PLAINTIFF'S EXHIBIT

CT-290

A/C Pipe Producers Association

ADVISORY

A/C Pipe
Producers Association

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AN OPEN LETTER TO CUSTOMERS

Dear Customer:

As you may be aware, the October 4, 1983 issue of Wall Street Journal reported that the U.S. Environmental Protection Agency (EPA) is considering a ban on the use of A/C pipe. We, the manufacturers of A/C pipe in the United States and Canada — CAPCO Pipe Co., Inc., CertainTeed Corporation, J-M Manufacturing Co., Inc. and Atlas-Turner, Inc. — are publishing this advisory to give you the facts and industry's position on this announcement.

The Situation

EPA recently notified the A/C Pipe Producers Association that under the authority of the Toxic Substances Control Act it plans to publish in the next year a proposed rule banning certain asbestos products. Categories under consideration for a product ban are roofing and flooring felts, asbestos felt-backed vinyl flooring, vinyl-asbestos floor tile and A/C pipe and fittings.

The Toxic Substances Control Act (TSCA)

TSCA is a far-reaching law. It authorizes EPA to obtain data on production and health effects of chemicals and mixtures. It may require manufacturers to test potentially harmful chemicals before marketing them. And if warranted, it empowers EPA to regulate the manufacture and distribution in commerce of chemical substances. One section of TSCA provides that any person may petition EPA to start a proceeding to require testing or regulation of chemicals and mixtures.

Before EPA may impose **any** regulatory requirements under TSCA, it must show that the manufacture and use of a substance or product, A/C pipe for example, presents an "unreasonable risk or injury to health or the environment." That burden can be upheld **only** if supported by substantial evidence and **only** after considering a wide range of risk and benefit factors. Finally, EPA must use the least burdensome requirements to regulate "unreasonable risks."

What It All Means

This recent action reopens a TSCA rulemaking started in 1979 when EPA published an Advance Notice of Proposed Rulemaking on Commercial and Industrial Use of Asbestos Fibers (Federal Register, pg. 60061, October 17, 1979; as amended by Federal Register, pg. 73127, December 17, 1979; EPA Docket No. OTS-61005).

An advance notice is the first step in the regulatory process. It describes EPA's concerns about an issue, discusses generally how it will be studied, defines regulatory options and invites comments on questions raised in the notice. An advance notice is followed by a proposed rule, wherein EPA presents scientific, technical and economic data supporting its proposal. There is a comment period and a public hearing for interested parties. Then, all this input is analyzed by EPA and a final rule issued.

The 1979 advance notice expressed concern that sources of human exposure to asbestos may present unreasonable health risks. Three regulatory options were mentioned: (1) declining limits on asbestos processing or imports, (2) bans on specific products, and (3) a ban on all but essential uses of asbestos.

EPA did not intend to include A/C pipe in its initial rulemakings in 1979. However, before the advance notice was published, a citizen petitioned EPA "to initiate a proceeding for the issuance of a rule to prohibit the manufacture and distribution of asbestos cement pipes." TSCA requires EPA to grant or deny a citizen's petition within 90 days. And since the agency was investigating asbestos-containing products anyway, the petition was granted and incorporated into the Advance Notice of Proposed Rulemaking on Commercial and Industrial Use of Asbestos Fibers. EPA cautioned, however:

> Granting a petition to initiate a proceeding to issue a rule does not mean that EPA will promulgate or even propose a rule (for A/C pipe). Such a decision will depend on the outcome of the regulatory analysis.

Why A/C Pipe Now?

We're asking the same question. One thing is clear: EPA's action is based on a **theory** that airborne occupational and environmental exposures from A/C pipe manufacture and use create an "unreasonable risk." **The potential ingestion of asbestos that may be released from A/C pipe into drinking water is not a concern in this matter.** Top officials in the Office of Toxic Substances have stated this without equivocation.

In the U.S., A/C pipe manufacturers are already regulated by a number of federal and state laws. Comparable laws exist in Canada. The Occupational Safety and Health Act (OSHA) regulates employee exposures to airborne asbestos. The Clean Air Act controls emissions to the outside air from A/C pipe plants and also imposes disposal requirements for asbestos-containing wastes. The Clean Water Act regulates effluent discharges from A/C pipe manufacturing facilities. These worker, air and water protection laws have been in place since the mid-1970's. Many, the Clean Water Act for example, require use of best available technology or "zero discharge."

In the spirit of industry-government cooperation, we not only complied with these regulations, but bettered them. A/C pipe manufacture became virtually a closed system: asbestos fiber handling and pipe machining are automated; process water and solid waste are recycled; state-of-the-art filtration systems eliminate 99.9% of asbestos in air discharges to the environment. And now, without any scientific justification, EPA theorizes that its own regulations, and those of OSHA as well, are not enough.

Industry's Position

For over a decade, the A/C pipe industry has shared EPA's interests that the manufacture and use of asbestos and A/C pipe be as safe as scientifically and economically feasible. We have labored responsibly and continuously to comply with the agency's evolving environmental regulations.

During this ten year period, the following facts formed the basis of industry's position on the safe manufacture and use of A/C pipe:

- asbestos is unique and irreplaceable in the manufacture of A/C pipe
- the risk, if any, from occupational exposures to asbestos have been minimized through manufacturer's compliance with OSHA standards and use of industry-recommended work practices for A/C pipe field operations
- there is no evidence that current environmental discharges from A/C pipe plants, if they occur at all, result in unreasonable risk
- a ban on A/C pipe is not supported by medical/scientific evidence
- prohibiting the use of A/C pipe would adversely affect water utilities by reducing competition and increasing costs of piping materials.

These same facts are the basis of industry's position today. The A/C pipe industry cannot support and indeed, will strongly oppose EPA's newest theory that A/C pipe may present an unreasonable risk to health and the environment.

A/C Pipe Producers Association
ADVISORY

Volume #1, Issue #22

August, 1984

CANADIAN ROYAL COMMISSION LINKS NO HEALTH RISKS TO INGESTED ASBESTOS, SAYS CONCERN "NOT JUSTIFIED"

An Ontario Royal Commission investigating the safety of asbestos recently concluded that the mineral's health effects are linked solely to inhalation, not ingestion. The Commission's findings are based on an exhaustive, four year analysis of the medical and scientific literature. Sworn testimony by "an international who's who of asbestos experts" was presented during fifty days of formal hearings. Experts under contract and the Commission's staff also conducted research on asbestos-related matters.

The findings, released in May, 1984, are considered the most comprehensive independent examination of asbestos and its potential health effects. The report makes a number of important observations about asbestos in drinking water.

> The fibres (in drinking water) are almost invariably extremely short, that is, below 1 micron in length. The small dimension of these fibres, coupled with our finding that asbestos disease is occasioned by inhalation rather than ingestion, leads us to conclude that asbestos in drinking water is not a health hazard.

*****

> It would appear that fibres entering the body through inhalation and ingestion are dealt with quite differently. Fibres which are swallowed tend to pass right through the gastrointestinal tract and be immediately removed. Fibre penetration of the tissue or lining of the gut following ingestion is speculative at best.

*****

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> In summary, we find that oral ingestion of asbestos in concentrations currently found in water, food, or beverages in North America is not associated with any significant increase in disease. Although negative epidemiological studies cannot conclusively prove that there is no association, the populations studied have been sufficiently large that all but the smallest health effects would have been detected. For their part, the bulk of the animal studies have shown no association between oral asbestos ingestion and gastrointestinal cancer.

In its summary of the report, the Royal Commission concludes:

> The Commission links the health hazards of asbestos to inhalation, not swallowing. Neither biological nor epidemiological evidence indicates that swallowing asbestos creates a health risk. In addition, the fibres found in water, often numbering millions per litre, are very short. The Commission concludes that concern about asbestos in drinking water, beverages and food is not justified.

The Royal Commission on Matters of Health and Safety Arising from the Use of Asbestos in Ontario was created in April, 1980 by the Minister of Labour, Robert E. Elgie, M.D. J. Fraser Mustard, M.D., Ph.D., F.R.C.P., (C), F.R.S.C., Vice President of Health Sciences and Professor of Pathology at McMaster University, and President of Canadian Institute for Advanced Research, and Robert J. Uffen, Ph.D., P. Eng., F.R.S.C., immediate past Dean of the Faculty of Applied Sciences at Queen's University, served as Commissioners. J. Stefan Dupre, Ph.D., D. Sc. Soc., LL.D., Professor of Political Science at the University of Toronto, chaired the group.

The three-volume, 900 page report is available for $25 (U.S.) from the Ontario Ministry of Government Services, Publications Services Branch, Fifth Floor, 800 Bay Street, Toronto, Ontario, Canada M7A INB. Checks should be made out to the Treasurer of Ontario.

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Volume I, Issue 21

April, 1984

OCCUPATIONAL MEDICINE FORUM: NO CANCER RISK FROM ASBESTOS IN DRINKING WATER

A committee of the American Occupational Medicine Association (AOMA) has gone on record against there being a casual link between human health risks and asbestos in water. The committee's opinions, published in the Occupational Medicine Forum section of Journal of Occupational Medicine[1], were in response to the question, "What might be the health effects of ingested asbestos?"

The Occupational Medicine Forum presents questions of general interest received by the AOMA Committee on Occupational Medical Practice. Answers, according to AOMA, "usually are prepared by the Committee, representing the composite best judgment of its members." The replies do not necessarily represent an official position of the American Occupational Medical Assocation.

The Committee's reply observes that the potential health effect of asbestos in drinking water "has been an open question for several years." On the animal feeding studies, it is said:

> To the best of this Committee's knowledge, all of these studies have been negative for any increased evidence of gastrointestinal cancer.

And on investigations of human populations exposed to asbestos in water, the Committee concludes:

> Epidemiological studies conducted in Minnesota and Canada have permitted the conclusion that no cancer risk is associated with asbestos fibers in water.
>
> In summary, our Committee believes that at this time there is little evidence to support a health risk problem from asbestos fibers in drinking water.

REFERENCES

1. Mitchell, J.W., Occupational Medicine Forum, Journal of Occupational Medicine, 25(5), 361, 1983.

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Volume ~~20~~ I ISSUE 20

April, 1984

STATES, MUNICIPALITIES OPPOSE REGULATING ASBESTOS IN DRINKING WATER

A number of state health departments and municipal authorities have expressed opposition to regulating asbestos levels in drinking water. Their comments were submitted in response to the U.S. Environmental Protection Agency (EPA) Advance Notice of Proposed Rulemaking (ANPRM) on National Revised Drinking Water Regulations[1] (see A/C Advisory #19). The ANPRM questioned which, if any, of forty-four non-regulated substances found in drinking water should be regulated and, if so, what maximum contaminant levels (MCL) monitoring and reporting requirements would be appropriate.

The states of Georgia, Indiana, Kansas, North Dakota, New Mexico and Michigan were generally adverse to setting an MCL for asbestos in drinking water. Some of the strongest opposition came from the City of Seattle (Washington) Water Department:

> We oppose establishing a standard for asbestos in drinking water since virtually all research efforts have failed to establish a health risk associated with ingested asbestos.
>
> * * * * * *
>
> We conclude, from our review of available data, that no basis exists for regulation of asbestos fibers in water at the Federal level. There is simply no evidence available to demonstrate a health risk associated with ingested asbestos.

The State of New Mexico Environmental Improvement Division commented:

> We are opposed to the establishment of any MCL at this time for aluminum, antimony, molybdenum, asbestos, sulfate, copper ...

The Michigan Department of Public Health remarked:

> It is our opinion that none of the other inorganic chemicals (including asbestos) listed in the ANPRM require an MCL at this time.

The Kansas Department of Health and Environment, Bureau of Water Pollution said:

> Asbestos, copper, nickel and zinc are not potentially dangerous to health in drinking water.

And the Georgia Department of Natural Resources suggested:

> The proposed addition to the primary inorganics (regulations) of aluminum, antimony, molybdenum, asbestos ... should be included in Category III (non-regulatory health advisories), or until there is adequate evidence that the contaminants will produce adverse health effects.

The Indiana State Board of Health echoed this position, stating " ... positive evidence of adverse health effects should first be shown" prior to regulation.

The rulemaking docket will remain open to receive additional comments during EPA's deliberations. In September, 1984, the Agency is expected to propose in September, 1984 recommended maximum contaminant levels (RMCLs) and MCLs for those contaminants that may have adverse effects on human health.

REFERENCES

1. U.S. Environmental Protection Agency, National Revised Primary Drinking Water Regulations; Advance Notice of Proposed Rulemaking, Federal Register, Volume 48, Number 174, page 45502, Wednesday, October 5, 1983.

Erratum: The last issue of A/C Advisory, Volume I, Issue 18 (Concerns About Ingested Asbestos "Laid to Rest," Comments Industry Group) was misnumbered and should be Issue 19.

A/C Pipe Producers Association

ADVISORY

Volume I, Issue 18 11

February, 1984

CONCERNS ABOUT INGESTED ASBESTOS "LAID TO REST," COMMENTS INDUSTRY GROUP

The international asbestos-cement pipe industry has urged the U.S. Environmental Protection Agency (EPA) to "close the book on asbestos in water, assure the public that it need fear no adverse health effects, and declare that a primary drinking water regulation for asbestos is unwarranted." The recommendation is part of a sixty-nine page document comprising comments of the Association of Asbestos Cement Pipe Producers (AACPP) to EPA's Advance Notice of Proposed Rulemaking (ANPRM) on National Revised Primary Drinking Water Regulations.[1] AACPP is the trade association representing all North American companies that produce and market asbestos-cement (A/C) pipe, as well as twenty-five other firms manufacturing A/C pipe products throughout the world.

EPA's ANPRM, issued under authority of the Safe Drinking Water Act (SDWA), is part of a comprehensive reassessment of requirements and implementation experience of the National Interim Primary Drinking Water Regulations. The basic questions raised are (1) which contaminants should be regulated, (2) what recommended maximum contaminants levels (RMCLs) and maximum contaminant levels (MCLs), if any, would be appropriate and (3) what monitoring and reporting requirements would be appropriate? The notice invites comment on forty-four, non-regulated organic, inorganic, microbial and radionuclide substances, including asbestos. EPA cautions that "inclusion on the list does not necessarily mean that regulations will be developed."

AACPP's comments point out that a ten year, $30 million program of government and independent research has laid to rest any prior doubts about public health risks of ingested asbestos. Tentative conclusions that there is no cause for concern made by many independent scientific groups in the mid-1970's, have been confirmed. Substantial scientific data now show that there is no reason to believe adverse human health effects will result from drinking water containing asbestos, the comments assert. The following is a brief of the AACPP comments submitted to EPA.

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Animal Studies

Numerous state-of-the-art animal bioassays, many of them conducted as part of the National Toxicology Program, have confirmed that even very high levels of ingested asbestos cause no adverse health effects, including cancer, in animals. Rat and hamster lifetime bioassays performed by McConnell et al (1983, 1982, 1981), Smith (1980), Donham (1980), Ward (1980), Hilding (1981), Bolton (1982) and others demonstrate that ingested asbestos is not an animal carcinogen. Moreover, all recent reviews of these bioassays agree that the ingestion studies provide no evidence for concern about potential human health effects of asbestos in water.

Human Studies

Similarly, many epidemiology studies of populations exposed for many years to relatively high concentrations of asbestos in drinking water have typically found no increased cancer risks. Some commentators have been unwilling to conclude definitively on the basis of these studies that ingested asbestos is not a human carcinogen. However, the studies clearly demonstrate — especially when the massive doses and sensitivity of animal bioassays are considered — that it would be unreasonable to conclude that ingested asbestos is likely to cause adverse human health effects. Continuing research also has confirmed the unlikelihood that any significant number of fibers migrate from the gastrointestinal tract into gastrointestinal tissue where they might potentially pose carcinogenic risks.

Exposure Studies

The absence of any likelihood that asbestos ingestion will cause adverse health effects is confirmed by the de minimis human exposures from United States drinking water. Monitoring data compiled by EPA demonstrate that all but a small percentage of U.S. drinking water contains asbestos concentrations below 1 million fibers/liter, which on a weight basis is roughly equivalent to 1 part-per-trillion. These very low concentrations — significantly lower than any maximum contaminant levels ever set by EPA for other chemicals — are due primarily to natural erosion. Preliminary EPA studies find such concentrations represent but a small fraction of total human gastrointestinal asbestos exposures.

Costs of Monitoring and Treatment

Finally, even were there reason to believe asbestos in drinking water causes health effects, neither monitoring nor treatment techniques are economically and technically feasible or generally available, as is required for drinking water standards under the Safe Drinking Water Act. The only available monitoring technique, transmission electron microscopy (TEM), is very expensive. Assuming that 20% of the 60,000 community water systems to which a regulation might apply have asbestos in their water supplies, the total cost of putting into place asbestos analytical capability would be $3 billion plus $600 million in yearly operational and maintenance costs. Moreover, the precision and accuracy of TEM, especially at the low asbestos concentrations found in most water supplies, do not meet acceptable criteria for legally enforceable standards.

Only six communities throughout the nation treat drinking water for asbestos, indicating the absence of generally available treatment techniques. The limited data from these facilities indicate such treatment is very expensive. Assuming again that 12,000 water systems might be required to undertake the least burdensome treatment technique — modification of existing facilities — EPA's own data show that total construction costs would be in excess of $12 billion. Thus, no reasonable justification exists for diverting scarce public resources from control of the many potential health hazards in drinking water to the monitoring and treatment of asbestos.

AACPP therefore urges EPA to close the book on asbestos and declare in its next national drinking water standards proposal that no standard is warranted. EPA should join the World Health organization, other nations and numerous states in determining that no regulations need be established for monitoring or control of asbestos in drinking water. The Agency should fulfill its obligation to assure the American public that it need not fear any adverse health effects from the prevailing levels of asbestos in drinking water.

REFERENCES

1. U.S. Environmental Protection Agency, National Revised Primary Drinking Water Regulations; Advance Notice of Proposed Rulemaking, Federal Register, Volume 48, Number 174, page 45502, Wednesday, October 5, 1983.

A-C Pipe Producers Association

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Volume I, Issue 18

October, 1983

REVIEW OF SCIENTIFIC/MEDICAL STUDIES OF THE POTENTIAL HEALTH EFFECTS OF INGESTED ASBESTOS - ANIMAL STUDIES

This is the second part of a two part series reviewing scientific and medical research on the potential health effects of ingested asbestos. This issue summarizes animal feeding studies.

In 1977, the (U.S.) National Academy of Sciences' Safe Drinking Water Committee [1] provided underlying principles to guide the U.S. Environmental Protection Agency (EPA) when assessing effects of long-term, low dose exposures to carcinogenic substances. The very first principle was, "Effects in animals properly qualified, are applicable to man." The Committee stated, "This premise underlies all of experimental biology and medicine ... ," and the third principle declared, "The exposure of experimental animals to toxic agents in high doses is a necessary and valid method of discovering possible carcinogenic effects in man."

Animal studies support epidemiologic findings that there is no association between the ingestion of asbestos fibers in drinking water and adverse health effects. Test animals have been fed diets containing substantial portions of asbestos, without inducing related tumors or shortening lifespans.

Smith, W. E., "Asbestos, Talc and Nitrites in Relation to Gastric Cancer," American Industrial Hygiene Association Journal 34:227-228 (1973). This was a life span experiment in which hamsters were fed abnormally large amounts of asbestos. Dr. Smith concludes:

> In 45 hamsters maintained throughout their lives on diets containing 1% of the chrysotile or amosite varieties of asbestos, we found no gastric carcinomas and no tumors in the gastrointestinal tract except for a neoplasm in the mesentery of the colon. We are unable to relate that lesion to the treatment, since ashing has revealed no asbestos fibers in it.

Webster, I., "The Ingestion of Asbestos Fibers," Environmental Health Perspectives, 9:199-202 (1974). Dr. Webster fed baboons heavy doses of crocidolite over considerable periods of time to determine if peritoneal or gastrointestinal cancers could be induced. The report states:

> In none of the many baboons used was there any evidence of a peritoneal tumor or gastrointestinal tumor.

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Gross, P., et al., "Ingested Mineral Fibers: Do They Penetrate Tissue and Cause Cancer?" Arch. Environmental Health, 29(6):341-347 (1974).

> Twenty-one months of intimate contact of rat GI (gastrointestinal) mucosa with very high concentrations of chrysotile asbestos failed to produce cancer or any other kind of lesion. Short-term and long-term feeding (up to 1 ½ years) of chrysotile and crocidolite by a second laboratory resulted in no tumor production in the GI tract or mesothelium during the lifetime of the animals.

Bonser, G. M. and **Clayson**, D. B., "Feeding of Blue Asbestos to Rats," 45th Annual Report of the British Empire's Cancer Campaign, 242 (1976). An experiment was performed to ascertain whether feeding asbestos to rats would induce peritoneal tumors. Sixty-five rats were fed 1,500 milligrams of crocidolite asbestos per kilogram body weight for life. No tumors were observed.

Wagner, J.C., et al., "Animal Experiments with Talc," Inhaled Particles IV, Pergammon Press, 647-654 (1977). Thirty-two rats were fed 100 milligrams of chrysotile or talc over a five month period. No significant increased incidence in tumors was observed.

Smith, W. E., et al., "Health of Experimental Animals Drinking Water With and Without Amosite Asbestos and Other Mineral Particles," Journal of Environmental Pathology and Toxicology, 3:277-330 (1980). This study is the first and, to date, only experiment in which animals were actually exposed to asbestos fibers via drinking water for their entire lifetimes. Tumor incidence was compared with hamsters that did not consume asbestos. Dr. Smith concludes:

> In the present experiment, no malignant tumors were found in hamsters maintained on drinking water containing 13,000 million amosite fibers per liter.

Hilding, A.C., et al., "Biological Effects of Ingested Amosite Asbestos, Taconite Tailings, Diatomaceous Earth and Lake Superior Water in Rats," Archives of Environmental Health, 36:298-303 (1981). Rats were fed asbestos during their lifetimes and were examined at autopsy. The dose levels for the treated animals were the equivalent of 5.5 billion fibers per liter (low dose group) and 78 billion fibers per liter (high dose group) of drinking water. The investigators conclude:

> The most significant finding in our study was the total absence of gastrointestinal cancer in the animals exposed to the test materials.
>
> * * * * * *
>
> Under the conditions of our study, ingested asbestos ... had no demonstrable carcinogenic effect on the gastrointestinal tract or on other body tissues of the rat.

Bolton, R.E., **Davis**, J.M.G., and **Lamb**, D., "The Pathological Effects of Prolonged Asbestos Ingestion in Rats," Environmental Research, 29:134-150 (1982). Animals in three treatment groups were exposed to amosite, crocidolite and chrysotile asbestos in a margarine-based dietary supplement. The dose level resulted in an average weekly consumption of 250 milligrams of asbestos per rat per week. The researchers conclude:

> These studies show no evidence of widespread penetration of, or damage to, the gastrointestinal mucosae of laboratory rats following prolonged ingestion

of large amounts of asbestos fiber. No primary malignant tumors of the gastrointestinal epithelial tissues were found, and there was no obvious link between the other malignant tumors that developed and the asbestos exposure.

McConnell, E.E., et al., "Chronic Effects of Dietary Exposure to Amosite and Chrysotile Asbestos in Syrian Golden Hamsters," and "Chronic Effects of Dietary Exposure to Amosite and Tremolite in Fischer 344 Rats," Proceedings of the U.S. EPA Summary Workshop on Ingested Asbestos, Environmental Health Perspectives, in press. The National Institute of Environmental Health Sciences sponsored a $6 million study on the effects of ingested asbestos in rats and hamsters. Asbestos was administered at a dosage of 1% of total diet for the entire lifetimes of approximately 10,000 animals. First phase conclusions follow:

> The clinicopathologic results in this study showed that the chronic ingestion of 1% amosite or chrysotile (SR and IR) asbestos in the diet did not adversely effect body weight gain and seemed to enhance survival.
>
> * * * * * *
>
> Under the conditions of the bioassay, amosite asbestos and SR (short range) and IR (intermediate range) chrysotile asbestos were not carcinogenic when ingested by male and female Syrian golden hamsters.

The second phase was considered a definitive study for determining neoplastic and non-neoplastic effects. The agency concludes:

> Under the conditions of this lifetime bioassay, tremolite or amosite asbestos was not toxic, did not affect survival, and was not carcinogenic when ingested at a level of 1% in the diet by male and female F344 rats.

