

WHO  
International Reference Centre  
for  
Community Water Supply

262.1

73 HE

July 1973

Parkweg 13, The Hague, The Netherlands

# Health aspects relating to the use of uPVC pipes for community water supply

A Report of a Consultant Group

4

*Technical Paper Series*

262.1-73HE-5586

hac

WORLD HEALTH ORGANIZATION  
INTERNATIONAL REFERENCE CENTRE FOR COMMUNITY WATER SUPPLY

HEALTH ASPECTS RELATING TO THE USE OF  
UPVC PIPES FOR COMMUNITY WATER SUPPLY

A Report of a Consultant Group

Technical Paper no. 4

LIBRARY, INTERNATIONAL REFERENCE  
CENTRE FOR COMMUNITY WATER SUPPLY  
AND SANITATION (IIRC)  
P.O. Box 95100, 2509 AD The Hague  
Tel. (070) 814911 ext. 141/142  
RN: ~~07398~~ Wn 5586  
LO: 262.1 73 HE

July 1973  
The Hague - The Netherlands

This report contains the collective views of an international consultant group, which are not necessarily endorsed by the WHO International Reference Centre for Community Water Supply

## CONTENTS

	Page
1. Introduction	5
2. The use of unplasticized pipe for drinking water supply	6
2.1 Europe	6
2.2 U.S.A.	8
2.3 Other countries	9
3. Description of materials and production techniques for uPVC pipe	9
4. Toxicology of uPVC and its additives	12
4.1 uPVC	12
4.2 Lead	12
4.3 Organo-tin	13
4.4 Cadmium	13
4.5 Mercury	14
5. Leaching of lead from uPVC pipe	15
5.1 Lead level measurement experiences	15
5.2 Quality characteristics which affect lead leaching of uPVC drinking water pipe	20
5.3 Effects of pH temperature and sodium chloride	22
5.4 Effect of lead content in uPVC	22
5.5 Effect of polyphosphates	23
5.6 Test for extractable lead	23
6. Standards and specifications	28
6.1 Standards	28
6.2 Test methods and permitted levels for toxicological properties	32
6.3 Sampling procedures	32
6.4 Marking	33
6.5 Specifications of the uPVC pipe material	35
6.6 Summary of requirements	37
7. Summary and recommendations	38
7.1 Standards	38
7.2 Test methods and requirements	38
7.3 Lead stabilized uPVC pipe	39
7.4 Cadmium stabilizers in uPVC pipe	40
7.5 Tin stabilized uPVC pipe	40
7.6 PVC pipe formulation	41
References	41
Appendix 1. International Organization for Standardization. Extractability of lead and tin of unplasticized polyvinyl chloride (PVC) pipes for drinking water supply. Test Method. Draft International Standard ISO/DIS 3114.	45
Appendix 2. International Organization for Standardization. Permitted levels of lead and tin in unplasticized polyvinyl chloride (PVC) pipes for drinking water supply. Draft International Standard ISO/DIS 3113.	51
Appendix 3. Detailed comments by the Consultant Group on ISO Draft International Standards ISO/DIS 3113 and ISO/DIS 3114.	55

CONSULTANT GROUP ON HEALTH ASPECTS RELATING TO THE USE OF uPVC  
PIPES FOR COMMUNITY WATER SUPPLY

The Hague, 8 - 12 February 1973.

Participants

- Dr. V. Benes, Chief, Division of Toxicology and Reference Laboratory, Institute of Hygiene and Epidemiology, Prague, Czechoslovakia.
- Mr. H.J. Boorsma, Head, Chemical and Bacteriological Department, Government Institute for Water Supply, The Hague, The Netherlands.
- Mr. K.R. Bulusu, Assistant Director, Central Public Health Engineering Research Institute, Nagpur, India (Vice-Chairman).
- Mr. C.H.J. Elzenga, Chemical Engineer, Testing and Research Institute of the Netherlands Waterundertakings KIWA Ltd., Rijswijk, The Netherlands.
- Mr. T.S. Gable, Assistant Executive Director, National Sanitation Foundation, Ann Arbor, Michigan, U.S.A.
- Mr. D.A. Gill, Deputy Director, Water Research Association, Marlow, Bucks., England (Rapporteur).
- Dr. H. Gorchev, Program Manager, Water Supply Research, Environmental Protection Agency, Washington, D.C., U.S.A.
- Mr. J. Hrubec, Chemical Engineer, WHO International Reference Centre for Community Water Supply, The Hague, The Netherlands.
- Mr. J.H.F. Kalkman, International Organization for Standardization ISO, Technical Committee 138, Testing and Research Institute for the Netherlands Waterundertakings KIWA Ltd., Rijswijk, The Netherlands.
- Prof. W.F.J.M. Krul, Advisor, WHO International Reference Centre for Community Water Supply and Member of Panel of Experts of WHO, The Hague, The Netherlands (Chairman).
- Mr. A. de Lathouder, Head Research Department, Testing and Research Institute of the Netherlands Waterundertakings KIWA Ltd., Rijswijk, The Netherlands.
- Dr. N.I. McClelland, Director, Water Research, National Sanitation Foundation, Ann Arbor, Michigan, U.S.A. (Rapporteur).
- Mr. R.J. Meyer, National Sanitation Foundation, Consultant Thermoplastic Pipe and Chairman ASTM D20.17 Thermoplastic Pipe, Ann Arbor, Michigan, U.S.A.
- Dr. R.F. Packham, Chief Chemist, Water Research Association, Marlow, Bucks., England.
- Dr. C.L.M. Poels, Toxicologist, Testing and Research Institute of the Netherlands Waterundertakings KIWA Ltd., Rijswijk, The Netherlands.
- Dr. L. Scholz, Chemist, Bundesgesundheitsamt, Institut für Wasser-, Boden- und Lufthygiene, Berlin.
- Dr. G. Stefanov, Chief, Section Hygiene of Drinking and Waste Water, Centre of Hygiene, Medical Academy, Sofia, Bulgaria.

Secretariat

- Mr. J.M.G. van Damme, Manager, WHO International Reference Centre for Community Water Supply, The Hague, The Netherlands.
- Mr. A. Kepinski, Civil Engineer, WHO International Reference Centre for Community Water Supply, The Hague, The Netherlands.
- Mr. D.V. Subrahmanyam, Sanitary Engineer, Community Water Supply and Sanitation Unit, Division of Environmental Health, World Health Organization, Geneva, Switzerland.
- Mr. T.K. Tjiook, Chemical Engineer, WHO International Reference Centre for Community Water Supply, The Hague, The Netherlands.

HEALTH ASPECTS RELATING TO THE USE OF uPVC PIPES  
FOR COMMUNITY WATER SUPPLY

Report of a Consultant Group

A Consultant Group met in The Hague from 8 to 12 February 1973, convened by the WHO International Reference Centre for Community Water Supply (IRC) to review current practice in the use of uPVC pipes with specific reference to toxic substances which may leach out from the material of the pipe used for conveying drinking water. Mr. P. Santema, Director of the IRC opening the meeting, emphasized the importance of protecting drinking water quality in the context of increasing environmental contamination, and drew special attention to the need for surveillance of the possible health hazards of new water supply materials. Professor W.F.J.M. Krul was elected Chairman; Mr. K.R. Bulusu Vice-Chairman; and Mr. D.A. Gill and Dr. N.I. McClelland Rapporteurs. Dr. R.F. Packham and Mr. C.H.J. Elzenga assisted the Rapporteurs and the Secretariat in the drafting of the final report.

1. INTRODUCTION

uPVC pipes are widely used in the industrialized countries. However, it is in the developing countries that their increasing use is likely to have a substantial health impact through the provision of piped drinking water to the greatest number of people possible. In 1970 the Director-General of WHO reported to the Twenty-fifth World Health Assembly that over 1200 million people, or roughly 77% of the total population of 90 developing countries, were not serviced by a safe piped water supply. uPVC pipes have the advantages of, inter alia lower cost, ease of laying and corrosion resistance.

However, the very wide use of uPVC pipes has also brought to the fore the question of toxicity arising out of the leaching of heavy metal stabilizers and associated impurities from the pipe-wall

material into the water. The testing procedures and results from the WHO-supported research projects undertaken by the Water Research Association (WRA) in the United Kingdom and the Testing and Research Institute of the Netherlands Waterundertakings KIWA Ltd. have been at variance in some respects with those of the National Sanitation Foundation in the United States of America.

It had therefore become necessary to review the test procedures and analytical methods for the extraction of stabilizer material from pipes as well as experience on the leaching of lead from lead-stabilized pipes from as many countries as possible, and to arrive at a consensus on methods, procedures and standards.

The objectives of the consultant group were to reconcile the differences in the studies and procedures adopted in different countries, to give guidance on the health hazards of using uPVC pipes and on how to ensure their safety, to recommend procedures for the formulation and administration of standards by governments, and to delineate areas of research and coordination at international level.

The basic material for the report was provided by the background paper, prepared by Mr. C.H.J. Elzenga and by the statements of the participants of the meeting.

## 2. THE USE OF UNPLASTICIZED PVC PIPE FOR DRINKING WATER SUPPLY

### 2.1. Europe

Although in 1912 PVC production on a technical scale was made possible in Germany by direct reaction of hydrochloric acid and acetylene using catalysts, PVC pipe could not be manufactured before 1935, when the problems of heat stabilization and PVC quality were solved. In Germany, between 1936 and 1939, the I.G. Farben Industrie installed 400 drinking water installations on an experimental basis, using PVC pipe (1). The first DIN specifications were completed in 1941. After the Second World War contacts between plastic manufacturers and waterworks organizations resulted in many experimental projects in which uPVC drinking water pipe were used, but many problems

such as cold brittleness, installation technicalities, joints and fittings needed solving and were not solved till the later 1950's. In the Netherlands the first draft test specifications for uPVC drinking water pipe were completed by the Testing and Research Institute of the Dutch Waterundertakings (KIWA) in early 1954. This draft was approved in September 1956. The test specification included hygienic and toxicological requirements concerning the leaching of toxic materials from uPVC material. This part of the test specification was used as a model for setting up several European test specifications -- in Belgium, England, Italy and Norway -- and it was also used by ISO. In 1955 ISO established Subcommittee 6, which started its activities on the standardization of uPVC pipe. Subcommittee 6 was transformed into Technical Committee 138 in September 1970.

Since the end of the 1950's the water supply has been a big market in Europe for uPVC pipe, particularly for water mains and service pipes. Table 1 illustrates the use of uPVC drinking water pipe in the Netherlands (mains and service pipes according to the KIWA test specifications No. 49).

