

IV. ENVIRONMENTAL DATA

Environmental Concentrations

Dioxane concentrations ranging from 208 to more than 650 ppm, with an average of 470 ppm, were reported by Johnstone [31], in which a fatality occurred with a highly significant skin contact with the liquid. No exhaust ventilation was used.

Samples taken during a recently compiled survey of exposure conditions in both the production and drumfilling facilities in a US manufacturing concern in 1974 and 1975 revealed average breathing zone concentrations of about 12 ppm for 30 samples, and 4.28 ppm for 44 samples, in the general workroom atmosphere. The concentration of dioxane at point sources (leaks, vents, etc) averaged 46 ppm for 15 samples. Area monitoring was accomplished using carbon tubes and by grab sampling in 50 ml glass syringes (written communication, RE Peele, January 1977).

Average concentrations at the workplace of three manufacturing concerns were 1.07 ppm (range, 0.03-7.20 ppm) [34], 0.9 ppm (range, 0.6-2.0 ppm) [35], and 6.5 ppm (range, 0.1-23.6 ppm) (written communication, CU Dernehl, April 1976). The concentrations around the storage tanks containing dioxane taken in 1968 were 100 and 800 ppm [35], with no other details given. The concentrations around the storage tanks were not reported when area monitoring was conducted again in 1974 and 1975.

Environmental Sampling and Analytical Methods

(a) Introduction

Review of the literature has indicated that reporting of sampling and analytical methods for dioxane in air has not been extensive. Reid and Hofmann [9], in 1929, mentioned the reaction of dioxane with tetra-nitromethane to produce a yellow color that had been reported by Macbeth [75] in 1915, and erroneously said that the author had suggested its use for identification of dioxane. Subsequent to the report by Reid and Hofmann, this reaction was mentioned by others [1,2,76] in discussions of analytical methods for dioxane, but it apparently never was used.

In experimental exposures of humans and animals to dioxane vapor, Yant et al [19] reported in 1930 that dioxane was collected on activated charcoal and was determined gravimetrically. The dioxane concentrations monitored in this way were 1,000-30,000 ppm. Actual concentrations were probably lower, inasmuch as the charcoal probably adsorbed other materials.

In their 1936 report of animal exposures, Wirth and Klimmer [26] considered that no adequately accurate quantitative method for dioxane was available to monitor the nominal concentrations used that ranged up to 4,000 ppm.

Rowe [2], in 1963, and Browning [1], in 1965, mentioned that the interferometer and combustible gas methods could be used, but they did not report any actual use of these nonspecific methods for determinations of occupational exposure to dioxane. Goldberg et al [55] reported in 1964 that an interferometer had been used to monitor exposure chamber concentrations of dioxane for maintenance to within 10% of nominal concentrations of 1,500, 3,000, and 6,000 ppm.

The first report of a method that specifically mentions monitoring exposure of workers to dioxane was that of Chemodanova [77] in 1948. Dioxane is drawn through a solution of potassium dichromate at 10-15 liters/hour until a color change occurs, and is determined titrimetrically. The method is not specific for dioxane, but, in the absence of interfering substances, could be used effectively for dioxane. The reaction has been used for application to certain mixtures containing dioxane [78] and for analysis of dioxane in biologic samples [79].

The estimation of dioxane concentrations reported by Johnstone [31], in 1959, was the first found in the US literature for an occupational exposure. Johnstone did not describe his sampling and analytical methods.

A report indicating that gas chromatography could be used for dioxane analysis appeared in 1949 [80], and first reports about its use appeared in 1966 [81,82].

Infrared (IR) spectrophotometry was used to monitor continuously exposure chamber atmospheres operated at dioxane concentrations of about 100 ppm during a 2-year study reported by Torkelson et al [68] in 1974.

(b) Collection Methods

In general, air samples for evaluation of occupational exposure can be collected in glass syringes or plastic bags, drawn directly into measuring instruments, or components of the air mixture can be collected by bubbling air through a suitable solvent, or reactant, or over a suitable adsorbent or reactant, or by combinations of these.

