Lead in drinking water

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Health Council of the Netherlands: Committee Lead in drinking water

to

the Minister of Health, Welfare and Sport

the Minister of Housing, Spatial Planning and Environment

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Executive summary

In this report the Health Council of the Netherlands' Committee on Lead in Drinking Water, responses to a request for advice from the Minister of Housing, Spatial Planning and the Environment. The minister's request followed a move by the World Health Organization (WHO) to reduce its standard for lead in drinking water and the publication of a draft directive by the European Union (EU), incorporating the WHO's new standard. If the directive is passed in its present form, drinking water at the point of consumption will have to meet an interim standard limiting the lead concentration to 25 microgrammes per litre (µg/l) within five years and an ultimate standard limiting the concentration to 10 µg/l within fifteen years. The standard for lead in drinking water currently effective in the Netherlands is 50 µg/l.

The WHO's new drinking water standard for lead is based on the assumption that exposure to lead should be limited to 25 microgrammes per kilogramme body weight (µg/kg bw) per week, or 3.5 µg/kg bw per day. This level is referred to by the WHO as the 'provisional tolerable weekly intake' or PTWI, and applies both to children (including infants) and to adults. Kinetic research involving infants has indicated that exposure to more than the PTWI of lead increases blood lead concentrations and causes lead to accumulate in the body considerably. The WHO considers these phenomena to be detrimental to health.

Given that scientific literature on lead and health effects does not point to the existence of a 'no-observed-adverse-effect level' (NOAEL) for exposure to lead, and that the Committee can not rule out the possibility that the health of young children can be adversely affected even at blood lead concentrations lower than 100 µg/l, she endorses the WHO's view that it is undesirable to exceed the PTWI, causing blood lead concentrations to rise and lead to accumulate in the body considerably.

To gauge the proportion of overall exposure to lead in the Netherlands that is attributable to lead drinking water pipes, the Committee has made an estimate of overall exposure from data on the (average) concentrations of lead in the atmosphere, in food and in drinking water.

In the Netherlands, drinking water leaving the water companies' pumping stations has an average lead concentration of about 1 µg/l. Only in isolated instances have concentrations higher than 10 µg/l been recorded. The concentration of lead in the drinking water that eventually emerges from the consumer's tap depends to a considerable extent on the material from which the drinking water transport pipes are made. The Committee believes that the average lead concentration in drinking water which has passed through lead supply pipes or lead domestic piping is likely to be about 35 µg/l at the point of consumption.

The results indicate that foodstuffs (including drinking water) constitute the primary source of non-occupational exposure to lead in the Netherlands. Estimates suggest that if the average drinking water lead concentration is 10 µg/l, adults and children older than one year old are exposed to an average of about 3.5 microgrammes of lead per kilogramme body weight (µg Pb/kg bw) a week; if the drinking water lead concentration is 35 µg/l, they are exposed to about 7 µg Pb/kg bw a week. Drinking water accounts for, respectively, about 30 per cent and 60 per cent of the overall exposure in each case.

On average, infants (i.e. children less than one year old) experience higher levels of exposure to lead per kilogramme body weight. This is primarily because of their relatively high energy requirements. Breast-fed infants and bottle-fed infants whose feed is made up using water with an average lead concentration of 10 µg/l are exposed to about 7 µg Pb/kg bw a week. If the average drinking water lead concentration is 35 µg/l, a bottle-fed infant will be exposed to an average of between 24.5 and 38.5 µg Pb/kg bw a week for the first six months of life; between the sixth month and the twelfth month the level of exposure will be about 21 µg/kg bw per week.

The Committee has concluded that there is one group exposed to more than the WHO's PTWI: infants who in the first six months of life are bottle fed on formula milk made up using water which, as a result of passing through lead piping, has an estimated lead concentration of 35 µg/l. Given the number of households in the Netherlands with supply pipes or domestic drinking water pipes made of lead, an annual birth rate of 196,000 and the percentage that is bottle-fed, it may be assumed that, during infancy, eleven thousand children a year are for a period exposed through their food to levels of lead which exceed the PTWI.

To prevent bottle-fed infants exceeding the PTWI for lead through drinking infant formula, the Committee recommends adoption of the lower standard for lead in drinking water advocated by the WHO, namely 10 µg/l. When maintaining the currently effective standard for lead in drinking water, the Committee considers it possible, depending on the level of prenatal exposure to lead and the duration and the degree of super-PTWI intake in infancy, that there may be infants in the Netherlands who experience an overall level of exposure to lead in the range associated with neurological and cognitive effects such as behavioural problems and reduced IQ.

The Committee believes that replacement of lead drinking water pipes is the most effective way of bringing lead levels down to meet the proposed standard. The expectation is that by 2000 all lead supply pipes will have been replaced by pipes which do not act as sources of lead. The replacement of private lead drinking water piping is likely to take longer. In view of the fact that, the Committee considers it advisable to concentrate the preventive effort on parents who are bottle feeding or intend to bottle feed their babies on formula milk made up using drinking water which has passed through supply pipes or domestic drinking water pipes made of lead.

Because it is the government’s policy to provide the population with healthy drinking water, the Committee expects the government to first identify the households in which drinking water is delivered through lead piping and than provide the inhabitants with information at an early stage (before the birth of the baby) on methods preventing infants to be exposed to lead concentrations liable to exceed the PTWI. The information could, for instance, be offered via midwives, maternity care nurses and local clinics. To this, information from the Health Care Inspectorate, the Netherlands’ Bureau for Food and Nutrition Education and the information on baby food packaging should be adapted.

The Committee calls for further research into the, although prohibited, continued use of lead solder in the installation of copper drinking water systems. Such research could, in the Committee’s view, be combined with research into the significance of other materials used in drinking water systems (polyvinyl chloride (PVC), brass and bronze) as sources of lead in drinking water.

Chapter **1**

Introduction

1.1 Historical perspective

The health implications of exposure to lead were first described more than two thousand years ago. In 200 BC, the Greek poet and physician Nicander reported the classic symptoms of lead poisoning, including lead colic, constipation, pallor and paralysis (AlS94). The phenomena described by Nicander occur at relatively high levels of exposure. Such high concentrations of lead are not found in the environment in the Netherlands, although they can occur in exceptional circumstances such as certain workplaces.

In 1908, a committee of the Central Health Council, considered the problem of lead entering drinking water supplies from lead pipes. Knowing that exposure to lead could be harmful to health, the committee wished to establish whether exposure through tap water could induce these known detrimental health effects. The committee described factors influencing the transfer of lead to tap water and the resulting lead concentrations in the water. With a view to preventing the consumption of water with high lead concentrations, the committee advised to use lead pipes that were lined on the inside with another material. It was also suggested to run the tap for a while before taking water for consumption (GR08).

Following a case of lead poisoning in Helden-Panningen and the publication of experimental data from research with a few volunteers, in 1941 another Health Council committee proposed that, on health grounds, the concentration of lead in drinking water should not exceed 300 microgrammes per litre (µg/l) (GR41). In 1958, the

World Health Organization (WHO) published the first edition of its International Standards for Drinking Water, which proposed a standard of 100 μg/l for lead in drinking water. The 1984 edition of the WHO's publication subsequently became the basis for the standard that currently applies in the Netherlands, namely 50 μg/l. The WHO indicated that at a drinking water lead concentration of 50 μg/l or lower, the provisional tolerable weekly intake (PTWI) accepted at that time for adults and children, namely 50 μg/kilogramme body weight per week (μg/kg bw per week), would not be exceeded (Qui90).

