Environmental **Testing**

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Mentoring a Movement

Empowering People

Preventing Harm

About the Center for Health, Environment & Justice

CHEJ mentors the movement to build healthier communities by empowering people to prevent the harm caused by chemical and toxic threats. We accomplish our work by connecting local community groups to national initiatives and corporate campaigns. CHEJ works with communities to empower groups by providing the tools, strategic vision, and encouragement they need to advocate for human health and the prevention of harm.

Following her successful effort to prevent further harm for families living in contaminated Love Canal, Lois Gibbs founded CHEJ in 1981 to continue the journey. To date, CHEJ has assisted over 10,000 groups nationwide. Details on CHEJ's efforts to help families and communities prevent harm can be found on www.chej.org.
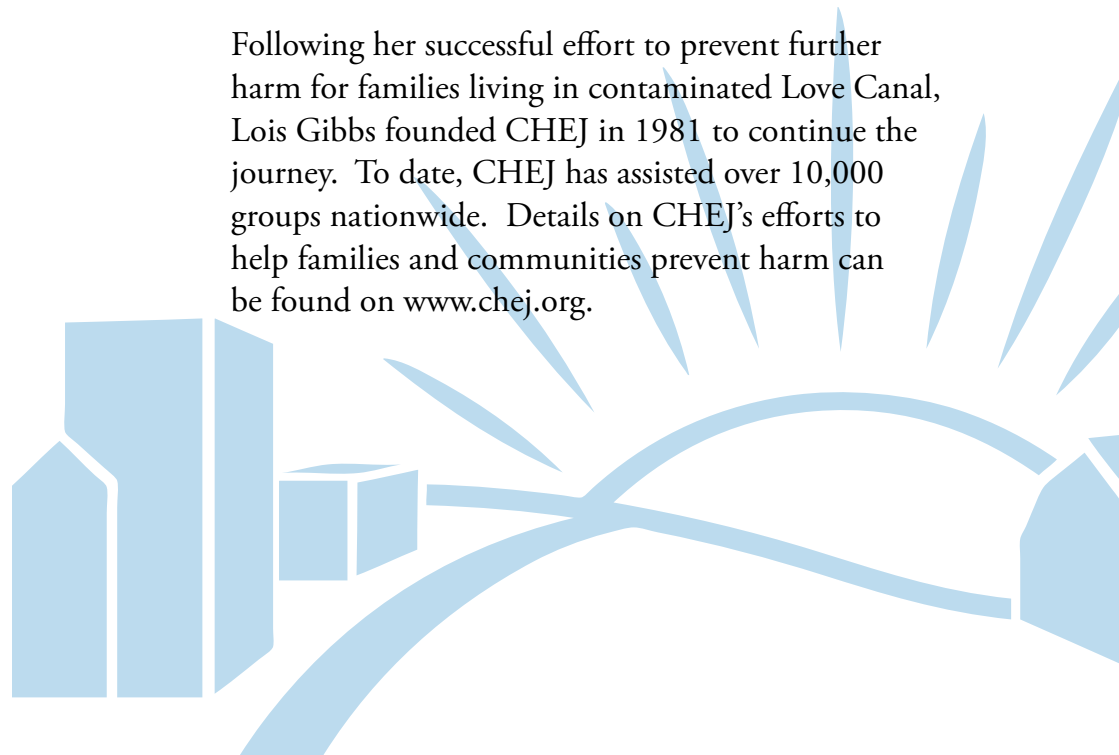
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Chapter 1

Introduction

You think you have an environmental problem and you want the area around your home tested. However, you don't know exactly what to ask for, where to test or what chemicals you should begin to test for. This guidebook will help you understand what steps you need to take in having your water, air or soil tested.

Where Do You Begin?

Begin by thinking about what you see as the problem. There are some simple questions you need to ask yourself: Do you think that your drinking water is contaminated? Will nothing grow in your soil? Does the air smell like rotten eggs? The answer to these questions will tell you where to begin.

Begin at the beginning. Don't ask, for example, to have the whole neighborhood (air, water and soil) tested first. It will be difficult to convince anyone that this is really necessary.

Start with one type of test in a limited area and when these results come back, look at what you have. Depending on the results, you can use this information to reasonably justify your need for further testing. One way to look at this is to think of it as developing a target to shoot at. The more specific you are, the better off you will be.

