Information literacy skills are required in finding reliable toxicological information resources

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Abstract
Chemicals are a part of modern life, but they are potentially hazardous. Consumers, regulatory authorities, information specialists, researchers, students, and toxicologists need access to evidence-based safety information about chemicals either in their ordinary life or in their work to protect their own health, that of other co-workers and ultimately the environment in which we all live. The most important open sources of safety information are databases such as PubMed and PubChem and open access scholarly journals, as well as websites of regulatory authorities and research institutions. This paper discusses the need for toxicological information literacy and its contents for all to identify reliable information. Reliable open access sources for toxicological information of chemicals are also provided.

Key words: *chemical safety; hazardous substances; public health; information literacy; access to information.*

Introduction

Our contemporary society would not be possible without the use of chemical substances. They are used in endless ways: to make plastics and all kinds of items, as food additives, as ingredients in cosmetics, as pesticides and in pharmaceutical preparations to mention but a few possible applications. The use of chemicals may pose health effects; hence it is necessary to study the chemicals in a toxicological perspective (1).

The word "toxicology" stems from the Greek word *toxikon* meaning a poison arrow. Initially toxicology was the study of poisons only (2). This evolved gradually to a modern science dealing with harmful effects of chemical and physical factors to living organisms. It secures safe use of chemicals. Today toxicology builds upon the most branches of biological and physical sciences such as biology, chemistry, molecular biology, public health, and engineering (3).

The need for chemical and toxicological information has increased, and the Internet is likely today's choice to find such information. As it is known, the quality of information on the Internet in general is questionable (4, 5). Many of the best sources of chemical information are available only by subscription. Numerous potential information users outside subscribing organizations are left empty-handed. The current open access movement is changing this slowly but steadily, see for example (6). The aim of this article is to discuss the toxicological information needs and toxicological information literacy of different groups of people. We also list reliable open access toxicological information resources.

Toxicological information users and their needs

There is a wide spectrum of ways that toxicological information is available, from original data of toxicity tests and scientific experiments to scientific papers, reports of expert authorities, instructions, safety data sheets, hazard and precautionary statements extending to the pictograms on the packaging of the chemical (to the public in their everyday life). The types of toxicological information and diversity of information sources pose challenges for students and experts (3). Urgent information is needed when an exposure to harmful chemical or poisoning has or is suspected to have taken place.

Students and teachers

Commonly, toxicological education begins in secondary school or in high school, preferably as a part of science or health education lessons. The information taught

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must be easy to understand and compatible with the students' anticipated interests and experiences. These kinds of topics include the hazards of smoking, alcohol, illicit drugs and environmental pollutants (7-10). Pupils in primary school should be familiarized with very hazardous chemicals, toxic plants, and animals.

At the university level, toxicology is taught as a part of pharmacy, medicine, or environmental health studies. Some universities also offer specialized toxicology education, such as the master's degree programmes in toxicology or PhD programmes in toxicology. It is essential that students taking toxicology courses should have good information literacy skills – it is a basic requirement for effective and active learning. These skills also need continuous improvement. The amount of information is expanding exponentially, and information technology is continuously evolving.

Important aspects of teaching information skills are academic publishing, sources of scholarly information, searching techniques, ethical issues, and presentation of the information. Productive collaboration between the library and the faculty has been proven to be beneficial in teaching and learning these skills as well as promoting the maturity of students into fully information literate persons (11-13).

Researchers and professional toxicologists

It is anticipated that toxicology researchers will have gained basic information skills before embarking on an academic career or employment in the enterprises producing or testing chemicals. However, there are areas such as open science, research data management and presentation skills where updated knowledge is needed. Scholarly publishing is being transformed from a traditional printed format to an open access model, both use peer review as the quality control. It is necessary to be aware of reliable open publishing channels in one's own discipline and how to deal with article processing charges. Data management planning and issues related to data storage and making data open may also raise questions. It is important that skills are updated and modern techniques such as chemical structure searching are put to effective use. Selected high quality open access databases are listed in *Table 1*.

Name	URL	Content
DOAJ	https://doaj.org/	Peer reviewed scholarly journals and articles.
PubChem	https://pubchem.ncbi.nlm.nih.gov/	Chemical information such as properties, biological activities, safety, and toxicity available in organized form. Structure based search possible.
PubMed	https://pubmed.ncbi.nlm.nih.gov/	Citations for biomedical and life sciences literature including full text links to selected free articles.
PubMed Central	https://www.ncbi.nlm.nih.gov/pmc/	Full-text archive of biomedical and life sciences journal articles.

Table. 1. *Selected high quality open access databases providing chemical and toxicological information mainly for students and researchers (3, 14, 15).*

Regulatory authorities and decision makers

The regulation of chemicals by society is based on two aspects. First, evidence based scientific knowledge about the effects of chemicals constitutes the foundation. Second, chemical legislation legitimizes the imposition of regulatory measures. However, the legislative process is not based on only the available scientific information. It is a political decision involving different stakeholders and often conflicting interests (16, 17). This can be seen clearly when decisions are made on locating new industrial plants that generate pollutant emissions. Industrialists are concerned with the new plant's financial prospects whereas politicians are interested in other issues such as employment and support to the economy. In contrast, environmental activists emphasize the detrimental impacts of the putative man-

ufacturing plant's emissions and its effects on the natural environment and human health, see e.g., case Finnpulp (18). The decision whether to build the plant must be based on a procedure that strives to reconcile these different interests.

Regulatory authorities must have a good knowledge about the appropriate legislation but also about updated scientific issues on a level applicable to their regulatory work (19-21). They produce – in collaboration with specialized toxicology experts – reports about the safety of chemicals and evaluate authorization applications of chemicals.