Collection of air samples in 50-ml glass syringes followed by direct injection into a gas chromatographic column has been used for determination of dioxane concentrations around point sources [written communication, RE

Peele, January 1977]. Impermeable plastic bags have been used for collecting air samples for monitoring work areas and point sources for dioxane concentrations [35]. Adsorption of dioxane in solutions of potassium dichromate has been used for monitoring of dioxane concentrations in workplaces where other substances were not present [77]. Drawing air directly into measuring instruments for analysis of dioxane concentrations in the workplace may have been used [2] and is applicable for IR analysis [68]. Collection of dioxane by charcoal has been used for monitoring point sources of dioxane as reported by Peele (written communication, January 1977) and for personal monitoring of dioxane exposure [35].

Special charcoal tubes have been developed for use with personal monitoring pumps [83]. The tubes contain a 100-mg section of charcoal through which air is sampled separated from a reserve section of 50 mg of charcoal. The purpose of the reserve section is primarily to indicate overload of the first section and secondarily to collect vapor that has penetrated the first section. If the amount of dioxane found on the reserve section of charcoal exceeds 10% of that found on the larger section, sample loss is indicated. These tubes, which are commercially available, were used in a collaborative testing program that involved 15 laboratories [84]. Air was sampled at 1 liter/minute for 10 minutes from chambers containing about 6, 60, 100, 150, and 200 ppm of dioxane. Four samples were collected by each laboratory at each concentration. Under the conditions of the test, there were no samples where the amount of dioxane on the reserve section of charcoal exceeded 10% of that on the main section. The data indicate that, under the conditions of the test, the upper limit of adsorption by the 100-mg section of charcoal was about 7 mg

of dioxane. This study was conducted in the absence of other air contaminants. In another study [85], air containing dioxane and 13 other chemicals was similarly sampled on 180 mg of charcoal. Dioxane was present at about 50, 100, 200 ppm, and the other chemicals at 0.5, 1, and 2 times their respective threshold limit values (TLV). There was some indication of reduced recovery of dioxane at 50 ppm [85]. This may have been due to decreased adsorption, decreased desorption, or reaction on the adsorbent. Studies of other factors which might influence the adsorption, such as water vapor and air flowrates, have not been reported for dioxane. Further details of this investigation are given in the next section.

(c) Analytical Methods

The analytical methods can be divided into two broad categories: (1) those based on dioxane chemical reactions, and (2) those based on its physicochemical characteristics.

The chemical method that has been used is oxidation of dioxane to CO₂ and water by potassium dichromate [77-79,86]. In one application of the method, a measured volume of air containing dioxane is drawn through a solution of potassium dichromate contained in two absorbing flasks connected in series until a color change occurs. The extent of reaction and thus the amount of dioxane is determined by titration with sodium thiosulfate [86]. The method is not specific for dioxane.

A chemical method is also used in dioxane detector tubes. These are glass tubes packed with chemicals that change color as a measured flow of air containing dioxane passes through the chemical. The length of color change is proportional to the dioxane concentration. Federal regulations on detector tubes provide that measurements with colorimetric indicator

tubes shall be correct to within 25% of the value read (42 CFR 84.50). Some currently available detector tubes can measure dioxane at 10 ppm, but they are not specific and are not certified by NIOSH [87-89].

Methods based on the physicochemical properties of dioxane include interferometry, IR spectrophotometry, and gas chromatography.

An IR spectrophotometer in conjunction with a suitable recorder can be used to record instantaneous concentrations or to record continuously. With this method, concentrations are measured directly and it is not necessary to collect individual samples or to transport them to a laboratory for analysis [90]. Dioxane absorbs sufficient IR radiation for analytical purposes at several wave numbers in the range of 800 to 1,300/cm. Torkelson et al [68] used an IR spectrophotometer with a 4.5-meter gas cell and measured light absorption at a wavelength of 11.4 μm for analysis of dioxane at concentrations around 100 ppm. The method is not adaptable to personal monitoring, but can be used for area and worksite monitoring in conjunction with sample collection in plastic bags [68], or with a sampling system similar to that used for vinyl chloride by Baretta et al [90], or by use of portable instruments [91]. Some IR instruments are sensitive to less than 0.10 ppm of dioxane [91,92]. IR analysis is subject to interferences from other air contaminants and these interferences are not easily detected or resolved without substantial knowledge of IR spectrophotometry.

