Inorganic Constituents and Aesthetic Parameters

Session Objectives

- To describe the process of setting Guideline Values for inorganic parameters and describe the narrow divide between toxic and essential elements.

- To describe some basic physico-chemical characteristics of water.

- To provide some examples of inorganic chemicals to illustrate the uses of GVs for inorganics and highlight priority substances.

- To describe the basis of monitoring of physical and chemical parameters.

Inorganic Constituents and Aesthetic Parameters

All substances are poisons; there is none which is not a poison. The right dose differentiates a poison and a remedy.

PARACELSUS
(1493-1541)

Introduction

Many of the inorganic and aesthetic constituents evaluated in the *Guidelines* are known to be essential for life. Chromium, copper, fluoride, iodine, manganese, molybdenum, and selenium are essential elements in human nutrition; arsenic and nickel are considered by some researchers as essential elements. Of the aesthetic constituents, iron, chloride, calcium and magnesium (hardness), sodium and zinc are essential elements.

A classification into "essential" and "toxic" elements is fraught with difficulties since as science advances, there is a constant shift of the elements from one group to the other. Toxicity is inherent in all elements, and is a function of the concentration to which humans are exposed. Paracelsus' statement remains valid, "The right dose differentiates a poison and a remedy". Ordinary salt, calcium, magnesium and iron, are all toxic above certain doses. This is illustrated in Figure 1 below.

The plateau of "safe and adequate intake of essential elements" are mainly a matter for nutritionists to decide.

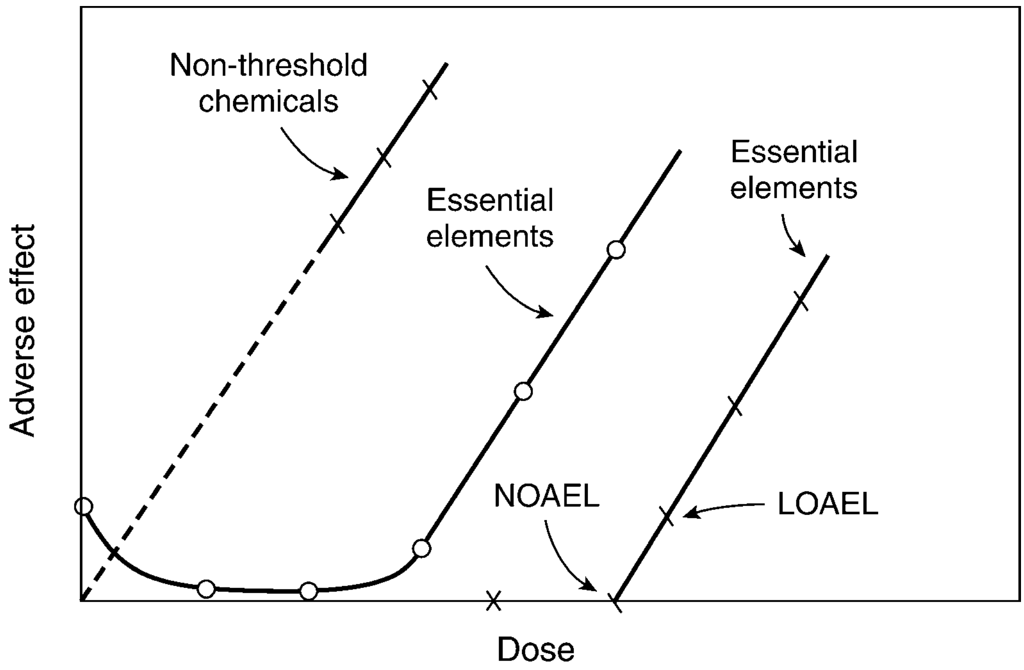


Figure 1. Dose-response curve (Source: Galal-Gorchev, 1995)

*Notes:*NOAEL: no observed adverse effect limit; LOAEL: lowest observed adverse effect limit
Threshold chemicals: only toxic above certain dose, therefore have a NOAEL
Non-threshold chemical: toxic at any dose, therefore do not have a NOAEL

No attempt has been made in the *Guidelines* to define a minimum desirable concentration of essential elements in drinking-water. The *Guidelines* are concerned with the quantification of toxic effects.

A few of the inorganic chemicals and aesthetic constituents of common interest to many countries will be discussed here to illustrate the approach taken in deriving, or not deriving, guideline values (GV). A complete list of inorganic substances for which GVs have been derived is given in Table A2.2 (A) in Annex 2 of Volume 1 of the Guidelines.

