A/C Pipe Producers Association

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Internal Correspondence

TO Board of Directors
International Affairs Committee

FROM J. F. Welch, Vice President

J.F. Welch

DATE July 6, 1984

7-11-84

SUBJECT Magazine Article - "Asbestos Fibers in Drinking Water With Special Reference to Asbestos-Cement Pipe Usage"

ACTION REQUIRED: Review for individual member company follow up

The enclosed article, authored by Dr. Brian T. Commins, appeared in the May-June, 1984 issue of Pipes and Pipelines International magazine. It is basically a synopsis of Dr. Commins' 1983 report, "Asbestos Fibres in Drinking Water," and may be valuable as a sales promotion tool.

Glossy reprints of this article are available for the price of 1 pound (U.K.) per reprint from Dr. Brian T. Commins, Commins Associates, 'Pippins', Altwood Close, Maidenhead, Berkshire, England SL6 4PP.

If you have any questions, please do not hesitate to call.

JFW/ajb

Enclosure

cc: A. Kahn, Esq.

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Asbestos fibres in drinking water with special reference to asbestos-cement pipe usage*

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1. Introduction

For many thousands of years asbestos fibres will have been present in some waters used for drinking purposes because a relatively common source of the fibres is naturally occurring asbestos mineral deposits, some of which come in contact with water supplies[1]. However, only in the last two decades or so has it become possible to detect and to identify satisfactorily asbestos in water, and in the early 1970s asbestos fibres were found in the source of water supply for the City of Duluth, Minnesota, USA[2]; this source (Lake Superior) was found to be contaminated by a mining discharge which contained asbestos, and concern arose. The measurement unit used to express the levels in water was millions of fibres per litre of water. The use of this particular measurement unit (one which is simply for the convenience of the analyst making the measurement) alarmed people, although we now know that even a million chrysotile fibres per litre is only typically 0.005 μg per litre[3], a level which is much lower than the concentration one normally considers as a trace substance concentration in drinking water. In addition, there has been concern regarding occupational exposure to asbestos via inhalation and the effects on the human lung, and it was natural to consider whether ingested asbestos was also a problem. In the 1970s there was a good deal of over-reaction to environmental issues generally, including the finding of asbestos in drinking water.

Most asbestos fibres in drinking water are extremely small. For the commonest type of fibre, chrysotile asbestos, they are typically 0.03 to 0.1 μm in diameter and 0.5 to 2 μm long[1]. The mass of a single fibril of chrsotile asbestos can be of the order of 10^{-17} g but typically for fibrils or bundles of fibrils, the mass range 10^{-16} to 10^{-12} g will apply[1].

The demand for asbestos products has increased dramatically this century, and over 3,000 uses have been identified[4]. The following countries are parti-

Fig 1. 300-mm diameter asbestos-cement pipe being laid in the city centre of Durban, South Africa.

** Based on a paper presented at the Associazione Nationale di Ingegneria Sanitaria Congress on Materials for Pipes, Rome 15—17 Dec. 1983 and lectures given at various venues in South Africa during February 1984. Further details of this subject can be obtained from the author's comprehensive Report 'Asbestos Fibres in Drinking Water' STR1, published May 1983.*

