3.0 SAMPLING EQUIPMENT

3.1   INTRODUCTION

This section is prepared to acquaint the spill responder with equipments which are used in soil or solid material sampling, water, slurry or liquid sampling, and air or vapor sampling. Their functions and factors which can lead to uncertainty in data quality are reviewed. The selection of proper sampling mechanisms, including equipment and material, is essential to the success of an environmental investigation and remediation. Minimally disturbed samples must be carefully collected and analyzed if the results are to have any meaning.

The ideal sampling equipment should be completely inert; economical to manufacture; easy to clean, sterilize and reuse; operable at remote sites without external power sources; and capable of delivering continuous and variable flow rates for well purging and sampling.

With few exceptions, most of the equipments discussed below may be used in the activities of spill response. The equipment is categorized according to the sample type. Selection of appropriate sampling equipments depends upon the sample type, sample reactivity, and site conditions. There is no one universal sampling equipment that can be used to adequately sample everything found in the environment.

3.2   EQUIPMENT FOR SOIL, SLUDGE, SEDIMENT OR SOLID MATERIAL SAMPLING

The soil or the material to be investigated can be powder, granule, sludge or mud, or it can be clumped or aggregate, or solid and hard. To meet these conditions, different sampling equipments have been developed and used as described below.

3.2.1   Scoop/Spade/Trowel for Soil, or Powdered or Granular Solids Sampling

Figure 3-1 Scoop & Trowel

For surface or near surface sampling, a scoop (Figure 3-1) or spade will suffice in most applications. Care should be exercised concerning compatibility of the material to be sampled and the tool to be used such as those plated with chrome or other materials. Mason or garden trowels may be used in this sampling if they are made of the proper material, such as stainless steel. Sometimes a flat, pointed mason trowel will be helpful in cutting a block of the desired soil when undisturbed profiles are required. Polypropylene, polyethylene, and teflon may also be used to make scoops and spades.
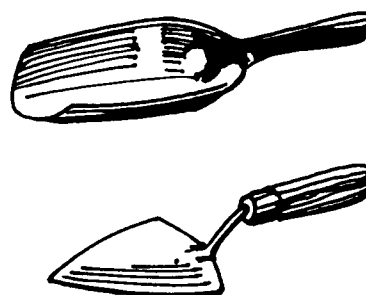
### 3.2.2   Trier for Soil and Materials in Powder, Granule, or Sludge Forms

Figure 3-2A Sampling Triers

A typical sampling trier (Figure 3-2A) is a long tube cut in half lengthwise, extending almost the entire length of the tube. The tip and edges of the tube slot are sharpened so that the trier can be inserted into the material to be sampled and rotated to cut a core of the material. Similar in shape to the trier is a grain, powder, or thief sampler (3.2.3). It tends to have a smaller, less tapered slot, with a converged sharp point at its tip. A trier is preferred over the grain sampler when the

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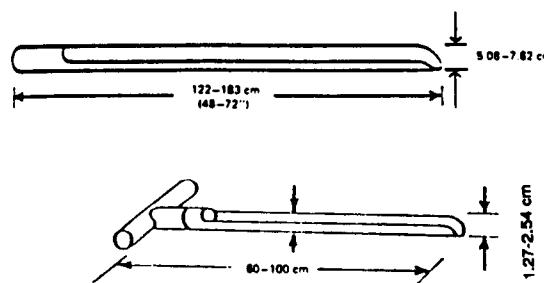
powdered or granular material to be sampled is moist or sticky.

Another modified sampler of this sort is the footstep soil sampler or Hankinson soil sampling tube (Figure 3-2B). They have been made for sub-soil probe. These modified samplers have been claimed to reach depths exceeding 15 feet.
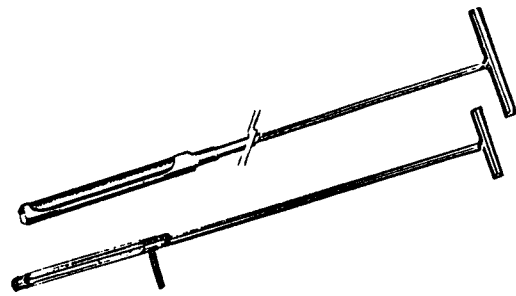

Figure 3-2B Hankinson & Footstep Soil Samplers

3.2.3 Thief Sampler for Dry Granules or Powdered Sample

Figure 3-3 Thief Samplers

A thief sampler (Figure 3-3) consists of two slotted concentric tubes, usually made of stainless steel or brass. The outer tube has a conical pointed tip that permits the sampler to penetrate the material being sampled. The inner tube is rotated to open and close the sampler. A thief sampler is useful for sampling drying granules, pellets, powdered material.
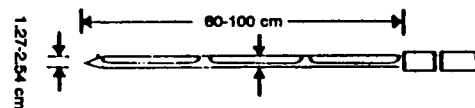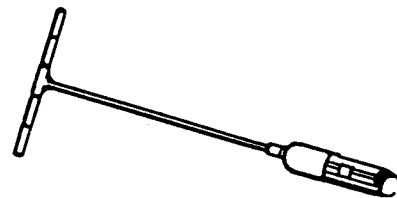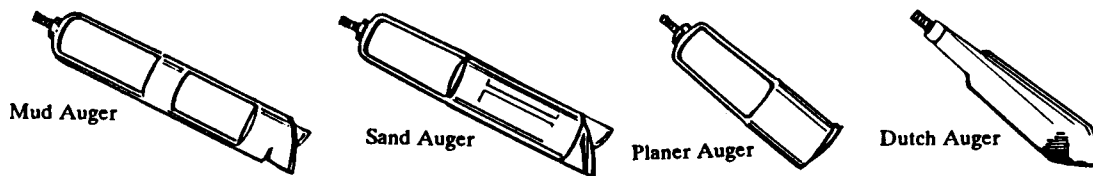

3.2.4 Hand Auger for Soil Sample

A hand auger system (Figure 3-4A) consists of an auger bit connected with a bucket type cylinder. A T-shaped handle with various lengths of extension is employed to obtain samples from different depths. Also, various designs of hand augers have been made for different soils, soft or hard. There are four different hand augers shown in Figure 3-4B, and their appropriate usages are indicated in Table 3-1. A removable liner of rigid acetate or stainless steel which can be installed in the auger to protect the sample from contamination has also been made available. By removing the liner with the sample from the auger and capping the ends of the liner, the sample can be transported without further exposure to the field environment.

Figure 3-4A Regular Hand Auger

Figure 3-4B Mud Auger, Sand Auger,Planer Auger, and Dutch Auger.

Mud Auger   Sand Auger   Planer Auger   Dutch Auger

3.2.5 Split-Spoon Sampler for Soil Sample

One of the most popular types of soil samplers is the Split Tubes or Split Spoon Sampler (Figure3-5). This sampler is a tube split into two equal halves along the length and held together by a head and a hardened shoe. The drive head is attached to the upper end of the tube and serves as a point or attachment for the drill rod. The removable tapered nose piece or shoe attaches to the lower end of the tube, facilitating cutting. The sampler is forced into the soil by jacking, hydraulic driving or sledge hammering.

Figure 3-5 Split Spoon Sampler
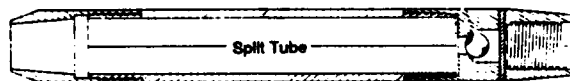
The sampler can be equipped with a ball check valve in the head which prevents the washing out of the

sample as it is being hoisted from the hole. A basket-like sample retainer can also be fitted to the lower end of the tube to hold the loose, dry soil sample in the tube as it is being lifted from the hole. After being withdrawn from the hole, the sampler head and shoe are unscrewed and the sampler can be split open.

This sampler can also be designed to accommodate optional liners for collecting and delivering samples from the field to the laboratory without disturbing them.

3.2.6 Thin Wall Tube Sampler (Shelby), Hand Corer or Hand Sediment Sampler for Cohesive Type Soils and Clays, Sludges, and Sediments

3.2.6.1 Thin Wall Tube Sampler (Shelby tube) Figure 3-6A shows a piece of hard-drawn, seamless, thin wall steel tubing. One end can be attached to a drilling head and the other end to a sharpened cutting edge. The thin wall construction is for minimum disturbance to soil during sampling. It can be used to profile strata in the sample. The thin steel tube containing the sample may be removed from the sampler and used as a container for transportation to the laboratory. Similar to a split-spoon sampler, this thin wall sampler can also be equipped with a ball check valve assembly in the head to prevent the loss of the sample when it is being removed from the hole.
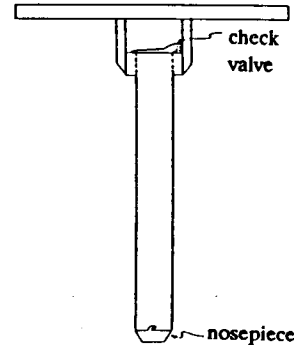
**Figure 3-6A** Thin Wall(Shelby) Tube Sampler

3.2.6.2 Hand Corer or Hand Sediment Sampler Figure 3-6B shows essentially a thin wall tube corer, which is modified by adding a handle and a check valve on top to prevent sample washout during retrieval through an overlying water layer. This sampler is for sampling sediment or sludge. Operation may be performed by hand and by use of optional extension handles. It also has the advantage of collecting a minimally disturbed sample which can profile any strata in the sample. Various liners, plastic or stainless steel, are available for minimizing sample disturbance and cross-contamination.

Figure 3-6C Veihmeyer Soil Sampling Tube

Figure 3-6B Hand Corer/Sediment Sampler
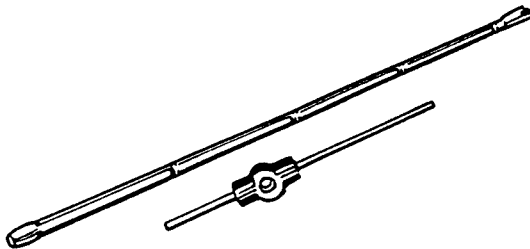
The Veihmeyer soil sampler(Figure 3-6C) is another tool for taking core samples. It is a tube with a larger outside diameter at the cutting end than the rest of the tube and with tube depth reference markings.

3.2.7 Sludge Getter for Sludges

This Sludge Getter (Figure 3-7) is a stainless steel grab sampler with a conical bottom cup which allows penetration into viscous or sludge type materials. In use, the six feet unit is pushed into the sludge to the desired depth. The top handle is lifted about one half inch (½") and rotated to the side, allowing the sludge material to move into the sample cup. The handle is then turned to secure the lid over the cup, the lid is locked into position, and the unit is removed from the sample spot.


Figure 3-7 Sludge Getter

The sample can be trowled out of the cup, or a plastic cup liner can be used for allowing the sample to fall directly into the the cup liner and be removed. The unit may be washed with a solvent or cleaned with steam to decontaminate it.

