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Copper is transported throughout the body, and is found in high concentrations in liver, brain, kidney, and muscles. A 70-kg adult body contains between 80 and 150 mg copper. Fetal copper concentrations are ten times those of adults (Venugopal and Luckey, 1978).

Copper is excreted principally in bile along with unabsorbed dietary copper. Small amounts are excreted in urine and perspiration. Balanced against biliary excretion, net copper absorption in the GI tract is about 5 percent (Venugopal and Luckey, 1978).

Control of copper absorption, distribution, and excretion is achieved primarily by the liver, but also by carrier proteins in blood (albumin and ceruloplasmin), and cells of the intestinal lining. Hereditary defects in copper metabolism produce diseases characterized by progressive damage to the liver, CNS, and other organs. These include Indian childhood cirrhosis and Mencke's kinky hair syndrome, which are generally fatal in childhood; persons with Wilson's disease can live a normal life when treated with penicillamine (Scheinberg, 1981; Vaughan et al., 1979; Lefkowitch et al., 1982).

Acute Toxicity

Acute ingestion of copper salts stimulates vomiting and, as a consequence, acute poisoning is usually not severe. If the metal is not removed by vomiting, however, copper poisoning results in injury to the liver, kidney and CNS (Gosselin et al., 1976). Exposure to copper has been reported to result in hemolytic anemia (destruction of red blood cells) similar to that seen in persons with glucose-6-phosphate dehydrogenase (G-6-PD) deficiency.

Signs and symptoms of copper poisoning include vomiting, burning pain in the mouth, esophagous and stomach, diarrhea, abdominal pain, bloody stools, headache, weak pulse, jaundice, decreased or absent urine output, convulsions, paralysis, and coma. Early deaths are due to shock, later ones to liver or kidney failure.

Acute copper ingestion often occurs when acidic beverages have been stored or passed through containers made of copper. Copper toxicity increases with the water solubility of the salts.

Chronic Toxicity

With the exception of persons with the hereditary disorders (Wilson's disease, Mencke's syndrome, Indian childhood cirrhosis) noted above, chronic copper poisoning from exessive ingestion is rare, and is not thought to result in disease in normal individuals (Gosselin et al., 1976; Doull et al, 1980; NAS, 1977). Tissue levels of copper do not increase with age (in adults), although blood levels do (Doull et al., 1980). The significance of the latter is unknown.

Mutagenicity

Copper may have mutagenic potential in that it can diminish the fidelity of DNA synthesis (Sirover and Loeb, 1976). However, no other evidence of mutagenicity was found.

Carcinogenicity

Copper miners and smelter workers reportedly have a higher incidence of lung cancer than the general population (Newman et al., 1976; Agnese et al., 1959). However, the significance of this finding is vitiated by their concomitant exposure to arsenic, a recognized carcinogen (Furst and Radding, 1979).

Copper implanted or copper sulfide injected into animal tissues apparently does not cause tumors, whereas copper sulfate and copper chloride injected into roosters' testes have been reported to cause testicular tumors (teratomas) (Gilman and Ruckerbauer, 1962; Sunderman et al., 1974; Furst, 1971; Falin and Anissimora, 1940; Bresler et al., 1964). Copper has apparently not been tested for carcinogenicity by other routes. Copper has been reported to act as a possible promoter for rodent skin tumors induced by dimethylbenzanthracene (Furst, 1977). In summary, the evidence of carcinogenicity for copper is weak, at best.

Effects on Reproduction

There is little evidence of adverse reproductive effects of copper in humans of animals (EPA, 1980b).

Tin (Inorganic)

Absorption and Metabolism

Tin is poorly absorbed from the GI tract, and hence most of what is ingested is excreted in feces (Venugopal and Luckey, 1978). Absorbed tin can be found mainly in the liver, lungs, and kidneys with trace quantities in other tissues (NAS, 1977; Hammond and Beliles, 1980).

Acute Toxicity

Inorganic tin has very low oral toxicity, due principally to its poor intestinal absorption. No toxic effects were reported in rats fed inorganic tin compounds for 13 weeks at concentrations of 450-650 mg/kg of food. In humans, nausea, vomiting and diarrhea have been reported from consumption of various canned foods and drinks: e.g., fruit juices containing 1400 ppm, vodka punch containing 2,000 ppm, and canned salmon containing 650 ppm (NAS, 1977).

Chronic Toxicity

There are a variety of chronic effects from oral ingestion of tin salts when high doses (at least 0.3 percent of the diet) are used. Deleterious effects on growth and development, the liver, the blood, the GI system and the male reproductive system have been reported. With lifetime consumption of tin at 5 ppm in drinking water, mice and rats reportedly had mild liver and kidney changes (Venugopal and Luckey, 1978). Whether the latter finding can be extrapolated to a human context is questionable, however, since this level of consumption is approximately the average human daily exposure in food.

Effects on Genes and Chromosomes

No information was available.

Carcinogenicity

While Venugopal and Luckey report that orally ingested tin salts may be carcinogenic, the accuracy of this observation is in doubt (Venugopal and Luckey, 1978; Furst and Radding, 1979). A recent bioassay of stannous chloride conducted under the auspices of the National Toxicology Program was negative (NTP, 1982).

Effects on Reproduction

No information was available.

Cadmium

Absorption and Metabolism

Cadmium is poorly absorbed from the gastrointestinal tract. Thus, most ingested cadmium is excreted in feces. The percentage absorbed varies from 0.5 to 12 percent in various animal species (Hammond and Beliles, 1980). Limited human evidence indicates that about 5 to 7 percent is absorbed (Pahola et al., 1972; NAS, 1980). Younger animals absorb a greater fraction of ingested cadmium than do older ones. Cadmium absorption is enhanced by a dietary deficiency of calcium, vitamin D, iron, zinc, copper, or protein. Inhaled cadmium is more efficiently absorbed; 50 percent or more present in cigarette smoke or metal fumes is absorbed (Ryan et al., 1982).

Absorbed cadmium is widely distributed throughout the body, concentrating preferentially in the kidney and liver. The metal accumulates in the body (at least up to age 50), with a biologic half-life estimated to range from several months to 47 years (Ryan et al., 1982). At birth the body burden of cadmium has been estimated to be 1 ng, which increases to 15-50 mg by age 50 (NAS, 1977). Excretion of absorbed cadmium is thought to occur principally in the urine, though other routes have not been well-investigated (Hammond and Beliles, 1980). As noted above, cadmium appears in breast milk.

Acute Toxicity

Acute toxic effects of ingested or inhaled cadmium are attributed to irritant effects. Cadmium is more toxic when inhaled, particularly if soluble salts of cadmium are involved. When ingested, symptoms of acute poisoning include nausea, vomiting, salivation, diarrhea, and cramps. The human oral LD_{50} has been estimated to range from 350 to 8900 mg (Hammond and Beliles, 1980). Death may occur from shock, renal or cardiopulmonary failure. Numerous health effects due to high-dose (0.5-1 mg cadmium/kg body weight) injections in animals are not generally observable when exposure is oral or by inhalation (Ryan et al., 1982).

Chronic Toxicity

Chronic cadmium exposure may result in damage to the kidney, lungs, bones, and cardiovascular system. The threshold for kidney damage is thought to be about 150 to 250 μg/gram of wet kidney tissue (NAS, 1980). Such injury may occur whether the route of exposure is oral or pulmonary. Damage to the lung occurs only with inhalation of cadmium (usually in an occupational context), and may result in emphysema and scarring of the lung. The bone disease attributable to cadmium exposure consists of softening of bones (osteomalacia), often with spontaneous multiple fractures. This affliction occurred mainly among middle-aged to elderly women in Japan who had eaten cadmium-contaminated rice. Epidemiologic investigations and some animal evidence indicates that cadmium exposure may play a role in the development of high blood pressure (Klaassen, 1980).

Effects on Genes and Chromosomes

Two dominant lethal mutation assays in mice using cadmium salts were negative (NAS, 1977). Results from studies of human cultured lymphocytes exposed to cadmium *in vitro* have been conflicting. Analyses of chromosomes of persons occupationally exposed to cadmium have reported a variety of structural anomalies in several studies cited by IARC (1976). Such chromosomal damage was not demonstrated in another study involving 5 workers and 4 patients with itai-itai disease (cadmium-induced osteomalacia) (Bui et al., 1975). Results from a variety of other tests have been mixed. A recent review of the literature concluded, "[T]here is no substantial evidence that human exposure to cadmium results in heritable genetic damage" (Ryan et al., 1982).

Carcinogenicity

The carcinogenicity of cadmium has been reviewed by the International Agency for Research on Cancer (1976, 1982b). Numerous studies cited in these reviews indicated that injected cadmium compounds produce local tumors in rats. Subcutaneous injections of $CdCl_2$ and $CdSo_4$ resulted in testicular tumors in rats and mice. There is only one adequate feeding study in animals in which rats fed up to 50 ppm of cadmium chloride in the diet did not show an increased incidence of tumors.

Epidemiologic evidence suggests that occupational exposure to cadmium oxide may increase the risk of prostate cancer and lung cancer (Kipling and Waterhouse, 1967; Lemen et al., 1976; Potts, 1975). However, because of small sample size and potentially confounding exposures to other substances, the carcinogenicity of cadmium in humans is not firmly established. Furthermore, a more recent study appears to indicate that occupational exposure to cadmium may not result in increased mortality from cancer for any site (Sorahan, 1981).

Effects on Reproduction

Injected cadmium chloride causes birth defects in rats, mice, and hamsters. When $CdCl_2$ was administered to CD strain rats in doses of 4 to 12 mg/kg on Days 13 to 16 of gestation, there were dose-related increases of fetal deaths, of congenital anomalies such as cleft palate, club foot, small jaws, and small lungs, and a decrease in fetal weight (Chernoff, 1973). A variety of skeletal and neurological defects were produced in the offspring of mice given subcutaneous injections of $CdCl_2$ (0.33-0.35 mg/kg) on Day 7 of gestation (Ishizu et al., 1973). Cadmium sulfate administered intravenously (2 mg/kg) to hamsters on Day 8 of gestation increased fetal resorption and caused major facial malformations (Ferm and Carpenter, 1967). Cadmium at 10 ppm in drinking water was teratogenic to mice (Schroeder and Mitchner, 1971). Sheep fed 12-15 ppm cadmium and cadmium sulfate in the diet during Weeks 13 and 14 of gestation bore normal offspring, though goats fed 75 ppm $CdCl_2$ in the diet did not (Mills and Dalgarno, 1972; Anke et al., 1970). EPA (1980e) noted one report in which 0.1 ppm cadmium in rats' drinking water produced no reproductive effects.

There have been no adequate studies reported on potential reproductive effects in humans. The human placenta is relatively impermeable to cadmium, yet neonatal cadmium blood levels are about half of maternal levels (NAS, 1977; Ryan et al., 1982; EPA, 1980e).

Acute exposure to cadmium has been reported to cause damage to the gonads and sterility of both sexes of experimental animals, regardless of the route of exposure (Venugopal and Luckey, 1978). Such damage includes testicular atrophy, cessation of spermatogenesis, and testicular necrosis in males and vascular changes in the ovary resulting in female infertility. These effects have been observed at doses far in excess of the estimated human intake of cadmium, and have not been reported in humans (Venugopal and Luckey, 1978; Klaassen, 1980).

Zinc

Absorption and Metabolism

Zinc is an essential nutrient, required for DNA and protein synthesis and for the activity of numerous intracellular enzymes. Absorption of zinc from the GI tract is variable, depending on the amount in the diet, but averages about 50 percent. A diet high in calcium, phosphate, and copper can decrease zinc absorption, as can some chelating agents.

Zinc is distributed to all tissues with high concentrations in muscle, skin, bone, liver, kidney, pancreas, eye, and the male reproductive system. Excretion occurs principally in feces, with contributions from unabsorbed dietary zinc, bile, pancreatic, and other GI secretions. Lesser amounts are excreted in urine, sweat, and breast milk (Venugopal and Luckey, 1978). Zinc absorption, metabolism, and excretion are governed by an efficient homeostatic mechanism.

Acute Toxicity

Zinc has low acute toxicity and quantities normally ingested are far below those required for the occurrence of toxic effects. However, oral zinc intoxication from acidic food or beverages stored in galvanized cans has been reported. Symptoms include vomiting, diarrhea, fever and stomach cramps. (Some cases may be due to cadmium contamination.)

