmers face-to-face to ask about pesticide use, and then extrapolates data to provide a national assessment of usage.

7.3. Expert committees providing advice to government

The Advisory Committee on Pesticides (ACP) is the primary expert committee that advises government ministers on matters of pesticide safety. Today a large part of the ACP's committee work includes discussion around general pesticide policy. (It is not clear how PSD, who are also responsible for pesticide policy, see this role). For example the risk of pesticide exposure to bystanders has been debated many times at ACP meetings. Other recent policy discussions have included providing advice to government ministers on specific pesticides, as required by FEPA. In another case, in 2002, the Committee considered toxicological uncertainty in chemical risk assessment (ACP, 2002a) and hazard triggers and comparative assessment as part of the revision of Directive 91/414 (ACP, 2002c).

The committee's membership has to declare any interests they have, and this is reported in the Annual Report. A few appointments in recent years have declared contacts with public interest groups. For example, during 2003, two of the 20 members had a declared interest (one of which was non-financial) in the public interest organisation the Pesticide Action Network (ACP, 2004).The variations in views were highlighted in an ACP minority statement tabled at the end of 2004. It centred around and challenged the ACP's published position (ACP, 2005) on a literature review of the effects of pesticides on human health carried out by a group of Canadian GPs for the Ontario College of Family Physicians (Sanborn et al., 2004).

7.4. *Farmers/growers/suppliers*

Traditionally the National Farmers Union has been very defensive in relation to pesticide usage. It is especially sensitive about the issue of pesticide residues in food, which takes up a large proportion of their lobbying activity. The NFU view is that there is no substantive evidence that current residues represent a health issue.

Growers allied to the NFU maintain that pesticide residues should not be considered in isolation within the debate about food quality, and that minimizing pesticide residues through reduction or alternative practices must been seen in the context of consumer demands for products with high visual impact, and the need for available and affordable produce (Wise, 2003). At the same time 'negative externalities' or adverse human health and environment effects have resulted from pesticide use. Despite these effects, farmers have continued to use pesticides because 'locked into' into a conventional agricultural system of pest control technology. Wilson and Tisdell (2001) have concluded that pesticides are an essential component of intensive commercial agriculture, and can deliver high yielding crop varieties. This would equate to a pesticides technological trajectory as per Dosi (1982).

Researchers have shown that when agricultural systems are adopted, agricultural yields become dependent on them, which then poses an 'economic barrier' to switching to, say, organic systems (Tisdell, 1991 cited in Wilson and Tisdell, 2001). Once the system has been adopted it becomes the dominant strategy in which subsequent and supporting research and development predominates. This is what Wilson and Tisdell (2001) call the 'pesticide trap', and as a result, it takes significant economic and political commitment to disentangle pesticides from the mainstream farming system.

The NFU has been a strong supporter of the Voluntary Initiative (VI) [56] as an alternative to a possible UK pesticides tax (see Section 7.2.1). Farmer participation in the VI is crucial, because many of the measures are aimed at improving pesticide spray techniques, rather than a fundamental reduction in pesticide use.

Food assurances schemes have grown up over the last 15 years and have provided base line standards for UK farmers. Most of the schemes come under the umbrella of Assured Food Standards (AFS) which runs the Little Red Tractor labelling scheme. AFS was formed by a multi-stakeholder group that has increasingly been relied upon by industry and the regulators as a market-controlled way of policing the food supply chain. Indeed DEFRA, see themselves merely as observers in the AFS process. The main schemes under the AFS cover beef/lamb, crops, dairy, horticulture, pigs and poultry. Each of the schemes has been developed by experts in the particular field and considered by the industry to represent the main base line standards required for modern farming, what is termed 'legal compliance plus good agricultural practice' (IGD, 2003).

AFS is a form of private regulation run by industry stakeholders which means they can differentiate standards. The AFS schemes are voluntary systems that set out production standards. They cover food safety (including pesticides), environmental protection and animal-welfare issues. The only assurance schemes that are not voluntary are organic schemes. (These are regulated by European Union legislation). The schemes check that farmers and growers are meeting the standards of production set by individual schemes. They do this through regular independent inspection. Although voluntary, it is in the commercial interest of farmers to comply with AFS, if they want to continue supplying the large food retailers.

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56. The Voluntary Initiative is run by the pesticides industry as a voluntary measure for reducing the environmental impacts of pesticides.

A review of assurance schemes commissioned by the Food Standards Agency concluded that there was an urgent requirement for the schemes to improve communication with consumers about the standards they enforce. The report cited a Consumers Association (CA) *Which?* article in which schemes were not seen as helpful for consumers because they did not provide simple explanations on the packaging nor contact details for more information. There was also a false consumer perception that the government was involved in the schemes, As a result, the roles of interested sectors, such as producers, should be made clear. Ownership of the standards and scheme operations must be seen as neutral and impartial, the CA concluded (Kirk-Wilson, 2002).

Pesticide use is of particular importance because of its high level of permitted use in the horticultural sector (under the Assured Produce scheme) and in cereal arable farming (under the Assured Combinable Crops Scheme). Horticultural fresh fruit and vegetables tend to have relatively high levels of pesticide residues, compared with processed food which, in general terms, has had the residues processed out of it. As a result, all stakeholders involved in the horticultural sector are sensitive to the pesticide residue debate. This state of affairs has led to more room for stakeholder discussion (including discussion with environmental and consumer public interest groups), interest in reducing pesticide use, and in alternatives to pesticides, especially if it leads to a reduction in pesticide residues in food.

