Safety and Environmental Concerns for Compounds and Products

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(continued)

II. Compounding Processes

All PVC must be mixed with other materials (compounded) before it is suitable for use. The reasons for this, and the methods for accomplishing it, are covered in detail in Volumes I and II and the earlier chapters of this volume of this Encyclopedia.

Producers of end products which handle more than a few million pounds per year of materials usually find it more economical to combine the compounding and fabrication steps in the same facility. Smaller fabricators, and those who produce small amounts of specialized products, may purchase their supply in ready-to-use form, usually as processed pellets, but sometimes as a dry powder blend. This chapter will discuss the compounding and fabrication steps as separate operations because of the differences in hazards and risks which are seen in those areas. Product application is treated as a third area.

A. Raw Materials

Fabrication operations range in size from small operations which receive the raw materials in bags, drums, and other small packages, to operations large enough to use bulk storage for most or all ingredients. The opportunity for worker exposure or release to the environment therefore covers a wide spectrum, with the manual handling at small operations usually providing a higher probability of spillage, but also having more limited opportunity for a significant release. In any case, the hazard of the substance is the same; it is the risk which changes. The discussion which follows centers on these hazards.

(16CFR1500.45), and various architectural codes for the flammability of interior furnishings.

The toxic properties of PVC were discussed in Chapter 5 of Volume I of this encyclopedia and will not be repeated here. Chlorinated PVC (CPVC) has very similar gross properties and should be handled in the same manner. At one time chloroform was used as a swelling agent to assist in the chlorination step, but that practice was stopped several years ago and thus it is no longer a source for even the minimal release of chloroform which may have been possible earlier. A further result of the chlorination step is that essentially all of any residual VC has been removed.

Concentrations of VC above the OSHA action level (0.5 ppm) can develop in the free space after extended storage of PVC in closed containers. Provisions for ventilation or respiratory protection should be provided if workers enter silos or railcars which have been used for PVC storage or transport. To a lesser degree, some buildup can occur in warehouses or transportation vehicles used for bagged product. Generally, there is enough natural ventilation to prevent exposures over the action level, but the possibility of such levels exists in tightly closed areas where a large volume of bagged material is present.

Similarly, some VC can be expected to escape during the compounding step, especially at the first heating or fluxing stage. The

After liquid stabilizer or plasticizer has been added to PVC, the mixture no longer is dusty. Before that stage, adequate ventilation should be provided to hold the amount of dust in the air to less than 15 mg/M^3 of total dust for a time-weighted average (TWA) over 8 hours, or 5 mg/M^3 of respirable dust (particle size below 10 microns). Very little suspension PVC contains a significant respirable fraction. This is the OSHA standard of 29CFR1910.1000(a). The American Conference of Governmental and Industrial Hygienists (ACGIH) recommends 10 mg/M^3 for total dust, rather than the value of 15 listed by OSHA. Neither organization lists PVC as a specific substance controlled by these limits, but prudence dictates that these values be observed.

Any PVC that has been spilled on concrete or steel walkways can create a very unsafe walking condition and should be removed at once. This is especially true of stairs and catwalks around silos and railcar unloading stations.

2. Stabilizers

Stabilizers may be divided conveniently into two major categories for the purpose of this discussion: FDA-approved and non-FDA-approved. Table 1 contains a list of classes of substances which are in common use for this purpose.

The Food and Drug Administration is responsible for the implementation of the Food Druc and Cosmetic Act which includes the setting of regulations for food additives. Polymers and other substances which come into contact with food are classed as indirect food additives, because of the presumption that some component of the package can migrate into the food and thus become an additive under the terms of the regulations. Rules for controlling food additives are codified at 21CFR170-189, with polymers being grouped under Part 177, and most stabilizers under Part 178. Antioxidants, plasticizers, and such can be found at Part 175 and other locations.

Packaging materials or containers intended for aseptic conditions such as in meat or poultry packaging plants, must meet several FDA standards for approval, but the actual compliance is monitored by the Department of Agriculture under rules published at 9 CFR 300 et seq.

It is necessary for a producer to obtain specific approval from the FDA to use any substance in a food-contact use that is not on the approved lists. Approved substances are those specifically listed in the rules named above, those on the Generally Regarded as Safe (GRAS) list, and those with prior sanction because of broad general use before 1958. In addition, any substance approved as a direct food additive is acceptable also as an indirect additive.

The metallic component of FDA-approved stabilizers is limited to salts of calcium, zinc, or tin, all of which have limited toxicity to

substantial levels, it has been subjected to more rigorous controls. The FDA has approved several dialkyl tin salts for use in food applications, after reviewing test results (21CFR178). Nevertheless, the Interagency Testing Committee (ITC) recommended a group of alkyl tin stabilizers to EPA for further testing (47FR54626, 3 December 1982). The EPA has concluded that a proposed test program by a group of manufacturers will be adequate to answer the questions raised by the ITC, and this program will explore the chemical and environmental fate of this class of substances.

The EPA stated (48FR51361) that the tin stabilizers are not expected to be released rapidly into the environment, and that the material which is released is the reaction product formed during the stabilization step, such as dibutyl tin dichloride, rather than the intact alkyl tin (7). Total tin release to the environment from either compounding operations or use in pipe was estimated to be very low by the EPA. Migration rates from new PVC pipe was projected to be about 10^{-8} mg/m^2/sec. EPA calculated that the added tin concentration for an average receiving stream resulting from plastic pipe use would approximate 7×10^{-6} ppb. This is well below background in most areas.

Alkyl tins decompose slowly in the environment by hydrolysis, photolysis, and biodegradation, with a halflife in the range of a few weeks. The bioconcentration factor (BCF) for the organosalts are in

The non-FDA-approved stabilizers in common use include salts of barium, cadmium, and lead, all of which are toxic heavy metals. Lead stabilizers are approved for use in potable water pipe throughout the world except in North America. These materials are used widely for non-food (or drinking water) applications because of their greater price efficiency as compared to the approved stabilizers.

Each of these metals is listed in Appendix VIII of the Resource Conservation and Recovery Act (RCRA) rules (40CFR261) which makes them potentially subject to the hazardous waste rules of RCRA. In general, if the Extraction Procedure Toxicity Test (the EP test) of Appendix II, 40CFR261, applied to a substance produces an extract containing more than a specified concentration of the metal, any waste that is discarded of that composition must follow the hazardous waste rules. The test consists of contacting approximately 1/3-inch particles with 16 times their weight of dilute acetic acid solution, and measuring for the extracted substance after 24 hours. The specified maximum concentrations for these three metals are:

Barium	100 mg/l
Cadmium	1 mg/l
Lead	5 mg/l

Thus waste stabilizer is a hazardous waste and scrap compound may be, depending on its extractability. However, very few compounds will fail the EP test, especially when formed into the finished article.

as hazardous wastes when discarded but not when in use. California has such a rule and is issuing broad variances to avoid the obvious impossible situations which would result from its strict enforcement.