3.2.8 Bottom Sampling Dredge or Ponar Grab for Sludges or Sediments

Figure 3-8 Ponar Grab for Sludges

This device (Figure 3-8) is a clamshell type scoop activated by a counter lever system. The shell is opened, latched in place and slowly lowered to the bottom. When tension is released on the lowering cable, the latch releases and the lifting action of the cable on the lever system closes the clamshell. This grab type dredge is capable of sampling most types of sludges and sediments from silts to granular materials. The drawbacks for the system are that it cannot penetrate more than several centimeters and can not collect undisturbed samples.
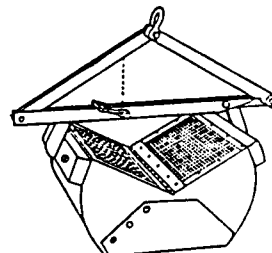
3.3 EQUIPMENT FOR LIQUID MATERIAL AND WATER SAMPLING

Liquids include both aqueous and nonaqueous solutions, and are subdivided as surface waters, containerized liquids, and groundwaters. Containerized liquids can be any size of sealed and unsealed containers varying from drums to large tanks. To meet a variety of situations, one should be familiar with the available tools to make a job easier and to assure the job is done properly.

3.3.1 Dipper or Pond Sampler for Surface Water

The dipper (Figure 3-9) consists of a glass or plastic beaker clamped to the end of a two or three piece telescopic aluminum or fiberglass pole that serves as the handle. Sometimes, instead of the beaker, a sample container itself can be strapped to the clamp directly. This is particularly good for analyses of volatile organics.

3.3.2 Extended Bottle Sampler for Surface Water
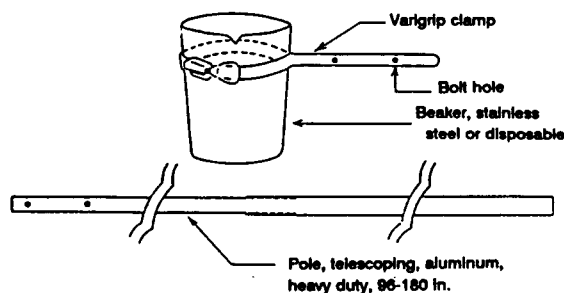
Figure 3-9 Dipper/Pond Sampler

Figure 3-10 Bottle Sampler
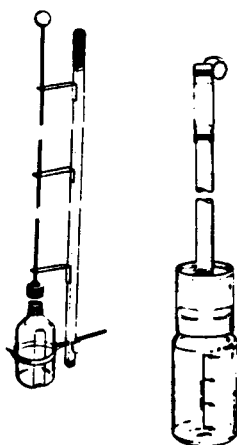
These bottle samplers (Figure 3-10) consist of a 6 foot long metal tube or reinforced plastic holder and a sample container. One of the designs is a stainless steel clamp that is attached to the end of the tube and can be adjusted to hold a sample jar of desired size. The jar cap can be remotely removed and replaced while the bottle is submerged by turning the handle grip rod, which is attached to the cap by means of a screw clamp or a suction cup. In the second design, the sample bottle is screwed onto the sampling head, and the sampler lowered to the desired sampling location and depth. The ring at the top is then pulled, opening the spring-loaded plunger in the head assembly and allowing liquid to flow in. When the bottle is observed to be full, the ring is released to stop liquid flow.

Since the sampler is exposed to the sampled medium, it must be decontaminated before shipment or reuse.

3.3.3 Weighted Bottle or Bacon Bomb Sampler for Surface or Well Water

The weighted Bottle Sampler (Fig.3-11, Right) consists of a glass or plastic bottle, sinker, stopper, and a line

that is used to lower, raise, and open the bottle to sample liquid or free-flowing slurries. The bomb sampler (Figure 3-11 left) uses the same principle as the weighted bottle sampler. It consists of a cylindrical chamber, a line, and a removable cover. The cylindrical chamber has an internal tapered plunger that acts as a valve to admit the sample. The line attached to the top of the plunger is used to open and close the valve. The removable cover provides a point of attachment for the sample line and has a locking mechanism to keep the plunger closed after sampling. These samplers are suited for collecting viscous materials or water in storage tanks, tank cars, ponds, lagoons and wells at different depths. The material used to construct these samplers are brass, bronze, and stainless steel.
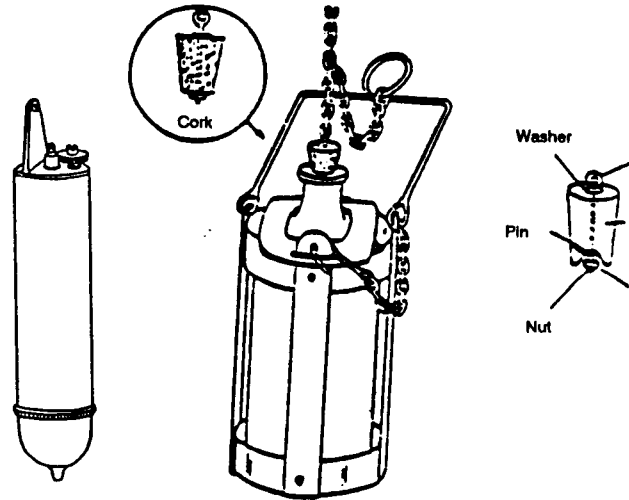
Figure 3-11 Weighted Bottle(right)/Bacon Bomb(left)Sampler

3.3.4   Suspended-Sediment Sampler for Surface Water in River or Stream

Figure 3-12 Suspended-Sediment Sampler

This sampler (Figure 3-12) contains glass or plastic sample bottle sealed in the sampler head, an intake nozzle oriented upstream for filling, and a rear port for air to escape. It samples at the vertical points of river or stream cross-sections and can continue to take its sample throughout the time of submergence, or start and stop the sampling process by an electrically operated valve in the sampler head.

3.3.5   Kemmerer Sampler for Surface and Subsurface Water

Figure 3-13 Kemmerer Sampler

The Kemmerer sampler (Figure 3-13) is a mechanically operated depth-specific sampler. It consists of a short length of tubing and each end is fitted with a spring activated rubber stopper. End stoppers are locked open before lowering the unit into the water. When the sampler reaches the desired depth, the operator activates the spring mechanism by dropping down the messenger, and the rubber stoppers are pushed against each end of the tube, thereby entrapping the liquid sample. This sampler is very practical for collecting discrete, at-depth samples from surface water or vessels where the collection depth exceeds the lifting capacity of pumps. Samples may be obtained by using the Kemmerer sampler for depths up to 300 feet. Use of the rubber stopper and spring assembly could cause bias in the analysis of trace organics and metal constituents of the sample. Selection of other assemblies, i.e. all metal for organic analysis or all plastic for trace element analysis, will avoid this problem.

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3.3.6   Composite Liquid Waste Sampler (COLIWASA) for Liquids and Slurries

The COLIWASA (Figure 3-14) consists of a glass, plastic, or metal tube equipped with an end closure that can be opened and closed while the tube is submerged in the material to be sampled. It is primarily used to sample liquids and slurries contained in drums, shallow tanks, pits, and similar containers. It is especially useful for sampling wastes that consist of several immiscible liquid phases. The drawbacks associated with using a COLIWASA are decontamination and cost. The sampler is difficult, if not impossible, to decontaminate in the field, and it is a high cost apparatus.

3.3.7   Bailers for Surface Water and Groundwater

Figure 3-14 Composite Liquid Waste Sampler (COLIWASA)

Figure 3-15 Teflon Bailer

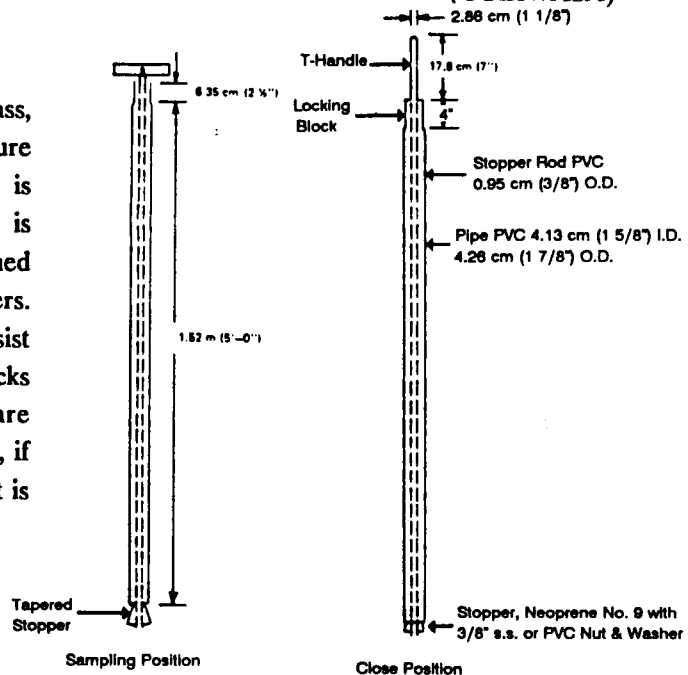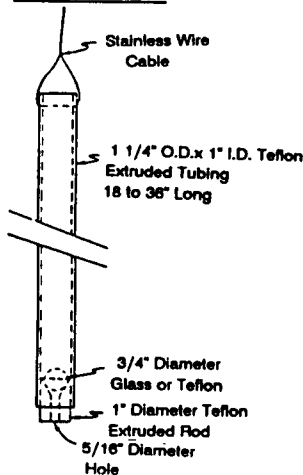The bailer (Figure 3-15) consists of a length of tube fitted at the bottom end with a check valve that allows liquid to flow into the tube as it is lowered into the liquid, and keeps the liquid from flowing out as the tube is brought back to the surface. Other bailers, referred to as "point source" bailers, also have a check valve at the top, which reduces the possibility of mixing the liquid sample with the liquid contained in the installation while the bailer is withdrawn. The advantages of the bailer are: 1) simple construction and economical; 2) available in a wide variety of structural materials; and 3) with minimal sample disturbance if handled carefully. Their disadvantages are: 1) aeration during transferring from bailer to sample bottle; 2) inability to collect discrete samples; 3) inefficiency with deep water table; and 4) cross-contamination from an inadequately cleaned bailer and its rope or cable.

3.3.8 Suction Lift Pumps for Liquids or Water

As the name implies, suction pumps are operated, generally in a low volume, by a partial vacuum in a sampling tube. The vacuum allows the pressure exerted by the atmosphere on the water in the well to force water up the tube to the surface. Because of this, the practical limit of suction lift is approximately 25 feet. In addition, these pumps may result in degassing and volatilization caused by the negative pressure that is applied, and atmospheric contamination at the surface. In spite of these drawbacks, suction pumps are readily available, relatively portable, and inexpensive. Two types of suction lift pumps are introduced below.

3.3.8.1   Non-Submersible Centrifugal Pumps--In the centrifugal pump, the fluid is displaced by the action of an impeller rotating inside the pump chamber. This discharges water by centrifugal force. The resulting pressure drop in the chamber creates a suction and causes water to enter the intake pipe or tube in the well.

These pumps can provide substantial yields, and are readily available and inexpensive.

The disadvantages are that they require a foot or check valve on the end of the suction pipe to aid in maintaining a prime and may be difficult to clean between sampling events. In addition, the materials with which these pumps are constructed may frequently be incompatible with certain sample constituents.

Figure 3-16 Peristaltic Pump

3.3.8.2   Peristaltic Pumps (Figure 3-16)--The major components of this apparatus are the peristaltic pump, which consists of a rotor and several ball bearing rollers within a pump head, and a flexible tubing. The peristaltic pump can be battery operated and portable for a wide range of applications in the field. Since it works by squeezing the flexible tubing which creates a vacuum and draws the water sample through the intake line, the only contact between the pump and sample is the tubing. The tubing can be easily changed to avoid cross-contamination. In addition, these pumps sample with little agitation.

