Impact of digital information resources in the toxicology literature

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Abstract
Purpose - The purpose of the study reported here was to assess the degree to which new forms of web-based information and communication resources impact on the formal toxicology literature, and the extent of any change between 2000 and 2005.
Design/methodology/approach - Empirical examination of the full content of four toxicology journals for the year 2000 and for the year 2005, with analysis of the results, comparison with similar studies in other subject areas, and with a small survey of the information behaviour of practising toxicologists.
Findings - Scholarly communication in toxicology has been relatively little affected by new forms of information resource (weblogs, wikis, discussion lists, etc.). Citations in journal articles are still largely to "traditional" resources, though a significant increase in the proportion of web-based material being cited in the toxicology literature has occurred between 2000 and 2005, from a mean of 3 per cent to a mean of 19 per cent.
Research limitations - The empirical research is limited to an examination of four journals in two samples of one year each.
Originality/value - The only recent study of the impact of new ICTs on toxicology communication. Adds to the literature on the citation of digital resources in scholarly publications.
Keywords Toxicology information, Science communication, Scholarly communication
Paper type Research paper

Introduction
The purpose of this study was to assess the extent to which digital information has become significant in the formal scholarly and professional literature of toxicology. More specifically, the interest was not in digital equivalents of printed products - electronic journals, computerised abstracting and indexing services, etc. - but in novel information entities - web pages, email lists, weblogs, wikis etc.

The study follows on from a comprehensive analysis of the communication of toxicology information, and the impact of new ICTs upon it (Robinson, 2002). The study examined the toxicology domain, its information resources and the communication of information and knowledge within it, from a number of perspectives, including: analysis of the nature of toxicology as a discipline and of toxicological knowledge; historical study of the development of the discipline and its information infrastructure; construction of resource lists; bibliometric analyses; quantitative and qualitative evaluation of retrieval systems and services; examination

of vocabularies and terminologies. It was therefore an example of domain analysis, as described by HjÝrland (2002).

Part of this study involved an empirical investigation of the extent and impact of new forms of information resources in the formal toxicology literature in the year 2000. An updating study was performed for the year 2005, to assess developments and changes, and is reported here.

Toxicology and its information resources

Toxicology, the "science of poisons", is concerned with actual and potential harmful effects of chemical substances upon humans and animals. It is a coherent subject in its own right, but overlaps with many other subject areas, especially chemistry, pharmacology, medicine, environmental sciences, and (increasingly) genomics. It thereby has multidisciplinary and interdisciplinary character, and in particular has two main strands: the scientific, by which the mechanisms of toxicity are characterised, and the legislative/regulatory, by which appropriate safeguards of human and animal health are maintained (Robinson, 2002; Gallo, 1996; Koeman, 1996).

Toxicology is a rapidly developing subject with a long history and - not surprisingly, given its wide scope, multidisciplinary nature, and economic, as well as scientific, importance - a rich and well-developed set of information resources (Robinson, 2002; Wexler *et al.,* 2000; Kissman and Wexler, 1983).

Robinson (2002) carried out a compilation of significant toxicology information resources extant around the turn of the millennium, according to a systematic procedure for creating resource lists (Robinson, 2000). Conclusions drawn from this were that the main formal communication systems and resources within toxicology had been little affected by new ICTs, although access to "traditional" resources - journal articles, reports, conference papers, etc. - had been made more convenient by electronic databases and by the Web. The newer forms of communication had had most impact on the area of informal "pre-primary" information transfer.

It is therefore possible to identify toxicological examples of most of the newer forms of resource. Websites predominate, but it is also possible to identify (with one current example shown for each):

- open access internet journals
  Particle and Fibre Toxicology
  http://www.particleand fibretoxicology.com
- metasearch engines for toxicology material
  ToxSearch (National Library of Medicine, Washington DC)
  http://toxsearch.nlm.nih.gov
- web rings
  Forensic Entomology web ring
  http://nav.webring.yahoo.com/hub?ring=forent&list
- web logs
  The Toxicology Weblog (Walther-Straub Institute, Munich)
  http://radio.weblogs.com/01002537
- electronic discussion lists

toxlist listserv (Syracuse Research consultants)
http://syracuseresearch.com/esc/tox-toxlist.htm

- wikis
  Chemical Safety page (Chemical Information Sources wiki, Indiana University)
  http://cheminfo.informatics.indiana.edu/cicc/cis/index.php/Chemical_Safety
- internet portals
  ToxIndex: internet toxicology portal (Soteros Consultants Ltd.)
  http://www.toxindex.com
- public information portals
  Toxicology Source (Cambridge Toxicology Group consultants)
  http://www.toxicologysource.com

The purpose of the study reported here was to assess the degree to which these new forms of resource impacted on the formal toxicology literature, and the extent of any change between 2000 and 2005.