There is no question as to the cumulative toxicity of many of these metals to humans, and workers should receive full training, and protective equipment as appropriate, to prevent overexposure. OSHA and the ACGIH have set (29CFR1910.1000 et seq.) the following exposure limits (mg/M^3):

	OSHA		
	8-hr TWA	Ceiling	ACGIH
Calcium	-	-	5
Cadmium (dust)	0.2	0.6	0.05
Barium	0.5		0.5
Lead	0.05		0.15
Tin	0.1	-	0.1
Zinc chloride (fume)	1	-	1

As in many other cases, the ACGIH recommends lower values for some of these metals than does OSHA.

Current OSHA Hazard Communication rules (48FR53280, 25 Nov. 1983, new section 29CFR1910.1200), as well as many local community "right-to-know" laws, require extensive disclosure by the supplier of the composition and hazards of all commercial substances and require that workers be informed of these hazards and be supplied with a

Phthalates - The principal phthalate ester in use in PVC is di-(2-ethylhexyl) phthalate (DEHP, sometimes mistakenly termed DOP). It amounts to about a third of the total plasticizer use, primarily because of its high efficiency and good properties at normal use temperatures.

It has very low acute toxicity, with rodent LD_{50} values (dose necessary to kill half the animals in 14 days) in the 30 g/kg range (about the same as sugar) and mild irritation properties (12). OSHA has set an 8-hour TLV of 5 mg/M^3. The ACGIH recommends the same value, with a Short-Term Exposure Limit (STEL) of 10 mg/M^3. The EPA recommends a water quality criteria of 15 mg/l in human drinking water, based on animal feeding studies (13), but the solubility in fresh water is only 0.34 mg/l, and it is about half that soluble in seawater (14).

Esters with alcohol chain lengths of four carbons or greater do not have sufficient solubility in water to present significant acute toxicity symptoms in a variety of aquatic species (15,16).

DEHP does not hydrolyze as rapidly in water as do some of the shorter chain analogs (17). It has the potential to bioaccumulate in the food chain because of its low water/oil solubility ratio, but it also is absorbed strongly by sediments, and biota have been reported to contain less DEHP than the sediments above which they live (18,19). In addition, it is metabolized readily by the host. The ubiquitous

metabolites are positive in a variety of teratogenicity and *in vitro* mutagenicity tests (29-31). That concept is supported by the fact that DEHP is a promoter of mouse liver tumors, but not of skin cancer, and is not an initiator of either liver or skin cancer (32). One study reported inhibition of the development of neoplastic indications in rats treated with diethylnitrosoamine (33), while another reported promotion of this effect (34).

Scientists at the NTP have reviewed the evidence for the carcinogenicity of DEHP and have concluded "that DEHP has been shown to be carcinogenic to rodents in a valid chronic test. Further experimental inquiry will be required, however, to accurately assess the potential health risks posed to humans by exposure to small amounts of this plasticizer (35)." The NTP has included DEHP in the Third Annual Report on Carcinogens (36). The IARC has concluded that there is "sufficient evidence" for animal carcinogenicity, but that there is inadequate evidence to evaluate the carcinogenicity of DEHP in humans (37).

Metabolism occurs after absorption in the gastrointestinal tract following hydrolysis to the monoester (38). The alcohol metabolites appear to be the primary toxic substances, as concluded from specific studies on members of the series and the fact that the esters of lower alcohols are even less toxic and are not carcinogenic in bioassays. In addition, phthalic anhydride itself (39), and of course, its immediate hydrolysis product, phthalic acid, is not

no-effect level exists which is below normally expected ambient exposures (61).

The monoethylhexyl phthalate ester, the primary metabolite, has a no-effect level of 50 mg/kg as a teratogen in rats; above that dose maternal toxicity and weight loss of the embryos were seen (45-46). The parent ester increased fetus malformations when fed at the maternally-toxic doses of 1% or more in the diet (47).

DEHP causes testicular atrophy in rats and is positive in the dominant lethal assay at 1 ml/kg dosage (48-50).

An insufficieny of toxicity data in 1980 (13,51) led to listing of the substance by the Interagency Testing Commission (ITC) for consideration for further testing to determine if regulations should be imposed by the EPA. That agency established a multi-tier testing program to be performed by a group of manufacturers. The results were reported in 1984 (15). The Agency had concluded earlier (52) that, prior to obtaining data indicative of more serious consequences, the ester presents risks below a level at which regulation normally would be taken. The NTP is exploring the question of genotoxicity and other related factors (53). The Consumer Product Safety Commission (CPSC) established a Chronic Hazard Advisory Panel to advise it on hazards for consumer products containing DEHP (48FR56628, Dec. 22, 1983). The Panel released its report in September 1985, concluding that DEHP is a nongenotoxic animal carcinogen, and that more research is needed to determine if

Table 2

Environmental Data for Some
Commonly Used Plasticizers

Plasticizer	Rat Oral Toxicity LD_{50}, g/kg	Solubility in Water, mg/l	Biodegradability	Bioconcentration Factor	In Vitro Tests	Teratogenicity
DEHP	31	0.34	Good	Metabolized	Negative	Negative
Chlorinated Paraffin	>10	Insol.	Nil	High	Positive	Negative
DEHA	9.1	---	Good	Metabolized	Negative	Negative
TCP	---	---	Slow	Low	Negative	Negative
TOTM	>3.1	---	Slow	Metabolized, Excreted	Negative	---

Sebacates - The esters of sebacic acid can be considered homologue of the adipates. DEHS has an LD_{50} in rats of 1.3 g/kg, and like the adipates, is negative in the short-term mutagenicity tests (12).

Citrates - Acetyl tributyl citrate is an FDA-approved component in some food wrap and other food application compounds. It has low acute toxicity and is not a mutagen in the short-term Ames tests (12,60).

The Belgian Plastics Association issued a summary recently (34) of data relating to human exposure to plasticizers. It was estimated that the maximum exposure was less than 200 mg/day under extreme conditions. Studies were discussed which indicate that at doses higher than those necessary to induce liver damage in rodents, primates detoxify DEHP metabolites by combination with glucuronic acid through a procedure not found in rodents. This detoxification avoids the induction of excess peroxisomes in liver cells which are thought to be the base cause of rodent tumor development.