NIEHS officials reported in October, 1982 that the lifespans of rats fed chrysotile and crocidolite asbestos also were not affected by exposure. In-house histopathological reviews also showed no carcinogenic effect. These results will be peer-reviewed and published in 1983. These animal feeding studies are the most extensive ever carried out to assess the possible effects of ingested asbestos fibers.

REFERENCES

1. Safe Drinking Water Committee, "Drinking Water and Health," National Academy of Sciences (1977).

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A/C Pipe Producers Association

ADVISORY

Volume I, Issue 17

September, 1983

REVIEW OF SCIENTIFIC/MEDICAL STUDIES OF THE POTENTIAL HEALTH EFFECTS OF INGESTED ASBESTOS - EPIDEMIOLOGIC STUDIES

To determine whether the swallowing or ingestion of asbestos in drinking water represents a health hazard, two types of studies have been conducted: (1) statistical or epidemiological studies, in which the medical experience of one group, exposed to a high level of ingested asbestos, is compared to the experience of another group, exposed to a lower level or no ingested asbestos; and (2) animal studies, in which conclusions are derived from the ingestion, by animals, of asbestos under scientifically controlled conditions. The next two issues of A/C Advisory will review the scientific and medical research conducted on the potential health effects of ingested asbestos. Issue #17 will focus on the conclusions of epidemiologic studies. Issue #18 will address animal feeding studies.

Mason, et al in 1974 conducted a study to determine whether fibers present in the drinking water in Duluth, Minnesota produced increased cancer mortality. The study concluded:

> Thus, in Duluth, one would expect a greater excess of cancer in the esophagus and stomach than in the rectum, but this did not occur.[1]

In 1976, B. S. **Levy** of the Minnesota Department of Health continued the investigation made by Mason. Levy was the Acting State Epidemiologist for Minnesota and his co-authors were associated with the University of Minnesota School of Public Health and the Mayo Clinic.

Gastrointestinal cancer incidence data for the cities of Duluth and St. Paul were gathered and compared in the same manner as in the Mason study. (Minneapolis and St. Paul have populations similar to Duluth, but they have few, if any, asbestos fibers in their water supplies). The authors concluded:

> ... there was no consistent pattern of statistically significant differences observed.[2]

The Levy study was updated in 1981 by Eunice **Sigurdson**, R.N., M.P.H., of the Minnesota Department of Health. She reaffirmed previous findings, stating:

> ... there is currently no observed etiologic or causal association between exposure to amphibole fibers in the Duluth drinking water supply and the development of cancer.[3]

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In 1976, Thomas R. **Fears** of the National Cancer Institute published an article addressing the question: "Is there an increase in risk from cancer associated with naturally-occurring asbestos?" The abstract of the study states:

> The study of cancer mortality rates in these matched counties provides no evidence that naturally-occurring asbestos is a great hazard to the general population of counties with asbestos deposits. [4]

Donald T. **Wigle**, M.D., Ph.D. and M.P.H., Bureau of Epidemiology, Health and Welfare, Canada, conducted an extensive study in 1977 of municipalities in the Province of Quebec. These comparison studies presented an unusual scientific opportunity to analyze cancer mortality in populations exposed to as much as 1.3 billion fibers per liter of drinking water. Despite the extremely high levels of asbestos in drinking water, this study concludes:

> A study of twenty-two municipalities in Quebec did not reveal excess cancer mortality that could be related to the presence of asbestos fibers in drinking water supplies. [5]

The Wigle study was also updated in 1981 by **Toft, Wigle et al.** Similar conclusions were made:

> The mortality rates for persons living in two localities in which asbestos was present in high concentrations in water samples from the distribution system were analyzed. Although there are serious limitations to this type of study, no consistent increase of mortality rates for any cancer was demonstrated. [6]

Two studies were made in Connecticut concerning the use of asbestos-cement water pipe and the incidence of cancer. The first was co-authored by officials of the U.S. Center for Disease Control, U.S. Environmental Protection Agency (EPA), Yale University School of Medicine and Connecticut Department of Health Services. The **Harrington** study stated:

> This study detected no changes in incidence rates or patterns in Connecticut for cancers of the stomach, colon, or rectum over the period 1935-1973, that could be construed as related to the introduction around 1950 of A/C pipes to carry domestic water supplies to some or most of the residents of certain towns. [7]

The second study was entitled "Asbestos Cement Pipe and Cancer in Connecticut, 1955-1974." The principal investigator, J. Wister Meigs, M.D., is Director of the Connecticut Cancer Epidemiology Unit and Clinical Professor of Epidemiology, Yale University School of Medicine. The **Meigs** study used essentially the same methods as those used in the Harrington study, but the procedures and techniques were more sensitive and refined. The study was supported in part by the National Cancer Institute and the U.S. Environmental Protection Agency.

Following are the conclusions of the Meigs study:

These analyses give no consistent indication that use of A/C pipe in Connecticut public water supplies has been followed by increases in incidence either of "all cancers" of the individual sites considered.

Therefore, the lack of coherent evidence of cancer risks from use of A/C pipe is reassuring. (Emphasis in article). It is consistent with most reports from other areas of the United States.[8]

The **Kanarek** study[9] was conducted in five California counties in the San Francisco Bay Area by Dr. Robert C. Cooper (principal investigator), doctoral candidate Marty Kanarek (project coordinator) and others. The study found a statistical correlation between the ingestion of asbestos in drinking water and certain cancers. The Kanarek study was an indirect study in which census tracts with differing amounts of asbestos fibers in their drinking water were compared for cancer incidence, after attempting to take into account certain variables.

By its own admission, the study is of limited value in its relevance to asbestos-cement pipe:

> Samples were taken before and after passage of water through lengths of asbestos-cement pipe. In most of the districts sampled, there was not a substantial increase in fiber counts after passage through asbestos-cement pipe. The amount of asbestos-cement pipe in the various distribution systems was not included as a variable in the analysis because of difficulty of determining its locations, age and dimensions.
>
> The study design was that of an indirect epidemiological approach in which the observational unit was the census tract. Studies such as this one can only suggest associations, and cannot pinpoint definite causation. (Quotation from doctoral thesis).

The U.S. Environmental Protection Agency (EPA) has stated of the Kanarek study:

> The University of California investigators are among the first to report finding an association between ingested asbestos and cancer rates. They caution that causative inferences must necessarily be limited because of the indirect nature of the data being compared. This means that the results of this study do not prove that there is a link between Bay Area water and cancer.[10]

When reanalyzing the statistical associations observed, one of the co-authors (Conforti) stated:

> Although the indirect method of analysis is an inexpensive design for a first look at an epidemiologic hypothesis, the underlying assumptions of the method make definitive conclusions untenable.

* * * * *

> These findings in no way lend themselves to the interpretation regarding the possible regulation of asbestos in drinking water. Only research of the direct method design would allow for such conclusions.[11]

In 1982, the **U.S. Environmental Protection Agency** reported findings of an epidemiologic study of A/C water pipe use and gastrointestinal cancers in Escambia County, Florida. Asbestos levels ranged from 700,000 to 32.7 million fibers per liter for a period of approximately twenty-five years. Agency scientists concluded:

> The results of the analyses in this study do not show any statistical association between the deaths due to certain cancer types and the use of A/C pipe in Escambia County, Florida.[12]

In August, 1982, Dr. Lincoln **Polissar** of the Fred Hutchinson Cancer Research Center published an important study on asbestos in drinking water, cancer incidence and cancer mortality in Washington State. This research was also funded by the U.S. Environmental Protection Agency. Naturally-occurring asbestos levels in this study ranged from 37 million to 556 million fibers per liter of drinking water. The population has been exposed to such levels for over fifty years. The author concluded:

> Results of this study and prior studies of cancer in relation to waterborne asbestos are inconsistent and provide little evidence that asbestos in community water supplies has altered the risk of any cancer.[13]

A case-control, interview-based study also was conducted on this same population group. Such studies seek to determine whether persons with a given disease are more apt to have been exposed to the agent under investigation (asbestos) than disease-free individuals. The principal investigator, again Dr. Lincoln **Polissar**, reported:

> We found no convincing evidence for increased cancer risk from imbibed asbestos.[14]

This is the most sophisticated epidemiologic study ever conducted on the question of the potential health effects of ingested asbestos.

REFERENCES

1. Mason, T. J., et al, "Asbestos-Like Fibers in Duluth Water Supply: Relation to Cancer Mortality," Journal of the American Medical Association, 228: 1019-1020 (1974).

2. Levy, B. S., Sigurdson, E., et al, "Investigating Possible Effects of Asbestos in City Water: Surveillance of Gastrointestinal Cancer Incidence in Duluth, Minnesota," American Journal of Epidemiology, 31: 598-604 (1976).

3. Sigurdson, E. E., "Interim Report of Cancer Incidence in Duluth During 1969-1976 as an Investigation of Health Effects of Amphiboles in Municipal Water Supply," Minnesota Department of Health (1981).

4. Fears, T. R., "Cancer Mortality and Asbestos Deposits," American Journal of Epidemiology, 104(5): 523-526 (1976).

5. Wigle, D. T., et al, "Cancer Mortality in Relation to Asbestos in Municipal Water Supplies," Archives of Environmental Health, 32: 185-190 (1977).

6. Toft, P., Wigle, D. T., et al, "Asbestos in Drinking Water in Canada," The Science of the Total Environment, 18: 77-89 (1981).

7. Harrington, J. M., et al, "An Investigation of the Use of Asbestos Cement Pipe for Public Water Supply and the Incidence of Gastrointestinal Cancer in Connecticut, 1935-1973," American Journal of Epidemiology, 107:96-103 (1978).

8. Meigs, J. W., et al, "Asbestos-Cement Pipe and Cancer in Connecticut, 1955-1974," Journal of Environmental Health, 42: 187-191 (1980).

9. Kanarek, M. S., et al, "Asbestos in Drinking Water and Cancer Incidence in the San Francisco Bay Area," American Journal of Epidemiology, 112: 54-72 (1980).

10. U.S. Environmental Protection Agency, "EPA Position on Study Entitled 'Asbestos in Drinking Water and Cancer Incidence,' " (1978).

11. Conforti, P. M., "Effect of Population Density on the Results of the Study of Water Supplies in Five California Counties," accepted for publication, Environmental Health Perspectives, October, 1983.

12. Millette, J. R., et al, "An Epidemiologic Study of the Use of Asbestos-Cement Pipe for the Distribution of Drinking Water in Escambia County, Florida," accepted for publication in Environmental Health Perspectives, October, 1983.

13. Polissar, L., et al, "Cancer Incidence in Relation to Asbestos in Drinking Water in the Puget Sound Region," American Journal of Epidemiology, 116: 314-328 (1982).

14. Polissar, L., "Cancer Risk from Asbestos in Drinking Water: Summary of a Case Control Study in Western Washington," accepted for publication in Environmental Health Perspectives, October, 1983.

A/C Pipe Producers Association

ADVISORY

Volume 1, Issue 16

September, 1983

ASBESTOS INGESTION STUDIES FAILED TO PRODUCE CARCINOGENIC EFFECT, SAYS EPA RESEARCHER

A U.S. Environmental Protection Agency (EPA) scientist has concluded that "the long-term, high-level ingestion of various types of asbestos fibers in more than one animal species failed to produce any definite, reproducible, organ-specific carcinogenic effect." [1] The statement, made in an article authored by Dr. Lyman W. Condie, Target Organ Toxicology Branch, Toxicology and Microbiology Division, Health Effects Research Laboratory, Cincinnati, Ohio, will be published in the October issue of Environmental Health Perspectives.

In the article, "Review of Published Studies of Orally Administered Asbestos," Condie critically examines ingestion studies that have attempted to answer the question of whether or not ingested asbestos is a health hazard. In all, eleven (11) studies are analyzed. The extensive animal feeding experiments conducted by the U.S. National Institute of Environmental Health Sciences (see A/C Advisory, Volume 1, Issue 10) are not reviewed as they were not published at the time.

From the very early study of Bonser and Clayson (1967) to the more recent studies of Hilding, et al. (1981) and Bolton and Davis (1982), Condie assesses the experimental findings and comments on the strengths or weaknesses of each. On the Webster study, the only asbestos feeding study involving primates, Condie cautions, "The five year exposure time appears too short for the carcinogenesis process to occur if the time element of the baboon's reaction to asbestos is similiar to that of a human." And on the oft-quoted Gibel et al study involving administration of asbestos filter material to rats, he notes, " ... the authors stated that no conclusions could be made from their test results regarding the pathogenesis of the tumors caused by the oral intake of asbestos material." This is because the results are confounded by the presence of several unidentified chemicals in the filter material.

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Condie concludes:

> The bulk of the experimental evidence indicates that the long term, high-level ingestion exposure to various types of asbestos fibers failed to produce any definite, reproducible organ-specific carcinogenic effect. Although comparisons between studies are confounded by different rat strains utilized, by different dose levels or exposure conditions, and by different types of asbestos employed, the vast majority of the asbestos ingestion studies were either negative or equivocal.
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> * * * * * *
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> These studies also cast some doubt on the hypothesis that peritoneal mesotheliomas and gastrointestinal cancers result from the ingestion of asbestos fibers cleared from the lungs following inhalation exposure.

REFERENCES:

1. Condie, Lyman W., "Review of Published Studies of Orally Administered Asbestos," accepted for publication in Environmental Health Perspectives, October, 1983.

A C Pipe Producers Association

ADVISORY

Volume I, Issue 15

July, 1983

SOUTH AFRICAN MEDICAL JOURNAL COMMENTS ON ASBESTOS IN POTABLE WATER

The South African publication, "SA Medical Journal," has published an editorial [1] stating that concerns about asbestos in drinking water should be dismissed. Noting that "... far more people in the world ingest asbestos than inhale asbestos," the Journal traces the evolution and pending resolution of the asbestos in drinking water issue.

The editorial cites important research conducted in Europe, Canada and the United States, observing:

> No one disputed the hazards of inhaled asbestos in uncontrolled conditions and in high concentrations, but there was (Ed. note: referring to 1973) no firm evidence that those who ingest asbestos from drinking water are at risk in either the short or the long term.

The article then reviews briefly the scientific and medical evidence on the potential health effects of asbestos in drinking water, concluding:

> No evidence whatsoever exists that ingested asbestos fibres in the concentrations possible in ordinary environments constitute a health hazard: fears relating to potable water in contact with asbestos under realistic conditions may now be abandoned.

REFERENCES

1. Gluckman, J., "Editorial - Asbestos in Drinking Water," South African Medical Journal, 63 (12 February), 217-218, (1983).

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A C Price Producers Association

ADVISORY

Volume I, Issue 14

July, 1983

INDEPENDENT REPORT CONCLUDES HEALTH RISK OF ASBESTOS IN DRINKING WATER 'SENSIBLY ZERO'

A critical review of the sources, occurrence and health implications of asbestos in drinking water concludes that " ... the health risk of ingested asbestos would seem to be sensibly zero or, at the most, exceedingly low."

The seventy-three page scientific report, "Asbestos Fibres in Drinking Water," is authored by B. T. Commins, BSc, MSc, PhD, CChem, FRSC. Dr. Commins has thirty years experience in environmental issues and has been involved in projects with the World Health Organization, Organization for Economic Cooperation and Development, NATO and the U.S. Public Health Service. Dr. Commins, now an independent consultant in environmental pollution, was also with the Water Research Centre (United Kingdom) where he published "Asbestos in Drinking Water: A Review" in 1979.

The May, 1983 study considerably extends and updates the 1979 review. The contents include:

- o Prefaces by R. L. Zielhuis, M.D., PhD, Coronel Laboratory for Occupational and Environmental Health, University of Amsterdam and I.T.T. Higgins, M.D., Professor of Epidemiology, University of Michigan School of Public Health.
- o Introduction (types and uses of asbestos; potential sources of asbestos in drinking water)
- o Sampling and Analysis of Asbestos Fibres in Drinking Water
- o Concentrations of Asbestos in Drinking Water
- o Asbestos Exposure and Health Implications
- o Bibliography

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Commins evaluates ten years of medical and scientific research on the subject. Particular emphasis is placed on more recent epidemiologic and animal feeding studies. The "Resume of Health Implications of Asbestos in Drinking Water" states:

> 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.

A report prospectus and ordering information are attached.

COMMINS ASSOCIATES B. T. Commins BSc., MSc., PhD., CChem., FRSC
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Announcing the publication of:

'Asbestos Fibres in Drinking Water'

May 1983, by B T. Commins

A comprehensive Scientific and Technical Report with worldwide coverage, written and published by an Independent expert with 30 years of environmental experience including numerous International assignments with organisations such as WHO, CEC, OECD, IUPAC, NATO and USPHS.

The Report considers the Sources, Measurement, Concentrations found, and Health Implications of ingested asbestos in drinking water, and includes a section related to the usage of asbestos cement pipes. The author has written numerous scientific papers including the well known 'Asbestos in Drinking Water: a review' TR100 published by the Water Research Centre in 1979.

The critical review of the available evidence indicates that ingested asbestos in drinking water appears to be sensibly a zero or at the most an exceedingly low health risk, and 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; the author envisages that such piping will have extensive applications in Third World Countries.

The Report will be of special interest to Engineers, Scientists and Administrators, especially those in Water Industries of the World. The Report has attempted to define the technical and scientific terms used and it is also intended for the interested lay reader.

Well over 200 Reports and Publications have been reviewed and comments are provided on some of the key presentations made at the important United States Environmental Protection Agency, October 1982 Workshop on Ingested Asbestos, the Proceedings of which will be published in late 1983

The Report includes Forewords by Professor R.L Zielhuis, MD, PhD, University of Amsterdam and Professor I. Higgins, MD, University of Michigan, and contains a list of 213 references. The Report can be obtained by contacting the above address: price £25 plus postage, etc., extra, UK £0.90, Europe £1 10 SURFACE or £1.80 AIR MAIL, Elsewhere £1.80 SURFACE or £3 40 AIR MAIL. Cheques in advance please, made payable to Commins Associates.

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A/C Pipe Producers Association

ADVISORY

June, 1983

Volume #1, Issue #13

FLORIDA STUDY - NO ASSOCIATION BETWEEN A/C PIPE USE AND GASTROINTESTINAL CANCERS

U.S. Environmental Protection Agency (EPA) epidemiologists have found no evidence of a correlation between use of A/C water pipe and gastrointestinal (GI) cancers in Escambia County, Florida. The study[1], conducted by the Health Effects Research Laboratory, culminates several years of investigation.

Escambia County water has chemical characteristics that make it corrosive to water distribution and consumer plumbing materials. It is typically acidic (pH = 5.2) and very soft (calcium hardness = 1.4 milligrams/liter; alkalinity = 1 milligram/liter calcium carbonate equivalents). Distribution system corrosion was evidenced initially by "red water" complaints from areas served by cast iron pipe. When A/C pipe was installed in the Montclair portion of the system in 1957, it also experienced corrosion, apparently because the water was not treated consistently. Asbestos levels in drinking water ranged from 0.2 to 32.7 million fibers per liter (mfl) in 1975 to "below detectable limits" to 4.7 mfl in 1977, after lime treatment was implemented and monitored systematically.

Since changing treatment practices prevented accurate estimation of historical exposures to asbestos in drinking water, Escambia County census tracts were divided into three "potential exposure" groups — high, low and no exposure. In the "potential high exposure" groups at least 90% of the population was served by A/C pipe for 25 years or more. In the "low exposure" groups, less than 90% of tract population was served by A/C pipe or if over 90% was served, the pipe was less than 25 years old in 1976. In the "no exposure" group, the population was served by cast iron pipe or was not on public water supply.

Cancer data was hand-compiled by the Escambia County Health Department. Cancer mortality by sites (bladder, kidneys, GI, pancreas, liver, lungs and other) was recorded and sex-site specific standard mortality ratios (SMR's) calculated for each

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exposure census tract. Twelve other variables e.g. socioeconomic status, occupation, population density, that might influence cancer deaths also were obtained for each tract.

For each cancer site, exposure group to exposure group differences in SMR's were determined by an analysis of covariance. The results: there were no cancer sites for which the SMR's differed significantly between high, low and no potential exposure groups. The investigators concluded:

> The results of the analyses in this study do not show any statistical association between the deaths due to certain cancer types and the use of AC pipe in Escambia County, Florida. This conclusion is consistent with the results of a previous study of cancer incidence in Connecticut towns using A/C pipe[2]. No other published epidemiologic studies have specifically considered AC pipe.

The authors discuss the possible influences of confounding variables such as smoking, occupational factors, alcohol consumption, population density and population mobility in these ecologic type studies. The statistical sensitivity of the study is also reviewed. The paper notes that increases in GI cancer mortality (total and for individual sites) may not have been identified as statistically significant due to the relatively small number of cancer deaths.

REFERENCES

1. Millette, J.R., Craun, G.F., Stober, J.A., Kraemer, D.F., Tousignant, H.G., Hildago, E., Duboise, R.L., and Benedict, J., "An Epidemiology Study of the Use of Asbestos-Cement Pipe for the Distribution of Drinking Water in Escambia County, Florida," accepted for publication in Environmental Health Perspectives, October, 1983.

2. Meigs, J.W., Walter, S.D., Heston, J.F., Millette, J.R., Craun, G.F., Woodhull, R.S., and Flannery, J.T., "Asbestos Cement Pipe and Cancer in Connecticut 1955-1974," Journal of Environmental Health, 42(4): 187-191 (1980).

ADVISORY

April 1983

Volume I, Issue #12

NO APPARENT RELATIONSHIP BETWEEN IMBIBED ASBESTOS AND LEVELS IN URINE

Microscopists at the University of Washington, Department of Environmental Health, have completed a twenty-one month study of the ratio of asbestos fibers retained or excreted by persons consuming drinking water with high asbestos levels. The purpose of the study, which was funded by the U.S. Environmental Protection Agency (EPA), was to determine whether asbestos fibers were present in the urine of residents of the Everett area of Washington state, where tap water contains about 200 million fibers per liter. Reflecting on the current levels of asbestos in drinking waters throughout North America, the researchers sought to address "some obvious points of concern:"

1. Do significant numbers of asbestos fibers penetrate the wall of the intestinal tract?
2. Are they found in other organs of the body and body fluids?
3. What is their effect, if any, during long term exposures of twenty years or more?

The latter question was addressed in part by an epidemiologic study of asbestos in drinking water, cancer incidence and cancer mortality in Everett and Seattle. Results of that study (see A/C Advisory, Volume I, Issue 9) gave "little evidence that asbestos in community water supplies has altered the risk of any cancer."

A small group of people in Everett, all in good health and without histories of kidney disease or occupational exposure to asbestos, consumed drinking water containing approximately 200 million fibers per liter. This group was compared to a control group of Seattle residents where levels of chrysotile asbestos in the drinking water are 100 times less, i.e. 2 million fibers per liter. Urine samples from the test and control groups were taken over a twenty-one month period and asbestos fibers counted by means of a transmission electron microscope. Limits of detection ranged from 70,000 to 300,000 fibers per liter. Lengths of asbestos fibers in the drinking water ranged from 0.3 to 5.0 micrometers; fiber length in the urine samples range from 0.5 to 1.2 micrometers.

The investigators concluded:

> Although the concentrations of fibers in the urines varied throughout the sampling period of twenty-one months duration, none were consistently and significantly higher than the concentrations of fibers estimated for the control waters. There was, however, a significant difference ($p = 0.05$) between the counts of fibers in the urines of less than three years resident time (Everett area) compared to the urines of donors of twenty-four plus years residence.
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> The concentration of fibers in the urines of Everett donors combined (0.97×10^6 fibers per liter) was not significantly different than the concentration for Seattle/Bellevue control donors, even though the numbers of fibers in the drinking water of the latter were at least 100 times less.
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> At present, the data is inconclusive but would suggest no relationship between high concentrations of fibers in drinking water and the numbers estimated for voided urine.

In discussing the results, the investigators raise the possibility that fibers may have escaped detection due to masking by mucous residues or morphological deterioration as a result of gastrointestinal passage.

The anatomical and physiological aspects of the kidneys also are reviewed with an eye towards understanding how asbestos fibers find their way into the urine.

REFERENCES

1. Boatman, E. S., Merril, T., O'Neill, A., Polissar, L. and Millette, J. R., "The Use of Quantitative Analysis of Urine to Assess Exposure to Asbestos Fibers in Drinking Water in the Puget Sound Region," accepted for publication in <u>Environmental Health Prospectives</u>.