In 1993, the WHO revised its advice, recommending that the concentration of lead in drinking water should not exceed 10 μg/l. The new recommendation was based on the assumption that it was hazardous to expose infants to more than 25 microgrammes of lead per kilogramme body weight (μg Pb/kg bw) per week. This PTWI figure was arrived at by a joint working group set up by the WHO and the Food and Agriculture Organization (FAO), known as the Joint FAO/WHO Expert Committee on Food Additives or JECFA, and was based on kinetic research data (WHO86a, WHO87). The research in question indicated that exposure to 5 μg Pb/kg bw or more per day led to increased lead concentrations in the blood and to rapid accumulation to higher concentrations of lead in the body as when the exposure was between 3 and 4 μg/kg bw per day. At exposure levels as the latter, blood lead concentrations remained constant. The new drinking water standard was then calculated for an infant weighing 5 kg taking in half the tolerable daily dose of lead via formula milk prepared using 0.75 litres of water. Such an infant should not take in more than 25 μg/kg bw per week (or 3.5 μg/kg bw per day) via its milk, from which it follows that the drinking water should not contain more than about 10 microgrammes of lead per litre. By aiming the new standard at a relatively vulnerable group (i.e. infants), the WHO hoped to protect the population as a whole against the health problems associated with lead (WHO93). This approach to the formulation of a standard is unique; the Committee knows of no other substance for which an exposure limit is set on the basis of research data concerning infants.

1.2 Lead in tap water

In the Netherlands, domestic tap water is approved as 'drinking water'. Under the Water Supply Decree, tap water has to be of a quality that is not detrimental to public health. The nation's drinking water companies supply about 1.3 billion cubic metres of drinkable water a year to six million households (Hov95). Tap water arrives via a system of transport, distribution and service pipes (supply pipes) managed by the water supply companies and via domestic pipes (drinking water systems) owned by the householders. The materials from which the pipe systems are made and the quality of the water entering them largely determine the composition of the consumer's tap water.

For their transport and distribution pipes, the Netherlands' water supply companies mainly used polyvinyl chloride (PVC), asbestos cement and cast iron. The average lead concentration in drinking water leaving the production stations is generally less than 1 µg/l, and the maximum 10 µg/l (Ver92). However, higher concentrations can occur in the drinking water that eventually emerges from the tap. Any rise in lead concentration between the production station and the tap depends on the material with which the water comes into contact on the way. Private drinking water systems sometimes contain lead pipes, although, copper and, to a lesser extent, plastic pipes are more common. The use of lead pipes and lead solder in unions between copper pipes leads to increased lead concentrations in drinking water at the point of consumption. Lead pipes are found mainly in systems installed before 1945. The use of lead solder has been banned within the drinking water industry since 1 March 1995. Other materials used in the construction of drinking water systems can also act as sources of lead in tap water; these materials include PVC (in which lead salts are used as stabilizers), brass and bronze. However, the amount of lead entering water supplies from these sources appears to be small in comparison with the amount attributable to lead pipes.

A recent survey of the make-up of the Netherlands' infrastructure indicated that there were still about 450,000 drinking water systems in use that contained lead piping, and about 393,000 lead supply pipes. This equates to around 7.5 per cent of all drinking water systems and 6.5 per cent of supply pipes. The water supply companies envisage replacing most lead supply pipes by the year 2000 and all by 2005 (DGM96, VEW94).

1.3 The request for advice from the minister of VROM

The European Commission on Lead in Drinking Water recently drew up a draft directive in which, on the basis of the WHO's recommendation (see 1.1), a new standard of 10 µg/l was proposed. Given that the final version of the directive will have to be implemented in the Netherlands, the Minister of Housing, Spatial Planning and the Environment asked the Health Council to prepare a report on what is presently known about the risks associated with lead in drinking water. The full text of the minister's request for advice is included in Annex A.

In first instance the minister questioned whether the levels of exposure to lead in the Netherlands were too high in health terms. She also asked whether reducing the standard concentration from the present 50 µg/l to 10 µg/l, as proposed, would benefit public health, and whether exposure to lead via tap water particularly affected any certain sections of the community. In the second part of her request, the minister went on to ask what could be done to prevent exposure to lead; in particular, she inquired whether, for instance, more rapid replacement of lead pipes, a ban on the use of lead solder or the installation of special ‘lead-free’ taps would be advisable.

1.4 Establishment of the Committee and the structure of this report

In response to the minister’s request, the President of the Health Council of the Netherlands established the Committee on Lead in Drinking Water, referred to in the rest of this report as ‘the Committee’. With the publication of this report, the Committee has completed the task for which it was formed.

Chapter 2 of this report deals with the present patterns of exposure to lead in the general population and in certain groups at risk, and considers the extent to which drinking water acts as a vehicle for such exposure. The potential health problems associated with various levels of exposure to lead are set out in chapter 3. Possible ways of reducing exposure to lead are considered in chapter 4. Finally, explicit answers to the minister’s questions are provided in chapter 5.

Chapter **2**

Exposure to lead in the Netherlands

2.1 Sources of external exposure

2.1.1 Air

In the Netherlands, most atmospheric lead (in the form of anorganic lead compounds) originates from the combustion of leaded petrol by motor vehicles. As leaded petrol is phased out, these emissions will gradually cease, with elimination expected by the year 2010 (CCRX95). Van Wijnen and colleagues compared (median) blood lead concentrations in children aged between one and six in the late seventies with corresponding data from the early nineties and found a more or less across-the-board reduction of more than 50 per cent. The reduced lead levels were attributed to the introduction of low-lead and unleaded petrol (Wij96). Brunekreef had previously demonstrated by research in urban areas that traffic was a major determinant of lead exposure levels (Bru85). Other sources of atmospheric lead include manufacturing industry (in particular the metal industry), power stations and waste incineration plants.

In 1993, the Netherlands' annual average concentration of lead in the atmosphere was 0.035 $\mu g/m^3$. Average concentrations are higher in cities with high levels of traffic and industrial activity. Even in such urban areas, however, the annual average at pavement height has not been above 0.5 µg/m^3 since 1994*. Indoors, airborne lead concentrations can be raised by smoking (CCRX95).

2.1.2 Soil particles and house dust

Lead deposition in the soil takes two forms: *diffuse deposition* of lead aerosols (from vehicular and industrial emissions) and *local deposition* caused by the tipping (and, in some cases, subsequent wind dispersal) of general refuse, slag and fly ash from waste incineration plants and coal-fired combustion plants. Because lead adheres to soil particles, relatively little is leached out and the remainder accumulates in the soil. Soil lead levels in the Netherlands' natural habitats vary according to soil texture and the concentration of organic material (CCRX90). In 1993, concentrations of between 8 and 127 milligrammes/kilogramme dry material (mg/kg dm) were recorded. In a survey of fifteen 'non-suspect' rural sites between 1986 and 1990, the average soil lead concentration for all soil types was found to be 27 mg/kg dm (CCRX95). Soil pollution by lead occurs primarily in urban areas, where local industry and motor traffic are liable to contaminate street dust, as well as the soil itself. In 1994, for instance, soil samples obtained in Arnhem contained between 15 and 925 mg/kg dm (Die94). Samples of dust from three different kind of streets in Rotterdam proved to have geometric mean lead concentrations of 556, 976 and 2346 µg/g dm respectively (Kla97). In non-urban areas, relatively high lead concentrations are found in the soil beside roads, on shooting ranges, on industrial estates, on flood plains and at sites where harbour mud has been deposited (CCRX95).