Table 1 - uPVC drinking water pipe  $\varnothing > 50$  mm for cold water supply in the Netherlands

Year	Km installed
1962	2400
1963	2800
1964	3300
1965	3000
1966	2900
1967	2700
1968	2000
1969	2000
1970	1900
Total 1962-1970: 23000	

For the United Kingdom, the use of uPVC water pipes continues to increase considerably as indicated by the collated sales figures for uPVC pipe to BS 3505/3506 (unplasticized PVC pipe for cold water supply) given in Table 2.



Table 2 - Sales figures for uPVC pipe for cold water supply in the United Kingdom.

Year	1966	1967	1968	1969	1970
Sales of uPVC pipe to BS 3505/3506 (tons)	9169	12710	15041	18810	30343

## 2.2. U.S.A.

Plastic pipe for potable water applications in the U.S.A. is evaluated by the National Sanitation Foundation (NSF) to ensure conformity with NSF Standard 14. The purpose of this standard is to establish the necessary public health and safety requirements for thermoplastic materials, pipe, fittings, and joining materials based on specific use and application, including potable water, and to provide for conditions and provisions of evaluation thereof.

The development of Standard 14 was preceded by a three year study that started in 1952 (2), undertaken at the request of the plastics industry and endorsed by the leading health and water utility officials, to determine the suitability of plastic pipe for use with potable water. Specific aims were to establish whether (a) any substances that might be deleterious to health were extracted from the plastic by an aggressive potable water, and (b) the passage of water through plastic affected the appearance, odour, or taste of the water. An advisory committee representing industry and regulatory and user groups guided the study. Twenty-two samples of plastics most commonly used for conducting cold water as well as proposed new formulations and a few plastics not recommended for use with potable water were subjected to hundreds of chemical, organoleptic, and toxicological tests. Tin stabilized PVC pipe was included in the 22 samples.

Basic extraction and testing procedures developed during the three-year study are utilized today in the continuing evaluation and listing programme at NSF. The Standard is reviewed at intervals of not more than three years to ensure that the current requirements are

effective and consistent with advancing technology.

The analytical methodology is similarly reviewed and updated to provide better instrumentation and internal quality control in the testing programme.

All samples to be evaluated at NSF are collected on a random basis by NSF personnel from manufacturing plants, warehouses, or points of installation at unannounced visits and intervals. Permission to use the NSF seal on plastic pipe for potable water application is contingent upon demonstrated compliance with Standard Number 14.

To date, more than 20000 samples of plastic pipe have been evaluated. According to the Plastic Pipe Institute, the total plastic pipe produced in 1972 for water supply and distribution was 668,500,000 lbs (approx. 303,200,000 kg) of which 564,000,000 lbs (approx. 255,800,000 kg) were PVC (46% of the total plastic pipe production by end use). The actual value of PVC pipe produced in 1972, according to PPI, was U.S. \$ 548,300,000. For the U.S.A., the use of uPVC water pipes increased considerably as indicated by the total plastic pipe production of 123,000,000 lbs (55,800,000 kg; 36% of the total plastic pipe production by end use) in 1967.

### 2.3. Other countries

As the potential market for sale of uPVC pipe is limited by shipping costs, uPVC pipe is usually manufactured locally, for Latin America mostly by U.S.A. owned or affiliated manufacturers (3). In Asia some European owned manufacturers are operating. There is a large manufacturing capacity based in Japan.

## 3. DESCRIPTION OF MATERIALS AND PRODUCTION TECHNIQUES FOR uPVC PIPE

Two types of polymerized vinylchloride are used for uPVC pipe production: emulsion PVC and suspension PVC.

For uPVC drinking water pipe in England, Germany, the Netherlands and the United States suspension PVC is used. The advantages of this type of PVC are greater purity, larger particle size and less water uptake.

Suspension PVC may still contain small quantities of polymerization catalysts such as inorganic mercury compounds, organic peroxides, azo-compounds, persulfates and other products acting as redox systems, water-soluble suspension catalysts as organic colloids -- gelatin, pectin, polyacrylates, polymethacrylates, polyvinylalcohol --, and inorganic compounds such as talcum, calcium phosphate and magnesium phosphate. uPVC pipe is made by the extrusion of thermoplastic PVC using single or multiple screw extruders. Multiple screw extruders are more commonly used at present. Figure 1 illustrates a vented single screw extruder (3).

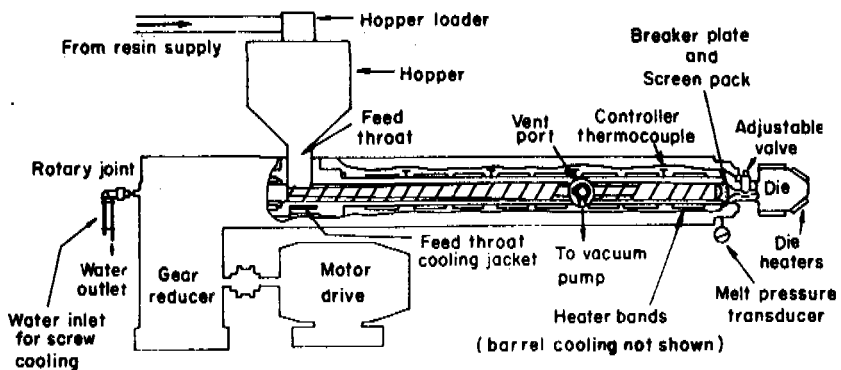


Figure 1 - Vented single screw extruder

Owing to the high chloride content, PVC is unstable at temperatures exceeding  $120^{\circ}\text{C}$ .

Because of thermoplastic deformation of the PVC during extrusion at temperatures of approximately  $150^{\circ}\text{C}$  to  $200^{\circ}\text{C}$ , heat stabilizers have to be added to the PVC material before it enters the extruder.

Lubricants are added as well to reduce internal and external friction during extrusion and light stabilizers and pigments to reduce PVC deterioration by UV radiation and to prevent the growth of phytoplankton. Some manufacturers use PVC granulate already containing the required additions.

In most European countries such toxic lead compounds as lead

stearate, dibasic lead stearate and dibasic lead sulfate are used as heat stabilizers and lubricants. Dibasic lead phosphate acts as a light and heat stabilizer. Lead stabilizers are relatively insoluble in PVC.

Non-toxic compounds such as calcium stearate act as lubricants and as weak heat stabilizers. Lead compounds are sometimes used in addition to products with synergistic action such as barium and cadmium laurates. Barium-cadmium compounds, however, are usually not allowed in food packing material but it is known that they are sometimes used for uPVC drinking water pipe produced outside the U.S.A.

It is clear that the use of toxic stabilizers for uPVC drinking water pipe is permissible only when leaching of the toxic compounds occurs only to an insignificant level. Consequently,

- (a) The quantity of toxic stabilizers or their reaction products present on the surface of the pipe must be as low as possible. These compounds give rise to an initial high lead or cadmium concentration in the drinking water during the period directly after installation.
- (b) The toxic stabilizers must not migrate to the surface area, for such migration will give rise to prolonged high levels of toxic substances in the drinking water.

In the U.S. no lead and cadmium compounds are used for uPVC drinking water pipe production. As a result, tetravalent organic tin compounds were developed for heat and light stabilization. These compounds are soluble in PVC.

Less organotin is required for stabilization in uPVC pipe and according to the National Sanitation Foundation its cost per unit pipe produced is now equal to or slightly less than that of lead. In addition, tin stabilizer is not used as a lubricant, so the tin has less tendency to form a metal-rich film on the inner surface of the pipe than lead, which is used, in whole or in part, as the lubricant

#### 4. TOXICOLOGY OF uPVC AND ITS ADDITIVES

##### 4.1. uPVC

Polyvinyl chloride, in common with other polymers of high molecular weight, is generally regarded as non-toxic as it cannot be absorbed from the gastrointestinal tract. However, additives such as lead, organotin and cadmium, which may be used in uPVC pipe production, are of toxicological interest. Other potentially hazardous compounds may occur as impurities in uPVC pipe.

##### 4.2. Lead

The Joint FAO/WHO Expert Committee on Food Additives evaluated the available information on lead intake of man from environmental sources (air, water, food) in 1972 (4). Absorption of lead (ingested or inhaled) depends on dietary factors and particle size. About 10% of lead ingested from food and water and as much as 40% inhaled from the air may be absorbed. As lead is a cumulative poison, the Committee established in adults a provisional tolerable weekly intake of 3 mg of lead per person, equivalent to 0,05 mg/kg body weight per week. This level does not apply to infants and children, who are a high-risk group. In relation to International standards for drinking-water <sup>\*)</sup>, the Joint FAO/WHO Expert Committee said: "The levels of lead encountered in water supplies are probably about 0.01 mg. However, the International standards for drinking-water suggest a tentative limit for lead of 0.1 mg. Assuming a consumption of 2.5 l of water per day the maximum lead intake from this source would be 250  $\mu$ g; this would contribute significantly to the total amount of lead taken in by man". This statement will presumably be taken into account in preparing the fourth edition of International standards for drinking water.

If lead pipes are used, drinking water may contribute significant-

---

\*) World Health Organization (1971) International Standards for Drinking Water, Geneva, 3rd Edition.

ly to the total intake of lead in man. After a relatively short period of use, the intake of lead from uPVC pipes will be much less than from lead pipe.

#### 4.3. Organotin

Organotin compounds may vary in their acute toxic effects. Evaluation of the toxicological risk of residues of ten organotin compounds were performed on the basis of an ADI for man of 0.0005 mg/kg body weight (5).

No data on the compounds used as tin stabilizers in uPVC are available, although the establishment of an ADI for such materials would be highly desirable. Although the dietary maximum level of tin is unknown, extensive human experience does not indicate the existence of any acute toxicity hazard.

Radeva and Agelieva (7) carried out animal feeding tests on rats with an organotin stabilizer of American make. After 6 months of daily oral administration of the stabilizer in three dosages, i.e. 0.5, 1.0 and 5.0 mg/kg body weight, it was concluded that the results showed a tendency towards accumulation of the organotin stabilizer in the liver of rats.

#### 4.4. Cadmium

The toxicity of cadmium was evaluated by the Joint FAO/WHO Expert Committee on Food Additives 1972 (4).

Absorption of cadmium from the air is insignificant. Preliminary results on total diet studies indicate intakes varying, according to the country, from 50 to 150  $\mu$ g per day.

Municipal waters in industrialized countries generally contain less than 1  $\mu$ g/litre of cadmium. The tentative upper limit set in International standards for drinking-water is 10  $\mu$ g/l.