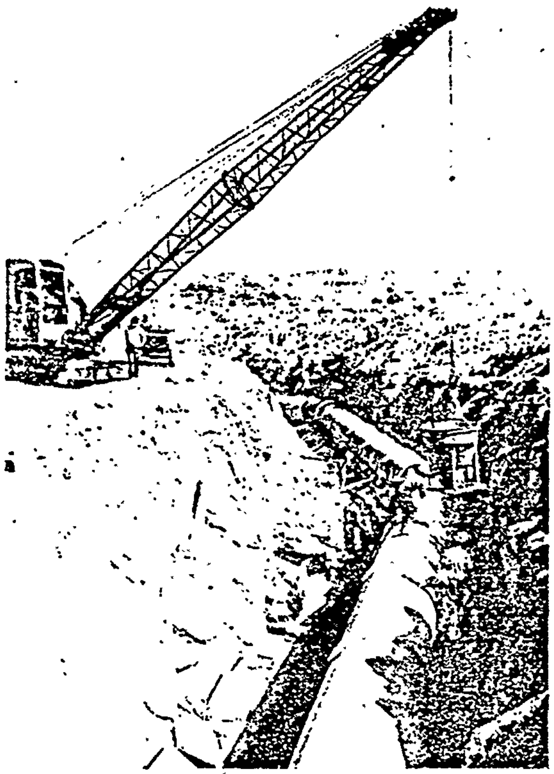

Fig. 2. A 1100-mm diameter sewer outfall in asbestos-cemènt is given a concrete haunching in rocky ground at Mabobame in the Transvaal, South Africa.

cularly noted for their production of asbestos: USSR, Canada, South Africa, Zimbabwe, China, Italy, Brazil, USA and Australia[5]. Because of the widespread use of asbestos and products containing it, inevitably some contamination of the environment has arisen; the problem of environmental contamination was greater in the past because of the existence then of fewer control measures.

2. Potential sources of asbestos in drinking water

Asbestos fibres are often found in water; the fibres can be introduced into source waters by the dissolution of natural asbestos-containing minerals, from industrial effluents and atmospheric fallout[3,6,7]. Sedimentation, resuspension, migration and chemical reactions affect the movement, abundance and fate of asbestos in water; some of these mechanisms will affect the asbestos fibres in distribution systems conveying potable water. The use of asbestos-cement water pipes will in some cases also contribute to the level of asbestos in distributed water[1].

2.1 Natural and effluent sources of asbestos in drinking water.

A major source of asbestos in drinking water supplies in some countries is natural contamination arising through water making contact with asbestos mineral deposits[6]. Although it is difficult to assess how widespread natural asbestos contamination is, asbestos deposits are fairly common in a number of parts of the world and one might anticipate that such natural contamination is also fairly widespread. Concentrations as high as 2,000 million fibres per litre have been recorded[8], and levels of several hundreds of millions of fibres per litre are not unusual; the more widespread natural contamination level is, however, probably relatively low. Effluent discharges to water bodies used for potable supply can also be the cause of a significant level in drinking water[3,7]. Concentrations of up to several hundreds of millions of fibres per litre of drinking water have been reported where effluents have contaminated water sources[3]; nowadays the control of such effluents is generally carefully maintained and levels of more than 10 million fibres per litre would be unusual. In addition asbestos fibres leaching from asbestos waste dumps adjacent to water sources may cause some contamination[1].

2.2 Airborne sources, asbestos-cement tanks, asbestos-cement roofs, etc.

Airborne sources of asbestos arising from the weathering, etc. of asbestos products may contaminate surface water supplies. However, because in general the levels of asbestos in air are low[9-13], and since the volume of water which could be possibly contaminated is normally vast, the extent of the contamination is almost certainly, generally, very low indeed.

Asbestos-cement storage tanks are clearly potential sources of contamination; relatively-high levels of asbestos may occur where water is allowed to make contact with the cement surface and the water is not drawn off regularly, as might occur in some situations.

Asbestos-cement roofing tiles can apparently be a particularly significant source of asbestos fibres where roof run-off water is collected for potable purposes. Levels of over 500 million fibres per litre of water have been recorded in some situations[14].

2.3 Asbestos-cement pipes

Although some literature reports have suggested[15,16,17] that significant levels of asbestos can arise when these pipes are used, the general concensus of opinion is that the degree of fibre contamination to the water is relatively low[1,12,15,16], except perhaps in some circumstances where the water is particularly aggressive[13,14]; this is discussed in section 5.

3. Sampling and analysis of asbestos in water

3.1 Sampling

The difficulties of sampling are often underestimated. Glass or polyethylene collection bottles (one litre capacity) can be used[14]. Before use they must be ultrasonically cleaned: washing carefully with double-distilled water is important too[20,22,23]. Where possible, each sample should be collected in duplicate because of the fact that sometimes very discrepant results are obtained. Discrepancies can be caused by chance inclusions of a fibre bundle in one sample and not others, or by chance contamination occurring in one bottle; even an invisible tiny bundle of fibres can produce a result of several million fibres per litre[1]. Samples should be collected at normal flow rates to provide a representative result; samples collected at hydrants may be totally unrepresentative of the water quality in a distribution system[1].

