Water Treatment Chemicals and Construction Materials

Session Objectives

- To describe the sources of contamination deriving from water treatment chemicals and construction materials.
- To demonstrate the need for product control rather than water quality analysis in controlling contamination from these sources.
- To describe some key contaminants deriving from the use of polyelectrolytes, PAHs and PVC.

Water Treatment Chemicals and Construction Materials

Introduction

Chemical contaminants in drinking-water may originate from a variety of sources, including treatment chemicals used in the production of drinking-water or from materials of construction which come into contact with water during treatment, storage and distribution.

A listing of some chemicals used in water treatment, and drinking-water system components such as pipes, joining and sealing materials, process media and mechanical devices is given in Annex 1. Both chemicals and system components may release contaminants into the drinking-water (1, 2).

Processes used for manufacturing of water treatment chemicals may result in the presence of impurities that are of potential health concern. For example, a wide range of polyelectrolyte are used as coagulant aids in water treatment, and the presence of residues of the unreacted monomer may cause concern. Many polyelectrolytes are based on acrylamide polymers and copolymers, in both of which the acrylamide monomer is present as a trace impurity. Some polyelectrolytes may release epichlorohydrin, formaldehyde, ethylene dichloride or ammonia into the water. Chlorine used for disinfection has sometimes been found to contain carbon tetrachloride and mercury. Metals such as As, Ba, Cd, Cr, Pb, Hg, Sn, Se, and Ag may be found as impurities in a variety of water treatment chemicals.

Contaminants may originate from construction materials: metals such as copper, lead and cadmium are released from pipe material and solder; asbestos fibres from the inner walls of asbestos-cement pipes; polynuclear aromatic hydrocarbons from coal-tar-based pipe linings and coatings on storage tanks; traces of unreacted vinyl chloride monomer from PVC pipes; organic chemicals from *in situ* polymerized and solvent-applied coating; and radionuclides from sand and granular activated carbon used as filtration media.

Ensuring the safety of water treatment chemicals and construction materials

During the development of the 1993 WHO *Guidelines for Drinking-water Quality*, the subject of potentially hazardous chemicals in drinking-water derived directly from treatment chemicals or construction materials used in water supply systems was discussed. The conclusion reached by the experts was that such chemicals are best controlled by the application of national regulations governing the quality of the products themselves rather than the quality of the water.

For this reason, the *Guidelines* have not specifically addressed contaminants derived from water treatment chemicals, construction materials, paints or coatings. Nevertheless some of the contaminants arising from these sources were evaluated because of their world-wide importance and include, for example, asbestos, vinyl chloride, acrylamide, epichlorohydrin, di(2-ethylhexyl) adipate and phthalate, and benzo[a]pyrene.

National authorities in some countries such as the Netherlands (3), the United Kingdom (4) and the United States of America (2) have issued specification and recommendations for chemicals and construction materials thus ensuring the safety of the water delivered to the consumer.

Where specifications have not been developed, contamination from these sources may adversely affect the quality of drinking-water.

National drinking-water standards (or WHO guideline values, GVs) may be used to derive limits for impurities in water treatment chemicals. Using the approach adopted by the US National Research Council and National Sanitation Foundation (NSF) (2, 5), a recommended maximum impurity content (RMIC) in the treatment chemical is calculated using the following equation:

$$RMIC\ (mg / kg) = \frac{NS\ (mg / l) \times 10^6}{MD\ (mg / l) \times SF}$$

were NS is the national standard (or GV), and MD the maximum dosage of the water treatment chemical. A safety factor (SF) of 10 is judged as reasonable to limit to 10% of a given NS the contribution by a given impurity in a water treatment chemical. A sample calculation of a RMIC is as follows:

Contaminant (Pb) : NS = 0.02 mg/litre

Water treatment chemical: Maximum dose (MD) 500 mg/litre
Safety Factor 10

$$RMIC = \frac{0.02\ mg\ Pb / litre \times 10^6\ mg / kg}{500\ mg\ chemical / litre \times 10}$$

= 4 mg Pb/kg chemical

If a national drinking-water standard (or WHO GV) is not available, new toxicity testing and evaluation may be necessary.