Domestic dust consists not only of soil and street dust particles, but also, for instance, of carpet fragments, hair and flakes of paint. The use of leaded paint can contribute to increased lead concentrations; in the United States, this is considered to be a serious problem (EPA94). Various researchers have established a link between lead concentrations in house dust and blood lead concentrations. Landrigan and colleagues, for instance, found such a correlation when studying a group in which individual blood lead concentrations did not exceed 200 µg/l (Lan96). In the Netherlands, however, the Committee believes that paint particles account for a relatively small proportion of the lead to be found in house dust, because the use of leaded paint has been banned in this country since the seventies.

* In the Netherlands, the annual median atmospheric lead concentration is not allowed to exceed 0.5 µg/m^3 and the 98th percentile in any twenty-four hour period must not exceed 2.0 µg/m^3 (Sch94).

2.1.3 Food

The extent of an individual's exposure to lead via food depends largely on what they eat and their eating patterns. Both these determinants are in turn dependent on the individual's age. Most of an infant's diet, for instance, consists of its mother's milk and

bottle feed*. From the age of about six months onwards, milk is increasingly combined with solid baby food (Bra93). The diet of a child of more than a year old is increasingly similar in its make-up to that of an adult.

The lead content of a given foodstuff depends in part on the conditions in the locality where the (constituent) plant or animal was grown or reared. Factors such as soil condition, air pollution, the lead content of animal feed and the presence of lead in packaging material and cooking equipment all influence the amount of lead that ends up 'on the dinner table'. Various product quality assurance programmes are in place in the Netherlands, as part of which the concentrations of various substances in agricultural produce are monitored. So, for instance, data are available on the concentrations of lead in tea, wheat, vegetables, fish, poultry and animal organs (Kla95).

2.1.4 Drinking water

As indicated in section 1.2, the annual average lead concentration in drinking water supplies in most areas of the Netherlands does not exceed 1 µg/l. The lead concentration in the water actually consumed by the individual householder depends on the interaction between the tap water and the fabric of the pipes through which it passes. Most of the lead found in drinking water is particulate and in the form of compounds containing carbonates and hydroxyl ions (Ver92). In an acidic environment, such as the stomach, these compounds break up, leading to the release of lead ions.

Interaction between lead pipes and the water flowing through them can result in tap water with lead concentrations of several hundred µg/l. The ultimate concentration of lead brought about by such interaction depends on various factors, such as the length of time the water remains in the pipes (water which has stood in a lead pipe for twelve hours will be about 90 per cent saturated with lead), the temperature, the acidity

* The term bottle feed includes both ready-made baby milk and formula milk. By formula milk, the Committee means milk made up from by dissolving a complete or follow-up infant feed powder in drinking water. Expressed milk administered by bottle is not considered by the Committee to be bottle feed.

and the bicarbonate content of the water, the length and diameter of the pipes and the presence of a protective lining (Hov86a). The Committee estimates that the average lead content of tap water which has passed during the day through lead supply pipes or lead domestic pipes is likely to be 35 µg/l. This figure is based on the results of a lead pipe test (see Annex C) and analysis of consumer tap water samples. Lead solder used in drinking water pipe joints is most likely to lead to significant lead concentrations in the first few months after installation of the pipes in question. During this initial period, the concentrations associated with lead solder can be comparable with the concentrations one would expect in water supplied via lead pipes. Depending on the amount of solder used and the manner of its use, most of the lead-soldered joints cease to give rise to substantial concentrations within a few years; thereafter, the average lead concentration is unlikely to exceed 10 µg/l (Fre89, Lee89).

Most of the lead pipes still found in the Netherlands are in the old city centres of Amsterdam, Rotterdam, The Hague and Groningen (DGM96). Many drinking water companies serving areas in which the water has a high lead-bearing capacity and in which lead drinking water pipes are still in use, have started drinking water conditioning programmes. These companies have reduced the acidity of the water and softened it by removing bicarbonate, thereby cutting drinking water lead concentrations to below 50 µg/l (Hov95, Ver92, Tie95). By implementing a similar policy, certain Scottish drinking water companies have effected a significant reduction in average blood lead concentrations within the space of two years (NRC93). Research in Glasgow, Groningen and Haarlem has shown that the presence of lead drinking water pipes is linked to raised blood lead concentrations (Dui97, Min97, Wat96).

2.1.5 Other sources

Lead can enter food and drink from lead-glazed earthenware, crystal, lead-soldered tins, pans, kettles and so on. Consumption of foodstuffs or drink that has been in contact with such sources increases exposure to lead (WHO96). DeMejia and colleagues demonstrated that the amount of lead released from lead-glazed crockery is influenced by the type of food and the manner of its preparation. When prepared using such crockery, relatively acidic food is associated with higher blood lead concentrations (Mej97). Objects containing lead compounds, painted with leaded paint or covered in (house) dust that has lead in it can all be sources of exposure to lead if placed in the mouth.

Table 1 Infant exposure to lead (in microgrammes of lead per kilogramme body weight per day) through complete and follow-up bottle feed made using drinking water with lead concentrations of 10, 25, 35 and 50 µg/l.[a]

age in months (weight in kilogrammes)	total milk intake per day in ml	total exposure to lead (µg/kg bw per day) through formula milk made with water containing lead in the following concentrations:			
		10 µg/l	25 µg/l	35 µg/l	50 µg/l
0 - ½ (3.5)	500 - 600	1.3 - 1.6	3.3 - 3.9	4.6 - 5.5	6.5 - 7.8
½ - 1 (3.8)	550 - 650	1.3 - 1.6	3.3 - 3.9	4.6 - 5.5	6.5 - 7.8
1 - 2 (4.6)	600 - 700	1.2 - 1.4	3.0 - 3.5	4.3 - 4.8	5.9 - 6.9
2 - 3 (5.3)	700 - 800	1.2 - 1.4	3.0 - 3.5	4.2 - 4.8	6.0 - 6.8
3 - 4 (6.0)	800 - 900	1.2 - 1.4	3.0 - 3.5	4.3 - 4.8	6.1 - 6.8
4 - 5 (6.6)	850 - 950	1.2 - 1.3	2.9 - 3.3	4.1 - 4.6	5.8 - 6.5
5 - 6 (7.2)	850 - 1000	1.1 - 1.3	2.7 - 3.2	3.7 - 5.0	5.4 - 6.3
6 - 7 (7.7)	700 - 800	0.8 - 0.9	2.1 - 2.4	2.9 - 3.3	4.1 - 4.7
7 - 8 (8.2)	600 - 700	0.6 - 0.8	1.6 - 1.9	2.4 - 2.7	3.4 - 3.9
8 - 9 (8.5)	500 - 600	0.5 - 0.6	1.4 - 1.6	1.9 - 2.3	2.6 - 3.2
9 - 12 (9.4)	500 - 600	0.4 - 0.5	1.2 - 1.5	1.7 - 2.0	2.5 - 2.9

[a] The concentrations 10 and 50 µg/l were chosen because they are, respectively, the proposed new standard and the existing standard for lead in drinking water. Furthermore, the Committee believes that 10 µg/l is a reasonable estimate of the average lead concentration in tap water which does not pass through lead pipes. The draft EU directive on lead in drinking water proposes an 'interim standard' of 25 µg/l. The suggestion is that the interim standard should be achieved within five years of the directive coming into force, and the ultimate standard of 10 µg/l within ten years. As indicated in subsection 2.1.4, the Committee believes that the average lead concentration in the tap water which does pass through lead pipes or through copper pipes newly connected using lead solder is likely to be about 35 µg/l.

