

#### IV. ENVIRONMENTAL DATA

##### Sampling and Analytical Methods

There are many general methods of sampling and analysis for alcohols. Many of these methods were found to be suitable for related alcohols or other organic vapors and can be adopted for isopropyl alcohol.

Sampling with plastic bags [77-80] or glass bottles [81] involves obtaining a definite volume of the environmental air at a known temperature and pressure. This type of "grab" sample is collected over a very short time, from a few seconds to a maximum of 2 minutes. Thus, sampling techniques involving the use of these collection devices are best suited for information on ceiling concentrations. However, the transportation of the collected samples is often inconvenient due to the bulkiness of the containers. [78] Reports on the use of plastic bags and glass bottles specifically for sampling isopropyl alcohol have not been found in the literature.

Another type of collection device involves the passage of a known volume of air through an absorbing or adsorbing medium to collect the isopropyl alcohol. [82-86] With such devices, samples can be collected over recorded periods of time and the resultant data analyzed to calculate the TWA concentration. Impingers and bubblers can be used to collect isopropyl alcohol vapors in water by sampling at a known rate for a specified period of time. U-shaped glass tubes containing water have been used to collect isopropyl alcohol vapors. [86] Efficiency data have not been found, but, in order to maintain a high efficiency, it is often necessary to use more than one impinger, bubbler, or U-tube in series. The

main disadvantage of such a sampling system is that it is not convenient for obtaining a breathing zone sample. Since the collection medium is liquid, some loss of the sample can occur due to spillage.

Of the various techniques, adsorption offers the greatest ease of collection. Activated charcoal [84,85] and silica gel [33,82,83] are common adsorbents. Hahn [33] collected 720 mg of isopropyl alcohol on approximately 23 g of purified, dry silica gel. Liquid isopropyl alcohol was pulled by a water jet pump into silica gel in a glass tube 26.5 cm long and 3.0 cm in diameter. A second tube of the same size was connected in series with the first one to determine the amount of isopropyl alcohol adsorbed. The alcohol was then desorbed by passing steam through the tubes and condensing it in a large coil cooler. The second tube yielded no isopropyl alcohol and so the author concluded that 23 g of silica gel was sufficient to adsorb 720 mg of isopropyl alcohol. Analysis revealed that the efficiency of yield was 97-99%. The amount of silica gel and the size of the glass tubes required are large. Hence, this technique may not be suitable for taking personal samples in breathing zones of employees. Details, such as specificity, sensitivity, and precision, were not recorded. Silica gel has a greater tendency to adsorb moisture than does charcoal and therefore functions best in dry environments. However, the necessity still exists for a sampling technique convenient for industrial environments, which are seldom dry.

Collection on charcoal is suitable for taking breathing zone samples and convenient because of the short sampling time required. Transportation of samples is also convenient because of the small size of the containers. The chief advantage of the charcoal tube is that it is a small, portable

sampling device that contains no liquid. The disadvantage is that the amount of sample which can be taken is limited by the weight of the sample that the tube will hold before overloading occurs. When the amount of sample obtained for the backup section of the charcoal trap exceeds 25% of that found in the front section, the possibility of sample loss exists. Also, during storage of the sample, the more volatile compounds will migrate throughout the charcoal tube until steady state is reached. [87]

The precision of the charcoal tube method is limited by the reproducibility of the pressure drop across the charcoal tubes. Because the pump is usually calibrated only for a single tube, this drop will affect the flowrate and cause the volume to be imprecise. The other disadvantage is that isopropyl alcohol tends to be displaced from charcoal by a large amount of less polar organic vapors. [87]

Despite the limitations of the charcoal tube, it is the method of choice. Details concerning its use are presented in Appendix I. Because the charcoal tube collects a large number of organic vapors, the use of a specific analytical method is mandatory.

The choice of an appropriate analytical method depends largely on the collection technique. If the sample is in a water solution, as in the case of impingers and bubblers, colorimetric analysis [86,88] and the Knipping-Ponndorf method [89] are suitable. These methods are also suitable for samples collected on silica gel. Isopropyl alcohol is desorbed by passing steam through the gel and condensing the steam. In one of the colorimetric analyses, [88] isopropyl alcohol is oxidized by a measured quantity of potassium dichromate in the presence of concentrated sulfuric acid. Excess dichromate is determined by further reaction with *s*-diphenylcarbazide to

form a colored complex. The concentration of the complex can then be measured with a spectrophotometer. The concentration of the isopropyl alcohol can be calculated from the amount of dichromate used up in the oxidation. The major drawback is that interference can be caused by a large number of oxidizable substances, including other alcohols and some metallic ions.

