PLAINTIFF'S EXHIBIT

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# PIPES IN THE THIRD WORLD

If the ambitious programmes of developing countries and United Nations' agencies to achieve the targets of the International Drinking Water Supply and Sanitation Decade are implemented in full, the market for pipes to carry drinking water and sewage will grow enormously in the next few years. In previous special features on pipes, *World Water* has examined the pros and cons of different pipe materials (*January 1979*) and looked at ways of protecting underground lines from internal or external attack (*August 1980*). This time, our review includes two of the most commonly used materials in the Third World — asbestos-cement, and concrete. Below, we look at the dilemma facing designers and purchasers of pipes in assessing some hotly disputed American statistics which suggest that in certain circumstances fibres leached from asbestos-cement drinking water mains increase the threat of stomach cancer. On page 63, a recent development in concrete pipe technology, in which steel reinforcement is replaced by glass fibres, is explained by one of the designers.

## Disputed cancer threat - a dilemma for pipe designers

In an industry in which the potential market is so vast, and the decision-making so often based on individual preference, it is perhaps not surprising that promotion of one pipe material relies as much on highlighting the shortcomings of competing materials as it does on stressing the benefits of the pipe on offer. Fear of future opprobrium may be the overriding consideration in the mind of purchasing engineers fed a carefully concocted mixture of fact, rumour and gossip.

So it may be that, in essentially similar circumstances, one client may choose to use pvc pipe for his sewer project because it has been brought to his attention that elsewhere in the world the alternative concrete or asbestos-cement pipes have been eaten away by sulphate attack from septic sewage, while another will opt for concrete for fear of fatigue failures or sunlight attack reported on pvc pipes.

The latest controversy, and one of immense importance at the commencement of the Water Decade, involves reports that, in soft water areas, fibres may be leached from the inside of asbestos-cement pipes and that drinking the water supplied through a-c mains increases the risk of gastric cancer. The issue has received considerable publicity in the USA, where an estimated 320,000km of asbestor-cement pipe supplies drinking water to some 60 million people, about one sixth of them in areas where the water has been classified as "aggressive".

US epidemiologist, James R. Millette, horrified an audience of predominantly American and European water scientists in the Netherlands last year, when he extended these statistics through some contentious evaluations of medical risk to suggest that as many as 1,000 extra deaths a year from gastro-intestinal cancer may be caused by exposure to asbestos fibres in drinking water. (*World Water* September 1980).

In assessing the implications of Dr Millette's claims, and the recommendations for avoiding the extra cancer risk that have resulted from them, it is vital to recognise that much of his interpretation of medical and epidemiological evidence is strongly contested, and that verification is difficult as any carcinogenic effects become evident only after a lifetime of ingestion.

Having said that, the US Environmental Protection Agency — Millette's employer — includes in its water quality criteria the estimate that ingestion of 300,000 asbestos fibres per litre of water over a 70-yr lifetime would result in one additional death per 100,000 people. Noting that studies are still going on, EPA "encourages utilities to take appropriate corrosion control and other measures to minimise levels of asbestos fibres in the drinking water".



*The electron microscope reveals fibres exposed by "aggressive" water flowing through an asbestos-cement pipe.*

Design criteria in the Third World in the context of the Water Decade may well be very different to those in the US. If asbestos-cement is the most economic option, then the number of lives saved by the extra length of pipe obtainable for the same investment will inevitably outweigh any statistically predicted deaths a generation later from fibre-induced cancer. Nevertheless, no engineer can relish lives and deaths as balancing parameters in his design equation, and the thought of building cancer into a pipe network, whatever the compensating reduction in waterborne disease, is at best uncomfortable and at worst horrific.

Potential cures for the problem of fibre-leaching are also more readily applied in the industrialised world than in developing countries. Soft water is more easily "hardened" where a water treatment plant is automatically part of the supply scheme, and similarly iron, zinc or manganese salts can be added safely under controlled conditions. It seems that deposition of metals inside a-c pipe provides a protective coating preventing fibre release.

So should asbestos-cement pipes be used in water supply networks where the source water is soft and no treatment is practical? In the US now, a-c pipe manufacturers themselves advise against the use of their products in areas where the water is classified as "highly aggressive" (i.e. an aggressivity index of less than 10 — see box).