3.2 Sample preparation prior to analysis

Once collected, samples should be stored in the dark and they should be analysed within a week or so of collection. Immediately prior to analysis the samples should be untrasonically agitated[20]. The next stage consists of using a variety of possible techniques to allow electron microscope specimens to be prepared from the sample of water; low temperature ashing or ozone treatment may be necessary[20]. These procedures and those which are involved in the electron microscopical analysis are highly specialized. Considerable experience is needed to get good results, and one analysis may take many hours to complete; the cost can be several hundred US dollars per analysis.

3.3 Electron-microscopical analysis

The details of the analysis have been described elsewhere[1,3,20]. Transmission electron-microscopical analysis rather than scanning electron-microscopical analysis is required; in addition either electron-diffraction analysis and/or X-ray energy-dispersive analysis is essential.

3.4 Statistical evaluation of the results

Standardized procedures are now available for interpreting the results; proper statistical evaluation is an essential requirement for analysis. The analytical results are not precise as in normal chemical analysis; typically the 95% confidence limits for a sample result containing one million fibres per litre water may be as wide as 0.4 to 2.2 million fibres per litre[1].

4. Concentrations of asbestos fibres in water

A number of the earlier studies involved the use of rather unreliable sampling methods and poor sample preparation techniques, as well as inadequate identification and quantification for asbestos fibres. The results reported here have been selected on the basis of reliable data; any analyses by optical microscopy and by scanning electron microscopy have been rejected.

Although some publications have reported concentrations expressed in mass terms, i.e., μg or ng per litre, most results are provided as a number concentration, i.e., as millions of fibres per litre of water. The results given here are given as millions of fibres per litre but it is important to recognize that the mass concentrations are generally very low. For example: typically, one million fibres per litre chrysotile is only 0.005 μg per litre, and typically one million fibres per litre

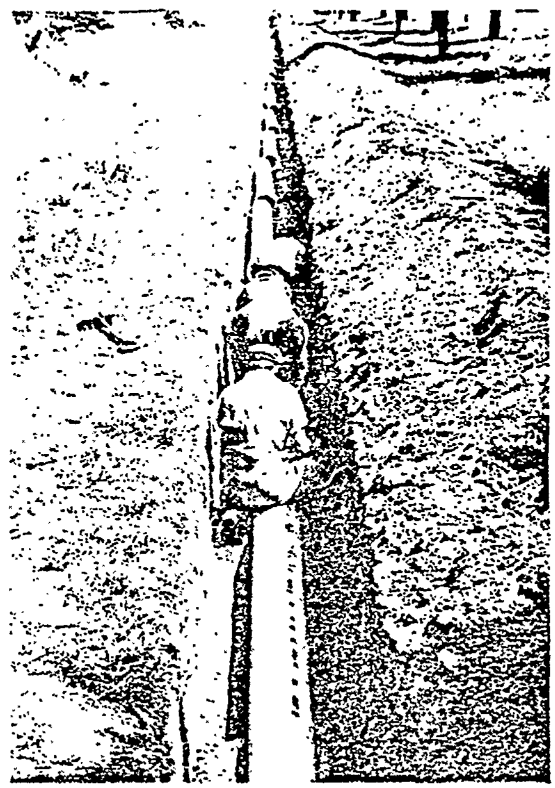

Fig. 3. 6-in diameter 'Everite' sewer pipe is laid at Springs in South Africa's Transvaal.

amphibole asbestos is 0.2 μg per litre[3]. The conversion factor depends on the precise fibre dimensions and the density of the mineral fibre.