Chronic Toxicity

Repeated low-dose ingestion of zinc is essential to sustain life: an effective homeostatic mechanism virtually assures that temporary exposures to concentrations moderately greater than what is necessary will not result in toxicity. Concentrations of up to 0.25 percent (or 2,500 ppm) in the diet have not caused toxicity in rats. Above this dietary level one finds growth retardation, anemia, and abnormal bone formation (Hammond and Beliles, 1980). There has been a report of zinc poisoning in two adults from extended consumption of water from galvanized pipes with the zinc concentrations of 40 mg/liter. Symptoms consisted of nausea, loss of appetite, muscular pain and stiffness, and irritability (NAS, 1977).

Effects on Genes and Chromosomes

The National Academy of Sciences (1977) concludes that there are no data to suggest that zinc is mutagenic in animals or humans. The NIOSH Registry of Toxic Effects of Chemical Substances (1981) reports no positive results for zinc in tests of mutagenesis.

Carcinogenicity

Zinc injected into the testicles of rats and roosters has produced testicular tumors, an effect which has been ascribed in part to hormonal factors and the high levels of zinc already present in the testes (Hammond and Beliles, 1980). Zinc has not been found to be carcinogenic by other routes of exposure (Sunderman, 1971).

Effects on Reproduction

Zinc at 4000 ppm (0.4 percent) in the diet of pregnant rats was reported to cause increased resorption and fetal death (Schlicker and Cox, 1968). Zinc injection or feeding at doses ranging from 15 to 50 mg/rat per day reportedly resulted in infertility and reduced testicular size (Venugopal and Luckey, 1978). However there is little evidence that zinc excess in drinking water will result in reporductive effects. Zinc deficiency is more likely to produce adverse outcomes (NAS, 1977).

Antimony

Absorption and Metabolism

Antimony metal occurs in +3 (trivalent) and +5 (pentavalent) oxidation states, which are distributed and metabolized differently. Trivalent antimony has a greater affinity for red blood cells than pentavalent compounds, which are found at higher levels in plasma. Antimony is poorly absorbed from the GI tract, and tends to cause vomiting. Thus, when given medicinally, antimony is administered by injection or intravenously. Intraveneously administered, antimony concentrates in the liver, thyroid, and heart. Trivalent antimony is excreted primarily in feces, while the pentavalent form is excreted principally in the urine (NAS, 1980).

Acute Toxicity

Antimony is chemically similar to arsenic, and produces arsenic-like toxic symptoms. There are few reports of human toxicity, and most of these have originated in industrial or medicinal exposures. Symptoms of acute ingestion include vomiting, diarrhea, collapse, irregular breathing, and decreased temperature (Hammond and Beliles, 1980). Besides the GI tract, the skin, liver, lungs, and heart may be affected, with toxic effects on the heart potentially the most serious. Oral LD_{50}s for trivalent compounds are lower than for pentavalent ones--e.g., in rats the LD_{50} for antimony trichloride is 675 mg/kg, while that for antimony pentachloride is 1.115 g/kg (NAS, 1980).

Chronic Toxicity

The chronic toxic effects of antimony administration depend on which compound is being tested. Trivalent antimony chloride given to rats for 10 days at 135 mg/kg by gavage resulted in degeneration of the heart muscle. The same compound given to guinea pigs for 10 days at 12 and 20 mg/kg resulted in anemia. When fed to guinea pigs for 6 months at doses from 0.0025 to 2.5 mg/kg, the lowest dose produced no toxicity (Arzamastsev, 1964). A similar no-observed-effect level was found for antimony trioxide fed to rats at doses less than 2 g/rat per day (NAS, 1980).

Humans exposed chronically to antimony in industrial settings have developed respiratory symptoms, including pneumoconiosis, dermatitis, and GI symptoms. Confounding exposure to arsenic may contribute to industrial antimony disease (Hammond and Beliles, 1980).

Effects on Genes and Chromosomes

Human white blood cells were exposed to 2.3 nanomoles of antimony sodium tartrate *in vitro*. Of 100 examined for chromosomal changes, 12 were demonstrated to have aberrations (chromatid breaks). No conclusions were drawn (Paton and Allison, 1972).

Carcinogenicity

Epidemiologic evidence of occupational cancer due to antimony is inconclusive (NAS, 1980). Antimony potassium tartrate at 5 ppm in drinking water given to 76 mice for their lifetime reportedly showed no increased tumor incidence (Kanisawa and Schroeder, 1970). The lack of higher dose levels precludes making a judgement about the carcinogenicity of antimony.

Effects on Reproduction

Two Soviet studies cited by the National Academy of Sciences (1980) seem to indicate that antimony can produce adverse effects on reproduction. Female antimony workers were reported to have a greater incidence of miscarriage, premature deliveries, menstrual disorders, and gynecologic inflammation than did a nonexposed group. A study involving exposure of 30 pregnant rats to aerosolized antimony metal appeared to show decreased fertility relative to unexposed controls, but no teratogenic effects (NAS, 1980). There is not enough evidence to draw any reliable inferences about potential reproductive effects of antimony.

Appendix E

DETAILS OF WORKER SAFETY AND HEALTH

General Testing Needs

The exposures of plumbers to solvent vapors, solder fumes, and other substances require better definition than is possible using currently available data. The existing studies for plastic pipe solvent cement (NIOSH, 1976; CDHS, 1980a; CDHS, 1980b; NIOSH, 1982) altogether have evaluated the exposures of fewer than 50 plumbers in a limited number of workplace environments (fewer than 10). The sampling that has been done has been performed using a variety of methods of uncertain comparability. Furthermore, there has been no attempt to define the systemic exposures of plumbers via dermal absorption, a potentially significant exposure route.

The situation with regard to the exposures of plumbers to other materials with which they work is even worse. SRI has not found a single study of the exposures of plumbers to solder fumes (including lead), although field observations indicate that those exposures may occasionally be severe.

Finally, the composition of the materials with which plumbers work is not at all certain. For instance, the presence or absence of DMF in cements will substantially affect its toxicity--especially its absorption through the intact skin. However, it is not clear which (if any) of the commercially available cements contain DMF. Benzene has also been found in air samples taken at a plumbing site (CDHS, 1980s), but its expected accompanying aromatic solvents (e.g., toluene) were not found. It is not clear whether benzene was present as a contaminant of the cement or whether it arose from another source. The constituents of cutting oils are important determinants of potential toxicity, but the composition of the specific cutting oils used in thread cutting (or cutting off) on metal pipes is not certain.

If the questions surrounding the expected introduction of plastic pipe into greater use are to be resolved, then some additional work is needed. This additional work should include a survey of the composition of the products available to the plumber, an environmental evaluation of the exposures of plumbers to the various contaminants found in their workplace, and a final health hazard evaluation of the total exposure profile.

In order to accomplish a valid assessment of the health hazards to plumbers associated with the use of plastic and metal piping one should attempt to:

I. Determine the extent of the information needed

   A. Determine the composition of the materials of interest

      1. Solvent cements

      2. Cutting oils

      3. Solders/fluxes

   B. Determine the population at risk

      1. Extent of use of specific materials from A. above

      2. Number of plumbers using each

      3. Number of plumbers performing specific tasks

   C. Complete the literature review--especially the NIOSH studies scheduled to be completed in the near future

II. Define the methods to be used

   A. Materials for which environmental sampling is to be performed

      1. Methods to be used

      2. Number of samples within each use/composition sample cell

B. Materials for which biological sampling is to be performed

1. Methods to be used

a. Expired air sampling

b. Urine/blood sampling

c. Skin patches; gloves; other.

2. Number and type of samples to be taken within each defined cell

III. Determine the survey protocol

A. Define a geographical area within which adequate job sites will be available

B. Obtain the cooperation of relevant groups

1. Plumbers' union locals

2. Pipe manufacturers/cement manufacturers/trade associations

3. Associated General Contractors/Specialty contractors

C. Specify content of surveys to be performed (from I. and II. above)

IV. Perform study

V. Analyze data and report

Biological Monitoring Considerations

The potential for dermal absorption of the solvents used in plastic pipe cements is significant. It is notoriously difficult to determine such dermal exposure directly. Although the use of gauze patches on representative skin areas, or of specially prepared gloves may be useful in some circumstances (the patches and the gloves are subjected to chemical extraction with an appropriate solvent after exposure), these methods are unlikely to give satisfactory results in the solvent exposures. The major problem is that the substances of concern are volatile; the continued evaporation of these materials during the sampling period would make analysis of the patches fruitless unless they were changed very frequently, with consequent unacceptable disturbance of the workers being monitored. In addition, the potential for significant changes in the permeability of the skin to these materials (due to abrasion of the skin, defatting due to previous exposures, ambient temperatures and the like) is great. Thus it seems most reasonable to attempt to define the systemic exposures to these solvents due to dermal absorption by actually measuring systemic uptake. There are several methods available; the choice depends on the metabolic pathways followed by the material subsequent to intake. The least invasive method is to measure the compound of interest (or its metabolite if it is metabolized) in the expired air. Other possible methods (in decreasing order of desirability for field studies) are the collection of urine or blood, with subsequent analysis.

The solvents of major interest to us in this study are THF, cyclohexanone, MEK, and DMF. We have briefly evaluated the availability of rational biological methods for each of these solvents:

- THF--There exists no information on the metabolism of THF. It is very volatile and most probably is eliminated in expired breath.
- Cyclohexanone--Cyclohexanone is metabolized to cyclohexanol, which is presumably detectable in the expired breath. Cyclohexanol is glucuronidated in the liver (Elliot et al., 1959) or excreted unchanged. A certain percentage of cyclohexanone is undoubtedly excreted in the expired breath.
- MEK--MEK is metabolized to 2-butanol, 3-hydroxy-2-butanone and 2,3-butanediol. MEK and the first two metabolites are quite volatile and probably are excreted via the breath as well as the urine. Only 11 percent of an administered dose was accounted for in urine in metabolic tests with guinea pigs; similar results were found in rats (Di Vincenzo et al., 1976, Dietz and Traiger, 1979). The main urinary metabolite in rats was the glucuronide of 2-butanol. In dogs, 30-33 percent of an administered dose was eliminated in expired air. Humans exposed to MEK dermally eliminated the compound in the expired air, beginning 15 minutes after first contact. Within 2 hours, a steady-state elimination concentration of 6.5 micrograms/liter was achieved (Munies & Wurster, 1965). In general, ketones are not readily metabolized and may be eliminated unchanged in the expired air and to some extent in the urine (Opdyke, 1977).
- DMF--DMF is metabolized to N-methylformamide and formamide via microsomal oxidation in the liver and other organs with these

enzymes. It can be detected in the blood of persons exposed, and DMF, monomethylformamide, and formamide can be detected in human urine after inhalation exposure. Formic acid and DMA (dimethylamine) are the hydrolysis products and they have not been detected in the urine or stomach contents of patients or experimental animals.

There is a linear relationship between DMF exposure and 24-hour monomethylformamide (MMF) excretion (Krivanek et al., 1978) in subjects exposed to 9 to 33 ppm for 6 hours daily on 15 consecutive days. No compound was present 48 hours after exposure (and very little after 24 hours). No increase in MMF was seen in urine after repeated doses. The mean value for the end-of-exposure sample (7 hour-sample) was 4.7 ug/ml or 436.6 ug total.

Conclusions

From the above considerations, it appears reasonable to assume that appropriate methods for the determination of total exposure to DMF, MEK, and cyclohexanone can be developed using the expired air samples. If DMF is of interest, urine samples could be taken. In any case, it would be most useful to attempt to define the constituents of solvent cements on job sites prior to taking samples so as to ensure use of appropriate methods and minimize disruption of work and invasion of worker privacy.

Appendix F

SMOKE TOXICITY DETAILS

Summary of Smoke Toxins

Table F-1 provides a summary of the sources and physiologic effects of the principal combustion gases from synthetics and natural materials likely to be present in residences.

Evidence from Human Studies

In fires, approximately 96% of civilian deaths and 69% of injuries result from fires in residential occupancies (one- and two-family dwellings, apartments, hotels, motels, and all other) (NFPA statistics for 1977-1981). Of civilian fire deaths, 75% were accounted for by one- and two-family home fires alone. Where accidental ignitions alone were involved (not arson), 67% of the deaths were in fires where the material initially ignited was building contents (upholstered furniture, bedding, clothing, floor covering, rubbish, etc.). These kinds of material provide the bulk of the fire load in most buildings (NFPA, 1982). Addressing the problems of combustion hazards from such sources would result in a major reduction in the loss of life from fire, in the opinion of NFPA (1982).