The concentration of contaminants released from products used in contact with drinking-water may be initially high, but rapidly decline with continued product contact with water. The NSF has adopted an approach whereby leachate tests are conducted to determine the slope of the contaminant concentration curve. If the initial (day 1) laboratory concentration of the contaminant is less than or equal to the 90-day No-observed-adverse-effect level (NOAEL), divided by 100, and the contaminant concentration is calculated to be at or below 10% of the national standard, then no additional toxicity data may be required.

Polyelectrolytes used in water treatment

A wide range of polyelectrolytes are available and the presence of unreacted monomer may cause concern. For example acrylamide polymers and epichlorohydrin-based polymers may release in drinking-water the unreacted monomers acrylamide and epichlorohydrin. To control this type of contamination, some countries have established maximum authorised dose of polyacrylamide used as a coagulant in drinking-water treatment (range 0.25-1 mg/litre), and specified maximum acrylamide content in polyacrylamide (varying from 0.025 to 0.1%). A standard of 0.1% of monomer at a maximum dose of polyacrylamide of 0.5 mg/litre would correspond to a maximum theoretical concentration of acrylamide in water of 0.5 µg/litre (same as WHO GV of 0.5 µg/litre for an excess lifetime cancer risk of 10^{-5}).

Because of concern about certain contaminants, Switzerland and Japan do not permit the use of polyelectrolytes, including polyacrylamide, in drinking-water treatment (6). Other countries, such as the United Kingdom, Germany and the USA, establish limits on contaminant levels and application doses, as described above, which they can monitor and enforce.

A WHO Consultant Group examined the health aspects relating to the use of polyelectrolytes in water treatment and recommended that:

(a) polyelectrolytes should be used only after careful evaluation of the toxic hazards of particular products

(b) countries wishing to use polyelectrolytes should establish a national committee to evaluate potential health hazards arising from their use

(c) limits should be specified both for the maximum applied dose of a polyelectrolyte and for its content of toxic monomer.

Polynuclear aromatic hydrocarbons (PAHs)

PAHs are present in the environment from both natural and anthropogenic sources. A GV of 0.7 pg/litre corresponding to an excess cancer risk of 10^{-5} was recommended for benzo[a]pyrene. There were insufficient data available to derive GVs for other PAHS. The following recommendation was made in the *Guidelines* for the PAH group:

> "Contamination of water with PAHs should not occur during water treatment or distribution. Therefore, the use of coal-tar-based and similar materials for pipe linings and coatings on storage tanks should be discontinued. It is recognised that it may be impracticable to remove coal-tar linings from existing pipes. However, research into methods of minimising the leaching of PAHs from such lining material should be carried out"

Asbestos-cement pipes

Because of the lack of evidence for any health risk from ingested asbestos, no GV was proposed in the *Guidelines* for asbestos in drinking-water (see WHO Press Release attached in session V). However, one concern with A/C pipes is that cement is subject to deterioration on prolonged exposure to aggressive water - due either to the dissolution of lime and other soluble compounds or to chemical attack by aggressive ions such as chloride or sulphate - and this may result in structural failure of the A/C pipe. The American Water Works Association has set specifications for the type of A/C pipes to be used for different degree of aggressiveness of the water, as reflected in the "aggressiveness" Index or the Langelier Index. Pipes made of A/C, as well as almost all other materials, may not perform satisfactorily when in contact with highly aggressive water. Adjustment of certain water quality parameters, such as pH, alkalinity and/or hardness, may thus be necessary to control cement corrosion.

PVC pipes

Contaminants that may leach from PVC material include di(2-ethylhexyl) phthalate used as a plasticizer, antioxidants such as phenols and aromatic amines, lead, cadmium and organotin compounds used as heat stabilizers, acrylic processing aids, and residual vinyl chloride monomer (VCM). Based on cancer risk assessment, a GV of 5µg/litre has been recommended for VCM by WHO, corresponding to an excess cancer risk of $10^{-5.}$

Low concentrations of VCM have been detected in drinking-water as a result of leaching from PVC pipes used in water distribution systems. A number of product standards exist which specify a quality of PVC pipes that limits the quantity of free VCM present. For example, NSF-International requires that the residual vinyl chloride monomer content of PVC material as determined in the wall of the finished product should be less than or equal to 3.2 mg/kg (2).