Outside the USA and Canada, very few analytical results are available. In the USA[3] a survey of over 1,500 samples representing 365 cities gave results as follows: 24.6% of samples contained less than one million fibres per litre; 9.3%, one to 10 million fibres per litre; and 11.2% greater than 10 million fibres per litre. In Canada (359 samples), 75% of supplies contained less than one million fibres per litre, 20% one to 10 million fibres per litre and 5% greater than 10 million fibres per litre[20]. A few samples from Sweden, Netherlands, UK, Germany and Switzerland suggest results around one million fibres per litre[1].

For various studies carried out in USA and Canada, it has been possible to conclude that natural asbestos contamination can produce levels as high as over 2,000 million fibres per litre and effluent discharges over 600 million fibres per litre[1]. Contamination from the use of asbestos-cement pipes is rarely significant and in many studies it is consistently lower than that produced by natural or effluent discharge sources of asbestos[1]. In some cases levels of asbestos from the use of asbestos-cement pipes has been suggested to be above 100 million fibres per litre[3]; careful examination of the results however shows no proven evidence for the pipes causing this level of contamination[1]. More typically, the contamination of water supplies by asbestos-cement pipes is at the most a few million fibres per litre, and this is usually where the water has been classified as highly aggressive[1].

5. Asbestos-cement pipes and their use for conveying potable water

5.1 Asbestos-cement pipe usage

The type of asbestos pipe used in different parts of the world may vary somewhat. Although most nowadays contain about 15% of asbestos, some utilize only chrysotile asbestos but others also incorporate some amosite and/or crocidolite[1]. Some pipes contain added silica mixed with the cement base material[1]. In some countries, autoclaved pipes are used and in certain parts of the world, lined or coated pipes (e.g. bitumen) are popular. Asbestos-cement pipes started to be manufactured and used around 1916. Italy seemed to be the first country to make and use them[12,18]. It has been estimated that some 2½ million km of pipe have been installed (i.e., approximately 60 times round the world). Estimates of usage, where data is available[1] (expressed as thousands of kilometres of pipe laid) are: USA (536), Japan (336), UK (257), Italy (125), Indonesia (99), India (97), Australia (90), South Africa (86), Nigeria (70), Germany (54), Greece (44), Argentina (41), Netherlands (36), Malaysia (27), Chile (17), New Zealand (16), Austria (15), Belgium (14), Switzerland (12), Denmark (10), Sweden (6), Kuwait (6).

5.2 Asbestos-cement pipe and fibres released to water

There has been considerable confusion regarding the quantity of fibres being released to water, and recently a review of the situation has been published[1]. Most studies have indicated either zero or a rather low level of fibre release[1,12]. Some anomalous results have arisen because:

(a) the disaggregation of fibre bundles of natural asbestos can occur in distribution systems, which leads to an increase in fibre number concentration;

(b) samples for analysis were collected at water hydrants, or after water disturbance (caused by system flushing), leading to highly unrepresentative and atypical deposits being sampled;

(c) of highly-aggressive water passing through asbestos-cement pipes for a short period of time, quite atypical of the general water quality;

(d) asbestos-cement pipes being installed and used contrary to the manufacturer's standard recommendations;

(e) inadequate statistical design or analysis in the investigation of fibre release under field testing conditions[1,12].

It should be noted that even where the water conveyed through asbestos-cement pipes is highly aggressive, the release of fibres in some cases may be very low because of natural protection by manganese or iron in water supplies or natural organic substances in some situations[1,12,19]. Although some idea of the quantity of fibres released can be predicted from a knowledge of certain water quality parameters such as alkalinity, pH and hardness, there is at present no wholly satisfactory means of prediction for a wide range of circumstances and conditions[1]. The Langelier Index and the Aggressiveness Index have been useful in a number of situations[12]. Where the water is highly aggressive it is recommended that advice be sought from the manufacturer regarding the use of asbestos-cement pipes[21]; proper considerations can avoid operational difficulties later[21]. One might anticipate that there will be better control of the quality of distributed water in the future which will minimize not only fibre release from asbestos-cement but also general corrosion problems is distribution systems, including also the plumbing in buildings, etc.