2.2 Infant exposure

Infants (i.e. babies less than a year old) are exposed to lead principally through their food. Because infants and children generally require more energy per kilogramme body weight than adults, they consume more food and breathe in more air per kilogramme body weight than adults. As a result, children can suffer comparatively high levels of exposure. Another significant factor is that children absorb a higher proportion of ingested lead via the intestines than adults do (see section 3.1).

Much of an infant's diet consists of its mother's milk and bottle feed. Data from 1995 indicates that infants in the Netherlands receive a high proportion of bottle feed from an early age: shortly after birth, about 69 per cent of infants are entirely or partially breast fed, but the figure drops to 56, 49 and 27 per cent by the sixth week, the third month and the sixth month, respectively (CBS96). Almost no babies are breast fed beyond the twelfth month. The likelihood of a baby being breast fed increases in proportion to the mother's level of education and in inverse proportion to her smoking and drinking (Geu93). After the first five or six months, milk is supplemented with solid baby food and drinks.

In estimating infants' food-related exposure to lead, the Committee referred to the dietary advice contained in 'The Dutch Manual of Paediatric Medicine' (Bra93) and the 'Chief Medical Inspectorate for Public Health's bulletin Infant diet' (GHI91). It should be emphasized that in reality an individual infant's diet may differ considerably from that assumed for the purposes of the Committee's calculations. In practice, the diet advised by the staff at the local clinic is adjusted to suit the infant's personal requirements. The Committee has assumed that bottle feed is prepared using lead-free milk powder and tap water that is not hot and has not been heated in a lead-soldered kettle; should infants be fed on milk prepared in these ways they will then suffer higher levels of exposure from their food.

Table 1 contains data on exposure to lead through bottle feed made using drinking water with lead concentrations of 10, 25, 35 and 50 µg/l. The average body weight at each age is also indicated. No distinction is made by gender (CBS96).

Exposure to lead through breast milk is not covered. The concentration of lead in a mother's milk is generally about 5 to 10 per cent of her blood lead concentration (WHO95). Thus, given an average maternal blood lead level of 45 µg/l (a figure based on the lead concentrations found in blood from the umbilical cords of newborn babies; Dui95), breast milk is likely to have lead concentrations of between 2.3 and 4.5 µg/l. An infant consuming an average of about 150 ml of milk per day per kilogramme body weight will therefore be exposed to between 0.3 and 0.7 µg/kg bw a day.

It will be apparent from the table that an infant's milk intake rises until the fifth or sixth month, then drops. However, the level of milk-related exposure to lead per kilogramme body weight is falling even in the first few months, because the infant's body weight increases more rapidly than its milk consumption.

From the fifth or sixth month (and sometimes sooner), the infant's diet is supplemented with solid baby food. This might typically consist of a few spoonfuls of vegetables, potatoes, legumes, porridge, yoghurt, egg, fruit, or bread with something spread on it. At this age, infants also start drinking other liquids, such as tea (sometimes with milk), water or diluted fruit concentrate or juice. Ready-made proprietary baby foods are also used. The Committee did not have access to any data on the amount of lead in proprietary baby foods and therefore decided to exclude them from its calculations regarding food-related exposure to lead.

Exposure to lead through home-made solid baby foods was estimated using the infant dietary advice referred to earlier and data on average lead concentrations in foodstuffs (Dok94). The Committee's calculations suggested that on average, from the fifth month to the eighth month, daily exposure to lead through solid baby food was between 0.1 and 0.5 µg/kg bw, given lead concentrations of between 10 and 50 µg/l in the drinking water. In each of the subsequent months (months eight to twelve, inclusive), exposure to lead through solid baby food apparently increases. Depending on the drinking water lead concentration, infants in this age group are exposed to an average of between 0.7 and 1.5 µg Pb/kg bw per day through solid baby food. The levels of tea consumption appeared to be particularly influential in this context (see Annex D). To take account of exposure to lead through the intake of soil particles and house dust by infants aged six months and over, a further 0.3 µg/kg bw per day should be added to the exposure figures cited above. This additional exposure figure has been calculated assuming that the average lead concentration in soil particles and dust is 150 µg/g dm (see subsection 2.1.2) and that infants in this age group take in between 12.5 and 21 mg per day (as suggested recently by the WHO (WHO95); see section 2.3).

Infants are exposed to lead not only through their food, but also through the air they breathe. A baby inhaling between four and six cubic metres (m^3) of air a day with an average lead concentration of 0.035 $\mu g/m^3$ (see subsection 2.1.1) will breathe in between 0.02 and 0.04 µg Pb/kg bw per day. Those in urban areas could be exposed to five or ten times as much airborne lead (CCRX95). A child whose parents or carers smoke will also breathe in more lead.

If one aggregates the figures relating to the various forms of exposure, overall infant exposure to lead per kilogramme body weight appears to be highest in the first five to six months of life. The most important source of exposure during this period is the baby's milk. If the baby is drinking formula milk made using drinking water with an average lead concentration of 35 µg/l, the average weekly exposure to lead will be between 24.5 and 38.5 µg/kg bw. If the drinking water has a lead concentration of 50 µg/l, exposure rises to between 35 and 56 µg Pb/kg bw per week. From the sixth month onwards, solid baby food's significance as a source of lead increases, but overall exposure to lead per kilogramme body weight continues to fall. By the time an infant reaches the age of twelve months, its overall weekly exposure to lead is about 9.1 µg/kg bw if the drinking water has a lead concentration of 10 µg/l, a little over 21 µg/kg bw at a concentration of 35 µg/l, and a little over 28 µg/kg bw at 50 µg/l. Bottle feed accounts for 60 per cent of overall exposure at an average drinking water lead concentration of 35 µg/l and 70 per cent at 50 µg/l.

Table 2 The estimated average dietary exposure to lead (in µg/kg bw per day) experienced by children more than a year old and by adults, given drinking water lead concentrations of 0, 10 and 35 µg per litre, based on VCP'92 data.

population group (average body weight in kilogrammes)	number of persons in VCP sample	average exposure to lead (µg/kg bw per day) at the following drinking water lead concentrations:		
		0 µg/l	10 µg/l	35 µg/l
VCP population as a whole (58.3)	6,218	0.36	0.5	0.87
children 1-4 years old (13.5)	351	0.63	0.83	1.33
children 4-19 years old (40.7)	1,343	0.42	0.51	0.75
adults 19-65 years old (70.8)	4,025	0.31	0.47	0.86
adults 65 years old and older (71.8)	499	0.36	0.51	0.9
pregnant women (68.8)	58	0.34	0.47	0.8

Given that the annual birth rate is about 196,000 and that about 7.5 per cent of households' drinking water passes through lead pipes (see section 1.2), it follows that about fifteen thousand infants a year could receive milk made up using tap water with an average lead concentration of 35 µg/l. Allowing for the percentage of infants that are breast fed, it is likely that about eleven thousand infants are consequently exposed to more than the PTWI of 25 µg Pb/kg bw per week for the first six months of their lives. (see Annex E.)

In view of the foregoing, the Committee considers infants to be a group at risk in relation to lead; they experience relatively high levels of exposure per kilogramme body weight (GR85).