In another colorimetric technique, [86] 2 ml of 10% potassium persulfate is added to 2 ml of water containing isopropyl alcohol. The mixture is maintained at 50-54 C in a water bath for 30 minutes and then cooled. To this, 0.2 ml of 1% potassium persulfate is added and the mixture is again maintained at 50-54 C for 30 minutes. It is then cooled to room temperature. To this mixture, 0.2 ml of 5% bisulfite solution is added, the resulting solution is mixed, and 2 ml of 40% sodium hydroxide solution added, followed by 0.2 ml of 20% solution of salicylic aldehyde in ethyl alcohol. The total mixture is shaken, heated and maintained at 80 C for 15-20 minutes, and cooled. A bright yellow-orange complex is formed and the absorption determined colorimetrically. Acetone was found to interfere while other primary alcohols did not. The sensitivity was reported to be 0.002 mg in 2 ml of water.

In the Knipping-Ponndorf method, [89] isopropyl nitrite, formed by reaction with sodium nitrite, is removed with carbon tetrachloride. Nitrous acid is then liberated from isopropyl nitrite by reaction with sulfuric acid, a known excess of potassium permanganate, and manganous sulfate solution. The unreacted potassium permanganate liberates iodine from potassium iodide. The iodine is then titrated with sodium thiosulfate solution. The amount of isopropyl alcohol can then be calculated from the

amount of sodium thiosulfate used. Data on the specificity, accuracy, precision, and sensitivity of either of these methods have not been found in the literature.

Other analytical methods that may be used are infrared spectroscopy and gas chromatography. These methods are especially useful when the samples are collected on charcoal or silica gel. However, infrared analysis is a qualitative rather than a quantitative technique. [90] Gas chromatography offers the greatest specificity and sensitivity and is suitable for analyzing grab samples and samples collected on charcoal. The advantage is that interferences are minimal. If they do occur, they can generally be eliminated by altering the instrumental conditions. [87] The retention time of isopropyl alcohol in a carbowax-chromosorb column is reported to be 12.8 minutes, while for an amine-carbowax-Teflon column it was 9.8 minutes. [91] A detection limit of 2 ppm has been reported for a 4-ft long chromosorb column at 94 C. [92] Gas chromatography can also be used for the simultaneous analysis of 2 or more solvents suspected to be present in the same sample by converting from an isothermal to a temperature-programmed mode of operation. Details of this method are given in Appendix II.

Detector tubes are used frequently for a quick, direct detection of the isopropyl alcohol concentration in air. [93] However, the British Occupational Hygiene Society considers the detector tubes as unreliable and does not recommend them. [93] Information on the accuracy and precision of detector tubes has not been found in the literature. They have been shown to measure total alcohol concentrations ranging from 100 to 3,000 ppm. [94] These tubes may be useful for detecting leaks in closed systems and testing

for the presence of isopropyl alcohol vapor in confined spaces. They may also be used to make a rough estimate of the air concentration of isopropyl alcohol. Based on this estimate, decisions on what volume of air to sample can be made.

The charcoal tube-gas chromatographic method is the method of choice, and details are given in Appendices I and II. Other sampling and analytical methods equivalent in accuracy, precision, and sensitivity may be used.

### Engineering Controls

A major use of isopropyl alcohol is as a solvent in operations that may involve spraying, surface coating, pouring, mixing, and oven-drying (Stanford Research Institute, written communication, February 1975). Most of these operations are open to the air, and isopropyl alcohol vapor may be released into the atmosphere. The principles set forth in Industrial Ventilation - A Manual of Recommended Practices, published by the American Conference of Governmental Industrial Hygienists Committee on Industrial Ventilation, [95] and Fundamentals Governing the Design and Operation of Local Exhaust Systems, Z9.2-1971, [96] published by the American National Standards Institute, should be applied to control atmospheric concentrations of isopropyl alcohol. Application of surface coatings such as shellacs, lacquers, or varnishes can produce high atmospheric levels of solvent vapor. In enclosed areas, the concentrations can exceed the lower explosive limit, particularly if application is by spraying. [97] Such operations should always be ventilated by portable blowers and correctly positioned portable ducts. As far as possible, the alcohol vapors should

be controlled at the source rather than by general ventilation. Operations involving the use of isopropyl alcohol at an elevated temperature, such as drying, evaporation, etc, may require special attention in the placement of local ventilation controls. Such controls must be explosion-proof (Stanford Research Institute, written communication, February 1975). Since other substances are present where isopropyl alcohol is used, special care must be taken to make sure that substances that form explosive mixtures are not vented into the same system.