Fire-retardant Plasticizers - The addition of organic substances such as plasticizers to PVC reduces its inherent nonflammability. For example, DEHP has a flash point of 325°F (open cup) which places it in the NFPA flammability hazard group 1, or "must be heated to ignite". However, it and compositions with PVC will burn if exposed to a sufficiently strong ignition source. Appropriate fire

tests at this time. Also proposed are tests to define further the neurotoxicity of the ortho TCP isomer, and its chronic toxicity in lower aquatic life forms. In the proposal the EPA noted that because of the generally low toxicity of TCP and its strong tendency to remain in the finished article or absorbed on soil, it was not likely to present significant environmental exposure as the result of waste disposal. Tris (2-ethylhexyl) phosphate has been reported by the NTP to show "equivocal" evidence of increasing adrenal tumors in male rats, liver cancer in female mice, and thyroid tumors in male and female mice (64). The reports noted that no mutagenic effects were seen in bacteria. The phosphates as a class are delayed neurotoxins, and ingestion should be avoided.

Chlorinated paraffins with chain length of 10-30 carbon atoms and 40-70% chlorine are useful in many higher temperature applications. These are viscous oils at room temperature with insignificant vapor pressure or water solubility. They have very low acute toxicity, do not biodegrade, and are not mutagenic or teratogenic. They also induce increased activity by liver enzymes, as do the other plasticizers discussed here (65).

Because of their persistence in the environment and tendency to bioaccumulate in the aquatic environment, the ITC placed this class on the recommended testing list in 1977, and the EPA accepted the testing proposal of an industry group in 1982 (47FR1017). Partial

application, but later decided to refer this problem to OSHA, then reversed itself again. The present status is not clear.

As will be discussed in more detail later in this chapter, the inorganic fillers reduce the combustibility of the final product and often make it more sturdy. Therefore, the net environmental effect is positive, as well as having a desirable economic impact.

Colorants - Several different terms have been used in the past for materials used to impart color to or mask color development in plastics. Some of the most common are dyes, pigments, colors, and so on. A more general term is colorants (48FR46773, Oct. 14, 1983), which include both dyes (generally thought of as chromophoric organic molecules) and pigments (generally inorganic materials). Colorants may range from colorless materials designed to improve whiteness by their reflectant capacity, or by obscuring the yellowing which may occur during processing, to substances which possess strong color values.

Here, again, if food, drug, or cosmetic contact is intended, and the material may be expected to become a component of the product, the FDA must approve the substance and this has led to a series of numbered "FD and C" dyes. Recently several of these have been restricted in use or banned because of the carcinogenicity of the dye, or one of its precursors. Those which are approved are listed in 21CFR, Parts 74, 81, and 82.

Substances which yield extractable concentrations greater than that allowed are classed as hazardous and must follow RCRA rules if discarded from a commercial operation. This rule does not apply to household or retail trash. Most commercial applications of heavy metal colorants can pass this test, and therefore there is little concern for leaching of the colorant from discarded products.

There is the usual problem of controlling exposures from dusts of these heavy metal salts. One method in common use is to prepare a master blend of the color or dye with a part of the resin and some liquid component, such as a stabilizer, for charging to the blender or mixer. This often is done away from the general work area and by persons of greater technical training. This procedure helps avoid cross-contamination of colors and conserves expensive materials as well as reducing the dust exposure.

The same stringent rules of personal hygiene should be applied here that were discussed under lead stabilizers.

Light Stabilizers - These materials are added in small proportions to some formulations. The usual FDA regulations apply to food contact uses.

Many of the light stabilizers belong to the class of substituted benzophenones. These have very low toxicity, are nonirritating, and

1. Storage and Handling

Some of the hazards connected with the raw materials have been discussed earlier. These hazards usually become apparent only if the materials are spilled or otherwise mishandled. Good housekeeping in a workplace is a reflection of good safety practices also, and efforts spent in reducing spillage is rewarded in reduced accident rates. Good lighting, open aisles, proper storage, and segregation of materials all are necessary for an efficient operation, and contribute significantly to safety, as well.

Pallets of bags or drums should never be stacked more than three high, and preferably only two high, to avoid tilting and slippage. Adequate maneuvering space for forklift trucks must be available, and operation on slopes or ramps should be avoided. Glued or strapped pallets add to the protection from falling containers, but an excess of glue can sometimes cause the bags to rip and increases spillage. Care should be taken in cutting strapping to avoid a whipping effect, or bags falling when the tension is released, and all strapping materials should be removed to avoid a tripping hazard.

Workers should enter silos, transport vessels, or process vessels only under the control of an effective confined space entry program and after all electrical equipment has been locked and tagged out of service. A rescue harness and an outside observer are required by many safety programs. NIOSH recently announced plans for developing

elevated temperatures, often with electrical heating units closely spaced to cooling water troughs. The operation is principally a materials handling unit process, and thus a variety of physical hazards is present.

Proper mechanical guards and electrical safety devices have been the key to maintaining safe conditions. Equipment should have, as a minimum, the mechanical protection required by the OSHA standards of 29CFR1910.216, and conform to the electrical standards of Subpart S of that rule, Secs. 303-4. Equipment manufacturers often design to higher standards, and insurance or local codes may require these improved levels of protection. For example, ground fault protection, especially in areas subject to wet floors, is highly desirable and frequently mandatory.

Walking areas should be designed to prevent slips and falls in the event of spillage of water or plasticizer/stabilizer oils (or both combined - particularly) and also from resin or pellets on the dry floors. Sturdy outdoor grade carpets are useful in nonmanufacturing areas because of the better protection they provide against slips and falls as compared to tile, concrete, or steel walking surfaces.

Equipment and walkways must be arranged so that workers cannot fall into or on heated or moving equipment or product. In addition to the requisite guardrails, triplines and similar protective devices are useful here.

3. Wastes and Emissions

Empty containers should be collected and removed promptly, as should all scrap and waste from the operation. Whether this waste will be regulated under RCRA depends on the type and the results of the EP Extraction test discussed earlier, and whether the total amount of "hazardous" waste exceeds the RCRA small generator exemption. In any event, current social (and legal) policy places the ultimate responsibility for the future on the generator of the waste, regardless of who actually hauled the waste away or disposed of it. It is far easier to take the necessary steps to assure proper disposal at the time of generation than it is to try to convince local politicians (or the EPA) or concerned neighbors years later that the red color or the oil seeping from a landfill is FDA-approved, and therefore is not a health hazard.

The EPA promulgated effluent limitation standards for the plastics molding and forming industries on December 17, 1984. See 49FR49026, for the new rules to be codified at 40CFR463.