2.3 Child and adult exposure

To gain an impression of the overall level of exposure to lead experienced in the Netherlands by children more than a year old and by adults, the Committee obtained estimates of the levels of exposure attributable to the ingestion of food and the inhalation of air. At the Committee's request, the average intake of lead in food was calculated by the National Institute for the Quality Control of Agricultural Products in collaboration with the Nutrition Division of TNO (Netherlands Organization for Applied Scientific Research); these organizations linked data from the 1992 Food Consumption Survey (VCP'92) to the most recent data on the levels of lead in primary agricultural produce (covering the period 1990-1995) and data on levels of lead in foodstuffs (1988/1989). Details of the calculation method and the results are given in Annex D. To gauge the extent to which drinking water influences overall dietary exposure to lead, calculations were performed for three different drinking water lead concentrations (0, 10 and 35 µg/l). Any additional exposure attributable to the consumption of food cooked in water that contains lead is difficult to quantify; in view of this fact and the Committee's belief that any such additional exposure was unlikely to be high, it was decided to ignore this possible source of lead.

The calculated exposure data is summarized in Table 2. Separate estimates are given for the average dietary exposure to lead experienced in the Netherlands by people aged one to four years, four to nineteen, nineteen to sixty-five and over sixty five, as well as by pregnant women. Given the available information, the Committee considers the results to represent the most reliable estimates of overall dietary exposure to lead.

From Table 2, it will be apparent that children aged one to four experience the highest levels of dietary exposure to lead per kilogramme body weight. This is because children in this age group need more energy per kilogramme body weight. Taking the VCP population as a whole, drinking water accounts for about 0.9 litres (standard deviation 0.5 litres) of the two litres or so of liquids (soup, milk, soft drinks, coffee, etc.) consumed by the average individual each day. If the drinking water has an average lead concentration of 10 µg/l, it accounts for about 30 per cent of the individual's overall dietary exposure to lead; at a drinking water lead concentration of 35 µg/l, this figure rises to 60 per cent. The figure of 0.9 litres represents the total quantity of drinking water consumed directly and used to make tea, coffee and soup.

For a complete picture of overall exposure to lead, one needs to include the intake of soil particles and house dust. Attempts have been made to quantify soil and house dust intake. The intake appears to be age dependent. Children aged between one and four take in more soil than older children and adults, because of their 'hand-to-mouth habits' (Cla89). In the Netherlands, Clausing and colleagues found that one- and two-year-old city children took in an average of about 100 milligrammes (mg) of soil particles a day in good weather. Van Wijnen also found that the weather (the season) was one of the factors influencing the amount of soil entering the body. Children aged one to five years old staying in kinder gartens or on camping sites took in between 0 and 90, and 30 and 400 mg dw a day, respectively (Wij90). Stanek and colleagues calculated median soil particle intake levels of 13 and 138 mg per day for, respectively, 50 per cent and 95 per cent of the children studied (aged one to four); the averages for these groups of children were 45 and 208 mg per day, respectively (Sta95). A recent WHO evaluation indicated that on average children take in between 12.5 and 21 mg of soil particles (WHO95). Calabrese and colleagues suggested that adults take in an average of about 50 mg a day (Cal90).

Because of the paucity of information available the Committee made an estimation of the amount of ingested soil and house dust. As a result, one-to-four-year-olds are particularly likely to experience higher levels of exposure to lead in areas where the soil is polluted with lead (old city centres). If a child takes in about 100 milligrammes of soil and dust particles a day (which seems a realistic supposition; see above) with an average lead concentration of 150 mg/kg dm (see subsection 2.1.2), he or she will be exposed to about an extra 1 µg/kg bw per day. From a study in which the blood lead concentrations of inner city children in Amsterdam and Rotterdam were compared with children in outlying areas, we know that children living in city centres experience higher levels of exposure to lead. The two groups of children studied had average blood lead levels of 64 and 45 µg/l, respectively. Some 6.7 per cent of the inner city children had a blood lead level of between 100 and 150 µg/l and 2.7 per cent a blood lead level higher than 150 µg/l; in outlying areas, the corresponding figures were 2 per cent and zero (Wij96).

In calculating exposure to lead by inhalation, the Committee assumed that the annual average atmospheric lead concentration was 0.035 $\mu g/m^3$ (see subsection 2.1.1) and that people aged one year and above inhaled between 6 and 18 m^3 of air a day (WHO86). On this basis, the additional daily exposure to lead by inhalation works out at between 0.2 and 0.8 µg. Relative to body weight, people of all ages are exposed to about 0.01 µg/kg bw per day. In urban areas, the levels of exposure may be several times higher.

On the basis of these figures, neither children aged one or more nor adults appear to belong to groups at risk with respect to lead exposure, in contrast to bottle-fed infants. It should be noted, however, that the figures apply to the population as a whole; particular groups such as workers in the metal and (vehicle) recycling industries may form exceptions. In none of the age groups considered does the consumption of drinking water containing lead in concentrations typical for water that has passed through lead pipes appear to cause weekly levels of overall exposure in excess of 25 µg Pb/kg bw.

The data on estimated overall exposure to lead discussed in sections 2.2 and 2.3 is presented in Figure 1 as a function of age. The sources of lead considered include inhaled air and food; a tap water lead concentration of 35 µg/l is assumed. In the figure, the line labelled PTDI represents a daily exposure level equal to one seventh of the WHO's 'provisional tolerable weekly intake' (PTWI; see section 1.1). Where infants are concerned, tea consumption is included under the heading 'solid (baby) food'; where older children and adults are concerned, tea, coffee and soup consumption comes under the heading 'drinking water'.

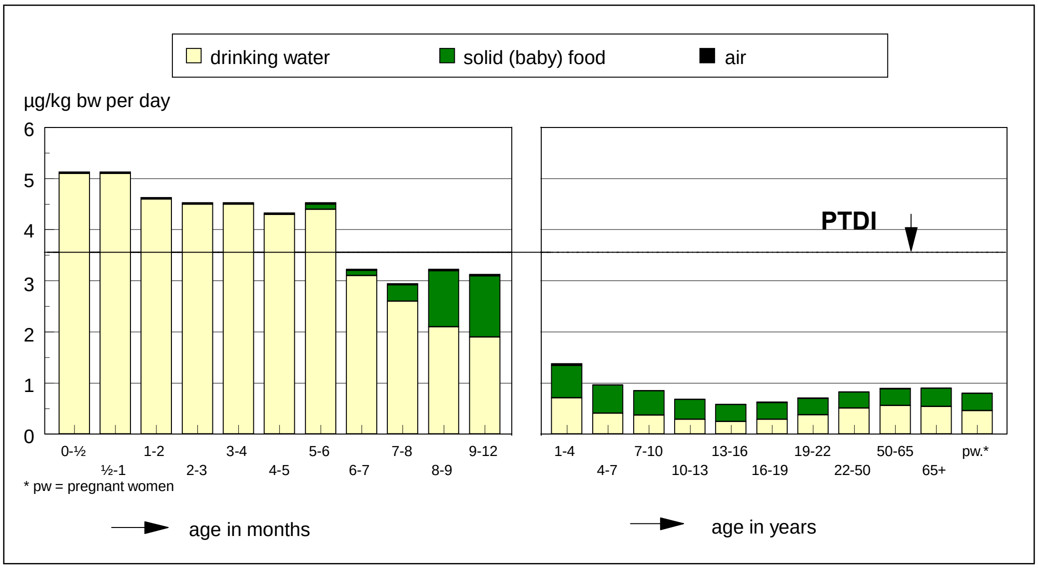

Figure 1 Breakdown of overall daily exposure to lead (in microgrammes per kilogramme body weight) according to exposure medium (drinking water, inhaled air and food) as function of age, assuming a drinking water lead concentration of 35 µg/l.