Gas chromatography provides a quantitative analytical method which can be specific for dioxane [85]. Every compound has a specific retention time in a given gas chromatographic column, but several compounds in a mixture may have similar retention times [93]. This problem can be

overcome by altering the stationary phase of the gas chromatographic column, by changing the column temperature, or by other analytical parameters. Altering conditions usually will change the retention times and separate the components. Data on chromatographic characteristics of dioxane under a variety of conditions are available [82,94-97].

A mass spectrometer can be used subsequent to gas chromatography to identify the substance present in a gas chromatographic peak more positively. Linked gas chromatograph-mass spectrometer instruments yield data allowing this identification. A charcoal capillary tube traps and transfers the material associated with a gas chromatographic peak to a mass spectrometer for qualitative identification when only unlinked units are available [98]. Mass spectra of dioxane have been reported [99].

Samples collected in syringes or plastic bags can be injected directly into the gas chromatographic column. Dioxane collected on charcoal must be removed by desorption before analysis.

As was discussed in the previous section on Collection Methods, the use of carbon disulfide for desorption of dioxane has been studied [84,85]. In one study [85], liquid dioxane was applied directly to 180 mg of charcoal in amounts equivalent to those that would be present in 10 liters of air at 60 and 100 ppm. The respective amounts desorbed in repeated trials were 90-95% and 85-98% of the amounts injected. The effect of six other solvents coadsorbed with dioxane was also studied. Amounts of dioxane desorbed were 81-91% and 83-99% at the two concentrations of dioxane, respectively. These data indicate that, with the six compounds used, there may have been some interference with dioxane desorption at the lower concentration equivalent. Atmospheres of large chambers containing

50, 100, and 200 ppm of dioxane and six other, unnamed, substances at 0.5, 1, and 2 times their respective TLV's were sampled through 180 mg of charcoal and recoveries of 78-87, 84-98, and 91-96% of the expected amount of dioxane were found at the three concentrations, respectively. Although the authors did not consider these values to be less than those found when the dioxane was added directly to the charcoal, the data seem to indicate some loss of dioxane either in sampling or by incomplete desorption at 50 ppm.

In the interlaboratory study conducted by NIOSH [84], atmospheres containing about 6, 60, 100, 150, and 200 ppm of dioxane were sampled at 10 liters/minute for 10 minutes by 15 laboratories. The laboratories determined desorption factors by injecting an amount of dioxane onto charcoal equivalent to the amount that would be collected by sampling at 100 ppm. The average desorption efficiency was 91.6%, but the desorption efficiency values determined by individual laboratories varied from 81.5 to 97.4%. These data indicate that careful determination of the desorption efficiency and attention to detail in desorbing dioxane from the samples are necessary. Altering the solvent may change the desorption efficiency [100].

The data from the interlaboratory study [84] were analyzed for sources of variation. The average amounts of dioxane recovered ranged from 88 to 92% of the nominal amount of dioxane collected and were not dependent on the concentration sampled.

At the lowest concentration of dioxane studied, the method underestimated the nominal concentration, with 95% confidence, by 0-20%, the sampling and analytical errors combined had a coefficient of variation

of 9%, and the total error of the method for determination of a single sample, including sampling, analytical, day-to-day, and laboratory variations, had a coefficient of variation of 36%.

