

2 General principles and basis for prioritizing chemicals

2.1 Principles for assigning priorities for risk management

The two main criteria for identifying specific chemicals of concern to public health in any particular setting are:

- high probability of consumer exposure from drinking-water
- significant hazard to health.

Chemicals judged to be more likely to occur and to be highly hazardous to human health should be given greater priority for risk management than those judged less likely to occur in the drinking-water and to have lower health hazards. The period of exposure should also be considered, because health effects caused by chemicals in drinking-water generally result from long-term exposure. Few chemicals in drinking-water have been shown to cause acute health problems in the short term, except through intentional or accidental contamination on a large scale. In such instances, the water frequently (but not always) becomes undrinkable due to unacceptable taste, odour or appearance (WHO, 2004).

Risk management strategies for chemicals in drinking-water should also take into account the broader context. For example, if drinking-water is not the main route of exposure for a chemical, then controlling levels in water supply systems may have little impact on public health. Thus, risk management strategies need to consider alternative routes of exposure (e.g. food) that equal or surpass the importance of exposure through drinking-water (WHO, 2004). The management strategies should also consider national and local disease surveillance data, and epidemiological studies (provided that these are available and reliable). Unusual prevalence of certain illnesses in the community (e.g. arsenicosis), may justify an investigation of specific chemicals in drinking-water. Often, disease surveillance data or relevant epidemiological studies are not available at community level; therefore, other approaches are needed. Section 2.2 (below) provides guidance on assigning priorities in situations where data are limited.

Where there are adequate data on drinking-water quality, it may be possible to establish priorities for managing risks due to chemicals simply by studying such data. However, in many locations these data too may be lacking, and limited resources may mean that it is impractical to attempt to conduct comprehensive field studies on a broad range of chemicals in drinking-water. In such situations, it is important to focus available resources on investigations of a limited number of chemicals that are likely to occur in drinking-water at concentrations near or exceeding guideline values. Similarly, any initiatives to build national or local capacity for sampling and analysis through equipment procurement or training should be targeted at chemicals that have been identified as priorities through a methodical desktop analysis.

Priority should also be assigned to chemicals in drinking-water that may significantly degrade aesthetic quality or cause significant problems for the operations and maintenance of water supply systems. While aesthetic considerations may not have a direct impact on public health, changes in taste, odour or appearance of drinking-water may prompt some consumers to turn

to other sources of drinking-water that may be microbiologically unsafe. Similarly, chemicals that cause operational problems, such as corrosion or encrustation of distribution systems, may have an indirect impact on public health by compromising the ability to maintain the water supply.

2.2 Setting priorities with limited information

In many parts of developing countries, and in rural areas of some developed countries, water quality data are limited or nonexistent, as are data on impacts of site-specific health issues due to chemicals in drinking-water. This situation makes it difficult to determine priorities for risk management based on the two criteria outlined above (i.e. probability of exposure and high health hazard). In such cases, the priority for risk management can be determined based on probability of exposure alone. Health-based targets for chemicals (e.g. the guideline values in the *WHO Guidelines for Drinking-water Quality* — WHO, 2004) are concentrations that would generally have a negative health impact if consumed over a lifetime. Therefore, the likelihood of a particular chemical occurring at concentrations that would cause health impacts is the most appropriate indicator that the chemical may be of concern in such situations.

Human exposure to any particular chemical through drinking-water requires a source of that chemical and a pathway from the source of contamination to the consumer. Pathways for transport of chemicals may be through natural features such as aquifers, surface water bodies, soils and rock, or overland flow, or through human-made components of water supply systems.

The concentration of a chemical in water may be reduced before the water reaches consumers — physical, chemical and biological processes may reduce the concentration of particular chemicals between their sources and consumers. For example, human-made interventions, such as drinking-water treatment, are a well-known means of lowering chemical concentrations, and many natural processes will also significantly reduce chemical concentrations in drinking-water (as discussed in Section 2.3, below). Specialized expertise may be needed to rigorously evaluate the effects of such processes in any particular setting, but a general understanding of the processes may enable informed judgements to be made that may be adequate for decision-making purposes. The ability of general and specific water treatment processes to achieve concentrations of chemicals below their respective guideline values is discussed in the *WHO Guidelines for Drinking-water Quality* (WHO, 2004). Where detailed information about reduction in concentration of a chemical as it travels from water source to consumer is lacking, an initial conservative approach would be to assign priority for management of chemicals in drinking-water solely on the likelihood of the occurrence and estimated concentration of those chemicals in a particular setting.

The presence of a particular chemical in drinking-water does not necessarily result in human exposure to a concentration that may cause concern; for example, the concentration of the chemical may be well below the guideline value. Part B of this publication provides guidance on assessing the likely occurrence of chemicals associated with the main sources of chemicals in drinking-water.

Appendix 1 includes a summary of potential sources of all chemicals for which guideline values have been set or considered.

2.3 Factors affecting chemical concentrations along pathways

As indicated above, chemicals that occur within a catchment may not necessarily be present in drinking-water in significant concentrations, because water treatment and natural processes can reduce the concentrations of particular chemicals between their source and the consumer. The principle natural processes involved are discussed briefly below.