On the basis of an estimated daily consumption of 2.5 l, this would amount to a maximum cadmium intake of 25  $\mu$ g per day. There may also be some cadmium dissolved from galvanized pipes. Elevated levels occur in food, particularly in crustacea and shellfish, in association with zinc, and the levels are even higher if there is contaminat-

ion of the estuaries with cadmium. Cadmium could also enter food from contaminated water used to irrigate crops. Cadmium is apparently a non-essential trace metal that is virtually absent at birth and accumulates with age, reaching a maximum of about 25 to 30 mg in persons not occupationally exposed. Its biological half-life is between 16 and 33 years. A provisional tolerable weekly intake of 400-500  $\mu$ g per individual has been proposed. The target organ for ingested cadmium is the kidney. Renal damage may occur when the concentration of cadmium in the renal cortex exceeds 200 mg/kg. Levels of cadmium in the renal cortex of persons not occupationally exposed varies from 30 mg/kg in Sweden and 25-50 mg/kg in the U.S.A. to 50-100 mg/kg wet weight in Japan.

In view of the closeness of these levels to the critical level of 200 mg/kg, the Joint FAO/WHO Expert Committee felt that present-day levels of cadmium in the kidney should not be allowed to rise further, and recommended that every effort should be made to limit, and even to reduce, the existing pollution of the environment with cadmium.

#### 4.5. Mercury

Mercury is a high toxic accumulative metal. Organo-mercury compounds may vary in their acute toxic effects. No acceptable daily intake for men can be estimated on the basis of the information at present available. The tentative upper limit of concentration set in the WHO-International Standards for drinking-water is 1  $\mu$ g/l. The figure given is related to levels found in natural water.

KIWA reported mercury contents of 5 to 9.10<sup>-6</sup> percent in weight in PVC material from three different uPVC drinking-water pipe manufacturers using a neutron activation method of estimation. Mercury contents in extracts according to the KIWA standards no. 49 were below the detection limits of 1  $\mu$ g/l using an atomic absorption spectrophotometric method of estimation.

## 5. LEACHING OF LEAD FROM uPVC PIPE

### 5.1. Lead level measurement experiences

Standards and specifications generally include a general requirement about the composition of the material such as "The material shall contain no ingredients in an amount demonstrated to migrate into water in quantities considered toxic. The water that has been in contact with the plastic material must meet official quality standards. Additions may only be utilized when required to achieve polymerization and make possible the extrusion of uPVC pipe. Innocuous traces of materials may be used in so far as the specifications can be met".

There is evidence that when in service, pipes complying with the standards relating to the use of lead stabilizers in uPVC will not produce concentrations of lead in drinking water in excess of the upper limit of concentrations established by WHO. (0.1 mg/l).

- (a) In 1959, Boelens (8) examined water samples from 24 uPVC mains in the supply area of the Overijssel Waterworks before and after a period during which the water remained in the pipe, ranging from a few hours to 9 months. The period that the pipe had been in service ranged from 2 months to 5.5 years. Sixty tests were made and only two samples contained a lead concentration greater than 0.05 mg/l after a period of standing that lasted 4 months and some days. The lead concentrations respectively amounted to 0.07 mg/l and 0.10 mg/l. The nominal diameters of the pipes ranged from 15 to 100 mm.
- (b) In 1961, the Bundesgesundheitsamt of Berlin carried out a similar survey in some other parts of the supply area of the same water-undertaking.(9) Water samples were taken from the uPVC mains before and after a period of standing. Out of 20 samples the lead content of one sample exceeded 0.05 mg/l. The lead concentration amounted to 0.09 mg/l after a standing period of 12 hours.
- (c) The KIWA Committee on Plastic Water Pipes took water samples from 11 uPVC water mains at three different times after standing periods from 12 - 14 hours.(10). The mains were located in various supply areas of waterworks throughout the Netherlands. From 33 water samples, 14 proved to have a lead content that exceeded 0.05 mg/l.



- None of the samples exceeded the Dutch standard of 0.3 mg/l.
- (d) Everard reports experiments in which hard water was allowed to stand in uPVC pipes manufactured to BS 3505 for periods ranging from 22 hours to 28 weeks (12). The lead content of the water after these periods was reported as 0.1 mg/l in nearly all cases.
- (e) Lasintin and Monteriolo (13) examined water samples from Italian uPVC mains of length varying from 250 m to 4 km. The lead content of the uPVC from which these pipes were made varied between 0.031% and 1.619%, the pipes having been in service for periods ranging from a few weeks to three years. It was found that the concentration of lead was less than 0.07 mg/l in 31 out of 32 pipes. A concentration as high as 0.09 mg/l was found only in a new 4 km main. After three years' service the lead content of the water in the same pipe was 0.01 mg/l.
- (f) Cosoveanu (14) carried out a series of tests on uPVC pipe of Rumanian manufacture and showed too that the quantity of lead extracted by water from a new pipe decreased rapidly.
- (g) Tests conducted in Peru (Bracale, Chuy) in 1967 led to the following conclusions (private communication):
1. The concentration of lead in the extracting water is extremely low for uPVC pipe stabilized with lead and is much lower than the limit permitted by standards for potable water.
  2. The quantity of lead decreases with time, as is shown experimentally in the laboratory and by analysis of samples taken from the distribution systems, so that the total amount of extractable lead is removed in no more than 90 days.
  3. Under normal service conditions, therefore these pipes present no risk to the health of the users of potable water systems. (Peru specifies that only calcium and zinc may be used as stabilizers for drinking water pipes).
- (h) Paramasivam and Dandekar (15) tested uPVC pipe samples from four Indian manufacturers against IS 4985 - 1968 (private Communication). One sample fully complied with the current ISO draft standard. In the other three samples, the lead levels in the first extract exceeded the ISO maximum permissible level (1.0 mg/l), but the

Table 3. Lead concentration in water from a new 25 mm nominal bore uPVC service pipe. \*)

Period in service days	Total volume of water passed m <sup>3</sup>	Static sample		Flowing sample
		Standing period hours	Lead content mg/litre	Lead content mg/litre
0	0	14	0.11	0.01
1	0.83	14	0.03	0.06
4	1.64	62	0.09	0.02
5	2.46	14	0.02	0.02
6	3.26	14	0.01	0.02
7	4.10	14	0.02	0.01
8	4.91	14	0.01	0.01
11	5.74	62	0.02	0.01
12	6.54	14	0.06	0.01
13	7.38	14	0.02	0.01
14	8.30	14	0.02	0.02
15	9.00	14	0.02	0.01
18	9.85	62	0.02	0.01
29	17.2	14	0.01	0.02
32	18.2	62	0.01	-

\*) Length of pipe prior to sampling point 6,1 m.

levels in the third extract were within the ISO limit (0.3 mg/l).

(i) Stefanov (private communication) reported the test results of lead-stabilized uPVC pipe of Austrian make. The lead levels in the first, second and third extract were far below the ISO maximum permissible levels, amounting to 0.07, 0.05 and 0.05 mg/l respectively. After 72 hours of intensive washing the natural level of 0.007 mg/l for lead was reached.

(j) The WRA studied water mains  $\geq 25$  mm nominal bore in service in the United Kingdom (16). The pipes were made in accordance with BS 3503. The sampling programme was designed to cover as many different situations as possible. Distribution systems are therefore surveyed to supply water covering a range of compositions. Samples from old and new pipes of various sizes and manufacturers were obtained wherever possible. Many pipes were sampled under both normal and night flow conditions. Of 77 samples examined 73 were found to have a lead concentration of 0.01 mg/l or less and none exceeded 0.05 mg/l. In addition to the general survey a newly installed pipe was sampled during a period of 32 days to determine the trend of lead levels.

Table 3 gives the results.

Recently the WRA investigated the loss with time of extractable lead (using the nitric/perchloric acid extraction method) when a new 32 mm nominal bore uPVC pipe had water passed through it continuously at a rate of 0.2 l./sec. The results are given below:

Table 4 - Loss with time of extractable lead from uPVC pipe, 32 mm nominal bore.

Period of flushing (days)	0	3	9	27	81
Extractable lead mg/m <sup>2</sup>	28.3	9.4	5.2	3.5	2.7
% removal of extractable lead	-	67	82	88	91

A high proportion of the extractable lead was removed in the first 9 days of flushing, but further removal was slow.

In another series of tests a large batch of uPVC pipe was extracted 5 times with a nitric/perchloric acid mixture and then reextracted after periods of storage of between 3 and 243 days. Half of the pipes were stored empty while the others were stored full of water. In all cases a small amount of extractable lead was recovered (usually less than 1 mg/m<sup>2</sup>), but there was no evidence that this increased with the period of storage. The recovery of extractable lead tended to be rather less with pipes stored full of water.

(k) In 1969 KIWA, in cooperation with the Duinwaterleiding van 's-Gravenhage, collected water samples from water mains and connected uPVC service pipes in the Netherlands (16). The pipe was made in accordance with KIWA standard No. 49. The water quality concerned included the greatest possible differences occurring in the Netherlands.

Eleven of the 18 mains were made of uPVC, 4 of asbestos cement and 3 of cast iron. In 9 of the 18 water samples from the mains no lead could be detected (less than 0.001 mg/l), but in one uPVC water main the lead level increased 0.05 mg/l (0.055 mg/l) as laid down by the former WHO International Standards. The water appeared to be contaminated with ferric hydroxide flakes, so that adsorption of lead may have occurred. Water samples taken from a connected uPVC service water pipe did not contain any measurable lead in normal flow conditions.

Flow samples were taken from 22 uPVC service pipes connected to the mains already mentioned. The length varied from 4 to 452 m. The oldest pipe had been laid in September 1955, the newest had only been in service for 1 month. The nominal bore varied from 16 to 50 mm. The lead levels appeared to be <0.01 mg/l in all cases.

In all, 25 uPVC service pipes were sampled after standing periods ranging from 10 minutes to 114 days. For 10 of the 25 samples the lead concentration in the water at the end of the standing period amounted to <0.001 mg/l; for 8 samples ≤0.01 mg/l; for one sample 0.015 mg/l, for another 0.03 mg/l, for another

0.04 mg/l and for another the exceptionally high value of 0.6 mg/l. The standing period in the last uPVC pipe amounted to 84 days. After flushing the uPVC pipe with a quantity of water equal to twice the content the lead concentration amounted to 0.01 mg/l. (There is evidence for lead contamination from a duplex brass tap). In addition to the field survey, the initial lead leaching from 8 different uPVC pipes of 4 different makes was studied, using the drinking water of The Hague. The nominal bores amounted to 16 and 25 mm. Fig. 2 and 3 give the results. It can be seen that the main lead leaching during flow is restricted to the first 30 minutes and that the highest lead concentrations occur in the pipes with the smallest diameter.

In the KIWA studies the average increase in the lead concentration in the drinking water after standing in uPVC pipe was found to be 0.004 mg/l (with the exception of one high value of 0.6 mg/l). Under conditions of flow the average increase in the lead content in the water was 0.001 mg/l.