(d) Recommendations

Although factors such as water vapor and air flow rates that may effect adsorption of dioxane by charcoal have not been reported, and the desorption by carbon disulfide is variable and incomplete, collection and desorption of dioxane by these methods are recommended in conjunction with gas chromatography for monitoring exposure of workers. The adsorption capacity of the charcoal is sufficient, and desorption constant enough for use as recommended in Appendices I and II. While the method is indirect, involving collection, desorption, and analysis, it can be specific for dioxane, while simultaneously analyzing for other substances, and the combined sampling and analytical methodology, as specified in Appendices I and II, have been found adequately accurate and precise.

Samples that are representative of the breathing zones of individual workers may be collected by the use of commercially available personal sampling pumps attached to the workers for drawing air through the charcoal tubes. Other methods of collection such as plastic bags, glass syringes, and direct sampling into analytical apparatus, such as IR analyzers, may be used for monitoring worker exposure, provided the samples adequately represent workers' breathing zones. Other sampling and analytical methods should be at least as good as those recommended in Appendices I and II.

V. WORK PRACTICES

The principal method of manufacturing dioxane is by dehydrogenation of ethylene glycol [3]. It can also be produced by catalytic dimerization of ethylene oxide or by reaction of bis(2-chloroethyl) ether or 2-chloroethyl-2-hydroxyethyl ether with strong aqueous sodium hydroxide [7,8].

Dioxane is miscible with water and is a solvent for both organic and inorganic compounds. It forms an azeotrope with water, which boils at 87.8 C at atmospheric pressure, and contains 81.6% dioxane by weight; at 260 mm, this azeotrope boils at 60 C and contains 84.6% dioxane by weight [7]. Dioxane shows the characteristic properties of aliphatic ethers, as it is stable in the presence of acids, alkalis, metallic sodium, ammonia or mild oxidizing agents [3]. It is hygroscopic and forms peroxides, acetaldehyde, ethylene acetal and acidic materials on standing. Peroxides which may form during storage, especially in the presence of light, are explosive and must be destroyed chemically before distillation or evaporation to avoid possible explosion [3]. Dioxane may contain bis(2-chloroethyl) ether, a potentially dangerous precursor, as an impurity. If there is any possibility of this or similar alkylating ethers being present, strict precautions must be taken to prevent any exposure to them.

Dioxane has flammable and toxic properties [10]. At room temperature, liquid dioxane can give rise to vapor-air mixtures within the explosive range. Jones and coworkers [101] described limits of flammability and pressures for dioxane. The lower flammable limit in air (dried on calcium chloride) was 1.97% by volume at standard temperature and

pressure. The pressure that developed reached 80 psi when 3.54% of dioxane was present. Higher concentrations of dioxane in air could not be reached, since some of the dioxane condensed out in the copper tubing at higher concentrations. The upper limit of flammability for dioxane in air (dried on calcium chloride) at 100 C and at standard pressure was found to be 22.25% by volume. The ignition temperature for 2.15% dioxane was found to be 476 C and, as the concentration of dioxane was increased until 4.03% dioxane was present, the ignition temperature was lowered to 438 C [101].

(a) Personal Protective Equipment and Protective Clothing

(1) Protective Clothing

Protective clothing should be used when working with dioxane in amounts or procedures that may cause skin contact. The clothing should be both impervious to penetration and resistant to degradation by dioxane. Materials coated with neoprene seem to be suitable for work with dioxane, since no penetration, leakage, breakage, or shrinkage were seen at the end of 7 hours (written communication, RW McKee, November 1976). Neoprene-coated gloves, boots, overshoes, and bib-type aprons that cover boot tops will sometimes be necessary. Impervious supplied-air hoods or suits should be worn when entering confined spaces, such as pits or tanks, unless they are known to be safe.

If skin comes into contact with dioxane, promptly wash or shower to remove dioxane from the skin, thereby preventing penetration of dioxane through the skin. Clothing that is wet with dioxane can be easily ignited; hence, wet clothing must be removed immediately. This clothing must not be reworn until the dioxane is removed from the clothing. The employer should ensure that all personal protective clothing is inspected regularly for

defects and is maintained in a clean and satisfactory condition by the employee.