Pesticides used in the cereal sector are more of an issue in terms of their environmental effects, where it is generally recognized by all stakeholders that water pollution and a reduction in biodiversity are of concern. Although covering all aspects of farming, the Voluntary Initiative also has a number of projects that focus on this sector of farming.

7.5. Multiple food retailers

Assured Food Standards also has support from UK food retailers, who see it as a way of proving that they are delivering environmental and sustainable food. The Co-op has been critical of the Assurance Produce Scheme (APS) saying that the rate of progress has been slow (Barker, 2003). The Co-op believes that the APS can help to deliver small steps in improvements and practices both in terms of effectiveness and efficiency of pest and disease control, while supporting a change in how people think about farming and growing controls. The Co-op concludes that such development is not inherent within the APS and rarely exhibited by the European industry standard scheme EUREP GAP (Good

Agricultural Practice). In the long term they would like to see a more sustainable scheme (Barker, 2003).

There are two separate systems that retailers are supporting: integrated farm management (IFM) which relies on pesticide use 'only when absolutely necessary' (Linking Environment and Farming) (LEAF, 2005) within a conventional farming system; and organic farming, which, in terms of pest and disease management, relies on no use of synthetic pesticides. Some food retailers rely on their own initiatives, such as the Co-op and Marks and Spencer who have their own pesticides policies, and Tesco who has its Nature's Choice branding.

There is a lack of consistency in pesticide policy among UK multiple food retailers. Tesco has developed its own environmental standards known as Nature's Choice. Although food retailers such as the Co-op and Marks and Spencer have their own distinctive pesticide policies, they both remain involved with developing integrated crop management practices with other retailers and the National Farmers Union, with the notable exception of Tesco.

Developed in 1992, Nature's Choice requires all its fruit, vegetable and salad suppliers to comply with specified safety, quality and environmental standards of production. Since 2004, the scheme has developed and is now subject to independent certification. It is governed by a committee made up of suppliers, independent academics, auditors and Tesco managers. The committee reviews the use of pesticides throughout the supply base. All products are risk-assessed for compliance with best agricultural practice and a controlled list of products has been developed. One of the seven pillars of Nature's Choice is described by Tesco as the 'rational use of pesticides'. Currently all of Tesco's 2,500 UK growers grow their crops according to Nature's Choice standards (Tesco, 2005). The fact that Nature's Choice is now subject to independent scrutiny is a step forward, although details of the scheme are not widely published, so it is difficult to make wider objective assessments.

Waitrose has worked to reduce pesticide use, although there is little published information on the subject (Waitrose, 2008). Waitrose relies on its industry links with Linking Environment and Farming (LEAF), Assured Produce. Although it regularly tests its produce for pesticide residues, it has not published results on its website.

During 2006 the food retailer J Sainsbury instituted a long term and substantial review of its pesticide policy. Its policy is to reduce pesticides in Sainsbury brand food. It wants to reduce chemical pesticides and use natural alternatives wherever possible, to minimise negative impacts and improve biodiversity, and to ensure worker health and safety. Sainsbury's consider the most effective way of reducing pesticide use is through integrated crop management (ICM) (see Section 6.9).

ASDA's Environment Policy is brief and talks in very general terms. The company is committed to compliance with national and international environmental legislation. There is no specific mention of pesticides, nor of their membership of Assured Produce on the store website (www.asda.co.uk). There are other UK retailers who have developed less of an individual profile concerning pesticide policy. Somerfield allies its pesticide policy to its link with Assured Food Standards (see below), and statutory requirements under UK legislation as outlined by the regulator, the Pesticides Safety Directorate (www.somerfield.plc.uk). Organic farming is mentioned in terms of: "a range of best value organic 'everyday' products making organics an acceptable and affordable choice for all the family". There is no reference to pesticides policy on the Morrison's website.

Multiple food retailer pesticide policies

In recent years, food retailers and the food industry have increasingly tried to influence their market share of more sustainable food and farming techniques (van der Grijp et al., 2003). Since 2000, they have developed pesticide policies that are at odds with government policy. This particularly includes the UK retailers the Co-op, Marks and Spencer and J Sainsbury. This is a new departure for them as their previous policy was to follow the government lead and leave supply chain issues to them. This meant that they took little interest in pesticide supply, use and development. The two main facets of their policy now are to remove the use of specific hazardous pesticide active ingredients from their supply base, and to encourage aspirational goals around zero residues in their customers' food. These policies are global because they not only involve suppliers and growers from the UK, but also include their counterparts from around the world. The spur for this move has been generated from feedback from the customers. Since 2000, the food retailers have increased their dialogue with non-governmental organisations (NGOs) [with an interest and concern over pesticide use], in their efforts to reduce the level of pesticide residues in food. The Co-op and Marks and Spencer have broken ranks with the other supermarkets (and other stakeholders) as they both decided to take a hazard based approach to pesticide assessment, by 'banning' their suppliers and growers from using certain pesticide active ingredients on a precautionary basis, that are nevertheless considered safe to use by the UK regulator (the Pesticide Safety Directorate). The Co-op and Marks and Spencer see this as a genuine move to improve the sustainability of food production, but their competitors say it is competitive marketing. This concept of hazard-based as opposed to a risk-based approach is discussed in Chapter Two (see Vol. 1, page 40).