Closed systems using isopropyl alcohol are more successful in controlling isopropyl alcohol vapor in air. However, frequent tests should be conducted for leaks. Based on the data obtained during field visits, the major isopropyl alcohol-manufacturing processes in the US are currently closed processes (Stanford Research Institute, written communication, February 1975).

## V. DEVELOPMENT OF STANDARD

### Basis for Previous Standards

The present federal standard (29 CFR 1910.1000) for isopropyl alcohol exposure is an 8-hour TWA of 400 ppm. It was based on the recommendation first made in 1959 by the American Conference of Governmental Industrial Hygienists (ACGIH). [98] The ACGIH based this recommendation on the human experiment reported in 1943 by Nelson et al [34] who found that at 400 ppm, isopropyl alcohol caused mild irritation of the eyes, nose, and throat. A concentration of 200 ppm or less was estimated by the exposed subjects to be most suitable for an 8-hour exposure period. The results of this very simple and subjective study have been widely adopted as a basis for isopropyl alcohol standards.

In 1945, Cook [99] reviewed a list of maximum allowable concentrations of various contaminants recommended by the US Public Health Service and the American Standards Association. A value of 400 ppm for isopropyl alcohol was referred to as an "accepted and tentative" value. Altman and Dittmer [100] indicated that, in 1962, the US Navy established 400 ppm as the maximum acceptable concentration in a submarine. In 1961, the Hygienic Guides Committee of the American Industrial Hygiene Association [101] also accepted a minimum concentration of 400 ppm of isopropyl alcohol for a TWA concentration for a normal workday.

Documents on standards established in other countries were not found in the literature. Elkins (written communication, August 1975) reported



that the MAC for isopropyl alcohol in Czechoslovakia is 205 ppm and the USSR limit is 80 ppm. Reports on the basis for these standards have not been found.

#### Basis for the Recommended Environmental Standard

It is evident from the chapter on Biologic Effects of Exposure that there are few toxicologic data over wide exposure ranges suitable for establishing a standard for isopropyl alcohol in the occupational environment. For example, in one study [45] four out of 6 rats inhaling isopropyl alcohol at 16,000 ppm for 8 hours died within 14 days. In another study [47] no adverse effects were observed in men ingesting daily doses of 2.6 mg/kg and 6.4 mg/kg for 6 weeks. Irritation of the eyes, nose, and throat occurred in people inhaling isopropyl alcohol at 400 and 800 ppm for 3-5 minutes. [34] Thus, a TWA of 400 ppm for 8-hour exposure periods accompanied by a ceiling value of 800 ppm has been recommended on the following basis. The present Occupational Safety and Health regulation classifies isopropyl alcohol as a flammable liquid of Class IB in 29 CFR 1910.106(a)(19)(ii). The lower explosive limit of isopropyl alcohol is 2% by volume or 20,000 ppm. Since an accepted margin of safety for fire and explosion protection is 10 (29 CFR 1917.11(a)(2) and 29 CFR 1915.11(a)(2)), a level of isopropyl alcohol below 2,000 ppm would make the atmosphere safe from fire hazard. However, mild irritation of eyes, nose, and throat has been reported at levels of isopropyl alcohol at about 400 ppm, and even at 800 ppm, these effects were not severe. [34] While it is recognized that the report by Nelson et al [34] is inadequate as the sole basis for a standard, it is only used to substantiate the need for a workplace exposure

limit where minimal irritation occurs. A TWA of 400 ppm is therefore recommended with a ceiling level of 800 ppm at which minimal irritation occurs.

Special medical surveillance, including preplacement and annual physical examinations, is recommended for employees engaged in isopropyl alcohol manufacture. An epidemiologic investigation by Weil et al [39] established that a carcinogen was present in the original isopropyl alcohol-manufacturing process. The present manufacturing process differs from the one examined by Weil et al [39] in that dilute, rather than concentrated, sulfuric acid is used, the reaction conditions are different, and the resulting oils differ in composition. It cannot be assumed that these changes in the 2 processes have been sufficient to eliminate the carcinogen. However, no other epidemiologic study has been reported in the new process. Therefore, special medical surveillance, engineering controls, and work practices have been recommended for employees working in isopropyl alcohol-manufacturing plants. Because of the suspected presence of a carcinogen, it is recommended that records of medical and environmental data be kept for 30 years.