A C Pipe Producers Association

ADVISORY

March, 1983

Volume #1 Issue #11

"NO SIGNIFICANT ADVERSE EFFECTS OF PROLONGED ASBESTOS INGESTION," CONCLUDE EDINBURGH SCIENTISTS

A research team at the Institute of Occupational Medicine and the University of Edinburgh has reported no excess malignant tumors or gastrointestinal abnormalities in laboratory rats administered asbestos for periods up to twenty-five months.[1] The principal investigators, Drs. R. E. Bolton and J. M. G. Davis, also observed "no penetration and/or damage to any of the gut tissues was found."

The study was a follow up to the scientists' earlier research[2] which also showed "no evidence of wide-spread penetration or damage." 115 Wistar rats, divided into three treatment groups, and positive and negative control groups were used. Animals in the treatment groups were exposed to amosite, crocidolite or chrysotile asbestos in a margarine based dietary supplement. The dose level resulted in an average weekly consumption of 250 milligrams of asbestos per rat per week. This corresponds to 0.27% by weight of food consumed. Animals were kept on the dietary regimen for twenty-five months and observed for the remainder of their lifespans.

The authors concluded:

> These studies show no evidence of widespread penetration of, or damage to, the gastrointestinal mucosae of laboratory rats following prolonged ingestion of large amounts of asbestos fiber. No primary malignant tumors of the gastrointestinal epithelial tissues were found, and there was no obvious link between the other malignant tumors that developed and the asbestos exposure.
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>
> The finding that prolonged ingestion of asbestos in laboratory rats is not associated with an increase of gastrointestinal neoplasia is in agreement with the other published chronic exposure studies.

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. . . our work suggests that the normally healthy gastrointestine maintains an effective barrier against the potentially damaging effect of ingested asbestos, and no convincing evidence of fiber penetration was found. Indeed, the intestinal mucosae would appear particularly well adapted to prevent such penetration by foreign matter.

REFERENCES

1. Bolton, R. E., Davis, J.M.G., and Lamb, D., "The Pathological Effects of Prolonged Asbestos Ingestion in Rats," Environmental Research, 29, 134-150, 1982.

2. Bolton, R. E., and Davis, J.M.G., "The Short Term Effects of Chronic Asbestos Ingestion in Rats," Annals of Occupational Hygiene, 19, 121-128, 1978.

ADVISORY

March, 1983

Volume #1 Issue #10

EPA WORKSHOP SETS STAGE FOR RESOLVING ASBESTOS IN DRINKING WATER CONTROVERSY

The U.S. Environmental Protection Agency (EPA) has started its decision making process to determine whether asbestos in drinking water should or should not be regulated under the Safe Drinking Water Act. The announcement came at the closing of the agency's Summary Workshop on Ingested Asbestos held at the Breidenbach Environmental Research Center.

The purpose of the Summary Workshop was to gather and evaluate EPA-sponsored studies on exposure/potential health effects of ingested asbestos. Ten years of research in human and animal toxicology, epidemiology, physiology, and pathology and in vitro studies were reviewed by scientists from government and academia. Workshop proceedings will be published in the October, 1983 issue of Environmental Health Prospectives. Here are some highlights.

NIEHS Studies of Orally Administered Asbestos

Eugene McConnell, M.D. of the National Institute of Environmental Health Sciences (NIEHS) reported the long awaited findings of its seven year animal feeding studies. The first phase, whose conclusions were released in 1981, demonstrated no carcinogenic or cocarcinogenic effects from lifetime feeding of asbestos to hamsters.

The second phase, involving over 5,000 rats, was considered the definitive study for determining neoplastic and non-neoplastic effects from oral administration of asbestos. Dose levels were 1% of total diet by weight.

Dr. McConnell reported that histopathologic analysis of test animals fed crocidolite and chrysotile asbestos for their lifetimes showed no carcinogenic effects. The lifespans of rats fed asbestos also were not shortened, nor were there any increased incidences of non-neoplastic disease such as gastrointestinal inflammation, diverticulitis, ulcerations, etc. McConnell characterized the seven year study as "one of the best I have ever dealt with."

The NIEHS data will be peer reviewed by the Board of Scientific Counselors and formally released sometime in 1983.

Case Control Epidemiologic Study - Puget Sound

Preliminary results were reported by Dr. Lincoln Polissar of the Fred Hutchinson Cancer Research Center. The research, as yet unpublished, was a refinement of the census tract epidemiologic study that showed little evidence of cancer risk from asbestos in community water supplies (see A/C Advisory, Volume I, Issue 9). In the hierarchy of studies using human data, a case control study is more powerful than an ecologic or census tract study. It collects data on persons with disease (cancer in this case) and a similar "control" group without disease. Analysis then determines whether persons with disease were more exposed to a potentially causative agent (asbestos in drinking water) than disease-free persons.

The researchers used data in "low migration" census tracts to isolate "eligible" and "control" cases. Each case was then interviewed and personal histories taken to determine historical exposures to asbestos in drinking water. No statistically significant correlations were found between cancer incidence and the concentrations of asbestos in drinking water in the area.

Reanalysis of the San Francisco Bay Area Study

Using sophisticated mathematical techniques for "data image enhancement," a University of California-Berkeley biostatistician reported on an EPA-funded reanalysis of the Kanarek et al epidemiologic study. The study, published in two parts in 1977 and 1980, showed a statistical correlation between certain cancers and asbestos levels in Bay Area drinking water.

Dr. Michael Tarter's analysis of San Francisco census tracts, where asbestos exposure levels were high, actually showed a negative association between asbestos levels and cancer incidence, i.e. incidence rates were lower where exposure was higher. He tagged this observation "the San Francisco effect" and cautioned that until it is fully understood, "one must be very careful about interpreting the Kanarek studies."

Observations by EPA Office of Drinking Water

Dr. Joseph A. Cotruvo (Director, Criteria and Standards Division, Office of Drinking Water) delivered the keynote address. He observed that the debate on the potential risks of asbestos in drinking water had been ongoing since 1971, noting, "very few other issues have had the volume and intensity of study and resultant information that has been presented here."

From his perspective the epidemiological and animal data show " ... there is a substantial question as to whether there is risk at all from small amounts of asbestos fibers in drinking water ... if there is a risk, the magnitude of that risk must be quite small at levels typically found in drinking water or perhaps even at atypical levels, such as the 100-million plus fiber per liter concentration."

Cotruvo concluded that no toxic effects were demonstrated in lifetime animal feeding studies. If there was a risk from ingested asbestos, he said, it had not been reproducibly demonstrated by epidemiologic studies.

In reviewing where and how EPA would proceed from the Workshop, he announced that the agency is "on track to make a decision." Extensive additional research probably would not add to the knowledge of the subject and a decision will be made on what evidence is currently available, he said. EPA is expected to issue an Advance Notice of Proposed Rulemaking (ANPRM) in the Federal Register within two to four months. Although the ANPRM encompasses the agency's complete revision of existing National Primary Drinking Water Regulations, additional contaminants, including asbestos, will be mentioned in the ANPRM and public comments solicited.

A/C Pipe Producers Association

ADVISORY

January, 1983

Volume 1 Issue 9

ASBESTOS IN DRINKING WATER - CANCER INCIDENCE STUDY COMPLETED

The Fred Hutchinson Cancer Research Center has reported findings of an epidemiologic study [1] of asbestos in drinking water, cancer incidence and cancer mortality in the Puget Sound region of Washington State.

"Results of this study and prior studies of cancer in relation to waterborne asbestos are inconsistent, and provide little evidence that asbestos in community water supplies has altered the risk of any cancer," concluded principal investigator, Lincoln Polissar. The study was funded by the Health Effects Research Laboratory of the U.S. Environmental Protection Agency (EPA). It is the first part of a two-part study investigating exposure to asbestos in Washington community water supplies.

The Puget Sound region of western Washington is an excellent setting to conduct an epidemiologic study. The state's three largest metropolitan areas (Everett, Seattle and Tacoma) have used the same water sources since the early 1900's. Moreover, each city receives water from a different river, each with large variations of naturally-occurring asbestos in it. In Everett, the high exposure municipality, asbestos levels ranged from 37.2 to 556 million fibers per liter (MFL) with a mean concentration of 206.5 MFL. The "low asbestos concentration" study areas of Seattle and Tacoma had a mean asbestos concentration of 7.3 MFL, a twenty-eight fold difference. In the researchers' words, "concentrations have probably changed little over the past 60 years."

The Seattle-Everett-Tacoma metropolitan area was subdivided into census tracts grouped by asbestos concentration. Data on cancer incidence were obtained from a surveillance registry; cancer mortality information came from death certificates. Duration of exposure to asbestos in drinking water was estimated and divided into long term (greater than 30 years) versus short term (less than 30 years) groups.

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Six different risk ratios were calculated for each sex and cancer site combination. (Note: a risk ratio is the risk of cancer in populations exposed to high asbestos concentrations divided by the risk of populations exposed to low concentrations. In mathematical terms, a ratio of unity — 1.0 — suggests no risk. Risk ratios less than 2 are subject to doubt regardless of statistical significance.) The ratios differed in type data used (incidence or mortality), definition of case and control groups and definition of exposure.

The 332 resultant risk ratios were evenly split above and below unity "suggesting a chance mechanism for most of the results." Of the statistically significant ratios, 6 of 30 were greater than unity, none in gastrointestinal sites. Twenty-four were less than unity, although the authors caution "there is no biologic reason to expect ... a protective effect of asbestos."

The results are summarized as follows:

> From the data we have analyzed, we conclude that the cancer risk from asbestos in drinking water in the Sultan River area is, at most, very low, although there is suggestive evidence for some anatomic sites.

The case-control phase of this research will remedy misclassification of exposure, a major shortcoming of all previous epidemiologic studies of imbibed asbestos. By using in-person interviews, Polissar and his co-workers anticipate "a more accurate determination" of risk.

REFERENCES

1. Polissar, L., Severson, R.K., Boatman, E.S., and Thomas, D.B., "Cancer Incidence in Relation to Asbestos in Drinking Water in the Puget Sound Region," American Journal of Epidemiology 116, 314-28, 1982.

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A/C Pipe Producers Association

ADVISORY

June, 1982

Volume I Issue 8

ASBESTOS FEEDING STUDY FINDS NO GASTROINTESTINAL CANCER IN TEST ANIMALS

A lifetime study[1] of rats fed asbestos, taconite tailings and Lake Superior water recently concluded, "Autopsy studies revealed no significant increase in the incidence of malignant tumors in any experimental group compared with that in the control group." The study, initiated in 1973, was conducted by physicians at St. Luke's Hospital, Duluth, Minnesota, the University of Illinois' Abraham Lincoln School of Medicine and the University of Minnesota School of Medicine.

The objective of the research was to evaluate the carcinogenecity of ingested mineral fibers in various forms. In discussing the study's rationale, the authors acknowledge how little was known in 1973 about the biological effects of ingested asbestos. They point out that although workers inhaling asbestos dust "probably suffer some gastrointestional exposure by swallowing mucus containing asbestos fibers ... there was no assurance that this was the equivalent to direct ingestion of amphibole (asbestos)-contaminated water."

The test animals, 190 Sprague-Dawley rats, were divided into seven exposure groups:

(1) Control (no exposure)

(2) Unfiltered Duluth tap water (average fiber content 100 million fibers per liter)

(3) Lake Superior water sediment (average fiber content 5,000 million fibers per liter)

(4) Taconite plant tailings (average fiber content 100,000 million fibers per liter)

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(5) Low dose asbestos (chrysotile and amosite; 20 milligrams per rat per day; approximately 5,460 million fibers per liter)

(6) High dose asbestos (300 milligrams amosite per rat per day; approximately 78,000 million fibers per liter)

(7) Diatomaceous earth (20 milligrams per rat per day)

Complete gross and microscopic autopsies were performed on 187 of the 190 test and control animals. The entire gastrointestinal tract of each animal was inspected and transilluminated; tissue specimens were removed from representative pre-selected sites and from all abnormal areas. The investigators concluded:

> The most significant finding in our study was the total absence of gastrointestinal cancer in animals exposed to the test materials. Any direct carcinogenic action of ingested asbestos fibers should have its primary impact on the gastrointestinal mucosa.
>
> * * *
>
> Under the conditions of our study, ingested asbestos, taconite tailings, unfiltered Duluth (Lake Superior) tap water, Lake Superior reservoir sediment and diatomaceous earth had no demonstrable carcinogenic effect on the gastrointestinal tract or on other body tissues of the rat.

REFERENCES

1. Hilding, A.C., Hilding, D.A., Larson, D.M., and Aufderhiede, A.C., "Biological Effects of Ingested Amosite Asbestos, Taconite Tailings, Diatomaceous Earth and Lake Superior Water in Rats," Archives of Environmental Health 36, 298-303 (November-December) 1981.

A/C Pipe Producers Association

ADVISORY

June, 1982

Volume I Issue 7

CANADIAN DEPARTMENT OF NATIONAL HEALTH AND WELFARE RELEASES ASBESTOS IN DRINKING WATER RESULTS

Results of a Canadian government study[1] show no consistent increased cancer deaths for persons living in localities where high levels of asbestos are present in drinking water.

Asbestos is an important mineral commodity in Canada. Although it occurs naturally in many parts of the country, its mining is concentrated in the Province of Quebec. The presence of asbestos in municipal water supplies prompted the Department of National Health and Welfare to survey the asbestos content of Canadian drinking water. Samples of raw, treated and distribution water were collected from seventy-one locations. These were analyzed according to the U.S. Environmental Protection Agency (EPA) interim procedure for determining asbestos content of water. The results then formed the basis of an epidemiological study.

The sampling portion of the study concluded that chrysotile was " ... the major asbestos type present in drinking water with some 5% of the population receiving water with asbestos concentrations greater than 10 x 10^6 (10 million) fibers per liter." The median fiber lengths were between 0.5 and 0.8 micrometers. Where very long fibers (up to 50 micrometers) were observed, these did not form a majority of the fibers present.

The epidemiological study analyzed the relationship between mortality (death) rates and asbestos levels in drinking water. The seventy-one sampled cities were divided into two exposure groups — those with levels greater than 100 million fibers per liter and those with less than 5 million fibers per liter. Within these two groups, death rates from

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various causes were compared. The study concluded:

> Although there are serious limitations to this type of study, no consistent increase in mortality rates for any cancer was demonstrated. This finding is consistent with the previous, but more limited, epidemiology study carried out in Quebec.

The study to which the authors referred also was conducted by the Canadian Department of National Health and Welfare[2]. It involved an investigation of municipalities in the asbestos mining regions of Quebec where populations were exposed to asbestos levels as high as 1.3 billion fibers per liter of drinking water. That study concluded:

> A study of twenty-two municipalities in Quebec did not reveal excess cancer mortality that could be related to the presence of asbestos fibers in drinking water supplies.

REFERENCES

1. Toft, P., Wigle, Meranger, J. C. and Mao, Y., "Asbestos in Drinking Water in Canada," The Science of the Total Environment 18, 77-89, Elsevier Scientific Publishing Company, Amsterdam, 1981.

2. Wigle, D. T., "Cancer Mortality in Relation to Asbestos in Municipal Water Supplies," Archives of Environmental Health, 185-189, 1977.

A/C Pipe Producers Association

ADVISORY

May, 1982

Volume I Issue 6

ANIMAL STUDY REPORTS NO PENETRATION OF GASTROINTESTINAL TRACT BY ASBESTOS FIBERS

Results of an animal ingestion study conducted at the University of Illinois School of Public Health indicate, " ... asbestos fibers do not penetrate the gastrointestinal tract of the baboon and migrate to the various tissues."[1]

The principle investigator's earlier findings[2,3] suggested asbestos may penetrate to baboon's GI tract and be recovered in urine and other tissues. However, several limitations were noted in these studies. These included the observance of only a small number of fibers in the test tissues and urine, the short time allowed for possible penetration and migration, the absence of blood samples, administration of low cumulative doses of only one fiber type and lack of reproducibility of elevated (observed) fiber counts.

The objective of this research was to improve upon the earlier baboon studies and determine whether previous results could be corroborated. Among the experimental improvements were that two types of asbestos were administered, the cumulative dose was higher, blood samples were obtained and a greater variety of tissues examined. During a 16-day period, two types of asbestos (100 mg. of chrysotile and 100 mg. of crocidolite) in water were administered by gavage i.e. injection into a tube inserted in the test animal's stomach. The fiber length and diameter distributions of the asbestos were similar to those that occur in several U.S. water supplies. At time of sacrifice, blood, urine and twenty-two tissues were analyzed for the presence of asbestos.

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The authors concluded, "The low fiber counts observed in the present comprehensive study do not support the hypothesis that ingested asbestos fibers can penetrate the gastrointestinal tract of the baboon and migrate to various tissues." This study was supported by a grant from the U.S. Environmental Protection Agency (EPA).

REFERENCES

1. Hallenbeck, W. H., Markey, D. R. and Dolan, D. G., "Analyses of Tissue, Blood, and Urine Samples from a Baboon Gavaged with Chrysotile and Crocidolite Asbestos," Environmental Research 25, 349-360, 1981.

2. Hallenbeck, W. H., and Patel-Mandlik, K. J., "Presence of Fibers in the Urine of a Baboon Gavaged with Chrysotile Asbestos," Environmental Research 20, 335-340, 1979.

3. Patel-Mandlik, K. J., Hallenbeck, W. H., and Millette, J. R., (1979). Asbestos fibers. 1. A modified preparation of tissue samples for analysis by electron microscopy; 2. Presence of fibers in tissues of baboon fed chrysotile asbestos, Journal of Environmental Pathology and Toxicology 2, 1385-1395, 1979.

A/C Pipe Producers Association

ADVISORY

May, 1982

Volume I Issue 5

AUTHORITY REPORTS 'NO EXPERIMENTAL EVIDENCE OF HARMFUL EFFECTS' FROM MINERAL FIBER INGESTION

J. M. G. Davis, M.D. of the Institute of Occupational Medicine in Edinburgh, Scotland has stated, "So far there is no experimental evidence of harmful effects following mineral fibre ingestion and human epidemiological evidence that the ingestion of asbestos may increase levels of gastrointestinal cancer is disputed by some workers."

This statement, published in the Annals of Occupational Hygiene, was in response to the question, "Is there any evidence of damage when asbestos or other mineral fibres are administered by gastro-intestinal route?" The discussion followed a presentation by Dr. Davis entitled "The Biological Effects of Mineral Fibres," which addressed the history of asbestos-related disease and research on biological effects of asbestos, other naturally-occurring mineral fibers and man-made fibers.

REFERENCES

1. Davis, J. M. G., "The Biological Effects of Mineral Fibres," Annals of Occupational Hygiene, Volume 24, No. 2, 227-224, 1981.

ADVISORY
A/C Pipe Producers Association

February, 1982

Volume #1 Issue #4

FIELD STUDY SHOWS STRENGTH RETENTION OF A/C PIPE IN CORROSIVE WATER ENVIRONMENTS

Results of a field study of asbestos-cement (A/C) water distribution pipe in the ground for many years show nearly all still exceed structural requirements for new pipe. The study was part of an ongoing quality assurance program.[1]

Forty-five samples of A/C pipe from geographically diverse areas and of varying ages were analyzed for loss of structural integrity and evidence of corrosive water attack. Emphasis was on older pipe installations conveying waters that ranged from nonaggressive to highly aggressive (corrosive). More than 50 percent of the systems were 30 years or older; a number were 40 to 45 years old.

New A/C pipe is subjected to physical inspection followed by strength and composition testing to control finished quality. Four tests are used: hydrostatic, flexure, crushing and free lime. Detailed test procedures are set forth by two nationally recognized standards-setting organizations, American Water Works Association[2] and American Society for Testing and Materials[3]. All except the free lime test were used in this reported evaluation of the A/C pipe field samples.

Field technicians obtained and verified the service history of A/C pipe samples provided by cooperating water utilities. Testing was carried out in a laboratory, mostly on 305 mm (12 in.) long samples per the three test methods cited above. In addition, a depth of penetration analysis was performed on a small section or "coupon" from each sample. This was done by scraping away any soft material, if present, on the inside surface of the pipe and then measuring the remaining wall thickness with a micrometer.

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Representative results appear below:

Sample No.	Age	Diameter	Pressure Class	AI*	Crush (lb/in.) Specified	Sample	Crush (lb/in.) Specified	Sample
3	38	8 in.	100	11.2	4000	4080	Not tested	
11	31	8 in.	150	8.2	5500	9760	Not tested	
23	31	8 in.	150	9.0	5500	5760	Not tested	
40	39	6 in.	150	10.4	5400	6320	600	900
42	42	6 in.	150	10.3	5400	6290	600	975

Inorganic coatings, apparently from the corrosion of metallic system components, or from ions naturally present in the water, were deposited in situ on some of the pipe samples. The protection thereby provided against aggressive attack was indeterminate. Data from industry and U.S. Environmental Protection Agency (EPA) studys[4] show that metal salt-based corrosion inhibitors added to the water can, under certain conditions, retard corrosive water attack on A/C pipe provided the inhibitor is added properly and continuously. In addition, the long-term performance of factory-applied organic coatings was found to be excellent.

Overall, the data substantiate the ability of A/C distribution pipe to convey moderately to highly aggressive water over a long period of time with little or no apparent loss of strength. When present, the degree of corrosive attack is correlated with the Aggressive Index of the water. Even where corrosion as measured by depth of penetration occurred, structural integrity was maintained.

References:

1. Herr, J. F., "Transite Pipe Field Study Program," Johns-Manville Corporation Research and Development Center, Report No. E 425-T-1424, August 22, 1980.

2. Listed standards available from American Water Works Association, 6666 West Quincy Avenue, Denver, CO 80235. American Water Works Association Specifications:
AWWA C400-80 (A/C Distribution Pipe, 4 in. through 16 in.).
AWWA C402-77 (A/C Transmission Pipe, 18 in. through 42 in.).

3. Listed standards available from American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103. American Society for Testing and Materials:
ASTM C296-78 (Standard Specification for Asbestos-Cement Pressure Pipe).
ASTM C500-79a (Standard Methods for Testing Asbestos-Cement Pipe).
ASTM C668-79 (Standard Specification for Asbestos-Cement Transmission Pipe).

4. Buelow, R. W., Millette, J.F., McFarren, E.F., Symons, J.M., "The Behavior of Asbestos Cement Pipe Under Various Water Quality Conditions, A Progress Report," American Water Works Association Journal, February, 1980, pp. 91-101.

A/C Pipe Producers Association

ADVISORY

January 1982

Volume #1 Issue #3

EVIDENCE POINTING 'STRONGLY AWAY' FROM ASBESTOS INGESTION AND CANCER LINK, EXPERTS REPORT

Two British scientists, Dr. Robert Murray and Dr. Kevin Browne, have stated in The Lancet,[1] that "the evidence from animal experiments, occupational exposure, and epidemiology is beginning to point strongly away from any association" between asbestos fibers and an excess mortality from gastrointestinal tumors.

Drs. Murray and Browne rely on two major recent animal experiments. They point to a study conducted by the Institute of Occupational Medicine in Edinburgh, Scotland that "confirmed the absence of asbestos-related gut tumors in a large-scale study in rats monitored for their whole lifespan,"[2] and to studies presently being conducted with laboratory animals by the U.S. National Institute of Environmental Health Sciences (NIEHS). With respect to these latter studies, the Environmental Protection Agency (EPA) has stated, "the initial results did not detect any adverse effects on the test animals from asbestos in the diet."[3]

Regarding the observance of excess gastrointestinal cancers in some occupational groups heavily exposed to airborne asbestos, Drs. Murray and Browne state, " ... among the less heavily exposed, no excess has been found." They mention the suggestion of Turner-Warwick and Parkes that, "except for the lung, asbestos might act, not as a local carcinogen, but systematically via the immune system."[4] They also refer to a study by Goldsmith, which provides evidence that "the increases in background rates at different sites appear to be an example of cancer promotion following impairment of defense mechanisms rather than site specificity."[5]

The authors also cite the Connecticut study conducted by Meigs, et al., in which cancer incidence data collected over a 35-year period indicated "no increases in incidence either of all cancers or of the individual sites considered."