Impact of e-resources: citation study

To assess the impact of new types of information resources, samples of the toxicology journal literature were examined. Reference to new information items might be made in a number of places, particularly as entries in a cited references list, or as footnotes, or parenthesised items in the text; and its citation might be done in many ways (Bird and Casserly, 2003). For these reasons, it was decided that no automated method would be reliable and a set of journals would have to be examined cover-to-cover. This would also allow elements such as instructions to authors to be examined.

This follows the methodology used by other studies of the citation of electronic sources in library/information science journals (Zhang, 1998, 2001; Vaughan and Shaw, 2003), in conference papers in information science (Maharana *et al.*, 2006), and in electronic journals in a variety of subject areas (Herring, 2002). One distinction is that these studies considered all electronic formats, including e-journal articles, while this study focused on novel forms of communication.

Four scholarly/professional journals with a strong toxicology focus were chosen:

- *Toxicological Sciences* (formerly *Fundamental and Applied Toxicology*): a US journal, with a strong academic bias, and coverage of all aspects of toxicology.
- *Human and Experimental Toxicology*: a British journal, emphasising experimental toxicology studies.
- *Archives of Toxicology*: a European journal, emphasising mechanistic aspects.
- *Veterinary and Human Toxicology*: a US journal, with a "practitioner" focus, emphasising clinical treatment of poisoning.

These four journals, because of their various national origins and emphasis on different aspects of the subject, give a good representation of the current journal literature.

2000 situation

All the printed issues of each journal published in 2000 were scanned cover-to-cover. The following were recorded:

- total number of significant items - articles, reviews, summaries, commentaries;
- number and percentage having any reference, in any form, to novel digital information formats.

Then, only for those articles having some reference to digital information:

- total number of references, and percentage of digital items.

Web resources were sometimes mentioned in the text of an article, sometimes in the reference list, and sometimes both, with no clear rationale. For consistency, those mentioned in the text were treated as additional references in the counts.

The results are shown in Table I.

Take in Table I. Reference to novel information formats in the toxicology literature in 2000

The results in Table I show the very limited penetration of novel information formats into the toxicology literature in the year 2000. Less than 5 per cent of the articles in any journal had any reference to such a format; and even in those articles which did make such a reference, less than 10 per cent of the references were of this form in all cases. The overall penetration of these novel information entities, at that time, was very small.

All of the digital items found were web pages. (The only other "contenders" were two Hazardous Substance Databank records, and a substance directory on CD-ROM, all from *Veterinary and Human Toxicology* - these were not included, as being digital counterparts of printed resources.) They were largely used to reference governmental agency material, particularly from the US sources such as the Environmental Protection Agency, National Institutes of Health, Food and Drug Administration and National Toxicology Program, and from the European Commission. Other references were to commercial data sources, and to statistics from groups such as the American Heart Association.

The great bulk of references were to "traditional" information sources: largely journal articles, but also books, reports, conference proceedings, patents, theses, etc. Some of the reports, from government sources, would have been likely to be available on the Web, but only the address of the issuing agency was given. Similarly, the "methods" sections of many papers described equipment, laboratory supplies, methods, etc., identifying these by the name and postal address of the organisation, as required in the journal's "instructions to authors"; it is likely that many of these organisations would have had a web presence by that time, but this form of reference was not used.

Personal communication was described as such, as a reference or an acknowledgement; it is likely that much of this might take the form of e-mail material, but this was not made clear. Similarly, "data on file" or "unpublished data" were a

common form of reference, without any example of this being made available electronically.

The small extent of referencing of digital formats in 2000 is perhaps surprising, in view of the apparent eagerness of some of these journals at that time to embrace new technologies. *Toxicological Sciences*, for example, urged its readers to visit its website, and to utilise its online versions. Its authors had to submit electronic forms of manuscripts, and to give an e-mail address for correspondence (though only one author added a personal web-page address). However, this enthusiasm for technology in producing and delivering the product did not appear to have affected the nature of the scientific record itself, even in this journal, which was more advanced in its adaption to the Web environment than the other three.