Inorganic Constituents

Asbestos in drinking-water: no health hazard

Because of numerous inquiries from governments, industry and academia on the potential adverse health effects from asbestos in drinking-water, WHO issued the attached Press Release.

Asbestos is used in a large number of applications, particularly construction materials, such as asbestos cement (A/C) sheet and pipe, electrical and thermal insulation, and friction products, such as brake linings.

Asbestos is introduced into water by the natural dissolution of asbestos-containing minerals as well as from industrial effluents, atmospheric pollution, and A/C pipes in water distribution systems. High levels of asbestos have been found in drinking-water from corrosion of A/C pipes.

The asbestos content of food has not been well studied because of the lack of a simple, reliable analytical method. Based on crude estimates, intake of asbestos in food may be significant compared with that in drinking-water. Concentrations of 7 million fibres per litre (MFL) in beer and 12 MFL in soft drinks have been reported.

Asbestos is a known human carcinogen by the inhalation route. Based on the inhalation route, IARC has assigned it to Group 1 (the agent is carcinogenic to humans), while recognising that asbestos behaved differently by the oral route.

Asbestos was not found to be carcinogenic in several animal feeding studies. Epidemiological studies of population exposed to high levels of asbestos in drinking-water (200 MFL) did not reveal any excess cancer risk. It was therefore concluded that ingested asbestos is not hazardous to health and there was no need to establish a GV for asbestos in drinking-water.

Another question that needs to be answered is: Can high concentration of asbestos fibres in drinking-water become airborne and create a health hazard?

In a study in New York State, asbestos contamination in excess of 10 billion fibres per litre was detected in a community's drinking-water. Mean airborne asbestos concentrations were significantly higher in a small number of homes with water containing this elevated concentration of asbestos than in three control homes; however, the difference in concentrations was primarily due to increased numbers of short (<1 μm) fibres, which are considered to contribute little to health risk. Moreover, all fibre concentrations determined in this limited study were within the range of those measured in indoor and outdoor air in other investigations.

In another study, using a conventional drum-type humidifier, testing showed that release of asbestos fibres to air from water containing 40 $\pm$ 10 MFL was negligible.

The final question - does corrosive water transported in A/C pipe pose any specific or unique health risk? Corrosive water does not create a specific health risk as it relates to A/C pipe since asbestos fibres in drinking-water do not pose a health risk and are not transferred into the air. However, corrosive water is an important problem that must be addressed by all water utilities no matter what type of water pipe material is used in the distribution system or homes. Proper selection of the quality of A/C pipes is important and some national institutions have issued standards for A/C pipes suitable for water with different degrees of aggressiveness.

Fluoride and dental health

Fluoride levels between 0.5 and 1 mg/litre provide substantial protection against dental caries. However, for fluoride, the margin between beneficial and toxic effects is rather small (see Figure 1). Excessive exposure may lead to adverse health effects varying from mottling of teeth to crippling skeletal fluorosis.

The *Guidelines* recommend a GV of 1.5 mg/litre on the assumption that the daily per capita consumption of drinking-water is about 2 litres. At this level, dental fluorosis may occur in a certain proportion of the population. In setting national standards for fluoride, it is particularly important to consider climatic conditions, volumes of water intake, and intake of fluoride from other sources (e.g. food, air).

Nitrate and nitrite

Nitrate and nitrite in drinking-water may be of natural origin, or can be leached from septic tanks, pig farms and feed lots. Use of fertilizers (too much and at the wrong time of the year) can also result in nitrate pollution.

High concentration of nitrate, and especially nitrite in drinking-water may cause methaemoglobinaemia. Groups especially susceptible to methaemoglobin formation are young infants, children and pregnant women.

Epidemiological studies indicate that at levels of nitrates less than 50 mg/litre (as nitrate), there does not seem to be any problem with methaemoglobinaemia. There are considerable uncertainties as to the level of nitrite which may cause such clinical effects. On the assumption that nitrite was ten times more potent than nitrate (on a molar basis) with respect to methaemoglobin formation, the *Guidelines* recommend a provisional GV of 3 mg/litre (as nitrite). In addition, since nitrite and nitrate exert similar toxicological effect and may occur simultaneously, the following condition was also specified:

$$\frac{C_{nitrite}}{GV_{nitrite}} + \frac{C_{nitrate}}{GV_{nitrate}} \leq 1$$

where C = concentration in drinking-water
GV = guideline value

Lead and IQ

In 1986 the Joint FAO/WHO Expert Committee on food Additives (JEFCA) established a provisional tolerable weekly intake (PTWI) of lead from all sources of 25 μg lead/kg body weight (equivalent to 3.5 μg/kg body weight per day) for infants and children on the basis that lead is a cumulative poison and that there should be no accumulation of body burden of lead. In 1993, the Committee reconfirmed this PTWI and extended it to all age groups.