- (1) In the U.S.A., the NSF measured the lead levels in a series of extractions on three samples of uPVC pipe. One sample was pipe made in the U.S.A. from drain waste and vent applications, and two were fabricated to conform with BS 3503. Lead levels exceeded the established WHO maximum permissible limits in each of the first three extractions made on the U.S. made sample. In one of the British samples lead in the first extraction exceeded the WHO limit, but the third extraction conformed. All extractions made on the second British sample contained acceptable lead levels within the WHO limits .

## 5.2. Quality characteristics which effect lead leaching of uPVC drinking water pipe

As drinking water in Europe and the U.S.A. has normally been treated, no big changes in water quality may be expected. In practice, lead leaching from uPVC pipe appears to be very low and no effect of the water quality on lead levels could be determined.

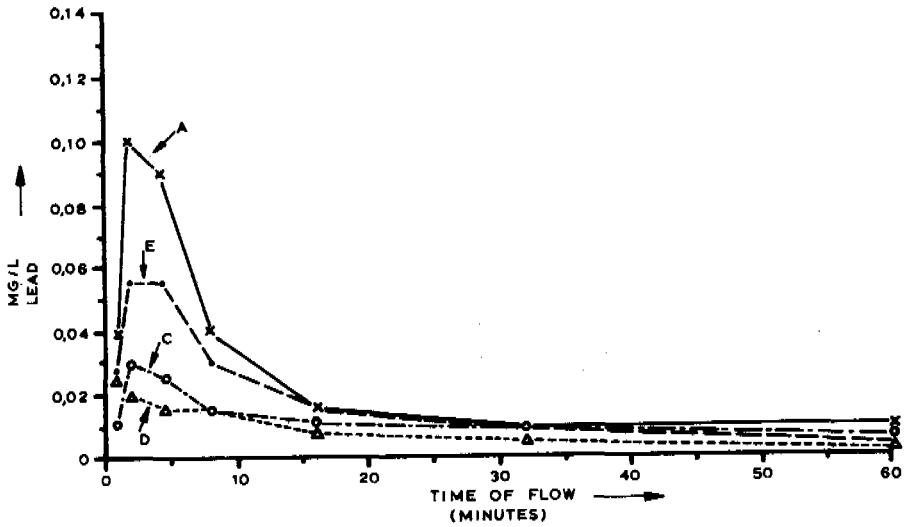


Fig. 2 Lead concentration in uPVC pipes 4 m long with a diameter of 16/14 mm during the first hour of flow using The Hague drinking water (rate of flow of water 0.067 m/sec.)

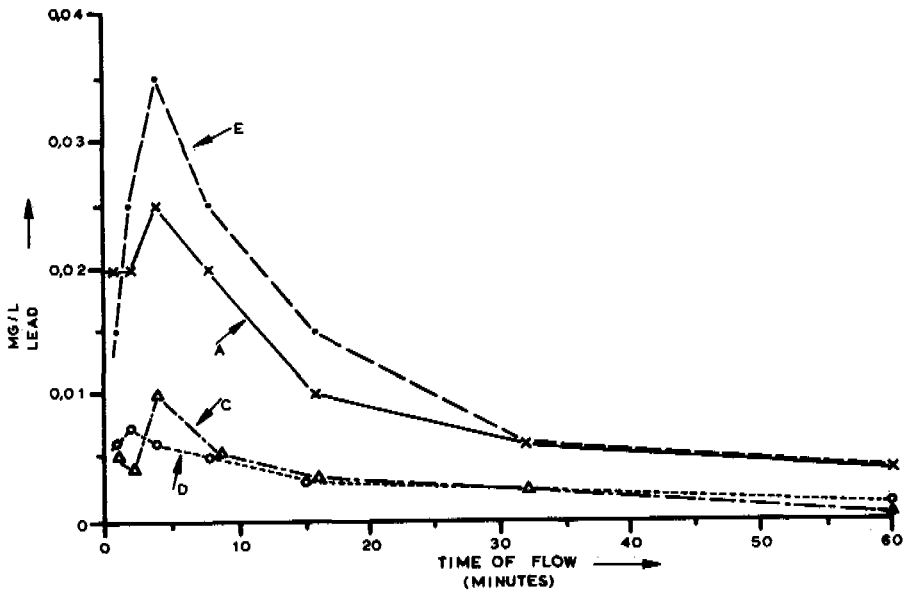


Fig. 3 Lead concentration in uPVC pipes 4 m long with a diameter of 25/22.6 mm during the first hour of flow using The Hague drinking water (rate of flow of water 0.067 m/sec.)

### 5.3. Effect of pH, temperature and sodium chloride

Sontheimer and Wagner (18) studied the effect of acidity, temperature and sodium chloride on lead leaching from new uPVC pipes. Fig. 4 and 5 show the effects of pH and temperature.

Fig. 4 - The effect of pH on lead leaching.

Standing period: 24 hours

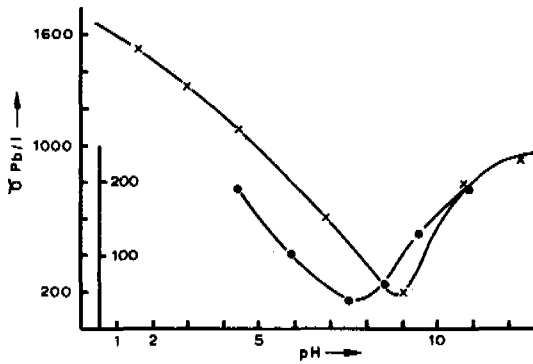
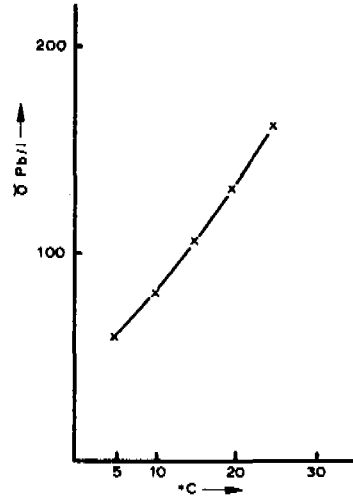


Fig. 5 - The effect of temperature on lead leaching.

Standing period: 24 hours



● — ●  
x — x

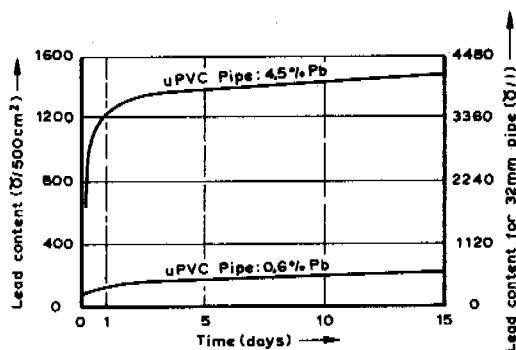
after 5 extractions with 0.01 Molair  $\text{NaHCO}_3$   
without pre-treatment (extractant: 0.01 Molair  $\text{NaHCO}_3$ )

Sodiumchloride did not effect the lead leaching between 5 and 100 m Mol/litre

### 5.4. Effect of lead content in uPVC

Niklas and Meijer (19) studied the effect of the lead content of new uPVC material on lead levels in drinking water. The standing periods lasted up to 15 days at a temperature of 20°C. Fig. 6 gives the results. It can be concluded that lead levels were about seven times higher using uPVC pipe with 4.5% lead in weight than using pipe with 0.6% lead.

Fig. 6 - Effect of lead content of new uPVC pipe on lead levels in drinking water.



### 5.5. Effect of polyphosphates

The effect of sodium hexametaphosphate on the extraction of lead from uPVC pipe was investigated by the WRA. It was found that the presence of 5 mg/l of sodium hexametaphosphate more than doubled the amount of lead extracted initially from new pipe with water. On a sample of pipe that had been in service for 9 months the effect was negligible.

### 5.6. Test for extractable lead

The results of surveys of lead concentrations in uPVC distribution systems with tests based on ISO procedures indicate that no long-term health hazard arises from the use of lead stabilizers in pipes meeting the required standards. The potential hazard is essentially short-term in nature and cannot realistically be assessed in relation to WHO standards for drinking water, in which the levels set for toxic substances are based on exposure to those substances during a lifetime. According to Packham, a test of shorter duration with a stable extractant involving some degree of agitation would have advantages, especially in terms of convenience over procedures of the ISO type (20, 21). Packham finds it questionable, however, whether an arbitrary test is a satisfactory basis for a standard. The test as it stands provides a measure of the level of extraction at some indefinite time in the life



of a pipe. Since stabilizers may be leached from uPVC at different rates, depending on the nature of the stabilizers and the way the uPVC is processed, the test provides no indication of either the initial or the ultimate rates of leaching. It is based on the widely held belief that all extractable lead stabilizers contain a lead rich layer at the surface of the pipe.

After having tested several extractants, one with 0.5% nitric acid and 0.85% perchloric acid was selected as extractant, because it effectively leached lead compounds without effecting the uPVC. From the investigations of Packham it appeared that the time of agitation is less important than the number of extractions. The procedure proposed includes six extractions, each of 60 minutes.

The KIWA compared the testing procedures for lead leaching according to the ISO method and the WRA. The "total" lead leaching according to the WRA method was compared with the "total" lead leaching according to the ISO method and the lead concentrations during flow tests, using drinking water of The Hague (17). Table 5 gives the results. In so far the "total" lead leaching is concerned, it was concluded that neither the WRA method nor the ISO method correlate with the initial lead levels after the first period of standing directly after the installation of new uPVC pipe. As would be expected lead concentrations in the ISO extracts (pH 4.6) are commonly higher than those when drinking water with a pH of about 7-8 is used. It is to be expected in practice that the differences between the lead levels of the first and second extracts in some way indicate the decrease in lead levels after successive periods of standing. In relation to the lead levels of the extracts, the ISO method indeed simulates an "aggressive" type of drinking water.

As for the uPVC pipes used in the investigations of the KIWA (four different makes, three different diameters each), the "total" lead leaching calculated from the ISO extracts (pre-flushing during 1 hour) amounted to 16-87% of that determined according to the WRA method using successive extractions for 1 x 1 hour and 3 x 1/2 hour. An almost similar comparison made by the WRA in four different British makes of uPVC pipe resulted in a recovery of 30-64%.

In order to determine the influence of the duration of the pre-

Table 5. Lead leaching from new uPVC drinking-water pipe, correlation between flow tests (0.67 m/sec.) and extraction tests.