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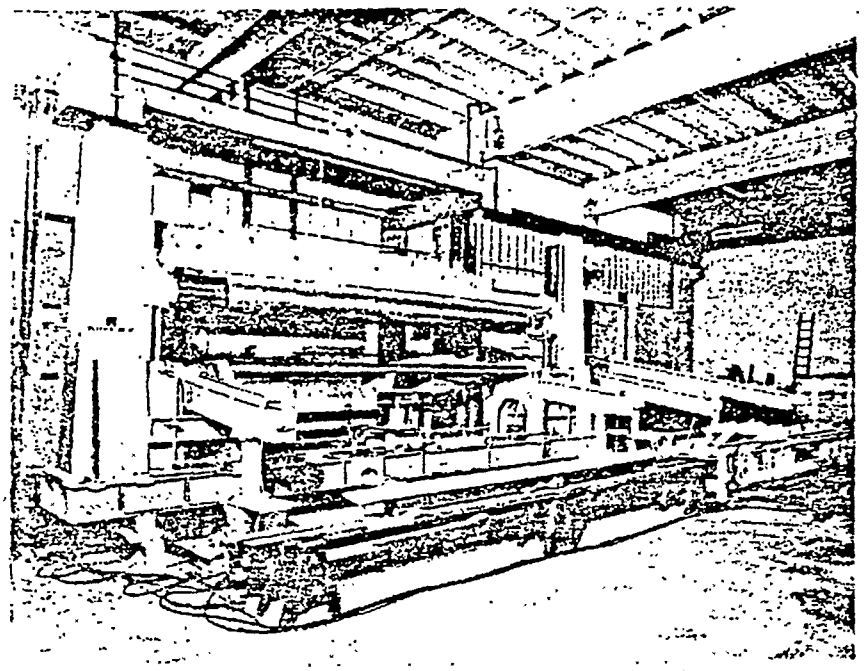

*Manufacturing plants like this Mazza installation belonging to Austrian manufacturer Interasbest offer a relatively cheap and simple way of producing asbestos-cement pipes in the developing countries. A-c pipes will therefore be highly competitive in many countries where extra lengths for the same investment will mean more lives saved. How should the alleged cancer link be evaluated in these circumstances?*

# The alleged cancer link

The only undisputed evidence of a link between asbestos fibres and gastro-intestinal cancer comes from studies of people exposed to airborne asbestos at work. It has long been accepted that airborne asbestos fibres are a health hazard, and virtually all countries have strict regulations nowadays controlling ventilation of workplaces where people may be exposed to high fibre counts.

However, Dr Millette argues that gastrointestinal cancer cannot be linked to inhalation of fibres. To affect the stomach, the fibres would have to be ingested, he maintains. So, the theory goes, fibres must have been retained in the phlegm and later cleared and swallowed. Hence, ingested asbestos has led to gastrointestinal cancer. There are several studies which indicate a stomach cancer incidence rate of more than three times normal in occupationally exposed asbestos workers, with long time intervals (sometimes 20-30 years) between exposure to asbestos and the onset of cancer.

No details have been released of how EPA converted its airborne exposure data into a recommendation for maximum levels of asbestos fibres in drinking water, and the claim that 300,000 firbres/litre over a lifetime increases the cancer death risk by 1 in 100,000 is regarded as arbitrary and illogical by the industry.

Dr Millette accepts that tests on animals and studies of people exposed to high fibre counts in drinking water have failed to show any link between ingested fibres and stomach cancer. Recent studies carried out by the National Institute of Environmental Health Sciences in the US have involved feeding very high doses of asbestos fibres to rats and hamsters over their lifetimes. Comparison with a control group showed no major differences in mortality rates, and no evidence of a carcinogenic effect.

Studies in Canada, where very high fibre counts occur naturally in water supplies close to asbestos areas, have also concluded that no extra cancer threat exists. An industrial discharge introduced fibres into the water supply of Duluth, Minnesota, in 1966 and tests have been carried out there too, without revealing a link, though the time since exposure is still too short to be conclusive.