Use of respirators as a means of control is not recommended. Respirators must be used only when both the engineering and the administrative controls are inadequate to protect the employee from isopropyl alcohol exposure. Table I-1 lists the types of respirators that should be used at various concentrations of isopropyl alcohol. Because there is a distinct odor of isopropyl alcohol at both the recommended action level and the TWA, [35,36] employees should change the cartridge or the canister immediately after detecting the odor of isopropyl alcohol.

However, the maximal service life for an organic vapor cartridge is 40 minutes at 1,000 ppm; for a full facepiece with chin-style canister, it is 10 minutes at 5,000 ppm; and for a full facepiece with front- or back-mounted chest-type canister, it is 10 minutes at 20,000 ppm. [102,103] An air-purifying respirator is not recommended for entry into areas where the concentration of the vapor exceeds the lower explosive limit. Self-contained breathing apparatus must be used in such atmospheres.

Sampling and analytical methods described in Appendices I and II have been tested by NIOSH and found suitable for monitoring isopropyl alcohol. [87]

It is recognized that many employees handle small amounts of isopropyl alcohol. Under these conditions, it is not necessary to comply with all provisions of the recommended standard. However, concern for employee health requires that protective measures be instituted below the enforceable limit to ensure that exposures stay below that limit. Therefore, environmental monitoring and recordkeeping are recommended for those work situations which involve exposure above 200 ppm. Occupational exposure is hence defined as exposure to isopropyl alcohol at or above the action level of 200 ppm.

## VI. WORK PRACTICES

Work practices and safety precautions for handling isopropyl alcohol are the subject of numerous reports. [1,104-108] Reports of work practices designed for the prevention of isopropyl alcohol exposure are not available. In general, good engineering controls should be used to control continuous low-level exposures and to minimize excursions.

The flash point (closed cup) of isopropyl alcohol is 53 F (11.6 C). It is therefore classified as a flammable liquid of Class IB in 29 CFR 1910.106(a)(19)(ii). The lower and upper explosive limits in air at 20 C are 2.0% (20,000 ppm) and 12.0% (120,000 ppm) by volume. [2,104] The Bureau of Explosives classifies isopropyl alcohol as an "inflammable liquid." [107] The Manufacturing Chemists Association cautions that isopropyl alcohol vapors mixed with air at ordinary temperatures are explosive within certain limits. [1] Hence, fire and explosion are the principal safety hazards of isopropyl alcohol. Engineering controls should prevent the accumulation of explosive concentrations of isopropyl alcohol in the air. Such control equipment must be sparkproof. Recommended work practices are intended to ensure that no flames or other sources of ignition, such as smoking, be permitted in the area where isopropyl alcohol is stored or handled. Since the accepted margin of safety for flammable substances is a factor of 10 (29 CFR 1917.11(a)(2) and 29 CFR 1915.11(a)(2)) precautions against the fire and explosion hazards must be taken whenever isopropyl alcohol vapor may accumulate and exceed 10% of the lower explosive limit (2,000 ppm). Special precautions are necessary for entering a vessel which may contain isopropyl alcohol [105,109] and for

flame- and spark-generating operations, such as welding, cutting, and transferring the alcohol. [1,104] Moreover, smoking must also be prohibited.

Since the presence of a carcinogen is suspected in the isopropyl alcohol-manufacturing area, [39] and since the identity of the carcinogen is not known, it is necessary to protect the employees from all agents in this area. Routine checks must be done to ensure that the process is completely enclosed. If leaks occur, these must be promptly corrected, regardless of the isopropyl alcohol concentration in the environment. If employees must withdraw samples from the process, an impervious suit including gloves, boots, and air-supplied hood must be worn. Any waste or residues produced in the isopropyl alcohol-manufacturing area shall be collected in an impervious container with an appropriate label and incinerated properly so that no carcinogenic products are released in the air.