Figure 3-17 System for Grab Sampling for organics from a monitoring well
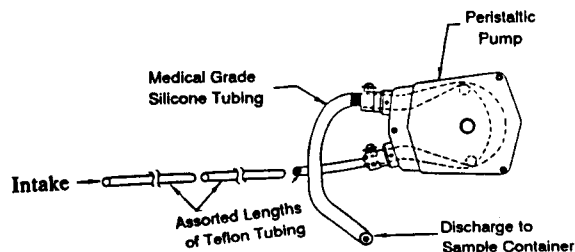
The disadvantages are: 1) low pumping rates make it difficult to evacuate the well bore in a reasonable amount of time, 2) the choice of appropriate materials for flexible tubing is restrictive. Also the commonly used silicone tubing has a propensity for absorbing many organic compounds and inert flexible tubing is not flexible enough to be used in these pumps. An alternative sampling arrangement, suggested by Scalf et al. (1981) as a method for sampling for organic contaminants, utilizes a peristaltic pump and a two-way stoppered bottle with Teflon tubing as shown in Figure 3-17.

Hand operated diaphram pumps are also available and can be used over a wide range of pumping rates, which facilitates rapid evacuation of a well bore initially and lowers the controlled pumping rate for subsequent sampling.

3.3.9   Positive Displacement Pumps for Water

Positive displacement pumps use positive pressure, generated from a pumping mechanism which is placed in the well, to drive the water from the sampling installation to ground surface. This minimizes the potential for aerating or stripping volatile organic from the sample during removal from the well. Positive displacement pumps include submersible centrifugal pumps, gear-drive pumps, gas operated submersible piston pumps, gas-squeeze pumps, and gas drive pumps. Other pumping systems such as air lift and jet pumps use positive pressure as well, but only to drive a carrier gas or fluid.

The chemical alteration produced in the water as a result of positive pressure are small compared to the alterations from negative pressure; for this reason, positive displacement pumps are commonly preferred over suction-lift pumps. In addition, positive displacement pumps can lift a sample from a depth which far exceeds

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the limits of suction-lift pumps and a depth at which bailers become laborious or impractical. It should also be noted that degassing occurs as a result of a decrease in pressure. Raising a sample from its natural position at a depth of a hundred or a few hundred feet and subjecting it to atmospheric pressure can mean a change in pressure of several atmospheres in a sample. Thus, although the application of positive pressure pump does not cause degassing directly, a sample would undergo a decreasing pressure as it moves up the well column and degassing could occur. Therefore, even with positive displacement techniques, for gas sensitive parameters, care should be taken in the manner in which the sample is taken from the outflow.

To further understand these positive displacement sample collection techniques, several types of positive displacement pumps are introduced below.

3.3.9.1 **Submersible Centrifugal Pumps**--These work in a manner similar to the centrifugal suction-lift pump previously explained, except that in this case, both the pump and electric motor are lowered into the well. As the impeller rotates and fluid is brought into the pump chamber, fluid is displaced up the well.

Until recently, most submersible centrifugal pumps were developed for or by the water well industry, and were designed for wells having a diameter of four inches or bigger. They were frequently constructed with materials and used lubricants which interfered with sample analysis, particularly of organics. At present, there are two small diameter submersible centrifugal pumps available: the helical rotar pump and the Johnson-Keck Pump.

Figure 3-18 Helical Rotor Pump

3.3.9.1A **Helical Rotor Pump** (Figure 3-18)--The helical rotor pump consists of a sealed electrical motor, which drives a helical rotor. An electric power cord provides 12-volt DC power to the pump from a battery pack at the surface. Water enters the pump through a screened intake in the middle of the pump and is drawn upward through a rotor-stator assembly via centrifugal force. The pump itself is 1.75 inches in outside diameter and 33 inches in length. It is capable of pumping lifts up to 125 feet with maximum flow rates of approximately 0.3 gpm. The housing is stainless steel with inner workings fabricated of inert or nearly inert materials. The pump itself is lightweight, less than ten pounds, but the supporting battery pack and hose reel are typically in excess of 50 pounds. Other disadvantages are that the pump must be cycled on and off approximately every 20 minutes to avoid overheating of the motor. It is somewhat difficult to clean between sampling events because it is moderately difficult to disassemble.

3.3.9.1B **Johnson-Keck Pump**--As the name implies, this pump was designed by Johnson-Keck and is for groundwater quality monitoring. It can be used in two inch diameter wells or greater, and is constructed of stainless steel and teflon. Experience with this pump is little reported; however, it appears to be a reasonably efficient means of obtaining water from depths below the limit of suction lift and with minimal disturbance to the chemical integrity of the sample. The pumping rate is such that at least for small diameter installation, it would be an adequate means of removing the standing water from the well. In some instances, degassing within the pump unit or in the outflow line may be of concern.

3.3.9.2 **Submersible Gear-Drive Electric Pumps**--This type of pump is made with a stainless steel body, a highly efficient electric motor, and a set of two teflon gears. The motor drives the set of teflon gears, which draws water through a fine mesh intake screen at the top of the pump. Water is drawn through the gear and pushed in a continuous stream through the discharge line to the surface for sampling. There are several different power sources for these pumps. The basic unit is factory equipped with a series of four six-volt DC rechargeable batteries. These batteries may provide power for approximately four hours of continuous operation and may be recharged overnight by using a 120-volt trickle-charger unit. For a longer duration and an increased pumping rate, these batteries may be supplemented or replaced by one of the following sources: 1) an auxiliary DC

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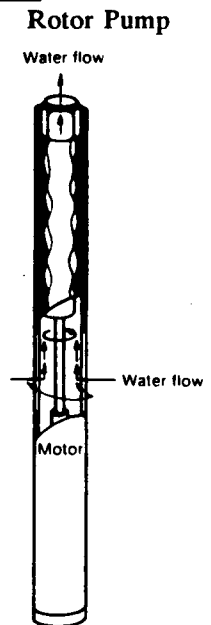
generator; 2) an auxiliary battery pack; 3) two vehicle batteries wired in parallel to provide 24-volts; or 4) an adapter unit to facilitate the use of a 120-volt AC power supply.

The only parts that should require replacement under normal field use are the teflon gears. With prolonged purging and/or sampling of water with high suspended solids, these gears may wear, which diminishes pump output. The gears are inexpensive and simple to replace. The weight of the entire system is less than 50 pounds, so it is highly portable. Reasonably high pumping rates can be achieved to depths of 150 feet, and the depth range can be extended through the use of an auxiliary power source. The disadvantages are:

1) there is no control of flow rates;
2) sampling in wells with high levels of suspended solids may require frequent replacement of gears; and
3) the potential for pressure changes produced at the drive mechanism.

3.3.9.3 Submersible Gas-Operated Piston Pumps--Pumps of this type consist of a plunger (piston) or set of plungers moving inside a stationery submerged cylinder (barrel). Another type, a reverse one, of piston pump is the traveling barrel type, in which the piston is held stationery inside a moving cylinder. Although the operating principle for both is identical, the latter type is fairly uncommon.

The cylinder, and sometimes the piston, is fitted with one-way check valves in such a way as to direct the water moved by the piston toward the surface. The pumping capacity depends on the inside diameter of the cylinder, the stroke rate of the moving piston, and the length of the stroke. Once these three parameters are fixed, the output of the pump will have little variation. The piston can be operated by means of a mechanical device or by a gas driven mechanism. Pumps driven by the mechanical device are often referred to as "rod pumps", and those powered by a gas-driven mechanism are referred to simply as "gas-operated" or gas-driven piston pumps.

Like centrifugal pumps, piston pumps, which were initially developed for water and petroleum production, and in terms of water quality monitoring, the rod pumps possess the same disadvantages as the large diameter centrifugal pumps and do not have much value that would require further elaboration here.

Two gas-operated piston pumps reviewed below are single acting and double acting piston pumps.

3.3.9.3A Single-Acting Gas Driven Piston Pumps

An example from Hillerich (1977) is given in Figure 3-19. This pump consists of a gas chamber in the bottom of the pump housing in line with a water chamber in the top, sharing the same piston rod. A gas pressure alternately applied to the air chamber from the end of the chamber drives both pistons up and down. On the upstroke, water is drawn through a check valve into the water chamber on one side of the piston. At the same time the water is expelled from the chamber on the other side of the piston, through the check valve, and into the water discharge line. On the downstroke, water is moved from one side of the piston to the other through a check valve on the piston itself.
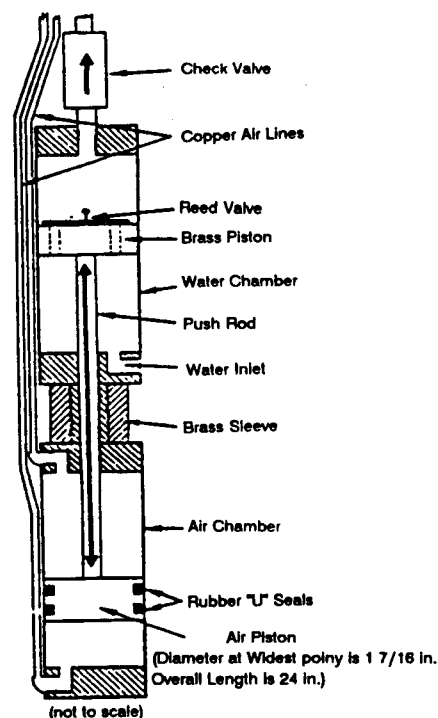
Figure 3-19 Single-Acting Gas Driven Piston Pump

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3.3.9.3B Double-Acting Gas Driven Piston Pump--This double acting gas driven piston pump (Figure 3-20) uses two water chambers on either side of a gas chamber and a switching unit through which a common connecting rod passes to a piston in each cylinder. Through an arrangement of O-ring seals, button bleed valves, and needle-valve restrictions in the switching unit, the driving gas both enters and exhausts from the intermediate chamber as it alternately drives the two-piston assembly up and down. Two check valves in each water chamber operate so that on the upstroke, water is expelled from the upper chamber as water is drawn into the lower chamber from well; on the downstroke, water is expelled from the lower chamber and water from the well is drawn into the upper chamber.

The flow rate of the pump may be varied over a limited range by increasing or decreasing the driving gas pressure to the pump. Rates of from 0.25 to 0.50 gpm are achievable at pumping lifts up to 500 feet with these pumps. The design of this double acting piston pump offers a better driving gas consumption than the previous single acting pump, but it may also be prone to more frequent malfunction because of more mechanical

Figure 3-20 Double-Acting Gas Driven Piston Pump

components. It is convenient but bulky, weighing several hundred pounds. Adding the compressed gas equipment, the entire system may be less desirable for moving from place to place.

In general, gas driven piston pumps are well suited for groundwater monitoring because they are portable and can be made of very inert materials. Thus, there is a reduced possibility for sample contamination. No aeration of the sample can occur, and the pump is relatively easy to operate and to disassemble for cleaning and maintenance. The pump can provide a continuous sampling over extended periods of time and uses compressed gas economically. The disadvantages are: 1) the unit itself is relatively expensive; 2) particulate material may damage or inactivate the pump unless the intake is filtered; 3) the pump has the potential of causing pressure drops and degassing in the sample because of its intricate valving mechanism; and 4) the tubing may be difficult to clean making it difficult to avoid cross-contamination.