The authorities also create information packages and maintain websites about chemical and toxicological properties of chemicals (*Table 2*). One could say that they act as safety information brokers and disseminators.

Name	URL	Content
American Association of Poison Control Centers	https://www.aapcc.org/	Representative of US poison centers.
eChem Portal	https://www.echemportal.org	Portal to sources of chemical information.
European Association of Poison Centres and Clinical Toxicologists	http://www.eapcct.org/index.php?page=links	Links to poison centers in several countries.
European Chemicals Agency (ECHA)	https://echa.europa.eu/	Chemical information and regulation of chemicals in the European Union.
European Food Safety Authority (EFSA)	https://www.efsa.europa.eu/	Food-related risks and food safety.
European Medicines Agency (EMA)	https://www.ema.europa.eu/en	Regulation of human and veterinary pharmaceutical and herbal products in the European Union.
European Monitoring Centre for Drugs and Drug Addiction	https://www.emcdda.europa.eu/	Information on illegal drugs in Europe.
Food and Drug Administration (FDA, USA)	https://www.fda.gov/home	Regulation of foodstuffs, pharmaceutical products, medical devices, and tobacco in the USA.
International Chemical Safety Cards	https://www.ilo.org/dyn/icsc/showcard.home	Health and safety information on chemicals, especially for the workplace and emergency services.
National Institute of Alcohol Abuse and Alcoholism	https://www.niaaa.nih.gov/	Information about alcohol.
National Institute of Environmental Health Sciences (NIEHS, USA)	https://www.niehs.nih.gov/	Information on the effect of the environment and environmental hazards to people.
National organizations of different chemicals	URLs in (14) or can be searched from the Internet: https://www.chemsafetypro.com/	General and national specific information about chemicals.

Name	URL	Content
National Toxicology Program (NTP, USA)	https://ntp.niehs.nih.gov/	Toxicological information about potentially hazardous substances.
Societies of toxicology National, pan-national and global sources	Examples: https://www.toxicology.org/ https://www.iutox.org/	Collaboration between scientists. Discussions. Scientific meetings. Member societies.
Stockholm Convention	http://chm.pops.int/	Information on Persistent Organic Pollutants (POP). Includes also links to Basel Convention (hazardous waste) and Rotterdam Convention (substances of Prior Informed Consent / importing of hazardous chemicals and pesticides).
US Environmental Protection Agency (US EPA)	https://www.epa.gov/	Information on environmental pollutants and environmental protection.
World Health Organization (WHO)	https://www.who.int/	Global perspective: chemicals, alcohol, tobacco, biological weapons, air pollution.

Table. 2. *Selected high quality websites of recognized operators providing information about all chemicals (3, 14).*

Chemically risky occupations

Many workers in several occupations are potentially exposed to hazardous chemicals (22). Ideally these chemicals should be replaced with less harmful alternatives or preferably completely safe alternatives. Since often this is not possible, the workers and their superiors need to be aware of the toxic properties of chemicals. The management and lower-level supervisors must encourage workers to avoid personal exposure e.g., by instructing the employees about the risks when handling these substances and what kind of protective equipment they should use. Pictograms, chemical labels and safety data sheets are used for this purpose. Workers who disseminate safety information among their colleagues play a key role in ensuring the safety of the entire workplace.

Accidents in the transportation of hazardous products pose risks not only to the drivers, but also to the rescue teams and to the environment. Therefore, professional drivers of vehicles carrying such products are trained to understand the chemical labels and the cargo is labeled with pictograms designed by competent authorities (23).

Consumers

The substantial number of chemicals ubiquitous in today's world and the unfamiliarity of the public with scientific terms may raise concerns and even "chemophobia" (irrational fear of chemicals) (24, 25). Scientific journals and databases are not suitable sources of information for lay-persons. The information needs to be edited and simplified to a level where it can be understood without an academic background; this can involve the preparation of safety data sheets and international chemical safety cards.

While Internet search engines like Google and webpages like Wikipedia are commonly used, there are well known issues regarding their reliability. The internet is a huge virtual universe of material - anyone can publish "findings" without subjecting their data to peer review. Thus, it is amazingly easy to distribute incorrect or falsified information. Without a prior knowledge of toxicology, it is difficult or impossible to discern the difference between jewels and rubbish (4, 5). National and international chemical regulatory authorities maintain websites in their field of operation (Table 2). These websites offer verified information in formats suitable for non-specialists.

Conclusions

The present Internet environment usually confuses links found with the search engines with reliable information

sources. This may lead even to the misconception that all the information listed on the search engines is equally valid and can be used as scientifically based facts and knowledge.

The most challenging aspect in toxicological information literacy is that it also needs an awareness of the basic literacy of several scientific disciplines. One must have a good knowledge of chemistry, biology, biochemistry, pharmacology, pathology, physiology, molecular biology, medicine, public health, and economics. Extra challenge is to make overall picture about information of these specialized disciplines. In addition, toxicologists need to articulate intelligibly and to understand when statistics have been used correctly, have a sound understanding of research practices and a good knowledge about the basic language and symbols needed in discussing about chemical compounds.

This very breadth of the knowledge is also the greatest challenge that information specialist and library work about toxicology must overcome in combatting mis- and malinformation about chemical substances. The library must also be active in disseminating these skills and reliable sources of toxicological information to everyone, not just to one's own students and academics.

At the very least, individuals without good toxicological information literacy skills should not openly counsel people on safety issues surrounding many kinds of chemicals; a life and death matter to humans and the other species with which we share our existence on planet Earth. The libraries have an increasingly important role in actively producing and disseminating reliable and evidence-based information to everyone.

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