The molding and forming industries are defined by EPA to include "processes that blend, mold, form, or otherwise process plastic materials into intermediate or final products. The regulations apply to both existing and new facilities, and are divided into three categories of effluents. Only direct discharges are affected. Those sending their wastes to public treatment systems are not limited to

for these operations and successfully removed the major portion of the incoming wastes.

The EPA has not scheduled the plastics forming industry for a specific air emissions rule under a New Source Performance Standard (NSPS). Some associated operations which are controlled include storage of volatile liquids, and vinyl coating and printing (mid-1984). Under this latter rule, printing inks must contain no more than 50% volatile solvent, or abatement equipment must be installed that reduce emissions by 85%. Final rules for pressure-sensitive tapes and adhesives were promulgated at 48FR48368, Oct. 18, 1983. These rules set allowable limits for quantities of volatile organic solvents released in the air per unit of production. The general trend is to phase out organic solvents and replace them at least partially with water-based coatings.

The EPA has commenced study of the application of polymeric coatings to substrates (Docket No. A-83-42) and has issued a source category survey for comment.

Existing plants in these process categories will not be covered by these new source performance rules. However, they, and all existing plants in nonspecified categories, are covered by other sections of the Clean Air Act which require the states to produce rules to reduce the same classes of emissions. The states must develop a state

EPA has under consideration revisions for the RQ's based on its reevaluation of the chronic health effects of these materials, and many of the salts of the heavy metals will be assigned RQ's in the 10-100 lb. range. Users of these salts as stabilizers should be alert for issuance of these revised values. See 50FR13514, 4 April 1985 for a discussion of this reevaluation process.

The discussion in this section applies equally to both the compounding and the processing industries.

C. Fabrication Processes

1. General

Fabrication of final or intermediate products may begin with the basic raw materials, in which case the discussions in Part II of this chapter apply, or it may use preprocessed compounds and have to deal only with situations specific to the final stages. In either case there are many similarities in the hazards and potential risks which may be present. The larger the operation, the more likely it is that both processes will be located in the same facility.

One significant difference between the two processes is that the wastes from the fabrication step are likely to be innocuous as far as having significant health and environmental hazards. The absence of risk from exposure to fabricated products has been recognized by

Guards and shielding are required for all such machinery by OSHA rule 29CFR1910.216, but aggressive preventive maintenance programs are necessary to assure proper operation and integrity of these devices.

Many of these operations are on a large scale, using high-speed, automatic equipment which feed conveying lines and packaging machinery in complex arrangements. Operators and maintenance workers must act promptly in case of a malfunction to prevent expensive losses of materials and products. Adequate care is necessary in both equipment design and supervisory instructions to avoid accidents in such situations.

Accident report analyses show that the great majority of disabling accidents in the plastics industry, as in the other manufacturing groups, is caused by slips, falls, striking against or by, or the various other categories that cover hitting or being hit by solid objects. Some of the causes which might be expected to be related to the plastic materials being processed, such as burns or toxic effects, represent a surprisingly small proportion of such causes.

Table 3 contains a comparison of Bureau of Labor Statistics data for 1982 injuries with similar data collected by the SPI in a survey of 437 companies with 589 facilities employing 77,344 workers. Both the resin producers and the processors groups exceeded the safety record of the total private sector in all categories. Within these groups the larger companies and the larger facilities generally had better

Table 3

1982 Injury Statistics for Plastic Producers and Processors

National Data	Incidence per 100 employees: All Injuries/Illnesses	Lost Work Days	Severity
Private Sector	7.7	3.5	53.7
Manufacturing	10.2	5.4	75.0
Plastics Industry			
Resin/Material Suppliers (113)*	5.01	1.97	49.5
Processors (223)	6.05	2.16	35.7
Machinery, Equipment (68)	13.0	3.92	50.5
Moldmakers (40)	13.1	2.51	40.4
Total (437)	8.7	3.28	60.5

* number of facilities reporting

It is generally believed that PVC has GRAS status at the FDA because of its widespread use for food packaging before 1958. In 1975 the FDA proposed (40FR40529, Sept. 3, 1975), however, to withdraw this status for rigid formulations because of concern for migration of residual VC into the package contents. No further action has been taken on that proposal, and major reductions have been made in the residual VC concentrations, so that the FDA has stated on several occasions over the years that it is considering a formal withdrawal of the 1975 proposal. It has not acted yet, however. The food additive petition number 4T2959 was assigned to this matter in November 1984.

The miniature liquor bottle market had been denied to PVC in 1973 when it was found that the contents were "adulterated" with ppm levels of VC. The Bureau of Alcohol, Tax, and Firearms (BATF) has asked the FDA for advice as to the suitability of reinstituting this use, and the SPI survey referred to above is one step which the FDA required before it would respond to the BATF request. However, plastic bottles as a class now are permitted for liquor use (47FR43944, codified at 27CFR 19.11).

Most of the 7.8% of foods packaged in PVC are contacted by flexible materials. The survey showed 5.35% packaged at least partially in flexible films, and 1.95% in packages with PVC-containing coatings. The safety of these classes of packages never was questioned by the FDA, but nevertheless, a "cloud" was placed over all forms of PVC for food contact use by the 1975 proposal.

increasing sensitivity of analytical methods reveals a growing number of trace contaminants, both natural and man-made, in all of our foodstuff. It will be necessary for both Congress and the agencies to adopt a more realistic and scientifically based attitude toward minor components before this situation can be resolved in an acceptable manner.

The issue in the case of PVC packaging or potable water pipe revolves around the question of whether the components of the package, and in some cases the impurities in these components, can migrate into the package contents in sufficient quantity so as to present a significant, or even a detectable risk to human health. Before the Monsanto decision, the FDA had assumed that all of the potential migrations would occur into the package, ignoring the loss from the wall in the opposite direction or the retention of a portion of the migrant within the polymer matrix.

The diffusion of small molecules from and through plastic matrices follows a Fickian process involving a relaxation process of the localized swollen polymer (73-75). A concentration gradient is established in the wall of a pipe or food container which provides the driving force for solute movement, and at equilibrium the migration rate is a function of the square of time, the temperature, and the residual concentration. The principal limiting factor is the original concentration, but theoretical and practical considerations also set a lower limit of concentration below which little significant migration occurs (76-78). Experience has confirmed the theoretical prediction that at VC concentrations in rigid PVC of 1 ppm or less, the concentrations in water will be below the

successor, the National Toxicology Program (86,87). The standard practice has been to accept any positive study in animals as indicative of human hazard, and to equate the human risk as being equal to that of the most sensitive test species. Quantitative risk is estimated by a series of "prudent" conservative assumptions, ignoring all comparative pharmacokinetics or other relevant data, to give a result that may be several orders of magnitude too high (88), if indeed, it has any applicability to humans (89).