The Co-op launched their Pesticides policy in July 2001 (Co-op, 2001). It announced that the Co-op was banning a list of 20 pesticides which were particularly harmful to humans, especially to the young and other vulnerable people. Although some pesticides, such as DDT and aldrin, had been banned in the UK for many years, others such as lindane, chlorfenvinphos, and phorate were still approved for use in the UK at that time (Buffin, 2001).

Pesticide issues were listed as the third most important area of concern, after bovine spongiform encephalopathy (BSE) and genetically modified food. From 1,040 surveyed respondents, 76% believed pesticides are harmful to wildlife, and 60% thought they are likely to pollute watercourses (Co-op, 2001). The Co-op were thus able to take a progressive stance whilst adopting a pragmatic approach through co-operation with Farmcare, the Co-op's farming arm, (representing the largest farming enterprise in the UK). The Co-op has a strong ethos of integrated crop management (also known as integrated farm management) which they assert has developed from organic farming (Croft, 2002).

In addition to the 20 pesticides banned, the Co-op has a restricted list of 30 pesticides that can only be used by specific agreement with the Co-op, and where a supplier or grower has proved that no suitable alternative exists. The Co-op then encourage the grower to consider non-chemical control measures, including biological, mechanical or cultural controls, before approval is granted (Croft, 2002). The Co-op has passed on this information in the form of specific crop protocols, or Product Advisory Sheets, which also include information about approved pesticides, such as their potential health and environmental effects. This enables the grower, with the help of the food retailer, to make comparative risk assessment decisions (Barker, 2003). In this way the Co-op is increasingly taking on a role as pesticide regulator.

Since 2001, the Co-op has published a number of reports and policy papers on pesticides. It has worked with a progressive new advisory panel of independent academics (who are co-incidentally members of the regulatory Advisory Committee on Pesticides) and public interest environmental NGOs to develop its policy. The panel reviews pesticides against a hazard framework (Barker 2003), as opposed to the risk assessment model followed by the regulator (Pesticide Safety Directorate). The Co-op has said publicly that it would like to see the PSD supporting comparative data as a part of the approvals process.

The Co-op has been keen to publish the results of pesticide residue testing results on its website (www.co-op.co.uk) through its *Co-op and the Responsible Use of Pesticides* webpage. This is considered by many food retailers to be a very sensitive issue. Web-published results show that residues were found in 40% of samples tested, from cumulative data collected between June 2001 and July 2004.

Another food retailer, Marks and Spencer, launched its pesticide policy a few months after the Co-op in September 2001 (Buffin et al., 2001). It was focussed around significant reductions in the levels of pesticide residues in their produce. The retailer also banned the suppliers from using 60 pesticide active ingredients, some of which were approved for use by the UK government.

Marks and Spencer see themselves as acting ahead of the official UK regulator (Pesticide Safety Directorate) whom they consider to be a 'slow moving beast'. This action, called a 'compliance plus' approach, has meant that Marks and Spencer are working to replace the banned pesticides with safer alternatives. Its team of agronomists has worked closely with its 47 fresh produce suppliers, including 1,000 farmers and growers worldwide. Marks and Spencer have been looking to help its suppliers with advice, resources and research opportunities to enable them to avoid using persistent pesticides (Buffin et al., 2001).

Like all food retailers, Marks and Spencer are very sensitive to the 'pesticide residue in food issue'. As such, their long-term aspiration is to sell residue free produce. By 2003 Marks and Spencer hoped to achieve the following percentage of pesticide free produce: 90% vegetables (excluding potatoes); 80% potatoes; 80% salads; and 60% of fruit (Buffin et al., 2001)[57].

Approving pesticides on the basis of hazard cut-off criteria versus risk assessment is an important debate. Regulators like PSD have developed their expertise on the basis of a risk assessment. They are critical of the approach taken by the Co-op and Marks and Spencer which uses certain hazard cut-off criteria to ban the use of particular pesticides. Many stakeholders across the food sector are also critical of the Co-op. During the progress of the current research, Sainsbury, another supermarket, has re-examined its pesticide policy. This move is significant because Sainsbury has a much bigger market share of the UK food retail market, compared with the Co-op and Marks and Spencer.

57 At the time approximately 63% of fresh fruit and vegetables were considered residue-free, down to the limit of detection (Pesticide Residues Committee 2002).

7.6. Food Manufacturers

The food and consumer products giant Unilever has developed a *Sustainable Agriculture Initiative*, which established 10 sustainability indicators including one covering pest management. Unilever acknowledge that once pesticides are applied to crops, a small but significant proportion can escape to water and air or accumulate in foods, affecting ecosystems and human health. Sustainable practices can substitute natural controls for some pesticides, reducing dependence on synthetic substances. The parameters used include: the amount of pesticide (active ingredient) applied (per hectare or per tonne of product); type applied (using a profiling, positive list, and weighting factor); and percentage crop under integrated pest management (Unilever, 2002). The Initiative is overseen by an independent committee of academic experts and environmental public interest representatives.

7.7. Pesticide manufacturers

The main industry lobby organization for pesticides in the UK is the Crop Protection Association (CPA). It represents 21 companies marketing pesticides in the crop protection, amenity, home and garden sectors including: BASF, Bayer Crop Science, Dow AgroSciences, Du Pont, Monsanto Agriculture and Syngenta Crop Protection. In general terms the CPA's remit covers the same pesticides approved under the European Directive 91/414. The CPA's main strategy is to help provide affordable food and support the UK government's strategy for sustainable farming and food by providing a range of effective and affordable pesticides.