2.3.1 Mixing and dilution

Mixing of source water as it enters a stream, river or lake will lower the concentrations of specific chemicals if the levels of those chemicals are lower in the receiving body of water. (Similarly, dilution by mixing two sources of water in a water supply system can reduce chemical concentrations.) Thus, larger water bodies with high flow rates and good mixing characteristics may be less vulnerable to chemical contamination from discharges or runoff than smaller sources with low volumes and flow rates.

2.3.2 Volatilization

Organic chemicals with a low boiling-point, such as some chlorinated solvents, frequently disperse from surface water by volatilization, particularly if the water is turbulent. Such chemicals are known as volatile organic compounds.

2.3.3 Adsorption

Both inorganic and organic chemicals may be adsorbed to soil, sediment or rock, particularly in the presence of clay, or of soils or sediment rich in organic carbon. Adsorption can occur as water percolates through soil or rock, or as it flows over sediments. However, this process is less significant for inorganic chemicals at low pH. In the case of organic chemicals, those with a high octanol/water partition coefficient (i.e. those that are more fat soluble) are more likely to adsorb to soil, or to sediments and particles in the water column than chemicals with a low coefficient. This effect can be a major factor in reducing the mobility of chemicals in the environment and reducing their concentration in water. Water treatment processes designed to act as barriers to pathogens (e.g. coagulation and filtration) will remove particles and will thus significantly reduce the concentrations of substances that are adsorbed to particles.

2.3.4 Chemical environment

Metals such as iron and copper are generally most soluble in acidic water (i.e. $\text{pH} < 7$), and solubility increases as the pH drops. Other metals, such as aluminium and zinc, are more soluble in alkaline water, especially when the pH is above 10. In mildly acidic water (i.e. $\text{pH} 4.5\text{--}6.5$), metals such as iron and copper have a low solubility under extreme anaerobic and aerobic conditions. This is due to the formation of sulfide minerals that have a low solubility under highly anaerobic conditions, and the formation of low-solubility hydroxide and oxide minerals under highly aerobic conditions.

2.3.5 Biological degradation

Many microorganisms can break down organic chemicals in the environment. For a lot of chemicals, this is one of the most important mechanisms for reducing environmental concentrations, and it is particularly important in soils and sediments.

2.3.6 Groundwater vulnerability

Groundwater is abstracted from many different types of aquifers, some of which may be highly susceptible to pollution as a consequence of human activity. The vulnerability of groundwater sources is important when assessing the risks to groundwater posed by various activities. Some aquifers are protected by one or more layers of impermeable material, such as clay, that lie above the saturated zone and that will prevent or retard the transport of chemicals from their sources to the saturated zone. Also, aquifers at certain depths may be protected from chemicals (even from some naturally occurring chemicals) that may be present at other depths in the geological profile.

2.4 Frequent priorities for risk management

As discussed above, for risk management purposes, priority should be assigned to specific chemicals on the basis of site-specific assessments. However, it is also important to pay particular attention to chemicals that have been found in many locations worldwide to present serious human health hazards due to exposure through drinking-water. These chemicals are mentioned below and are discussed in greater detail in the *WHO Guidelines for Drinking-water Quality* (WHO, 2004).

2.4.1 Arsenic, fluoride and selenium

Arsenic, fluoride and (to a lesser extent) selenium are naturally occurring chemicals that have been responsible for severe health effects due to exposure through drinking-water in many countries. Their distribution in groundwater is widespread and their possible presence in surface water should not be ruled out, because groundwater discharge is frequently a major contributor to surface water bodies.

2.4.2 Nitrate

Nitrate may be naturally occurring, although its presence in drinking-water is more often associated with contamination by excessive use of fertilizers (both inorganic and organic), in combination with inappropriate farming practices and/or sewage. This chemical occurs widely throughout the world in both groundwater and surface water, and presents a particular problem in shallow wells. Nitrate is a major problem for bottle-fed infants, in whom the risk of methaemoglobinemia (“blue-baby syndrome”), increases as the concentration of nitrate rises above 50 mg/l. The risk is increased by the presence of nitrite, which is a much more potent methaemoglobinemic agent than nitrate, and by the presence of microbial contamination, which can lead to gastric infections in infants.

2.4.3 Iron and manganese

Significant concentrations of iron and manganese occur throughout the world. Although these chemicals are not suspected of causing direct health effects through their presence in drinking-water, they can cause severe discoloration of water, which may lead to consumers turning to other, microbially unsafe sources of drinking-water. Iron and manganese also frequently cause operational problems.

2.4.4 Lead

High concentrations of lead in drinking-water can cause severe health effects. The presence of lead in drinking-water is primarily a consequence of lead plumbing and lead-containing metal fittings in buildings. Although lead may be present in source waters, this is unusual except in some mining areas. Generally, lead is not a high priority for routine monitoring programmes because of the variability from building to building, but possible risks posed by lead in drinking-water should be assessed in localities where lead has been extensively used in plumbing materials, particularly if the water supplied is corrosive or is likely to dissolve lead. If lead concentrations significantly exceed guideline values, it may be appropriate to apply mitigating measures, such as corrosion control or replacement of pipes and plumbing materials. This is discussed further in Chapter 8.

2.5 Reference

WHO (2004). *Guidelines for drinking-water quality*, 3rd ed., World Health Organization, Geneva.