(2) Respiratory Protection

Information on the selection and use of respirators has been provided in Table I-1; further details can be obtained from the Respiratory Protection Devices Manual [102] published by the American Industrial Hygiene Association and the American Conference of Governmental Industrial Hygienists in 1963. The American National Standard Practices for Respiratory Protection, ANSI Z88.2-1969 [103], also classifies, describes, and gives the limitations of respirators. This has also been incorporated in 29 CFR 1910.134 (b),(d),(e), and (f).

For respiratory protection from a volatile carcinogen like dioxane, it is proposed to recommend use of positive-pressure respirators, so that facepiece leakage, a problem with negative-pressure respirators, will not occur.

NIOSH periodically issues a list of approved or certified respiratory protective devices. All devices approved by the Mining Enforcement and Safety Administration are listed in Information Circular 8559 and supplements. All types of devices certified by the Testing and Certification Laboratory of NIOSH are listed in a separate publication. These are available from the Testing and Certification Laboratory, NIOSH, Morgantown, West Virginia, 26505.

(3) Skin and Eye Protection

Only one report of dermatitis linearis was described in the literature [32] when dioxane came into contact with the skin. In this case, the eczema developed on an area of the arm and hand where the skin

had been damaged previously. Penetration of skin to cause systemic effects is probably more important than local skin effects in the case of dioxane. As was discussed in Chapter III, dioxane can cause skin irritation and can penetrate skin readily. Hence, protective clothing that will prevent skin contact should be used whenever liquid dioxane is handled.

Irritation of the eyes and nose has been noticed by human volunteers [19,22] at various levels of exposure to dioxane. Also, liquid dioxane instilled in rabbits' eyes was very irritating [39,58]. Hence, eye protection must be provided for and used by employees working with dioxane. Chemical-type goggles, safety glasses with splash shields, or plastic face shields (8-inch minimum), made completely of dioxane-resistant material, should be used. Where splashes of dioxane occur, eyecup goggles that meet the specifications of Section 6.1.1 of the American National Standard Practice for Occupational and Educational Eye and Face Protection should be worn. This is incorporated in 29 CFR 1910.133 (a)(2)(vi).

(b) Bulk Handling, Storage, and Use

Piping and valves at the unloading station should be of dioxane resistant material and should be carefully inspected prior to connection to transport vehicles. The containers should be unloaded with care and stored and supported properly. Embankments and other safeguards should be provided to prevent the spread of liquid escaping accidentally from storage and process containers. Personal protection must be provided during both inspection and connection. Periodic inspection during unloading is also recommended to avoid the possibility of leaks. Eyewash fountains and safety showers must be immediately available. The employer should ensure that the equipment is in proper working order through regularly scheduled

inspections performed by qualified maintenance personnel.

All personnel involved in unloading must be made aware of the toxic, flammable, and explosive properties of dioxane and the necessity for wearing proper personal protection. Additional precautions suitable for transfer of dangerous materials including flagging of the materials must be taken. All spilled dioxane should be properly flushed away with water and care should be taken to prevent undecontaminated dioxane-containing material from entering drains or sewers.

All systems where dioxane is handled should be inspected daily for signs of leaks by personnel attired in specified protective equipment including protective clothing. If there is a leak, it should be corrected immediately using nonsparking tools. Work in the dioxane area should normally resume only after necessary repair or replacement has been made, the room ventilated, and the concentration of dioxane determined by monitoring to be at or below the environmental limit.

Dioxane must be stored in tightly closed containers in a cool, dry, well-ventilated area away from heat, sparks, open flames, moisture, and strong oxidizers. Storage facilities should be designed to contain spills completely within a surrounding dike and to prevent contamination of workroom air. Dioxane when stored must be checked for peroxide content in accordance with the manufacturer's recommendations. All piping and equipment should be marked as containing dioxane. Piping should be located so that the possibility of mechanical damage to it is minimized. Nonsparking tools must be used when opening or closing metal containers of dioxane. Containers must be bonded and grounded when pouring or transferring liquid dioxane. At least two separate means of exit should be

provided from each room or building in which dioxane is stored or handled in quantities that could create a hazard. Storage containers should be periodically inspected for leakage.

