Health risks of micropollutants - the need for a new approach
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ABSTRACT

Micropollutants in water provide a challenge to both science and society. The final consideration is to understand whether they are harmful to human health or to aquatic life and to determine what actions should be taken. The numbers of substances that are being identified requires a new approach to risk assessment and to solving the problem based on proper prioritisation of the needs for more targeted and multidisciplinary research delivering high quality data. The concept of threshold of toxicological concern has been applied to food and could usefully be applied to water. However, this approach also needs to be combined with practical and pragmatic assessments of the behaviour of substances in water and their removal by drinking water treatment. Such an approach provides a bridge from problem identification to problem solving.

Key words | micropollutants, risk assessment, threshold of toxicological concern

INTRODUCTION

Water is not only a solvent but also a significant carrier of both natural and anthropogenic chemicals in varying concentrations. The fact that water was one of the main receiving media for the dilute and disperse policy for the disposal of waste, including treated effluent from sewage works attracted interest in the late 1970s as the analytical capability to measure such substances at low concentrations developed. The interest regarding micropollutants in water and drinking water has grown significantly since that time and as analytical capability has increased smaller concentrations of a range of substances have become detectable.

The concern over micropollutants, which are defined as present at a few micrograms per litre or less, but often below a nanogram per litre, has been reflected in the call for information on the implications for health of both humans and aquatic life. In 1984 the first edition of the WHO Guidelines for Drinking Water Quality set health-based guideline values for 13 inorganic substances, of which 5 could be thought of as micropollutants and 18 organic substances, all micropollutants. By the second edition in 1993 there were health-based values for 17 inorganic substances and 75 organic substances. The situation over standards for the protection of aquatic life is very similar.

Since then even more substances have been identified particularly in effluents discharging to surface waters and in surface waters. The numbers continue to increase and the research effort going into identification and analysis is substantial. However, identification only relates to the hazard and does not provide much information with regard to the risks to either aquatic life or humans. The mere presence of a substance or group of substances does not necessarily imply that there is a significant risk. To date most of the efforts to determine risk have related to individual substances and have been significantly constrained by a lack of adequate data on which to base a risk assessment. If the analytical effort is to be of value it must relate to what needs to be done by society, whether this be decision to control discharges or to do nothing. However, the decisions need to be informed by adequate and high quality data if we are to take evidence-based decisions that are part of a wider strategy. If science is to be seen as important in the decision-making process and not to
become irrelevant then new thinking and new approaches are required that will drive change in the way in which research is carried out. There is increasingly a public view that science just identifies problems and always follows this up with demands for more funding to get more information. Scientists should recognise that responsible science that is valued by society needs to not only to identify problems but also develop practical solutions. There is, therefore an urgent need to begin to develop new approaches for determining just how important the risks from micropollutants are and to establish the priorities for controlling micropollutants, bearing in mind that such controls may impact significantly on society and may require further scientific and technological developments in order to minimise the impact of such changes.

THE REQUIREMENTS FOR RISK ASSESSMENT

The process of risk assessment requires that we have a good knowledge of the levels of exposure to a chemical or group of chemicals. However, this needs to relate not just to exposure from one source but all sources and it is important that scientists begin to take a much more holistic approach to exposure assessment. Traditional risk assessment also requires that we have adequate hazard characterisation, the actual effects of a chemical, and the dose response related to those effects. This combination provides the basis for carrying out a risk assessment. In other words we need to know the key toxic effect and the dose response to determine a safe or acceptable level of exposure and we then need to compare this with the actual levels of exposure. In the case of drinking water this must take into account the impact of water treatment and must include an understanding of how drinking water treatment and water supply work.

Unfortunately it is difficult to obtain a suitable assessment of overall exposure, which is compounded by the increasing number of substances being identified and the problems of taking an adequate range of samples. Often it is also difficult to find adequate data on the toxicity and, particularly on the dose response. It is surprising that even a chemical such as fluoride, which has a major impact on health in many parts of the world due to high concentrations in water, has a poorly characterised dose response as identified in the IPCS Environmental Health Criteria document (2002). In contrast many man-made chemicals are well studied because this is part of the requirement for approval for use. This is certainly true of pesticides and, with regard to mammalian toxicology, most pharmaceuticals, even though the data may not be openly available in the literature.

As indicated above, there is also a vital requirement for high quality data. This means that we need to incorporate proper quality control and all research, whether it is analysis or toxicology, should be carried out to the highest standards. This applies to wherever the research is carried out. In turn it requires a level of self-scrutiny that science sometimes finds very uncomfortable and which goes beyond the scrutiny of the peer reviewed publication, which can only go so far with the information made available and the time available to the reviewer.