Isopropyl alcohol is a moderate eye irritant. [55] In view of this, use of personal protective equipment, such as safety glasses or goggles, is recommended when isopropyl alcohol contact with the eyes is likely. Isopropyl alcohol is usually not a skin irritant, as is obvious from its extensive use as rubbing alcohol. Protective clothing is normally not required for operations involving the use of isopropyl alcohol. If an employee's clothes become contaminated with isopropyl alcohol, a change of clothing shall be made available as a good hygiene practice. Although it is not required, it has been observed that some employers do provide fire-retardant clothing to employees (Stanford Research Institute, written communication, February 1975).

Safety showers, eyewash fountains, and fire extinguishers shall be located in or near areas where isopropyl alcohol splashes are likely to occur and shall be properly maintained.

Handwashing facilities, soap, and water must be available to the employees. As a good hygiene practice, it is recommended that any spills on the body be promptly washed, and that employees wash their hands before eating.

In summary, precautions must be exercised against the fire hazard of isopropyl alcohol. It is also important that employees be informed before job placement of hazards associated with the use of isopropyl alcohol and when any changes are made in the process that may alter their isopropyl alcohol exposure. Appropriate emergency procedures should be stressed. Recommended labels and posters must be displayed. The US Department of Labor "Material Safety Data Sheet," or a similar OSHA-approved form, must be filled out. In addition, all employees in the isopropyl alcohol area should know where the safety sheet is posted. If all of these work practices are observed and good engineering controls are installed, employees working with isopropyl alcohol should be adequately protected from overexposure, fire, explosion, and other hazards associated with isopropyl alcohol.

## VII. REFERENCES

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## VIII. APPENDIX I

### METHOD FOR SAMPLING ISOPROPYL ALCOHOL IN AIR

The sampling and analytical methods presented in Appendices I and II are based on that described in the Method No. S65 of the Physical and Chemical Analysis Branch of NIOSH. [87]

#### General Requirements

Isopropyl alcohol concentrations shall be determined within the employee's breathing zone and shall meet the following criteria in order to evaluate conformance with the standard:

(a) Samples collected shall be representative of the individual employee's exposure.

(b) Sampling data sheets shall include:

- (1) The date and time of sample collection.
- (2) Sampling duration.
- (3) Volumetric flowrate of sampling.
- (4) A description of the sampling location.
- (5) Other pertinent information such as temperature and pressure.

### Recommended Method

The following method of sampling is recommended. If other methods can be proved to be equivalent, they may be used.

(a) Personal samples shall be collected in the breathing zone of the employee without interfering with his freedom of movement and shall characterize the exposure from each job or specific operation in each production area.

(b) A portable, battery-operated personal sampling pump whose flow can be accurately controlled to within 15% at 200 ml/minute, and an activated charcoal tube should be used to collect the samples.

(c) The activated charcoal tube should be attached to the employee. The shirt collar is convenient for this purpose.

(d) The sampler shall be operated at a flowrate of 0.20 liter/minute or less. It should be noted that some pumps are designed for high flowrates and some for low. Care should be taken to use the proper pump with proper flowrate, eg, up to 200 ml/minute flow range.

(e) Breathing zone samples shall be collected to permit calculation of a ceiling exposure for every operation involving exposure to isopropyl alcohol.

(f) At least one unused activated charcoal tube from the same batch shall be provided to the analytical laboratory to determine the blank correction.



### Equipment for Air Sampling

(a) Battery-operated personal sampling pump: It should have a clip for attachment to the employee. All pumps and flow meters must be calibrated using a calibrated test meter or other reference, as described in the section of this appendix entitled Calibration of Equipment.

(b) Charcoal tubes: Glass tubes with both ends flame-sealed, 7 cm long with a 6-mm outer diameter and a 4-mm internal diameter, containing 2 sections of 20/40 mesh activated coconut-shell charcoal separated by a 2-mm portion of polyurethane foam. The adsorbing section contains 100 mg of charcoal, the backup section 50 mg. A 3-mm portion of the polyurethane foam is placed between the outlet end of the tube and backup section. A plug of silylated glass wool is placed in front of the adsorbing section.

### Calibration of Equipment

Since the accuracy of an analysis can be no greater than the accuracy with which the volume of air is measured, the accurate calibration of a sampling pump is essential to the correct interpretation of the volume indicated. The frequency of calibration is dependent upon the use, care, and handling to which the pump is subjected. Pumps should also be recalibrated if they have been misused or if they have just been repaired or received from a manufacturer. If the pump receives hard usage, it should be calibrated more frequently if necessary. Regardless of use, maintenance and calibration should be performed on a regular schedule and records of these should be kept.