2005 situation

To assess the changes which had come about over a time period which saw a greatly increased adoption of the Web as an information environment, the process was repeated for publications in the year 2005. *Veterinary and Human Toxicology* ceased publication at the end of 2004 - due to cutbacks in educational funding in the USA, and withdrawal of support by the sponsoring academic institution (Robertson, 2004) - and therefore the 2004 issues were used for this journal.

Toxicological Sciences was available only in e-journal form at the study location (British Library, London), and was examined in this format; printed issues were used for the other three journals. Scanning, of the kind which formed the basis for this study, was easier in print format. Carrying out the equivalent examination of the e-journal was more time consuming and prone to error, because of the journal's tendency to "hide" some material in supplementary sections, for which additional windows had to be opened. The search facility was used as an adjunct to "eye balling", to minimise the possibility of overlooking references in the text.

It was clear that, in the 2005 sample, some materials available on the Web (e.g., substance data or regulatory reports) were cited as digital items, with a web address, by some authors and not so by others. In this study, the former were treated as digital citations, and the latter were not. This was for two reasons. It was not possible to be sure whether those authors who did not make any mention of the Web resource had used the material in digital form, or were aware that it was available in this way. In any event, the purpose of the study was to assess the impact of web resources into the scholarly literature, and if they were not cited as such then their impact must be nil. The results, in the same form as for 2000, are shown in Table II.

Take in Table II. Reference to novel information formats in the toxicology literature in 2005

Between 2000 and 2005 (2004 for *Veterinary and. Human Toxicology*), the percentage of items with digital references increased for all four journals, from a mean of 3 per cent to a mean of 19 per cent. Increases for individual journals were between a factor of 6 and 14. The greatest extent in 2000 was 4 per cent, while in 2005, the minimum was 10 per cent, while the maximum was 24 per cent.

The percentage of digital references, in those items which had any, also increased, though not by so dramatic a factor, from a mean of 5 per cent to a mean of 8 per cent: the maximum percentage for any one journal increased from 8 per cent to 11 per cent.

This shows that the citing of some new forms of resources became much more widespread through this period: although four out of five articles taken over the four journals still cited only "traditional" resources by the end. The extent to which such new resources were cited grew more slowly: only for one journal was more than one in ten citations to a new form of resource. This indicates that, despite an increasing recognition of web-based resources, their penetration into the scholarly and professional literature of toxicology is limited.

A wider range of material was included, compared with the 2000 situation, which could be categorised as follows:

Regulations and guidelines	15%
Substance data	15%
Laboratory procedures and methods	12%
Unpublished data and reports	12%
Official bodies and programmes	11%
Genomic data sources	10%
Data analysis techniques and software	8%
"General" information	5%
Laboratory facilities and equipment	4%
News and announcements	3%
Nomenclature and terminology	3%
Images	2%

All of this variant material was present on web pages. No mailing lists, discussion forums, personal email messages, weblogs, wikis etc. were cited at all.

The largest contributions (15 per cent of the total) come jointly from national and international legislation, regulations and guidelines relating to toxic materials, and to chemical and biological hazards, and from the extensive files of data on toxic and potentially toxic substances maintained to support such regulation. These form the regulatory background to the largely scientific and medical studies reported in the four journals. Coming from bodies such as US National Institutes of Health, the US Food and Drug Administration, the European Commission, and the Organisation for Economic Co-operation and Development, they are now largely communicated through the Web. Web-based information on these bodies themselves, and their various programmes, accounts for 11 per cent of the total.

The next largest contributions (at 12 per cent) include descriptions of a variety of laboratory and environmental methods, procedures and "good practice guidelines" (with descriptions of laboratories themselves, and laboratory equipment and materials adding another 4 per cent), and also a variety of unpublished reports, bibliographies and data compilations. Web-based data sources in genomics - a type of resource which has gained greatly in importance since 2000 - amount for 10 per cent, largely in

the more "academic" *Toxicological Sciences* journal. Standards and software for data analysis and statistical reporting account for 8 per cent of the total.

"General" information covers 5 per cent of the total, coming largely from the practitioner-oriented, and rather eclectic, *Veterinary and Human Toxicology* journal. This includes a wide variety of topics and materials, including census data, prescribing data, information on pet keeping, the metal composition of coinage, and encyclopaedia articles on a variety of subjects.

Smaller coverage goes to web-based image resources (generally for pathology images), terminology, nomenclature, and definitions of terms and concepts, and news items, press releases, and announcements from a variety of sources.