The National Academy of Science has urged that a better scientific foundation be laid for this process (82), and this is one of the problems with which the FDA is struggling in its effort to develop a carcinogen policy (44FR17070, 47FR4972).

The FDA has indicated, however, that it will apply its so-called constituent policy, which it has been using on an informal basis for direct food additives such as dyes, to indirect additive also. See 49FR13018, April 2, 1984. Under this policy additives which themselves are not carcinogenic, but which contain impurities which are suspected of carcinogenicity, will be evaluated by a conservative risk assessment procedure. If the resulting risk is found to be sufficiently small, the additive may be deemed to be safe. this policy allows FDA to avoid application of the Delaney Clause to this particular application.

A much wider variety of foods is packaged in PVC in Europe than here (61,90), including butter and butter substitutes, cooking oil, wine, and

employees as that described for meat wrappers. A more realistic, and higher risk hazard does develop occasionally when an inadequately stabilized batch of compound is processed. An explosive release of HCl can occur under these conditions and there are reports of extruder heads being blown off the equipment with serious results. Simple "press heat stability" tests of each batch of compound can eliminate this hazard.

Sangha, et al., have shown (94) that, in the 150-175°C temperature range (300-350°F) normally used for PVC processing, the emitted vapors are less toxic than those from Douglas fir at the same temperature. The toxicity increases rapidly at higher temperatures, but of course PVC never is exposed deliberately to such temperatures. Workers at Harvard report that little HCl is found in hot wire cutting of PVC film below 150°C (300°F) but reaches a maximum by 200°C (400°F), and that the acid is associated with particulate plasticizer emissions (95).

Studies by NIOSH have led to their conclusion that the solution to the "asthma" problem is to supply adequate point ventilation at the workplace, and/or to use lower temperature cutting devices (96).

C. Potable Water Use

One of the major growth areas of PVC has been in the extrusion of rigid shapes for water use. Irrigation pipe, drains, conduits, and vents have made up a substantial portion of this application, but potable water pipe

A contractor for the EPA has estimated that the average home contains about 500 lb. of PVC in its building materials, exclusive of consumer goods and plumbing or siding (106). This compares to about 200 ft. of PVC pipe for a house fully plumbed with plastic and several tons of combustible clothing and furniture. As is discussed in the next section, it is unlikely that the plumbing, specifically, or plastics in general, make any significant contribution to fire toxicity under real life conditions.

The controversy over leaching has several facets. These include the extraction of substances from the pipe, the passage of external ground contaminants through the pipe into the water, and the addition of solvents from joint cements to the water.

The argument reached a crescendo when a union coalition persuaded the California Housing and Community Development Commission to reject the recommendation of its staff that California adopt the Uniform Plumbing Code which would extend the use of CPVC and other plastic pipe to uses inside residential structures. These materials had been acceptable for distribution lines, for drain, waste, and vent lines inside homes, and for all uses in commercial buildings for several years. One basis for this decision was a study (107) which reported the presence of several organic solvents and DEHP in water after laboratory tests of simulated use conditions. The DEHP later was found to be the result of laboratory contamination of the samples, and the solvents were those expected as

- In fire-rated construction, fire stops and other construction details permit the plastic drain, waste, and vent systems to pass the fire rating tests.

The report suggested further studies of worker health effects from solvents, and pointed out that plastic pipe reduced the frequency of traumatic injury to plumbers as compared to the use of metal fittings.

This latter conclusion was supported by an analysis of the OSHA data for lost work days of California plumbers in 1979 (111), which showed a significantly lower incidence of lost-time accidents for those causes traceable to plastic pipe use than for accidents caused by metal pipe working.

There had been suggestions that persons working with plastic pipe are exposed to harmful materials during the cutting of the pipe and from the cementing steps. Much plastic pipe is cut with knives or tubing cutters which generate no particulate matter, but when cut with saws plastics yield "sawdust" that is coarser than that from either metal or wood. In one test (79) an 18-tooth handsaw gave no material below 150 micron size when cutting PVC or CPVC pipe, and the exposure of the worker to respirable dust was 0.4 mg/m^3, or approximately background, during the test. Under the same conditions copper and iron pipe gave material down to, but not below, 30 microns, while maple wood produced 0.1% of particles below 30 microns. Thus, while the particles from plastic are coarser than

Table 4

Toxicity Data for Several Common Pipe Cement Solvents

	CHO Cyclohexanone	MEK Methyl Ethyl Ketone	THF Tetrahydrofuran	TOL Toluene	DMF Dimethylformamide
Oral Rat LD_{50}, g/kg	1.6	3.4	3.0	5.0	2.8
Irritation					
Eye, ppm	75	350	---	300	---
Skin	Mild	Moderate	Moderate	Mild	Mild
OSHA Exposure Limit, ppm	50	200	200	200	10
Aquatic Toxicity, TL_{96}, ppm	10-100	>1000	---	10-100	---
Biodegradability	Good	Good	Good	Good	Good
Bioassay	---	---	---	Negative	---
ITC Test Program	Yes	Yes	No	No	No

Data primarily from Ref. 12.

Table 5

Pipe Cement Solvents Extracted from PVC Pipe as a Function of Time

Solvent	Concentration (ppm) 2 hrs.	8 hrs.	24 hrs.	48 hrs.	120 hrs.	240 hrs.
First Filling						
MEK	0.2	0.58	0.7	1.5	2.2	2.3
THF	1.0	2.9	2.7	7.8	5.6	4.2
CHO	0.1	0.2	0.1	1.2	1.9	0.5
DMF	3.1	4.9	16	11	31	7.1
Second Filling						
MEK	0.1	---	0.4	0.4	0.5	---
THF	0.5	---	1.9	2.0	2.4	---
CHO	0.7	---	1.9	0.3	0.1	---
DMF	1.9	---	8.3	7.1	5.6	---

Data from Reference 110.

Federal regulation of potable water pipe has been assigned to the EPA by a memorandum of understanding between it and the FDA (44FR42775). No direct rulemaking has been started by the EPA, but many potential contaminants are regulated by the Interim Primary Drinking Water Regulations at 40CFR141. Local use is controlled by a variety of building codes and local regulations, most of which are permissive for the use of plastic plumbing in the absence of specific regulations to the contrary. Included in those codes which allow unlimited application of plastic piping are those of the Southern Building Conference, the Building Officials and Code Administrator International, the National Plumbing Code, and the Department of Housing and Urban Development of the Federal Housing Administration (29CFR200.929 et seq.). The aim of the industry has been to get direct approvals in place, rather than simply the absence of disapproval. These efforts undoubtedly will be the center of continuing controversy by their opponents.