As an alternative to sampling the atmosphere in fire environments for toxic gases, we can attempt to find out how much of which gases has been inhaled by fire victims. Several studies of this type have been done; none is free of criticism. In the United Kingdom, analysis of blood samples from eight fire fatalities have revealed 60 or more volatile components, including aromatic hydrocarbons, organic nitriles, and various other

Table F-1

SOURCES AND PHYSIOLOGIC EFFECTS OF SELECTED THERMODECOMPOSITION GASES OTHER THAN CO AND CO_2

Sources of Thermodecomposition Gases*	Highlights of Physiologic Effects	Estimate of Short-term 10 Minute Lethal Concentration (ppm)
Hydrogen cyanide (HCN)		
From combustion of various products such as wool, silk, polyacrylonitrile, nylon, polyurethane, and paper, in varying amounts; flammable; difficult to analyze accurately	A rapidly fatal asphyxiant poison; toxicity suspected in some recent fires involving upholstery and fabrics but no definitive data	350
Nitrogen dioxide (NO_2) and other oxides of nitrogen		
Produced in small quantities from fabrics and in larger quantities from cellulose nitrate and celluloid (prepared from cellulose nitrate and camphor, in decreased use today)	Strong pulmonary irritant capable of causing immediate death as well as delayed injury; notorious from the 123 death in 1929 Cleveland Clinic fire caused by burning "nitrocellulose" x-ray films	| 200
Hydrogen chloride (HCl)		
From pyrolysis of some wire insulation materials such as polyvinyl chloride (PVC), also chlorinated acrylics and retardant-treated materials	Respiratory irritant; potential toxicity of HCl coated on particulate greater than that for an equivalent amount of gaseous HCl	| 500, if particulates are absent
Other halogen acid gases		
From combustion of fluorinated resins or films and some fire-retardant materials containing bromine	Respiratory irritant	HF ä 400 COF_2 ä 100 HBr | 500

Table F-1 (Concluded)

Sources of Thermodecomposition Gases*	Highlights of Physiologic Effects	Estimate of Short-term 10-Minute Lethal Concentration (ppm)
	Sulfur dioxide (SO_2)	
From compounds containing sulfur; the common oxidation product of such components in fires	A strong irritant, intolerable well below lethal concentrations	500
	Acrolein	
From pyrolysis of polyolefins and cellulosics at lower temperatures (400°C); significance, if any, in actual fires is undefined	Potent respiratory irritant	30-100

*All these gases can be lethal in sufficient concentration. In most common fire situations, these combustion gases would be expected to contribute to death rather than be primary causes of death.

Source: Terrill et al. (1978); PRC (1980).

molecules, a few of which could not be identified (Anderson and Harland, 1980). In general, the blood from fire fatalities showed more complex patterns than that from healthy control or nonfire deaths. The significance of these stated differences is unclear at present, because in all cases the deaths could have been accounted for alone by the carboxyhemoglobin (COHb) levels in the blood. Cyanide levels were also elevated and may have contributed in an additive way, but blood specimens were not obtained until 24 to 72 hours after death, vitiating confidence in the quantitative values for this toxicant and other chemicals like the organic nitriles. Further, alcohol levels in the blood indicated that many of those dying in the fires were grossly intoxicated at the time of death. It may be noted that the amounts of acetonitrile quantified in the blood of three victims from domestic fires and two from a nursing home were comparable to cyanide concentrations, whereas propionitrile concentrations were at least an order of magnitude less. Neither of these nitriles is as toxic as hydrogen cyanide (NIOSH, 1982).

Postmortem analysis of blood specimens for HCN and other components has been done in other studies in attempts to ascertain the major causes of fire deaths. In a demographic study sponsored by the National Science Foundation, probably the most comprehensive and only systematic one of its kind, blood specimens were analyzed from 511 fire deaths in the state of Maryland over a 5-year period. Victims with more than 50% COHb, the level generally assumed to be lethal, represented 48% of the total (Benjamin et al., 1982). About 16% more of the victims with less than 50% COHb had preexisting cardiovascular disease and/or exposed to HCN. Low levels of CO, together with chemical irritants whose toxicity could not be assessed, were present in 10% of the specimens. The authors concluded that between 10% and 18% of the fire deaths did not appear to have materially involved CO or heat. Many of the latter deaths were delayed and involved lung injury or damage to the throat. In one case, that of a fire fighter who appeared to have recovered from the immediate effects of the fire but died later, extensive pulmonary hemorrhaging and edema were found at autopsy; the deceased also had arteriosclerosis.

In a study of fire deaths in New York City, the primary cause was attributed to CO inhalation in 70% of those that succumbed (PRC, 1980). CO levels in fires usually rise rapidly, with concomitant changes in escape capability and rapid formation of COHb, causing death.

In some studies, attempts were made to evaluate whether blood levels of HCN might account for some portion of the deaths. The analyses were vitiated by the fact that, because HCN in blood is unstable, special sample handling and rapid acquisition of specimens following removal of the injured from fire areas are needed (PRC, 1980), and the matter of the magnitude of the contribution of cyanide to fire deaths is not resolved. Since nitrogen-containing polymers (e.g., polyurethane, polyacrylonitrile, wool, polyamides) may make up as much as 5% of the combustible materials in fires (PRC, 1980), some contribution from HCN to fire deaths is to be expected, but nowhere near that of CO.

Evidence from Animal Toxicity Studies

Methodologies--There are a variety of laboratory tests to evaluate the toxicity of combustion products in animals as a means to characterize the material's fire hazard, ostensibly under fire conditions. All have shortcomings that have been discussed critically elsewhere (Alarie, 1982; Benjamin et al., 1982; Caplan et al., 1982; Levin et al., 1982), and these sources may be consulted for details on the methods.

The test methods used do not duplicate room fires. They generate smoke by use of cup or tube furnaces and/or radiant heat under flaming or nonflaming conditions, either collecting the smoke over some fixed period of time for the animal exposure (static conditions) or passing an air stream through the furnace to the exposure chamber (dynamic conditions). Either fixed or slowly rising temperatures are used to heat the samples. Exposure chambers vary considerably. The test animals are almost invariably rats or mice, because of their economy in use and because a considerable amount of biological and toxicological information on them exists. A variety of physiological and biochemical measurements may be conveniently made on these animals, but lethality is invariably quantified, usually together with some additional parameters intended to assess the time required for incapacitation. Monitoring of CO (and sometimes HCl, HCN, and oxygen) levels and temperature in or near the chambers containing the animals, as well as measurements of respiratory rate, neurological response of motor performance or visual observations for effects, are done in some but not all tests.

The static arrangement is said to simulate, to some degree, exposure to a fire in or near the room of origin, in a situation of limited flow-through ventilation where smoke accumulates; the dynamic system simulates a steady-state burning with victims exposed to the moving smoke plume.

Although some attempts have been made to correlate small-scale laboratory tests with large-scale tests (Alarie et al., 1981; Alarie et al., 1983) the consensus of investigators in the field is that these test methods cannot be used at present with confidence for that purpose or for regulating materials based on test results (Workshop, 1983).

Their only present advantage is to serve as screens for detecting unusually toxic combustion materials or for guidance in the whole process of test development. To be useful for this purpose, any study should include use of suitable reference materials, such as Douglas fir. Dose-response curves are usually (but not always) obtained to aid in determining thresholds for the measured efect (Figure F-1 is an example).

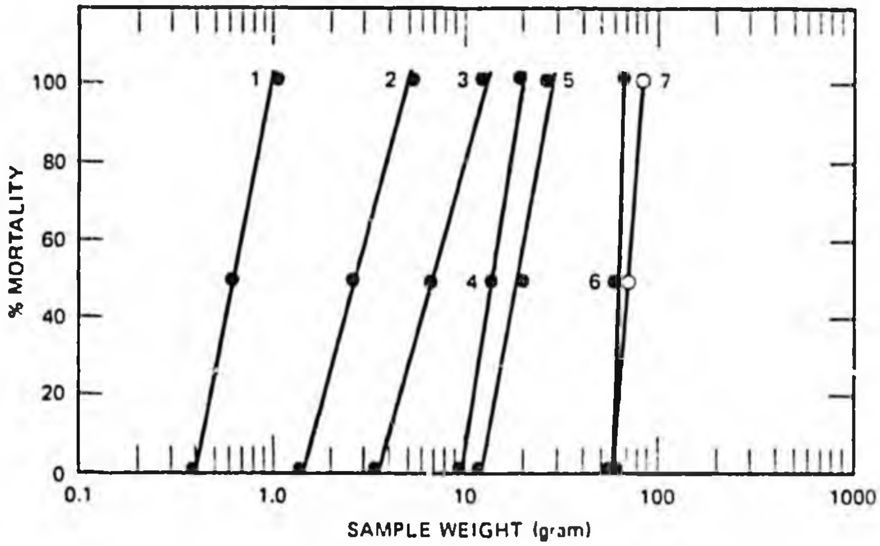
Shortcomings of the toxicity screens usually stated are (1) questions of relevance to real fire situations; (2) limitations of animals, in particular rodents, for predicting human health hazards; (3) variability in toxicity results; and (4) the inability to incorporate toxicity data in the total hazard equation. Mathematical modeling for the last-named objective is still many years away. The tests in use measure time to incapacitation or some similar sublethal effect, as well as lethality, since smoke can be seen in a tenth of the total time that is required for it to reach toxic levels (Clarke, personal comment, Workshop, 1983) and these factors relate more to detection and time for escape. The time for escape is emphasized because to some it appears unrealistic to try to reduce fire load below some critical level; there is always too much combustible material, so escape time should be maximized (Packham, personal comment, Workshop, 1983).

Test Results on Intact Plastic Pipe--There are almost no published reports on the toxicity of gases generated from the plastic pipes under consideration here. There is much more information on the toxicity of gases evolved from the unformulated plastics themselves. For as comprehensive an assessment as possible, both types of studies are reviewed.

Hilado and Huttlinger (1983) compared the toxicity in Swiss-Webster young adult male mice of two samples of polybutylene pipe obtained from Shell Oil Company (Houston, TX) with that of a sample of Douglas fir. The method is referred to as the NASA-USF toxicity screen. Test conditions used were those of a rising temperature at 40°C/min from 200°C-800°C without forced air flow; a Lindberg horizontal tube furnace and quartz boat containing the sample are used for pyrolysis.

Time to incapacitation (staggering, convulsions, or collapse of the animal) and time to death were measured. Average times to death with the polybutylene pipe samples ranged from 21.5 to 24.4 minutes, compared with 16.8 to 18.6 minutes for Douglas fir. Similarly, average times for the three indices of incapacitation were greater for the polybutylene pipes than for Douglas fir.

Dr. Rosalind Anderson of A. D. Little, Inc. (Cambridge, MA) is currently testing three samples of PVC, CPVC, and ABS pipes for DWV uses from different suppliers in the so-called NBS (developed at the National Bureau of Standards) and Pittsburgh (developed in Dr. Alarie's laboratory at the University of Pittsburgh) tests. It is not expected that the results will be available before May 1, 1983.



1 polytetrafluoroethylene
2 urea-formaldehyde foam
3 phenol-formaldehyde foam
4 polyvinyl chloride (homopolymer)
5 flexible polyurethane foam
6 Douglas fir
7 fiber glass reinforced polyester

HA-4910-4

FIGURE F-1 CONCENTRATION-RESPONSE CURVES OBTAINED WITH MICE FOR LETHALITY DURING 30 MINUTES OF EXPOSURE AND 10 MINUTES OF RECOVERY

Source: Anderson and Alarie (1978).

Alarie and his colleagues (1982) at the University of Pittsburgh have studied the toxicity of three commercial samples of PVC and other plastics in their method, with mice as the test animal species. The PVC samples were designated as white PVC-coated cable for electrical applications and gray corrugated and solid PVC pipes; steel conduit served as the reference. All three PVC samples were classified as "more toxic than wood"; the two pipe formulations were classified "as fast acting as wood" and the coated cable "faster acting." Death of the mice was attributed to HCl release, with CO being a contributor to the toxicity. The steel conduit was almost totally inert toxicologically and, as could be anticipated, was classified as "better than wood" in this test.

All three samples gave off approximately the same amount of smoke to produce the LC_{50} values, or about 6 grams. The amount of HCl produced in the first 10 minutes of the exposure was trapped and quantified to be equivalent to an average exposure of about 6,400 ppm during that period. Using the data of Boethner et al. (1969) that 0.58 gram of HCl evolves from 1.0 gram of PVC consumed, an average of 8,550 ppm of HCl should have been produced. The amount found by Alarie is underestimated slightly, as he suspected, but still in the range. The difference may be due to plating of the acid on surfaces. Therefore, it may be reasonably concluded that an average HCl exposure of 6,400 ppm is sufficient to kill 50% of the test animals within 10 to 15 minutes.