5.3 Advantages of asbestos-cement pipes in relation to some other piping materials

Apart from the relatively-low cost, and ease of manufacture and use in different parts of the world, asbestos-cement pipes have some other advantages. With proper precautions, any fibre exposure to workers manufacturing and to operatives laying the pipes can nowadays be controlled to very low and acceptable levels.

Asbestos-cement does not corrode in the manner that iron piping can. It is essential to coat iron pipes with bitumen or other similar material to prevent serious corrosion. Some asbestos-cement pipes are coated, but this practice only applies to a few areas or situations in some countries where waters are aggressive; autoclaved pipes have also proved to be very satisfactory in many countries. The practice of coating of any type of pipe is currently being investigated by a US National Academy of Sciences Committee[12]; among the reasons for reviewing such coatings are the possible health implications of certain organic materials dissolving into water supplies[12].

One particular feature of asbestos-cement is that the products used to manufacture it are natural materials. These materials often come in contact with various water supplies in nature and the water contains some of these natural dissolved materials. Asbestos fibres are similarly of natural origin; this important characteristic of asbestos-cement piping does not apply to other piping material such as pvc, polyethylene, etc. In health terms it is often the organic substances which are of greatest concern in water supplies and asbestos pipes do not provide organic contamination.

Finally, asbestos-cement piping is really the only material which happens to have been the subject of extensive health testing. This is because both toxicological (animal experimentation) and epidemiological (human studies) tests have been carried out in relation to ingested asbestos in drinking water, and any health effects would seem to be sensibly zero (see section 6). No other materials have been so tested and given essentially a clean bill of health.

6. Asbestos exposure and health implications

6.1 General considerations

It has been known for a long time that occupationally-inhaled asbestos dust can have a serious effect on the lungs of people exposed to high concentrations [24-26]. In some studies an apparent excess of gastro-intestinal cancer has been reported in asbestos workers [1]; this association has however not been definitely proven and the explanation that such cancers might arise as a result of indirectly ingesting asbestos via the inhalation route is not universally acceptable [1]. In fact if gastro-intestinal tumours were to arise in occupational circumstances, they would seem to be more likely to occur by systemic migration of asbestos deposited first in the lung [1]; other occupational carcinogens, smoking or dietary habits, may in any case also account for gastro-intestinal rumours being found.

Food and certain beverages are a source of ingested asbestos, although little quantitative data is available[1]. For the general public, ambient air and dust can also provide a limited source of some ingested asbestos[1]. Occupational situations especially in the past have given rise to much higher exposures of asbestos capable of being ingested.

6.2 Animal experimentation

One of the most important recent findings is that despite numerous animal feeding studies, the accumulated evidence would indicate that ingested asbestos is not carcinogenic. The animal experiments[1] included at least a dozen studies and a total of almost 10,000 animals, in which some were fed very high doses of asbestos, e.g. up to 300 mg per rat per day. In one study the rats were fed 10% asbestos in their diet and yet no carcinogenic effects were detectable.

The available evidence for a significant proportion of asbestos passing through the gastro-intestinal mucosa is weak and this has been checked in a number of species, including primates; one fibre in 10,000 or even one in 100,000 has been suggested[27].

All the known relevant animal feeding studies were reviewed at the EPA Workshop on Ingested Asbestos held in Cincinnati in October 1982[28]. The general views expressed at that meeting were that ingested asbestos had been shown to be essentially non-carcinogenic to animals.

6.3 Human epidemiological studies

There have been several long-term epidemiological studies carried out in the USA and Canada; in some of these studies, the levels of asbestos in drinking water were very high[1]. Critical examination of the findings has not revealed any firm evidence for adverse health effects in human populations drinking water containing asbestos fibres[1]. However, it has to be admitted that because of certain confounding variables, the sensitivity of the methods used was somewhat limited. Any effect of ingested asbestos from drinking water, if one exists at all, would appear to be relatively small, otherwise it should have been consistently observed in the studies where the levels of asbestos in the water were high. In a few studies some statistically-significant associations between specific cancer sites out of many examined have been observed[1]; they have not been consistently detected in other studies and would appear to be chance findings. These views are consistent with those presented at the US EPA Workshop on ingested asbestos held in October 1982[28].