Assuming a 50% allocation of the PTWI to drinking-water for a 5-kg bottle-fed infant consuming 0.75 litres of drinking-water per day, the health-based guideline value is 0.01 mg/litre (rounded figure).

The most significant health effect from lead is the association of lead exposure with reduced cognitive development and intellectual performance in children. Results of studies on children with blood lead concentrations below 25 μg/dl indicate that, on average, the intelligence quotient (IQ) is reduced by 1-3 points for each 10 μg/dl increment in the blood lead concentration. Existing epidemiological studies do not provide evidence of a threshold.

Steps are now being taken to reduce all sources of lead exposure of children with some apparent success in various countries. In countries where lead has been removed from petrol, and where there is no specific source of excess lead exposure, blood lead concentrations in children are decreasing and are now approximately 4-6 μg/dl. The almost complete elimination of lead-soldered side-seams in canned foods in a number of countries has also contributed to the reduction in lead exposure. Corrosion control measures are being implemented to reduce the lead content of drinking-water and new plumbing and fittings now seldom contain lead.

Aesthetic Aspects

Contrary to the 1984 *Guidelines*, the 1993 *Guidelines* do not propose guideline values for substances and parameters that affect the acceptability of drinking-water to consumers. The Review Groups were of the opinion that guideline values should be recommended only for those substances that are directly relevant to health. A list of substances which may give rise to consumer complaints is given in Table A2.5 in Volume 1 of the *Guidelines.*

In the case of characteristics based on human sensory evaluation, judgement is often subjective. Aesthetic/organoleptic characteristics are very much subject to social, economic and cultural considerations, and the establishment of standards for the aesthetic quality of drinking-water should take into consideration implementation possibilities, and the existing socio-economic and environmental constraints. When resources are severely limited, establishment of priorities becomes even more important, and such priorities should be set in relation to their direct impact on health. Some countries have elected to set enforceable standards for constituents of health significance, whereas recommendations only are made for aesthetic and organoleptic characteristics.

Total dissolved solids

Total dissolved solids (TDS) in drinking-water consist mainly of chloride, sulphate, carbonates, sodium, magnesium and calcium. Excessive dissolved solids in drinking-water may lead to objectionable taste, and corrosion or encrustation in water distribution system. At concentrations greater than approximately 1000 mg/litre, the taste of water becomes increasingly unpalatable.

As far as health aspects are concerned, there is no evidence of adverse physiological reactions at TDS levels greater than 1000 mg/litre. On the contrary, there are vague indications from epidemiological studies that high levels of certain salts (calcium and magnesium) may have beneficial health effects.

It should be emphasized that the factor of acclimatization to TDS is particularly important. Many people enjoy highly mineralized waters containing more than 2000 mg/l of TDS.

Removal of TDS from drinking-water is an expensive proposition, and if a national standard for TDS is being considered, it should take into account the feasibility of implementation.

Turbidity

Particles in drinking-water are aesthetically objectionable, and can serve as shields for pathogenic microorganisms. Moreover, many toxic chemicals such as pesticides and heavy metals are selectively adsorbed on suspended particulate matter. The efficiency of disinfection may be reduced in the presence of turbidity: the disinfectant is unable to reach the target organism because of a physical barrier and/or chemical reactions with turbidity particles may occur thus decreasing the available disinfectant concentration. Where disinfection is practised, the turbidity should preferably be less than 1 Nephelometric Turbidity Unit and always below 5.

The effect of turbidity depends on its physico-chemical characteristics. Certain water supplies, such as groundwater, may contain non-organic turbidity, which may not affect disinfection. The complex factors involved in the potential health risk from the presence of turbidity precluded the derivation of a health-based GV.

References

WHO (1994) Fluorides and oral health. WHO Technical Report Series 846. Geneva.

WHO (1993) Evaluation of certain food additives and contaminants (lead). WHO Technical Report Series 837. Geneva.