In recent years, the size of the UK pesticides market has been in the region of 30,000 tonnes of active ingredient sold per year. Industry protagonists remain upbeat about the long term prospects. They assert that crop protection chemicals have made a significant contribution to feeding the world, reducing mortality and increasing the availability of fresh, healthy food (Pragnell et al., 2003). They are certain the key role played by crop protection chemicals (pesticides) will remain.

Since the 1950s, farm subsidies under the Common Agricultural Policy (CAP) have provided significant support for the agribusiness market – artificially assisting 'pesticide-hungry' crops, such as oil seed rape. Reform of CAP, moving away from production support, is likely to have a huge impact on pesticide use. The arguments favouring reform, which include sustainability and the benefits of free trade, are being fiercely resisted by a strong lobby to preserve the 'farm economy', according to the pesticide multinational Syngenta (Pragnell et al., 2003).

In the UK the Voluntary Initiative (VI) was adopted in 2001 by the pesticide and agricultural industries which aimed to minimise the impact of pesticides in the environment (House of Commons, 2005). The Crop Protection Association and the pesticide industry have invested heavily (in terms of staff time and money) in the VI as a response to the threat of an impending pesticides sales tax imposed by the UK government. The pesticide industry has traditionally provided a powerful lobby over the last 50 years. In recent times this has been threatened by the genetic modification debate (not covered in the present research), and the question of introducing a pesticides tax.

From the start, the pesticide lobby was opposed to a pesticides tax, because of the negative impression it gave of the industry as a whole, as well as the economic implications. The impetus for a tax had come from regulators at the then Department of Environment, Transport and the Regions (DETR) who wanted to examine the possibility of reducing the environmental effects of pesticides, and covering a way to pay for the external financial costs of pesticides (DEFRA, 2000). At the time the cost of removing pesticide residues from drinking water had been estimated at £120 million per year (Pretty et al., 2000), A detailed report on the possibility of a tax, carried out for DETR, concluded that a tax could be designed to meet the objective of reducing the environmental effects of pesticides.

The pesticides tax had support from environmental organisations such as the Pesticide Action Network, Friends of the Earth and Royal Society for the Protection of Birds, but intense lobbying from the agri-food industry at the highest level won the day. In February 2000 (ie almost immediately) the government was persuaded of the possible merits of a voluntary industry-backed scheme, and the Treasury announced a set of voluntary proposals it had agreed with the British Agrochemicals Association (now the CPA) (HM Treasury, 2000). The original package was revised and a final submission was made in February 2001. The revised proposals were put forward by a signatory group consisting of the pesticide and farming industries[58]. In April 2001 the Government accepted the package, and a proposals document provides the basis of the agreement between Government and the signatories, which thus forms the framework of the Voluntary Initiative.

58 Crop Protection Association, National Farmers Union, National Farmers Union of Scotland, Country Land and Business Association, Agricultural Industries Confederation (formerly UKASTA), National Association of Agricultural Contractors, Agricultural Engineers Association, Ulster Farmers Union.

The implementation of the VI is overseen by a diverse steering group that includes the original signatories, and regulatory interests and environmental organisations. Not only does the VI steering group comprise a wide political church, but the roles of the membership vary. The pesticide industry provides the secretariat, and is actively involved in decision making processes. At the same time the CPA has strong vested interests in the outcome, as they have banked heavily on the promise that the VI will deliver more of a reduction in the environmental impacts of pesticides than the as yet hypothetical pesticides tax. There are multiple conflicts of interest on the steering group. Many steering group members are also signatories to the VI and are actively involved in the specific project proposals. They are in effect operating, monitoring and supervising their own activity.

The Voluntary Initiative has been criticised by the House of Commons Environment, Food and Rural Affairs Committee because the VI's targets for crop management plans and water quality were not sufficiently challenging. The Committee was also concerned that the Department for Environment Food and Rural Affairs was not only unable to provide assurances of environmental benefits from the VI, but appears to have had little confidence in the usefulness of the research it commission to provide tools for this assessment (House of Commons, 2005).

7.8. Public interest NGOs

A number of public interest non-governmental organisations (NGOs) have been involved in the pesticide debate since the early 1980s. The Pesticide Action Network (PAN) UK has campaigned against a number of hazardous individual pesticides including: paraquat, lindane and endosulfan. PAN is heavily involved in all the issues raised in this paper, and all the stakeholder groups and discussions. They have developed a Pesticide Use Reduction Policy for the UK and for Europe, which incorporates policy options for removing the hazards posed by pesticides. PAN UK hosts PAN Europe, a network of like minded groups and individuals campaigning against pesticide problems (see www.pan-uk.org). PAN's advantage was that is was a single issue group was that limited resources could be devoted to covering a technocratically complicated issue such as that posed by pesticides. Friends of the Earth (FoE) in London, on the other hand, had high-profile periodic pesticide campaigns which it developed, dropped and then re-visited, as other campaign priorities in other areas emerged.

Friends of the Earth have particular interests in pesticide residues in food. They are members of the VI Steering Group, and are actively involved in PAN Europe networking.

RSPB's main interest involves the biodiversity and environmental impacts of pesticides. RSPB is a member of the Pesticides Forum, VI Steering Group. There are a number of studies which suggest that pesticide use is leading to a decline in certain bird populations (RSPB, 2005, Campbell and Cooke, 1997). The Soil Association is increasingly interested in pesticide issues. Historically, as organic protagonists, they have avoided the pesticide debate because organic farming avoids using synthetic pesticides. Women's Environmental Network has been involved in the campaign against the use of lindane. World Wide Fund for Nature (WWF) do not work directly on pesticides issues, but have a particular concern about pesticides that are suspected of being endocrine disruptors, and pesticides that accumulate in the human body.