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Drs. Murray and Browne take issue with the conclusions of a California study by Kanarek[7] referred to in an earlier article in The Lancet. They point out two major problems of interpretation with the conclusions of the Kanarek study. "Firstly, as these workers point out, certain cancers, including stomach, lung, and colon, show an association with social class, and considerable social class differences appear in their figures ... they correct for this by correcting for three different levels of education and income. But unless these are perfectly correlated with the factors responsible for the large differences in cancer rates between social classes, the residual variation may well cause a spurious correlation to appear between geographical feature and cancer rate for some organs."

"Secondly, the computer has made possible the large-scale dredging of population data for positive associations, and probabilities obtained in this way should not be taken at face value."

About the authors:
Dr. Robert Murray-Order of the British (OBE); Fellow of the Royal College of Physicians, Glasgow (FRCP-Glas); Honorary Diploma of Technology, Bradford (Hon. D. TECH-Brad); Diploma of Public Health (DPH); Fellow of the Faculty of Occupational Medicine (FFOM); Honorary Institute of Occupational Safety and Health (Hon. IOSH); Diploma of Industrial Health (DIH).

Dr. Kevin Browne-Master of Arts (MA); Bachelor of Medicine and Surgery (MBBS); Master of Science (MSc).

References:

1. Murray, R., Browne, K., response to "Asbestos in Water," The Lancet, August 22, 1981, 415.
2. Bolton, R. E., Davis, J.M.G., Lamb, D., "The Pathological Effects of Prolonged Asbestos Ingestion in Rats," Environmental Research (in press).
3. Turner-Warwick, M., Parkes, W. R., "Circulating Rheumatoid and Antinuclear Factors in Asbestos Workers," British Medical Journal, 1970, 492-95.
4. Goldsmith, J. P., "Asbestos as a Promoting Agent for Non-Pulmonary Cancer: The Epidemiological Evidence from Eight Cohorts." Proceedings of the First Symposium on Epidemiology in Occupational Health (Helsinki, 1981), Scandinavian Journal of Work Environment Health (in press).
5. Meigs, J.W. Walter, S.D., Heston, J.F., et al., "Asbestos Cement Pipe and Cancer in Connecticut 1955-1974," Environmental Health, 1980, 42:187-191.
6. Conforti, P.M., Kanarek, M.S., Jackson, L.A., Cooper, R.C., Murchie, J.C., "Asbestos in Drinking Water and Cancer in the San Francisco Bay Area 1969-1974 Incidence," Journal of Chronic Disease, 1981, 34:211-44.

A/C Pipe Producers Association

ADVISORY

October 1, 1981

Volume #1 Issue #2

MINNESOTA STUDY FINDS NO LINK BETWEEN INGESTED ASBESTOS AND CANCER

Interim results of an epidemiology study[1] conducted by the Minnesota Department of Health recently reported no link between the ingestion of asbestos fibers in Duluth drinking water and the incidence of cancer.

"In our opinion, there are currently no observed etiologic or causal associations between exposures to amphibole (asbestos) fibers in the Duluth drinking water supply and the development of cancer," concluded principal investigator Eunice E. Sigurdson, R.N., M.P.H., in an interim report. The ongoing study is funded by the Health Effects Research Laboratory of the Environmental Protection Agency (EPA) in Cincinnati, OH.

The stated purpose of the study is to determine the effect on cancer incidence, if any, from the ingestion of amphibole fibers in the Duluth water supply during the time period 1969-1981. Fibrous amphiboles occur in Duluth's drinking water as a result of a nearby mining operation which discharged tailings into Lake Superior. Levels from one to 64 million fibers per liter (MFL) have been measured in tap water samples. Electron microscope studies show that the mean fiber length is 1.13 micrometers (microns) and the mean fiber width is 0.18 micrometers, a 6.5 to 1 length-to-width (aspect) ratio.

The study compared Duluth cancer incidence during the period 1969-1971 with rates in Minneapolis and St. Paul, two cities with very similar age, sex, race distribution, socio-economic, occupational, and ethnic characteristics. In contrast to Duluth however, the water supplies in Minneapolis and St. Paul are virtually free of asbestos fibers. Cancer incidence during 1969-1971, (approximately ten years following the initiation of exposure to asbestos in Duluth water) are considered baseline rates to compare cancer incidence. The report concluded that "Rate differences between different geographic areas and through time occur without any apparent biologic reason."

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Comparing 1974-1976 Duluth cancer rates with the 1969-1971 results, the researchers reported that cancer decreased among males for all (84) sites combined and for total gastrointestinal (GI), stomach, and colon sites in males and females. No cases of peritoneal mesothelioma were observed during the eight years of observation.

These results are similar to those reported in an earlier study published by B.S. Levy, Sigurdson,[2] et al in 1976. That work compared gastrointestinal cancer incidence for Duluth, Minneapolis, and St. Paul. The authors concluded,

> "This study detected no excess in total GI cancer incidence among Duluth residents in 1969-1972 and therefore suggests no effect in this period possibly attributable to high concentrations of asbestos-like fibers in Duluth tap water, a finding consistent with two recent mortality studies regarding this situation..."[3-4]

References:

1. Sigurdson, E. E., Minnesota Department of Health, "Interim Report of Cancer Incidence in Duluth during 1969-1976 as an Investigation of Health Effects from Ingestion of Amphibole Fibers in the Municipal Water Supply," April 30, 1981.

2. Levy, B. S., Sigurdson, E. E., Mandel, J., Lauden, M., and Pearson, J., "Investigating Possible Effects of Asbestos in City Water, Surveillance of Gastrointestinal Cancer Incidence in Duluth, Minnesota," American Journal of Epidemiology, Volume 103, Number 4, 1976.

3. Mason, T. J., McKay, F. W., Miller, P. W., "Asbestos-Like Fibers in Duluth Water Supply: Relation to Cancer Mortality," Journal of the American Medical Association, 228, 1974.

4. Minnesota Department of Health: Gastrointestinal Cancer Mortality Data, 1955-1971, unpublished.

ADVISORY

A/C Pipe Producers Association

July, 1981

ISSUE #1 VOLUME #1 This first in a series of "advisories" is designed to keep water utilities and public health officials current on information regarding usage of asbestos-cement pipe. Each Advisory issue will factually summarize data contained in scientific papers, government studies, media reports, and technical and educational source material.

GOVERNMENT ANIMAL FEEDING STUDIES SHOW NO CARCINOGENIC EFFECT OF INGESTED ASBESTOS

Preliminary results of government-sponsored studies on the effect of ingested asbestos on laboratory animals show no carcinogenic or cocarcinogenic effect.

The studies are being conducted by the National Institute of Environmental Health Sciences (NIEHS) under the direction of the Public Health Service's National Toxicology Program. The Environmental Protection Agency (EPA) has contributed a portion of the funding.

The aim of the NIEHS/EPA studies is to assess the biological (carcinogenic) effects of asbestos fibers which are ingested, or taken into the body through the digestive tract, as in drinking water.

The studies call for asbestos to be fed continuously in the diet over the entire lifespan of the animal, which is defined as the age at which the animal begins eating solid food until its death.

A total of 1,850 male and female hamsters were fed asbestos, and an equal number of hamsters were fed a control diet with no asbestos over their lifetime of 18-23 months. Two types of asbestos fibers (chrysotile and amosite) commonly used in the manufacture of asbestos-cement products were administered.

The dose of asbestos (1% of total diet by weight) fed to the hamsters was millions of times greater than levels which occur in drinking water consumed by the public in a lifetime, in areas where asbestos occurs naturally in the drinking water.

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NIEHS reports, "There was no indication of major differences in the mortality rate between the hamsters receiving the asbestos diet or the control diet." Preliminary analysis of the hamster data indicates that no carcinogenic or cocarcinogenic effect was observed.

The analysis included thorough gross pathological evaluation at time of autopsy, as well as microscopic examination of some thirty tissues from test animals.

In addition, preliminary results of rat studies in which a total of 5,158 rats were fed asbestos and control diets were also reported. The lifetime exposure phase of the study concluded, "... longevity was not affected by exposure to the various types of fibers."

These findings are consistent with a number of other studies of animals fed asbestos in food or drinking water. In 1980, the Health Research Institute at Fairleigh-Dickinson University reported no malignant tumors related to treatment in hamsters maintained on drinking water containing 13 billion asbestos fibers per liter.

References:

1. NIEHS, Biological Effects of Ingested Asbestos Status Report January 22, 1981, National Toxicology Program, Public Health Service.

2. NIEHS, Biologic Effects of Ingested Asbestos Status Report February 15, 1980, National Toxicology Program, Public Health Service.

3. Moore, J.A., NIEHS Oral Asbestos Studies, National Bureau of Standards Special Publication 506. Proceedings of the Workshop on Asbestos: Definitions and Measurement Methods held at NBS, Gaithersburg, MD, July 18-20, 1977.

DESIGN & CONSTRUCTION

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AWWA No M16

Work Practices for Asbestos-Cement Pipe

AMERICAN WATER WORKS ASSOCIATION

MANUAL OF WATER SUPPLY PRACTICES

CTD031793

Table of Contents

PHYSICAL PROPERTIES OF ASBESTOS-CEMENT PIPE

Hydrostatic Strength[1]	Average Modulus of Rupture - Full OD - All Pressure Pipes	
	Sizes 4" - 12"	3700 pounds per square inch (psi)
	Sizes 14" - 36"	4000 psi
Crush Strength[2]	Average Modulus of Rupture - Full OD	
	Pressure pipes (all sizes)	7000 psi
	Sewer pipe (4" - 5")	3200-4500 psi
	Sewer pipe (6" - 36")	5900 psi
	Ducts and conduits (all sizes)	3200-4500 psi
Flexural Strength[3]	Modulus of Rupture (minimum for test use)	
	Class pressure pipe (all sizes)	3700 psi
	Transmission pipe (all sizes)	3500 psi
	Sewer pipe (4" - 5")	1900-3000 psi
	(6" - 36")	3500 psi
	Ducts and conduits (all sizes)	1900-3000 psi

Modulus of Elasticity	$2.5 - 3.5 \times 10^6$ psi
Density	100-115 lb/ft^3
Thermal Conductivity	K=5.5 BTU/Hr/^{o}F./ft^2/in.
Thermal Coefficient of Expansion	$4 - 5 \times 10^{-6}$ in./in./^{o}F.
Specific Heat	0.27 BTU/lb/^{o}F at 212^{o}F.
Moisture Coefficient of Expansion	$1.5 - 2.0 \times 10^{-5}$ in./in./%moisture content
Hazen-Williams' Coefficient	C = 140
Manning's Coefficient	n = 0.010
Axial Compressive Stress	8000 psi (full pipe cross section)
Axial Tensile Stress	500 - 3000 psi (depending on blend)
Shear Stress	Laminar: 1000 psi Across pipe axis: 4000 psi
Permeability	0.3 - 0.5 grains/hr/ft^2/ in. Hg/in. thickness
Poisson's Ratio	0.2
Dielectric Constant	dry: 20 wet: 100
Water Absorption (24 hour immersion)	15-20% (depending on blend)
Hardness (Rockwell M)	ID = 87 OD = 60

1 Formula for Hydrostatic Modulus of Rupture

$$MR = P \frac{OD^2 + ID^2}{OD^2 - ID^2}$$

2 Formula for Crush Modulus of Rupture (one foot length)

$$MR = 0.159 \frac{W(OD + ID)}{(OD - ID)^2}$$

3 Formula for Flexural Modulus of Rupture (mid point load)

$$MR = \frac{PL}{6S}$$ (Where s = section modulus $in.^3$)

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CORROSION/81

The International Corrosion Forum Sponsored By the National Association of Corrosion Engineers / April 6-10, 1981 / Sheraton Centre, Toronto, Ontario, Canada.

STRUCTURAL PERFORMANCE OF ASBESTOS CEMENT PIPE IN CORROSIVE POTABLE WATER ENVIRONMENT

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ABSTRACT

Field experience with asbestos-cement (A/C) water distribution pipe used in potable water service for conveying corrosive (aggressive) waters is reported. Forty-five samples of A/C pipe from geographically diverse areas and of varying ages were analyzed for signs of corrosive water attack and loss of structural integrity. All but 3 of the samples tested for crush strength exceeded the requirements for new pipe. Corrosion penetration was minimal or absent in most cases, particularly for pipe conveying low to moderately aggressive water. The long term performance of factory applied coatings was found to be excellent. Iron based inorganic coatings, apparently from the corrosion of metallic system components, were deposited in situ on some of the pipe samples but the protection thereby provided against aggressive attack was indeterminant. Data from other industry and EPA studies show that metal salt based corrosion inhibitors added to the water can, under certain conditions, retard aggressive water attack on A/C pipe provided the inhibitor is added properly and continuously to the water stream.

Composition, manufacture and testing of A/C pipe are also discussed. Data on the variability of crush and hydrotest results are presented. Conclusions regarding the long term performance of A/C pipe and the efficacy and need for protective coatings are given.

CTD031797

Introduction and Background

Asbestos cement (A/C) pipe was first manufactured in Europe at the turn of the century by hand rolling flat asbestos-cement sheet stock into a cylinder while still wet. However, the resulting product had little strength. In the early 1900's an Italian, Mazza, developed a process for rolling a continuous film of asbestos-cement on a removable cylinder (mandrel) and the modern A/C pipe industry was born.

Autoclave cured A/C pipe is formed from a mixture of three (3) main ingredients, plus water:[1]

	Percent by weight
Asbestos fiber	15-20
Silica flour	34-32
Portland cement	51-48

The asbestos fiber is also a blend of various fiber types, typically "white" (chrysotile) and "blue" (crocidolite). Silica flour is produced by grinding quartz sand in a ball mill until a fine powder is produced.

The manufacture of A/C pipe, shown in Figure 1, begins with automated opening of plastic sealed bags of fiber, followed by mechanical processing of the asbestos to "debundle" the asbestos into the individual fibers which give the pipe its characteristic high strength. The opened fiber is then mixed with the other materials, slurried, and the pipe is formed under high pressure on a continuous pipe making machine. After initial cure, the mandrel is removed and tne pipe goes to the final curing process, autoclaving. This high temperature (171-185^{o} C) (340-365^{o} F) high pressure (689-1034 kPa) (100-150 psi) steam curing, causes the free lime byproduct of the cement hydration to be 99% reacted with the finely ground silica flour, imparting superior strength and corrosion resistance over water or air cured A/C pipe.

Following autoclaving each pipe is machined, fitted with a push on type coupling and subjected to quality control tests. Machining assures a close tolerance fit of pipe couplings and appurtenances, an important factor in the low water loss experienced with installed A/C pipe systems.

Testing A/C Pipe

New A/C pipe is subjected to physical inspection followed by strength and composition testing to control the finished quality. Four tests are principally used:

Hydrostatic tests

Flexure test

Crushing test

Uncombined calcium hydroxide (free lime) tests

Three types of hydrostatic tests are used on A/C pipe. The first, "proof" testing checks the burst resistance of each pipe up to 3.5 times its rated pressure. In addition, a test to 4 times rated pressure is conducted on one pipe of each lot, usually one out of 300 pieces. For research purposes, samples of the pipe may be tested to burst to determine ultimate strength. The latter test was used to develop the burst data presented later herein.

The hydrostatic and flexure tests are conducted on all A/C pipe to 200 mm (8 in) in diameter, with larger sizes subjected to hydrostatic testing only. In the flexure test, the pipe is subjected to a point load applied at the center with the ends supported on rigid blocks. This test verifies the resistance of the pipe to bending loads. Crush and free lime tests are conducted on each pipe lot.

Detailed test procedures for A/C pipe are set forth by two nationally recognized standards setting organizations:

American Water Works Association:[2]

AWWA C400-80
AWWA C402-77

American Society for Testing and Materials:[3]

ASTM C296-78
ASTM C500-77
ASTM C500-79a
ASTM C668-79

For purposes of the work reported herein, crush, flexure, and hydrostatic tests were used to evaluate the pipe samples. Tests were run on 305 mm (12 in) long pipe samples to compare structural integrity to standard specifications. Figure 2 shows a photograph of the standard 3 edge crushing test; Figure 3 depicts the hydrostatic test equipment. Table 1 provides AWWA standard crush and hydrotest strength requirements for A/C water distribution pipe.

CTD031799

Variability of Crush and Hydrotest Results

As part of an overall evaluation of test procedures, more than 7500 pieces of Class 150 A/C pipe, ranging in diameter from 100-600 mm (4-24 in) were tested.[4] The results are plotted on the frequency distribution plot shown in Figure 4. The left hand scale and dashed line drawing provide the results of a 1965 study of 412 samples, all Class 150. The right hand scale and solid line drawing provides the results of an earlier study of 7100 samples. The results are expressed in terms of the generalized modulus of rupture (MR) which can be related to the crush loading for a 305 mm (12 in) long sample as follows: [5]

$$MR = \frac{\text{Crush} \times (\text{ID pipe} + \text{WT})}{(\text{WT})2}$$

where:

MR - modulus of rupture, kPa

ID - interior diameter of pipe, m

WT - wall thickness of pipe, m

Crush - crush load, N/m

For 200 mm (8 in) Class 150 pipe, of 18 mm (0.71 in) wall thickness, the frequency distribution indicates that crush tests varied from 55.6 kN/m (3810 lbs/ft) to 106.2 kN/m (7279 lbs/ft).

Hydrotest data exhibited similar variation. A test of 27 pieces of pipe produced the results shown in Figure 5. Hydrostatic modulus of rupture (MR) varied from 22.1 to 33.2 x 10^6 kPa (3200-4800 psi). For thick walled pipe, MR is related to burst strength as follows:[6]

$$MR_{Hyd} = \text{Burst Pressure} \times \frac{(OD^2 + ID^2)}{(OD^2 - ID^2)}$$

where:

OD - outside diameter

ID - inside diameter

For 150 mm (6 in) Class 150 pipe, the mean burst pressure was 5861 kPa (850 psi) and the standard deviation was 517 kPa (75 psi). Thus, all samples could be expected to test above the AWWA C400-80 standard of 440 kPa (632 psi).

CTD031800

These data for new pipe provide a basis for understanding the variation in crush and hydrotest data shown by the samples from the field surveys discussed below. A/C pipe is designed and manufactured so that all pieces will meet or exceed standard strength requirements. As a result, most pipe lengths are substantially stronger than standards require. Nevertheless, substantial variation in test results even on the same Class and size of pipe can be expected.

Aggressive Water Index

The Aggressive Index (AI) in AWWA C300-80 as given is one of several indices used to characterize the corrosive tendencies of potable water and was used to characterize the waters in this test program discussed below. It is not a direct measure of corrosivity, rather, the AI indicates the calcium carbonate ($CaCO_3$) stability of the water, i.e. whether or not $CaCO_3$ is deposited on the pipe walls creating a surface coating which protects against corrosion. The AI is calculated from the following formula:

$$AI = pH + \log (AH)$$

where:

AI - Aggressive Index

pH - power of H^+, standard pH units

A - Total alkalinity, mg/l as $CaCO_3$

H - Calcium hardness, mg/l as $CaCO_3$

The deposition of a $CaCO_3$ coating is dependent on pH, alkalinity, hardness (calcium + magnesium concentration), total dissolved solids (TDS) and water temperature. Given all these variables, the AI does not always correctly predict corrosivity. For example, low alkalinity waters are generally corrosive even though the AI might indicate otherwise, because the low concentration of $CaCO_3$ prevents the formation of a protective coating. A corrosion expression which reflects these conditions in predicting corrosive attack on A/C pipe is presented in Reference 8.

A/C Pipe Field Study

As part of ongoing quality assurance programs, a field study on 45 field installations of A/C water distribution pipe was conducted.[7] Emphasis was on older installations in geographically diverse areas handling waters ranging from non-aggressive to highly aggressive. Field technicians obtained and verified the history of A/C pipe samples provided by cooperating water utilities and testing was carried out

CTD031801

in the laboratory on 305 mm (12 in)* long samples per the test methods previously discussed. In addition, a depth of penetration study was performed on a coupon from each sample by scraping away any soft material from the inside surface and measuring the remaining wall thickness with a micrometer.

A summary of the overall field survey results are shown in Table 2. Of the 25 samples that could be crush tested, only three, Nos. 17, 33 and 41 failed to exceed the requirements of AWWA C400-80. The remaining 20 samples could not be tested because of inadequate sample strength or damage. Two samples were hydrotested, No. 40 and 42. Both tested over 6205 kPa (900 psi) exceeding the AWWA C400-80 specification of 440 kPa (632 psi) by nearly 50%.

As shown in Table 3 the degree of interior corrosion is apparently a function of the aggressivity of the water and is essentially independent of service life. A tabulation of the samples exposed to the most aggressive waters, shown in Table 4, reveals that only one of the samples, No. 33 failed to meet AWWA crush test standards. This sample was not the most severely attacked of the group and its low crush strength was probably not indicative of the general condition of the system from which it was taken. The data also show that thin protective coatings of the asphaltic type are apparently quite effective. Table 5 lists the coated samples, only one of which showed any evidence of even slight corrosion. This particular sample was of an older type of pipe, differing markedly in composition and curing process than the other samples. It was also observed in some of the samples that upstream corrosion of metallic pipe components caused the deposition of an iron based reddish coating on the A/C pipe. This did not seem to confer any additional corrosion resistance to the pipe, as examination of Table 2 will show.

In earlier work, two full length samples of 20.3 cm (8 in) diameter Class 150 pipe were removed from the Cleveland, Ohio water system and tested for flexure, crush and hydraulic strength.[9] The pipe had been in service for 28 years handling water of an average aggressive index of 11.2. The results of the analysis are shown in Table 6. All tests were run by an independent laboratory in accordance with AWWA Standard test procedures.

Finished Water Additives

Substantial research into the use of metallic ion based water additives for corrosion protection of A/C pipe has also been carried out. Extensive work by Buelow, et al, of the U.S. Environmental Protection Agency found that zinc chloride ($ZnCl_2$) added to aggressive waters would protect A/C pipe from corrosion, as long as addition to the finished water was continuous and pH was 8.2 or higher.[10] In 1978, the

* A few samples were less than 305 mm (12 in) long; data was extrapolated in these cases.

A/C pipe manufacturing industry through the Association of Asbestos Cement Pipe Producers (AACPP) set up a Task Force on Aggressive Waters to carry out cooperative research on A/C pipe corrosion. A number of aggressive water research projects have been carried out on in situ pipe protection using water stream additives. One study verified the results of the EPA study and went on to show that the protective effect of $ZnCl_2$ additive was predicated on continued addition to the water stream.[11] Other research indicated some protection against corrosion from ferric chloride additives, again requiring continuous addition to maintain protection.[12] Companion work to the A/C pipe field study supported indications that $ZnCl_2$ additives could reduce corrosive attack on A/C pipe, but the degree of protection conferred by a 0.5 - 1.0 mg/l $ZnCl_2$ concentration was indeterminant.[13]

Based on this extensive work, plus other studies and field experience, neutralization of aggressive waters by pH adjustment and/or lime (calcium carbonate) addition is the preferred approach. This process is well established in drinking water treatment technology and, most importantly, it can protect all components of the distribution system, metallic and non-metallic alike, from interior corrosion.

Conclusion

Photographs of some of the actual samples studied in the field survey, providing many years of service in water ranging from moderately to highly aggressive, are shown in Figure 6. They graphically illustrate the high resistance to internal corrosion of A/C pipe and its excellent long term strength retention. The data substantiate the ability of asbestos-cement water distribution pipe to convey moderately to highly aggressive potable waters over a long period of time with only minimal corrosion and little or no apparent loss of strength. The degree of corrosive attack correlated with the measured aggressive index of the conveyed water, but even where corrosion occurred the structural integrity was maintained. Those samples which had interior asphaltic coatings showed essentially no signs of corrosive attack even when conveying highly aggressive waters.

References

1. Cohn, M. M., Sewers for Growing America, Certain-teed Corporation, 1966, p. 145.

2. Listed standards available from American Water Works Association, 6666 West Quincy Avenue, Denver, Colorado 80235.

3. Listed standards available from American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103.

4. Norwood, B. A., "Proposed Redesign of Pressure Pipe SPR/p/23," Johns-Manville Corporation, Report No. 425-967, December 15, 1965.

5. Singer, F. L., Strength of Materials, Harper Brothers, New York, New York, 1951, p. 175.

6. Asbestos Cement Pipe Design and Installation, American Water Works Association, Manual of Water Supply Practice, pending.

7. Herr, J. F., "Transite Field Study Program," Johns-Manville Corporation, Report No. E 425-T-1424, August 22, 1980.

8. Richlie, D. A., "Reaction Rate Expression Predicting the Effect of Aggressive Waters on Asbestos Cement Pipe," paper prepared for Corrosion '81, National Association of Corrosion Engineers Conference, Toronto, Canada.