In summary, it can be said that the Web is now becoming a widely-used - though by no means universal - way of communication of information of relevance to toxicology in the form of what has traditionally been described as "grey literature". It is also becoming significant for data on substances, whether this is toxicological, physical, chemical or economic and use data. This, in effect, gives more convenient access to well-established types of information resources, which would hitherto have been accessible only on paper, or through proprietary computer databases.

There was no evident relationship between citing of digital resources, and the particular subject of the article, national affiliation of authors, etc. Citing was most commonly a small number of items per article, though two articles (dealing with the general topic of allergy and with legal and regulatory issues, respectively) each cited over 30 such resources.

There is no indication here that newer forms of communication - weblogs, wikis, discussion lists etc. - are playing any role in this formal communication of toxicology knowledge.

The journals themselves had generally adapted to a web environment to a greater extent than in 2000, although the instructions to authors still gave no advice on the citation of non-traditional material; the same is true in other subject areas (Bird and Casserly, 2003). All except *Veterinary and Human Toxicology* had an electronic version alongside print, operated through a journal web page, gave author emails for all articles, offered links to references through CrossRef, Medline, etc., provided DOI identifiers for articles, etc.

Veterinary and Human Toxicology appeared rather different in nature, deliberately espousing a "magazine-like" printed format, with a good deal of non-scientific content, including job advertisements, announcements of meetings, opinions columns, and cartoons and jokes; the latter often with little obvious relevance to toxicology. This format, deliberately designed to be accessible to professional readers, especially those whose first language is not English (Robertson, 2004), might seem to lend itself to inclusion of more web-based material. It is ironic to note that the last issue of this journal before it ceased publication had an unusually high proportion of digital citations, and intriguing to speculate how this might have developed had publication continued.

Discussion

These results are generally in accordance with those of earlier studies of the citation of e-resources, albeit in other subject areas. These found an initial very small impact of e-citation (Zhang, 1998), increasing somewhat with time (Zhang, 2001, Herring, 2002), to a level equivalent to print sources (Vaughan and Shaw, 2003, Maharana *et al.*, 2006). It should be noted that these studies included resources such as journal articles in electronic form, which were not included here, and that they focused on citing sources published in e-journals themselves, or on the information science subject area: both factors likely to promote e-citation. That being so, the rather higher rates of e-citation, e.g., 35 per cent (Maharana *et al.*, 2006) and 26 per cent (Herring, 2002) seem generally comparable to the mean 19 per cent found here for the 2005 case.

They are also in accordance with the findings of researchers who have carried out extensive longitudinal studies of, largely American, scientists and technologists (Tenopir and King, 2000; King and Tenopir, 2001). While ICTs are used for many purposes, especially for informal communication, the traditional journal is still the overwhelmingly important medium for presentation of substantive information.

It is also noticeable that very few "Internet journals" with toxicology content can be identified, compared with the many still current in printed (and, in some cases, also electronic) form (Robinson, 2002), confirming the view that even peer-reviewed e-journals have had limited impact (Harter, 1998). Robinson (2002) identified only two such journals relevant to toxicology: *Internet Journal of Medical Toxicology* and *Internet Journal of Forensic Medicine*. In the intervening years, *Internet Journal of Medical Toxicology* has ceased publication, while four others have been started: *Internet Journal of Toxicology*, *Journal of Toxicological Sciences*, *Journal of Occupational Medicine and Toxicology*, and *Particle and Fibre Toxicology*. All are open access journals, available in electronic form only. Their initiation may indicate a move toward this form of resource for toxicology, but should be set against the large number of "conventional" journals in the field, over 70 being identified in Robinson's 2002 study.

Further verification of the low impact of new communication tools is given by a small survey of practising toxicologists carried out in mid-2005, as part of a Masters Dissertation project (Papageorgiou, 2005). Twenty-nine responses were received from 63 members of American and British toxicology associations who were asked to complete a short questionnaire on their information behaviour. The relevant results were:

- printed and electronic journal, and computerised databases, are used frequently by virtually all;
- websites and email messaging are used frequently by virtually all;
- a majority made some use of discussion forms and mailing lists;
- very few made any use of weblogs, wikis, portals, or instant messaging/chat.

Accepting the small sample, this confirms that reliance is still on the "traditional" forms of communication (journals, data collections), albeit facilitated by electronic access, that the Web and email are used for informal communication, and that the newer forms of resource have made little impact.