Self-policing of potable water pipe is supplied through participation in the voluntary National Science Foundation (NSF) program of inspection and certification. Many plumbing codes require the presence of the NSF seal on plumbing supplies, either directly, or indirectly by requiring adherence to the ASTM standards which in turn specify compliance with NSF standard No. 14. Under this system the NSF performs on-site inspection of production facilities and makes nonscheduled tests of pipe and resin formulations for physical properties and extractability. Extraction levels for water contaminants must not exceed the maximum contaminant levels (MCL) set by the EPA under the Safe Drinking Water Act. Typical results from the NSF program are shown in Table 6 (85).

Table 6

Static Extraction of Chloroorganics
from New PVC or CPVC Pipe

Substance	Extraction No.[1]	No. of Samples	Results, ppb ND[2]	1-3	3-5	5-10
PVC Pipe						
Total Haloforms[3]	1	7	7	0	0	0
	2	7	4	3	0	0
	3	7	5	2	0	0
1,1,1-trichloroethane	1	6	6	0	0	0
	2	6	5	1	0	0
	3	6	6	0	0	0
Trichloroethylene	1	6	4	2	0	0
	2	6	4	2	0	0
	3	6	3	3	0	0
Tetrachlorethane	1	6	5	1	0	0
	2	6	6	0	0	0
	3	6	5	1	0	0
CPVC Pipe						
Total Haloforms	1	11	3	4	4	0
	2	12	2	7	3	0
	3	12	1	7	2	2
1,1,1-trichloroethane	1	11	8	3	0	0
	2	11	10	1	0	0
	3	11	11	0	0	0
Trichloroethylene	1	11	9	2	0	0
	2	11	11	0	0	0
	3	11	9	2	0	0
Tetrachloroethylene	1	11	4	7	0	0
	2	11	10	0	1	0
	3	11	9	1	1	0

Notes: [1] 1st extraction, 24 hrs. at 37°C
2nd extraction, 24 hrs. at 37°C
3rd extraction, 72 hrs. at 37°C
[2] Limit of detection, 0.3 ppb
[3] Primarily chloroform

Adapted from ref. 79.

ahead with their own program in an effort to get some credible data on the record.

The EPA is expected to promulgate Maximum Concentration Limits (MCL's) for a variety of halogenated materials, including vinyl chloride during 1986. Recommended MCL's (RMCL's, not enforceable as standards) are to be set at zero for all suspect carcinogens, while MCL's are to be set at 1-10 ppb, depending on the strength of the evidence of human carcinogenicity.

This is not to be confused with the strength of the carcinogen, or potency. That criterion is not considered in this rulemaking. Vinyl chloride is expected to have a 1 ppb MCL assigned, while the other halomethanes and ethylenes will be limited to the 5-10 ppb range. Noncarcinogens such as methyl chloroform will have health-based MCL's in the several hundred ppb range.

Meanwhile, EPA has received mixed advice from its National Drinking Water Advisory Council on its inquiry as to the desirability of banning lead water pipe, and/or lead-containing solders. Considerable data has been accumulated on public exposure to heavy metals through these sources (121), and the EPA continues to consider the steps needed to reduce the health risks involved from these exposures.

There appears to be no health, safety, or environmental reason why PVC or CPVC pipe should not continue to participate fully in the residential and commercial plumbing market. The interrelationship between the self-policing by the industry and the regulatory and building code systems

free chlorine and hydrogen chloride from the chlorine components, and water. Even under strenuous incineration conditions, however, the free chlorine content is minor.

The tendency to form free chlorine is reduced even further when PVC is burned because of the facile removal of HCl from the polymer chain upon heating (123,124). Combustion proceeds at the interface between the air (oxygen) supply and the fuel surface, or interface if a gas (125). Thus extensive preheating occurs before solid surfaces are hot enough to ignite themselves or to supply a source of combustible gas because of pyrolosis. ordinarily, both solid surfaces and evolved gases are burning at the same time, especially at the flame front, as is apparent in watching the burning of a fresh piece of firewood burn in a fireplace. Articles of PVC thus are subject to considerable preheating, and most of the chlorine content is removed as HCl, reducing the opportunity of the chlorine to participate in further reactions. The normal combustion products from PVC are found to be, in decreasing amounts: carbon dioxide, hydrogen chloride, and carbon monoxide, with much smaller amounts of benzene, and a variety of C_1-C_7 hydrocarbons. Benzene, and smaller amounts of toluene, are formed by cyclization of fragments of the dehydrochlorinated polymer chain. The shorter alkane and alkene products also are formed by fragmentation and recombinations. The authors cited above show that the fraction of carbon evolving as carbon monoxide is a function of the temperature and the air supply. Reduced oxygen availability increases the carbon monoxide ratio, as expected. Increased temperature also increases that ratio, due to more rapid char formation, with resultant poorer penetration of the oxygen into the burning mass.

The key question relevant to the safety of the public is whether these combustion products are more hazardous than those produced by potential substitutes, particularly the "natural" materials used before the introduction of synthetic materials, such as wood, cotton, and wool. A companion issue is whether the use of synthetic materials has increased the combustibility of interior furnishings, that is, the ease of ignition, and the rate of flame spread once a fire is initiated. Each of these points will be discussed below.

The unfortunate fact is that there are no reliable tests which can measure these important properties under real fire conditions, despite the significant research effort that has been expended during the last 15 years (103,128-134). One major problem is that results vary with time as the condition of the sample changes during static tests (135). Laboratory simulation of the amount and toxicity of combustion products can be made under carefully measured conditions, but none of these can depict adequately an area fire of mixed fuels under real life conditions.

An advisory committee of NFPA recently reviewed the results of a workshop on toxic hazard assessment of combustion products that was held on February 23-24, 1984 (136). They concluded that lethality was the most appropriate endpoint for presently-available tests, and that a ten-fold difference in test results is needed to constitute a significant difference in lethality between test substances. The participants were not optimistic that a more accurate test system would be available in the near future (137). An active test development program is underway at the National Bureau of Standards (138).

Nevertheless, test results do find their way into regulatory procedures, and they are useful for making relative evaluations of new products and new combinations of materials under fixed conditions. Some of the more prominent of the toxicity tests are summarized briefly in Table 7.