3.3.9.4 Syringe-Sampler or Syringe-Type Sampling

Devices--Another pneumatic sample collection device is the syringe sampler (Figure 3-21), also called the " Pneumatic Depth-Specific Sampler". The simplest and most inexpensive syringe sampler is composed of a disposable 50 ml plastic syringe modified by cutting off the plunger and the finger grips, and a flexible tubing which is

Figure 3-21 Syringe-Type/Syringe Sampler
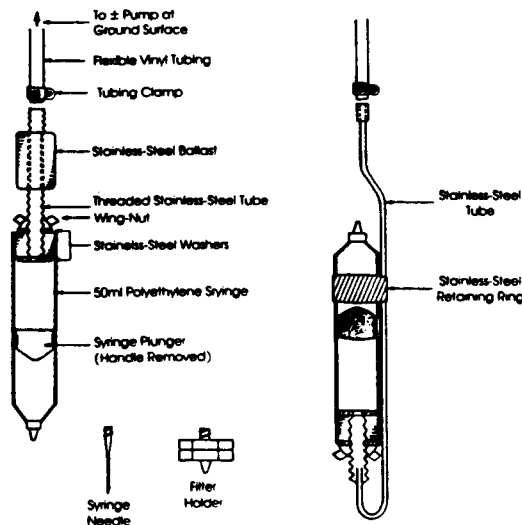
used not only to sustain the syringe but also to provide compressed air or gas for actuating the syringe. To collect a discrete sample, one lowers the syringe to the desired depth in the well and then actuates the syringe, applying positive or negative pressure via the tubing. If water is to be collected from depths of greater than 10-15 feet below the level of standing water in the well, positive pressure must be applied to the syringe while it is being lowered to the sampling depth to keep the plunger from moving. When the desired depth is reached, the pressure in the tubing is released and reduced to atmospheric pressure (or slightly less), and the sampled water enters the syringe. After the syringe is filled, it is withdrawn from the well.

Significant advantages of this method of taking samples are: 1) it can be rinsed down a hole with the water to be sampled; 2) aeration is eliminated and the possibility of degassing is reduced; 3) discrete sampling can be done at any depth; 4) the syringe can be used to sample slowly recharging wells or as a sample container and for wells as small as 1½" inside diameter; 5) the syringes can be made of inert materials, and are inexpensive and highly portable. The disadvantages are: 1) the syringe is inefficient for large volume sampling and can not be used to evacuate a well; and 2) the use of syringes is limited to water with a low suspended solid concentration, and some leakage has been found to be caused from high suspended solid content.

3.3.9.5 **Gas-Operated Squeeze or Gas Squeeze Pumps**--There are several different designs of gas-squeeze (Bladder (Figure 3-22) and Diaphrams) pumps, but all have several common features and are operated with the same principle. These pumps consist 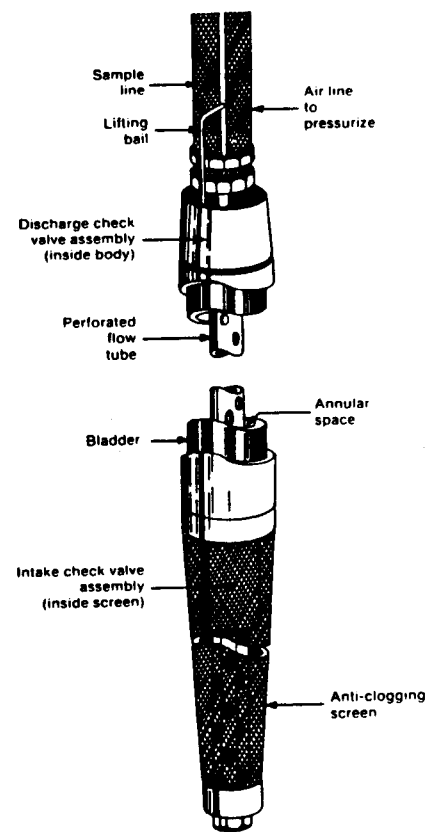of a flexible membrane enclosed inside a long and rigid housing, a screened intake check valve, a perforated tube inside the bladder (membrane), a discharge check valve, and two tubing lines. One of the two tubings is to allow pressurization of the annular space between the bladder and the housing, and the other one is to allow sample discharge to the surface. When the pump is submerged, water sample enters the bladder through the intake check valve. After the bladder is filled, gas pressure is applied to the annular space between the bladder and the rigid housing, forcing the water upward through the discharge tubing. When the pressure is released, the discharge check valve closes, preventing the water sample from flowing back down into the bladder, and water from the well again refills the bladder through the intake check valve and the cycle is repeated.

The advantages of this pump are: 1) it has a fair range of pumping rates; 2) it has a wide variety of materials that can be used to meet the needs of the parameters of interest; 3) it is relatively portable, though the accessory equipments may be cumbersome; 4) there is no contact between driving gas and the samples, thus eliminating possible contamination or gas stripping; 5) the pump can be as small as one inch, and is easy to disassemble for cleaning and repair; and 6) these pumps are capable of pumping and lifting in excess of 200 feet.

Figure 3-22 Gas-Operated Bladder Pump

Their disadvantages are: 1) deep sampling requires large gas volume and longer cycles; 2) pumping rates can not match the rate of other submersible pumps; and 3) these pumps can be relatively expensive.

3.3.9.6 **Gas Drive Pumps**--A wide variety of gas-driven sampling devices are available. In principle, the gas-

driven pumps (Figure 3-23) use a positive gas pressure to force water from the well to the ground surface. Water enters the pumps through a screened intake and a check valve at the bottom end when the pressure is released. When the pressure is applied, it closes the check valve at the bottom and opens the check valve in the discharge line and forces the water into the sample line extending from the bottom of the chamber to ground surface.

The advantages of this pump are: 1) the pumps are highly portable and inexpensive; 2) pumps can be used in wells of 1½" inside diameter and in boreholes without casing; 3) discrete depth sampling and delivery of a sample at a controlled, nearly continuous rate are possible; and 4) pumps can be constructed entirely of inert materials. The disadvantages are: 1) oxidation may occur, causing precipitation of metals if air is used as the compressed gas; 2) stripping of volatiles and CO_2 can occur; and 3) an air compressor must be transported for deep sampling locations, thus reducing portability.
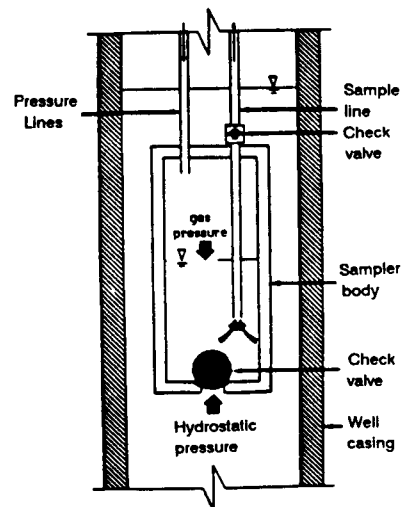
Figure 3-23 Operating Principles of gas Drive Sampling Devices

Figure 3-24

Continuous discharge/High Lift Pump(2 stages)

A continuous flow gas drive was developed for trace organic pollutants in groundwater as shown in Figure 3-24. This device consists of two single-stage glass pumps, placed in the well in line, one below the other. It is powered by high purity nitrogen gas metered alternately to each stage by a four-way solenoid valve and electric timer. The pumps are constructed from heavy wall glass tubing, and each contains two ground glass ball and sock check valves. Inside the upper stage are two glass lines which serve to convey nitrogen to and water from the second (lower) stage. Teflon tubing is used to connect the two stages to deliver nitrogen from the surface supply to the pump and to convey discharged water from the pump to appropriate sample containers.
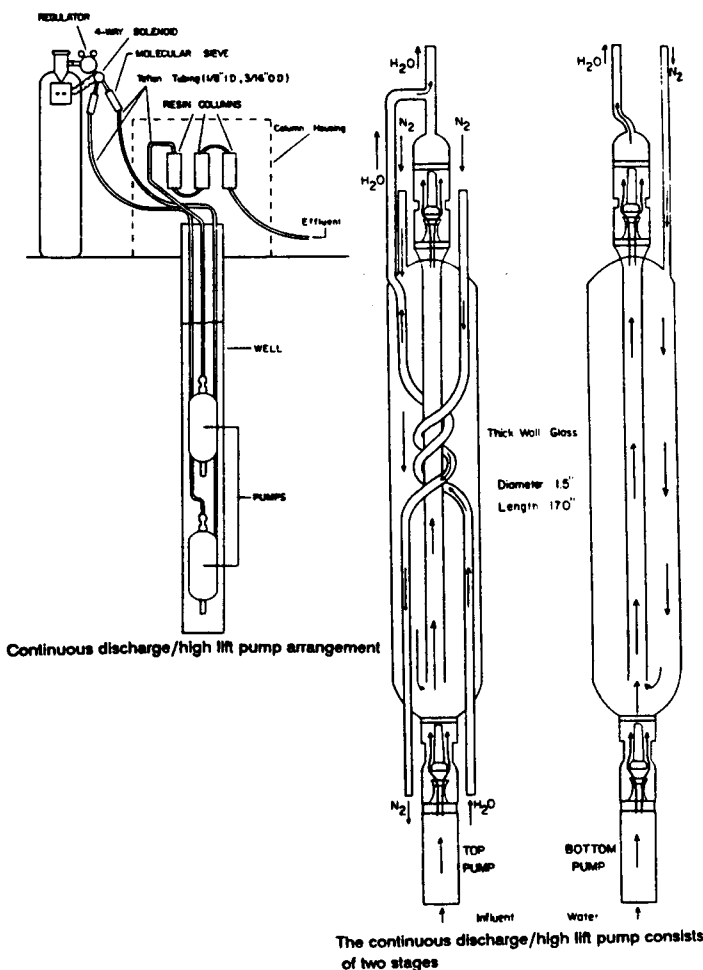
During operation, nitrogen is alternatively forced into each of the two single-stage pumps by timed operation of the four-way solenoid valve to obtain sequential filling and emptying of the pump chambers. The air in the pump, which is in the state of being filled, is vented to the atmosphere via the nitrogen inlet line in order to allow water to flow through the lower check valve. Once the filling is completed for that stage (pump), the nitrogen pressure is diverted back into it, forcing the water through the upper check valve into the discharge line. During this

The continuous discharge/high lift pump consists of two stages

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pumping cycle, the other pump is operating in the fill mode. The net result is a continuous stream entering the discharge line.

The advantages of this pump are: 1) the pump can be constructed of non-contaminating, non-adsorbing materials; 2) variable flow rates up to 45 gph are obtainable; and 3) the pump can be used in well casings with a diameter of about two inches. The disadvantages are that the pump requires high purity nitrogen gas, in addition to the problems mentioned earlier in this sub-section with the single step gas drive pump.

3.3.9.7 Other Pump Systems--Gas-Lifts and Jet Pumps--Gas (or air)-lift jet pumps use positive pressure and may be good for well purging, but they are not very helpful for sampling, particularly for volatile organics.

Gas (or air)-Lift Pumps consist of a gas or air line extending into the sampled water and a gas or air at high pressure being used to blow the water out of the well. The gas or air acts as a carrier fluid, or reduces the effective specific gravity of the water column, causing the water column to rise to ground surface. The advantages of these systems are that the devices are highly portable and can be permanently installed and used for well development or purging. The method is considered unsuitable for sampling because it can strip volatile compounds, contaminate the sample by the gas or air, affect pH sensitive parameters such as metals, and cause oxidation by air or oxygen-containing gas.