9. Bigham, G. F., "Witness Excavation of Asbestos Cement Pipe & Witnessing Tests at the Plant," Pittsburg Testing Laboratories, Cleveland, Ohio, Report No. CL 9973, May 29, 1975.

10. Buelow, R. W., Millette, J. F., McFarren, E. F., Symons, J. M., "The Behavior of Asbestos Cement Pipe Under Various Water Quality Conditions, A Progress Report," American Water Works Association Journal, February, 1980, pp. 91-101.

11. Puskar, V., "Aggressive Water Project - Tests Conducted During the Period of September 1979 - January 1980," ASARCO Research Report, March 6, 1980.

12. Hawkins, F. E., "Certain-teed Corporation Fiber Sealing Experiments," Certain-teed Corporation Research Project No. 343, August 3, 1979.

13. Richlie, D. A., "Verification of EPA Experiments on the Effects of Aggressive Waters Containing Zinc on A/C Coupons," Johns-Manville Corporation, Internal Correspondence, March 11, 1980.

TABLE 1

AWWA Crush and Hydrotest Standards for A/C Pipe

Nominal Pipe Size		Class 100 Internal Pressure		Class 100 External Load		Class 150 Internal Pressure		Class 150 External Load		Class 200 Internal Pressure		Class 200 External Load	
(in)	(mm)	*psi*	kPa	*lb/lin ft*	kN/m	*psi*	kPa	*lb/lin ft*	kN/m	*psi*	kPa	*lb/lin ft*	kN/m
4	100	417	2900	4100	60	616	4200	5400	79	809	5600	8700	127
6	150	441	3000	4000	58	632	4400	5400	79	815	5600	9000	136
8	200	472	3300	4000	58	653	4500	5500	80	824	5700	9300	136
10	250	490	3400	4400	64	650	4500	7000	102	826	5700	11000	161
12	300	490	3400	5200	76	658	4500	7600	111	830	5700	11800	172
14	350	500	3400	5200	76	650	4500	8600	126	826	5700	13500	197
16	400	500	3400	5800	85	654	4500	9200	134	825	5700	15400	225

*It is necessary to apply a load factor (see AWWA C401) to the three-edge bearing loads obtained in the crushing tests specified in Sec. 5.2.4 of this standard in order to correlate then to the field loads.

Source: Reference 2

TABLE 2

Field Survey Results

Sample No.	Source	Size (mm)	Size *(in)*	Class	Age (yr)	AI	Penetration (mm)	Penetration *(in)*	Remaining Wall Thickness (mm)	Remaining Wall Thickness *(in)*	Color	Crush Sample kN/m	Crush Sample *lbs/ft*	Crush Specification kN/m	Crush Specification *lbs/ft*
1	San Jose, CA	100	4	--	41	12	0.254	0.010	17.91	0.705	gray-brown	--	--	--	--
2	Bellbrook, OH	150	6	--	30	--	0.051	0.002	17.14	0.675	brown	--	--	--	--
3	Malvern, PA	200	8	100	38	11.2	0.381	0.015	15.52	0.611	gray-brown	59.5	4080	58.4	4000
4	Dedham, MA	200	8	150	25	(8.6)	2.083	0.082	19.23	0.757	brown	157.3	10780	80.3	5500
5	Norfolk, MA	250	10	150	32	(9.2)	0.660	0.026	26.14	1.029	gray-brown	--	--	--	--
6	Bryan, TX	250	10	--	39	--	1.372	0.054	27.91	1.099	brown	--	--	--	--
7	Cozad, NB	50	2	--	30	--	0.203	0.008	14.53	0.572	gray-brown	195.6	13400	--	--
8	Lordstown, OH	250	10	150	27	12.2	0.203	0.008	26.49	1.043	white	140.4	9620	102.2	7000
9	Franklin, MA	200	8	150	38	(9.2)	0.102	0.004	21.97	0.865	black[d]	--	--	--	--
10	Bernardsville, NJ	150	6	150	46	10.3	0.229	0.009	18.39	0.724	brown	154.4	10580	78.8	5400
11	East Warwick, RI	200	8	150	31	8.2	1.372	0.054	20.60	0.811	brown	142.4	9760	80.3	5500
12	Mount Pleasant, NY	75	3	150	32	--	0.457	0.018	13.89	0.547	reddish-brown	134.5	9220	97.8	6700
13[b]	Brunswick, ME	200	8	150	32	(11.0)	1.854	0.073	15.57	0.613	brown	96.3	6600	80.3	5500
14	Quincy, IL	200	8	150	17	--	0.076	0.003	25.58	1.007	gray-brown	167.0	11440	80.3	5500
15	Watson, CA	50	2	--	38	--	0.178	0.007	11.94	0.470	reddish-brown	--	--	--	--
16	Avon, CA	200	8	100	39	--	0.330	0.013	26.95	1.061	brown	--	--	--	--
17[c]	Santa Rosa, CA	100	4	200	37	--	0.254	0.010	24.16	0.951	black[d]	78.8	5400	127.0	8700
18	Fox Lake, IL	100	4	150	27	12.4	0.102	0.004	12.85	0.506	reddish-brown	118.9	8150	--	--
19	Sherrard, IL	100	4	200	28	12.5	0.102	0.004	15.70	0.618	gray-brown	133.8	9170	127.0	8700
20	Paradise, CA	200	8	150	14	10.0	0.254	0.010	21.34	0.840	dark-brown	124.9	8560	80.3	5500
21	Wareham, MA	200	8	150	43	(8.1)	1.016	0.040	16.81	0.662	gray	87.1	5970	80.3	5500
22	Holliston, MA	200	8	--	7	9.0	1.092	0.043	18.80	0.740	light brown	--	--	--	--
23	Sandwich, MA	200	8	150	31	9.0	2.134	0.084	15.60	0.614	reddish-brown	84.1	5760	80.3	5500
24	Hyannis, MA	200	8	150	19	8.3	0.051	0.002	21.79	0.858	black[d]	--	--	--	--
25	Port Arthur, TX	200	8	150	28	--	0.076	0.003	21.21	0.835	gray	--	--	--	--
26	Galesburg, IL	200	8	--	20	11.8	0.406	0.016	19.81	0.780	gray-brown	--	--	--	--

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TABLE 2

(Continued)

Sample No.	Source	Size (mm)	Size (in)	Class	Age (yr)	AI	Penetration (mm)	Penetration (in)	Remaining Wall Thickness (mm)	Remaining Wall Thickness (in)	Color	Crush Sample kN/m	Crush Sample lbs/ft	Crush Specification kN/m	Crush Specification lbs/ft
27	Coats, NC	200	8	100	20	11.6	0.076	0.003	16.38	0.645	black[d]	63.0	4320	58.4	4000
28	Dover, DE	150	10	150	30	11.9	0.381	0.015	26.29	1.035	brown	189.7	13000	102.2	7000
29	Shaw AFB, SC	200	8	150	10	(8.8)	4.440	0.175	14.60	0.575	brown	--	--	--	--
30	Salinas, CA	150	6	150	45	11.6	(64 lb. density old machine)					--	--	--	--
31	Terra Bella, CA	200	8	150	15	(11.3)	0.254	0.010	--	--	reddish-brown	123.8	8480	80.3	5500
32	West Boyleston, MA	200	8	150	38	9.3	0.051	0.002	21.49	0.846	black[d]	--	--	--	--
33	East Brunswick, NJ	200	8	150	19	(9.8)	1.499	0.059	20.27	0.798	brown	14.9	1020	80.3	5500
34	Minot, ND	250	10	150	--	--	0.152	0.006	26.21	1.032	gray-brown	--	--	--	--
35	San Antonio, TX	100	4	150	--	--	0.203	0.008	12.72	0.051	gray-brown	81.1	5560	78.8	5400
36	Bayshore, NY	200	8	150	22	10.1	1.016	0.040	19.58	0.771	dark gray	149.4	10240	80.3	5500
37	Louisville, KY	100	4	150	20	--	0.076	0.003	17.17	0.676	dark brown	127.3	8720	78.8	5400
38	West Boyleston, MA	200	8	150	39	9.3	2.388	0.094	17.68	0.696	brown	--	--	--	--
39	Lunnenburg, MA	150	6	150	30	9.0	0.051	0.002	19.30	0.760	black[d]	--	--	--	--
40[e]	Simsbury, CT	150	6	150	39	(10.4)	1.626	0.064	17.75	0.699	dark brown	92.2	6320	78.8	5400
41	Savannah Beach, GA	150	6	--	25	--	3.506	0.138	10.29	0.405	reddish-brown	26.7	1830	--	--
42[f]	Louisville, GA	150	6	150	42	10.3	0.178	0.007	15.49	0.610	gray	91.8	6290	78.8	5400
43	Stanley County, NC	300	12	150	15	--	0.000	0.000	30.07	1.184	gray	--	--	--	--
44	Chiefland, FL	200	8	150	30	12.5	1.372	0.054	16.53	0.651	gray-brown	--	--	--	--
45	Wareham, MA	250	10	150	13	7.6	0.102	0.004	21.84	0.860	black[d]	--	--	--	--

Notes:

(a) AI in parentheses run by J-M. Others reported by water utilities.
(b) Sample 13 water reported by utility to be 9.7 - use average of 10.4
(c) Sample 17 must be an old style pipe. Wall thickness of 0.951 much greater than the 0.66 required to 4-200.
(d) Black coloration means asphalt coating.
(e) Hydrotested at 6274 kPa (910 psi).
(f) Hydrotested at 6722 kPa (975 psi).

Source: Reference 7

TABLE 3

Corrosion of A/C Pipe Compared to Aggressive Index

Pipe Interior	A.I.	Total Samples	Avg. A.I.	Avg. Depth of Penetration (mm)	Avg. Depth of Penetration (in)	Avg. Years	Avg. Remaining Wall (Percent)
Plain	Below 10.0	9	8.9	1.854	0.073	26	91
Plain	10.0 - 10.9	6	10.3	0.864	0.034	33	96
Plain	11.0 - 11.9	4	11.6	0.356	0.014	26	99
Plain	12.0 +	5	12.3	0.046	0.016	31	98
Asphalt	7.6 - 11.6	7	--	--	0.004	28	100

Source: Reference 7

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TABLE 4

Corrosion of A/C Pipe
Exposed to Strongly Aggressive Waters

Sample	AI	Years	Depth of Penetration (mm)	Depth of Penetration (*in*)	Solid Wall Remaining (Percent)
4	8.6	25	2.083	0.082	90
5	9.2	32	0.660	0.026	98
11	8.2	31	1.372	0.054	95
21	8.1	43	1.016	0.040	94
22	9.0	7	1.092	0.043	95
23	9.0	31	2.134	0.084	88
33	9.8	19	1.499	0.059	93
33	9.3	39	2.388	0.094	88

Source: Reference 7

CTD031807

TABLE 5

Cleveland, Ohio A/C Pipe Test Data

Sample	Flexural Load[1] 10^6Pa	psi	Crush Test[2] kN/m	lbs/lin ft	Hydro Test[3] kPa	psi
1	55.8	8100	----	----	5445	790
2	64.4	9340	124.0	8500	----	----

NOTES:
1. AWWA Standard 52.4 x 10^6Pa (7600 psi)
2. AWWA Standard 80.3 kN/m (5500 psi)
3. AWWA Standard 3620 kPa (525 psi)

Source: Reference 9

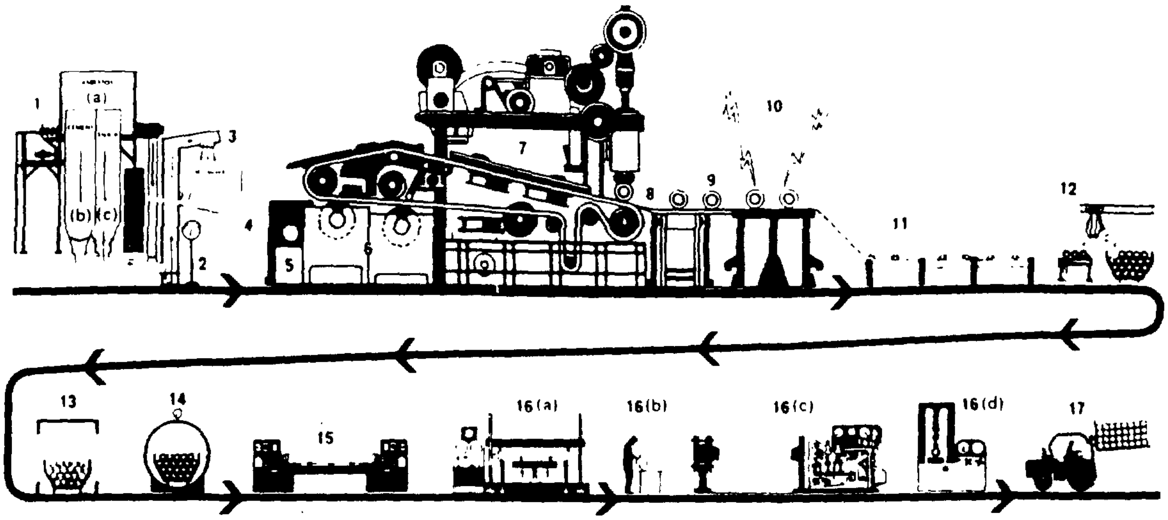
TABLE 6

Performace of Asphaltic Coated A/C Pipe

Sample	AI	Years	Penetration (mm)	Penetration (in)	Solid Wall Remaining (Percent)
9	9.2	38	0.102	0.004	100
17	---	37	0.254	0.010	99
24	8.3	19	0.051	0.002	100
27	11.6	20	0.076	0.003	100
32	9.3	38	0.051	0.002	100
39	9.0	30	0.051	0.002	100
45	7.6	13	0.102	0.004	100

Source: Reference 7

CTD031809



FLOW CHART OF TRANSITE PIPE MANUFACTURE

1 **Production line bins** raw materials enter the line as follows
   (a) **asbestos**–from the willow where the fiber is separated into individual strands and thoroughly mixed
   (b) **cement**–directly from receiving hoppers
   (c) **silica**–from grinding mill
2 **Electronic Scales**–for precise weighing accurate control for uniform results
3. **Dry Mixer** blends raw materials thoroughly
4 **Conveying Trough** water carries stock to wet mix vat
5 **Wet Mix Vat**–thorough dispersion of reinforcing fibers
6 **Screen Cylinder Mold** picks up slurry and deposits on moving felt
7 **Vacuum Box**–excess water removed
8 **Felt** deposits stock on **Mandrel** wall thickness built up under pressure to proper size
9 **Mandrel (with pipe)**–removed from machine next mandrel positioned
10 **Electrolytic Loosener**–frees pipe from mandrel prevents distortion
11 **Slow-down Conveyor**–provides pre-cure time, initial set
12 **Mandrels** removed and pipe stencilled for identification
13. **Air Cure Room**–strict control of time temperature and humidity
14. **Autoclaves** high pressure steam curing imparts maximum strength and excellent chemical stability
15 **Lathes**–trim and machine ends to exact dimensions
16 **Testing Equipment** checks for adherence to rigid specifications
   (a) **flexure testing** machine
   (b) **inspection**
   (c) **hydrostatic tester**
   (d) **crush tester** (laboratory)
17 **Materials Handling Equipment** transfers pipe to shipping area

Courtesy: Johns-Manville Corporation

Figure 1 A/C Pipe Manufacturing Process

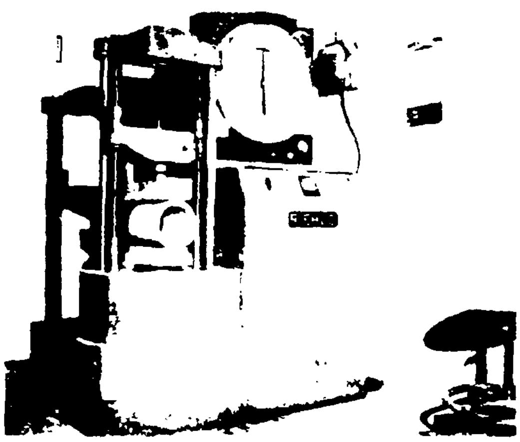


Figure 2 Crush Test Apparatus

Figure 3 Hydrotest Apparatus

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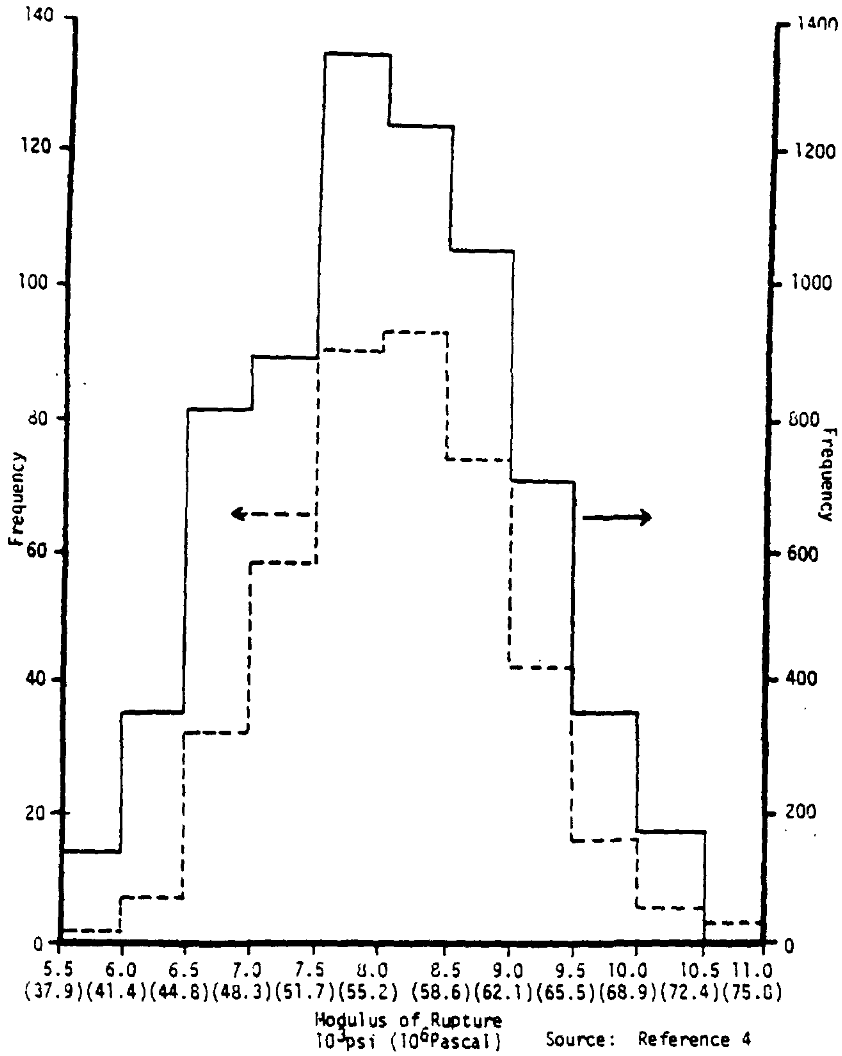

Figure 4 Crush Tests Data Frequency Distribution

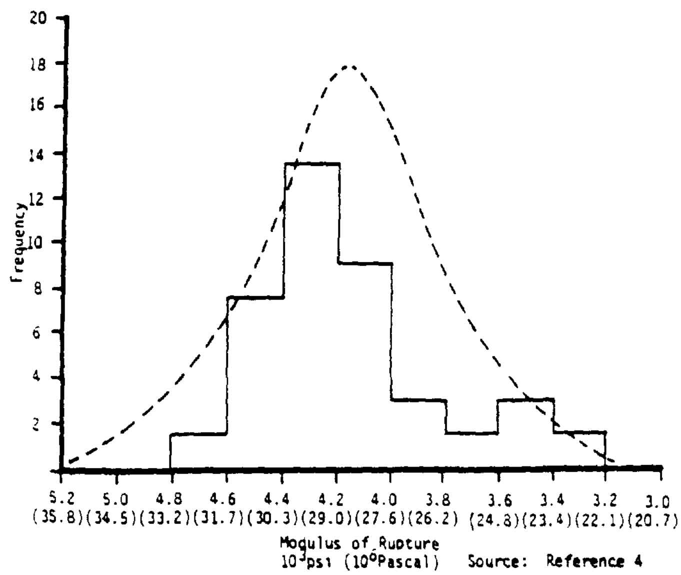

Figure 5 Hydrotest Data Frequency Distribution

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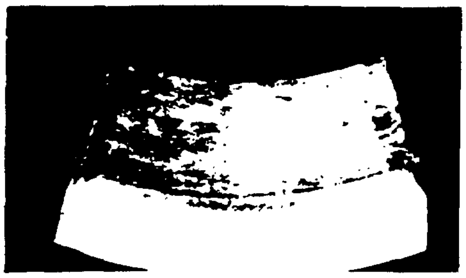
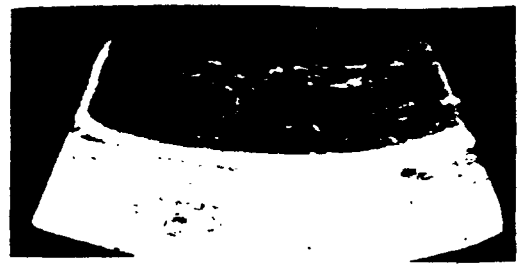


LOUISVILLE, GA 42YRS. A.I.10.3



DEDHAM MA 25YRS A.I.8.6 0.082

EAST WARWICK, R.I. 31YRS. A.I.8.2

WAREHAM, MA. 43YRS. A.I.8.1 0.138

Figure 6 Field Test Samples

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STRUCTURAL PERFORMANCE OF ASBESTOS CEMENT PIPE IN CORROSIVE POTABLE WATER ENVIRONMENT

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ABSTRACT

Field experience with asbestos-cement (A/C) water distribution pipe used in potable water service for conveying corrosive (aggressive) waters is reported. Forty-five samples of A/C pipe from geographically diverse areas and of varying ages were analyzed for signs of corrosive water attack and loss of structural integrity. All but 3 of the samples tested for crush strength exceeded the requirements for new pipe. Corrosion penetration was minimal or absent in most cases, particularly for pipe conveying low to moderately aggressive water. The long term performance of factory applied coatings was found to be excellent. Iron based inorganic coatings, apparently from the corrosion of metallic system components, were deposited in situ on some of the pipe samples but the protection thereby provided against aggressive attack was indeterminant. Data from other industry and EPA studies show that metal salt based corrosion inhibitors added to the water can, under certain conditions, retard aggressive water attack on A/C pipe provided the inhibitor is added properly and continuously to the water stream.

Composition, manufacture and testing of A/C pipe are also discussed. Data on the variability of crush and hydrotest results are presented. Conclusions regarding the long term performance of A/C pipe and the efficacy and need for protective coatings are given.

Introduction and Background

Asbestos cement (A/C) pipe was first manufactured in Europe at the turn of the century by hand rolling flat asbestos-cement sheet stock into a cylinder while still wet. However, the resulting product had little strength. In the early 1900's an Italian, Mazza, developed a process for rolling a continuous film of asbestos-cement on a removable cylinder (mandrel) and the modern A/C pipe industry was born.

Autoclave cured A/C pipe is formed from a mixture of three (3) main ingredients, plus water:[1]

	Percent by weight
Asbestos fiber	15-20
Silica flour	34-32
Portland cement	51-48

The asbestos fiber is also a blend of various fiber types, typically "white" (chrysotile) and "blue" (crocidolite). Silica flour is produced by grinding quartz sand in a ball mill until a fine powder is produced.

The manufacture of A/C pipe, shown in Figure 1, begins with automated opening of plastic sealed bags of fiber, followed by mechanical processing of the asbestos to "debundle" the asbestos into the individual fibers which give the pipe its characteristic high strength. The opened fiber is then mixed with the other materials, slurried, and the pipe is formed under high pressure on a continuous pipe making machine. After initial cure, the mandrel is removed and tne pipe goes to the final curing process, autoclaving. This high temperature (171-185^{o} C) (340-365^{o} F) high pressure (689-1034 kPa) (100-150 psi) steam curing, causes the free lime byproduct of the cement hydration to be 99% reacted with the finely ground silica flour, imparting superior strength and corrosion resistance over water or air cured A/C pipe.