6.4 Appraisal of animal and epidemiological studies in relation to health implications for humans ingesting asbestos in drinking water.

The doses of asbestos used in the negative animal experiments were so high that when equated to human exposure, they represent 200,000 to almost a million times the quantity present in the most contaminated drinking waters on record[1]. One such experiment, where the dose was equivalent to 1% of the animal's diet, when equated to man would correspond to 15.6 g of asbestos per day; this calculates to a huge safety factor, approaching 10^9 in comparison with the typical daily human exposure of not more than 0.02 μg chrysotile in drinking water[1].

It has been estimated that possibly one fibre in every 10,000 could enter and may get through the gastro-intestinal mucosa[27]; in the case of human beings ingesting typical drinking water containing up to 2 million fibres per litre, the total quantity capable of migrating to elsewhere in the body would be only 0.05 μg in a lifetime.

Taking account of (a) the negative animal ingestion studies, (b) the apparent rare event of a fibre penetrating the gastro-intestinal tract mucosa and (c) the lack of firm evidence for adverse health effects from epidemiological studies, it is suggested that the level of a carcinogenic effect in the normal population, even where the water being drunk contains many hundreds of millions of fibres per litre, would seem to be sensibly zero or at the most very small indeed. For the more typical low-level exposure to asbestos in drinking water, i.e. from a low degree of contamination including that which may result from the use of asbestos-cement pipes, even where the water may be moderately aggressive, the overall health risk would seem to be sensibly zero or at the most, exceedingly low.

It has been reported on 17 March 1983, in answer to a UK Parliamentary Question regarding health hazards arising from the use of asbestos-cement pipes, that 'the ingestion of water with levels of asbestos such as those found in the UK presents no risk to health'[29]. It is worth

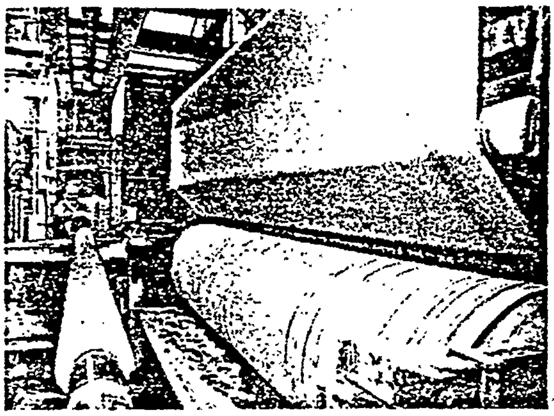

Fig. 4. The fibre-cement matrix prior to being wound onto a steel mandrel to form an a-c pipe during manufacture.

noting too that the World Health Organization in its forthcoming Guidelines on Drinking Water Quality has not specified a guideline value for asbestos in drinking water.

7. Conclusions

Asbestos contamination of water supplies is common; major sources are naturally occurring asbestos and effluent discharges. The methods of analysing asbestos in water involve highly-specialized procedures. Typical levels of chrysotile asbestos in water are in the range 0.2 to 2 million fibres per litre of water, although there are several cases where several hundreds of millions of fibres per litre of water have been detected as a result of natural asbestos contamination. The fibres detected are generally very tiny, often 0.03 —0.1 μm diameter and 2 μm long. Food and certain beverages are also sources of ingested asbestos, although little quantitative data is available.

Asbestos fibres found in drinking water arise mainly as a result of natural asbestos contamination, effluent discharges to water sources and the use of asbestos-cement pipe distribution systems. As a result of extensive animal experimentation, and a series of human epidemiological studies carried out in areas where asbestos levels in water are elevated, it has been possible to come to some firm conclusions regarding the health implications of ingested asbestos .Although occupationally-inhaled asbestos is associated with various diseases including cancer, there appears to be no firm evidence of adverse health effects from epidemiological studies of populations exposed to asbestos in drinking water, and animal ingestion studies are wholly negative. It can be concluded that at the higher levels in drinking water, e.g. from natural contamination or from effluent discharges to water sources in some areas, any health effects would appear to be sensibly zero or at the most very small indeed; while for the lower levels in water, e.g. those solely due to the use of asbestos-cement pipes, the health risk of ingested asbestos would seem to be sensibly zero or, at the most, exceedingly low. Although there may then be no greater health risk for extremely aggressive waters, the levels of asbestos fibre could be increased.