The figure shows that infants experience the highest levels of exposure to lead per kilogramme body weight; indeed, in the first six months of life, exposure exceeds the PTWI. Children between one and four years of age take in about 10.5 µg/kg bw a week. The average overall exposure for individuals aged five and over is 7 µg/kg bw per week at most; pregnant women are exposed to similar levels. If, where children aged between one and four years are concerned, one additionally takes into account exposure to lead from the ingestion of soil particles and house dust, as described above, overall exposure proves to be about 1.7 times higher, at 17.5 µg/kg bw per week.

Chapter **3**

Health implications of exposure to lead

3.1 Kinetics; internal exposure

Thus far, we have considered the sources of lead and the level of exposure experienced by individuals of various ages. Another Health Council committee previously defined exposure to a substance as: “... contact between an organism and a substance, as a result of which the substance may affect the organism.” (GR96). Such (*external*) exposure is often expressed as a quantity of the substance per kilogramme body weight and reffered to as the dose. Depending on the exposure route and the form in which the substance is ‘made available’ to the organism, the substance may ultimately enter the body; this is referred to as *internal* exposure (or body burden). The amount of the substance in the body is a product of the level of exposure, the processes of absorption and excretion by and between the various tissues and organs and excretion by the body.

Lead absorbed by the body appears to concentrate mainly in three bodily compartments: the blood, the soft tissues (liver, kidneys, nerve tissue) and bone. The percentages of absorbed lead found in these three compartments are 1, 9 and 90, respectively, in adults (WHO95) and 1, 29 and 70 in children (CCRX95). About 76 per cent of absorbed lead is excreted by the body via the kidneys, about 16 per cent via the gastro-intestinal tract and about 8 per cent via the sweat, bile, hair and nails. Lead can also leave the body of a lactating woman via her milk. The concentration of lead in human milk is 5 to 10 per cent of the lead concentration in the individual’s blood. The lead concentrations in the various compartments reflect the level of exposure in the preceding period, taking into account the substance’s half life* in the relevant compartment.

The half life of lead in blood is about thirty-six days, in soft tissues about forty days and in bone about thirty years (WHO95). In most research blood lead concentrations are used to describe the lead exposure.

The level of lead absorption by the lungs is influenced by factors such as particle size and inhalation rate. Adults can be expected to absorb between 30 and 50 per cent of the quantity inhaled. Children absorb about the same percentage, or possibly a little more (WHO95).

Exposure to lead by ingestion follows the consumption or intake of lead in food, drinking water, and soil and (house) dust particles (including inhaled particles which lodge in the upper air ways and are subsequently swallowed). The proportion of ingested lead absorbed depends in part on the age of the exposed individual. In adults, about 10 per cent of ingested lead is absorbed, but up to the age of six years, children absorb between 40 and 50 per cent. Absorption via the gastrointestinal tract is greater if lead is ingested between meals or when the individual is in a period of fasting; under such circumstances, adults can absorb as much as 35 per cent (Sar94).

Other factors influencing the proportion absorbed are the form of lead involved, the nutritional condition of the exposed individual and digestive factors. Low calcium or iron intake, for instance, are associated with higher blood lead concentrations, as is a low iron status (WHO96). This is significant where women of reproductive age are concerned, since they are susceptible to low iron status (Sta95).

From studies with children orally eposed to lead, it showed that the excretion of lead by the body exceeded the intake at daily exposure levels below 5 µg/kg bw. Whenever the exposure was about 5 µg/kg bw per day, the retention was positive and about 0.43 µg/kg bw per day. This exposure resulted in a rise of the blood lead concentration within six months between 10 and 20 µg/l (Zie78). Infants showed a somewhat constant blood lead concentration whenever their daily lead exposure didn't exceed 3 to 4 µg/kg bw per day. Through an exposure of about 8 or 9 µg/kg bw a day, their blood lead concentrations doubled within 6 months (Ryu83, Ryu85).

In an adult, a 1 µg per day increase in food-related exposure (not corrected for body weight) will push up the blood lead level by between 0.4 and 0.6 µg/l once bodily equilibrium has been re-established; in children, a similar increase in exposure will raise the blood lead level by 1.6 µg/l. Similarly, a 1 µg/l rise in drinking water-related exposure will increase an adult’s blood lead level by 0.6 µg/l. These relations are valid only when relatively low exposures are considered (WHO86b, WHO95).

* Half life: the period required for the quantity of a substance in the body to be halved by excretion (abbreviation: T½).

3.2 Health implications for children

Even before birth, babies can be exposed to lead. This can have an effect on mental development which remains measurable many years after birth. Such effects are known to occur at maternal blood lead concentrations (or umbilical cord blood lead concentrations) of 100 µg/l and above. Such blood lead concentrations are also associated with reduced birth weight and premature birth (NRC93). Neurotoxic substances such as lead pose a risk during pregnancy because the unborn child’s neurological system is still developing and has yet to acquire mature levels of resistance. The nervous system of a foetus is therefore particularly sensitive to toxic substances. During pregnancy, furthermore, lead is released from the bones in larger quantities and low iron status is more likely (see section 3.1), with the result that the fetus is exposed to higher levels of lead.

One bodily response observed at blood lead concentrations as low as 30 µg/l is reduced aminolevulinic acid dehydratase enzyme (ALAD enzyme) activity. Reduced ALAD enzyme activity is associated with increased ALA synthase activity, which impairs haemoglobin synthesis (WHO95). It is not known whether such changes in enzyme activity are detrimental to health in the long term, but the Committee cannot exclude this possibility.

Neurological or cognitive phenomena, such as neurological behavioural retardation or reduced IQ, are associated with blood lead concentrations as low as 100 µg/l (Bel94, Goy94, McM95, NRC93, Poc94, Ton96). Doubling the blood lead level of children aged between four and ten from 100 to 200 µg/l can reduce IQ test scores by up to five points (SAHC93). In many cases, there is uncertainty regarding the level and duration of exposure required to bring about the blood lead concentrations and health problems referred to. To this, the large body of research data on the subject provides no evidence of a NOAEL (no-observed-adverse-effect level). Thus, the possibility that human health is impaired even at blood lead concentrations lower than 100 µg/l cannot be excluded (NRC93, Win94).

Between 150 and 200 µg/l, the body responds by increasing the level of erythrocyte-protoporphyrin (which is related to the production of red blood cells) and vitamin D metabolism is disturbed. At blood lead concentrations of 250 µg/l or higher, haemoglobin levels can be reduced and reaction times impaired, at concentrations of 300 µg/l or higher, nerve conduction is impaired and higher than 700 µg/l, children can suffer from anaemia and peripheral neuropathy (nerve disorders, possibly characterized by behavioural problems, restlessness; Coë74). Levels of exposure sufficient to induce blood lead concentrations of 1000 µg/l or higher can cause serious brain damage in children (NRC93). At such concentrations, lead colic (one of the 'classic' symptoms of lead poisoning; see section 1.1) can also occur.

3.3 Health implications for adults

Like children, increased ALAD enzyme activity is observed in adults at blood lead concentrations as low as about 50 µg/l (NRC93). Silbergeld and colleagues have suggested that there is no NOAEL for lead; they caution against any exposure to lead at any age, because of the possible irreversible neurological effects (Sil90).