Jet Pumps basically are composed of a circulating pump at the surface and two tubes extending down the well from the pump to an ejector-venturi assembly at the submerged end of the tubes. As the circulating water passes the ejector-venturi assembly, the pressure is reduced as a result of the increased velocity, causing water to be drawn from the well and mixed with the circulating water.

Jet pumps are relatively simple devices and are easily transported. It can be used for pumping at great depths and is useful for purging monitoring wells. Its disadvantages are: 1) a large amount of water needs to be pumped before the circulating water has a composition that is close to the water in the well; 2) the water entering the venturi assembly is subjected to a pressure drop, and can therefore undergo degassing and/or vaporization; and 3) the circulating pump at the surface can contaminate the pumped water because of its materials and lubricants. Because of these multiple deficiencies with regard to sampling, jet pumps are unpopular.

3.4   SUMMARIES AND CHARACTERISTICS OF SOME SAMPLING EQUIPMENT FOR LIQUIDS AND SOLIDS

No one sampling method is applicable to all situations; however, for nearly all situations there may be at least one appropriate sampling device available. The most representative samples are obtained with one of these devices if the appropriate sampling device is chosen for a particular sampling situation.

This section describes examples of sampling equipment and suggests potential uses for the equipment. Because each sampling situation is unique, the cited equipment and applications may have to be modified to ensure that a representative sample is collected and its physical and chemical integrity is maintained. The information in this section is general in nature and therefore limited. It is the responsibility of those who conduct the sampling programs to evaluate the situation and make appropriate modifications.

Table 3-1 provides a review of, and criteria for selecting soil sampling equipment.

Table 3-2 contains examples of sampling equipment and potential applications. Again, these sampling devices may not be applicable to a user's situation due to sample - or site-specific factors.

Table 3-3 summarizes the characteristics of some sampling pumps available for small diameter monitoring wells. Based on these and other considerations of site-specific factors and targeted compounds, appropriate sampling devices may be found. For a brief direction on bigger diameters of monitoring well, see Table 3-4.

Table 3-5, prepared by Pohlman and Hess with EPA support, illustrates the general relation of groudwater

TABLE 3-1.   REVIEW AND CRITERIA FOR SELECTING SOIL SAMPLING EQUIPMENT

Type of Sample	Obtain Core Sample		Most Suitable Core Types			Operations in Stony Soils		Most Suitable Soil Moisture Conditions			Access to Sampling Sites During Poor Soil Conditions		Relative Sample Size		Labor Requirements	
	Yes	No	Clay	Sand	Inter	Fav.	Unfav.	Wet	Dry	Inter	Yes	No	Sm.	Lg.	Single	2/more
A. Hand Auger																
1. Screw-Type Augers		X			X		X	X			X		X		X	
2. Barrel Augers																
a. Post-Hole Auger (IWAN)		X	X			X		X			X			X	X	
b. Dutch Auger		X	X			X		X								
c. Regular Barrel Auger		X	X			X				X	X		X		X	
d. Sand Augers		X		X		X				X	X			X	X	
e. Mud Augers		X	X			X		X			X			X	X	
Tube-Type Samplers																
a. Soil Probes																
(1) Wet Tips	X				X		X	X			X					
(2) Dry Tips	X				X		X	X			X		X			X
b. Veihmeyer Tubes	X				X					X			X		X	
c. Thin-Walled Tube Samplers	X		X				X			X	X			X		X
d. Peat-Samplers	X		X				X	X			X			X		X
B. Power Auger																
1. Hand-Held Screw Type Power Auger		X			X	X				X	X			X		X
2. Truck Mounted Auger					X											
a. Screw Type	X				X	X		X				X		X		X
b. Drive Sampler	X		X			X			X			X		X		X
3. Tripod Mounted Drive Sampler	X		X							X		X	X			

TABLE 3-2 EXAMPLES OF SAMPLING EQUIPMENT FOR PARTICULAR SAMPLE OR WASTE TYPES

Sample (Waste) Type	Drum	Sacks and bags	Open-bed truck	Closed-bed truck	Storage tanks or bins	Waste Piles	Ponds, Lagoons, & Pits	Conveyor Belt	Pipe
Free-flowing liquids & slurries	Coliwasa	N/A	N/A	Coliwasa	Weighted Bottle	N/A	Dipper	N/A	Dipper
Sludges	Trier	N/A	Trier	Trier	Trier	a	a		
Moist powders or granules	Trier	Trier	Trier	Trier	Trier	Trier	Trier	Shovel	Dipper
Dry powders or granules	Thief	Thief	Thief	Thief	a	Thief	Thief	Shovel	Dipper
Sand or Packed Powders & granules	Auger	Auger	Auger	Auger	Thief	Thief	a	Dipper	Dipper
Large-Grained Solids	Large Trier	Large Trier	Large Trier	Large Trier	Large Trier	Large Trier	Large Trier	Trier	Dipper

a This type of sampling situation can present significant logistical sampling problems, and sampling equipment must be specifically selected or designed based on site and waste conditions. No general statement about appropriate sampling equipment can be made.

TABLE 3-3 CHARACTERISTICS OF SAMPLING DEVICES AVAILABLE FOR SMALL DIAMETER MONITORING WELLS

Device	Minimum Well Diameter	Approximate Maximum Sampling Depth	Typical Sample Delivery@ Maximum Depth	Flow Control Ability	Materials* (Sampling Device Only)	Potential For Chemical Alteration	Ease Of Operating Cleaning & Maintenance
Bailers	½"	Unlimited	Variable	Not Applicable	Any	Slight-Moderate	Easy
Syringe Samplers	1½"	Unlimited	0.2 gal.	Not Applicable	Stainless 316, Teflon or poly-Ethylene/glass	Minimum-Slight	Easy
Suction-Lift (Vacuum) Pumps	½"	23-25 ft.	Highly Variable	Good	Highly Variable	High-Moderate	Easy
Gas-Drive Samples	1"	300 ft.	0.2 gpm	Fair	Teflon, PVC, polyethylene	Moderate-High	Easy
Bladder Pumps	1½"	400 ft.	0.5 gpm	Good	Stainless 316 Teflon/Viton, PVC, Silicone	Minimum-Slight	Easy
Gear Drive Submersible Pumps	2"	200 ft.	0.5 gpm	Poor	Stainless 304 Teflon/Viton	Minimum-Slight	Easy
Helical Rotor Submersible Pumps	2"	125 ft.	0.3 gpm	Poor	Stainless 304 EPDM, Teflon	Slight-Moderate	Moderately Difficult
Gas-Driven Piston Pumps	1½"	500 ft.	0.25 gpm	Good	Stainless 304 Teflon, Delrin	Slight-Moderate	Easy to Moderately Difficult

Notes: * Materials dependent on manufacturer and specification of optional materials.
   ** Costs highly dependent on materials specified for devices and selection of accessory equipment.

TABLE 3-4   PURGING EQUIPMENT SELECTION & SAMPLE WITHDRAWAL EQUIPMENT

Diameter Casing	Bailer	Peristaltic Pump	Vacuum Pump	Airlift	Diaphram "Trash" Pump	Submersible Diaphram Pump	Submersible Electric Pump	Submersible Electric Pump w/Packer
1.25-inch Water level								
< 25 ft.		X	X	X	X			
> 25 ft.				X				
2-inch Water level								
< 25 ft.	X	X	X	X	X	X		
> 25 ft.	X			X		X		
4-inch Water level								
< 25 ft.	X	X	X	X	X	X	X	X
> 25 ft.	X			X		X	X	X
6-inch Water level								
< 25 ft.				X	X		X	X
> 25 ft.				X			X	X
8-inch Water level								
< 25 ft.				X	X		X	X
> 25 ft.				X			X	X

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TABLE 3-5   Evaluation and Selection of Groundwater Sampling Equipment

GROUND-WATER PARAMETERS

				INORGANIC							ORGANIC				RADIO-ACTIVE		BIOL.
Device	Approximate Maximum Sample Depth	Maximum Well Diameter	Sample + Delivery Rate or Volume	EC	pH	Redox	Major ions	Trace Metals	Nitrate Fluoride	Dis-solved Gases	Non-volatile	Volatile	TOC	TOX	Radium	Gross Alpha & Beta	Coliform Bacteria
GRAB																	
Open bailer	no limit	1/2 in.	variable	•			•	•	•		•				•		•
Point-source bailer	no limit	1/2 in.	variable	•	•	•	•	•	•		•	•	•	•	•		•
Syringe sampler	no limit	1/2 in.	0.01-0.2 gal	•	•	•	•	•	•		•	•	•	•	•	•	•
POSITIVE DISPLACEMENT (submersible)																	
Gear-drive	200 ft.	2 in.	0-0.5 gpm									•					
Bladder pump	400 ft.	1 1/2 in.	0-2 gpm	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Helical rotor	160 ft.	2 in.	0-1.2 gpm	•	•	•	•	•	•	•		•	•	•	•	•	
Piston Pump (gas-drive)	500 ft.	1 1/2 in.	0-0.5 gpm	•			•	•	•		•				•	•	
Suction lift																	
Centrifugal	variable	3 in.	variable	•			•		•						•	•	•
Peristaltic	26 ft.	1/2 in.	0.01-0.3 gpm	•	•	•	•	•	•		•				•		
Gas Contact																	
Gas-lift	variable	1 in.	variable	•			•		•						•		
Gas-drive	150 ft.	1 in.	0.2 gpm	•			•	•	•						•		
In Situ Sampling Devices																	
Pneumatic	no limit	not applicable	0.01-0.13 gal	•	•	•	•	•	•		•				•	•	•

PORTABLE SAMPLING DEVICES[*]

* Sampling devices in this table are divided into: 1) portable devices for sampling existing monitoring wells; 2) in-situ monitoring devices (often multi-level) that are permanently installed. Sampling device construction materials (including tubing, haul lines, etc.) should be evaluated for suitability in analyzing specific groundwater parameters.

\+ Sample delivery rates and volumes are average ranges based on typical field conditions.

• Indicates device is generally suitable for application (assuming device is cleaned, operated properly, and is constructed of suitable materials).

EC--Electrical Conductivity; TOC--Total Organic Carbon; TOX--Total Organic Halogen.

parameters to sampling devices. There are 12 types of sampling devices and 14 groundwater parameters (including inorganic, organic, radioactive, and biological) considered, and notes regarding sampling depths, well diameters, sampling delivery rates, and construction materials are included.

3.5 EQUIPMENT FOR AIR, GAS OR VAPOR SAMPLING

Pollutants in air can be in the form of gases, vapors, particulates, or a mixture of any of the three. Gases and vapors consist of substances dispersed as molecules in the atmosphere, while particulates consist of aggregates of molecules sufficiently large that they are said to behave like particles. Further more, any dispersed and suspended matter, whether solid or liquid, in which the individual aggregates are larger than single small molecules, about 0.0002 micron in diameter, but smaller than about 500 micron, is referred to as a particulate. Additional terms used to further describe particulate matter include dust, fly ash, smoke, soot, aerosols, droplets, mist, fog and fumes.