In effect, asbestos-cement piping has been subjected to rigorous testing in the various studies, and properly used it seems to be satisfactory in terms of health and the fibres it may release to water. Few other products have had such exhaustive testing. Thus normally there seems no reason whatsoever not to continue to use asbestos-cement pipes for water distribution systems. Where waters are classified as being highly aggressive however, it would be prudent to seek expert advice in order to avoid any possibility of excessive loss of fibres from the walls, which might lead to operational difficulties in the long term in some situations. Under the appropriate conditions, the use of asbestos-cement pipes for conveying potable water appears to be a satisfactory practice for both the Developed and the Developing World.

No further research on the subject is planned by the US EPA, and the World Health Organization in its Guidelines for Drinking Water Quality has not specified a Guideline value for asbestos in drinking water.

Finally it is worth reflecting on the history of the interest in ingested asbestos from drinking water. A great deal of time and money has been spent in the last 10 or so years in evaluating the subject, and now it would seem that the controversy has for all practical purposes ended, and maybe the issue can be regarded as essentially a non-problem. Perhaps research effort should now be sensibly diverted into various other environmental issues.

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29. Reply by the UK Under-Secretary, UK Department of the Environment, in answer to a question regarding any hazard arising from the use of asbestos-cement water mains. Extract from Hansard 17th March 1983 of Parliamentary Questions for written answers.

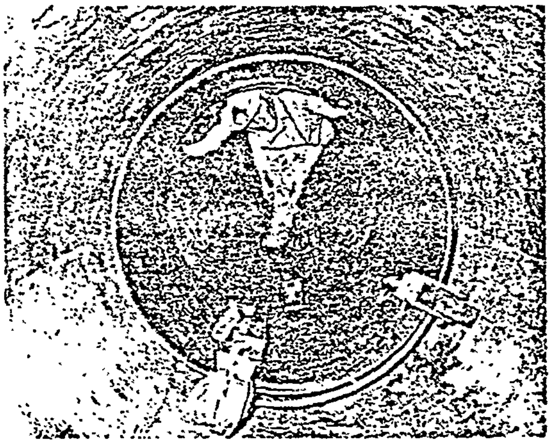
120-year old cast iron sewer revitalized

PART of an old cast iron sewer known as the 1864 Water of Leith Sewer, because of its location and the year in which it was built, has been given a considerably extended life by using a lining material which was developed from the techniques originally using in the production of spacecraft fuel tanks.

The sewer, which runs through Leith Docks, recently collapsed and it was found that the probable cause was a bomb dropped near it during the second world war. This had caused hairline fractures over about 14 m of the pipe. The level of the impounded water in the dock being 4 m above the pipe means that the groundwater pressure is very high, and consequently water leaked into it causing the eventual breakdown of the sewer.

During the repair work, a survey of the rest of the sewer was undertaken and it was found that parts of the pipe invert had eroded badly and were wafer thin. Lothian Regional Council decided that it was necessary at this stage to reline that part of the sewer readily accessible from the open excavation as a part of the repair work.

Stanton and Staveley RPM (reinforced plastic matrix) sewer lining was chosen for the work because it has an inherent structural strength combined with a smooth finish and low coefficient of friction. It was also available on short delivery in the required diameter.



A length of RPM sewer relining prepared for grouting. The rag hanging down is a temporary plug left to allow air to escape during the grouting operation.

Lilley Construction of Glasgow was chosen as the contractor for the first stage which involved relining a length of 510 m with 900-mm diameter circular RPM, which was carried out working in both directions from the excavations originally made to reach the collapse. There was considerable build-up of corroded iron and other material in the pipe which was cleaned out using

(continued on cover iii)