The main unions with an interest in pesticide human health issues are the Transport and General Works Union (TGWU), UNISON and the GMB. Their members represent workers who use pesticides professionally. The agricultural section of the TGWU has worked with public interest NGOs on pesticide campaigns. It has been involved in initiatives to reduce pesticide use going back to the 1980s (Cook and Kaufman, 1982).

In 2005, DEFRA/PSD published draft National Pesticide Strategy for consultation among stakeholders. It was produced as a national response to the EU thematic strategy on pesticide use (see above). PAN UK has produced a Pesticide Use Reduction Policy for the UK (PURE UK) which could form the basis of a National Pesticide Strategy. The policy would require the government to:

- minimise the hazards and risks to health and environment from pesticides;
- improve controls on the use and distribution of pesticides;
- reduce the levels of harmful pesticide active ingredients, in particular by replacing the most dangerous with safer alternatives (including non-chemical);
- encourage low-input or pesticide-free crop production;
- establish a transparent system for reporting and monitoring progress including the development of appropriate indicators;
- adopt mandatory use reporting systems co-ordinated centrally.
- The proposed PURE-UK has five key elements: production of a UK pest management review; the development of alternatives; systematic data analysis and information collection; regulatory development; and funding change.

7.9. *International perspective*

At the global level, the World Health Organisation (WHO) and the Food and Agricultural Organisation (FAO) have involvement in pesticide standard setting, especially in relation to pesticide residues in food. The WHO has periodically produced data on global estimates of pesticide poisoning (see Vol. 1, page 146) (WHO, 1973, WHO, 1990). As a result of the global nature of pesticide development, trade, supply, use, many in the food supply chain have to act at the global level.

The big multinational pesticide companies sell their products in many countries across all continents. This has presented human health and environmental problems due to the poor conditions of use in developing countries (Weir and Schapiro, 1981, Bull, 1982, Dinham, 1993, Hough, 1998, Hough, 2003, Pretty, 2005). Because the problems are global, it is in the interest of public interest Non-governmental organisations to operate at a global level, (as well as regional, national and local). Examples of this include the Pesticide Action Network Dirty Dozen campaigns which started in the 1980s, calling for the banning of the most hazardous pesticides.

The FAO has adopted a number of measures to reduce the health and environmental hazards caused by pesticides and established principle concerning the export and sales of pesticides international trade in pesticides. This has been done through the Rotterdam Convention which provides legally binding obligations for the implementation of the Prior Informed Consent process. The Convention promotes the exchange of information if, amongst other criteria, in the international trade in pesticides is the chemical in question is banned or severely restricted in the exporting country.

Disposal of pesticides is another area where there has been global and regional networking. The FAO has a disposal programme that involves the World Bank, pesticide industry, national governments and the NGO sector. This is relevant because in this particular case, the pesticide paradigm does not impede the network because the main objective is to disposal of toxic chemicals, whether or not pesticides should be used as part of conventional agriculture. There are no fundamental stumbling blocks, so in this case the network works relatively well. The main stumbling blocks are more practical in terms of finding the high level of resources required to fund disposal.

Maximum residues limits are set at the national level, or for Europe at the EU level, the United Nations CODEX Alimentarius Commission has an important role in setting international standards for pesticide residues in food. The Joint Meeting of Pesticide Residues (JMPR), organised by the Food and Agriculture Organisation and the World Health Organisations was set up in 1963 and produces toxicological evaluations of pesticide active ingredient. These include toxicological end-points such as acceptable daily intakes (ADIs) for active ingredients. The JMPR was set up to address consumer health concerns and to support free trade.

7.10. European Union

As with many other national issues, UK policy and the regulation of pesticides are increasingly being addressed at the European level. The evaluation and authorisation system of pesticide active ingredients in the UK, and the other Member States, is gradually being taken over by the European Union through the adoption of Directive (91/414). Individual Member Sates are required to amend their national legislation in order to meet the requirements of the directive. In the UK, for example, this has been achieved through the Plant Protection Products Regulations (2003) under which, at some (as yet unspecified) time in the next decade, all agricultural pesticides will be regulated. At present a dual member state/EU system operates. The European Commission is also guided by expert committees that come under the European Food Safety Agency. Expert risk assessment advice for pesticides is provided by the Panel on Plant Health, Plant Protection Products and Their Residues in a similar (but not identical) way that the Advisory Committee on Pesticide (ACP) operates in the UK. The link between the EU and Member Sates is provided by the Regulatory Committee of the Standing Committee on the Food Chain and Animal Health (SCFCAH) which is made up of representatives of the EU Member State. It is this committee which makes the final binding decision of pesticide active ingredient authorisation across the EU. Although the decisions are made through the EU mechanisms, the Member States still have collective power through the SCFCAH. Pesticides are a small part of the committee's work which in total covers the whole of the food chain. Although Member States have voting powers, individually they are only one of 27 Member States who have weighted authority, based on the relative size of their country. In recognition of the role of EFSA, European network governance has evolved including the pesticide stakeholders.

From 2003, the European Food Safety Authority (EFSA) has an increasingly important role carrying out pesticide risk assessment for the European Union. It is a relatively new agency whose primary responsibility is to provide independent scientific advice. It has the specific task of carrying out the risk assessment of pesticide active ingredients for the European

Community. The European Commission (DG SANCO) has retained the task of risk management (of EFSA pesticide active ingredient risk assessments). The separation of risk assessment and risk management came about because of the fall-out from the BSE crisis of the 1990s (Barling et al., 2002).