Alarie (April 5, 1982) attempted to extrapolate the quantity of PVC solid pipe in his test that would fill an average room (8 x 10 x 12ft) with sufficient smoke to kill humans in about 10 to 15 minutes. Making certain assumptions that appear reasonable, he concluded that 2.35 pounds of the sample would be required. Noting that humans are likely to be more sensitive than mice in regard to the irritant effects of the HCl given off by PVC, he applied a conservative correction factor (derived from other studies with cannulated and noncannulated mice, conducted in his laboratory) and also used another line of argument to arrive at a figure of 0.34 to 0.62 pound being sufficient to produce adverse effects in humans. This would correspond to between 18 to 30 inches of solid pipe, or a somewhat longer piece of corrugated pipe.

Test Results on Unformulated Polymers--The thermal decomposition of PVC plastics in a tube furnace and the effects of the products on pulmonary function have been assessed using the guinea pig as an animal model (Jaeger et al., 1982). Pure PVC resin (from B.F. Goodrich Chemical), a technical-grade sample (whose composition was unknown but did include DEHP) and an electrical-grade PVC formulation were compared. CO levels in the atmosphere were quantified over the 30-minute exposure period.

The authors found that "death, while possibly hastened by exposure to CO, was usually delayed and was associated with substantial abnormalities in pulmonary mechanical function." There was, however, no correlation with known HCl release. The electrical-grade sample had a higher peak concentration and time-weighted average release of HCl than the technical-grade sample. Pure PVC released the most HCl, consistent with its greater chlorine content on a weight basis. The toxicity (lethality) of the three samples varied in the following order, however: pure PVC electrical-grade PVC technical-grade PVC. Irritant effects based on pulmonary function tests were similar with all three and were attributed in part to the HCl.

Petajan (1976) evaluated the toxicity of thermally degraded PVC foam in a "static box" with young adult male Long-Evans rats. Arterial blood COHb was increased to between 30% and 45% without death. Severe acidosis was also present, more than expected from the amount of COHb, which the author attributed to the animals' holding their breaths, since respiratory rate was also diminished during this period. After sacrifice, the rats were found to have increased pulmonary injury (severe bronchitis with edema and hemorrhaging).

Hilado (1983) has reported the following test results in the NASA-USF animal tests for generic plastics like those of interest here:

Sample	Time to Death (minutes)	LC50* (mg/l)
PVC	16.6 ± 0.33	--
ABS	17.1 ± 2.5	13.8
CPVC	22.2 ± 0.69	35.0

*PSC conditions.

Kimmerle (1976) evaluated the toxicity in rats of pyrolysis products of ABS and ABS foam relative to other thermoplastics and to spruce wood, using a furnace apparatus and test conditions standardized by the German government (DIN test). An equal volume of each material was burned. He concluded from the results shown in Table F-2 that the toxicity of pyrolyzed ABS foam could not be due to CO and HCN in the air because of the presence of lung damage, the low percentages of COHb levels, and delayed deaths. In the case of spruce wood, mortality was clearly due to the CO given off. Higher temperatures were required for mortality from combustion of ABS than of spruce wood.

ABS and PVC pellets of unspecified composition were tested in the NBS method using EC_{50} and LC_{50} values (Levin et al., 1982). EC_{50} is defined as the concentration (mass loading of material divided by exposure chamber volume) that was necessary to incapacitate 50% of the rats in the standard 30-minute exposure. LC_{50} is the most common measure of lethality and is the concentration necessary to cause 50% of the animal population to die in some fixed period, usually during the 30-minute exposure and a 14-day postexposure period.

Table F-2

TOXICITY OF THE PYROLYSIS PRODUCTS OF THERMOPLASTIC MATERIALS ON RATS
(Tests with Equal Volumes: 300 by 10 by 5 mm)

Sample	Temp. (°C)	Concentration in Air: CO (ppm)	Concentration in Air: HCN (ppm)	COHb (%)	Number of Deaths Out of 20
ABS	350	150	100	5.8	0
	400	350	150	14.2	13
ABS foam	350	100	20	6.2	0
	400	100	100	7.3	2
Spruce wood	300	1,000	0	27.6	0
	350	7,500	0	72.7	19

Source: Kimmerle (1976).

Data for flaming and nonflaming modes and for 440°C were obtained as given in Table F-3.* The lower the value, the less material is required to produce the effect in 50% of the test animals. Thus, ABS and PVC pellets show EC_{50} and LC_{50} values that are, in general, comparable to those for Douglas fir. That is, they produced combustion products with toxicity similar to that of Douglas fir. However, ABS (flaming mode) and PVC (nonflaming mode) did differ from the Douglas fir references in that there was significant mortality during the 14-day holding period after the exposure. If the PVC exposure was shortened from 30 minutes to 10 minutes at all three test temperatures, there was no incapacitation during the exposure and only one of three animals died during the 14-day postexposure period. At temperatures just below ignition (nonflaming mode), the relative release of CO for a comparable mass load factor was: Douglas fir | red oak | ABS and PVC. With HCN release, however, wool released about 2 times more HCN than ABS for the same mass load loading. These numbers suggest that toxicity of ABS and PVC is comparable to that of natural materials, but other gases or the smoke may contribute to their toxicity in addition to HCN and CO.

Additivity/Sensitivity--Animal test screens are almost entirely restricted to the evaluation of one material at a time. Actual fire situations are much more complex. Awareness of this dilemma has led to speculation on the possibility that synergistic effects may arise from more than one material burning or from combinations of toxic gases in the atmospheres that would be missed under screening conditions.

The early literature addressing this question yields conflicting results (Armstrong, 1976). Armstrong states that:

> Studies on binary mixtures can never be a completely adequate explanation of the physiological effects encountered in real fire

---

*The ignition temperatures for the ABS and PVC pellets, Douglas fir, red oak, and wool in the NBS furnaces were: 575, 600, 465, 480, and 650°C, respectively.

Table F-3

TEST RESULTS WITH THE NBS METHOD

EC_{50} Values (mg/l)

Material	Number of Tests	Flaming	Nonflaming	440°C
ABS	= 3	11	17	15
PVC	= 2	12	9	14
Douglas fir	8	16	15	H
Red oak	3	42	24	H
Wool	4	27	17	25

LC_{50} Values (mg/l)

Material	Number of Tests	Flaming	Nonflaming	440°C
ABS	= 4	18	28	30
PVC	2	16	18	23
Douglas fir	8	36	23	H
Red oak	3	54	30	H
Wool	4	38	24	29

situations. All fires, regardless of the material involved, are complex mechanisms involving thermal degradation and high-temperature free radical reactions. It is unlikely that two situations will ever exist in which the identical set of combustion products will be obtained. To assign synergistic properties to a given pair combination under synthetic mixture conditions may never do more than further confuse the issue, since it ignores the possible presence of unidentified components in the fire gases, whose lethality may be several orders of magnitude greater than either or both in the synthetic mixture. It also ignores the possible neutralizing effect of the two separately toxic components by addition or substitution reactions in the fire environment to form relatively innocuous products.

Before any realistic assessment of synergisms meaningful to the real fire situation can be made, it is essential that a great deal more knowledge must be obtained in these several areas.

Smith et al. (1976) attempted to resolve the question of synergism for CO and HCN using the pure gases. When rats were exposed to these gases at levels slightly below their 5-minute LC_{50} values, they were incapacitated or died in up to 50% shorter time than with either gas alone. The decrease in time and nature of the signs observed indicated that the effects of the two gases together were additive. When the gases were premixed at these exposure levels, the effect of the combination on the animals was greater, reminiscent of reports of synergism in the earlier literature in tests with rats and mice exposed to the mixtures in similar fashion (Caplan, 1982). Although conceivable, experimental demonstration of combined effects is still not unequivocal (PRC, 1980) and further research is required before the matter is resolved.

Additional Relevant Toxicity Information

Tewarson (1979) reviewed the literature on fire toxicity as part of the testing program on the effects of fire-exposed electrical wiring systems on escape potential from buildings. He cites a study of the concentrations of five products monitored by fire fighters during the first 15 minutes of 120 fires that occurred in Boston. HCl, CO, and benzene were detected in 92%, 37%, and 68% of the fires, respectively, at levels as high as 371, 4,800 and

62 ppm. These compare with the critical values for human escape listed in Table F-4.

The frequency of concentrations of HCl, CO, and benzene above the STEL values in the Boston fires were 37%, 11%, and 0.01%, respectively. HCl and CO, at the highest concentrations, exceeded the tentative critical values for human escape. No deaths were recorded in these fires, however, and the usefulness of the data obtained for the present evaluation has been questioned on other grounds (Benjamin et al., 1982). The physiological effects on humans of low HCl levels (less than or equal to 100 ppm) are listed in Table F-5, and those on animals in Table F-6.

Animals exposed to PVC fire products show a rapid fall in blood oxyhemoglobin without simultaneous rise in carboxyhemoglobin in initial phases, indicating effects of irritants (i.e., HCl, etc.). During exposure, significant decrease in blood pH occurs, which indicates metabolic acidosis. Animals that die have carbon particles in the respiratory tract and suffer corneal opacification. In studies on mice, other irritants in addition to HCl were considered to be responsible for depressions in respiratory rate.

Table F-4

TENTATIVE CRITICAL VALUES FOR HUMAN ESCAPE FROM FIRES AND SHORT-TERM EXPOSURE LIMIT

Compound	Tentative Critical Values for Human Escape (ppm)	STEL Values (ppm)*
HCl	50 to 100	5
Benzene	1,500 to 4,000	25
CO	1,500 to 4,000	400
CO_2	40,000 to 80,000	15,000
O_2	60,000 to 100,000	

*STEL value is defined by the Harvard School of Public Health as the highest level to which fire fighters may be exposed up to 15 minutes comtinuously without causing intolerable irritation, medical effects, or impairment of the ability to respond to emergencies. Data for acrolein and NO_2 not included.

Table F-5

SUMMARY OF REPORTED PHYSIOLOGICAL EFFECTS OF INHALATION OF SMALL AMOUNTS (0-100 PPM) OF HCl BY HUMANS

HCl Concentration (ppm)	Effects
0.013	Odor perception
0.67-0.134	Odor threshold
0.67-0.134	Threshold for change in the rhythm and depth of respiratory movement
0.134	Threshold reflex effect on eye sensitivity to light
0.260	Threshold for olfactory sensation for the most sensitive persons
0.262	Threshold reflex effect on electrical activity of the cerebral cortex
0.273	Threshold reflex effect on eye sensitivity to light
0.335	Threshold effect on digito-vascular toxicity
0.402	Threshold reflect effect on optical chronaxie
1-5	Odor threshold
5	No organic damage
10	Irritation, work is undisturbed
35	Irritation of throat after short exposure
10-50	Work is difficult but possible
10-50	Does not prohibit work, but harmful to teeth, nose, mucosa of mouth, and face
50-100	No one can work
50-100	Work is impossible
	Intolerable in 60 minutes

Table F-6

SUMMARY OF REPORTED PHYSIOLOGICAL EFFECTS OF INHALATION OF HCl BY ANIMALS

HCl Concentration (ppm)	Exposure Time (min.)	Species	Effect
17	10	Mice	Small ulcerations of the respiratory mucosa
30	10	Rabbits	Cessation of ciliary activity without recovery
60	5	Rabbits	Cessation of ciliary activity without recovery
128	10	Mice	Ulcerations of nasal mucosa
491	10	Mice	Moderate to marked polymorphonuclear leukocyte of the palpebral and global conjunctiva
670	120	Rabbits	Fatal in some cases
670	120	Guinea pigs	Fatal in some cases
712	10	Mice	Damage to underlying skeletal structures with necrosis of the skeletal cartilage
1,075	10	Mice	Necrosis of exposed cornea, marked polymorphonuclear infiltration of the eyelids
1,350	90	Cats	Severe irritation, dyspnea, and clouding of the cornea
1,350	90	Rabbits	Same as above
1,350	90	Guinea pigs	Same as above
1,949	10	Mice	Necrosis of exposed cornea, marked polymorphonuclear infiltration of the eyelids
3,071	10	Mice	Globes extensively damaged and weakened and spontaneous rupture of the globe occurred

Table F-6 (Concluded)

HCl Concentration (ppm)	Exposure Time (min.)	Species	Effect
3,400	90	Cats	Death after 2 to 6 days
3,400	90	Rabbits	Same as above
3,400	90	Guinea pigs	Same as above
4,300	30	Rabbits	Fatal in some cases due to laryngeal edema or rapidly developing pulmonary edema
4,300	30	Guinea pigs	Same as above
7,190	10	Mice	Massive damage to nose with necrosis of the mucosa, submucosa, cartilage, and underlying bone. The delicate naso and maxilloturbinate bone was totally destroyed
7,190	10	Mice	Death

SB

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#2

STATE OF CALIFORNIA George Deukmejian, Govenor

DEPARTMENT OF HOUSING AND COMMUNITY DEVELOPMENT
DIVISION OF CODES AND STANDARDS - ADMINISTRATIVE OFFICE
Mailing Address: P. O. Box 1407, Sacramento, CA 95807
6007 Folsom Blvd., Suite A, Sacramento, CA 95819
(916) 445-9471

July 18, 1983

Mr. Rocky P. Weller
Committee on Labor & Commerce
Alaska State Senate
Juneau, AK 99811

Dear Mr. Weller:

The State of California is currently engaged in a three phase evaluation of plastic and metal residential plumbing systems. These phases are:

1. Preparation of an environmental review document to summarize existing information,

2. Additional water quality and worker health laboratory studies, and

3. Preparation of an environmental impact report (EIR).

Phase 1 was completed in March 1983. Copies of the report are available for $62.33. I am enclosing one copy of the 588-page report. Please send payment to the above address.