Devices which are suitable for collecting one form of pollutant are not usually suitable for collecting others and, hence, an incorrect selection of sampling methods may lead to erroneous results. If sampling is to be appropriately conducted, prior knowledge of the physical state in which a substance exists must be available or else a judgement must be made.

For gas and vapor sampling, there are five categories of devices: 1) collection in bags or containers; 2) absorption devices; 3) adsorption devices; 4) impingers, and 5) freezing-out sampling. For particulate matter sampling, there are also five categories of apparatus: 1) filtration; 2) impingers; 3) impactors; 4) electrostatic precipitation; and 5) thermal precipitators.

3.5.1 Collection In Collapsible Bags or Rigid Containers

These devices are used to obtain only instantaneous or grab samples. Grab samples are usually collected when analysis is to be performed on gross amounts of gases in air (e.g., mine gases, sewage gases, methane, carbon monoxide, oxygen, carbon dioxide). The devices should not be used for collecting reactive gases such as hydrogen sulfide, oxides of nitrogen, and sulfur dioxide unless the analysis can be made directly in the field. Such gases may react with dust particles, moisture, wax sealing compound, or glass, altering the composition of the sample.
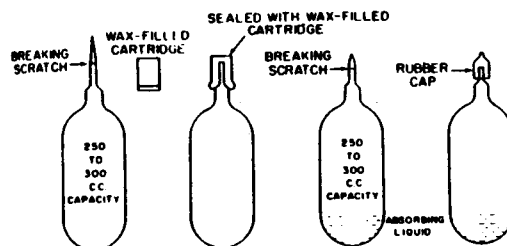
Figure 3-25 Evacuated & sealed Bottles

In areas where the atmospheric composition stays constant, the grab sample may be representative of the average as well as the momentary concentration of the components; thus, it may truly represent an integrated equivalent. Where the atmospheric composition varies, numerous samples must be taken to determine the average concentration of a specific component.

Figure 3-26 Gas or Liquid displacement collector

Rigid containers include vacuum flasks or bottles, glass bottles (Figure 3-25), gas or liquid-displacement collectors (Figure 3-26), metallic collectors, and plastic syringes. Samples are collected by: 1) breaking the heat-sealed end to let the sampled air in and then resealing with a wax-filled cartridge if a pre-evacuated flask or bottle is used; 2) draining the pre-filled liquid, mostly water, at the site and allowing the sampled air in and then sealing the passage if a liquid displacement collector is used. A third method is to allow a sufficient amount of air through the container at the site by a pumping device until the original gas or air in the container is completely displaced by the air being sampled.

3-18
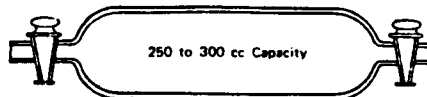
Figure 3-27 Double-acting Rubber Bulb Aspirator

Flexible or collapsible bags are another device for collecting air or gas samples. Filling a bag usually can be done by using hand operated squeeze bulbs(Figure 3-27) with check valves on each end. In most cases, this procedure is satisfactory, but care should be taken to avoid contamination from the sampling bulb or possible losses of the constituents on the walls of the sampling bulb. Proper selection of bag materials is also important, for some will permit losses of contaminants by diffusion through the walls, and others may contribute contaminants to the air being sampled. Other chemical reactions can occur in the bag too, depending upon what is in the air and the storage temperature. It is generally advisable to perform analysis as soon as possible after collecting the sample.
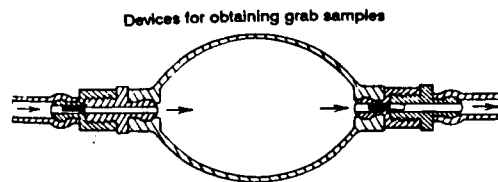
A good practice is that the bags should be leak tested and pre-conditioned for 24 hours before they are used for sampling. Pre-conditioning consists of flushing the bags 3 to 6 times with the test gas, the number of times depending on the nature of the bag material and the gas. In some cases, it is recommended that the final refill remains in the bag overnight before the bag is used for sampling. Such pre-conditioning usually is helpful in minimizing the rate of decay of a collected gas.

3.5.2 Collection In Sorbent Vessel Tubes or Canisters

Most air sampling for gases and vapors are performed by absorbing or adsorbing the contaminants of interest in a suitable sampling medium. Ordinarily, the absorbing medium is a reactive liquid of some kind, but solid absorbents may also be used. By contrast with absorption, adsorption consists of retention of gaseous substances by solid adsorbents which, in most cases, do not chemically combine with gases or vapors. Solid adsorbents require less manipulative care than do liquid absorbents; they can provide high collection efficiencies, and with improved adsorption tube design and a better definition of desorption requirements, they are becoming increasingly popular.

Solid sorbent media can be divided into three categories: organic polymeric sorbents, inorganic sorbents, and carbon sorbents. Organic polymeric sorbents include materials such as a porous polymeric resin of 2,4-diphenyl-p-pheylene oxide (Tenax) and styrene-divinylbenzene copolymer (XAD) resins. These materials have the important feature that minimal amounts of water are collected in the sampling process; thus, large volumes of air can be sampled. A major disadvantage is the inability of the polymeric sorbents to capture highly volatile organic compounds (e.g. vinyl chloride) as well as certain polar materials (e.g. low molecular weight alcohols and ketones).

Inorganic sorbents are silica gel, alumina, a magnesium aluminum silicate (Florisil), and molecular seives. These sorbents are considerably more polar than the organic polymeric sorbents and efficiently collect polar organic compounds. Unfortunately, water is also efficiently captured, and this, in turn, causes a rapid deactivation of the sorbent. For this reason, inorganic sorbents are not often used for sampling volatile organic compounds.

Silica gel has been used widely as an adsorbent for polar or readily polarized contaminants in air samples. The general order of decreasing polarization or attraction is: water, alcohols, aldehydes, ketones, esters, aromatic compounds, olefins, and paraffins.

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Carbon sorbents (Figure 3-28) are relatively nonpolar compared to the inorganic sorbents, and water is less of a problem, although the problem may still prevent analysis in some cases. Carbon sorbents exhibit much stronger adsorption properties than organic polymeric sorbents. This superior adsorption allows the efficient collection of volatile organic compounds such as vinyl chloride. But this strong adsorption of organic compounds, unfortunately, is also a disadvantage because it is difficult to remove most of the collected chemicals and it requires using a solvent. The sampler needs to consider both the capturing ability and the ease of recovering the compound when choosing the sorbent material for sampling organic compounds. Between the two processes of desorptions, thermal desorption is most useful for compounds having boiling points less than 300°C; solvent extraction is most useful for compounds boiling above 150°C and is used extensively for semi-volatile organic compounds.

Figure 3-28 Activated Charcoal Sampling Tube
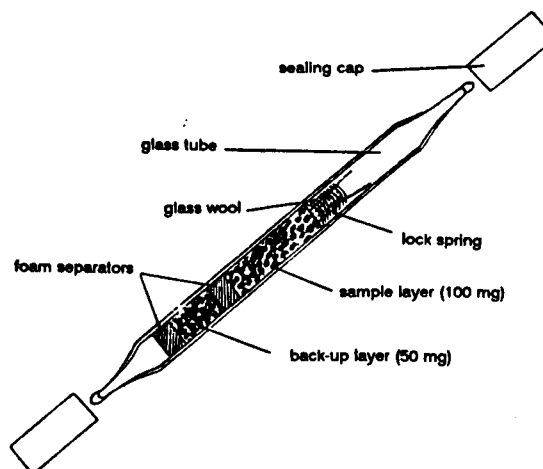
The most popular sorbent for capturing semi-volatile organic compounds is polyurethane foam. The advantages of the polyurethane foam are its efficiency in collecting many semi-volatile organic compounds and its low resistance to air flow; thus, large volumes of air can be sampled. Other sorbents for sampling semi-volatile organic compounds such as styrene-divinylbenzene copolymer resin in granular form (Amberlite XAD-2); porous, cross-linked styrene-divinylbenzene polymeric resin (Chromosorb 102); porous styrene-divinylbenzene resin (Poropak R); Florisil; and silica gel have also been used, but not as widely as polyurethane foam because of their higher resistance to air flow.

Generally, an adsorbent collection system (Figure 3-28) consists of a vessel packed with charcoal or synthetic resin specifically selected for targeted contaminants and a calibrated sampling device to draw ambient air through the vessel. Air contaminants are retained as a thin layer of molecules on the surface of the packed sorbent material in the vessel. Analysis is then done by chromatography after desorbing the contaminants by either thermal desorption or solvent extraction. The selection of the proper sorbent material for the concerned compounds and the determination of total sample flow through the vessel are critical. Table 3-6 shows some sorbent materials and their use.

3.5.3 Direct Reading Equipment

Various direct reading equipments, portable and fixed site monitors that can be used to evaluate airborne concentrations of gases and vapors, are available today. Table 3-7 summarizes the types of direct reading equipment available, along with typical operating characteristics and examples of gases and vapors for which the equipments have been used successfully. Table A-4 of Section 1.5.5, Screening Techniques for Organics in Air, also lists some typical commercially available equipment for organic compounds in ambient air. As references, Table 3-8A shows another summary of sampling and analytical methods for organic compounds in ambient air and Table 3-8B for selected toxic organic compounds.

TABLE 3-6

SORBENT PROPERTIES AND APPLICATIONS

| SORBENT | GENERALLY SUITBALE FOR | EXISTING METHODS | | REMARKS |
		CHEMICALS	LIMIT	
Florisil	Highly chlorinated Compounds, PCBs, Pesticides, Phthalates	PCBs BHCs Phthalates	1 ng/m^3 1 ng/m^3 5-20 ng/m^3	Phthalate Contamination
Silica Gel	High Molecular Wt. Organic Compounds	Dioxins Furans	10^{-13} gm/m^3 10^{-12} gm/m^3	Special GC/MS analysis for dioxin and furans is very expensive
P.U.F. (Polyurethane Foam)	PCBs, Pesticides Dioxins, Furans	EPA Methods		Special sampler needed
PORAPAK-N	Volatile organic solvents, degreasers and volatile halo- genated atomatics	Benzene Chloroform Perchloro- ethylene Chloro- toluene	10 ug/m^3 1 ug/m^3 1 ug/m^3 1 ug/m^3	NYS DOH analysis
Tenax	Same as PORAPAK	EPA Methods		Breakdown of polymer and resulting contamination limits shelf life of cleansed adsorbant to 30 days max.
Carbon	Almost universal adsorbant	At low concentrations chemicals do not desorb efficiently		Researchers are tyring to coat particles to increase desorption efficiencies

Combinations of different adsorbants lead to a combination of characteristics to sample for a wide range of chemicals at great sensitivity.

from "Quality Assurance Manual for Speical Ambeint Air Studies, Bureau of Toxic Air Sampling, Division of Air Resources, NYSDEC".