Ventilation switches and emergency respiratory equipment should be located outside storage areas in readily accessible locations known to be free from dioxane exposure. Recommended electrical equipment and equipment storage have been described in the National Electrical Code, Articles 500 and 501, respectively.

Liquid dioxane is classified as a class I(b) flammable liquid. Spray finishing operations must be performed in accordance with 29 CFR 1910.107 and 29 CFR 1910.94(c). Dip tank operations must be performed in accordance with sections 1910.108 and 1910.94(d). Whenever dioxane is being handled, exclusion of open lights and other sources of ignition such as smoking should be strictly adhered to. As is mentioned in the discussion of ventilation, below, local exhaust ventilation should be used to control vapor from open or partially open systems. A scrubber such as a water tower or activated charcoal filter should be installed in the venting system to prevent dioxane vapor from escaping to the outside atmosphere. All outside exhaust vents must be located away from working area. Recording of accidents is important for future reference should the incident result in adverse health effects.

(c) Sanitation Practices

Plant sanitation should meet the requirements of 29 CFR 1910.141. Appropriate locker rooms should be made available for changing into required protective clothing in accordance with 29 CFR 1910.141(e). Clothing that is contaminated with liquid dioxane should be immediately

removed and placed in a closed container in a cool, dry, well-ventilated area for later disposal or decontamination. All personnel who work with dioxane should shower thoroughly before leaving the workplace at the end of a workday.

No smoking or eating should be permitted in areas where liquid dioxane is handled, processed, or stored. When handling liquid dioxane, hands not protected by gloves should be washed thoroughly with soap or mild detergent and water before eating, smoking, or using toilet facilities. Eyewash fountains and drench-type safety showers must be immediately available wherever liquid splashes may occur. Eyes splashed with dioxane must be promptly flushed with copious amounts of water. If skin is contacted with liquid dioxane, skin should be promptly washed or a shower taken to remove any dioxane from the skin.

(d) Equipment Maintenance

Cleaning of dioxane tanks and equipment should be performed under appropriate supervision. The tanks should be first emptied, flushed thoroughly with water, purged with fresh air, and tested for dioxane vapor and oxygen deficiency before entry is made. No tank or vessel should be entered unless it has a manhole opening large enough to admit a person wearing proper protective clothing and safety equipment such as safety harness, life line and emergency respiratory equipment. Constant observation should be maintained on the personnel inside the tank, and rescue personnel must be readily available. Emergency entry may be made only if a self-contained breathing unit is provided and protective clothing is worn, such as a protective suit with neoprene coating or a combination supplied-air suit with auxiliary self-contained air supply. Ventilation

should be continued during an emergency by blowing or drawing fresh air through the system. Safety precautions for emergency rescue require that all maintenance personnel be informed of the toxic and hazardous properties of dioxane and be instructed on the necessity of wearing personal protective equipment.

(e) Ventilation

Since dioxane is used principally as a solvent, most operations should lend themselves to control of dioxane vapor through the use of closed systems. Where complete enclosure is not feasible, local exhaust ventilation should be utilized to keep the vapor out of the workroom atmosphere [10]. This local exhaust ventilation system should be so designed as to prevent the accumulation or recirculation of dioxane in the workroom, to maintain dioxane concentrations at or below the limit of the recommended standard, and to remove dioxane from the breathing zones of the employees. Natural ventilation, if used, should be supplemented with forced-draft, explosion-proof fans. Exhaust systems discharging into outside air must conform with applicable local, state, and federal air pollution regulations. Discharged air can be treated to remove dioxane by passing such air through filters of activated charcoal. Water scrubbers can also be effective and may be more efficient.