An additional requirement for risk assessment is that the scientific contribution is completely objective. Scientists are part of society and are influenced by attitudes and values. Sometimes there is a tendency to include value judgements in the reporting of scientific data and in drawing conclusions from that data. On some occasions scientists try and bring greater significance to their work by overstating the potential risks and this is often seized upon by the media resulting in a distorted scientific debate. Equally there are occasions when risks are understated and this too is inappropriate, having the potential to create distrust in science and scientists.

The problems of carrying out adequate risk assessment are also made more difficult by the artificial separation of risk assessment and risk management. The two sides are closely linked simply because the assumptions built into the risk assessment, that are influenced by science policy and belief have such a major influence on the outcome of the risk assessment and will, therefore, also significantly impact on the framework within which risk management decisions are taken.

WHAT NEEDS TO CHANGE

One of the most important areas that results in confusion and misinterpretation of the results of scientific research in
this field is that of understanding the uncertainty inherent in the data. Scientists have generally found communicating, and sometimes understanding, uncertainty in their research. This is often communicated in a very subjective manner, which can be very unhelpful. It is also important to understand where the uncertainty derives from and the reasons for the uncertainty. Such understanding improves the value of the data and helps to identify the requirements for adequate study design. This is the case for both analytical data and for data on toxicity.

The identification of hazards and subsequent risk assessment also requires that scientists embrace a multidisciplinary approach that will result in improved design of studies, which need to become much more systematic if they are to be of real value in assisting society to make the decisions and choices that will result in an improved environment while maintaining the health and well-being of communities. It may be easy to carry out small studies on what are random samples but if the results are to have meaning then it is essential that we are able to put them into an appropriate context. This too implies that there will be a much greater need for collaboration to develop programmes of research, at both a national and international level, which will provide a route to developing solutions as well as identifying problems. However, determination of occurrence and exposure will require consideration of the sources and the potential barriers to a substance reaching humans or aquatic life. This will include the behaviour of a substance in the aquatic environment, including loss of the substance in water, the impact of other substances, such as humic acids, in water that will reduce bioavailability to aquatic organisms and the adsorption to particulate matter and sediment. It will also include removal in drinking water treatment in relation to human exposure. However, it is also important that accurate quantification is also carried out in order to actually characterise exposure.

Scientists seeking funding for more comprehensive programmes of research on exposure to micropollutants or on the health effects are often faced with a circular argument. To justify funding on exposure requires evidence that there is a risk to health or the environment but to justify research on toxicity, which is potentially very expensive and faces limited laboratory resources, requires sufficient evidence of significant exposure. In order to face this problem the implied risks are sometimes overstated on the basis of very limited information or on the lack of information in order to avoid accusations of scaremongering to try and raise funds to support the appropriate research on occurrence and exposure. This justification therefore requires a more structured argument that will inevitably result in prioritisation of the substances of importance.

The concentrations of micropollutants are, by definition, very small. While there is considerable debate over various aspects of the effects of low doses of such chemicals many remain so uncertain as to be speculative at this time. Currently there is no compelling data that suggests any practical way of moving from the view that the dose makes the poison and that the dose response is the key with the effect decreasing in incidence and severity as the dose decreases. The discussions concerning hormesis are interesting but the actual data are mostly controversial. Many regulatory authorities still subscribe to the linear low dose theory for carcinogens by which it is considered that there is a risk, all be it very small, at any dose. However practical this has proved to be there is increasing recognition that there will be a practical threshold to the effects of any chemical as a consequence of detoxification, DNA repair and cell deletion. In addition a number of putative carcinogens have been shown to operate through a mechanism that requires other effects, such as cell toxicity, to occur before the risk of carcinogenicity can be realised. It is also often suggested that the effects of mixtures will be synergistic and that by this means low doses can have a large effect. However, there is little evidence to support this and the primary impact is an additive outcome for chemicals of similar structure and/or mechanism of action.