Lead leaching mg/100 cm <sup>2</sup>									Lead concentration mg/litre			
Manu- fac- turer	Dia- meter	WRA	ISO*)	Hague water 20	flow test Hague water		ISO		Flow tests with Hague water			
					0-1 hour	0-24 hours	1st ext.	3rd ext.	max. du- ring flow 0-4 min.	after 16 min. of flow	after 24 hours flow and 48 hours standing	after another 5 min. flow and 72 hours standing
E	16/14	0.47	0.28	0.05	0.03	0.08	6.3	0.60	0.06	0.02	0.55	0.15
	25/22.6	0.41	0.30		0.04	0.18	4.2	0.53	0.04	0.02	0.32	0.23
C	16/14	0.25	0.20	0.05	0.02	0.14	4.9	0.45	0.03	0.01	1.00	0.32
	25/22.6	0.24	0.20		0.01	0.01	2.8	0.48	0.01	0.003	0.14	0.05
A	16/14	0.24	0.17	0.06	0.04	0.24	3.9	0.27	0.10	0.02	0.65	0.28
	25/22.6	0.20	0.11		0.03	0.04	1.0	0.43	0.03	0.01	0.41	0.33
D	16/14	0.14	0.02	0.02	0.01	0.02	0.13	0.16	0.03	0.009	1.05	0.85 <sub>*)</sub>
	25/22.6	0.09	0.03		0.01	0.03	0.16	0.17	0.007	0.003	0.16	0.36 <sub>+) )</sub>

\*) 1 hour pre-washing

+) duplicate pipe after 5 min. flow and another 48 hours standing 0.06 mg/l

Table 6. Influence of the pre-flushing period on lead leaching from new uPVC pipes

Manufacturer	Diameter (mm)	Lead leaching as percentage of lead leaching by ISO method with 1 hour pre-flushing				ISO Method incl. 1 hour pre-flushing period mg/m of pipe
		0-1 hour	0-2 hours	0-4 hours	0-8 hours	
A	16/14	26	37	57	87	0.68
	25/22.6	27	36	38	38	0.73
C	16/14	11	17	25	40	0.83
	25/22.6	4	4	4	4	1.41
D	16/14	67	89	100	100	0.09
	25/22.6	26	37	63	111	0.19
E	16/14	11	14	18	23	1.14
	25/22.6	14	18	24	32	2.04

flushing period on lead leaching according to the ISO method (pre-washing during 1-6 hours), the integrated lead leaching during the first hour, the first 2, first 4 and first 8 hours of pre-washing with The Hague drinking water was determined for 8 different uPVC pipes of 4 different makes. The values are given in Table 6. It can be concluded that a considerable quantity of lead has leached during the pre-flushing and that the effect is greatest for the pipes with the smallest diameter.

The result of the test according to the ISO method is strongly affected by the period of pre-flushing.

The WRA flushed samples of 25 mm bore uPVC pipe for periods up to eight hours, then extracted for six hours with 150 mg/l carbon dioxide solution. The experiments were repeated using acetic acid/sodium acetate buffer and sodium bicarbonate solution as an extractant. Table 7 gives the lead concentrations of six hour extracts.

Table 7 - The effect of flushing time on the extraction of lead from uPVC pipes.

Flushing time (hours)	Mean lead content (mg/l) of 6-hour extract using		
	CO <sub>2</sub>	CH <sub>3</sub> CO <sub>2</sub> H/CH <sub>3</sub> CO <sub>2</sub> Na	NaHCO <sub>3</sub>
0	1.62	0.59	0.28
½	0.23	0.31	0.15
1	0.17	0.16	0.07
2	0.13	0.25	0.07
4	0.11	0.21	0.06
8	0.11	0.18	0.05
8 (static)	0.55	0.62	0.13

The results in Table 7 show that the extraction levels decreased with increasing flushing, although the absolute levels of extraction differed according to the extractant used. In all cases the results

obtained tended to level out after periods of flushing longer than one hour. Included in Table 7 are the results of an experiment in which new pipe samples were filled with tapwater and allowed to stand for eight hours prior to extraction. The extraction levels in this experiment were three to four times greater than those obtained after flushing the pipes with tapwater for the same period.

## 6. STANDARDS AND SPECIFICATIONS

### 6.1. Standards

Usually the test specifications include a general demand by which the uPVC pipe is not allowed to contain ingredients in an amount that has been demonstrated to pollute the water in concentrations considered toxic.

In contrast with plastic wrappings for food and food products, uPVC drinking water pipe is used for a long time and contact with chemicals is limited to drinking water. For uPVC water pipe this implies that both the initial and the long-term leaching of toxic substances into the water must be taken into consideration and that the toxicological consequences of leaching of toxic substances restricted to a short period direct after installation cannot be considered to the same extent as for wrappings. In Europe, test specifications for uPVC drinking water pipe include toxicological and sometimes organoleptic requirements. Toxicological tests are mostly restricted to the leaching of toxic heavy metals using three successive extraction tests simulating the worst circumstances that may be expected in practice. The maximum acceptable concentrations in the third extract should mostly be in accordance with the approved maximum allowable concentrations of toxic substances in drinking water.

Most of the stabilizers containing toxic metals used for the stabilization of uPVC may dissolve into the water to a certain extent and the uPVC material may very well contain up to 2% in weight.

No specific tests have been proposed for other non-metallic organic additions which may be present in small quantities.

In the United States of America the NSF has published Standard

no. 14 for Thermoplastic Materials, Pipes, Fittings, Taps and Joining Materials. Its purpose is to establish the necessary public health and safety requirements for the above mentioned thermoplastic materials.

The differences among test specifications and demands, especially between Europe and the U.S.A., have resulted in a different point of view concerning the acceptability of lead stabilizers for uPVC drinking water pipes. Studies by the NSF have shown that lead leaching from new uPVC pipes gives rise to lead levels in extractant water of  $>0.05$  mg per litre which are not in accordance with the Public Health Service Drinking Water Standards of 1962<sup>\*)</sup>. The point of view in several European countries is that lead leaching from uPVC is only significant a short period directly after installation and decreases rapidly to insignificant amounts. Most of the European test specifications concerning leaching of toxic heavy metals are based on that view.

Lead-stabilized uPVC pipe of good quality can meet most European standards but not the NSF standards (see table 8). In the present situation lead stabilizers are used in Europe and organotin stabilizers in the U.S.A.

Some standards applied on uPVC drinking water pipe are listed below:

International Organization for Standardization	ISO Draft International Standards ISO/DIS 3113 and 3114
Australia	Standard ASK138 - 1969
Federal Republic of Germany	DIN 8061 DVGW Arbeitsblatt 320 Mitteilungen XIX aus dem Bundesge- sundheitsamt.
France	NF T 54-003 (July 1972) NF T 54-016 (July 1972) NF T 54-017 (July 1972) NF T 54-019 (May 1969)

\*) PHS Publication No. 956

Table 8. Determination of extractable substances in uPVC pipe.

Procedure specified	Pre-treatment	Extractant
ISO Draft International Standard	1 - 6 hours pre-washing with water at 3m/min velocity. Rinse with distilled water.	150 mg/litre carbon dioxide in distilled water. Temperature $20^{\circ} \pm 5^{\circ}\text{C}$
Australia India United Kingdom	6 hours pre-washing with tap water at 3m/min velocity. Rinse with distilled water.	150 mg/litre carbon dioxide in distilled water. Room temperature.
Germany	1 hour pre-washing with tap water at 3 m/min velocity.	Sodium bicarbonate 0.01 N. Room temperature.
Ireland	1. Pushing a plug of cotton wool dampened with distilled water 2. 1-minute pre-washing with distilled water	0.01 m/0.01 m acetic acid/sodium-acetate buffer in distilled water. Room temperature.
Israel	1 minute pre-washing .... water at ..m/min velocity.	150 mg/litre carbon dioxide in distilled water. Room temperature.
The Netherlands	1 hour pre-washing with tap water at 3m/min velocity. Rinse with distilled water.	150 mg/litre carbon dioxide in distilled water. Room temperature.
Poland	1. Pushing a plug of cotton wool. 2. 1 hour pre-washing with tap water at $10 \pm 2$ m/min.	100 mg/l carbon dioxide in ..... water. Room temperature.
U.S.A. (National Sanitation Foundation)	1. Pre-washing in tap water. 2. Temp. conditioned at $72^{\circ}\text{F}$ for 24 hours.	Carbon dioxide in Ann Arbor water pH 5.0 Temperature $100^{\circ}\text{F}$

Extraction period	Max.lead permitted	Additional requirements
1. 48 hours 2. 48 hours 3. 48 hours	1.0 mg/litre - 0.3 mg/litre	dialkyl C4 and higher homologues, third extraction
1. 48 hours 2. 48 hours 3. 48 hours	1.0 mg/litre - 0.3 mg/litre	dialkyl tin C4 and higher homologues, third extraction "other toxic substances" third extraction.
1. 72 hours 2. 72 hours 3. 72 hours	under consideration	under consideration
1. 48 hours 2. 48 hours 3. 48 hours	1.5 mg/m <sup>2</sup> - 4.5 mg/m <sup>2</sup>	total barium, cadmium, tin, zinc and other toxic substances, first and third extract expressed as mg/m <sup>2</sup> surface area.
1. 48 hours 2. 48 hours 3. 48 hours	1.0 mg/litre 1.0 mg/litre 0.03 mg/litre	arsenic, cadmium, chrome, tin, mercury and barium, third extraction.
1. 48 hours 2. 48 hours 3. 48 hours	1.0 mg/litre 1.0 mg/litre 0.3 mg/litre	other toxic components as arsenic, cadmium, chromium, tin and mercury, first, second and third extraction.
1. 48 hours 2. 48 hours 3. 48 hours	1.0 mg/litre - 0.1 mg/litre	arsenic, zinc and cadmium, first and third extraction
72 hours	0.05 mg/l (EPA Stds.) NSF does not approve lead stabilized pipe for drinking water application.	the extract has to meet the US EPA Drinking Water Standards.



India	Standard IS 4985 - 1968
Ireland	IS 123
Israel	Standard SI 532
The Netherlands	KIWA Kwaliteitseisen No. 49
Poland	Standard PN - 65/C-89204
United Kingdom	BS 3505
U.S.A.	NSF Standard No. 14

Most standards include test methods and permitted levels for toxicological properties and prescriptions for sampling procedures, marking and the composition of the uPVC material.

The French standards do not prohibit the use of toxic stabilizers; however, no leaching of any substance from uPVC drinking-water pipe is allowed.

No test methods for the leaching of substances are described. According to the standards, test methods may be set up individually. Concerning the leaching of lead and tin from uPVC drinking water pipe, a draft test method No. T 54-027 has been set up recently.