The European Union has set a maximum VCM level of 1 mg/kg in materials made of PVC which are intended to come into contact with food (or drinking-water). It is further specified that VCM should not be detected in food (or drinking-water) at the limit of detection of 0.01 mg/kg (7). In order to enforce these standards, the European Union has specified the methods of analysis of VCM in PVC material (8), and in food or water (9).

The use of PVC pipes has been reviewed by a WHO Consultant Group, with special emphasis on leaching of heavy metal stabilizers and associated impurities from the pipe wall. Additives such as lead, organotin and cadmium may be used in PVC pipe production. Other potentially hazardous compounds such as mercury may occur as impurities in PVC pipe. The Group recommended that:

(a) National standards for PVC pipes should be developed setting limits on the amount of toxic stabilizers that can be extracted from the pipe.

(b) The International Organization for Standardization (ISO) should be regarded as the appropriate international body for the co-ordination of national standards and the development of uniform test procedures related to the extractability of toxic substances from PVC pipes.

(c) The use of cadmium compounds in PVC drinking-water pipe formulations is considered to be highly undesirable.

(d) Research should be carried out to determine leaching pattern of organotin stabilizers. Toxicological data on these materials are also needed in order to establish a tolerable daily intake.

(e) Toxic ingredients should be limited to the absolute minimum required for pipe production.

ISO has specified a test method for the determination of the extractability of prescribed constituents from the internal surface of plastic pipes, including PVC pipes, for the transport of water intended for human consumption. The constituents considered include monomers, initiators, emulsifiers, stabilizers, antioxidants, lubricants, polymers and copolymers for blends, UV absorbers, fillers and pigments. The method is applicable to extractable contaminants such as VCM, lead, tin, cadmium and mercury occurring as impurities in PVC materials. The purpose of the method is to verify that the extracted quantities do not exceed specified limits. However, ISO does not establish permissible limits for the quantities extracted (10).

Conclusions

Contamination of drinking-water by water treatment chemicals and construction materials may be controlled by the application of national specifications and regulations on the quality of the product. To support countries in developing control procedures for water treatment chemicals and construction materials, the Working Group on Protection and Control of Water Quality of the Rolling Revision of the Guidelines will prepare a monograph on the techniques for testing and control of materials and chemicals, ready for publication in 2001. This will be co-ordinated by NSF International in conjunction with the International Programme on Chemical Safety (IPCS).

In addition to the evaluation of chemicals as contained in the WHO *Guidelines for Drinking-Water Quality,* the IPCS has, in its Environmental Health Criteria documents, assessed the risk of several chemicals of direct relevance to water treatment and distribution systems: phenol, chlorophenols, mercury, lead, cadmium, tin and organotin compounds, tributyltin compounds, arsenic, Polycyclic aromatic hydrocarcarbons, aluminium, etc. International risk assessment from exposure to these chemicals will assist national authorities in identifying problem areas and in establishing specifications for chemicals and materials which come into contact with drinking-water.

References

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3. KIWA Ltd. Procedure to obtain a certificate of no objection on toxicological grounds. Rijswick, the Netherlands.

4. United Kingdom Committee on Chemicals and Materials. List of substances, products and processes approved under regulations 25 and 26 for use in connection with the supply of water for drinking, washing, cooking or food production purposes (December 1994). Drinking-water Inspectorate, Room B153, 43 Marsham Street, London SWIP 3PY. Facsimile: 44-71-2768405; Telephone 44-71-276-8901.

5. US National Research Council (1982) Water chemicals codex. National Academy Press, Washington, D.C.

6. Letterman, R.D. and Pero, R.W. (1990) Contaminants in polyelectrolytes used in water treatment. J. Am. water works Assoc. Vol 82, pp. 87-97.

7. Council of the European Communities Directive of 30 January 1978 on the approximation of the laws of the Member States relating to materials and articles which contain vinyl chloride monomer and are intended to come into contact with foodstuffs (78/142/EEC).