Raised blood pressure can be brought about by levels of exposure sufficient to cause blood lead concentrations of between 100 and 150 µg/l (NRC93). In an adult, a blood lead level of 200 µg/l or higher prior to examination is associated with increases in diastolic and systolic blood pressure of 0.5 and 1 mm Hg (1 mm Hg = 0.135 kPa), respectively. Changes of this order are not, however, regarded as very significant in public health terms (Sta96). In women at concentrations higher than 150 µg/l, increased erythrocyte-protoporphyrin levels are observed, in men similar effects are observed at blood lead concentrations higher than 250 µg/l. Impaired nerve conduction and disturbed red blood cell production (indicated by raised ALA and coproporphyrin concentrations in the urine) occur at blood lead concentrations of 400 µg/l and above. Blood lead concentrations higher than 500 µg/l are associated with reduced haemoglobin levels, discernable sub-encephalopathic neurological symptoms (such as cramp and depression; Coë74) and disturbed testicular function. In women, blood lead concentrations higher than 600 µg/l can have reproductive implications. Concentrations higher than 800 µg/l can lead to anaemia. As in children, adults experiencing levels of exposure sufficient to induce blood lead concentrations of 1000 µg/l or higher can suffer serious consequences such as brain damage. At such concentrations, kidney dysfunction (chronic nephropathy) can also occur (NRC93).

3.4 Conclusion

In the abovewritten, it appeared that some infants that are bottle-fed can be exposed to lead exposure concentrations exceeding the PTWI. As a result the blood lead concentrations will rise, possibly up to 100 µg/l or higher. The Committe finds it proven that at blood lead levels of 100 µg/l or higher, neurologic and cognitive effects can arise. Whether the exceeding of the PTWI by bottle-fed children will lead to the latter effects, the Committee can not tell. Neither can she exclude the fact that effects can arise at blood lead levels even below 100 µg/l (see also section 3.2).

On the basis of the scientific literature, the Committee concludes that blood lead concentrations of about 50 µg/l are not conclusively associated with health problems.

However, such concentrations are associated with biochemical changes (such as ALAD level disturbances), the health implications of which are uncertain. It appears likely that most children in the Netherlands have blood lead concentrations of about 50 µg/l. A certain part of the children's population, though, still has blood lead concentrations exceeding 100 and 150 µg/l. Recent tests on newborn babies in Groningen and young children in Rotterdam and Amsterdam show average blood lead concentrations of between 45 and 65 µg/l. Some 6.7 per cent of children in central Amsterdam and central Rotterdam were found to have a blood lead level higher than 100 µg/l and 2.7 per cent a level higher than 150 µg/l (Dui95, Wij96).

The Committee would emphasize that children less than two years old (thus including the fetus) appear to be particularly at risk. Clearly, in this respect too, they are more sensitive than older people to the health problems associated with exposure to lead. What is more, the observed neurological and cognitive effects are often irreversible. The Committee would also point out that children whose drinking water passes through lead pipes are likely to live in areas where it is likely they experience higher levels of exposure via other routes, such as inhalation and the intake of soil particles and house dust. This could mean that they run an increased risk of developing higher blood lead concentrations.

Assuming that there is no great variation in adult blood lead concentrations in the Netherlands, and average blood lead concentrations equal about concentrations found in a study in Groningen (average blood lead concentration in adults: 48 µg/l; Dui97), the Committee does not believe that the health of the Netherlands’ adult population is being adversely affected by lead.

Chapter 4

Influencing exposure to lead via drinking water

The Committee considers a method to be effective if its application is certain to reduce the concentration of lead in the affected drinking water to 10 µg/l or less. This concentration will guarantee infants not to exceed a weekly lead exposure of 25 µg/kg bw or higher when bottle-fed. Methods the Committee classifies ‘uncertain effective’, are called such whenever people’s behaviour affects effectiveness or whenever effectiveness is proven only in controlled-for tests. Methods classified as in-effective, in not any way result in a lead concentration of 10 µg/l or lower.

4.1 Effective method

Replacement of lead piping in supply systems and domestic drinking water systems

Replacement means: replacement of lead piping by new piping that itself does not release lead. A replacement is succesful whenever is made certain that both lead supply systems and lead domestic drinking water systems are replaced.

It is possible to avoid the use of lead solder or other materials which act as a source of lead if, for instance, tin-silver or tin-copper solder or compression fittings are used. Materials which contain lead (such as brass) could be avoided altogether if copper pipes with copper (compression) fittings or plastic pipes and fittings were used (Sla95).

4.2 Methods of uncertain effectiveness

Installation of lead-free water taps

Installation of 'lead-free water taps' involves connecting an additional lead-free domestic outlet to a lead-free supply. Ideally, the lead-free water tap should be installed in the part of the home where water is most frequently drawn for consumption and cooking. The effectiveness of the lead-free water taps depends largely on consumer behaviour.

Flushing

Flushing a lead pipe before drawing water for consumption considerably reduces the average level of exposure to lead associated with that source. Flushing, though, does not guarantee lead concentrations below 10 µg/l. It happened that after flushing for two minutes the lead concentrations still were up to 25 µg/l. Particularly in cases where lead easily dissolves into the water and lead piping is extensive, flushing will not easily lead to lead concentrations of 10 µg/l or lower. Over-vigorous flushing can dislodge lead particles, thereby causing higher levels of drinking water-related exposure. The method is classified as ‘uncertain effective’ not only because people's behaviour affects effectiveness but local circumstances do as well. Also, advising consumers to flush their pipes is at odds with the policy of promoting economical use of water pursued by various drinking water companies.

PET lining

Lead piping can be lined with a layer of polyethylene terephthalate (PET). The technique has been successfully used on *supply pipes.* Because domestic drinking water systems differ with respect to diameter of the pipes and the characteristics of the piping compared to supply pipes, PET lining has not yet proven to be succesfull with domestic drinking water systems. PET lining of a supply pipe is therefore only sensible if the pipe feeds a lead-free domestic drinking water system.

Addition of inhibitors to tap water

The amount of metal that enters drinking water from the pipes through which it passes can be reduced by adding inhibitors. The inhibitor combines with ions in the water or on the inside of the pipe to form salts which are not easily soluble. Orthophosphates, polyphosphates (zinc orthophosphate) and silicates can be used as inhibitors (Lee89). It is not clear from the research conducted to date which inhibitor is the most effective in preventing lead entering a water supply. However, it has been calculated that the addition of phosphates could reduce the concentration of lead in drinking water which passes through lead pipes to less than 10 µg/l. In practice, concentrations of between 10 and 30 µg/l have been achieved. The use of inhibitors does have certain disadvantages: pipework might become fouled by bacteria and plankton, and phosphate concentrations in waste water would rise (Hov86b, Sch89, Wag92).

4.3 Ineffective method

Conditioning

Conditioning involves reducing the acidity of the water and softening it by reducing its bicarbonate content. Conditioned water takes on less lead from the pipes through which it passes (Tie95). However, it is not possible to reduce the average lead concentration in tap water to less than 10 µg/l using the methods currently available (Ver92).

4.4 Public information

In accordance with the conclusions on possible health impairment through lead exposure and in view of realization of effective measures, the Committee finds that action should be taken. At short notice, public information campaigns, particularly campaigns aimed at reducing the amount of lead to which bottle-fed infants that live in houses with lead drinking water piping are exposed, are another useful way of keeping intake below the PTWI level. The Committee believes that public information should be targeted at a specific group, namely parents who do not breastfeed their babies and use drinking water that has passed through lead pipes to prepare bottle feed. In line with the government's policy, the Committee expects her to identify the households where lead drinking water piping is present and inform the inhabitants. Besides this information at an early stage (to be effective, information should ideally be provided before the birth of the child), information concerning methods on how to reduce the lead exposure of bottle-fed infants should be provided. To this end, information could be distributed via general practitioners, gynaecologists or midwives, maternity care nurses, hospitals, clinics, local authorities or Municipal Health Services. Parents should also be able to obtain information on request from these people and institutions. The Health Care Inspectorate, the Netherlands' Bureau for Food and Nutrition

Education and baby food manufacturers should also be encouraged to include appropriate advice in their material or on their packaging.