The EU has responsibility for pesticide approval, residues in food and
The European Union Thematic Strategy on Pesticide Use is driven by the Environment Directorate of the European Commission (European Commission 2002). It calls for Member States to adopt national pesticide plans in order to reduce the risks posed by pesticides. The UK response to this European initiative is outlined in section 6.10.1.

7.11. A summary of emerging pesticide policy initiatives

There are a number of pesticide developments currently being debated by the stakeholder groups mentioned above.

Public interest groups suggest that this can only be done by a fundamental reduction in the use of pesticides. The pesticide industry disagrees, saying that the risks can be reduced through technical means, such as spray operator training and regular 'MOTs' for spray machines. The UK House of Commons Environmental Audit Committee also proposed that the government should urgently prepare a national plan. Pesticide Action Network Europe has proposed the adoption of a Pesticide Use Reduction in Europe (PURE) Directive dealing with "measures for reduction of use and of impacts to health and environment from pesticides" (PAN Europe, 2002). The European Parliament voted in April 2003 for "urgent and mandatory action on pesticide use reduction". Sweden, Denmark and Norway have already introduced successful pesticide reduction strategies.

Since the 1980s, a number of Northern European countries initiated national pesticide use reduction programmes as a political commitment to address the adverse effects of pesticides. The Swedish programme began in 1986, and the Danish one started in 1987, and the Netherlands commenced in 1991. Pesticides sales in Sweden dropped by 60% between 1981 and 1985; Denmark had a 59% reduction over the same time, and the Netherlands saw a 50% cut between the 1980s and 2000 (PAN Europe, 2004). Initially these programmes used crude estimates of overall pesticide usage. The assumption is that there will be environmental and health benefits by reducing pesticide use. But there are limitations to this approach because the overall usage levels include data on all the individual pesticides, for which the levels of exposure are not known, and which possess different hazard criteria. Risk is a component of intrinsic hazard and exposure to that hazard. Both the hazard and exposure can vary considerably, and a perverse outcome from reducing the overall use of pesticides could in theory lead to an increase in risk if relatively benign products are reduced in relation to more risky pesticides. There are different types of hazard expressed by different types of pesticide. There may be acute hazards to the operator; it may be a threat to the consumer through residues in food, water or the atmosphere; or it may affect wildlife. Pesticides vary in relation to these properties making it difficult to rank their hazard potential. The relationship between use and risk is important, because pesticide usage data may only be available in crude terms, such as insecticide, herbicide, fungicide etc. Much of the data relates to sales rather than to actual usage by farmers and operators. The Danes have developed a more sophisticated way of measuring cuts in pesticide use through their Pesticide Use Reduction Programme. They have invented the 'treatment frequency index' as an important indicator that calculates spraying intensity and the environmental load for pesticide formulations. The advantage of this index is that it is not dependent on the weight or volume of pesticide applied. This takes account of modern lower dose pesticides, many of which kill pests at lower concentrations compared with older pesticide chemicals (Nielsen, 2005).

7.11.1. UK pesticide policies

In addition to the DEFRA/PSD initiative, the Food Standards Agency has published its independent Pesticide Residue in Food Minimisation Policy (FSA, 2003). It has been criticised by many in the agri-food sector, but supported by public interest groups and the Co-op and M&S. There have been concerns raised by some members of the ACP. The Agency is committed to minimising pesticide residues in food and has developed a detailed action plan to achieve this. The Agency's Board first considered an outline action plan in June 2003. This was developed into a more detailed plan that was approved by the Board in May 2004. The action plan focuses on what the Agency could do to support the food industry in successfully delivering its existing pesticide minimisation initiatives, and to provide the information that the public needs about this issue. The core activities that form the basis of the plan are:

- working with stakeholders, to identify measures that can be taken to provide the information the public needs about the regulatory controls and bodies that currently exist to protect consumer safety;
- drawing together documentation that provides examples of best practice and disseminating it to retailers and assurance schemes. The Agency will work with

stakeholders on ways to measure the uptake of best practice and report back to the Board;

- continuing to work with government departments and non-governmental organisations to promote measures that may minimise residues and meet consumers' preferences;
- exploring options for reducing residues in imported food.

The Agency thinks that encouraging the uptake of assurance schemes, such as the Assured Produce Scheme, is the most effective way of minimising pesticide levels in food. Assurance schemes set good agricultural practice standards for growers. The action plan also suggests that the food industry should take a more pro-active role to inform the public about existing pesticide minimisation initiatives. The practical and economic implications of the Agency's recommendations for individual crops will be carefully assessed to minimise any potential cost implications for stakeholders (FSA, 2003).
Both the Co-op and M&S pesticide policies have received support from public interest groups. One reason for this is likely to be the inclusion of NGOs prior to publication of the policy. Consumer concern regarding the possible impacts of pesticides has driven these retailers to re-think their attitudes towards pesticides use for food production.

Currently the Co-op is reviewing its list of restricted pesticides, focusing on, for example the most commonly found residues, and those pesticide active ingredients with potential for endocrine disruption. This may lead to more restrictions, and the development of alternatives. For example, there is an urgent need for an alternative to carbendazim. It is the most common residue found in testing programmes, though always below the Maximum Residue Limit (MRL). There is also a need for more research into alternatives, led by government and industry. More work is also needed on investigating the cocktail effect, whilst developing countries need help in finding alternatives to pesticides where the MRL has been reduced to the limit of detection. Food production is a global process and, as such, the Co-op believes that the needs of growers must be considered. There is scope for collaboration between government departments, potentially including the Department for International Development, to generate sustainable solutions, and access to the market for small growers abroad (Croft 2002).