8. Commission of the European Communities Directive of 8 July 1980 laying down the Community method of analysis for the official control of the vinyl chloride monomer level in materials and articles which are intended to come into contact with foodstuffs (80/766/EEC)

9. Commission of the European Communities Directive of 29 April 1981 laying down the Community method of analysis for the official control of vinyl chloride released by materials and articles into foodstuffs (81/432/EEC).

10. ISO (1990) International Standard 8795 Plastics pipes for the transport of water intended for human consumption - Extractability of constituents - test method. ISO, P.O.Box 56, 1211 Geneva 20, Switzerland.

ANNEX 1

I. DRINKING-WATER TREATMENT CHEMICALS

Coagulation and flocculation: acrylamide copolymers, aluminium chloride, aluminium sulphate, bentonite/montmorillonite, cationic polyacrylamide, diallyldimethyl ammonium/chloride acrylamide copolymer, ferric chloride, ferric and ferrous sulphate, kaolinite, poly (diallyldimethyl ammonium chloride), polyaluminium chloride, polyamines, starch, polyethyleneamines, resin amines, sodium aluminate.

pH adjustment: calcium carbonate, calcium hydroxide, calcium oxide, carbon dioxide, magnesium oxide, potassium hydroxide, sodium bicarbonate, sodium bisulfate, sodium carbonate, sodium hydroxide, sulfuric acid.

Corrosion control: dipotassium orthophosphate, disodium orthophosphate, monopotassium orthophosphate, phosphoric acid, polyphosphoric acid, potassium tripolyphosphate, sodium calcium magnesium polyphosphate, sodium polyphosphate, sodium zinc polyphosphate, tetrasodium pyrophosphate, zinc orthophosphate.

Corrosion inhibitor: sodium silicate

Sequestering: ethylenediamine tetraacetic acid (EDTA), tetrasodium EDTA

Disinfection and oxidation products: anhydrous ammonia, ammonium hydroxide, calcium hypochlorite, chlorine, iodine, potassium permanganate, sodium chlorate, sodium chlorite, sodium hypochlorite.

Fluoridation: ammonium hexafluoro silicate, calcium fluoride, fluosilicic acid, magnesium silico fluoride, potassium fluoride, sodium fluoride, sodium silico fluoride.

Defluoridation: aluminium oxide, bone charcoal, tricalcium phosphate, high-magnesium lime.

Algicide: copper sulphate, copper triethanolamine complexes.

Softening: calcium hydroxide, calcium oxide, sodium carbonate, sodium chloride.

Taste and odour control: activated carbon, chlorine, chlorine dioxide, copper sulphate, ozone, potassium permanganate.

Dechlorinator and antioxidant: sodium metabisulfite, sodium sulfite, sulfur dioxide.

ANNEX 1 (continued)

II. DRINKING-WATER SYSTEM COMPONENTS

Pipes and related products: copper, lead, stainless steel, brass, galvanized, concrete pressure, ductile iron, PVC, chlorinated PVC, asbestos/cement.

Protective (barrier): materials: coatings, paints, linings.

Process media:

Adsorption media: activated alumina, granular activated carbon, powdered activated carbon.

Filtration media: aluminium silicates (e.g. zeolites), anthracite, diatomaceous earth, gravel, sand, membranes.

Ion exchange: ion exchange resins.

Mechanical devices: chemical feeders, pressure gas injection systems, disinfection generators, electrical wire, pumps, valves and related fittings, water process treatment devices (e.g. mixers, reverse osmosis, screens, clarifiers, aeration equipment, etc.).