Ordinarily, pumps should be calibrated in the laboratory both before they are used in the field and after they have been used to collect a large number of field samples. The accuracy of calibration is dependent on the type of instrument used as a reference. The choice of calibration instrument will depend largely upon where the calibration is to be performed. For laboratory testing, standards such as a spirometer or soapbubble meter are recommended, although other standard calibration instruments such as a wet test meter or dry gas meter can be used. The actual setups will be similar for all instruments.

The calibration setup for personal sampling pumps with a charcoal tube is as shown in Figure XII-1. If another calibration device is selected, equivalent procedure should be used. Since the flowrate given by a pump is dependent on the pressure drop of the sampling device, in this case a charcoal tube, the pump must be calibrated while operating with a representative charcoal tube in line. Instructions for calibration with the soapbubble meter are as follows:

(a) The voltage of the pump battery is checked with a voltmeter to ensure adequate voltage for calibration. The battery is charged if necessary.

(b) The tips of a charcoal tube are broken to produce openings of at least 2 mm in diameter.

(c) The sampling train is assembled as shown in Figure XII-1.

(d) The pump is turned on and the inside of the soapbubble meter is moistened by immersing the buret into the soap solution and drawing bubbles up the inside until they are able to travel the entire length of the buret without bursting.

(e) The pump flow controller is adjusted to provide the desired flowrate.

(f) The water manometer is checked to ensure that the pressure drop across the sampling train does not exceed 2.5 inches of water at 200 ml/min.

(g) A soapbubble is started up the buret and the time it takes the bubble to move from one calibration mark to another is measured with a stopwatch.

(h) The procedure in (g) is repeated at least twice, the results averaged, and the flowrate calculated by dividing the volume between the preselected marks by the time required for the soapbubble to traverse the distance. If, for the pump being calibrated, the volume of air sampled is the product of the number of strokes times a stroke factor (given in units of volume/stroke), the stroke factor is the quotient of the volume between the 2 preselected marks divided by the number of strokes.

(i) Data for the calibration include the volume measured, elapsed time or number of strokes, pressure drop, air temperature, atmospheric pressure, serial number of the pump, and name of the person performing the calibration.

#### Collection of Samples

(a) Both ends of the charcoal tube are broken to provide openings of at least 2 mm, which is 1/2 of the internal diameter of the tube. A smaller opening causes a limiting orifice effect which reduces the flow through the tube.

(b) The smaller section of charcoal in the tube is used as a

backup section and should therefore be placed nearest the sampling pump. Tubing may be used to connect the back of the tube to the pump, but no tubing must ever be put in front of the charcoal tube. The tube shall be supported in a vertical position for sampling to prevent channeling. After the sample is collected, the tube must be capped; caps are provided with commercially available tubes.

(c) The recommended sampling flowrate is 0.20 liter/minute or less. A 3-liter sample is normally adequate. The calibrated flowrate should be set as accurately as possible using the manufacturer's directions. The temperature and pressure of the atmosphere being sampled must be recorded.

(d) The initial and final counter readings must be recorded. The sample volume can be obtained by multiplying the number of counter strokes times the volume cc/stroke factor.

(e) Immediately after sampling, the charcoal tubes should be capped with the plastic caps supplied by the manufacturer. Masking tape is the only suitable substitute for sealing the tubes. Rubber caps must never be used.

(f) One charcoal tube should be treated in the same manner as the sample tubes (break, seal, ship), except that no air is drawn through it. This tube will serve as a blank.

#### Special Consideration

(a) Where 2 or more compounds are known or suspected to be present in the air, such information, including their suspected identities, should

be conveyed with the sample.

(b) Pump must not be operated for more than 8 hours without recharging the battery.

(c) If high humidity or water mist is present, breakthrough volume can be severely reduced. If condensation of water occurs in the tube, isopropyl alcohol will not be trapped quantitatively. Therefore, in high humidity, the volume sampled should be reduced.

(d) The desorption efficiency of charcoal varies from batch to batch. Therefore, all the tubes used to collect a set of samples must contain charcoal from the same batch. Several unused charcoal tubes should accompany the samples. Information on the batch number of the charcoal must be supplied.

#### Shipping of Samples

Capped charcoal tubes should be packed tightly and padded before they are shipped to minimize tube breakage during shipping. Bulk samples must be submitted in addition to charcoal tubes. Bulk samples and charcoal tubes must be shipped in separate containers.