Marks and Spencer announced comprehensive changes to its pesticide policy after consultation with a range of stakeholders. From 1 January 2002 farmers supplying M&S from across the world started to phase out the use of 79 pesticides, including many persistent organochlorines and organophosphate nerve poisons. M&S has agreed challenging targets with its suppliers to reduce the incidence of residues in fresh fruit and vegetables from the UK and overseas, and wants to see a decrease in the multiple residues found in some samples (Buffin et al., 2001).

Public interest groups have also attempted to take the initiative and develop their own practical ways of encouraging the reduction in pesticide use. The Safer Alternatives Innovation Forum is public interest driven, with support from some retailers and growers. Pesticide residues are a particular issue that concerns consumers, NGOs, politicians/regulators, retailers and industry. In order to minimise and ultimately eliminate pesticide residues from food, PAN UK has created a Safer Alternatives Innovation Forum (SAIF) which hopes to show practical ways for farmers to deliver a significant overall reduction in pesticide use. The objectives of SAIF are to: establish a progressive forum which will focus on wider stakeholder involvement; prepare practical crop briefings and policy papers on a range of topics; and hold a public meeting to promote SAIF (Buffin 2004).

In 2005, the Royal Commission on Environmental Pollution (RCEP) published a report that recommended restrictions in the way pesticides are used to safeguard the health of those living near to sprayed fields, both to reduce any risk to residents and bystanders and to improve their access to relevant information. The report was written in response to a request from the then Minister for Rural Affairs, Alun Michael, in June 2004, The report was written in response to a request from the then Minister for Rural Affairs, Alun Michael, in June 2004, after campaigning that included the UK Pesticide Campaign. The report addressed the complex and controversial issue – is human health at risk from the use of agricultural pesticides?

The report's chair, Sir Tom Blundell said: "Government policy on exposure of bystanders and local residents is currently inadequate. Although pesticides are heavily regulated by government, there is a significant uncertainty in the science available about whether pesticide spraying can cause ill health and whether some members of the public are being exposed to high enough doses of pesticides from normal use in farming to make them ill." (RCEP, 2005b)

The RCEP identified a number of areas where more information is needed that should lead to improved protection for human health, including which symptoms might be caused by pesticides and whether pesticides are able to drift away from the field into people's property. There needs to be improved investigation of reported ill health by regulators, combined with better observation of the ill health the public are reporting (RCEP, 2005a).

The pesticide industry's response to the environmental threat posed by pesticides has centred on the 'Voluntary Initiative', set up in 2001 as an alternative to pesticides tax. If industry does not self-regulate and deliver, the government will impose a pesticides tax. One of the VI's key projects aims is to reduce herbicide pollution of water in six catchments, and the VI has claimed that it was working (CPA, 2005b). Friends of the Earth disagreed. Their analysis of progress in these catchments shows that it is not possible to attribute changes in pollution levels to the VI; that pollution incidents are still occurring; and that the advice given to farmers in the VI projects is very difficult to follow in practice (FOE, 2004).

Food retailers such as the Co-op has taken on elements of the role previously carried out by government by dictating to their suppliers which pesticides they may not use. This has included pesticides that are considered safe by the UK government. This creates further risks for the pesticide industry.

7.12. Conclusions

This chapter has described the contemporary UK pesticide stakeholders together with the policy areas of their work. The range and number of stakeholders has grown since the 1940s when they represented a smaller group who were largely involved in the productive development and use of pesticides for pest and disease management. This included the regulatory element of the policy stakeholders (pesticide industry, regulator, expert opinion, and the farming community). This grouping is largely as it was, but has had to adapt to the pressures to increased pesticide regulation. In addition to this these stakeholders have had to engage in pesticide policies to reduce the health and environmental effects of pesticides. This has included the government run National Pesticides Strategy and Pesticide Forum and the pesticide industry run Voluntary Initiative.

The stakeholders have worked within these policy frameworks to identify and to overcome the unintended consequences of pesticide use. Adverse effects emerge constantly. The importance of a historical approach is underscored because the pesticide policy parameters of the paradigm are in a constant state of flux, requiring defence and development from within. Their involvement in these policies is to reduce the pressure on the pesticide paradigm which they have to do in a concerted policy forum.