Conclusions

The formal communication system of toxicology has been little affected by new forms of information resource. Reliance is still placed on the "traditional" journal article, with citations largely to other "traditional" resources, though these may now be accessed electronically rather than in print form. A noticeable increase in the proportion of web-based material being cited in the toxicology literature has occurred between 2000 and 2005.

References

Bird, J.E. and Casserly, M.F. (2003), "Web citation availability: analysis and implications for scholarship", *College and Research Libraries*, Vol. 64 No. 4, pp. 300-317.

Gallo, M.A. (1996), "History and scope of toxicology", in Klaasen, C.D. (Ed.), *Casarett and Doull's Toxicology: The Basic Science of Poisons*, McGraw Hill, New York, NY, pp. 3-11.

Harter S.P. (1998), "Scholarly communication and electronic journals: an impact study", *Journal of the American Society for Information Science*, Vol. 49 No. 6, pp. 507-516.

Herring, S.D. (2002), "Use of electronic resources in scholarly electronic journals: a citation analysis", *College and Research Libraries,* Vol. 63 No. 4, pp. 334-340.

HjÝrland, B. (2002), "Domain analysis in information science: eleven approaches - traditional as well as innovative", *Journal of Documentation*, Vol. 58 No. 2, pp. 422-462.

King, D.W. and Tenopir, C. (2001), "Using and reading scholarly literature", *Annual Review of Information Science and Technology*, Vol. 34, pp 423-477.

Kissman, H.M. and Wexler, P. (1983), "Toxicological information", *Annual Review of Information Science and Technology*, Vol. 18, pp. 185-230.

Koeman, J.H. (1996), "Toxicology, history and scope of the field", in Niesink, R.J.M., de Vries, J. and Hollinger, M.A. (Eds), *Toxicology: Principles and Applications*, CRC Press, Boca raton FL, pp. 3-14.

Maharana, B., Kalpana, N. and Sahu, N.K. (2006), "Scholarly use of web resources in LIS journals: a citation analysis", *Library Review*, Vol. 55 No. 9, pp. 598-607.

Papageorgiou, I.V. (2005), *Information Resources in Toxicology*, unpublished MSc dissertation, Department of Information Science, City University London.

Robertson, W.O. (2004), "V and HT's future - like all futures - remains uncertain", *Veterinary and Human Toxicology*, Vol. 46 No. 6, pp. 352-353.

Robinson, L. (2000), "A strategic approach to research using Internet tools and resources", *Aslib Proceedings*, Vol. 52 No. 1, pp. 1-19.

Robinson, L. (2002), *Toxicology Information and Knowledge: The Impact of New Information and Communication Technologies*, unpublished doctoral thesis, University College London.

Tenopir, C. and King, D.W. (2000), *Towards Electronic Journals: Realities for Scientists, Librarians and Publishers*, Special Libraries Association, Washington DC.

Vaughan, L. and Shaw, D. (2003), "Bibliographic and web citations: what is the difference", *Journal of the American Society for Information Science and Technology*, Vol. 54 No. 14, pp. 1313-1322.

Wexler, P., Hakkinen, P.J., Kennedy G. and Stoss, W. (Eds) (2000), *Information Resources in Toxicology*, 3rd edition, Academic Press, London.

Zhang, Y. (1998), "The impact of Internet based electronic resources in formal scholarly communication", *Journal of Information Science*, Vol. 24 No. 4, pp. 241-254.

Zhang, Y. (2001), "Scholarly use of internet-based electronic resources", *Journal of the American Society for Information Science and Technology*, Vol. 52 No. 8, pp. 628-654.

Table I. Reference to novel information formats in the toxicology literature in 2000

	All journal issues			Articles with digital refs		
	Items	with digital refs.	%	Refs	Digital refs.	%
Tox. Sciences	297	13	4	611	28	5
Hum. Exp. Toxicol	94	1	1	38	2	5
Arch. Toxicol.	111	1	1	45	1	2
Vet. Hum. Toxicol	86	2	2	39	3	8

Table II. Reference to novel information formats in the toxicology literature in 2005

	All journal issues			Articles with digital refs		
	Items	with digital refs.	%	Refs	Digital refs.	%
Tox. Sciences	322	76	24	3370	238	7
Hum. Exp. Toxicol	87	12	14	879	95	11
Arch. Toxicol.	92	9	10	302	14	5
Vet. Hum. Toxicol	103	15	15	259	26	10