Preparation for phase 2 are now being made. We expect the results in about five months.

A draft EIR should be available in June, 1984.

If you would like further information, please contact me.

Sincerely,

Michael C. McMillan
EIR Coordinator

MM/nm

Enclosure: 1 copy ERD

HEALTH HAZARDS

ASSOCIATED WITH

PLASTIC PIPE

A STATUS REPORT

SEPTEMBER 1981

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WITH PLASTIC PIPE

A STATUS REPORT

OF

THE CALIFORNIA PIPE TRADES COUNCIL

OF

THE UNITED ASSOCIATION OF JOURNEYMEN

AND APPRENTICES OF THE PLUMBING AND PIPE FITTING

INDUSTRY OF THE UNITED STATES AND CANADA

PREPARED BY:

LEONARDINI AND FATHY, ATTORNEYS AT LAW
GENERAL COUNSEL
CALIFORNIA PIPE TRADES COUNCIL
SACRAMENTO, CALIFORNIA

INTRODUCTION

Thousands of pages have been written on the advantages and disadvantages associated with plastic pipe. The debate normally concerns its effectiveness and usefulness as a new product. Most recently, issues have focused on human health hazards and potential long-range environmental dangers. With this type of dispute the problems surrounding plastic pipe involve a staggering level of scientific abstraction. Public officials and policy makers (usually not scientists by training) oftentimes are faced with a morass of scientific jargon, chemical formulae and mathematical probabilities. Such scientific disputes, if taken out of context, can be an obstacle to the appropriate protection of the health and safety of the general public.

The following paper is a short summary of the main health and environmental issues in the plastic pipe dispute. It includes documents of policy makers, environmental scientists and health officials that comment upon the proper health and safety approach to the issue, all of which documents are part of the Public Record of the California Housing Commission. These documents illustrate that scientific assertions of the petrochemical industry, when analyzed by independent testing agencies, do not overcome the threat of severe safety risks, health risks and environmental contamination that may arise from the use of plastic pipe.

Lastly, this paper documents the extreme peril of relying upon media presentations and press packages of the Plastic Pipe and Fitting Association (PPFA).

The reader should carefully note the serious need for policy decisions with regard to plastic pipe that reflect truly unbiased research and independent analysis.

I

FIRE SAFETY

In early 1980, the California State Fire Marshal, at the specific request of the California Legislature, (ACR 98), analyzed and evaluated every major scientific document on "the potential flammability of plastic pipe and the fire hazards associated with its use." It concluded:

> "In multi- (3 or more) story fire-rated construction, additional in-depth fire testing is necessary to (a) ensure that plastic pipe will not contribute to unusual fire spread; (b) that the toxicity generated by the combustion of plastic pipe will not extend beyond the area of initial exposure in quantities sufficient to prove hazardous." ("Fire Hazards of Plastic Pipe" State Fire Marshal. May 1980.)

The State Fire Marshal was particularly concerned at the time with "through-penetrations" of fire-rated walls by a combustible material and by the loading of plastic pipe, i.e., "stacking", in high-rise construction.

His concern proved to be prophetic after the tragic fire at the MGM Las Vegas in November 1980. News accounts and independent investigations on the Nevada fire led the State Fire Marshal to conclude: "... plastic pipe may have played a contributing role in...(the) tragic fire...in Las Vegas, and many news accounts describe the precise problems I alluded to in my reports to the (State Housing) Commission." (See Exhibit 1.) The Fire Marshal went on to "strongly recommend" specific research and standards evaluation prior to any approval of plastic pipe for high-rise construction.

II

HEALTH HAZARDS FOR WORKERS

In May 1980, the California Department of Health Services did the first compilation of medical literature and research data on the potential hazards to workers when exposed to the wide variety of toxic chemicals found in plastic pipe and glues. As with the State Fire Marshal, the Health Department's effort was the first major push by an independent governmental agency to fully evaluate heretofore disparate and complex chemical data. Their conclusions (see Exhibit 2) are wide-sweeping and "suggest the possibility of serious and previously unrecognized health effects among workers who install plastic pipe....Consequently, it is not clear that such pipe can be used safely under present conditions."

Unfortunately, but not unexpectedly, the petrochemical industry deliberately misrepresented the major findings of the Health Department, specifically Cal/OSHA. The Plastic Pipe and Fitting Association (PPFA) went to such an extreme in twisting and contorting the facts on plastic pipe that on March 5, 1981, the Deputy Chief for Health of the California State Occupational Safety and Health Administration wrote to the California Housing Commission to correct the false information. "...The PPFA has inappropriately extracted parts of our overall study, developed misleading statements and made these available to the press." (Exhibit 3.) Dr. Wade continued, "...we carefully identified what is known of the real and potential toxicity of these materials as well as the areas where we have inadequate information." He re-emphasized the importance for "all interested parties" to look at the evidence collected 'in total" as presented in the May 1980 report.

The California Health Department in November 1980, publicly testified on the relevance of its May 1980 "Interim Report":

> "We think further study is urgently needed about the possibility that some events in and around the construction of pipes, particularly, and the pipes that we have been studying may be associated with increases of cancer in workers, particularly lymphomas.... We also have a long list of adverse effects." (Reporter's Transcript, Commission on Housing and Community Development Hearing, November 24, 1980, p. 70.)

The health survey of plumbers in California reported, among other things, 54 lymphomas out of approximately 10,000 respondents. This staggeringly high rate of lymphoma drew the specific attention of the USC Medical School where the country's foremost research in lymphoma is being conducted.

In late 1980, Alexandra Levine, M.D., after an analysis of the biological slides and medical records of the first five cases submitted to the medical school, commented: "It is noteworthy to me that all five of these patients with documented diagnosis of lymphoma have had quite extensive exposure to plastic materials which were used during the course of their work." (Exhibit 4.)

In sum, the medical research conducted by the California Health Department, the Occupational Safety and Health Administration, USC Medical School and others, clearly documents the potential for serious, long-range health problems from worker exposure to plastic pipe and its glues.

III

ENVIRONMENTAL CONTAMINATION

Perhaps the most frightening aspect of the multi-faceted issues with plastic pipe concerns general environmental contamination. The toxic chemicals in plastic pipe and its cement solvents appear to be capable of leaching into the environment and thereby causing unalterable damage to our plants, our aquatic life, and our food chain.

For example, a study done by the California Analytical Laboratories and reviewed by the State Department of Health Services, documents the previously unknown presence of "impurities" in plastic pipe. The impurities include known carcinogens such as chloroform, benzene, DEHP, acrylonitrile, and styrene, as well as other toxic chemicals on the EPA list of priority pollutants. (Exhibit 5.) This poses not simply a human health risk to workers who install plastic pipe, but as discussed in more detail below, to consumers who drink water from plastic pipe. Furthermore, it points to a definite risk to the environment generally from the waste discharge of water flowing through plastic pipes. The subject chemicals will add to the existing load of pollutants known to have serious environmental effects because they display all of the characteristics of such chemicals: they can be accumulated in living organisms and food chains, and may be widely dispersed in the environment.

Policy makers may find it helpful to reflect on the numerous requests from public interest groups -- consumer groups, environmental coalitions, womens groups, public interest lawyers -- who have called for comprehensive analysis and evaluation of these potential long-range contamination factors <u>before</u> plastic pipe use is allowed to expand. (Exhibit 6.)

IV

PLASTIC PIPE FOR POTABLE WATER

(Poly Vinyl Chloride [PVC]
and Chlorinated Poly Vinyl Chloride [CPVC])

In the course of its exhaustive research of the scientific literature on plastic pipe, the California Department of Health Services found a previously unheralded article indicating that plastic pipe leaches its solvents into the drinking water. To confirm the potentially incalculable health consequences of this article, the Department of Health Services commissioned the Montgomery Testing Laboratory to conduct the first government sanctioned study to measure the amount of solvents that leached into drinking water from plastic pipe.

The landmark Montgomery test is highly controversial because it simply provides raw test data. Moreover, because the simulated pipe configuration test incorporated an arguably improperly designed pipe "fitting density," experts in the State Department of Health Services estimate the possibility of a 50 percent sampling error. That is, the results of the Montgomery tests may be understated by as much as 50 percent ("Final Report on Potential Health Hazards Associated with the Use of Plastic Pipe in Potable Water System," Department of Health Services, p. 16).

Yet, even with a conservative evaluation of the data, alarming interpretations result. The Department of Health Services stated in their final report:

"With the possible exception of the leaching of the phthalates (DEHP), the principal public health finding of this study is the possibility of excessive amounts of solvents and carbon tetrachloride, chloroform and tetrachlorethene accumulating during the stagnant period between initial installation of plastic pipe and occupation of the dwelling." (Exhibit 7.)

The other conclusions in the final report of the Department of Health Services are tremendously complex and must be viewed in their proper context. For example, extensive "flushing" of the system "may" decrease the risk of abuse from the solvents leaching into the water. However, some of the so-called "volatile organic" chemicals in plastic pipe itself "can accumulate in chlorinated water" notwithstanding the flushing requirement. (See Exhibit 7, p. 35.) One of these chemicals (carbon tetrachloride) was present in the water at 10 times the EPA action level. Other equally dangerous chemicals (chloroform, tetrachloroethylene, DEHP) found at equally high and dramatic levels may not be reduced by flushing. For example, the Department stated:

"Because the possibility exists that some of these elements (carbon tetrachloride, chloroform, and tetrachloroethylene, DEHP) may be coming from the pipes themselves, particularly plasticizers, there is every possibility that they could build up on a longer interim after the initial flushing." (Reporter's Transcript, Commission on Housing and Community Development Public Hearing, November 24, 1980, p. 76.)

So damaging were the findings of the Montgomery tests and the Department of Health Services' evaluation, that the Plastic Pipe and Fitting Association (PPFA) proceeded to initiate a nationwide media strategy to "explain" the results.

In a January 19, 1981, letter from the National Association of Plumbing, Heating, Cooling Contractors (PHCC) to Dr. Marc Lappe', California Department of Health Services, the PHCC Technical Director complained to the California Health Department as to the reliability of the PPFA's explanation that the Health-commissioned tests showed plastic pipe and its glues were safe. The Contractors had received a number of inquiries from their members concerning the trustworthiness of the Plastic Pipe and Fitting Association's news accounts. The Technical Director of the Contractors requested back-up support information from the Plastic Pipe and Fitting Association. The information provided by the plastic pipe industry apparently was so poorly drafted, with unsigned reports, and missing data, that the Contractors decided to request review from the California Department of Health Services. In asking for Health Department reviews, the Contractors commented: "It is interesting to note how your report is reworded (by PPFA) or interpreted to mean something rather different from what was generated by your organization."

The California Health Department response (Exhibit 8) to the Contractors' request was directly to the point. According to Health, the Plastic Pipe Association's reports were "flawed," "incomplete" and "do not reflect accurately our own interpretation of the findings." The California Health Department reached "totally different conclusions regarding potential risks than did this (unidentified industry group of toxicologists) review committee." The PPFA press release was "factually in error and seriously misleading regarding our findings."

In particular,

1. "PPFA did not submit Table 19 of the Montgomery Study to PHCC which "contained the highest readings on chemicals of concern to us, and substantially changed our analysis of the final results. (Table 19 attached for comparison.)"
2. PPFA's characterization that "solvent levels did not exceed safety values "severely distort(s)

the actual findings of the (Montgomery) Report." Specifically, the Health Department found that "solvent levels did exceed recommended (safety) values..."