## 6.2. Test methods and permitted levels for toxicological properties

Table 8 gives a survey of some test methods and maximum permissible levels as stated in the standards.

## 6.3. Sampling procedures

A selection of sampling procedures included in standards from five countries is given below.

### Australia

Three test specimens shall be taken from different pipes selected at random by using statistical techniques.

### Federal Republic of Germany

The frequency of testing must be at least once a year. In case a change in the extrusion compound leads to renewed testing, the nominal size of pipe should at least be 40 mm.

### The Netherlands

With the exception of a minimum age of the uPVC pipe of 15 hours, no specific demands have been prescribed.

### United Kingdom

The uPVC pipes to be tested are grouped according to their method of manufacture and the type of extrusion compound used.

Test specimens shall be taken at least once a year from the smallest size of pipe within each group. A change in the method of manufacture or in the extrusion compound leads to the establishment of a new group.

### U.S.A.

Policy B of the NSF Standard includes a statement of policy relating to sample collection, testing, reporting and samples required.

Item I: "Actual laboratory examination of specimens of materials offered for use in the extrusion of plastic pipe is required and actual laboratory examination of specimens of extruded plastic pipe and fittings also are required before the right to use the NSF Seal and Listing Program on such materials and pipe is initially granted and at least once a year thereafter."

Item 2: "A sample of each "listed" raw material for making plastic pipe, fittings, valves, and/or traps will be tested at least once a year and, in addition, as frequently as may be deemed necessary by the Executive Director of the NSF testing laboratory."

## 6.4. Marking

A description of marking procedures incorporated in the standards of the five selected countries is given below.

### Australia

All pipes shall be indelibly marked at intervals of not more than 3 ft. using a distinctive colour. The following information shall be shown:

- the name of the manufacturer and or the trade mark
- the nominal size

- class of the pipe
- suitability for potable water
- number of the standard

#### Federal Republic of Germany

DVGW Arbeitsblatt W 320: "The pipes have to be marked at distances of about 1 m with DIN mark, name of manufacturer, number of extruder, code number concerning the composition of material, diameter and maximum working pressure.

#### The Netherlands

Chapter 2.10: "The pipes have always to be marked with the name of the manufacturer or the trade name (marque déposée), KIWA, uPVC, pressure class, nominal diameter x wall thickness (in mm), production period and number of extruder; the last two data may be in code.

#### United Kingdom

"All pipes shall be indelibly marked at intervals no greater than 3 m. The marking shall show the following in the order stated:

- (1) The manufacturers identification
- (2) The number of the British Standard, i.e. BS 3505
- (3) The nominal size and class.

Adhesive labels alone shall not suffice.

The marking shall be imprinted longitudinally in the following colours in accordance with BS 4159

Class B, red      Class D, green

Class C, blue     Class E, brown

It is strongly recommended that use is made of the scheme operated by the British Standard Institution whereby products meeting the standard may bear the official registered mark of BSI.

#### U.S.A.

An NSF Seal and Listing Program is applied on uPVC pipe meeting the NSF Standard No. 14. The material is "listed" by the NSF. Section 4 - Requirements for pipe, fittings, valves and traps - item 4.03: Marking and coding of pipe, fitting and traps, and appurtenances: "The manufacturer shall place on all thermoplastic pipe, fittings, valves and traps and appurtenances, the designations and identification

required in the latest applicable ANSI, ASTM or CS Standard(s) as determined by the NSF Joint Committee on Plastics. Provided however, that fittings and valves of such size and/or configuration as to preclude use of the complete marking shall be at least identified as to the manufacturer and type of material".

4.031 "The minimum pipe markings shall include: pipe size, type of material, pressure (PSI), ASTM Standard number, trade mark, code, and NSF logo. These markings shall be repeated at least every 24 inches along the length of the pipe. All required markings shall be legible and so applied as to remain legible under normal handling and installation practices."

4.032 Thermoplastic pipe, in addition to the above, shall bear an appropriate code which will assure identification on the pipe as to the month of production and resin formulae used in the production of said pipe.

Manufacturers shall maintain such additional records as are necessary to confirm identification of all pipe so coded.

#### 6.5. Specifications in uPVC pipe material

A number of standards include a specification of the uPVC material. As an example, specifications from the standards in five countries are given below.

##### Australia

The material from which the pipe is produced shall consist only of polyvinylchloride or modified polyvinyl chloride, to which shall be added suitable lubricants, pigments, stabilizers, and pastes thereof.

The total plasticizer content shall not exceed 1 part per 100 parts by weight of the uPVC content, and the total additives shall not exceed 20 parts by weight of the uPVC content.

##### Federal Republic of Germany

DIN 8061 chapter 2.1: "Modified uPVC without plasticizers have to be used. The choice of stabilizers etc. are a matter for the manufacturers, with the restriction that uPVC pipe has to meet the DVGW Arbeitsblatt and the quality demands of the Bundesgesundheitsamt." DVGW Arbeitsblatt W 320: "Products of unknown composition and rework material are not allowed to be used."

According to the 11. Mitteilung aus dem Bundesgesundheitsamt, uPVC drinking water pipe is safe for conveyance of drinking water if the material meets the prescribed composition.

Dibasic lead stearate, dibasic lead sulphate, and dibasic lead phosphate may be used up to 2% of lead in weight as a maximum.

#### The Netherlands

"The material from which the pipe is produced shall consist of unplasticized polyvinylchloride to which may be added only those additives which are needed to facilitate the manufacture of the polymer and the production of the pipe. Pigments may be added.

#### United Kingdom

The material from which the pipe is produced shall consist substantially of polyvinylchloride to which may be added only those additives that are needed to facilitate the manufacture of the polymer and the production of sound, durable pipe of good surface finish, mechanical strength and opacity. None of these additives shall be used separately or together in quantities sufficient to constitute a toxic hazard or to impair the fabrication or welding properties of the pipe or to impair its chemical and physical properties as defined in the standard.

#### U.S.A.

NSF Standard no. 14, section 3, item 3.00 General:

"Materials used in manufacture of pipe, fittings, valves, traps, joining materials and appurtances covered by this Standard shall meet the public health and safety as well as performance requirements as established herein for the intended use or application. All such materials shall be manufactured in a manner which will prevent introduction of possible contamination thereto.

Item 3.001 Such quality procedures and reports as are deemed necessary to continued uniform quality of the materials and continued compliance with the applicable ASTM requirements for said material may be required.

Item 3.002 "The addition of innocuous tracers to materials covered

by this Standard may be required when so recommended by the NSF Joint Committee on Plastics."

Item 3.003 "The manufacturer shall submit, at the time of requesting evaluation and qualification of a thermoplastic material and/or joining material, complete information for such material. When any change is made in the formula or in the source of supply of ingredients therein, such additional information shall also be submitted.

Said information shall be retained on a confidential basis."

Item 3.02 "Potable water application: Thermoplastic materials for pipe, fittings, valves, joining materials and/or appurtenances for potable water applications shall contain no ingredients in an amount which has been demonstrated to migrate into water in quantities which are considered toxic and shall conform to the specific requirements as stated in item 3.021 Toxicological and Organoleptic requirements and 3.022 - Physical requirements.

#### 6.6. Summary of requirements

1. Complete information on the composition of the material used for production must be submitted by the manufacturer to the testing agency before uPVC pipe can be tested according to existing specifications.
2. Based on the information of the manufacturer, tests on toxicity are commonly restricted to the leaching of a restricted number of heavy metals which are known to be present in the uPVC. Sometimes organoleptic properties are included.  
The NSF also includes materials such as compounds produced by materials suppliers and pipe or fittings manufacturers.
3. The test methods for the determination of the leaching of toxic materials are mainly based on extraction tests simulating the worst conditions to be expected in normal practice.
4. Changes in the composition of raw materials commonly entail new testing of the uPVC pipe produced. Manufacturers are often required to notify the appropriate testing institute of such changes beforehand.
5. The normal frequency of testing for toxicity amounts to at least once a year.

6. Basic data have to be marked on the outside of uPVC drinking-water pipe, as well as the seal of approval. Marking must be in such a way that the employment of uPVC pipe for other than drinking-water, is prevented.

## 7. SUMMARY AND RECOMMENDATIONS

### 7.1. Standards

uPVC pipes are widely used in industrialized countries. In developing countries their increasing use is likely to have a substantial health impact through the provision of piped drinking water to the greatest number of people possible. The advantages of uPVC pipes include low cost, ease of laying, corrosion resistance and the ease with which local production can be set up.

The use of heavy metal stabilizers in uPVC pipe represents a potential toxic hazard, but experience has shown that this can be controlled by establishing suitable standards placing limits on the amount of toxic stabilizer that can be extracted from the pipe. Only a small minority of the more than 50 member countries of the International Organization for Standardization (ISO) have so far produced national standards with toxicity clauses. These clauses specify different methods of extraction, different pretreatment procedures and different extraction fluids, sample sizes and durations and extraction temperatures. Standards for uPVC which deal, inter alia, with health aspects are being drafted by the ISO and it is to be hoped that these will bring some uniformity to the specifications. The development of national standards should involve collaboration between standardization organizations, testing institutes, and the appropriate national health authorities.

#### Recommendation

National standards for uPVC pipe should be prepared setting a limit to the amount of extractable toxic substances. National health authorities and testing institutes should be involved in the drafting of such standards and ISO should be regarded as the appropriate international body for the coordination of national standards and the development of uniform procedures.

## 7.2. Test methods and requirements

The test procedures and requirements specified in most uPVC pipe standards generally include the requirement that the uPVC material contain no ingredients in amounts demonstrated to migrate into the water in quantities considered toxic.

The test procedures specified in most uPVC pipe standards are in general related to the extractability of toxic ingredients and usually consist of a sequence of extractions with a simulated aggressive water. Extracts should be analyzed for cadmium and other toxic ingredients as well as for the stabilizer used in the uPVC pipe formulation. To comply with present requirements, the levels of stabilizer in successive extracts must be below the specified limits.

At present ISO has set up two draft standards for test methods and maximum permitted levels which are restricted for the extractability of lead and tin from unplasticized PVC pipes for drinking water supply. Some improvements to the ISO draft standards have been proposed by a consultant group.

### Recommendation

The detailed comments on the ISO draft standards ISO/DIS 3113 and 3114 set out in Appendix 3 should be drawn to the attention of ISO Technical Committee No. 138.

## 7.3. Lead-stabilized uPVC pipe

Experience of research and testing institutions as well as of waterworks authorities with extensive distribution systems of lead-stabilized uPVC pipe has shown that the amount of lead leaching into water from newly installed uPVC pipes falls rapidly with time when the pipe is put into use. In the United Kingdom and the Netherlands it has been shown that lead-stabilized uPVC pipes produced to BS 3505 and KIWA Standard no. 49 will after a period of days give rise to lead concentrations well below the 0.1 mg/l limit set in International Standards for Drinking-Water, 1971 (which took into account lead pipes still in use in Europe). The limit of 0.5 mg/l was laid down in previous editions of International Standards.