It can be seen that there is considerable variation among these protocols as to whether the system is static or flowing, the sample is burning or smoldering, and the results are reported as a measure of time exposed or size of the sample used. Smoldering conditions are recognized as producing hazardous conditions no matter what is the source of combustible material (131,134,141). Kaplan and coauthors (134), Clarke (131), and Huidener (142), have summarized the advantages and disadvantages of each method recently and they and the NFPA Standards Council (143) have suggested directions for future research to develop more meaningful results.

In general, these test methods show that PVC is about equal to or somewhat more toxic than the conventional materials such as redwood, oak, cotton, or wool, depending on the test conditions used. In all test methods all test materials can impart lethality, and the differences usually are seen in time to incapacitation, or degree of irritation (128,134). The primary cause of death routinely is from the carbon monoxide. The rate at which this result occurs is a function of the interaction of the oxygen and carbon monoxide (CO) concentrations, which are controlled by the amount and type of fuels and by the air supply and temperature (141,144-147).

The acute toxicity of CO is due to its displacement of oxygen in the hemoglobin to form carboxy hemoglobin (CHG), thus starving the organs of oxygen. Minor effects appear at about 15% CHG, severe effects are seen at 30%, and death can occur above 60% replacement. These effects are seen earlier in persons with reduced circulatory ability, and blood concentration is increased more rapidly for persons who are undergoing heavy exertion, or are under stress. Persons in a fire environment may also have their breathing rates increased by high levels of carbon dioxide or other acids. Hydrogen cyanide will act in a very similar manner to CO in displacing oxygen (142,148).

An equilibrium is established between the ambient and blood levels of CO, so long-term exposure does not result in cumulative effects, and there is a short period at the beginning of high exposure before harmful blood levels are established. A recent estimate suggests 2,000 ppm-hrs of constant exposure as a threshold for fatalities (144), if the exposure time is less than 4 hours. The results generally are reversible unless extremely high exposures have been received (149). Kaplan and Hartzell (150) have reviewed the incapacitation effects of CO on rodents and primates and have concluded that rodents are reasonable surrogates for humans. Their analysis suggest that 750-1,000 ppm-hrs will result in incapacitation in humans undergoing light activity.

Studies have found an unusually high percentage of victims of fires in public places have high blood alcohol levels as well as high CHG levels. Impaired orientation and escape ability may be contributing factors in these cases (130,145).

Several variations of this tunnel test are in use, such as the Union Carbide 4-ft. tunnel, the Monsanto 2-ft. tunnel, and the Forest Products 8-ft. tunnel (ASTM E286-69 (1975)).

A variation on the ASTM test is described under NFPA-253-79 and reports the heat flux on the sample from the radiant panel at the flame-out point (if any). Results are given in Btu/ft^2 or $Watts/cm^2$.

Other ASTM tests are designed for specific forms of products, rather than for finishes and surfaces in general. These include: ASTM D1929-77, Ignition Properties of Plastics, which measures the self-ignition temperature of plastics in a heated chamber, and the flash-ignition temperature of the pyrolysis gases; D1230-61 (1972); Flammability of Clothing Textiles, which reports the flame-spread time for a standard sample after a 1-sec. exposure to a gas flame; and D2633-76, Thermoplastic Insulated and Jacketed Wire and Cable, which includes a flame resistance test, among others.

ASTM reports a normal intralaboratory variation of 15-50% on these tests, and interlaboratory variations of up to 100%. Useful discussions of the principles and applications of these tests can be found in references 133,134,146,147,151.

Several other groups have published or recommended tests for plastic product flammability. These include NFPA, NEMA, ANSI, and UL, and the tests are used for approval or certification of many types of products.

The CPSC rule is the only flammability standard in force on a national basis. The Federal Aviation Authority regulates the flammability of passenger aircraft interiors (14CFR25) and recently has proposed a more stringent test for seats (48FR46250, Oct. 11, 1983). Many localities have adopted building codes developed by major organizations such as the Uniform Building Code (UBC) of the International Conference of Building Officials or the BOCA Basic Building Code by the Building Officials and Code Administrators International.

The UBC contained for several years a requirement that the combustion product of plastic building materials be no more toxic than wood, but withdrew that criterion in the mid-70's because of the lack of a suitable test (156). The current code makes no mention of smoke density or toxicity, and sets flame spread criteria, based on the tunnel test at a maximum of 25 for Class I occupancy, 26-75 for Class II, and 76-200 for Class III (general residency) uses. Many natural products cannot meet these requirements for public buildings, or Class I and II occupancy, which exclude common materials such as red oak, because it is used to establish the calibration point of 100 in the test. The UBC nd BOCA codes set similar standards for public buildings.

Perhaps the most effective force in controlling the flammability of construction materials is the insurance ratings imposed by the risk carriers. Their experience with past losses guides their assignment of premium rates and their recommendations for changes to reduce the risks and therefore the premiums. Such "self-policing" by users through

test within a laboratory varies from 10-50%, depending on the material, while the interlaboratory precision ranges from 30 to over 100% for most combustible materials. Wood gives higher results under the smoldering conditions than when flaming, while most plastics give higher density values under flaming conditions. The density and thickness of the sample has considerable effect on the results, with high density and thicker samples giving higher smoke generation (159). The NFPA 258-1982 test uses the same procedure. ASTM D2843-77 also is very similar.

A widely used flow test method was developed by Ohio State University, and is under study by ASTM (159). It also uses either flaming or smoldering conditions, and measures the optical density of the exit gases from the combustion chamber under controlled flow rates. Here, too, flaming conditions produce relatively more smoke from plastics than from wood. Smoke production also increases with air flow, and ASTM E-84, with three times the flow rate of the OSU test, yields higher smoke values than the OSU test. The same is true if the NBS test is run under flow conditions.

All of the ASTM, NBS, NFPA, and other tests include a disclaimer at the introduction which cautions that the tests "should not be used to describe or appraise the fire hazard or risk of materials, products, or assemblies under actual fire conditions". Efforts to measure these hazards under conditions more relevant to actual use situations have led to two types of large-scale studies, corner tests and room tests.

Two large studies to measure the combustion products of actual fires have been reported recently (167,168). Both of these studies found that, in the accessible sampling areas, carbon monoxide exceeded the ACGIH-recommended short-term levels and that oxygen levels were below short-term survival levels greater than 90% of the time. Hydrogen chloride above acutely toxic levels (500 ppm) was found 36-53% of the time. Other toxic gases reported frequently were acrolein and hydrogen cyanide.

One result of the Boston study (165) was a rule requiring all firefighters to wear breathing equipment when involved in structural fires. This action was reported to have reduced the inhalation injuries to firemen there by 80%.