Following autoclaving each pipe is machined, fitted with a push on type coupling and subjected to quality control tests. Machining assures a close tolerance fit of pipe couplings and appurtenances, an important factor in the low water loss experienced with installed A/C pipe systems.

Testing A/C Pipe

New A/C pipe is subjected to physical inspection followed by strength and composition testing to control the finished quality. Four tests are principally used:

Hydrostatic tests

Flexure test

Crushing test

Uncombined calcium hydroxide (free lime) tests

Three types of hydrostatic tests are used on A/C pipe. The first, "proof" testing checks the burst resistance of each pipe up to 3.5 times its rated pressure. In addition, a test to 4 times rated pressure is conducted on one pipe of each lot, usually one out of 300 pieces. For research purposes, samples of the pipe may be tested to burst to determine ultimate strength. The latter test was used to develop the burst data presented later herein.

The hydrostatic and flexure tests are conducted on all A/C pipe to 200 mm (8 in) in diameter, with larger sizes subjected to hydrostatic testing only. In the flexure test, the pipe is subjected to a point load applied at the center with the ends supported on rigid blocks. This test verifies the resistance of the pipe to bending loads. Crush and free lime tests are conducted on each pipe lot.

Detailed test procedures for A/C pipe are set forth by two nationally recognized standards setting organizations:

American Water Works Association:[2]

AWWA C400-80
AWWA C402-77

American Society for Testing and Materials:[3]

ASTM C296-78
ASTM C500-77
ASTM C500-79a
ASTM C668-79

For purposes of the work reported herein, crush, flexure, and hydrostatic tests were used to evaluate the pipe samples. Tests were run on 305 mm (12 in) long pipe samples to compare structural integrity to standard specifications. Figure 2 shows a photograph of the standard 3 edge crushing test; Figure 3 depicts the hydrostatic test equipment. Table 1 provides AWWA standard crush and hydrotest strength requirements for A/C water distribution pipe.

Variability of Crush and Hydrotest Results

As part of an overall evaluation of test procedures, more than 7500 pieces of Class 150 A/C pipe, ranging in diameter from 100-600 mm (4-24 in) were tested.[4] The results are plotted on the frequency distribution plot shown in Figure 4. The left hand scale and dashed line drawing provide the results of a 1965 study of 412 samples, all Class 150. The right hand scale and solid line drawing provides the results of an earlier study of 7100 samples. The results are expressed in terms of the generalized modulus of rupture (MR) which can be related to the crush loading for a 305 mm (12 in) long sample as follows: [5]

$$MR = \frac{\text{Crush} \times (\text{ID pipe} + \text{WT})}{(\text{WT})^2}$$

where:

MR - modulus of rupture, kPa

ID - interior diameter of pipe, m

WT - wall thickness of pipe, m

Crush - crush load, N/m

For 200 mm (8 in) Class 150 pipe, of 18 mm (0.71 in) wall thickness, the frequency distribution indicates that crush tests varied from 55.6 kN/m (3810 lbs/ft) to 106.2 kN/m (7279 lbs/ft).

Hydrotest data exhibited similar variation. A test of 27 pieces of pipe produced the results shown in Figure 5. Hydrostatic modulus of rupture (MR) varied from 22.1 to 33.2 x 10^6 kPa (3200-4800 psi). For thick walled pipe, MR is related to burst strength as follows:[6]

$$MR_{Hyd} = \text{Burst Pressure} \times \frac{(OD^2 + ID^2)}{(OD^2 - ID^2)}$$

where:

OD - outside diameter

ID - inside diameter

For 150 mm (6 in) Class 150 pipe, the mean burst pressure was 5861 kPa (850 psi) and the standard deviation was 517 kPa (75 psi). Thus, all samples could be expected to test above the AWWA C400-80 standard of 440 kPa (632 psi).

These data for new pipe provide a basis for understanding the variation in crush and hydrotest data shown by the samples from the field surveys discussed below. A/C pipe is designed and manufactured so that all pieces will meet or exceed standard strength requirements. As a result, most pipe lengths are substantially stronger than standards require. Nevertheless, substantial variation in test results even on the same Class and size of pipe can be expected.

Aggressive Water Index

The Aggressive Index (AI) in AWWA C300-80 as given is one of several indices used to characterize the corrosive tendencies of potable water and was used to characterize the waters in this test program discussed below. It is not a direct measure of corrosivity, rather, the AI indicates the calcium carbonate ($CaCO_3$) stability of the water, i.e. whether or not $CaCO_3$ is deposited on the pipe walls creating a surface coating which protects against corrosion. The AI is calculated from the following formula:

$$AI = pH + \log (AH)$$

where:

AI - Aggressive Index

pH - power of H^+, standard pH units

A - Total alkalinity, mg/l as $CaCO_3$

H - Calcium hardness, mg/l as $CaCO_3$

The deposition of a $CaCO_3$ coating is dependent on pH, alkalinity, hardness (calcium + magnesium concentration), total dissolved solids (TDS) and water temperature. Given all these variables, the AI does not always correctly predict corrosivity. For example, low alkalinity waters are generally corrosive even though the AI might indicate otherwise, because the low concentration of $CaCO_3$ prevents the formation of a protective coating. A corrosion expression which reflects these conditions in predicting corrosive attack on A/C pipe is presented in Reference 8.

A/C Pipe Field Study

As part of ongoing quality assurance programs, a field study on 45 field installations of A/C water distribution pipe was conducted.[7] Emphasis was on older installations in geographically diverse areas handling waters ranging from non-aggressive to highly aggressive. Field technicians obtained and verified the history of A/C pipe samples provided by cooperating water utilities and testing was carried out

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in the laboratory on 305 mm (12 in)* long samples per the test methods previously discussed. In addition, a depth of penetration study was performed on a coupon from each sample by scraping away any soft material from the inside surface and measuring the remaining wall thickness with a micrometer.

A summary of the overall field survey results are shown in Table 2. Of the 25 samples that could be crush tested, only three, Nos. 17, 33 and 41 failed to exceed the requirements of AWWA C400-80. The remaining 20 samples could not be tested because of inadequate sample strength or damage. Two samples were hydrotested, No. 40 and 42. Both tested over 6205 kPa (900 psi) exceeding the AWWA C400-80 specification of 440 kPa (632 psi) by nearly 50%.

As shown in Table 3 the degree of interior corrosion is apparently a function of the aggressivity of the water and is essentially independent of service life. A tabulation of the samples exposed to the most aggressive waters, shown in Table 4, reveals that only one of the samples, No. 33 failed to meet AWWA crush test standards. This sample was not the most severely attacked of the group and its low crush strength was probably not indicative of the general condition of the system from which it was taken. The data also show that thin protective coatings of the asphaltic type are apparently quite effective. Table 5 lists the coated samples, only one of which showed any evidence of even slight corrosion. This particular sample was of an older type of pipe, differing markedly in composition and curing process than the other samples. It was also observed in some of the samples that upstream corrosion of metallic pipe components caused the deposition of an iron based reddish coating on the A/C pipe. This did not seem to confer any additional corrosion resistance to the pipe, as examination of Table 2 will show.

In earlier work, two full length samples of 20.3 cm (8 in) diameter Class 150 pipe were removed from the Cleveland, Ohio water system and tested for flexure, crush and hydraulic strength.[9] The pipe had been in service for 28 years handling water of an average aggressive index of 11.2. The results of the analysis are shown in Table 6. All tests were run by an independent laboratory in accordance with AWWA Standard test procedures.

Finished Water Additives

Substantial research into the use of metallic ion based water additives for corrosion protection of A/C pipe has also been carried out. Extensive work by Buelow, et al, of the U.S. Environmental Protection Agency found that zinc chloride ($ZnCl_2$) added to aggressive waters would protect A/C pipe from corrosion, as long as addition to the finished water was continuous and pH was 8.2 or higher.[10] In 1978, the

* A few samples were less than 305 mm (12 in) long; data was extrapolated in these cases.

A/C pipe manufacturing industry through the Association of Asbestos Cement Pipe Producers (AACPP) set up a Task Force on Aggressive Waters to carry out cooperative research on A/C pipe corrosion. A number of aggressive water research projects have been carried out on in situ pipe protection using water stream additives. One study verified the results of the EPA study and went on to show that the protective effect of $ZnCl_2$ additive was predicated on continued addition to the water stream.[11] Other research indicated some protection against corrosion from ferric chloride additives, again requiring continuous addition to maintain protection.[12] Companion work to the A/C pipe field study supported indications that $ZnCl_2$ additives could reduce corrosive attack on A/C pipe, but the degree of protection conferred by a 0.5 - 1.0 mg/l $ZnCl_2$ concentration was indeterminant.[13]

Based on this extensive work, plus other studies and field experience, neutralization of aggressive waters by pH adjustment and/or lime (calcium carbonate) addition is the preferred approach. This process is well established in drinking water treatment technology and, most importantly, it can protect all components of the distribution system, metallic and non-metallic alike, from interior corrosion.

Conclusion

Photographs of some of the actual samples studied in the field survey, providing many years of service in water ranging from moderately to highly aggressive, are shown in Figure 6. They graphically illustrate the high resistance to internal corrosion of A/C pipe and its excellent long term strength retention. The data substantiate the ability of asbestos-cement water distribution pipe to convey moderately to highly aggressive potable waters over a long period of time with only minimal corrosion and little or no apparent loss of strength. The degree of corrosive attack correlated with the measured aggressive index of the conveyed water, but even where corrosion occurred the structural integrity was maintained. Those samples which had interior asphaltic coatings showed essentially no signs of corrosive attack even when conveying highly aggressive waters.

References

1. Cohn, M. M., Sewers for Growing America, Certain-teed Corporation, 1966, p. 145.

2. Listed standards available from American Water Works Association, 6666 West Quincy Avenue, Denver, Colorado 80235.

3. Listed standards available from American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103.

4. Norwood, B. A., "Proposed Redesign of Pressure Pipe SPR/p/23," Johns-Manville Corporation, Report No. 425-967, December 15, 1965.

5. Singer, F. L., Strength of Materials, Harper Brothers, New York, New York, 1951, p. 175.

6. Asbestos Cement Pipe Design and Installation, American Water Works Association, Manual of Water Supply Practice, pending.

7. Herr, J. F., "Transite Field Study Program," Johns-Manville Corporation, Report No. E 425-T-1424, August 22, 1980.

8. Richlie, D. A., "Reaction Rate Expression Predicting the Effect of Aggressive Waters on Asbestos Cement Pipe," paper prepared for Corrosion '81, National Association of Corrosion Engineers Conference, Toronto, Canada.

9. Bigham, G. F., "Witness Excavation of Asbestos Cement Pipe & Witnessing Tests at the Plant," Pittsburg Testing Laboratories, Cleveland, Ohio, Report No. CL 9973, May 29, 1975.

10. Buelow, R. W., Millette, J. F., McFarren, E. F., Symons, J. M., "The Behavior of Asbestos Cement Pipe Under Various Water Quality Conditions, A Progress Report," American Water Works Association Journal, February, 1980, pp. 91-101.

11. Puskar, V., "Aggressive Water Project - Tests Conducted During the Period of September 1979 - January 1980," ASARCO Research Report, March 6, 1980.

12. Hawkins, F. E., "Certain-teed Corporation Fiber Sealing Experiments," Certain-teed Corporation Research Project No. 343, August 3, 1979.

13. Richlie, D. A., "Verification of EPA Experiments on the Effects of Aggressive Waters Containing Zinc on A/C Coupons," Johns-Manville Corporation, Internal Correspondence, March 11, 1980.

TABLE 1

AWWA Crush and Hydrotest Standards for A/C Pipe

Nominal Pipe Size		Class 100 Internal Pressure		Class 100 External Load		Class 150 Internal Pressure		Class 150 External Load		Class 200 Internal Pressure		Class 200 External Load	
(in.)	(mm)	*psi*	kPa	*lb/lin ft*	kN/m	*psi*	kPa	*lb/lin ft*	kN/m	*psi*	kPa	*lb/lin ft*	kN/m
4	100	417	2900	4100	60	616	4200	5400	79	809	5600	8700	127
6	150	441	3000	4000	58	632	4400	5400	79	815	5600	9000	136
8	200	472	3300	4000	58	653	4500	5500	80	824	5700	9300	136
10	250	490	3400	4400	64	650	4500	7000	102	826	5700	11000	161
12	300	490	3400	5200	76	658	4500	7600	111	830	5700	11800	172
14	350	500	3400	5200	76	650	4500	8600	126	826	5700	13500	197
16	400	500	3400	5800	85	654	4500	9200	134	825	5700	15400	225

*It is necessary to apply a load factor (see AWWA C401) to the three-edge bearing loads obtained in the crushing tests specified in Sec. 5.2.4 of this standard in order to correlate then to the field loads.

Source: Reference 2

TABLE 2

Field Survey Results

Sample No.	Source	Size (mm)	Size (in)	Class	Age (yr)	AI	Penetration (mm)	Penetration (in)	Remaining Wall Thickness (mm)	Remaining Wall Thickness (in)	Color	Crush Sample kN/m	Crush Sample lbs/ft	Crush Specification kN/m	Crush Specification lbs/ft
1	San Jose, CA	100	4	--	41	12	0.254	0.010	17.91	0.705	gray-brown	--	--	--	--
2	Bellbrook, OH	150	6	--	30	--	0.051	0.002	17.14	0.675	brown	--	--	--	--
3	Malvern, PA	200	8	100	38	11.2	0.381	0.015	15.52	0.611	gray-brown	59.5	4080	58.4	4000
4	Dedham, MA	200	8	150	25	(8.6)	2.083	0.082	19.23	0.757	brown	157.3	10780	80.3	5500
5	Norfolk, MA	250	10	150	32	(9.2)	0.660	0.026	26.14	1.029	gray-brown	--	--	--	--
6	Bryan, TX	250	10	--	39	--	1.372	0.054	27.91	1.099	brown	--	--	--	--
7	Cozad, NB	50	2	--	30	--	0.203	0.008	14.53	0.572	gray-brown	195.6	13400	--	--
8	Lordstown, OH	250	10	150	27	12.2	0.203	0.008	26.49	1.043	white	140.4	9620	102.2	7000
9	Franklin, MA	200	8	150	38	(9.2)	0.102	0.004	21.97	0.865	black[d]	--	--	--	--
10	Bernardsville, NJ	150	6	150	46	10.3	0.229	0.009	18.39	0.724	brown	154.4	10580	78.8	5400
11	East Warwick, RI	200	8	150	31	8.2	1.372	0.054	20.60	0.811	brown	142.4	9760	80.3	5500
12	Mount Pleasant, NY	75	3	150	32	--	0.457	0.018	13.89	0.547	reddish-brown	134.5	9220	97.8	6700
13[b]	Brunswick, ME	200	8	150	32	(11.0)	1.854	0.073	15.57	0.613	brown	96.3	6600	80.3	5500
14	Quincy, IL	200	8	150	17	--	0.076	0.003	25.58	1.007	gray-brown	167.0	11440	80.3	5500
15	Watson, CA	50	2	--	38	--	0.178	0.007	11.94	0.470	reddish-brown	--	--	--	--
16	Avon, CA	200	8	100	39	--	0.330	0.013	26.95	1.061	brown	--	--	--	--
17[c]	Santa Rosa, CA	100	4	200	37	--	0.254	0.010	24.16	0.951	black[d]	78.8	5400	127.0	8700
18	Fox Lake, IL	100	4	150	27	12.4	0.102	0.004	12.85	0.506	reddish-brown	118.9	8150	--	--
19	Sherrard, IL	100	4	200	28	12.5	0.102	0.004	15.70	0.618	gray-brown	133.8	9170	127.0	8700
20	Paradise, CA	200	8	150	14	10.0	0.254	0.010	21.34	0.840	dark-brown	124.9	8560	80.3	5500
21	Wareham, MA	200	8	150	43	(8.1)	1.016	0.040	16.81	0.662	gray	87.1	5970	80.3	5500
22	Holliston, MA	200	8	--	7	9.0	1.092	0.043	18.80	0.740	light brown	--	--	--	--
23	Sandwich, MA	200	8	150	31	9.0	2.134	0.084	15.60	0.614	reddish-brown	84.1	5760	80.3	5500
24	Hyannis, MA	200	8	150	19	8.3	0.051	0.002	21.79	0.858	black[d]	--	--	--	--
25	Port Arthur, TX	200	8	150	28	--	0.076	0.003	21.21	0.835	gray	--	--	--	--
26	Galesburg, IL	200	8	--	20	11.8	0.406	0.016	19.81	0.780	gray-brown	--	--	--	--

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TABLE 2

(Continued)

Sample No.	Source	Size (mm)	Size (in)	Class	Age (yr)	AI	Penetration (mm)	Penetration (in)	Remaining Wall Thickness (mm)	Remaining Wall Thickness (in)	Color	Crush Sample kN/m	Crush Sample lbs/ft	Crush Specification kN/m	Crush Specification lbs/ft
27	Coats, NC	200	8	100	20	11.6	0.076	0.003	16.38	0.645	black[d]	63.0	4320	58.4	4000
28	Dover, DE	150	10	150	30	11.9	0.381	0.015	26.29	1.035	brown	189.7	13000	102.2	7000
29	Shaw AFB. SC	200	8	150	10	(8.8)	4.440	0.175	14.60	0.575	brown	--	--	--	--
30	Salinas, CA	150	6	150	45	11.6	(64 lb. density old machine)					--	--	--	--
31	Terra Bella, CA	200	8	150	15	(11.3)	0.254	0.010	--	--	reddish-brown	123.8	8480	80.3	5500
32	West Boyleston, MA	200	8	150	38	9.3	0.051	0.002	21.49	0.846	black[d]	--	--	--	--
33	East Brunswick, NJ	200	8	150	19	(9.8)	1.499	0.059	20.27	0.798	brown	14.9	1020	80.3	5500
34	Minot, ND	250	10	150	--	--	0.152	0.006	26.21	1.032	gray-brown	--	--	--	--
35	San Antonio, TX	100	4	150	--	--	0.203	0.008	12.72	0.051	gray-brown	81.1	5560	78.8	5400
36	Bayshore, NY	200	8	150	22	10.1	1.016	0.040	19.58	0.771	dark gray	149.4	10240	80.3	5500
37	Louisville, KY	100	4	150	20	--	0.076	0.003	17.17	0.676	dark brown	127.3	8720	78.8	5400
38	West Boyleston, MA	200	8	150	39	9.3	2.388	0.094	17.68	0.696	brown	--	--	--	--
39	Lunnenburg, MA	150	6	150	30	9.0	0.051	0.002	19.30	0.760	black[d]	--	--	--	--
40[e]	Simsbury, CT	150	6	150	39	(10.4)	1.626	0.064	17.75	0.699	dark brown	92.2	6320	78.8	5400
41	Savannah Beach, GA	150	6	--	25	--	3.505	0.138	10.29	0.405	reddish-brown	26.7	1830	--	--
42[f]	Louisville, GA	150	6	150	42	10.3	0.178	0.007	15.49	0.610	gray	91.8	6290	78.8	5400
43	Stanley County, NC	300	12	150	15	--	0.000	0.000	30.07	1.184	gray	--	--	--	--
44	Chiefland, FL	200	8	150	30	12.5	1.372	0.054	16.53	0.651	gray-brown	--	--	--	--
45	Wareham, MA	250	10	150	13	7.6	0.102	0.004	21.84	0.860	black[d]	--	--	--	--

Notes:

(a) AI in parentheses run by J-M. Others reported by water utilities.
(b) Sample 13 water reported by utility to be 9.7 - use average of 10.4
(c) Sample 17 must be an old style pipe. Wall thickness of 0.951 much greater than the 0.66 required to 4-200.
(d) Black coloration means asphalt coating.
(e) Hydrotested at 6274 kPa (910 psi).
(f) Hydrotested at 6722 kPa (975 psi).

Source: Reference 7

TABLE 3

Corrosion of A/C Pipe Compared to Aggressive Index

Pipe Interior	A.I.	Total Samples	Avg. A.I.	Avg. Depth of Penetration (mm)	Avg. Depth of Penetration (in)	Avg. Years	Avg. Remaining Wall (Percent)
Plain	Below 10.0	9	8.9	1.854	0.073	26	91
Plain	10.0 - 10.9	6	10.3	0.864	0.034	33	96
Plain	11.0 - 11.9	4	11.6	0.356	0.014	26	99
Plain	12.0 +	5	12.3	0.046	0.016	31	98
Asphalt	7.6 - 11.6	7	--	--	0.004	28	100

Source: Reference 7

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TABLE 4

Corrosion of A/C Pipe
Exposed to Strongly Aggressive Waters

Sample	AI	Years	Depth of Penetration (mm)	(*in*)	Solid Wall Remaining (Percent)
4	8.6	25	2.083	0.082	90
5	9.2	32	0.660	0.026	98
11	8.2	31	1.372	0.054	95
21	8.1	43	1.016	0.040	94
22	9.0	7	1.092	0.043	95
23	9.0	31	2.134	0.084	88
33	9.8	19	1.499	0.059	93
33	9.3	39	2.388	0.094	88

Source: Reference 7

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TABLE 5

Cleveland, Ohio A/C Pipe Test Data

Sample	Flexural Load[1]		Crush Test[2]		Hydro Test[3]	
	10^6Pa	psi	kN/m	lbs/lin ft	kPa	psi
1	55.8	8100	----	----	5445	790
2	64.4	9340	124.0	8500	----	----

NOTES: 1. AWWA Standard 52.4 x 10^6Pa (7600 psi)

2. AWWA Standard 80.3 kN/m (5500 psi)

3. AWWA Standard 3620 kPa (525 psi)

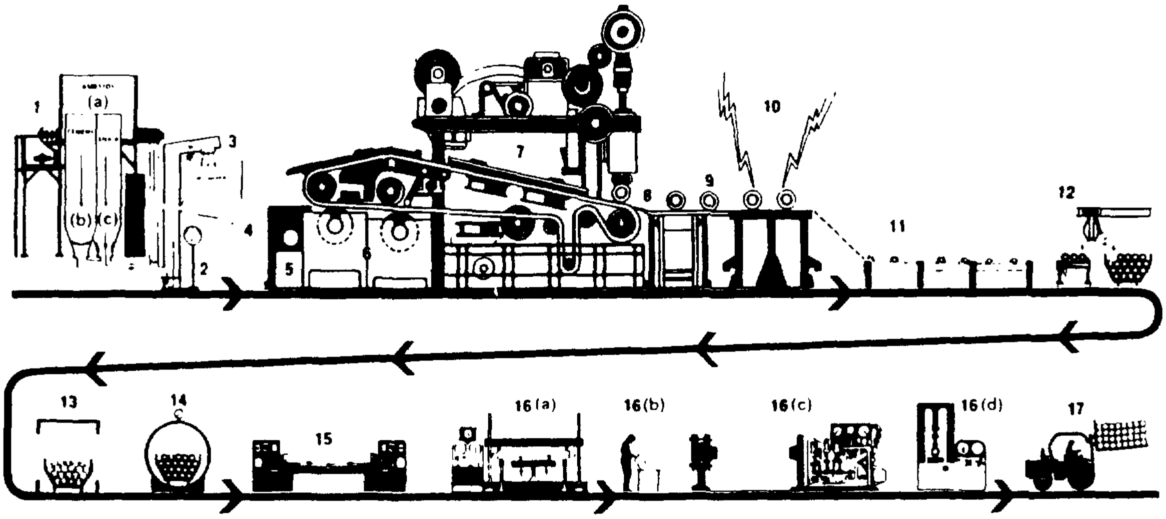
Source: Reference 9

TABLE 6

Performace of Asphaltic Coated A/C Pipe

Sample	AI	Years	Penetration (mm)	Penetration (in)	Solid Wall Remaining (Percent)
9	9.2	38	0.102	0.004	100
17	---	37	0.254	0.010	99
24	8.3	19	0.051	0.002	100
27	11.6	20	0.076	0.003	100
32	9.3	38	0.051	0.002	100
39	9.0	30	0.051	0.002	100
45	7.6	13	0.102	0.004	100