Inorganic and Aesthetic Parameters

Presentation Plan

Section	Key points	OHP
Introduction	• many of both the inorganic substances and aesthetic parameters evaluated in the *Guidelines* are known to be essential for life • classification of substances into 'toxic' and 'essential' is fraught with difficulties. With ongoing research there is a constant shift of substances between the two groups • toxicity is inherent in all substances, the dose or concentration of a substance differentiates between a poison and a remedy • safe and adequate intake and concentrations for essential substances is a matter for nutritionists • *Guidelines* do not define a minimum desirable concentration of essential elements, they only define toxic levels	**1,2**
Physico-chemical characteristics of water	• water has set of physico-chemical characteristics which affect quality in their own right and influences the ability of water to contain other substances • physical characteristics include: temperature, colour, turbidity, suspended solids and dissolved solids • chemical characteristics include: pH, alkalinity, acidity, hardness, dissolved oxygen and oxygen demand	**3,4**
Asbestos	• asbestos is widely used and may be a reinforcement in concrete • asbestos in water has been shown to have no adverse health effect • asbestos pipes should be protected from 'aggressive' water	
Fluoride	• margin between toxic and essential levels is very narrow • fluoride levels between 0.5mg/l & 1mg/l protect against dental caries • exposure to excess levels of fluoride may give rise to adverse health effects from mottling of teeth to crippling skeletal fluorosis • GV set at 1.5 mg/l on basis of consumption of 2 litres per day, above this dental fluorosis expected in some of population	**5**

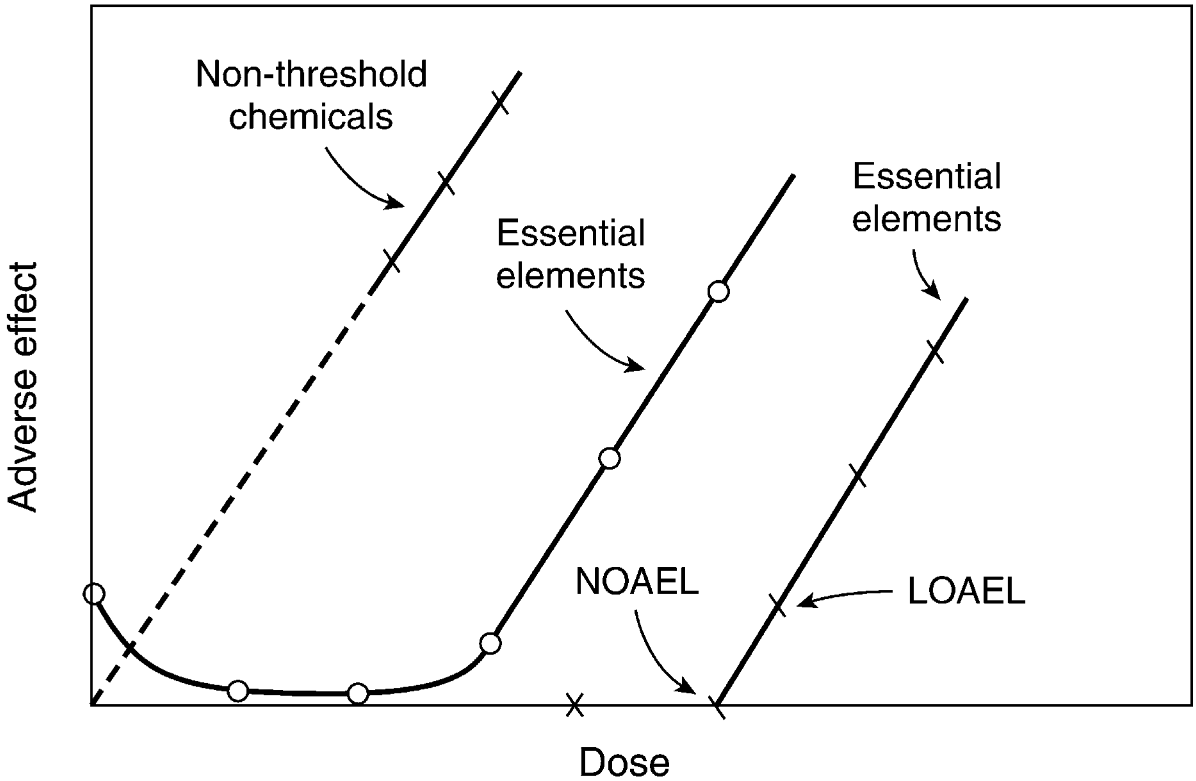
Section	Key points	OHP
Nitrate & nitrite	• may be of natural origin or leached from on-site sanitation, intensive animal husbandry, also from inappropriately applied fertiliser • high nitrate and nitrite concentrations may lead to methaemoglobinaemia in infants and pregnant women • GV of 50mg/l nitrate set, as below this epidemiological studies indicate that there is no significant risk of methaemoglobinaemia • uncertainty concerning concentration of nitrite that leads to clinical effects, assumed 10 times more potent than nitrate, GV of 3 mg/l given • as both may occur together, important that the sum of the ratio of concentration of nitrite to the GV and concentration of nitrate to the GV is ≤ 1	**6**
Lead	• exposure to excess lead may lead to intellectual impairment in children • no threshold for health effects have been identified • all exposure to lead is now being reduced and in the water supply this means removal of lead pipes and lead-containing fittings.	**7**
Aesthetic aspects	• no GVs set for these in the 2nd edition as these are highly societal influenced • turbidity should be kept to below 1TU as above this level disinfection may be compromised, although in some groundwaters have non-organic turbidity which does not affect disinfection	

Introduction

“All substances are poisons; there is none which is not a poison. The right dose differentiates a poison and a remedy”.