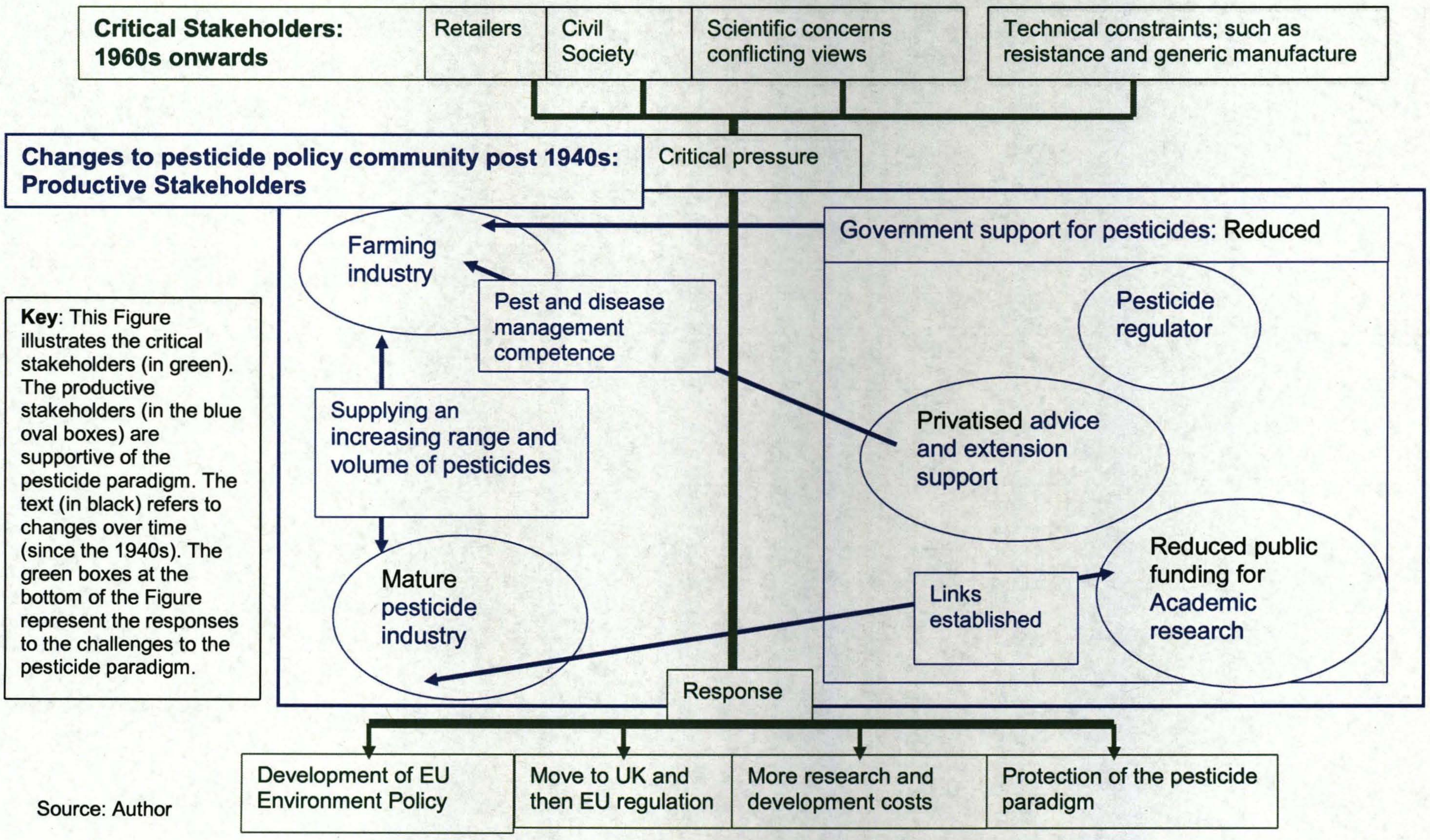
In addition to the regulatory pressures on the pesticide paradigm, there are institutional pressures that have presented their own extra additional challenges. This has occurred through additional non-PSD regulatory involvement from a different perspective and which has increased over time. This includes creation and involvement the Food Standards Agency (with its pesticide residue minimisation policy), the Environment Agency and Natural England. There is also the transfer for PSD as an executive agency of the Ministry of Agriculture Fisheries and Food to DEFRA and the policy implications of that move.

The national regulator PSD has also to work regionally within the EU framework, at the OECD, FAO and WHO. Although at a pesticide policy level strategy is devolved to the national level, as recognised by the EU Thematic Strategy on the Sustainable Use of Pesticides. There is however a potential conflict between the health and environmental effects of pesticides and free trade. National governments may set strict MRLs because of health or environmental protection concerns, but this might then restrict the movement of free trade because other countries or regions cut set less strict levels. This is why there is so much standard setting activity by the food supply chain to gain mutual trading recognition at the regional and international level, especially in the case of pesticide residues in food.

Since the 1960s, critical stakeholders have engaged in the UK pesticide policy arena, as summarised in Figure 7.1. This area has changed since the 1940s version as outlined in Figure 4.2. It is argued here that the critical pressure from these stakeholders has had an impact on the pesticide policy community that has the response (outlined in Figure 7.1) of more regulation, the development of environmental policy and defence of the pesticide policy paradigm. The critical stakeholders have brought their own pesticide policies which conflict with other stakeholder policies. This includes the NGOs, and more recently multiple food retailers. The NGOs conflict with the pesticide industry over the way to reduce pesticide risk. NGOs want to see an overall reduction in use, where as industry maintains that pesticide risk can be reduced without necessarily reducing the overall level of pesticides used. Multiple food retailers have policies which ban the use of certain active ingredients which the UK considers acceptable to use. Private companies would never have worked in this way in previous years. They also have stringent targets for zero residues in the food they sell. Other food supply chain stakeholders and regulators consider this unnecessary because if residues are below the MRL, they-0 are considered by them to be acceptable. But the criteria have changed. They no longer want to sell food containing pesticide residues in food, despite government assurances about safety. In this case safety around MRL and Acceptable Daily Intakes are no longer the issue.

There are multiple pesticide policies in the UK, many of which not mutually exclusive. The UK regulator is developing a pesticide policy which is stakeholder dependent, which weakens it down to the lowest common denominator, or levels where the strongest lobbyists prevail.

Figure 7.1 Post 1980s pesticide policy network



Source: Author