So while virtually all the evidence suggests that ingested asbestos fibres cannot be linked to cancer, EPA's recommendation seems likely to remain until an alternative explanation is found for the excess stomach cancer deaths among asbestos insulation workers.

Outside America, and particularly in Third World countries, where every extra kilometre of pipe obtained for the same investment means the saving of lives from waterborne disease, much stronger evidence of risk would seem to be needed before asbestos-cement pipe should be rejected on the grounds of cancer risk.

In many developing countries, asbestos-cement offers big advantages over alternative pipe materials. The machinery for manufacturing a-c pipes locally is cheap and simple to operate. Only two raw materials are necessary — cement, which is usually readily available and asbestos fibre, which can be imported cheaply.

The pipes themselves are comparatively easy to handle, lay and joint — laying rates will generally be lower than for concrete, steel, or iron, though depending on bedding requirements may be higher than pvc or grp. Like concrete, they must be protected from sulphate attack either externally from acid ground or internally from septic sewage.

In general, therefore, it is to be expected that asbestos-cement mains would be a natural choice in a number of developing countries installing water networks as part of the Water Decade programme. Many countries already have well-established a-c pipe manufacturing plants, and have been installing water supply networks with a-c pipes for more than a generation.

There do not appear to be any published data on fibre counts in a-c pipe systems in any developing country, and outside the USA and Canada no research seems to have been done to link cancer indicence with asbestos fibres in drinking water.

James Millette's conclusion that ingested fibres cause gastric cancer relies heavily on data collected on workers exposed to airborne asbestos. Indeed an attempt to verify the correlationship in Connecticut came up with the verdict that no direct link could be determined (see panel).

An important element in consideration of the use of asbestos-cement pipes is clearly the comparable risk associated with alternative materials, and US a-c pipe producers have been quick to counter cancer scares with risk statistics both from other types of pipe and from general activities. Perhaps the most telling, though also clearly of dubious statistical merit, is a table produced by the manager of Johns-Manville's Environmental & Engineering Division, HL Olson.

Picking up the claim that fibres from a-c pipe exceeding 300,000 per litre might increase chances of cancer by 1 in 100,000 (though he does not accept the validity of the claim), Mr Olson lists various risks which he maintains produce a similar increase in risk of death:

- Smoking an extra 14 cigarettes in a lifetime;
- Spending 10 hours in a coal mine;
- Drinking 5 litres of wine in a lifetime;
- Drinking water containing 0.02 parts per billion of arsenic (EPA's Drinking Water Standard is 50ppb);
- Travelling 60 minutes in a canoe;



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- Ten chest X-rays in a good hospital;
- Living for 20 months with a cigarette smoker; or
- Living for 20 months in an average brick building.

EPA itself has provided the manufacturers with the perfect counter to accusations of increased health risk from a-c pipes. After an EPA epidemiologist had questioned a decision in Lakeland, Florida to install a-c pipes in an area where the water was naturally high in asbestos fibres, the Agency was asked to give comparative evaluations of different pipeline materials.

The response, in August 1980, revealed EPA's greater concern with pvc pipes, and with those coated in different ways. Specifically, the report noted that in one instance a petroleum-based seal coat applied to promote curing of cement lined ductile iron pipe had led to low-level contamination with pcb — a proven carcinogen.

Coating materials tested included coal tar derivatives, vinyl, epoxy and other types of resin-based coatings. The coal tar coatings were said to have been proved to be responsible for a number of polynuclear aromatic compounds known to be carcinogenic; a solvent used to clean a vinyl coated pipe and to thin the coating for application was found to be present in the water at the parts per million level; and EPA expressed concern for the fact that many epoxy coatings use epichlorohydrin in their formulation since this compound is carcinogenic.

In summarising its conclusions, the Agency gave the a-c pipe manufacturers precisely the comment they had been hoping for:

"Since, as indicated previously, there is some health risk associated with most of the pipe materials in question, it would appear that selection should be toward the one in which the suspected health risk can be reduced or eliminated. Since the problem with the coatings is a leaching of contamination from the film into the water and independent of water quality, and the problem with the asbestos-cement pipe is dependent on the water quality which can be controlled through treatment, then it would appear that the pipe system with the least negative health effect prospects would be the asbestos-cement pipe".