3. Contrary to PPFA assertions that some chemicals found in the Montgomery tests were not found in the pipe but were induced from sloppy laboratory procedures, the Health Department stated "we resolved (that) issue...by repeat testing and concluded that the evidence pointed to the pipes or a combination of pipes and solvents as the source of DEHP and not laboratory artifact."

In a nutshell, the California Health Department found that the Plastic Pipe and Fitting Association had seriously misrepresented the real health and safety dangers with drinking water coming from plastic pipe.

As with the worker safety question, the plastic pipe industry again distorted, misrepresented, and inaccurately quoted California governmental reports on health and safety to the extent that each of these governmental agencies had to specifically correct the record. It is no wonder that the Director of the California Department of Consumer Affairs recommended:

> "It would be unwise to decide now to expose Californians in their homes to what may be an extremely serious health hazard." (Exhibit 9.)

V

POLYBUTYLENE PIPE FOR POTABLE WATER

Since the Montgomery test for plastic pipe drinking water safety was based on the hypothesis that solvents used to cement these plastic pipes leached toxic chemicals into the drinking water, the Department of Health Services did not request a study of polybutylene (PB) as this pipe does not require solvents for installation.

Yet because polybutylene is part of the generic plastic pipe grouping, it may have many of the same additives, stabilizers and plasticizers as PVC, CPVC and ABS.

In early 1981, the California Department of Consumer Affairs petitioned the State Housing Commission requesting the same stringent testing for PB as the Commission mandated for CPVC and PVC. In this context, the California Health Services Department analyzed the first research conducted on PB pipe itself. The results were alarming. (See Exhibit 10.)

In particular, the tests conducted by the California Analytical Laboratories found 50-500 ppm (parts per million) of DEHP (a known animal carcinogen) in the pipe itself. The United States Environmental Protection Agency (EPA), in a document published at the end of 1980 entitled "Priority Review Level 1 - Di-(2-ethylhexyl) Phthalate (DEHP)," recommends "appropriate action(s) under the Toxic Substance

Control Act, section 6 to prevent or reduce the carcinogenic risks from exposures to DEHP." (page 129).* Subsequent tests on other polybutylene pipe used for flexible connections to plumbing fixtures also found DEHP. (Exhibit 12.)

The results were all the more disturbing because the representative of Shell Chemical Company had testified on the public record that polybutylene pipe did not contain DEHP. The combination of Shell's apparent discrepancy in testimony and the data developed by California Analytical Laboratories finding DEHP, led the Department of Health Services to state:

> "It is disturbing that the (State Housing) Commission was given such apparently misleading testimony (by Shell), since the potential leaching of this compound (DEHP) if present in the type of polybutylene used for potable water poses a potential health hazard to consumers." (Exhibit 13.)

The Department of Health Services went on to conclude that "obviously this situation deserves immediate at-

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* The same EPA document reviewed the DEHP data from the Montgomery Tests on PVC and CPVC. (The test on PB had not been completed.) This document commented: "these data represent the most reliable data on levels or potential levels in drinking water from DEHP containing plastic pipe." (Exhibit 11.)

tention because of the health risks at stake."

To counter this substantive finding, Shell Chemical Company commissioned a first test to be conducted by Radian Labs of Austin, Texas. (Exhibit 14.) While purporting to show the absence of DEHP or any other toxic chemicals, the company's first test was so flawed as to be of little value. (Exhibit 15.)

At the April 20, 1981 public hearing before the California Housing Commission, the representative from the State Department of Health Services stated unequivocably that the chemical found by the California Analytical Labs was "without question" DEHP. Furthermore, the Health Department spokesperson specifically identified a three-member panel within the Health Department which had reviewed the California Analytical Laboratories Test. This impartial panel found the test to comply with strict EPA testing protocols and to be scientifically valid. The Health Department went on to assert that DEHP was also found, in smaller amounts, in Shell's own tests of the PB pipe conducted by Radian Labs.

Presumably embarrassed by the results of its first test, Shell Chemical Company conducted a second test on its product through the Radian Lab. Unfortunately for the industry, the second test revealed "unknown" chemicals that "have to be evaluated," according to the April 20, 1981 testimony of the Department of Health Services.

In a June 15, 1981 letter, the Department of Health Services expressed "cause for concern" to Shell with the chemicals BHT and alkylbenzene sulphonate, both of which were found in the Radian Lab tests.

> "Recent studies have shown that chronic, relatively low level ingestion of BHT can lead to reduced weight gain, increased liver size and raised serum cholesterol in a number of separate animal tests. Other studies have shown reduced litter size following exposure during embryonic development." (Exhibit 16.)

As of this writing, no additional information has been supplied on these chemicals for the Housing Commission's public record.

In conclusion, the Housing Commission agreed with the Department of Health Services, their own Director of the State Department of Housing and Community Development (Exhibit 17), and the Director of the State Department of Consumer Affairs (Exhibit 18) that polybutylene should not be authorized for use until the plastic pipe is thoroughly and impartially studied. (Exhibit 19.)

VI

CONCLUSION

It is now clear that every major California state governmental agency that has an interest in construction, including the State Department of Consumer Affairs, the State Department of Health Services, the State Department of Housing, the State Occupational Safety and Health Administration and the State Commission on Housing and Community Development, all advocate comprehensive analysis and evaluation of plastic pipe through the rigorously scientific and public procedures of the California Environmental Quality Act (CEQA) before any expansion of use is permitted. To do otherwise violates California law:

> "An adopting agency cannot avoid compliance with CEQA by adopting a 'model' code by reference where the code contains material that was previously found to be subject to CEQA. To do otherwise would violate both the State Building Standards Law and the California Environmental Quality Act." (Exhibit 20.)

Furthermore, major health, consumer and environmental interest groups, specifically the Sierra Club, the

Consumer Advisory Council, Women For, the Center for Law in the Public Interest, have unanimously called for plastic pipe to be scrutinized for long-range health and environmental contamination before plastic pipe is permitted for widespread use.

PAUL A. TAYLOR, PhD
PRESIDENT

CHARLES J. SODERQUIST, PhD
VICE PRESIDENT

[illegible]
VICE PRESIDENT

[illegible]
SECRETARY/TREASURER

California Analytical Laboratories, Inc.

401 NORTH 16th STREET
SACRAMENTO, CALIFORNIA 95814
(916) 444-9603

December 31, 1980
Lab No. 12343
Received: 11/17/80

Mr. Raymond Leonardini
Attorney at Law
717 "K" St., Suite 510
Sacramento, CA 95814

Dear Mr. Leonardini:

Attached are the results of our GC/MS analysis of two polybutylene pipe samples received at CAL from a representative of the City of Sacramento Public Works Department and logged under CAL I.D. 12343.

The method of sample preparation and the GC/MS techniques were essentially the same as those employed for the previous analyses of PVC, ABS and CPVC pipe (refer to CAL report of 12 November, 1980, CAL I.D. 12295 and 12298).

Over fifteen components were identified and their levels in the pipe samples estimated. It must be emphasized that the levels are rough estimates only.

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

Sincerely,

Charles J. Soderquist, PhD
Vice President
Agricultural and Environmental Chemist

CJS/slh

TABLE I

Sample	Compound	GC/MS reference scan no. [a]	Estimated level, ppm (mg/kg)
2343-1	butene	V72	0.1-1.0
	acetone	V92	0.5-5.0
	diethyl ether	V160	0.01-0.1
	methyl cyclopentane	V226	0.1-1.0
	methyl cyclohexane	V324	1-10
	3-methyl hexane	V373	1-10
	3-ethyl-3-methyl pentane	V386	1-10
	heptane	V437	1-10
	5 alkanes ($>C_{16}$)	B407, B421, B479 B496, B647	100-1000 total
	butylated hydroxy toluene (BHT)	B533	50-500
	bis (2-ethylhexyl)phathalate (BEHP)	B633	50-500
	a C_{18}-C_{19} alkene	B681	5000-50,000
2343-2	acetone	V93	0.5-5.0
	diethyl ether	V161	0.05-0.5
	methyl cyclohexane	V325	0.5-5.0
	2,3,3-trimethyl hexane	V388	0.5-5.0
	10 alkanes ($>C_{16}$)	B388, B407, B420, B478, B488, B507, B540, B549, B596, B646	100-1,000 total

NOTES: a V = Volatile Organic fraction, B = Base/Neutral (hexane-extracted) fraction.

OFFICE OF PESTICIDES AND TOXIC SUBSTANCES. U.S. ENVIRONMENTAL PROTECTION AGENCY

(November 28, 1980)

Addendum

Priority Review Level 1 - Di-(2-ethylhexyl) Phthalate DEHP

After this assessment was completed, Assessment Division received information from the California Department of Health Services, and from representatives of the Plumbers Union concerning actual and projected levels of DEHP in drinking water resulting from the migration of DEHP from plastic water pipe.

Water pipe made from polyvinyl chloride (PVC) and chlorinated polyvinyl chloride (CPVC) and plasticized with DEHP is in common usage and is rapidly replacing copper pipe in new home construction. While the California studies were primarily concerned with solvents used to join the pipe together, data were developed from conditions simulating use situations that indicated that DEHP may be present at up to 246 ppb in drinking water. Limited evaluations of measured levels in drinking water supplies of new homes were up to 110 ppb. These levels are considerably higher than previously recorded for drinking water and represent a risk of 9.4×10^{-5} and 2.9×10^{-5} respectively.

The DEHP levels reported in these studies varied considerably. Factors such as the physical and chemical properties of the water, dwell time, and analytical methodology frequently lead to discrepencies in reported levels for DEHP. However, these data represent the most reliable data on levels or potentials levels in drinking water from DEHP containing plastic pipe.

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March 18, 1981
Lab Nos. 12752/12754
Received: 3/3/81

Ray Leonardini
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Four pipe and fixture connector samples were received from Mr. John Gorman to be analyzed for organic constituents.

CAL I.D.	Sample Description
12752-1	gray fixture connector, PB2110--QEST-H-PB2100-NSF-PW FDR 11-180°F 100 psi ASTM-D-3309 CAS CERT- (unreadable)-B137.80 1/4 CTS-062 080279
12752-2	gray fixture connector, PB2110-IAPMO UPC PB2110-SDR11-1 BSF-pw 1/4 X 3/8-180°-100 psi-D3309-CSA-CERT
12754-1	gray pipe, PB2110--QEST-H-IAPMO-UOC-PB2110-SDR11-NSF-pw 3/8 X 1/2 180°-100 psi-D-3309-CSA-CERT-B137.8 1/23/77
12754-2	black pipe, PB2110--NSF pw ASTM-D3309 100 psi-(unreadable)-180°F-122 1106C-(unreadable)-1/2" CTS SDR-11 P

Sample Preparation: Samples 12752 and 2-foot lengths of samples 12754 were cleaned with detergent, rinsed with copious amounts of water and air dried. Representative subsamples were obtained by filing with a coarse rasp. Each subsample was rinsed with hexane and portions then placed in clean sample tubes with 5 mL of hexane (-a series) and with benzene)-b series). Identical tubes were filled with the same solvents (both were Nanograde quality) to serve as controls. The samples were held under ambient conditions for five days (for GC/MS) and for an additional five days until selective detector GC analysis was made.

Analysis I--GC/MS. Just prior to analysis by gas-chromatography mass-spectrometry (GC/MS), a 1.0 mL aliquot of the extract was removed and spiked with D-10 anthracene as an internal standard. A 5 μL portion was then injected and processed per the EPA Priority Pollutant (B/N fraction) protocol. Compounds were identified by computer searches of an EPA library, and quantities were estimated by comparison to the known amount of D-10 anthracene added.

Only the hexane extracts (-a series) were analyzed by GC/MS. The hexane blank was clean.

II. Specific-detector GC. Sample extracts were examined by electron-capture gas chromatography (ECD-GC) and thermionic-specific gas chromatography (TSD-GC); these detectors are generally selective for halogenated and nitrogen and/or phosphorus organics, respectively, although ECD-GC is suitable for the determination of phthalate ester plasticizers.

Results: The GC/MS analyses indicated that all four samples were qualitatively similar in that a series of C_{21}-C_{31} hydrocarbons was present in each; their total concentation was estimated to be in the 500-2,500 ppm (mg/Kg) range. Butylated hydroxytoluene (BHT) was present in each sample at the 10-50 ppm level. Bis (ethylhexyl) phthalate (DEHP) was also found at varying levels in each sample as indicated in Table I.

The TSD-GC analyses indicated that no nitrogen or phosphorus containing organic compounds, which were amenable to GC analysis, were present above 10 ppm.

The ECD-GC analyses indicated that DEHP was present in all samples. Identification and quantitation was based on co-chromatography with an authentic DEHP reference standard. Results are summarized in Table I.