Water Treatment Chemical and Construction Materials

Presentation Plan

Section	Key points	OHP
Introduction	• chemical contaminants in drinking-water originate from a variety of sources. • these sources include the water treatment process itself through the presence of impurities in the water treatment chemicals, drinking-water system components and contaminants originating from construction materials • some of these, such as polyelectrolytes, PAHs, copper, lead and cadmium are of potential health concern	
Ensuring the safety of water treatment chemicals and construction materials	• national regulations governing the quality of the products (i.e. the construction materials and treatment chemicals rather than the quality of the water itself is used to control potentially hazardous chemicals in drinking-water • national drinking-water standards (or WHO Guidelines) may be used in a standard formula to derive limits for impurities in water treatment chemicals. Where national drinking-water standards are not available new toxicity and evaluation may be required • the concentration of contaminants released from products used in contact with drinking-water may decline with continued product contact with water. Leachate tests determine the slope of the contamination concentration curve	**1**
Poly - electrolytes used in water treatment	• polyelectrolytes are widely available and the presence of unreacted monomers may cause concern. These may be released by certain polymers in drinking-water • as a result of the concern some countries do not permit the use of polyelectolytes in drinking-water or establish limits on contaminant levels and application doses • the health aspects relating to the use of polyelectrolytes in water treatment have been identified by a WHO Consultant Group and recommendations made for their use	**2**
Coalton linings	• may release PAHs • these are present in the environment from both natural and anthropogenic sources • a GV for benzo[a]pyrene has been established • it has been recommended in the *Guidelines* that where materials from which PAHs may leach are used, for example in pipe linings and coatings on storage tanks, alternative materials are used • Guidelines recommend alternative materials where PAHs may leach	**3**

Section	Key Points	OHP
Asbestos-cement pipes	• there is no GV for asbestos in drinking-water as there is no evidence that asbestos has any adverse effect on human health when ingested with drinking-water • concern that cement in asbestos-cement pipes may deteriorate after prolonged exposure to 'aggressive' water • specifications have been set for the types of pipes used depending on the degree of 'aggressiveness' – using the 'aggressiveness' Index or Langelier Index	**4**
PVC pipes	• a variety of contaminants may leach from PVC pipes. • a GV has been set by the WHO for one of these - residual vinyl chloride monomer (VCM) - of 5 μg/litre based on a cancer risk assessment • low concentrations of VCM have been detected in drinking-water due to leaching from PVC pipes. The use of PVC pipes has been reviewed by a WHO Consultant Group and recommendations made for their production and use • the EU has set standards for the amount of VCM in materials made of PVC which are intended to come into contact with food or drinking-water. • a standard test method has been specified for the determination of the extractability of prescribed constituents from the internal surface of plastic pipes used for the transport of water intended for human consumption	**5**
Conclusions	• control of contaminants from materials and chemicals used in treatment and distribution of water are best control through product control, not water quality monitoring • control of contamination of drinking-water by water treatment chemicals and construction materials may be addressed by national standards and regulations on the quality of the product • WHO is actively pursuing status to provide information on approved products and quality standards to Member States • the risk of several chemicals of direct relevance to water treatment and distribution systems has been assessed • international risk assessment from exposure to these chemicals can assist national authorities in identifying problem areas and establishing specifications for chemicals and materials in contact with drinking-water.	

NB: Annex 1 may be given as a handout as this is not included in the Guidelines.

Calculating Recommended Maximum Impurity Concentration (RMIC)

$$RMIC\ (mg / kg) = \frac{NS\ (mg / l) \times 10^{6}}{MD\ (mg / l) \times SF}$$

e.g. Pb NS = 0.02 mg/l; MD = 500mg/l; SF = 10

$$RMIC = \frac{0.02\ mg\ Pb / litre \times 10^{6}\ mg / kg}{500\ mg\ chemical / litre \times 10}$$

Recommendations of the WHO Consultant Group on Polyelectrolytes

- Polyelectrolyte should be used only after careful evaluation of the toxic hazards of a particular substance.
- Countries wishing to use polyelectrolyte should establish a national committee to evaluate potential health hazards arising from its use
- Limits should be specified both for the maximum applied dose of a polyelectrolyte and for its content of toxic monomer

Coaltar Linings

- May release PAHs.
- These are present in the environment from both natural and anthropogenic sources.
- Guideline value for benzo[a]pyrene has been established.
- *Guidelines* recommend alternative materials should be used where PAHs may leach.

Asbestos-cement Pipes

- No guideline value for asbestos.
- May deteriorate after prolonged exposure to ‘aggressive’ water.
- Specifications have been set using the ‘aggressiveness’ Index/Langelier Index.

PVC Pipes

- A variety of contaminants may leach form PVC pipes.
- Guideline value has been set for residual vinyl chloride monomer (VCM).
- Low concentrations of VCM have been detected in drinking-water due to leaching from PVC pipes.
- Standard test methods developed for ‘extractability’ of prescribed constituents.