## Is your water supply 'aggressive'?

A measure of the corrosive potential of drinking water in asbestos-cement pipes proposed by the American Water Works Association is known as the "Aggressiveness Index". The value of the index for any particular water is calculated from the formula:

$$AI = pH + Log_{10}(A \times H)$$

A is the total alkalinity in mg/l as $CaCO_3$
H is calcium hardness in the same units.

For hard waters, or those with high pH, the index will generally be above 12.0, and such waters are regarded as non-aggressive. Below an index of 10, the water is labelled highly aggressive, and can be expected to attack asbestos-cement pipes unless corrective measures are taken. Between 10 and 12, the description used is moderately aggressive.

Dr Millette's analysis of US water supplies indicates that about ten million people might be exposed to corrosive water flowing through a-c pipe, and another 30 million to moderately aggressive water.

While asbestos fibre concentrations in the tens of millions of fibres per litre have been measured in some supply systems, it is clear from studies in Connecticut that there is at least one other ingredient in the equation along with aggressive water and asbestos-cement. In 45 out of 56 Connecticut towns with highly aggressive water, no corrosion was evident in a-c pipes and no high fibre counts were recorded.

# Far East nations switch to copper plumbing

A marked switch in the choice of piping material for pumping installations in the Far East and South East Asia is noted by British pipe manufacturer IMI Yorkshire Imperial.

The company says that the recent phenomenal growth of the construction industry in the region has meant a big upturn in business for its copper pipework in Asia. Traditionally, Eastern buildings have specified iron or galvanised steel pipework on the grounds of lower initial capital cost. Now, IMI maintains that copper's advantages in terms of troublefree installation and low maintenance have brought other nations round to the same specifications as the Japanese, and to north America and Europe.

As a result, the market has seen a boom without parallel in IMI's 40-year involvement in the Far East, the company claims. A company spokesman describes the benefits of copper in Third World countries.

The corrosion behaviour of copper in water service applications is perhaps the principal reason why the material has become so widely used. In general, it is expected to have an indefinitely long life, ie as long as that of a building in which it is installed.

Copper compounds are not poisonous and no harmful effects are known from the drinking of water supplied through copper systems. Copper is resistant to corrosion when buried in many soils, but if the soil is known to be aggressive, or in cases of doubt, it is advisable to use plastic-sheathed copper tubes, such as IMI's Kuterlex.

Galvanized steel behaves rather differently in water service applications. Unprotected mild steel is readily corroded by fresh waters and is unsuitable for general use because of contamination of the water supply with iron rust, the relatively short life, and blocked pipes.

Some improvement is obtained by coating the steel with zinc (eg by using galvanized steel). Zinc is inherently even more reactive than iron, but it does tend to form protective films in some waters and these can reduce the rate of corrosion.

In some cold, hard supply waters a reasonably long life can be obtained from galvanized steel, but in many soft waters zinc is corroded away fairly rapidly and the appearance of rust in the water may not be long delayed. In hot supply waters, the zinc coating does not afford galvanic protection to the steel and rapid pitting failure can therefore occur. Pitting action may be stifled by deposition of calcium carbonate scales from hard waters but galvanised steel is, in general, an unreliable material for hot waters.

Copper is easier to install than galvanised iron or black steel. Cutting of light copper tubes is easily accomplished in about 25 per cent of the time it takes to cut galvanised pipe. The use of simple bending techniques together with capillary or compression fittings, enables copper to be installed quickly and easily. By contrast, the methods employed for installing galvanised steel are cumbersome and time consuming.

Galvanised pipe has to be threaded and jointing compound applied. A straight connection joint in a galvanised piping system would take a competent plumber 20 minutes whereas the equivalent joint with copper fittings would take between three and four minutes. Because of the ease of installation, the cost of a copper system may well be comparable with, or even less than, that of a steel system, even though the copper tubing itself may be more expensive.

Copper tubes are about half the weight of galvanized steel pipes giving the same flow of water, and the weight-saving is even greater with Table Z (thin-wall, hard-drawn) copper tu



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