### Recommendation

The specification for leaching of lead from lead-stabilized uPVC pipes for drinking water and the extraction procedures in ISO draft standards ISO/DIS 3113 and 3114 are almost the same as in BS 3505 and KIWA Standard no. 49. It is therefore concluded that lead-stabilized uPVC pipes produced and tested in accordance with ISO draft standards can be expected, after a short period of use, to leach lead only in very small quantities giving rise to concentrations that are well below the limit of 0.1 mg/l laid down in International Standards for Drinking Water.

#### 7.4. Cadmium stabilizers in uPVC pipe

Cadmium compounds sometimes have been used as an addition to lead compounds to stabilize uPVC drinking water pipe.

In view of the toxicity of cadmium and its cumulative nature (provisional tolerable weekly intake: 400 - 500  $\mu$ g per individual), its use in formulations for uPVC drinking water pipe is considered to be highly undesirable.

### Recommendation

In view of their high toxicity and retention in the human body, the use of cadmium compounds in uPVC formulation for uPVC drinking water pipe should be specifically excluded.

#### 7.5. Tin-stabilized uPVC pipe

Lead-stabilized uPVC drinking water pipes, although used widely in Europe, are not permitted in the U.S.A. for drinking water applications: organotin stabilizers are used instead. The National Sanitation Foundation has reported very low concentrations ( $\leq 0.01$  mg/l) of tin in extracts prepared according to their test procedure. Very little data are available in other countries on the leaching of organotin stabilizers or their possible degradation products into water. Limited experimental data on the release of dioctyl tin stabilizer into water from tin-stabilized pipe in Bulgaria (personal communication) indicated a rapid downward trend in extraction levels as in lead-stabilized pipe.

The types of organotin compound used to stabilize uPVC have a

wide range of acute toxicity effects. No data are available, however, on the risk from long-term exposure to low concentrations of these substances or of their degradation products, which have not so far been considered by the Joint FAO/WHO Expert Committee on Food Additives or the WHO Expert Committee revising International Standards for Drinking-Water.

#### Recommendation

Research should be carried out to determine the leaching pattern and ultimate concentration of organotin stabilizers and of their degradation products in water resulting from the use of tin-stabilized uPVC pipes. There is also a need for toxicological data on the effect of long-term exposure to these materials so that an acceptable daily intake can be fixed.

#### 7.6. PVC pipe formulation

Initial leaching of toxic ingredients from uPVC pipe is strongly related to the total quantity used for PVC pipe production.

#### Recommendation

Strenuous efforts should be made by manufacturers and others to produce pipes from ingredients that are known to be non-toxic. In the meantime, it is strongly recommended that the quantity of toxic stabilizers and all other toxic ingredients should be limited to the absolute minimum required for production.

-----

#### REFERENCES

1. Kunststoff-Handbuch, Polyvinylchlorid, Band II p.194.
2. A study of plastic pipe for potable water supplies (1955), National Sanitation Foundation, Ann Arbor, Michigan.
3. McJunkin, F.E., Pineo, C.S., Role of plastic pipe in community water supplies in developing countries, Agency for International Development, 1971.
4. World Health Organization, Evaluation of certain food additives and the contaminants mercury, lead, and cadmium. Sixteenth report of the Joint FAO/WHO Expert Committee on Food Additives, Technical Report Series 1972, No. 505.

5. World Health Organization, Pesticide residues in food. Report of the 1970 Joint Meeting of the FAO Working Party of Experts on Pesticide Residues and the WHO Expert Committee on Pesticide Residues. Technical Report Series, 1971, No. 474.
6. World Health Organization, Toxicological evaluation of some enzymes, modified starches and certain other substances. WHO Food Additives Series, 1972, No. 1.
7. Radeva, M., and Angelieva, R., Sbornik Utopisi: HEI, 21 (1970), p. 102-104.
8. Boelens, A.H.M., Lead release of hard PVC pipes, Water 1960, 44, 350-351.
9. Bundesgesundheitsamt Berlin, Untersuchungen an verlegten PVC-Rohren der Wasserleitungsmaatschappij Overijssel in Zwolle auf ihre hygienische Eignung als Kaltwasserleitungsrohre, Zwolle, Wasserleitungsmaatschappij "Overijssel" N.V., 1962.
10. KIWA, De toelaatbaarheid van het verwerken van toxische stoffen bij de vervaardiging van buizen van plastic. Mededeling nr. 3 van de Commissie Waterleidingbuizen van plastic, 1961.
11. Aanbevelingen van de VEWIN op artikel 4, lid 2 van de Waterleidingwet.
12. Everard, K.B., Hazard avoided and incurred by choosing PVC pipe. Int. Pipe and Pipelines, 1965, 10 (7) 35-39, (8) 32-35.
13. Visintin, B., Moneriolo, S., Results of 4 years experience in testing PVC pipes for water supply. Materie Plast. 1965, 31, 753-755.
14. Cosoveanu, G., Toxicity of PVC pipes made in Rumania and their use in potable water installations, Materie Plast. 1967, 4, 30-33
15. Paramasivam, R., Dandekar S.S., Unplasticized PVC pipes and water quality. Indian J. Environ. Hlth, 1973, 1, 21-28.
16. Packham, R.F., The leaching of toxic stabilizers from uPVC water pipe. Part II - A survey of lead levels in uPVC distribution systems. Water Treatment Examination, 1971, 20, 144-151.
17. Elzenga, C.H.J., Van Puffelen, J., The leaching of toxic stabilizers from uPVC water pipe. Project report on WHO file references W2/181/4 and W2/181/6.
18. Sontheimer, H., Wagner, I., Untersuchungen zur Bleiauswanderung aus bleistabilisierten Hart-PVC-Rohren. Gas und Wasserfach, 1969, 110, 487-492.
19. Niklas, H., Meijer, W., Auswanderung von Blei aus bleistabilisierten PVC-Rohren. Kunststoffe 1961, 51, 2-6

20. Packham, R.F., The leaching of toxic stabilizers from uPVC water pipe. Part I - A critical study of laboratory test procedures. Water Treatment Examination, 1971, 20, 108-124.
21. Packham, R.F., The leaching of toxic stabilizers from uPVC water pipe. Part III - The measurement of extractable lead in uPVC pipes. Water Treatment Examination, 1971, 20, 152-164.

---



INTERNATIONAL ORGANIZATION FOR STANDARDIZATION

DRAFT INTERNATIONAL STANDARD ISO/DIS 3114 \*

EXTRACTABILITY OF LEAD AND TIN OF UNPLASTICIZED  
POLYVINYL CHLORIDE (PVC) PIPES  
FOR DRINKING WATER SUPPLY.  
TEST METHOD.

UDC 621.643.29:678.743.22:628.1:615.9

---

\* The International Organization for Standardization has kindly permitted to add this document as an appendix to this paper.

This document has recently been submitted to all the ISO Member bodies for approval. Hence, they may in no way be referred to as international standards, until they have been revised in the light of all comments made and accepted by the ISO Council. Comments should be sent to the Secretariat of the Technical Committee ISO/TC for its consideration.

EXTRACTABILITY OF LEAD AND TIN  
OF UNPLASTICIZED POLYVINYL CHLORIDE (PVC) PIPES FOR DRINKING  
WATER SUPPLY. TEST METHOD

1. SCOPE

This International Standard is intended to describe the method of test to be applied for the determination of the extractability of certain stabilizers of unplasticized PVC, to verify if the extracted quantities do not exceed a certain concentration.

2. FIELD OF APPLICATION

This test method applies to pipes of unplasticized PVC.

It only relates to the extractability of two types of stabilizers:

- lead salts
- organic derivatives of tin, mainly dialkyltin C<sub>4</sub> and higher homologues.

3. PRINCIPLE

The pre-washing of test pieces during a fixed time.

The filling of the test pieces with water acidified with CO<sub>2</sub>, and the analysis of the quantity of the extracted stabilizer after a fixed time.

Note 1: The methods to be used for the determination of the quantity of material taken into solution, are not laid down. They shall permit to carry out the analysis with an accuracy of 0.01 mg/l for lead and of 0.001 mg/l for tin.

4. APPARATUS

- A glass pipe,
- A glass cock,
- Stoppers,
- Distilled water, acidified with CO<sub>2</sub> at a concentration of 150 mg/l

5. TEST PIECES

For each test: 3 pieces of the pipe, 500 mm of length, with an internal content at least equal to the volume of the extracting

liquid, required to determine the amount of dissolved material with the required accuracy.

## 6. PROCEDURE

### 6.1 Pre-washing

- 6.1.1 Close one end of each test piece with a stopper, in the middle of which a glass pipe is fitted provided with a glass cock. The stopper should be of PE or of any other material which will not affect the results.
- 6.1.2 Place the test pieces vertically with the open end upwards.
- 6.1.3 Let tap water flow in such a way into the test pieces that the rate of flow, regulated with the aid of the cock, is equal to 3 m/min and in such a way that the test pieces are continuously filled with water.
- 6.1.4 Maintain the water flow during a fixed period between 1 and 6 hours.
- 6.1.5 At the end of this period, stop the water flow, remove the stoppers and rinse out the test pieces with distilled water.

### 6.2 Extractability test

- 6.2.1 Close one end of each test piece, which has been subjected to the pre-washing, with the aid of a stopper composed of a material that does not contain any toxic substances nor influence the analysis.
- 6.2.2 Fill each test piece with distilled water, acidified with CO<sub>2</sub> at a concentration of 150 mg/l

Note 2: For each series of tests, a freshly made solution of distilled water, acidified with CO<sub>2</sub> shall be used.

Note 3: To prepare the CO<sub>2</sub> solution of 150 mg/l, it is practical to saturate a sufficient quantity of water with CO<sub>2</sub>, to determine the content of CO<sub>2</sub> by means of a suitable method and then to mix the saturated solution with a calculated volume of carbon dioxide free distilled water.

Close the other end by means of a stopper and maintain the filled test pieces at 20 ± 5°C for 48 hours.

- 6.2.3 1st extraction: At the end of 48 hours empty the water from the test pieces into suitable containers, and determine the



quantity of lead, if this is the sample for lead determination.

6.2.4 2nd extraction: Fill the test pieces again, with a fresh solution of distilled water, acidified with  $\text{CO}_2$  and maintain the test pieces, after having closed them again, at  $20 \pm 5^\circ\text{C}$  for 48 hours. At the end of this period pour the water out of the test pieces.