Paracelsus (1493-1541)

Dose-response of Chemicals



Source: Galal-Gorchev, 1995

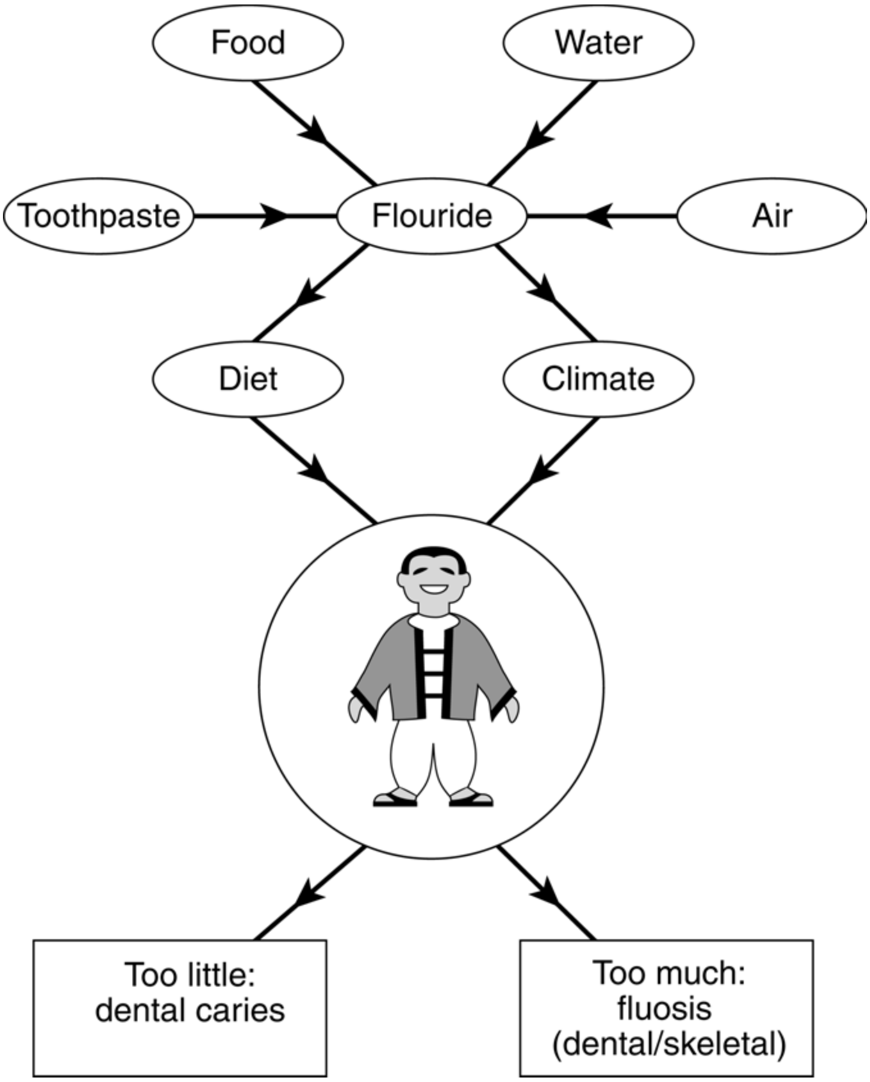
Physical Characteristics of Water

- Temperature
- Taste and odour
- Colour
- Turbidity
- Suspended solids
- Conductivity
- Total dissolved solids

Chemical Characteristics of Water

- pH
- Alkalinity
- Acidity
- Hardness
- Dissolved oxygen
- Oxygen demand
- Nitrogen
- Chloride

Sources of Fluoride and Impact on Health



Guideline Value for Nitrate and Nitrite in Drinking-water

$$\frac{C_{nitrite}}{Gv_{nitrite}} + \frac{C_{nitrate}}{Gv_{nitrate}} \leq 1$$

where: C = concentration

GV = Guideline Value

Lead and Health