A recent test of the effectiveness of smoke detectors and sprinklers in typical hotel settings showed little change in either the smoke density or room temperature from the presence of typical plastic-upholstered furniture from the room contents (169). The Coast Guard has confirmed that furniture in general is a major contributor to full-scale room fires (170). As expected, detectors and sprinklers were very effective in these settings. Ionization detectors operated faster than photoelectric types except in smoldering situations. Sprinklers appeared to increase the smoke density in the period after activation.

Detailed presentation of the results obtained from these many tests is beyond the scope of this discussion. The reader is referred to the monograph (152) or a brief review paper (175) by Hilado for summaries and leading references to many combustibility tests, and to Kaplan and coworkers (134) for extensive analysis of toxicity tests. The 1981-82 edition of the Modern Plastics Encyclopedia is a good reference for flammability data on specific plastic compositions.

Research continues on methods for more meaningful test methods. Some of the most active institutions include the National Bureau of Standards, Southwest Research Institute, and the University of Utah. The Society of the Plastics Industries or its members are sponsoring or cosponsoring several studies at these and other institutions, and is engaged in a series of demonstrations with fire schools and fire departments illustrating the combustion properties of building and furnishing materials.

The Vinyl Institute (VI), a branch of the SPI, has prepared a series of Technical Information Bulletins presenting detailed information on many of the issues related to the combustion toxicity of common building materials, and has developed a computer-based bibliography of references on combustion studies. It has also been very active in testing and in educational programs with fire fighter associations. Several effective and informative audio-visual aids are available from their headquarters in New York. One is a slide/tape program, "Vinyl in Todays Fire Environment", which was produced by the International Society of Fire Service Instructors. A film, which also is available on video tape,

Heating systems remain the primary source of home fires, and their relative contribution has been increasing rapidly since 1980 (176). Cooking, incendiary acts, electrical systems, and smoking are, in descending order, also major causes. Smoking remains the major cause of fire deaths, with over 25% of the cases ascribed to that act. It is encouraging that Congress recently passed a bill establishing an interagency task force under the CPSC to study a means to obtain a more nearly "fire-safe" cigarette. Heating systems, incendiary acts, children playing, electrical systems, cooking, and open flame are other major identified causes of fire deaths.

It is apparent that the major contribution to continuing the current downward trend in injury and death from fires can be made in the area of reducing their incidence. It is more productive to prevent fires than to try to protect from their combustion products, no matter what the level of toxicity. Proper application of synthetic building materials and furnishings, and especially of PVC, with its inherent noncombustibility, can make a major contribution to that effort. There is no evidence that the increased use of plastics has added to either the incidence of or fatalities from residential fires, or of firemen (143,177-181). Nevertheless, because of the economic pressure, and perhaps because of misunderstanding of the relative toxicity of substitutes, pressure continues at the local level to prescribe rules that would ban or restrict the use of plastics in construction (136).

Instances have arisen where PVC was suspected of environmental problems, but these appear to be attributable to other causes. The case of vinyl chloride contamination of the Dade Co., Florida water supply has been found due to biodegradation of higher chlorinated olefins, as was discussed in Chapter III of Volume I of this Encyclopedia. Vinyl chloride has been found in the emissions of the West Covina, California landfill (184). There are no known sources of VC in that area, but VC-contaminated PVC was suspected as a cause. However, substantial quantities of the other chlorinated olefins were found there also, and it is most probable that they are the sources of the VC in this instance as well as in Florida. Concentrations of VC in the neighborhood since mitigation measures were taken at the dump have not exceeded the California standard of 10 ppb, and the report states that the situation does "not constitute a public health emergency". The gases from several British landfills also contain VC, and in each of these the probable precursor chlorinated olefins were present (185). Earlier studies at other U.S. landfills also found these precursors, but did not use an analytical method suitable to detect VC (186), but more recent data show VC present at almost all such facilities in trace amounts.

In a third instance the EPA has measured vinyl chloride above a landfill known to have received heavily contaminated PVC sludges before 1974 (187). None of these cases suggest any concern for low-VC resins of the type produced today, nor do they represent any reason why PVC itself is not suitable for landfill.

components act both as a sink and a source of chlorine. In any event the quantities of dioxins found are quite low (190-193) and are not expected to add significantly to the natural levels of these substances. In addition, the newer and larger mass burn incinerators are required to have particulate removal equipment that lowers substantially the amount which may be expected to escape. The EPA has made several public statements that municipal refuse incinerators of the type now being installed in many cities will have no deleterious effect on human health.

There are many positive features to incineration of plastics. Their presence helps control the water content of the garbage, and thus the ease of handling and heat yield are improved. They contribute a significant heat output to those units having heat recovery, and the heat value of PVC is about twice that of the average garbage. Operators preparing pelletized fuel for shipment to central incineration units rely on the thermoplastic components to help adhere the pellets for easier and cleaner shipment.

Mass burn incinerators are in much more common use in Europe than here, and the level of per capita use of plastics, including PVC, also is several times higher there than here. Several thorough studies of European experience are presented in reference (182), and that technology now is coming into much wider use in this country. In particular, hydrogen chloride emission has not been a problem even in the absence of specific air pollution control equipment for that component.

Glossary of Acronyms

ACGIH	-	American Conference of Government and Industrial Hygienists, Cincinnati, OH 45211
ANSI	-	American National Standards Institute
ASME	-	American Society of Mechanical Engineers, New York
ASTM	-	American Society for Testing Materials
BOD_5	-	Five-day biological oxygen demand
CFR	-	Code of Federal Regulations, a compilation of promulgated Federal rules. 29CFR1910 refers to Chapter 29, Section 1910.
CHG	-	Carboxyhemoglobin, formed by reaction of carbon monoxide with the blood.
CMA	-	Chemical Manufacturers Association, Washington, DC 20037
CPSC	-	Consumer Product Safety Commission, Washington, DC
DEHP	-	di-2-Ethylhexyl Phthalate
EP	-	Extraction Procedure, designated by EPA for use in testing hazardous waste candidates
EPA	-	Environmental Protection Agency
FDA	-	Food and Drug Administration
FR	-	Federal Register. The official daily publication of the federal government. The number before the letters gives the volume, the following numbers are the page. Volume 49 is being published in 1984.
GRAS	-	Generally Regarded as Safe by the FDA because of broad use before 1958
ITC	-	Interagency Testing Committee, which recommends substances for consideration by EPA for toxicity testing
LD_{50}	-	Lethal dose for 50% death of the experimental animal within 14 days
NBS	-	National Bureau of Standards, Washington, DC
NFPA	-	National Fire Protection Association, Quincy, MA
NSF	-	National Sanitation Foundation, Ann Arbor, MI

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