6.2.5 3rd extraction: Refill the test pieces for the third time under the same conditions as described for the preceding extractions. At the end of 48 hours empty the water into suitable containers and, dependent on the substance to be determined, proceed to the 2nd determination of the quantity of lead, or to the determination of the quantity of tin.

## 7. EXPRESSION OF RESULTS

### 7.1 Lead

7.1.1 Calculate for the 3 test pieces the arithmetic mean of the quantities of lead found in the extracts after the first and the third extraction.

7.1.2 Express the results in mg/l, with an accuracy of 0.02 mg/l.

### 7.2 Tin

7.2.1 Calculate for the 3 test pieces the arithmetic mean of the quantities of tin found in the extracts after the third extraction.

7.2.2 Express the results in mg/l, with an accuracy of 0.004 mg/l.

## 8. TEST REPORT

The test report shall include the following indications:

8.1 complete identification of the pipe tested,

8.2 number of test pieces,

8.3 the method used for the determination of the quantity of lead in aqueous solution,

8.4 the method used for the determination of the quantity of tin in aqueous solution,

8.5 quantities of extracted lead for each test piece after the first and the third extraction,

8.6 the arithmetic mean of the extracted lead for the pipe after

- the first and the third extraction,
- 8.7 quantities of extracted tin for each of the test pieces after the third extraction,
- 8.8 the arithmetic mean of the extracted tin for the pipe after the third extraction,
- 8.9 details of the procedure which have not been provided for by this test method, and also the accidental circumstances which might have affected the results.

---



INTERNATIONAL ORGANIZATION FOR STANDARDIZATION

DRAFT INTERNATIONAL STANDARD ISO/DIS 3113 \*

PERMITTED LEVELS OF LEAD AND TIN IN UNPLASTICIZED  
POLYVINYL CHLORIDE (PVC) PIPES FOR DRINKING WATER  
SUPPLY

UDC 621.643.29:678.743.22:628.1:615.9

---

\* The International Organization for Standardization has kindly permitted to add this document as an appendix to this paper.

This document has recently been submitted to all the ISO Member bodies for approval. Hence, they may in no way be referred to as international standards, until they have been revised in the light of all comments made and accepted by the ISO Council. Comments should be sent to the Secretariat of the Technical Committee ISO/TC for its consideration.

PERMITTED LEVELS OF LEAD AND TIN IN  
UNPLASTICIZED POLYVINYL CHLORIDE (PVC) PIPES  
FOR DRINKING WATER SUPPLY

1. OBJECT

The object of the present International Standard is to fix the maximum levels for the extraction of certain stabilizers from unplasticized PVC.

2. FIELD OF APPLICATION

It applies to unplasticized PVC pipes intended for the transport of drinking water.

3. REFERENCE

ISO/DIS 3114 Extractability of lead and tin of unplasticized polyvinyl chloride (PVC) pipes for drinking water supply-Test method.

(At present at the stage of Draft)

4. SPECIFICATION

Under the test conditions for extractability described in ISO/DIS 3114 the extracted quantities of lead and dialkyl tin, C<sub>4</sub> and higher homologues, should not exceed the following values:

4.1 LEAD

- after the first extraction: 1.0 mg/l

- after the third extraction: 0.3 mg/l

4.2 Dialkyl tin, C<sub>4</sub> and higher homologues, measured as tin

- after the third extraction: 0.02 mg/l.

---

Detailed comments by the Consultant Group on ISO Draft International Standard ISO/DIS 3113 and ISO/DIS 3114

ISO/DIS 3113 - Permitted levels of lead and tin in unplasticized polyvinylchloride (PVC) pipes for drinking water supply.

- (a) Consideration should be given to the incorporation of the following general requirement:

"The composition of the uPVC pipes must be such that its use has no adverse effect on the potability of water either from the toxicological or, aesthetic standpoint."

- (b) The extracts obtained in the tests should be checked regularly for the presence of toxic heavy metals other than the specified toxic lead- and organotin containing stabilizers, especially cadmium and barium.

Consideration should be given to the inclusion of limits for such elements as might be utilized in uPVC and uPVC pipe production.

- (c) The analytical method used for lead in these tests should have a limit of detection of 0.1 mg/litre of lead or less. The method for tin should have a limit of detection of 0.01 mg/litre or less.
- (d) The current title of the document may give the impression that the limits given relate to the concentration of toxic elements expected in water.

The following amended title is proposed:

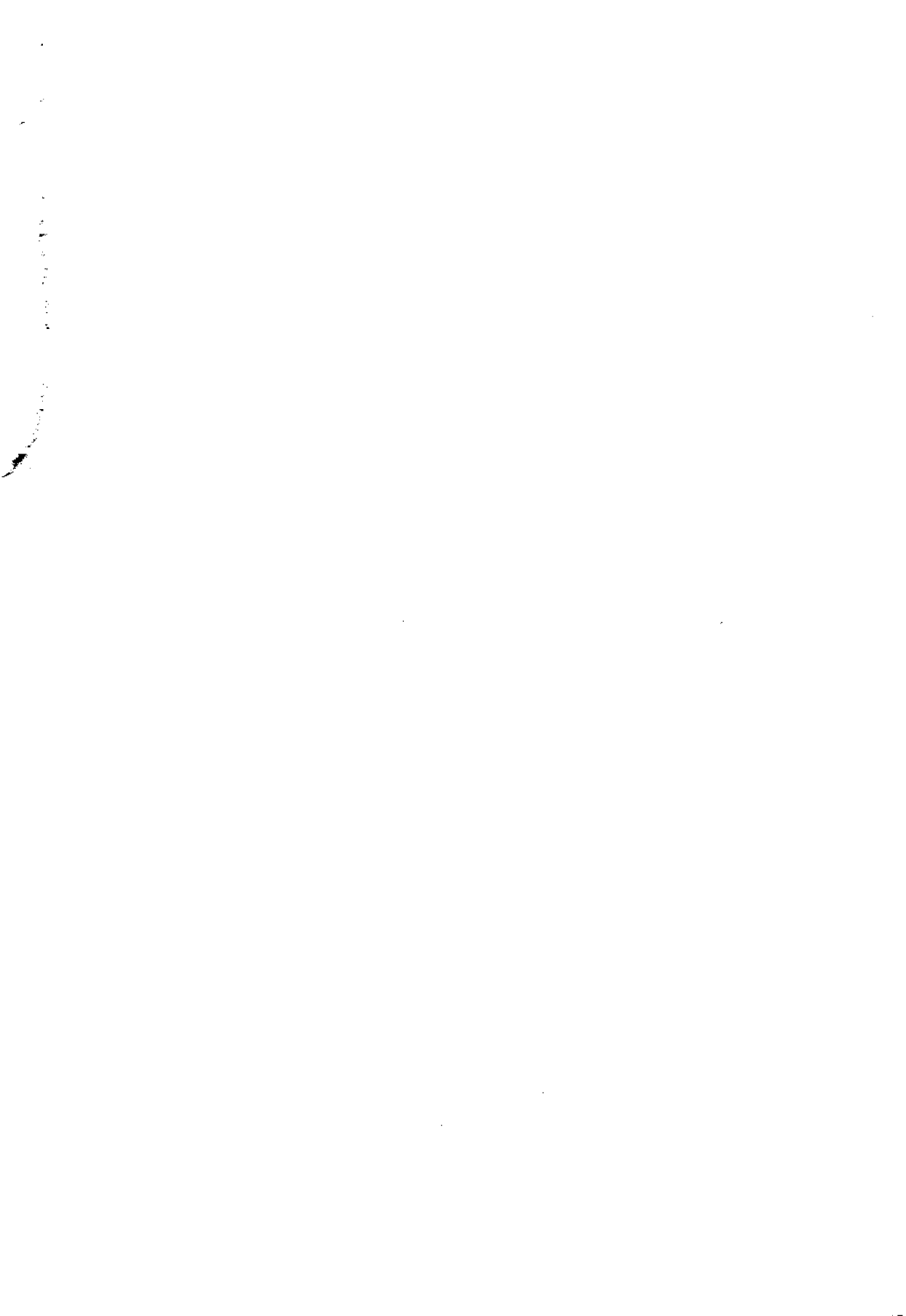
"Maximum concentrations of toxic substances in extractability tests on new unplasticized polyvinylchloride (uPVC) pipes intended for drinking water supply."

ISO/DIS 3114 - Extractability of lead and tin of unplasticized polyvinylchloride (PVC) pipes for drinking water supply. Test method.

- (a) The prewash period in the standard procedure is set within the wide limits of 1 - 6 hours. It is considered that a shorter period should be used ( $\frac{1}{2}$  - 1 hour) and that conditions for the installation of new pipes should require that uPVC pipes be continuously flushed for a period of more than 1 hour to remove excessive toxic components that might be present on the pipe inner wall before water from the pipe is used for human consumption.

- (b) The specification of 150 mg/l carbon dioxide solution as the extracting fluid is liable to error. It is proposed that the alternative procedure should be used of passing carbon dioxide into distilled water until the pH of the water is  $4.5 \pm 0.1$ . In this pH range the carbon dioxide content should be approximately 150 mg/l.
- (c) The extraction temperature of  $20 \pm 5^{\circ}\text{C}$  was considered to be of doubtful validity when the test is applied to pipe to be used in tropical and arid countries where exposed pipe and its contents could remain at temperatures up to  $45^{\circ}\text{C}$  for several hours. No specific recommendations are proposed to cover this point, but it might be considered further by the ISO Technical Committee.
- (d) The extraction times specified (3 x 48 hours) were considered to be inconvenient to use and alternatives, e.g. 3 x 24 hours, 3 x 72 hours or 2 x 24 hours and 2 x 72 hours, that did not require 6-day working should be given in the final standard.

---





## IRC PUBLICATIONS

### Technical Papers

- Technical Paper no. 1 - Plastic pipe in drinking water distribution practice, 1971
- Technical Paper no. 2 - The suitability of iodine and iodine compounds as disinfectants for small water supplies, 1972, B.C.J. Zoeteman
- Technical Paper no. 3 - The purification of water on a small scale, 1973 (also in French)
- Technical Paper no. 4 - Health aspects relating to the use of uPVC pipes for community water supply - Report of a Consultant Group, 1973
- Technical Paper no. 5 - Health aspects relating to the use of polyelectrolytes in water treatment for community water supply - Report of a Consultant Group, 1973

### Bulletins

- Bulletin no. 1 - Community Water Supply Research, 1972
- Bulletin no. 2 - Training Courses in Community Water Supply, 1972
- Bulletin no. 3 - Community Water Supply Research, 1972
- Bulletin no. 4 . The Story of CPHERI, 1972

---