Results of Table I should be considered as minimum values since the efficiency of extraction with either solvent is not known and is probably less than 100%.

Charles J. Soderquist, PhD
Vice President
Agricultural and Environmental Chemistry

Michael J. Miille, PhD
Director of GC/MS Services

CJS/slh

Ray Leonardini
Lab Nos. 12752/12754
March 18, 1981
page 3

TABLE I

Sample	Extractant	ppm DEHP found (mg/Kg)	
		by ECD-GC	by GC/MS
12752-1a	Hexane	4.0	4.5
-1b	Benzene	5.0	n.m.
-2a	Hexane	0.8	0.6
-2b	Benzene	0.7	n.m.
12754-1a	Hexane	≥20	32
-1b	Benzene	≥20	n.m.
-2a	Hexane	1.8	2.1
-2b	Benzene	1.4	n.m.

n.m. = not measured

MAR 31 1983

V CEQA SUMMARY

This chapter covers various information not presented earlier but required by the California Environmental Quality Act (CEQA) for Environmental Impact Reports. As this document is a preliminary environmental review, this section has not been fully developed. When the draft and final versions of the EIR are proposed, it is likely to expand and some of the findings will undoubtedly change or at least be stated more confidently.

A. Significant Unavoidable Environmental Impacts

For this preliminary environmental review of a very subtle and complex proposal, SRI chose to describe our current overall conclusions about the proposed plumbing code changes and our reasons for them, without making definitive findings of significance except where they were clearcut.

First, we discovered nothing to suggest that the issues discussed earlier as the prime ones are insignificant or that other issues are dominant. The only new issue of potential significance that surfaced was the permeation of buried plastic pipe by contaminants in soil and the resulting possible public health impacts. Although the possibility that such effects could occur from permeation of water supply lines from the meter to the house is plausible, any potential problem would also occur--probably in much greater proportion--from the public water distribution system. This problem should be re-examined when better understood and if found significant should influence state policies with respect to plastic use in both public and residential systems. With adequate education of building inspectors on the permeation issue, improper installation of plastic water service in contaminated soils should be rare.

As to public health impacts from chemicals leaching from water pipe into potable water, we find that significant impacts are possible but unproven, both for plastic pipes--especially the chlorinated varieties--and for metal ones, specifically copper systems. If the upper ranges of possible concentrations of leachates are regularly reached, the cumulative risks to public health may be high enough to be of concern by typical standards of acceptable risk, for example, a lifetime cancer risk of one in a million. The chemicals of concern are lead from the solder in copper pipes, possibly leading to neurologic disorders, and carbon tetrachloride, perchloroethylene, and trichloroethylene from plastic (especially PVC and CPVC) pipes, possibly resulting in cancer.

Two major considerations limit the significance of the findings. First, the status of information about long-term levels of leachates is exceedingly flimsy. Reasonable further testing could resolve at least part of the uncertainty (see Section VI). Second, the risk assessment procedure is moderately conservative. If risks still appear to be of concern after concentrations are better known, more attention would need to be devoted to assuring that the assessment procedure took into account detailed properties of the chemical. Finally, thorough initial flushing would effectively mitigate the effects of the rapidly leaching materials, especially the solvents used with plastic pipe. Overall, current information does not establish an environmental preference between copper and plastic pipe, with neither clearly likely to cause a great number of deaths or serious illnesses.

For worker safety and health, a similar situation exists. Both lead from solder fumes in installing copper pipe and solvents from installing ABS, PVC, and CPVC pipe could be hazardous if plumbers have high exposures by inhalation; dermal absorption could also be significant in the case of solvents. The diseases of concern for solder fumes are related to the lead exposure and are neurologic. The solvents may also cause nerve damage, and they may be involved in liver damage or reproductive problems as well. However, they are not implicated in cancer unless benzene is more common than thought. Unless the NIOSH report about to be released resolves the range of exposures satisfactorily, further testing would be useful before completing the EIR. Safety issues generally favor plastic over metal, which appears to lead to more burns (hot solder and especially flux) and strains and contusions (from heavier metal pipes). PB (like PE, although its uses are not proposed for change) poses little if any worker safety and health concern. Use of gloves, other protective equipment, ventilation, and simple care will significantly reduce any potential hazards from either plastic or metal pipe, but these practices have not achieved widespread acceptance among plumbers.

Fire safety is a very real concern with plastic DWV pipe; ABS is combustible, and PVC and CPVC will at least soften and slump in lines. If these plastics are installed as direct substitutes for metal, as they already are in non-fire-rated residences, they will degrade the fire resistance of structures. The gaskets in no-hub cast iron will also fail in fires and cause the pipe to fall, leaving fire passages. But the proposed code changes apply to fire-rated, fire-resistive construction that could retain its fire rating if appropriate installation procedures are developed and enforced. In such conditions, no degradation of fire resistance would occur. This issue thus turns on enforcement, not science. The potable water pipes, kept cooler by the water inside and of much lower mass, are not a significant fire safety issue.

As with fire safety, smoke toxicity is an issue in which plastic can only be less environmentally acceptable than metal. However, whether the difference is significant is less certain. Both ABS, which seems likely to contribute the majority of pipe mass in California, and the polyolefins PB and PE produce combustion products that are not highly toxic; few if any additional fatalities or serious injuries would be likely from their combustion. PVC and CPVC both produce significant quantities of hydrogen chloride vapor in fire environments, and this corrosive material could, under certain circumstances, make a difference in the probability of human survival in lines. The frequency of such occurrences is clouded by lack of a generally accepted test for smoke toxicity. This problem is currently being addressed both by the State of California Department of Industrial Relations and by the State of New York. We believe DHCD should pay close attention to results from those studies, but does not need to delay a decision solely on those grounds.

No other significant adverse impacts are likely to result from the expanded use of plastic plumbing pipe if relatively simple mitigation measures are taken. Plastic drain pipes may be slightly noisier than cast iron pipe. See the following section (V-B) for further elaboration.

Overall, the SRI study team sees little evidence that expanded use of plastic plumbing pipe would cause significantly greater environmental problems than the materials it would replace. Unfortunately, lack of evidence is not the same as lack of hazard. We believe it is especially important to gather more information on leaching of chemicals from both plastic and metal pipe systems into potable water and on the exposures of plumbers to material from plastic (ABS, PVC, CPVC) and metal (copper) plumbing systems.

Table V-1 summarizes our present assessment of our relative environmental concern about pipe systems. There we show our relative degrees of concern for different materials for each of the major areas of impacts. A high rating does not necessarily mean an impact that is significant in the sense of CEQA, but does mean that the material rated seems to us more likely to be environmentally harmful then other materials on that dimension. For example, the chlorinated plastics clearly are of highest concern for smoke toxicity, but may not pose any significantly higher impacts in the proposed new DWV uses (fire-resistive construction).

Table V-1

RELATIVE DEGREE OF CONCERN REGARDING
POTENTIAL ENVIRONMENTAL IMPACTS*

Impact Area	Potable Water				Drain, Waste, and Vent			
	Plastic		Metal		Plastic		Metal	
	PB/PE	PVC/CPVC	Copper	Galv. Steel	ABS	PVC/CPVC	Copper/ Gal.Steel	Ca Ir
Public Health	3	4	3	3	0	0	0	[illegible]
Worker Safety	1	2	4	2	2	2	3[+]	[illegible]
Worker Health	0	3	4	2	4	4	3[+]	[illegible]
Fire Safety	3	2	0	0	5	4	0	[illegible]
Smoke Toxicity	1	3	0	0	3	5	0	[illegible]
Other Impacts	0	0	0	0	1	1	0	[illegible]

*Key: 0 - No concern
1 - Considerably less concern than average
2 - Less concern than average
3 - About average concern
4 - More concern than average
5 - Considerably more concern than average

Note: High relative concern does not necessarily imply high absolute concern; significance of ratings depends on mitigation measures taken.

[+]More for copper, less for galvanized.

B. Insignificant Effects

The following environmental effects of expanded uses for plastic plumbing pipe may occur but are probably insignificant by any reasonable interpretation of CEQA:

- Plastic pipe systems may fail slightly more frequently than metal systems until a body of experience with installation errors has accumulated.
- Plastic pipe will consume slightly more petroleum than metal pipe, but slightly less energy overall.
- Plastic pipe will contribute a slightly different load of pollutants to public waste water treatment systems, but the direction of impact, let alone its magnitude, is uncertain.
- Plastic DWV pipe will be slightly noisier than metal systems if installed so as to contact wall surfaces; this may be more significant than otherwise in the multifamily, fire-rated construction that is affected in the DWV code changes.
- Plastic DWV pipe could be damaged by pipe cleaning equipment, but because of its resistance to corrosion, the frequency of such cleaning should be low.
- Plastic pipe will slightly decrease the life-cycle cost of plumbing and therefore of housing, but not enough to change demand patterns or growth.
- Small shifts in employment from metal pipe manufacturing to plastic pipe manufacturing will occur.
- A small reduction in the work of plumbers will occur, mostly as a result of repair and renovation work by do-it-yourselfers.

C. Effects of Alternative Actions

In addition to the proposed project, e.g., the proposed change to the 1982 Uniform Plumbing Code (UPC) allowing certain new uses of plastic plumbing pipe as described in the Project Description, this environmental review has examined the potential effects of alternatives to the proposed project on the quality of the natural and human environment The eventual EIR will consider alternatives as well as the project itself to provide a baseline for evaluating the significance of the impacts and to provide possible alternative courses of action should the proposed project create significant adverse impacts that cannot be successfully mitigated. With this goal in mind, the alternatives we have selected for analysis are no changes to the state code, partial approval of plastic pipe use, and complete rejection of all plastic pipe (that is, reversal of earlier provisions allowing certain uses of plastic pipe).

Under the no-action alternative, there would be no changes in the state code regarding the use of plastic plumbing pipe. All currently approved uses for plastic pipe would continue to be permitted and no new uses of plastic pipe would be allowed. None of the impacts attributable to the use of plastic pipe in expanded applications would be observed; any public health and worker safety and health effects of currently allowed plastic and metal piping systems would persist.

The partial approval alternative would amend the state code to permit certain new uses of plastic pipe, but not all of the new uses proposed under the project. Counting cold and hot water supply in a given application as one new use, the proposed project would change the code to permit 11 new uses of plastic pipe (i.e., 1 new use for ABS pipe, 3 for PB pipe, 1 for PVC pipe, and 6 for CPVC pipe). Considering all the possible combinations of these uses, over 2,000 partial approval alternatives are possible.

Our analyses of the environmental consequences of the proposed project have guided our selection of the subset of the partial approval alternatives to be considered in the EIR. That is, we define the partial approval alternative(s) to permit those new uses of plastic plumbing pipe that are least likely to have significant adverse effects on the quality of the natural and human environment. At present, the only partial alternative that seems reasonably certain to meet this requirement is to allow PB for hot and cold water supply both outside buildings and inside buildings that are not fire-rated or within the fire-resistive construction of fire-rated buildings. No other new uses of plastic pipe would be allowed. Parenthetically, there seems little reason to prohibit PB in exposed locations of fire-rated buildings so long as the penetrations of fire-resistant construction are designed to maintain the rating of that construction. The state of information on the impacts of this alternative is generally the same as on those of the metal water pipe currently allowed for these two uses. Although PB will certainly burn and metal will not, the additional risk of fire spread appears minimal, as does that of smoke toxicity. Leachates from PB have not been shown to be risk-free, but neither have those from copper or galvanized steel. Of the two plastic alternatives, PB is somewhat less likely to be a public health hazard than CPVC, although the relative ratings of PB, CPVC, copper, and galvanized steel will not be clear without further testing (see Section VI). PB is clearly a preferred material, from the worker safety and health viewpoint, compared both with metal systems and with plastics that require cementing.

Under the option of disallowing currently allowed uses of plastic pipe, any impacts of these materials would disappear and those of metal systems reappear. The possibility of permeation of water supply piping by organic contaminants would decrease to the extent that PVC and PE supply lines would be replaced by metal with impermeable joints (but even metal pipe joints can be permeable). Leachates from PVC and PB would be replaced by those from copper, with no clear impact, positive or negative, on public health. The metal pipes would be somewhat more likely to corrode in soil than plastic (galvanized steel is not recommended for buried supply lines). Only small changes in worker safety and health would result from the changes in water supply piping.