Source: Reference 7



FLOW CHART OF TRANSITE PIPE MANUFACTURE

1 **Production line bins** raw materials enter the line as follows
  (a) **asbestos** - from the willow where the fiber is separated into individual strands and thoroughly mixed
  (b) **cement** directly from receiving hoppers
  (c) **silica** - from grinding mill
2. **Electronic Scales** - for precise weighing accurate control for uniform results
3 **Dry Mixer** blends raw materials thoroughly
4 **Conveying Trough** water carries stock to wet mix vat
5 **Wet Mix Vat** - thorough dispersion of reinforcing fibers
6 **Screen Cylinder Mold** picks up slurry and deposits on moving felt
7. **Vacuum Box** excess water removed
8 **Felt** deposits stock on **Mandrel** wall thickness built up under pressure to proper size
9 **Mandrel (with pipe)**–removed from machine next mandrel positioned
10. **Electrolytic Loosener**–frees pipe from mandrel prevents distortion
11 **Slow-down Conveyor** -provides pre cure time, initial set
12 **Mandrels** removed and pipe stencilled for identification
13. **Air Cure Room** -strict control of time, temperature and humidity
14. **Autoclaves** high pressure steam curing imparts maximum strength and excellent chemical stability
15 **Lathes** - trim and machine ends to exact dimensions
16 **Testing Equipment** - checks for adherence to rigid specifications
  (a) **flexure testing** machine
  (b) **inspection**
  (c) **hydrostatic tester**
  (d) **crush tester** (laboratory)
17 **Materials Handling Equipment** transfers pipe to shipping area

Courtesy: Johns-Manville Corporation

Figure 1 A/C Pipe Manufacturing Process

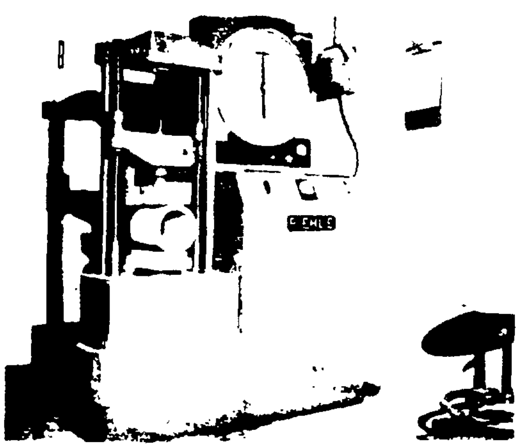


Figure 2 Crush Test Apparatus

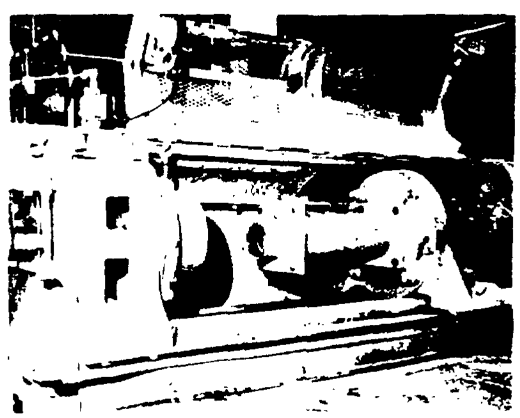


Figure 3 Hydrotest Apparatus

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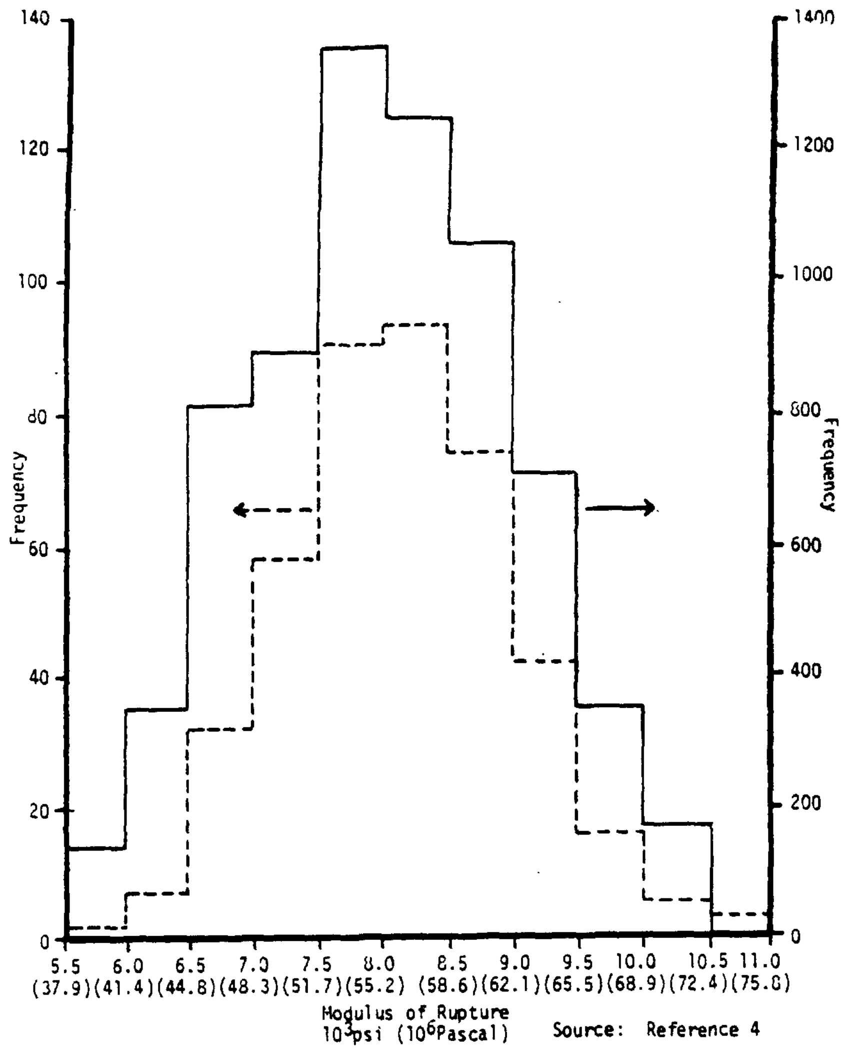


Figure 4 Crush Tests Data Frequency Distribution

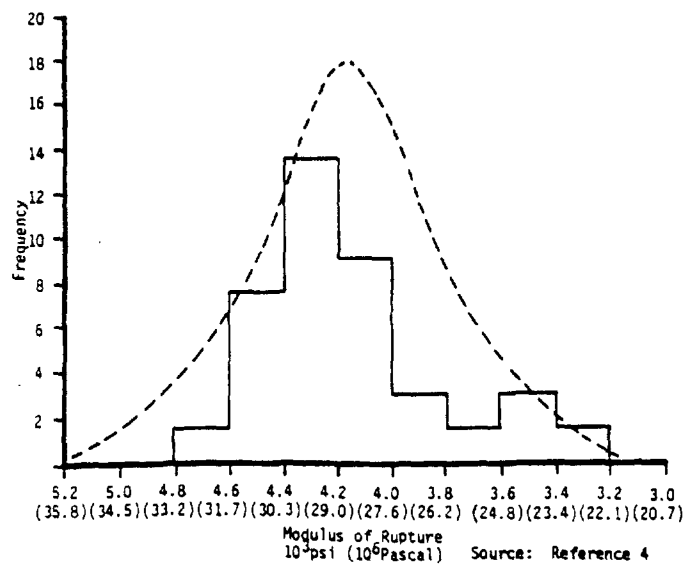
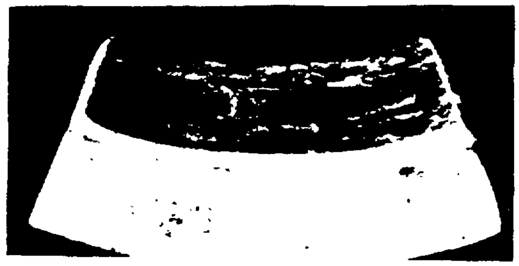
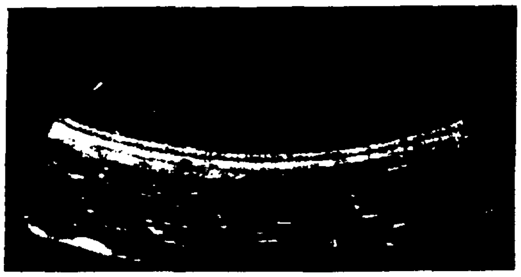


Figure 5 Hydrotest Data Frequency Distribution

LOUISVILLE, GA 42YRS A.I 10.3



DEDHAM MA 25YRS A.I.8.6 0.082



EAST WARWICK, R.I. 31YRS. A.I.8.2

WAREHAM, MA. 43YRS. A.I.8.1 0.138

Figure 6 Field Test Samples

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RECENT STUDIES ON ASBESTOS IN DRINKING WATER

Study	Type - Fiber Levels	Conclusions
Smith, et al (1980)	Animal feeding (lifetime) 1.3 billion fibers/liter	No incidence of disease attributable to asbestos
U.S. National Institute of Environmental Health Sciences (1981-1982)	Animal feeding (lifetime) Asbestos 1% of diet	Hamsters-no carcinogenic effect. Rats-no carcinogenic effect, inflammation, diverticulitis or ulcerations
Hilding, et al (1981)	Animal feeding (lifetime) 78 billion fibers/liter	No carcinogenic effect
Bolton, Davis et al (1982)	Animal feeding (25 mos.) Asbestos 0.27% of diet	No excess of malignant tumor; no mucosal abnormalities
Pigott (manuscript in preparation)	Animal feeding (lifetime)	No carcinogenic effect
Sigurdson, et al (1981)	Epidemiologic (ecologic) 1 to 64 million fibers/liter	No link between ingested asbestos and cancer
Toft, et al (1981)	Epidemiologic (ecologic) Various levels	No increase in mortality rates for any cancer
Polissar, et al (1982)	Epidemiologic (census tract) 206 million fibers/liter	No increased death or disease in exposed populations
Polissar, et al (1983)	Epidemiologic (case control) 206 million fibers/liter	No increased risk of cancer in exposed populations
U.S. Environmental Protection Agency (manuscript in preparation)	Epidemiologic (census tract) Over 10 million fibers/liter	No statistically significant differences between exposed and unexposed populations

REVIEW OF "CHRYSOTILE ASBESTOS FIBERS IN DRINKING WATER FROM ASBESTOS-CEMENT PIPE"

By

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I. INTRODUCTION

The paper, "Chrysotile Asbestos Fibers in Drinking Water from Asbestos-Cement Pipe" by Kanarek et al [1] is a supplementary analysis of data taken from a larger two part study [2,3,4,5,6] that examined the presence of asbestos fibers in drinking water and disease incidence in the San Francisco (California) Bay Area. In the paper, the authors question "the validity of aggressiveness indexes for prediction of fiber release from asbestos-cement pipes." Their arguments are based on a purported "demonstration of substantial increases in asbestos fiber counts in nonaggressive drinking water" flowing through asbestos-cement (A/C) pipe within selected distribution systems.

This review will comment on the Aggressiveness Index (AI) as a measure of asbestos release from asbestos-cement pipe, the assumptions and inferences made by the investigators, experimental design, sampling and data analysis techniques, and possible explanations for the study's observations.

II. ASSUMPTIONS ABOUT THE AGGRESSIVENESS INDEX

The underlying assumption of the paper is, in the authors' words, " ... that there is a positive correlation between fiber release from the walls of A/C pipe and the 'aggressiveness' or corrosiveness of water." It is further assumed that this correlation is quantitative, consistent and predictive. These assumptions are incorrect.

Prior to development of the Aggressiveness Index (AI), manufacturers recommended that the use of A/C pipe in water with a Langlier Index of -2.0 (AI=12.0) or less would be inconsistent with maintaining the 50-100 year design lifetime of water systems. In the early 1970's, engineering consultants requested that American Water Works Association (AWWA) and American Society for Testing and Materials (ASTM) specifications for A/C pipe further define conditions of product use in so-called aggressive and non-aggressive waters. It should be emphasized that the manufacturers' recommendations and AWWA/ASTM guidelines[7,8] were developed solely for the purpose of ensuring long-term, structural integrity of A/C pressure pipe. The AI was not conceived to be a predictor of asbestos fiber release. As the U.S. Environmental Protection Agency (EPA) Drinking Water Research Division has stated on this matter:

> The use of the AI as a predictor of the condition of the interior surface of the pipe in contact with the drinking water and its tendency to retain or release asbestos fibers has come about in spite of the fact that the original intention of the index was to outline water conditions that might cause structural failure of the pipe. The difference in application is very significant.[9] (emphasis in original)

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There is a substantial body of scientific evidence supporting the view that there is neither a quantifiable nor a predictive relationship between any corrosion index and levels of asbestos released from A/C pipe into drinking water.

In 1980, an EPA researcher testified:

> Further work has shown that the aggressive index is not the perfect indicator of whether a water will corrode an asbestos-cement pipe and release fibers.
>
> The calculation of the aggressiveness index alone is not always sufficient to predict actual behavior of A/C pipe.[10]

And in 1981, EPA again underlined the imprecision of the AI, almost flatly rejecting the AI-fiber release hypothesis:

> Substantial field and pilot plant data, combined with comprehensive evaluation of many of the important chemical complexation and precipitation reactions occurring in drinking water, give compelling evidence that the AI has immense shortcomings with regard to use as a predictor of fiber release and interior surficial pipe condition that enjoin against its use under most circumstances.[11]

The Agency's most recent published work on the Aggressiveness Index states:

> There are several major avenues by which the AI is open to criticism as an indicator of corrosivity and fiber release, the manner in which has most frequently been used.[12]

The EPA paper goes on to detail the deficiencies of the AI in reliably predicting fiber release, concluding:

> The Aggressiveness Index as traditionally conceived is not theoretically sound from a chemical standpoint to predict fiber release and degradation of the interior pipe surface in systems that are undersaturated with respect to calcite. Fortunately, it has generally proved to predict falsely pipe deterioration more often than to predict falsely pipe stability in field situations.
>
> * * * *
>
> Observations of A/C pipe sections from many localities conclusively demonstrate that natural inhibitory factors, such as those mentioned, are commonly the pipe protection mechanism, not calcite saturation.[12]

The AI is a technical guideline governing the selection of the proper type of A/C pipe for waters of differing aggressiveness. It is based on empirical observations and physical testing of specimens from A/C pipe systems. Based on published analyses[13], it can be concluded that the AI is comfortably conservative in assuring long-term structural integrity of the product.

In summary then, the basic assumption of the Kanarek et al paper i.e. that there is a valid correlation between the AI and fiber release, simply is incorrect. The AI was never meant to correlate with fiber release from A/C pipe and in fact, extensive studies by the U.S. Environmental Protection Agency demonstrate this rather conclusively.

III. EXPERIMENTAL DESIGN AND DATA COLLECTION

The original study design and collection of data, which are the bases for this paper, gave little or no consideration to selecting a sample population (representative distribution systems) in such a way that a valid generalization to a larger population (all distribution systems in the San Francisco area, for example) could be made.

The data suggests no purposeful sampling technique to determine whether the A/C distribution systems were contributing asbestos to water conveyed through them. The authors explain this away by stating the collection of "before" and "after" A/C pipe samples " ... was only one of several factors involved in this overall assessment of asbestos in drinking water supplies." The facts are that the study of fiber release from A/C pipe was a matter of tertiary importance to the authors. By its own admission, the original study had limited relevance to A/C pipe:

> Samples were taken before and after lengths of asbestos-cement pipe (See Table 18). Although, in some cases there were apparently substantial increases as a result of the water passing through the pipe, the data appear inconsistent. This study did not include the amount of asbestos-cement pipe in the various distribution systems as a variable in the analysis because of its questionable significance and the difficulty of determining its location, age, and dimensions.[14] (emphasis added).

An EPA funded report on the asbestos sampling plan for the San Francisco Bay area study states:

> The contribution (if any) of asbestos-cement pipe to the level of asbestos found in drinking water has yet to be determined. The Cooper study was not specifically designed to measure the

risk that might be attributed to the use of asbestos-cement pipe.[15]

The harshest criticism of the study's design and data collection/analysis comes from the Environmental Protection Agency, which funded the original project:

> The only suggestion of asbestos cement pipe being attacked by water with an aggressiveness index greater than 12 was in conjunction with an epidemiological study done in the Bay Area of California. The data on the pipe were not gathered specifically for the purpose of studying pipe corrosion but were pulled from the overall study data set. Some information about the systems such as previous tapping procedures and whether the pipe had been deteriorated from some other cause were not available. None of the pipe had been dug up for inspection, unfortunately. I did not feel after reviewing the data that I could consider this a complete picture of what is happening in these systems. A more complete study is necessary before I can conclude pipe corrosion occurs with water of an aggressiveness index of greater than 12.[16] (emphasis added)

With these facts in mind, any statistics generated from this sampling data base and any conclusions drawn from those statistics, must be considered of dubious value.

A closer examination of the samples themselves reveals equally serious compromises in sound science. The authors purport to have thirty-nine pairs of "before" and "after" water samples corresponding to "before" and "after" flowing through A/C pipe. There are not thirty-nine paired samples. Firstly, consider a day on which a single "before" sample is taken from a water treatment plant discharge and four "after" samples are taken from residential taps after flowing through varying lengths of A/C pipe. This sampling plan is not generating four independent "before/after" pairs. The four "before" samples are artificial — they are not independent of each other, they are the same observation because only one sample was actually taken. In the paper, nineteen of the thirty-nine pairs of samples were selected in this manner. Table 1 (page 8) lists the original data, indicating which pairs are from identical "before" samples. No attempt is made by the authors to account for this dependence. This is particularly ironic in light of the authors' statement that various taps were sampled "to determine the continuity of values throughout the distribution area." So, although the paper acknowledges the need for a supplementary analysis to account for this dependency, it was never undertaken.

Second, consider a given section of A/C pipe sampled on different days. Each repeated sample contributes information regarding the change in fiber counts within that section. Only to the extent that the given section of pipe is better characterized does each repeated sample contribute information with respect to characterizing the distribution system as a whole. These repeated samples logically should not be allowed to have as much influence in an analysis of the total system as a pair of measurements on different sections of pipe within the system. In the paper, fifteen of the thirty-nine samples are from sections of pipe with repeated measures. Again, no attempt was made by the authors to account for these two different sources of variation in fiber counts.

It should be mentioned that these "within-section" repeated measurements are desirable. They supply information concerning the variability of fiber counts over time. This information can be used to establish limits on the uncertainty associated with the expected number of counts for a given sample. Unfortunately, as seen above, the authors do not use the data to this end.

TABLE 1

PAIRED BEFORE AND AFTER RESULTS
CHRYSOTILE FIBERS PER LITER FROM COOPER ET AL[2]

Pair Number	System	Before A/C Pipe	After A/C Pipe
1	A	$< 1.0 \times 10^4$ (A)	$< 2.0 \times 10^4$ R1 (C)
2	A	6.0×10^4	$< 2.0 \times 10^4$ R1
3	A	$< 2.5 \times 10^4$	$< 1.0 \times 10^5$ R1
4	A	$< 2.0 \times 10^4$	$< 2.0 \times 10^4$ R2
5	A	2.0×10^5	1.5×10^5 R2
6	A	1.0×10^5	3.0×10^5 R2
7	A	$< 1.0 \times 10^4$	$< 2.0 \times 10^4$ R3
8	A	$< 2.0 \times 10^4$	1.4×10^5 R3
9	A	1.0×10^5	2.0×10^6 R3
10	A	$< 2.0 \times 10^4$	$< 2.0 \times 10^4$
11	A	4.0×10^5	1.0×10^5
12*	A	5.0×10^4	5.0×10^4 (B)
13*	A	5.0×10^4	3.5×10^5
14*	A	5.0×10^4	5.0×10^5
15*	B	$< 5.0 \times 10^3$	$< 7.0 \times 10^3$
16*	B	$< 5.0 \times 10^3$	$< 2.5 \times 10^4$
17	B	1.6×10^5	5.4×10^5 R4
18*	B	$< 2.5 \times 10^4$	1.5×10^5 R4
19*	B	$< 2.5 \times 10^4$	1.9×10^6 R5
20*	B	$< 2.5 \times 10^4$	5.4×10^4
21*	B	$< 2.5 \times 10^4$	$< 2.5 \times 10^4$
22	B	1.8×10^5	3.8×10^4 R5

Pair Number	System	Before A/C Pipe	After A/C Pipe
23*	B	7.6×10^5	2.0×10^5
24*	B	7.6×10^5	4.0×10^5
25	B	2.6×10^5	2.0×10^5
26	B	2.5×10^4	2.0×10^5
27*	C	5.0×10^4	6.2×10^6
28*	C	5.0×10^4	3.4×10^7
29*	C	5.0×10^4	2.5×10^6
30*	C	5.0×10^4	$< 1.0 \times 10^6$
31	-	2.5×10^4	2.0×10^5
32	-	$< 2.5 \times 10^4$	3.0×10^5
33*	C	2.0×10^5	6.0×10^6
34*	C	2.0×10^5	6.4×10^6
35*	C	$< 2.5 \times 10^4$	2.0×10^7
36*	C	$< 2.5 \times 10^4$	1.5×10^6
37	C	$< 2.5 \times 10^4$	5.4×10^4
38	-	4.0×10^4	4.0×10^4
39	-	$< 2.5 \times 10^4$	1.6×10^6

< The fiber count is below the lowest detectable limit listed.

* One 'before' sample for multiple 'after' samples.

RX Replication of same section of pipe.

IV. STATISTICAL ANALYSIS

Although the shortcomings of experimental design and data collection are sufficient to invalidate this research, there also exists erroneous data analysis. Assume for discussion purposes that there are indeed thirty-nine pairs of "before/after" samples with the results as reported: nineteen increases, eleven ties, nine decreases. The authors claim a two-sided significance level of 0.039 from a sign test corrected for continuity. This is not obtained by the standard formula [17]:

$$\begin{aligned} \chi^2 &= \frac{(/a - b/ -1)^2}{n} \\ &= \frac{(/24.5 - 14.5/ - 1)^2}{39} \\ &= 2.08 \end{aligned}$$

where each tie is treated as one-half an increase and one-half a decrease. The significance level of the above chi-square value is 0.150 — not considered to be a significant result.

So, not only does the study fail to employ sound scientific principles in data collection, it incorrectly calculated the significance associated with the most important test statistic.

V. CONFOUNDING FACTORS

The paper concludes that in comparison to the "before" water in one system (System C) " ... an increase of 115 times the number of fibers" was observed after passage through sections of A/C pipe. The authors go on to hypothesize a number of possible explanations for these apparent increases, including:

- breakup of naturally-occurring fiber after flow through A/C pipe
- size of pipe
- water flow rate
- alternate wetting and drying of (pipe) surfaces
- quality of joint materials used
- corrosive cleaners in use to flush sections of pipe
- tapping of pipe
- the possibility that hydrants or "dead ends" could have acted as "reservoirs" for fibers, producing artificially elevated fiber counts.

The paper then dismisses out of hand, without any supporting justification or substantiating data, the possibility that <u>any</u> of the above factors accounted for the apparent asbestos releases in System C. There is no explanation as to whether these factors might explain smaller apparent increases in Systems A and B.

Conspicuous by its absence in the list of potentially confounding factors is perhaps the most important — variations in levels of naturally-occurring asbestos in the source waters. Many of the source waters in the study have fiber concentrations in excess of one million fibers per liter (mfl) and some over 20 mfl. Other investigators have pointed out the ubiquitous nature of asbestos in Bay Area drinking waters:

> As can be seen from the charts (representative asbestos values in Bay Area water systems), none of the major water districts servicing the San Francisco Bay Area are free of asbestos fibers. Individual asbestos measurements range from 10^4 fibers per liter to 1.8×10^8 fibers per liter of finished water.[18]

To demonstrate the possibility (if not probability) of significant asbestos variations in source waters, consider the sources for System C. The Hetch Hetchy Aqueduct delivers water directly to the system's customers. The Hetch Hetchy system (0.13 mfl - 0.24 mfl) is fed by the Calaveras Reservoir (110 mfl) and the San Antonio Reservoir (0.46 mfl).

Portions of System C are also supplied by three treatment plants (0.03-2.1 mfl) and local runoff and wellfields whose asbestos content was not measured. The well and runoff water receives no further treatment which would reduce its asbestos content. Given the natural asbestos content of the different source waters, the variability in asbestos content in the treated waters and the distinct possibility that intermittent "slugs" of untreated high asbestos content water may have been delivered directly to System C by any number of sources, any asbestos levels observed in that system clearly are subject to wide variation regardless of the pipe material. The inability to control for such an important confounding factor clearly renders meaningless any conclusions regarding the role of A/C pipe in contributing asbestos to the drinking water.