The Committee believes parents in the target group should be advised regarding the following matters:

- the possibility of replacing the lead pipes in their domestic drinking water systems;
- the avoidance, by one of the following methods, of formula milk made using drinking water that has passed through lead pipes:
  - using ready-made baby food;
  - making up formula milk using bottled water.

In this context, it is evident that the lead concentration in bottled water will not exceed 10 µg/l. Results from the biannual bottled water quality checks over the last ten years indicate that no bottled water has a lead content of more than 5 µg/l and most has no detectable lead content (the detection limit being 1 µg/l; Buu97).

Chapter **5**

Answers to the minister's request for advice

Health implications and the effect of introducing a stricter standard

Question 1 What is the Health Council's view of the stricter standard proposed for lead in drinking water? (In your answer, please take account of any exposure to lead from other sources and concentrate on the situation in the Netherlands.)

The WHO's recommendation regarding the concentration of lead in drinking water is based upon the assumption that exposure to lead should be limited to 25 microgrammes per kilogramme body weight (µg/kg bw) per week, or 3.5 µg/kg bw per day. This level is referred to by the WHO as the 'provisional tolerable weekly intake' or PTWI and is based on research with infants, which indicated that exposure to between 3 and 4 microgrammes of lead per kilogramme body weight (µg Pb/kg bw) a day did not increase blood lead concentrations or cause lead to accumulate in the body considerably; these phenomena were associated with higher daily levels of exposure. The WHO considers such phenomena to possibly result in adverse health effects and therefore believes that lead intake should not exceed the PTWI. The WHO has calculated that if the concentration of lead in drinking water is limited to 10 microgrammes per litre, the lead intake of infants who are bottle fed on formula milk made up using drinking water drawn from a domestic tap should not exceed the PTWI.

The Committee endorses the WHO's view that higher blood lead concentrations and accumulation of lead in the body to considerable concentrations are undesirable. The Committee therefore believes that lead intake should not exceed the PTWI. In this context, the Committee would point out that it considers higher blood lead concentrations undesirable because it does not presently appear possible to identify a scientifically defensible blood lead level beneath which no adverse effect upon health may be expected.

Having compared estimates of overall exposure to lead with the PTWI, the Committee has concluded that, in circumstances typical for the Netherlands, the lead intake of bottle-fed infants receiving formula milk made up either with drinking water that has passed through lead pipes or with drinking water which, for whatever reason, contains the maximum concentration of lead currently permitted (50 µg/l) is liable to exceed the PTWI. The Committee considers it possible, depending on the level of prenatal exposure to lead and the duration and the degree of super-PTWI intake in infancy, that there may be infants in the Netherlands who experience an overall level of exposure to lead in the range associated with neurological and cognitive effects (i.e. exposure sufficient to raise the blood lead level to above 100 µg/l). Furthermore, the Committee thinks that these infants at risk are likely to live in an environment in which they experience levels of exposure to lead from other sources (such as soil particles and air) which are also higher than the national average.

The Committee therefore recommends introducing a stricter standard of 10 µg/l for lead in drinking water. The adoption of this standard would establish a certain safety margin. Such a safety margin is considered advisable because it is not yet possible to accurately quantify the level of or variation in the additional exposure to lead experienced by infants as a result of taking in soil particles and house dust that contains lead.

Question 5 If a new drinking water lead standard of 10 µg/l were adopted and implemented, what implications would lead continue to have for public health?

In the Netherlands, exposure to lead has been falling since the seventies. The blood lead concentrations have decreased consequently. Effectuation of the standard of 10 µg/l will result in a further decrease of the lead exposure for a section of the population. As stated before, the Committee aims for an exposure not exceeding the PTWI in order to avoid further rising of the blood lead levels after birth. Because the Committee finds it impossible to identify a scientific defensable blood lead concentration beneath which adverse health effects may be expected, she neither can estimate what implications lead would continue to have after adopting and implementing the standard of 10 µg/l. However, on the basis of current scientific knowledge, the Committee thinks that if average drinking water lead concentrations were limited to 10 µg/l, the risk of health damage arising from non-occupational exposure to lead would be none.

Question 6 Is action necessary or desirable to protect certain vulnerable groups from exposure to lead and, if so, what action is appropriate for the various age groups?

The Committee considers infants to be a group at risk because of their greater sensitivity (the extent to which their health is to be adversely affected by lead) and the high levels of exposure to lead they can experience if lead drinking water pipes are in use. Under normal circumstances, if drinking water passes through supply pipes or domestic pipes made of lead, the lead intake of an infant that is bottle-fed can exceed the PTWI.

In the Committee's view, the most effective way of protecting infants from exposure to lead in drinking water is to replace all supply pipes and domestic drinking water pipes that are made of lead. While lead piping is being phased out, the Committee believes that information should be given to the parents who are likely to make up formula milk for their babies using drinking water that has passed through lead pipes. Households with lead drinking water piping should be identified and the inhabitants should be informed. Information on how to reduce the lead exposure of the bottle-fed infant should reach them at an early stage (preferably before their babies are born).

Recommended action

Question 2 Taking account of your answer to question 1, do you believe that the risk to the health of the Dutch population posed by lead in drinking water is sufficient to warrant reducing the time period over which lead piping is to be phased out?

With a view to reducing the exposure experienced by all age groups, including infants, to safe levels, the Committee considers it desirable that supply pipes and domestic drinking water pipes made of lead are replaced by pipework which does not act as a source of lead. Since it is possible that baby milk made up using drinking water that has passed through lead pipes is prejudicial to health, the Committee supports the plans of the drinking water companies to replace lead service pipes before the year 2000. The present situation is that almost all lead supply pipes will actually be replaced in time, maybe a few a couple of years after. The Committee, though, cannot gauge the practical or financial implications of replacing all private lead drinking water pipes within fifteen years of the EU drinking water directive coming into force.

Question 3 Can you advise me regarding the health considerations relevant to the formulation of a policy on the use of lead solder in drinking water systems?

The Committee recommends that lead solder should not be used in drinking water systems. In the months following installation (and possibly thereafter), such solder can cause the concentration of lead in the drinking water to reach levels comparable with those to be expected in water that has passed through lead pipes.

Although the use of lead solder has been banned in drinking water systems by the water supply companies since 1 March 1995, it seems probable to the Committee that private individuals and independent plumbers still use lead solder. The Committee cannot say how widely it is used, however, and suggests that a survey be conducted to establish the extent of the problem. The Committee also recommends that research be carried out to determine the extent to which other materials used in drinking water systems, such as polyvinyl chloride (PVC), brass and bronze, can act as sources of lead.

Question 4 Can you advise me regarding the health considerations relevant to the possible formulation of a policy on the compulsory replacement of lead piping in domestic drinking water systems (based, for instance, on a requirement for domestic systems to be inspected upon a change of occupancy) or a policy requiring the installation of at least one 'lead-free water tap' in every home?

As indicated above, the Committee considers the replacement of supply pipes and domestic drinking water pipes made of lead to be the most effective way of reducing exposure to lead through drinking water. On balance, the Committee regards the compulsory installation of lead-free water taps as *interim solution* not-advisable. The effectiveness of this measure namely, would depend on the behaviour of the consumer.

Rijswijk, 28 April 1997,
for the committee

(signed)

ir HGM Bouman, scientific secretary	prof. dr JCS Kleinjans, chairman

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