Continued inspection and maintenance of ventilation systems is essential to prevent or promptly eliminate any leakage of dioxane. This also ensures effectiveness of the ventilation system which should be verified by periodic airflow measurements at least every 3 months. These measurements should be made by trained personnel using proper protective equipment and protective clothing. Measurements of ventilation system

efficiency should also be made by trained, appropriately attired personnel immediately when a change in production, process, or control is made, that may result in increased concentrations of airborne dioxane.

Where reliance is placed on general ventilation, there is, as with all solvents, the danger of excessive concentrations building up during cold weather when doors and windows are kept closed. The design of exhaust ventilation systems should incorporate the principles contained in Fundamentals Governing the Design and Operation of Local Exhaust Systems, Z33.1-1974 (ANSI) [104], and Industrial Ventilation--Manual of Recommended Practice [105]. Recirculation of exhausted air within the workplace should not be allowed. Cooling coils to condense dioxane vapor may be useful in some operations, either instead of or in addition to local ventilation.

Situations in which relatively small quantities of dioxane are used, possibly on an intermittent basis, may not lend themselves to the use of enclosed systems. However, even in such cases, the importance of preventing exposure to airborne vapor, even for brief periods, should not be underestimated. Operations resulting in the release of dioxane vapor should be controlled, where feasible, through use of local exhaust ventilation with additional protection, if indicated, through use of respiratory equipment.

(f) Emergency Procedures

Spills must be anticipated. Storage tanks must be diked to contain the contents of the tank. Drum storage areas also must be diked to contain the volume of dioxane present in the drums, so as to prevent release to other areas. Areas where major spills are likely to occur should be constructed so that they can be closed until properly protected personnel

can ventilate, enter, and clear the area. Warning signs should be posted so that no unauthorized personnel will enter the area. Normal work should be discontinued until the concentration of dioxane has been reduced to the recommended workplace environmental level. Combustion operations, if any, should be stopped until the spill is cleared. Disposal of dioxane should be performed in compliance with any applicable local, state, and federal waste disposal regulations that may be available. Consideration should be given to pumping the diked spill to another tank for later processing or decontamination and dumping. In addition, it is advisable to have facilities for transfer of the contents of a leaking tank to another suitable tank.

In general, if dioxane is spilled or leaked, the following steps should be taken: (1) Remove all ignition sources, (2) ventilate the area of spill or leak, (3) for small quantities, absorb on paper towels using appropriate protective gear such as gloves; evaporate in safe place (such as fume hood); allow sufficient time for vapor to completely clear hood, duct work, then burn the paper. Large quantities can be collected and burned in a suitable combustion chamber. Dioxane must not be allowed to enter a confined space, such as a sewer, because of the possibility of an explosion. Small portable spark-proof exhaust fans may be used in confined areas where local exhaust ventilation is not feasible. Workers should not return to any work area if the odor of dioxane is still perceptible or if there is other evidence of the presence of dioxane vapor. However, it should not be assumed that if dioxane cannot be detected by odor that a safe situation exists.

Maintenance personnel involved in emergency rescue or cleanup should be informed of the toxic and hazardous properties of dioxane and instructed as to the use of protective clothing and equipment. Nonessential employees should be restricted from areas of spills or leaks until cleanup has been completed. The employees in adjacent areas should be trained in evacuation procedures in the event that these work areas become involved.

Only personnel trained in emergency procedures and attired in protective clothing should shut off sources of dioxane, clean up spills, control and repair leaks, and fight fires in dioxane areas. The leaks should be corrected using non-sparking tools. For fire fighting procedures, alcohol foam, carbon dioxide, or dry chemical should be used. Proper protective respirators and protective clothing should be worn by all personnel in the hazard area until airborne dioxane has been removed.

Showers, eyewash fountains, and washroom facilities should be so located as to be readily accessible to employees in case of emergency. If liquid dioxane is splashed on the skin, contaminated clothing should be promptly removed and the skin washed with soap and water. If liquid dioxane contacts the eyes, they should be irrigated immediately with copious quantities of running water. Exposures should be promptly reported to the immediate supervisor by the affected worker or a fellow employee and a decision on the need for prompt medical attention reached.