There has been considerable interest in the toxicology community in the topic of how to prioritise substances for further examination and testing. The methodology that has emerged is that of the threshold of toxicological concern or TTC. This approach is based on determining a dose below which there is reasonable evidence that there will be either no appreciable risk of there being adverse effects on health. While not perfect, it provides a good basis for prioritisation with regard to potential toxins. The concept has been developed to help deal with prioritising the problems associated with low level contaminants in the diet, which is very similar to the position with drinking...
water. The approach may also be applicable to aquatic toxicity but there the role of structure activity relationships is much better developed. The detailed approaches have been published (Kroes et al. 2000; Kroes et al. 2004) and these cover a range of different mechanisms of toxicity. It has been used for establishing priorities for testing and further study of contaminants in food and provides a scientifically based but pragmatic way forward. It has also been suggested as a way forward in determining whether there is a need for more detailed analytical and toxicological data for chemicals that may potentially leach from materials used in contact with drinking water.

The TTC concept addresses chemicals under three structural classes (Barlow 2005):

- Class I. Substances with simple chemical structures and for which efficient modes of metabolism exist, suggesting a low order of toxicity.
- Class II. Substances which possess structures that are less innocuous than class I substances, but do not contain structural features suggestive of toxicity like those substances in class III.
- Class III. Substances with chemical structures that permit no strong initial presumption of safety or may even suggest significant toxicity or have reactive functional groups.

The generic TTCs derived for human exposure from toxicity data are 1.8 mg/kg per person per day for class I, 0.54 mg/kg per person per day for class II and 0.09 mg/kg per person per day for class III. However, a number of groups of high potency carcinogens that can be identified by structural alerts are not suitable for the TTC approach and would be considered separately. These are aflatoxin-like compounds, azoxy compounds, nitroso compounds, 2,3,7,8-dibenzo-p-dioxin and its analogues and steroids. The US Food and Drug Administration (FDA) has also considered this issue and has proposed a threshold of regulation for potent carcinogens of 1.5 \(\mu\)g/day.

With regard to pharmaceuticals there are usually more data available, although often not in the public domain. Here a pragmatic approach would be to prioritise by comparing the highest concentrations detected with the most common daily dose and using a threshold of 100 or 1,000 fold less as a means of determining those that require appropriate attention, although as with other substances there are some that may be less suitable for this approach such as the cytotoxic drugs.

However, an additional step, referred to above would be to consider the removal of the chemical in water treatment. Since water treatment is generally very effective at removing particles the behaviour in the aquatic environment and, for example, factors such as \(\log K_{oc}\) that reflect the potential for a substance to adsorb to particulate matter would be an important consideration.

### REGULATORY CHANGES

WHO has introduced the concept of water safety plans in the third edition of the *Guidelines for Drinking Water Quality*. This approach is now under serious consideration as for wider adoption as a means of assuring the safety of drinking water. It is based on assessing the hazards and risks from source to tap and is designed to take a more proactive approach to drinking water quality. One of the aspects of this approach that has been considered in Europe is how to deal with complex mixtures of substances such as endocrine disruptors. This approach is applied on a supply-by-supply basis and considers the barriers and their effectiveness. In this case different treatments would need to be studied and their efficacy demonstrated. Then means of operational monitoring to demonstrate that the treatment is working efficiently at all times would be developed. Such an approach would replace final water monitoring for a range of difficult to analyse substances but would provide a means of demonstrating safety.

Water safety plans also emphasise the importance of catchment control as a first barrier. With regard to micropollutants this is also important and is even more important when considered alongside effects on aquatic populations. However, catchment control requires that new approaches are taken to controlling discharges of substances and if this is to be achieved without significantly damaging the way in which society works then it will take time. Identification of the most appropriate ways forward, including investment in wastewater treatment is needed as an important part of finding a solution. This is, therefore an important part of the multidisciplinary approach that is needed.
CONCLUSIONS

Micropollutants have been with us for decades against a background of improving water quality and improving human health. If we are to continue the process of improvement then risk assessment for both human health and the health of aquatic ecosystems is an important part of the process. Scientists working in the field of micropollutants have been accused of identifying problems but not being interested in solutions. This perception needs to be changed and, if science is not to be by-passed or discredited in the eyes of society, then scientists must begin to take part in multidisciplinary investigations that are aimed at prioritising and solving the problems. These steps need to address the better characterisation of uncertainty, transparent quality control and better characterisation of exposure. An important part of this process is carrying out risk assessments that will be a key part in identifying priorities and demonstrating where the most important requirements for research lie without presenting an apparent doomsday scenario that cannot be justified if examined logically.

The use of approaches such as TTC and consideration of the behaviour of substances in water provide a pragmatic approach that can lead to problem solving research that will ensure that the importance of science is recognised and that will help to drive the continued improvement in the control of pollution of all kinds, taking a long-term holistic view.

REFERENCES