Further, the limited number of water samples also raises serious questions about the paper's observations. An EPA funded report on asbestos sampling in the San Francisco Bay Area comments on the problems of such limited sampling, as well as the previously mentioned likelihood of asbestos level variability:

> The individual asbestos fiber concentrations listed in previous sections of this report (Kanarek et al samples) are the values for a single grab sample of tap water taken from a census tract. Water sampling sites were chosen on the basis of 1) being representative of a specific water distribution system and 2) convenience of sampling. In order to more fully characterize the asbestos content of these water systems, it may be necessary to sample a small proportion of a very large flow of water. This would minimize the problems of utilizing grab samples and reduce the number of water samples to be analyzed. This would also take into account the intermittent and non-uniform occurrence of asbestos in water from various sources.[19] (emphasis added).

Finally, in the 1950's and 1960's substantial amounts of asbestos caulking rope were used with lead caulked valves and fittings. This rope is in contact with the water and could conveivably contribute asbestos to water in the distribution system.

VII. AGREEMENT WITH OTHER DATA

Interpretation of data should have coherence i.e. the results of a study are suspect if they conflict with findings from other studies. In this regard, the paper is in serious want of corroboration. Nothing in the extensive body of literature produced on the subject of potential fiber release from A/C pipe makes findings comparable to those made in this paper.

The results of an independent study conducted by one of the Bay Area's largest water utilities actually contradict the paper's findings and hypothesis.

TABLE 2

SYSTEM X
COMPARISON OF ASBESTOS LEVELS IN WATER BEFORE AND AFTER CONVEYANCE THROUGH A/C PIPE

Sample	pH	Alkalinity ($mg/L. CaCO_3$)	Calcium Hardness ($mg/L\ CaCO_3$)	AI	Chrysotile Asbestos (f/L.)
1-Treated Water	9.38	20	8.6	12.21	BDL
Tap Water[1]	9.38	19	8.6	12.20	BDL
2-Treated Water	8.09	103	35.9	12.14	BDL
Tap Water[2]	8.08	103	38.7	12.16	BDL

[1] Conveyed through approximately 1700 linear feet A/C pipe.
[2] Conveyed through approximately 2000 linear feet A/C pipe.

The paper discusses the "unusual" water chemistry of System C and theorizes that the high pH may be unduly and falsely weighting the AI towards nonaggressiveness. The authors also note the low calcium content of the water suggesting this may account for the apparent asbestos increases.

A comparison of System X (Sample 1) with the mean water quality values for System C follows:

TABLE 3

COMPARISON OF WATER QUALITY - SYSTEM C AND SYSTEM X (SAMPLE 1)

Sample	pH	Alkalinity (mg/L. $CaCO_3$)	Calcium Hardness (mg/L. $CaCO_3$)	AI Before	After
System C	9.2	53.2	23.05	11.93	12.54
System X (Sample 1)	9.38	20	8.6	12.21	12.20

Table 3 shows that both the alkalinity and the calcium hardness of Sample 1 are considerably lower than that of System C — a worst case scenario, if you will. Yet, Sample 1 demonstrates no asbestos pick up and no increase in AI as the water traverses the A/C pipe system. Although this is a limited comparison, these observations cast serious doubts over the hypothesis that the low calcium content of the water in System C explains the purported asbestos increases.

VII. CONCLUSIONS

The paper suffers from numerous weaknesses and errors. Its underlying assumption is fallacious — there is not, nor was there ever intended to be a positive correlation between the Aggressiveness Index (AI) and fiber release from A/C pipe. The original study's design, by its own admission, is of limited relevance to A/C pipe. The sampling procedure was extremely limited and did not generate independent "before/after" pairs. The most important test statistic is incorrectly calculated. Important confounding variables are overlooked or ignored — others are dismissed out of hand without explanation. Finally, the results have not been replicated or corroborated by other studies and are inconsistent with more contemporary knowledge on the subject.

REFERENCES

1. Kanarek, M. S., Conforti, P. M., and Jackson, L. A., "Chrysotile Asbestos Fibers in Drinking Water from Asbestos-Cement Pipe," Environmental Science and Technology,, Vol. 15, No. 8, August 1981.

2. Cooper, R. C., Kanarek, M., Murchio, J., Conforti, P., Jackson, L., Callard, R., and Lysmer, D., "Asbestos in Domestic Water Supplies in Five California Counties," Progress Report for Period April 25, 1977 to June 30, 1978. U.S. Environmental Protection Agency Contract No. R 804366-02, EHS Publication No. 78-2, 1978.

3. Kanarek, M. S., "Asbestos in Drinking Water and Cancer Incidence," Ph.D. dissertation, Department of Epidemiology, University of California at Berkeley, 1978.

4. Cooper, R. C., Kanarek, M., Murchio, J., Conforti, P., Jackson, L., Callard, R., and Lysmer, D., "Asbestos in Domestic Water Supplies in Five California Counties, Part II, 1969-1974, Population and Tumor Data Base," U.S. Environmental Protection Agency, Contract No. R 804366-02, EHS Publication No. 79-1, 1979.

5. Kanarek, M. S., Conforti, P. M., Jackson, L., Cooper, R. C., and Murchio, J. C., "Asbestos in Drinking Water and Cancer Incidence in the San Francisco

Bay Area," American Journal of Epidemiology, 112:54-72, 1980.

6. Conforti, P. M., Kanarek, M. S., Jackson, L. A., Cooper, R. C., and Murchio, J. C., "Asbestos in Drinking Water and Cancer Incidence in the San Francisco Bay Area: 1969-1974," Journal of Chronic Diseases, 34:211-224, 1981.

7. American Water Works Association Standard for Asbestos Cement Distribution Pipe, 4 In. Through 16 In., For Water and Other Liquids, AWWA C-400-77, 1977.

8. American Society of Testing and Materials, Standard Method of Testing Asbestos-Cement Pipe, ASTM C-500-76, 1976.

9. Schock, M. R., Logsdon, G. S., and Clark, P. J., "Evaluation and Control of Asbestos-Cement Pipe Corrosion," paper presented at the International Corrosion Forum, National Association of Corrosion Engineers, 1981.

10. Millette, J. R., Direct Testimony at Public Hearing on Proposed Addition to Section 19-13-B102 of the Connecticut Public Health Code, September 16, 1980.

11. Op. Cit. (Schock)

12. Schock, M. R. and Buelow, R. W., "The Behavior of Asbestos-Cement Pipe Under Various Water Quality Conditions: Part 2, Theoretical Considerations," Journal American Water Works Association, December, 1981.

13. Houck, D. H., "Structural Performance of Asbestos-Cement Pipe in Corrosive Potable Water Environments," paper presented at the Internationl Corrosion Forum, National Association of Corrosion Engineers, 1981.

14. Op. Cit. (Kanarek, 1978)

15. Tarter, M. E., and Leong, C. J., "Asbestos Sampling Plan for the San Francisco Bay Area, California," U.S. Environmental Protection Agency, Order No. C3253NAET, July, 1980.

16. Op. Cit. (Millette, 1980)

17. Snedecor, G. W. and Cochran, W. G., Statistical Methods - Sixth Edition, Iowa State University Press, Ames, Iowa, 1967.

18. Op. Cit. (Tarter)

19. Op. Cit. (Tarter)

NEWS

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**SUMMARY OF
SCIENTIFIC AND MEDICAL RESEARCH
ON
ASBESTOS-CEMENT PIPE AND HEALTH**

Some persons who have inhaled heavy concentrations of asbestos fibers in industrial settings have shown increases in gastrointestinal cancer. Since there is evidence that the inhalation of asbestos under certain conditions can be harmful, some have theorized that the ingestion of asbestos in drinking water may also be harmful. Considerable amounts of asbestos-cement (A/C) water pipe are used in North America, Europe and other parts of the world. Thus, questions have been raised about the possible health hazards associated with drinking water conveyed through A/C pipe.

In order to determine whether the swallowing or ingestion of asbestos in drinking water represents a health hazard, two types of studies have been conducted: (1) Statistical or epidemiological* studies, in which the medical experience of one group, exposed to a high level of ingested asbestos, is compared to the experience of another group, exposed to a lower level or no ingested asbestos; and (2) animal studies, in which conclusions are derived from the ingestion, by animals, of asbestos under scientifically controlled conditions.

One of the first major studies was conducted by a panel of government and independent authorities in pathology, epidemiology, analytical methods and public health. Commissioned in 1974 by the American Water Works Association Research Foundation, the committee concluded:

> **"No firm evidence shows that the proper use of asbestos-cement pipe poses a hazard to health by reason of ingestion of asbestos fibers. Calculations comparing the probable ingestion exposure in occupational groups to that likely to occur as a result of ingestion of potable water from asbestos-cement pipe systems suggests that the probability of risk to health from the use of such systems is small - approaching zero."**

EPIDEMIOLOGIC STUDIES

Thomas J. Mason, et al in 1974 conducted a study entitled "Asbestos-Like Fibers in Duluth Water Supply." The study undertook to determine whether fibers present in the drinking water in Duluth, Minnesota produced increased cancer mortality. The study concluded:

> **Thus, in Duluth, one would expect a greater excess of cancer in the esophagus and stomach than in the rectum, but this did not occur.**

In 1976, B. S. Levy of the Minnesota Department of Health continued the investigation made by Mason. Levy was the Acting State Epidemiologist for Minnesota and his co-authors were associated with the University of Minnesota School of Public Health and the Mayo Clinic.

* Epidemiology: the study of the distribution and dynamics of disease in human populations.

Gastrointestinal cancer incidence data for the cities of Duluth, Minneapolis and St. Paul were gathered and compared in the same manner as in the Mason study. (Minneapolis and St. Paul have populations similar to Duluth, but they have few, if any, asbestos fibers in their water supplies). After a thorough investigation, the authors concluded:

> **" ... there was no consistent pattern of statistically significant differences observed" among the three cities.**

The Levy study was updated in 1981 by Eunice Sigurdson, R. N., M.P.H., of the Minnesota Department of Health. She reaffirmed previous findings, stating:

> **... there is currently no observed etiologic or causal association between exposure to amphibole fibers in the Duluth drinking water supply and the development of cancer.**

Thomas R. Fears of the National Cancer Institute published an article in the American Journal of Epidemiology entitled "Cancer Mortality and Asbestos Deposits." The specific question posed in that study was: "Is there an increase in risk from cancer associated with naturally-occurring ›sbestos?"

The abstract of the study states:

> **The study of cancer mortality rates in these matched counties provides no evidence that naturally-occurring asbestos is a great hazard to the general population of counties with asbestos deposits.**

Donald T. Wigle, M.D., Ph.D. and M.P.H., Bureau of Epidemiology, Health and Welfare, Canada, conducted an extensive study in 1977 of municipalities in the Province of Quebec. Entitled "Cancer Mortality in Relation to Municipal Water Supplies," these comparison studies presented an unusual scientific opportunity to analyze cancer mortality in populations exposed to as much as 1.3 billion fibers per liter of drinking water. Despite the extremely high levels of asbestos in drinking water, this study concludes:

> **A study of twenty-two municipalities in Quebec did not reveal excess cancer mortality that could be related to the presence of asbestos fibers in drinking water supplies.**

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The Wigle study was also updated in 1981 with similar conclusions:

> **The mortality rates for persons living in two localities in which asbestos was present in high concentrations in water samples from the distribution system were analyzed. Although there are serious limitations to this type of study, no consistent increase of mortality rates for any cancer was demonstrated.**

The Commins report, published in 1979 under the aegis of the internationally prestigious Water Research Centre, entitled "Asbestos in Drinking Water: A Review," summarized the Wigle study in this fashion:

> **It is reassuring that a recently reported, detailed, epidemiological study carried out in 22 municipalities in Quebec failed to reveal excess cancer mortality that could be related to the presence of asbestos fibers in drinking water supplies. This was despite the fact that some of the water supplies fed to these municipalities were reported to be fairly heavily contaminated with asbestos fibers.**

The first of two studies made in Connecticut concerning the use of asbestos-cement water pipes and the incidence of cancer was entitled "An Investigation of the Use of Asbestos-Cement Pipe for Public Water Supply and the Incidence of Gastrointestinal Cancer in Connecticut." Referred to as the Harrington study, it was published in the American Journal of Epidemiology in 1978 and was co-authored by officials of the U.S. Center for Disease Control, U.S. Environmental Protection Agency (EPA), Yale University School of Medicine and Connecticut State Health Department.

As the Harrington study stated:

> **The possibility of studying reliable cancer incidence data over a 35-year period through the Connecticut Tumor Registry and linking these data with information gathered on asbestos cement pipe studies conducted by U.S. Environmental Protection Agency, prompted the present investigation.**

The findings of the Harrington study are consistent with a determination that the use of asbestos cement pipe does not create a health hazard:

> **This study detected no changes in incidence rates or patterns in Connecticut for cancers of the stomach, colon, or rectum over the period 1935-1973, that could be construed as related to the introduction around 1950 of A/C pipes to carry domestic water supplies to some or most of the residents of certain towns.**

The Meigs study, entitled "Asbestos Cement Pipe and Cancer in Connecticut 1955-1974," was published in the January/February, 1980, edition of The Journal of Environmental Health. The principal investigator, J. Wister Meigs, M.S., is Director of the Connecticut Cancer Epidemiology Unit and Clinical Professor of Epidemiology, Yale University School of Medicine. the Meigs study used essentially the same methods as those used in the Harrington study, but the procedures and techniques were more sensitive and refined. The study was supported in part by the National Cancer Institute and the U.S. Environmental Protection Agency.

Following are the conclusions of the Meigs study:

> **These analyses give no consistent indication that use of A/C pipe in Connecticut public water supplies has been followed by increases in incidence either of "all cancers" of the individual sites considered.**
>
> **Therefore, the lack of coherent evidence of cancer risks from use of A/C pipe is reassuring. (Emphasis in article.) It is consistent with most reports from other areas of the United States.**

Hence, the Harrington study and the Meigs study represent independent, thorough and competent epidemiological studies carried out for the sole purpose of determining the question at issue: whether the use of asbestos-cement pipe creates a hazard to public health. Both studies reached the conclusions: (1) that there was no association between the use of asbestos-cement pipe in Connecticut and incidence of cancer; and (2) in the opinion of the authors of the Meigs study, there was no need to change water distribution policies in this State because of the use of such pipe.

The Kanarek study was conducted in five California counties in the San Francisco Bay Area by Dr. Robert C. Cooper (principal investigator), doctoral candidate Marty Kanarek (project coordinator) and others. The study found a weak statistical correlation between the ingestion of asbestos in drinking water and certain cancers. The Kanarek study was an indirect study in which census tracts with differing amounts of asbestos fibers in their drinking water were compared for cancer incidence, after attempting to take into account certain variables.

By its own admission, the study is of limited value in its relevance to asbestos-cement pipe:

> **Samples were taken before and after passage of water through lengths of asbestos-cement pipe. In most of the districts sampled, there was not a substantial increase in fiber counts after passage through asbestos-cement pipe. The amount of asbestos-cement pipe in the various distribution systems was not included as a variable in the analysis because of difficulty of determining its location, age and dimensions.**
>
> **The study design was that of an indirect epidemiological approch in which the observational unit was the census tract. Studies such as this one can only suggest associations, and cannot pinpoint definite causation.** (Quotation from doctoral thesis).

The California Department of Health Services has taken the following view of the Kanarek

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study:

> **The UC (University of California) doctoral thesis abstract entitled: "Asbestos in Drinking Water and Cancer Incidence," contains no new or original evidence of a medical nature about cancer or asbestos, nor does it establish any causal link between asbestos in Bay Area drinking water and the incidence of cancer.**

The U.S. Environmental Protection Agency (EPA) has stated of the Kanarek study:

> **The University of California investigators are among the first to report finding an association between ingested asbestos and cancer rates. They caution that causative inferences must necessarily be limited because of the indirect nature of the data being compared. This means that the results of this study do not prove that there is a link between Bay Area water and cancer.** (Reference 13)

Kenny S. Crump, Ph.D., a highly respected, independent specialist in environmental risk assessment, has made the following observations about the Kanarek study:

> **It is generally accepted among epidemiologists that ecologic studies such as this ... should not be used to determine cause and effect relationships — irrespective of their findings.**
>
> * * * * *
>
> **Kanarek et al were unable to control many factors which might have been confounded with asbestos levels. These factors include smoking, eating and other personal habits; occupational exposures to carcinogens; and exposures to other environmental pollutants, such as organic contaminants in drinking water.**
>
> * * * * *
>
> **There were apparent discrepancies between two reported analyses of the six year data which this reviewer could not reconcile.**
>
> * * * * *
>
> **There was a lack of consistency with respect to many of the associations found by Kanarek et al. A number of the associations were found in one sex only.**
>
> * * * * *
>
> **This lack of consistency (with five similar studies conducted elsewhere) suggests that the positive associations found by Kanarek et al. are the result of confounding.**

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As if these independent opinions were not sufficient to invalidate the Kanarek study, a biostatistician at the University of California-Berkeley School of Public Health, Dr. Michael Tarter, reanalyzed the Kanarek data. He found in San Francisco a negative correlation between asbestos in drinking water and cancer, that is, in census tracts where asbestos levels were high, cancer incidence rates were lower than in census tracts not exposed to asbestos in drinking water. At the U.S. Environmental Protection Agency Summary Workshop on Ingested Asbestos (October 13-14, 1982), Dr. Tarter cautioned, "Until this finding is fully understood, one must be very careful about drawing any conclusions from the Kanarek study."

EPA recently reported findings of an epidemiologic study in Escambia County, Florida. Asbestos levels ranged from 700,000 to 32.7 million fibers per liter for a period of approximately twenty-five years. EPA scientists concluded:

> **There were no statistically significant differences in cancer mortality between high exposure, moderate exposure and no exposure groups.**

In August, 1982, Dr. Lincoln Polissar of the Fred Hutchinson Cancer Research Center published an important study in the American Journal of Epidemiology. This research also was funded by the U.S. Environmental Protection Agency. Naturally occurring asbestos levels in this study were from 37 million to 556 million fibers per liter of drinking water. The population has been exposed to such levels for over fifty years. The authors concluded:

> **Results of this study and prior studies of cancer in relation to waterborne asbestos are inconsistent and provide little evidence that asbestos in community water supplies has altered the risk of any cancer.**

A more accurate case control study also was conducted on this same population group. Such studies seek to determine whether persons with a given disease are more apt to have been exposed to the agent under investigation (asbestos) than disease free individuals. The principal investigator, Dr. Polissar, reported at the aforementioned EPA Summary Workshop on Ingested Asbestos, that no correlations were found between cancer incidence and asbestos in drinking water. This is the most sophisticated epidemiologic study ever conducted on the question of the potential health effects of ingested asbestos.

ANIMAL FEEDING STUDIES

Animal ingestion studies support and confirm the epidemiologic findings that there is no association between the ingestion of asbestos fibers in drinking water and the presence of a health hazard. Test animals have been fed diets containing substantial portions of asbestos, without inducing related tumors or shortening lifespans.

All of the following scientific authorities have concluded that animal experiments do not support the proposition that the ingestion of asbestos in drinking water is harmful.

Bonser, G.M. and Clayson, D.B., "Feeding of Blue Asbestos to Rats," 45th Annual Report of the British Empire's Cancer Campaign, 242 (1976). An experiment was performed to ascertain whether feeding asbestos to rats would induce peritoneal tumors. Sixty-five rats were fed 1,500 milligrams of crocidolite asbestos per kilogram body weight for life and no tumors were observed.

Smith, W. E., "Asbestos, Talc and Nitrites in Relation to Gastric Cancer," American Industrial Hygiene Association Journal 34:227-228 (1973). This too was a complete life span experiment in which hamsters were fed abnormally large amounts of asbestos.

> **In 45 hamsters maintained throughout their lives on diets containing 1% of the chrysotile or amosite varieties of asbestos, we found no gastric carcinomas and no tumors in the gastrointestinal tract except for a neoplasm in the mesentery of the colon. We are unable to relate that lesion to the treatment, since ashing has revealed no asbestos fibers in it.**

Webster, I., "The Ingestion of Asbestos Fibers," Environmental Health Perspectives, 9:199-202 (1974). Dr. Webster fed baboons heavy doses of crocidolite over considerable periods of time to determine if peritoneal or gastrointestinal cancers could be induced. The report states:

> **In none of the many baboons used was there any evidence of a peritoneal tumor or gastrointestinal tumor.**

Gross, P. et al., "Ingested Mineral Fibers: Do They Penetrate Tissue and Cause Cancer?" Arch. Environmental Health, 29(6):341-347 (1974).

> **Twenty-one months of intimate contact of rat GI (gastrointestinal) mucosa with very high concentrations of chrysotile asbestos failed to produce cancer or any other kind of lesion. Short-term and long-term feeding (up to 1½ years) of chrysotile and crocidolite by a second laboratory resulted in no tumor production in the GI tract or mesothelium during the lifetime of the animals.**

Smith, W. E., et al., "Health of Experimental Animals Drinking Water With and Without Amosite Asbestos and Other Mineral Particles," Journal of Environmental Pathology and Toxicology, 3:277-330, 1980.

In this study, hamsters were administered asbestos in drinking water for their entire lifetimes. Tumor incidence was compared with hamsters that did not consume asbestos. Dr. Smith concluded:

> **In the present experiment, no malignant tumors were found in hamsters maintained on drinking water containing 13,000 million amosite fibers per liter.**

Hilding, A.C., et al., "Biological Effects of Ingested Amosite Asbestos, Taconite Tailings, Diatomaceous Earth and Lake Superior Water in Rats," Archives of Environmental Health, 36:298-303 (1981).

Rats were fed asbestos during their lifetime and were examined at autospy. The dose levels for the treated animals were the equivalent of 5.5 billion fibers per liter (low dose group) and 78 billion fibers per liter (high dose group) of drinking water. The authors concluded:

> **The most significant finding in our study was the absence of gastrointestinal cancer in the animals exposed to the test materials.**
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> * * * * *
>
> **Under the conditions of our study, ingested asbestos ... had no demonstrable carcinogenic effect on the gastrointestinal tract or on other body tissues of the rat.**

Moore, J.H., "Biological Effects of Ingested Asbestos - Status Report, U.S. Department of Health, Education and Welfare, Public Health Service, National Toxicology Program, January, 1981."

The National Institute of Environmental Health Sciences sponsored a $6 million study on the effects of ingested asbestos in rats and hamsters. The asbestos was administered at the rate of 1% of total diet for the entire lifetime of the animals. Results released in 1981 were reported as follows:

> **There was no adverse effect of amosite asbestos on body weight gain or survival. Neither the amosite groups showed an increase rate of neoplasia in any organ or tissue compared to the control groups.**
>
> **Under the conditions of the bioassay, the ingestion of amosite asbestos was not carcinogenic in male and female Syrian golden hamsters.**

NIEHS officials reported in October, 1982 that the lifespans of rats fed chrysotile and crocidolite asbestos also were not affected by exposure. In-house histopathological reviews also showed no carcinogenic effect. These results will be peer-reviewed and published in early 1983.

These animal feeding studies conducted by the federal government are the most extensive ever carried out to assess the effect of ingestion of asbestos fibers on animals. Using the highest asbestos levels found in drinking water, a person would have to drinking 14 million gallons of water per day to consume an amount of asbestos shown to be non-hazardous in these laboratory animal studies.

CONCLUSION

Since 1973, when questions were first raised about the potential health effects of A/C pipe and asbestos in drinking water, U.S. government agencies — the Environmental Protection Agency, Food and Drug Administration, National Institute of Environmental Health Sciences, National Cancer Institute and others — have spent $12-15 million (U.S.) studying this matter. Today, nine years later, the conclusions from this extensive, independent research are clear. There are no apparent adverse health effects from asbestos in drinking water or the use of A/C pipe.

On October 13-14, 1982, EPA held its Summary Workshop on Ingested Asbestos. The purpose of this important meeting was to review all available medical evidence on ingested asbestos and A/C pipe. At that time, Dr. Joseph A. Cotruvo, Director, Criteria and Standards, Office of Drinking Water, announced that EPA would conduct no more research on the subject. The National Academy of Sciences (NAS) Committee on Safe Drinking Water is reviewing the epidemiologic studies on asbestos and drinking water, and will submit its conclusions and recommendations to EPA in early 1983. EPA will use the NAS report, along with the animal feeding study results and public comment, to develop a formal position statement on the issue.