Table 3-7   Direct Reading Physical Instruments

Principle of Operation	Applications and Remarks	Code*	Range	Repeatability (precision)	Sensitivity	Response Time
Aerosol photometry	Measures records and controls particulates continuously in areas requiring sensitive detection of aerosol levels; detection of 0.05 to 40 μm diameter particles. Computer interface equipment is available.	A and B	10^{-3} to 10^2 ug/liter	Not given	10^{-3} ug/liter (for 0.3 μm DOP)	Not given
Chemiluminescence	Measurement of NO in ambient air selectively and NO_2 after conversion to NO by hot catalyst. Specific measurement of O_3. No atmospheric interferences.	B	0-10,000 ppm	$\pm$ 0.5 - $\pm$ 3%	Varies: 0.1 ppb to 0.1 ppm	ca 0.7 sec, NO mode and 1 sec, NO_x mode; longer period when switching ranges
Colorimetry	Measurement and separate recording of NO_2,NO_x,SO_2, total oxidants,H_2S,HF,NH_3, Cl_2 and aldehydes in ambient air.	A and B	ppb and ppm	$\pm$ 1 - $\pm$ 5%	0.01 ppm (NO_2, SO_2)	30 sec to 90% of full scale
Combustion	Detects and analyzes combustible gases in terms of percent LEL on graduated scale. Available with alarm set at 1/3 LEL.	A	ppm to 100%	--	ppm	<30 sec.
Conductivity, electrical	Records SO_2 concentrations in ambient air. Some operate off a 12-V car battery. Operate unattended for periods up to 30 days.	A and B	0-2 ppm	<$\pm$ 1 - $\pm$ 10%	0.01 ppm	1-15 sec. (lag)
Coulometry	Continuous monitoring of NO, NO_2, O_3, and SO_2 in ambient air. Provided with strip-chart recorders. Some require attention only once a month.	A and B	Selective: 0-1.0 ppm overall, or to 100 ppm (optional)	$\pm$ 4% of full scale	varies: 4-100 ppb dependent on instrument range setting	< 20 min. to 90% of full scale
Flame ionization (with gas chromatograph)	Continuous determination and recording of methane, total hydrocarbons, and carbon monoxide in air. Catalytic conversion of CO to CH_4. Operates up to 3 days unattended.	B	Selective: 0-1 ppm; 0-100 ppm	$\pm$ 1% of full scale	Not given	5 min. (cycle time)
	Separate model for continuous monitoring of SO_2, H_2S, and total sulfur in air. Unattended operation up to 3 days.	B	0 - 20 ppm	$\pm$ 4% of full scale	0.005 ppm (H_2S); 0.01 ppm (SO_2)	5 min. (cycle time)
Flame ionization (hydrocarbon analyzer)	Continuous monitoring of total hydrocarbons in ambient air; potentiometric or optional current outputs compatible with any recorder. Electronic stability from 32 to 110°F.	B	0-1 ppm as CH_4 x 1 x 10 x 100 x 1,000 with continuous span adjustment	$\pm$ 1% of full scale	1 ppm to 2% full scale as CH_4; 4 ppm to 10% as mixed fuel	< 0.5 sec. to 90% of full scale

Table 3-7   Direct Reading Physical Instruments (Cont'd)

Principle of Operation	Applications and Remarks	Code*	Range	Repeatability (precision)	Sensitivity	Response Time
Gas chromatograph, portable	On-site determination of fixed gases, solvent vapors, nitro and halogenated compounds, and light hydrocarbons. Instruments available with choice of flame ionization, electron capture, or thermal conductivity detectors and appropriate columns for desired analyses. Rechargeable batteries.	A	Depends on detector	Not given	< 1 ppb (SF$_6$) with electron capture detector; <1 ppm (HCs)	--
Infrared analyzer (photometry)	Continuous determination of a given component in a gaseous or liquid stream by measuring amount of infrared energy absorbed by component of interest using pressure sensor technique. Wide variety of applications include CO, CO$_2$, Freons, hydrocarbons, nitrous oxide, NH$_3$, SO$_2$ and water vapor.	B	From ppm to 100% depending on application	$\pm$ 1% of full scale	0.5% of full scale	0.5 sec. to 90% of full scale
Photometry ultraviolet (tuned to 253.7 mμ)	Direct readout of mercury vapor; calibration filter is built into the meter. Other gases or vapors that interfere include acetone, aniline, benzene, ozone, and others that absorb radiation at 253.7 mμ.	A	0.005 - 0.1 and 0.03-1 mg/m^3	$\pm$ 10% of meter reading or $\pm$ minimum scale division, whichever is larger	0.005 mg/m^3	Not given
Photometry, visible (narrow-centered 394 mμ band pass)	Continuous monitoring of SO$_2$, SO$_3$, H$_2$S, mercaptans, and total sulfur compounds and ambient air. Operates more than 3 days unattended.	B	1-3,000 ppm (with airflow dilution)	$\pm$ 2 %	0.01 - 10 ppm	< 30 sec. to 90% of full scale
Particle counting (near forward scattering)	Reads and prints directly particle concentrations at 1 of 3 preset time intervals of 100, 1,000 or 10,000 seconds, corresponding to 0.01, 0.1 and 1 cubic foot of sampled air.	B	Preset (by selector switch); particle size ranges; 0.3, 0.5, 1.0, 2.0, 3.0, 5.0 and 10.0 μm; counts up to 10^7 particles per ft^3 (35 x 10^3/liter)	$\pm$ 0.05% (probability of coincidence)	--	Not given
Polarography	Monitor gaseous oxygen in flue gases, auto exhausts, hazardous environments, and in food storage atmospheres and dissolved oxygen in wastewater samples. Battery operated, portable, sample temperature 32 to 110° up to 95% relative humidity. Potentiometric recorder output. Maximum distance between sensor and amplifier is 1,000 feet.	A	0-5 and 0-25%	$\pm$ 1% of reading at constant sample temperature	Not given	20 sec to 90% of full scale

Table 3-7   Direct Reading Physical Instruments (Cont'd)

Principle of Operation	Applications and Remarks	Code*	Range	Repeatability (precision)	Sensitivity	Response Time
Radioactivity	Continuous monitoring of ambient gamma and X-radiation by measurement of ion chamber currents, averaging or integrating over a constant recycling time interval, sample temperature limits 32 to 120°F; 0 to 95% relative humidity (weatherproof detector); up to 1,000 feet remote sensing capability. Recorder and computer outputs. Complete with alert, scram, and failure alarm systems. All solid state circuitry.	B	0.1-10^7 mR/hr	± 10% (decade accuracy)	–	<1 sec.
Radioactivity	Continuous monitoring of beta or gamma emitting radioactive materials within gaseous or liquid effluents; either a thin wall Geiger-Muller tube or a gamma scintillation crystal detector is selected depending on the isotope of interest; gaseous effluent flow, 4 cfm; effluent sample temperature limits 32 to 120°F using scintillation detector and 65 to 165°F using G-M detector. Complete with high radiation, alert and failure alarms.	B	10-10^6 counts/min.	± 2% full scale (rate meter accuracy)	< 10^7 μCi of ^{131}I per cc of air and 10^{-7} μCi of ^{137}Cs per cc of water using a scintillation detector	0.2 sec. at 10^6 counts/min. (rate meter)
Radioactivity	Continuous monitoring of radioactive airborne particulates collected on a filter tape transport system; rate of airflow, 10 scfm; scintillation and G-M detectors, optional but a beta-sensitive plastic scintillator is provided to reduce shielding requirements and offer greater sensitivity. Air sample temperature limits 32 to 120°F; weight 550 pounds. Complete with high and low flow alarm and a filter failure alarm.	B	10 to 10^6 counts/min.	± 2% of full-scale (rate meter accuracy)	10^{-12} μCi of ^{137}Cs per cc of air using a scintillation detector	0.2 sec. at 10^6 counts/min (rate meter)

* Codes: A, portable instruments; B, fixed monitor or "transportable" instruments.

Table 3-8A

SUMMARY OF SAMPLING AND ANALYTICAL METHODS FOR ORGANIC COMPOUNDS IN AMBIENT AIR

Hydrocarbons

Method Designation	Compounds Determined	Sampling and Analysis Approach	Detection Limit	Accuracy	Precision	Relative Cost Instrument	Relative Cost Time/Materials	References	Limitations	Comments
A. ASTM D2820	C_1-C_3 Hydrocarbons	Direct gas injection onto GC/FID	0.01 ppmv	--	±10%	Low	Low	3, 52	Losses due to surface adsorption may occur in some cases, especially for less volatile compounds	GC/MS can be used for component identification. GC/PID is useful for aromatics.
B. --	C_2-C_{10} Hydrocarbons and other nonpolar organics with B.P. -100 to 175°C	Whole air collection in canister cryogenic concentration; GC/FID analysis	0.1 ppbv (100 ml. sample)	--	±10%	Moderate	Moderate	17, 58	Storage times greater than a week are not recommended. Reactive and water soluble compounds are not readily analyzed.	GC/MS can be used for component identification. If possible, a field GC/FID should be used to avoid sample storage problems.
C. --	C_6-C_{12} hydrocarbons and other nonpolar organics with B.P. 60-200°C	Adsorption on Tenax; thermal desorption GC/MS analysis	1-200 pptv (20 liter sample)	70-95%	±10-40%	High	Moderate	27	Blank levels usually limit sensitivity. Artifacts due to reactive components (e.g., O_3, NO_x) can be a problem. Sample can be analyzed only once.	GC/FID can be used to reduce analysis cost. If component identification is not required.
D. --	C_2-C_{12} hydrocarbons and other nonpolar organics with B.P. 60-200°C	Adsorption on Tenax; thermal desorption into canisters; GC/FID or GC/MS analysis	0.01-1 ppbv (20 liter sample)	80-100%	±20%	Moderate to high, depending on GC detector	Moderate	14	Carbon tetrachloride gives poor recovery precision due to adsorption onto metal surface. Blanks and artifact problems same as above.	Sample can be analyzed 3-4 times, thus allowing GC/FID quantification and GC/MS identification.
E. ASTM D3686/ D3687 or NIOSH P&CAM 127	Nonpolar volatiles (B.P. 0-150°C)	Adsorption on charcoal; desorption with CS_2; analysis by GC/FID	0.01-1 ppmv (10 liter sample)	--	±10%	Low	Low	2, 3	Sensitivity much poorer than for thermal desorption approaches.	Charcoal absorbs highly volatile compounds more efficiently than Tenax.

Table 3-8A (continued)

Method Designation	Compounds Determined	Sampling and Analysis Approach	Detection Limit	Accuracy	Precision	Relative Cost		References	Limitations	Comments
						Instrument	Time/Materials			
F. --	Nonpolar volatiles (B.P. 0-100°C)	Adsorption on carbon molecular sieves; thermal desorption into canister; analysis by GC/FID or GC/MS	0.01-1 ppbv (20 liter sample)	80-100%	±20%	Moderate to high, depending on GC detector	Moderate	14	High temperature (350°C) required for desorption may decompose labile compounds.	See Method D.
G. NIOSH P&CAM 206	PAH	Collection of particulate matter on high volume filter; ultrasonic extraction with cyclohexane/silica powder; analysis by normal phase HPLC	3 ng/m³ (1500 m³ sample)	95%	±5%	Moderate	Moderate	2	PAHs more volatile than benzo(a)pyrene may be lost by volatilization during the sampling period. Approaches similar to reference 40 may be required for such compounds.	PAH and other particle bound components may be determined using GC/MS.

Halogenated Hydrocarbons

Methods A-F can be used for volatile halogenated hydrocarbons as well, except that GC/ECD should be used in place of GC/FID in most cases.