Any major impacts of disallowing current uses of plastic pipe would be associated with the widespread use of ABS (and less widespread use of PVC) in DWV applications. Fire load and fire spread would be reduced in nonfire-rated construction. It is probable that few fatalities or little property damage would be avoided by this action, but both are possible benefits. Smoke toxins would also decrease somewhat, especially if PVC were replaced. The decrease in plumbers' exposures to solvent cements would be offset by increased work-related injuries from working with cast iron and, to some extent, with soldered joints in copper DWV. Whether the net effect on worker safety and health would be positive or negative is difficult to predict, given the current lack of information on plumbers' exposures.

Finally, the alternative that would disallow current uses of plastic would transfer some profits and jobs from the plastics to the metal pipe industries. Since large quantities of DWV are involved, these impacts would probably be greater than those for the prime project alternative of allowing expanded uses of plastic pipe. Houses could become more expensive, depending on the prices of cast iron and copper, but probably not enough to significantly affect the demand for housing.

In summary, the alternative of approving only the expanded uses of PB appears to pose fewer environmental risks than does the full proposed project given the state of current information. Because metal systems also pose some unique risks and may be comparable to plastic systems in other risk areas, we are not prepared to say that the no-project alternative or the alternative that would disallow current uses of plastic are environmentally preferable to the partial approval alternative, or even to the full proposed project.

D. Cumulative and Long-Term Implications

Increased use of plastic plumbing pipe can contribute to cumulative environmental impacts in two ways.

First, the sum of the environmental impacts of plastic pipe could be significant even when no one individual impact is deemed significant. In the case of plastic pipe, the most plausible example is for the various leachates that could each contribute to public health impacts. For example, no one leachate might reach the level of 10^{-6} lifetime risk for cancer, but the cumulative risk of all leachates acting together might exceed that level. Given the current uncertainties about the public health impacts, especially those concerning the long-term levels of leachates in drinking water, we are unable to determine whether the cumulative impact is significant. A similar situation is found with worker health impacts, where the risk of one solvent might be insignificant, but that of two or more could be significant. For fire safety, the cumulative impact of all the proposed new uses for plastic pipe are likely to be dominated by the new DWV uses; the contribution of PW pipe is likely to be negligible. The same is true of smoke toxicity, except that the combined affect of HCl, CO, and other toxicants could be significant even when the effects of any one alone were not.

A second issue of cumulative impact is the question of whether the expanded use of plastic water pipe would add to the impacts of other similar actions and in total create a significant effect even though the use of plastic water pipe is not itself significant. We can consider two levels of cumulative impacts:

- Cumulative impact of expanded and existing use of plastic plumbing pipe.
- Contribution of plastic plumbing pipe to total use of plastic products.

As has been made clear earlier, the expanded uses of plastic pipe are in many ways rather small in comparison to existing approved use of plastic pipe. Most new California houses are already being plumbed with ABS DWV if they are not fire-rated; the addition of 10% (by weight) more plastic pipe as PB or (less likely) CPVC water pipe will be of little consequence for fire safety, especially as water piping is less sensitive. The increase for plastic pipe in fire-rated construction, of course, is total since no plastic is being used now; however, if ways of maintaining the rating are developed as required by code, little fire safety impact would be expected. Similarly, the cementing of plastic potable water pipe is probably much less of a problem for workers than the cementing of already approved ABS DWV. Thus, the greatest issue of cumulative impact involves public health impacts, in which plastic in residences can add to plastic in public utility distribution systems. We have no way of estimating the relative contribution of each to the total hazard, as the source of contaminants found in the water supply (controls) during leaching tests is not known. We doubt that the combined effects of distribution and residential piping would be significant if neither one alone were, but we cannot rule out that possibility. Similarly, permeation of plastic distribution pipes by toxic substances is more likely than it is for residential piping systems, but the significance of either, in terms of an overall risk assessment, will not be clear for a long time.

With regard to plastics in total, the expanded uses of plastic pipe will be a relatively small contribution in most respects. Plastics are by now endemic in our society. Most of the contaminants of PVC and CPVC that could be public health hazards will be ingested in much greater quantities from other PVC products such as food containers or, in the case of some of the chlorinated methanes, simply from waste products reaching the raw water supply. Those from PB and PE are similar to those from PE food contact materials. If plasticizers do contaminate plastic pipe, they will still do so at much lower levels than they do in any number of plasticized products to which people are regularly exposed, such as flexible vinyl upholstery (where they would yield inhalation rather than ingestion exposures). But equally clearly, plastic pipe does contribute to the total load of plastic-related hazards in California--for example, to the total of all combustible plastics in residences. The hazards from the total use of plastics are undoubtedly appreciable, even though nearly impossible to estimate. Whether or not they are greater or less than the hazards of the materials they replace is perhaps even more difficult to state. About all that can be said is that plastic pipe is not an unusually prominent or special case among plastics in general.

CEQA also requires an assessment of whether long-term environmental costs will be incurred as a result of short-term economic or other benefits. Certainly, any public health impacts of plastic pipe that do occur will probably be delayed for decades, as will some of the worker health or smoke toxicity impacts. However, for the purpose of determining the environmental consequences of the expanded uses of plastic pipe, those should be counted as current impacts, and not discounted in comparison with current benefits. We believe that, when it is viewed from this perspective, this CEQA issue is irrelevant to the decision at hand.

E. Significant Irreversible Changes

CEQA also requires an assessment of environmental changes or consumption of resources that would be permanent and irreversible. For example, the mining of a mountain is an essentially irreversible impact, whereas most air pollutants and their impacts would disappear once the source of pollution is removed.

In the case of the expanded use of plastic plumbing pipe, there would be a small permanent commitment of petroleum resources (but not other energy sources) to the manufacture of the pipe constituents. Total energy resources would be conserved to a slight degree. If any deaths occurred as a result of diseases caused by leachates or occupational exposures, or from fire or smoke toxicity, they would also be irreversible. If plastic pipe were later disapproved, the occurrence of new fatalities would gradually disappear. Some of the leachates from plastic pipe are mutagens and some mutations can be heritable. Thus, it is possible that a heritable--and more likely than not adverse--mutation could persist in the population as a result of drinking from plastic water pipes. Neither the specifics of the leachates in water from plastic pipe nor the overall state of the art of genetic risk assessment allows an evaluation of this possibility at present. If the impacts of plastic pipe eventually were judged unacceptable, it is possible that the metal pipe industry would have declined by that time to the point at which it would prove difficult to revive, but that possibility is also extremely speculative. Overall, we believe that the reversibility of the impacts is not as important an issue to resolve as the magnitude and significance of current impacts.

F. Growth-Inducing Impacts

California's population is projected to increase from the 1980 total of 23.8 million people to 25.9 million by 1985 and to 27.9 million by 1990 (California Department of Finance, 1981). The proposed code change is not likely to significantly affect this forecast population growth for the following reasons. First, the reduction in the cost of housing construction that would result from use of the newly permitted plastics in place of currently approved plumbing materials is so small that it would have virtually no effect on the sales price or rent of dwelling units in the state. Therefore, there will be no change in the demand for housing and consequently no additional in-migration of residents who would be attracted by a drop in the price of housing. Second, the plumbing material substitutions that are likely to result from the proposed code change would not significantly affect employment opportunities in the state and so would not affect the in-migration and out-migration forecasts. Nor would either housing prices or employment opportunities significantly affect shifts in population from one part of California to another.

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PLASTIC PIPE AND PERMEATION; DOHS OVERSIGHT HEARING
OCTOBER 19, 1983

BACKGROUND PAPER FOR
ASSEMBLY WAYS AND MEANS SUBCOMMITTEE NO. 1
ON HEALTH AND WELFARE

Summary

This briefing document provides background information on the phenomena of plastic pipe permeation and discusses what the state has done to restrict the use of plastic pipe. The document is organized as follows:

I. Overview of the Issue

Permeation refers to the phenomenon by which chemical substances travel through the walls of plastic pipe from surrounding soils and contaminate fluids transported within the pipe. Permeation is of concern whenever drinking water is transported by plastic pipe through soils that are contaminated with hazardous substances. The evidence demonstrates that permeation does occur, although the data necessary to determine the extent and severity of the problem is not conclusive. Uncertainty rests both with the potential frequency of the problem and with the often unknown health effects resulting from chronic (long-term) exposure to low levels of toxic substances.

A. Types of Pipe:

There are three major types of plastic pipe commonly in use for water service. The types of pipe are refered to by their prime constituents: polybutylene (PB), polyethylene (PE) and polyvinylchloride (PVC). Pipe used for water mains is generally from two to twelve inches in diameter. Pipe used to service individual customers is two inches or less in diameter. Evidence indicates that the higher the density of the molecules of the plastics used in the pipe, the lower the permeability of the walls and the lower the rate of permeation.

B. Reports of Permeation:

Permeation has been reported in California and in the Netherlands and EPA data indicates that other states have also experienced permeation problems. Alleged incidents of permeation have been connected to contaminated soils in the vacinity of both the McColl and Stringfellow dumpsites. Permeation could also be a problem if plastic pipe is installed to carry drinking water near any of the hundreds of other identified California sites with known soil contamination.

The experience of one major California water utility demonstrates that the installation of plastic pipe in localized areas subject to soil contamination from the spillage of gasoline can lead to permeation. Other situations of concern include: a) cases in which pipe is installed in new housing developments located on old agricultural lands that have been sprayed with persistant pesticides; and b) application of common pesticides in a residential setting. In summary, the preconditions for permeation may be a common feature of residential and urban settings.

C. Related Public Health Issues:

Permeation is only one of several public health issues related to the use of plastic pipe. One major concern is the contamination of tap water from the leaching of plasticizing agents which are used in the manufacture of plastic pipe, and of solvents and glues used in connecting pieces of pipe. There are also concerns about toxic fumes that are generated during structural fires. Leaching and plastic fumes are major issues in an EIR being developed by SRI International for the State Department of Housing and Community Development (HCD). By contrast there is no scientific study of permeation being carried out in California.

D. Jurisdictional Issues:

Jurisdiction over the use of plastic pipe in California involves a split at the property line of the individual homeowner. The laying of water mains and the delivery of water up to, and away from the property line is regulated by the Sanitary Engineering Branch of the Department of Health Services (DOHS). The use of plastic pipe inside of the property line and within buildings is regulated by HCD. The failure to properly evaluate the threat of permeation in the five years that DOHS has known of the concern, and the failure to take appropriate preventive action, is partially due to this split in jurisdiction. In larger part, DOHS's failure on permeation is a function of:

- o very poor follow through once regulations are developed;
- o a tendency to downplay the potential severity of public health threats and;
- o understaffing.

E. Economic Interests:

The debate on permeation is often clouded by the large economic interests involved in the issue. Plumbers unions have generally been opposed to the use of plastic pipe on several grounds including:

- occupational health issues involved in using glues that contain synthetic organic compounds to join pieces of pipe and;

- public health issues of fire safety, leaching and permeation.

In addition, plastic pipe is generally less expensive than metal pipe and is more easily installed, particularly by homeowners and other nonprofessional plumbers that can use glue and avoid the soldering necessary with metal pipe. Plumbers have not been vocal in raising potential health concerns with nonplastic pipe. Yet there are also occupational and public health issues related to the use of asbestos in pipe, and the lead and cadmium used to solder metal pipe.

II. What is Known About Permeation?

The following is a summary of incidences of contamination and studies related to permeation. Events are presented chronologically where possible.

A. East Bay MUD:

In the late 1970's the East Bay Municipal Utility District (EBMUD) began to receive complaints about drinking water tasting and smelling of petroleum. After investigating several complaints EBMUD concluded that gasoline and other petroleum distillates must have been present in soils into which plastic water mains and service pipes were installed, and that these chemicals permeated through the walls of the pipe and into the tap water.

EBMUD conducted laboratory studies demonstrating that permeation occurs when PE and PB plastic pipe is allowed to soak in a solution of gasoline diluted with water. Results of an identical test of permeation through PVC pipe were negative. Several of the first incidents of petroleum distillate permeation were linked to: (1) the uncontrolled drainage of materials used to clean motorcycles and the corrosion of asphalt, and (2) the contamination of soil caused by the spillage of gasoline from the tanks of automobiles parked on a steep hill.

A third reported incident of permeation in the EBMUD service area involved the presence of butyl mercaptan in tap water. Mercaptans are added to natural gas to produce an odor for safety reasons. The mercaptans apparently permeated from a natural gas service pipe made of PE and through a PB water pipe with which the gas pipe was in direct contact. EBMUD conducted a simple laboratory test of permeation using butyl mercaptan and PE pipe. Strong mercaptan odors were detected in several of the samples.

Several aspects of the EBMUD experience deserve note:

- o Although one of the reported cases of permeation occurred on the premises of an operating chemical manufacturing plant, EBMUD did no test for substances other than gasoline and butyl mercaptan.