Method Designation	Compounds Determined	Sampling and Analysis Approach	Detection Limit	Accuracy	Precision	Relative Cost		References	Limitations	Comments
						Instrument	Time/Materials			
H. --	PCBs, PCNs organochlorine pesticides, and other semivolatile organics (B.P. 140-450°C)	Adsorption on solid adsorbent such as polyurethane foam (PUF), XAD-2, or Chromosorb 102; solvent desorption; GC/ECD, GC/MS, or CG/FID analysis.	3 ng/m³ (1500 m³ sample)	80-100%	±20%	Moderate to high depending on GC detector	Moderate	40 Lower volume approaches (41, 42, 50)	--	Similar approaches using low volume sampling trains may be more useful for detecting higher levels (1-10 µg/m³). Hydrocarbons with boiling points >140°C (>C8) can be determined.
I. --	Tetrachloro-dibenzodioxines	Collection on high volume filter; extraction (Soxhlet) with methylene chloride; column chromatographic cleanup; high resolution GC/MS analysis	~1 pg/m³ (1500 m³ sample)	--	±10-20%	Very High	High	48	TCDDs occur primarily in the particle bound state, but backup adsorption approaches such as reference 40 may be required to ensure no loss occurs through volatilization.	TCDD is highly toxic, hence the need for high sensitivity. These analyses are generally conducted in a special laboratory equipped to handle such materials.

Table 3-8A (continued)

Method Designation	Compounds Determined	Sampling and Analysis Approach	Detection Limit	Accuracy	Precision	Relative Cost Instrument	Relative Cost Time/Materials	References	Limitations	Comments
Oxygenated Neutral Compounds										
J. --	Aldehydes	Collection in dinitrophenyl hydrazine (DNPH); solvent extraction of DNPH derivatives; reversed phase HPLC analysis	1-5 ppbv (40 liter sample)	80-100%	±20%	Low	Moderate	19	Blank levels of aldehydes (particularly formaldehyde) will usually determine the detection limit. Reagents must be carefully prepared to avoid significant contamination.	Analysis within 24 hours is recommended.
K. --	Aldehydes (C₁-C₃)	Collection in 1% sodium bisulfate impinger; determine formaldehyde using chromotropic acid, acrolein using mercuric chloride-hexylresorcinol and C₂-C₃ aliphatic aldehyde by GC/FID	10-30 ppbv (assume 120 liter sample)	--	±10-20%	Low	Moderate	4	High levels of phenols, ethylene, and propylene cause negative interference with formaldehyde determination.	--
L. NIOSH P&CAM 556, 556, 559, 560, 562-566	Alcohols (C₁-C₃)	Adsorption on charcoal; desorption with CS₂ with 1% dissimilar alcohol; GC/FID analysis	100-1000 ppmv	--	±5-10%	Low	Low	2, 56	Humidity level must not be sufficient to allow condensation in tube. Sensitivity is inadequate for most ambient air monitoring purposes.	Direct analysis in the field using GC/FID (as in Method A) should provide 1-10 ppm sensitivity.
Miscellaneous Neutral Compounds										
M. --	Nitrosamines	Adsorption on Thermosorb N; desorption with acetone; GC/ thermal energy or GC/MS analysis	25 ng/m³ (200 liter sample)	85-100%	±10%	High	Moderate	49	Thermal energy analyzer is a nitrosamine specific detector and is rather expensive ($30-40K). GC/NPD may be a less expensive alternative in many situations.	Thermosorb N is a special adsorbent from Thermo-Electron Corporation.

Table 3-8A (continued)

Sulfur, Phosphorus, and Nitrogen Compounds

Most compounds in these classes can be determined using Methods A-F or H, depending on volatility characteristics, except that selective detectors may be used (e.g., GC/FPD for S or P compounds, GC/AFD for N or P compounds, etc.)

Basic Compounds

Method Designation	Compounds Determined	Sampling and Analysis Approach	Detection Limit	Accuracy	Precision	Relative Cost Instrument	Relative Cost Time/Materials	References	Limitations	Comments
N. NIOSH P&CAM 221	Aliphatic Amines (C₁ to C₆)	Adsorption on silica gel; elution with acid; neutralization; GC/FID analysis	500 ppbv (10 liter sample)	--	±3-5%	Low	Low	2	Sensitivity may not be adequate for ambient air monitoring.	GC/NPD can be used to obtain better sensitivity (see method below).
O. --	Aliphatic Amines (C₁-C₄)	Adsorption of alkali treated Porasil A; thermal desorption GC/NPD analysis	1-5 ppbv (60 leter sample)	80-100%	±5-10%	Moderate	Moderate	44	Requires careful conditioning of GC system to obtain adequate performance	--
P. NIOSH P&CAM 168	Aromatic Amines	Adsorption on silica gel; elution with ethanol; GC/FID analysis	100 ppbv (100 liter sample)	--	±10%	Low	Low	2	High humidy levels reduce adsorption capacity	Sensitivity could be improved using GC/NPD. HPLC can also be used (46).
Q. --	Aromatic Amines	Adsorption on Tenax GC; thermal desorption GC/FID or GC/NPD analysis	1 ppbv (100 liter sample)	--	--	Low	Moderate	45	Desorption of high boiling compounds is not complete.	Solvent desorption approaches may be more effective in some cases.

Nitrogen Heterocycles

These compounds can be determined by the methods described for hydrocarbons and halogenated hydrocarbons, depending on volatility, except GC/NPD or HPLC detection of these compounds may be required. Polar GC phases (e.g., Carbowax 20 M) should be used in most cases.

Table 3-8B   Summary of Sampling and Analysis Methods for Selected Toxic Organic Compounds

Compound	Most Appropriate Methods From Table 3-8A	Specific References	Comments
Acetaldehyde	J, K	4, 19	Compound very unstable, requires immediate analysis or derivatization.
Acrolein	J, K	4	Compound very unstable, required immediate analysis or derivatization.
Acrylonitrile	B, F	2	NIOSH Method S156 uses methanol as desorption solvent. GC/NPD will give improved sensitivity.
Allyl Chloride (3-Chloro-1-propene)	B, E, F	2	Compound is too volatile to allow use of Tenax/thermal desorption approach. NIOSH Method S116 uses benzene solvent desorption with GC/FID analysis.
Benzyl Chloride	B, C or D	27	Cryogenic trapping or Tenax adsorption appear to be the best approaches. Adsorption on XAD-2 may also be useful. GC/PID is a useful determinative method.
Carbon Tetrachloride	B, C or D	27	Cryogenic trapping or Tenax adsorption appear to be the best approaches. Storage of samples in contact with stainless steel surfaces can result in rapid loss of this compound. GC/ECD is a useful method.
Chlorobenzene	B, C or D	14, 27, 50	Cryogenic trapping or Tenax adsorption appear to be the best approaches. GC/PID is a useful method.
Chloroform	B, C or D	14, 27	Cryogenic trapping or Tenax adsorption appear to be the best approaches. GC/ECD is a useful determinative.
Chloroprene (2-Chloro-1,3-butadiene)	B, C or D	--	Cryogenic trapping or Tenax adsorption appear to be best approaches, although very little data is available. GC/PID is a useful determinative method.
o,m, or p-cresol (2,3, or 4-methyl phenol)	C, S, H (low volume)	4, 54	Either collection in sodium hydroxide impinger, Tenax adsorption, or resin adsorption/solvent extraction can be used. GC/PID is a useful determinative method.
1,4-dichlorobenzene	B, C or D	27, 50	Cryogenic trapping or Tenax adsorption appear to be the best approaches. Resin adsorption/solvent desorption approaches can be used. GC/ECD or PID are useful determinative methods.
Dimethylnitrosamine (N-nitrosodimethylamine)	M	49	Adsorption on Thermosorb N/thermal desorption appears to be the best approach. GC/NPD may provide sufficient selectivity in many cases.

Table 3-8B   Summary of Sampling and Analysis Methods for Selected Toxic Organic Compounds (Cont'd)

Compound	Most Appropriate Methods From Table 3-8B	Specific References	Comments
Epichlorohydrin (1-Chloro-2,2-epoxypropane)	B, C or D	27	Relatively little ambient air data are available in the literature. Cryogenic trapping or Tenax adsorption appear to be viable approaches.
Ethylene dichloride (1,2-dichloroethane)	B, C or D	14, 27	Cryogenic trapping or Tenax adsorption appear to be the best approaches. GC/ECD is a useful determinative method.
Ethylene Oxide	A, B, E	2	Compound too volatile to use Tenax adsorption. Cryogenic trapping is probably the best approach.
Formaldehyde	J, K	4, 19	Compound very reactive. Requires immediate analysis or stabilization.
Hexachlorocyclopenta-diene	C or D, H (low volume approach)	53	Very little data available for this compound in ambient air.
Maleic Anhydride	--	--	No suitable methods could be found.
Methyl Chloroform (1,1,1-trichloroethane)	B, C or D	27	Cryogenic trapping or Tenax adsorption appear to be the best approaches. GC/ECD is a useful determinative method.
Methylene Chloride	B, F	14	Cryogenic trapping, appears to be the most useful approach. This compound is not retained well by Tenax or other polymeric adsorbents. Adsorption on carbon molecular sieves in place of Tenax is a useful approach. Laboratory contamination with methylene chloride is a common problem.
Nitrobenzene	B, C or D	14	Tenax adsorption is probably the best approach. GC/ECD, PID or NPD are useful determinative methods.
Nitrosomorpholine	M	55	See Dimethylnitrosamine. HPLC may be useful in place of GC for this compound.
Perchloroethylene (Tetrachloroethylene)	B, C or D	14, 27	Cryogenic trapping or Tenax adsorption appear to be the most useful approaches. GC/ECD is a useful determinative method.
Phenol	C or S	4, 19	Trapping in basic impinger solution or Tenax adsorption appear to be the best approaches. GC/PID is a useful determinative method.

Table 3-8B   Summary of Sampling and Analysis Methods for Selected Toxic Organic Compounds   (Cont'd)

Compound	Most Appropriate Methods From Table 3-8A	Specific Methods	Comments
Phosgene	--	51	This compound is highly unstable and hence field determination is desirable. A manual colorimetric method using 4-nitrobenzyl-pridine appears to be the best approach for routine analysis (detection limit $\approx$0.05 ppm for 25 liter sample).
PCBs	H	40	Adsorption of XAD-2 or polyurethane foam followed by solvent extraction and GC/ECD analysis appear to be the best approaches. PCB formulations are composed of many individual compounds and the method of quantification required careful consideration.
Propylene Oxide	B, C or D	27	Cryogenic trapping or Tenax adsorption appear to be the best approaches, although the Tenax approach should be used with caution because of the low breakthrough volume for this compound.
Toluene	B, C or D	14, 17, 27, 41, 52	Cryogenic trapping or Tenax adsorption appear to be the best approaches. GC/PID is a useful determinative technique.
Trichloroethylene	B, C or D	14, 27	Cryogenic trapping or Tenax adsorption appear to be the best approaches. GC/ECD is a useful determinative technique.
Vinylidine Chloride (1,1-dichloroethane)	B, C or D	14, 27	Cryogenic trapping or Tenax adsorption appear to be the best approaches. GC/ECD is a useful determinative technique.
o,m,p-xylene (1,2; 1,3; or 1,4-dimethyl benzene)	B, C or D	14, 17, 27, 41, 52	Cryogenic trapping or Tenax adsorption appear to be the best approaches. Adsorption on XAD-2 and solvent extraction is also possible. GC/PID is a useful determinative method.

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