What is the Best Sampling Medium?

Generally the most reliable sampling medium is groundwater, followed by soil and then air. Air is particularly sensitive to numerous factors such as wind, temperature, humidity and release rate. Thus air is not very reliable in giving answers. The pros and cons of testing in each of these different media are discussed in this guidebook.

You want to use the medium that gives you the most reliable test results. Don't be blinded by your personal need to test the air in your home rather than the groundwater. If you do, you might end up with a limited sampling of the wrong media. Testing is expensive.

Whoever does the testing will only have a limited amount of money, so you want to spend that money in the best way possible.

What Do You Look For?

One of the most complicated questions is what

to look for in a sample. If you decide to look for heavy metals like arsenic, lead or chromium, but your well is contaminated with volatile organic compounds (VOCs) such as benzene, toluene, or trichloroethylene (TCE), the results will show nothing when in fact something is there. What you choose to look for depends on what is causing the problem. Where are the contaminants coming from? If it's a landfill, you need to find out what has been buried; if it's a gasoline station, then look for gasoline constituents; if it's a local factory or manufacturing plant, you will need to find out what is made there. In most cases, you won't know what the source is, or, as is the case with most landfills, even what the wastes are. So now what? The following section will outline some of the most common substances that you can look for when testing.

- **General Pollution Parameters**
  When testing groundwater or drinking water many state and local governments, with limited experience and resources, tend to look for a number of general pollution parameters. These include biological oxygen demand (BOD), pH, specific conductance, turbidity, chlorides, and total suspended solids. A list of these general pollution parameters is shown in Table 1. These parameters are limited and do not reflect the range of chemicals that typically leach out of a landfill. In the past, these parameters have been described as "traditional" pollution parameters.

  In addition, these indicators can have seasonal changes that are unrelated to leachate movement. If these parameters are the only measures used to evaluate your water, "evidence" of contamination is unlikely to be found. These measures were originally selected to identify problems stemming from sanitary landfills or from bacteria and were intended only to set minimum standards for public drinking water systems. They were not selected to identify toxic chemicals in your water.

- **EPA Drinking Water Standards**
  Often, the U.S. Environmental Protection Agency's (EPA) Drinking Water Standards are used to evaluate pollutants in drinking water. The EPA Drinking Water Standards are more useful than the general pollution parameters because they define what EPA calls maximum contaminant levels (MCLs) for specific chemicals. An MCL is the maximum allowable amount of a contaminant that can be present in drinking water. Levels that exceed the MCLs are considered a threat to public health. The EPA has two types of standards, Primary Drinking Water Standards and Secondary Drinking Water Standards. Primary Drinking Water Standards are legally enforceable standards that protect public health by limiting the levels of contaminants in drinking water from a public water system. Table 2 lists the EPA's Primary Drinking Water Standards. The main sources of contamination in drinking water and their health effects are also shown in Table 2.

In addition to Primary Drinking Water Standards, the EPA has established Secondary Drinking Water Standards. These standards, which exist for 15 contaminants, have been established only as guidelines. It is not mandatory that public water suppliers follow these guidelines. They test for these contaminants on a voluntary basis. The Secondary Drinking Water Standards have been established primarily for aesthetic considerations, such as taste, color and odor. Table 3 shows these Secondary Drinking Water Standards. For more information about EPA regulations regarding ground water and drinking water refer to the following web site: www.epa.gov/safewater. Existing Drinking Water Standards are further discussed in Chapter 3.

- **Screening Compounds**
  Sometimes it makes sense to look for general "screening" compounds as indicators of contamination. Total halogenated organics (TOX), total organic carbon (TOC), pH or specific conductivity are common examples. Screening compounds measure the total amount of a group of chemicals present in a sample. They are useful in giving you a "ballpark" estimate of how much of a certain group of chemicals are

present in your water. Depending on the results, you may decide to do more specific testing when you get your screening results back. For example, you have a lab run a TOX test which shows 50 parts per billion (ppb) of total halogenated organics (these are chemicals that include chlorine, bromine or fluorine, such as methylene chloride, or dibromomethane). This number is high enough that you now decide to test for specific chemicals to see what makes up the total of 50. If the TOX test shows only 2 or 3 ppb, then there aren't many halogenated organics in the sample, so you will want to look for other chemicals.

Screening measures may save you money, but they are too general to serve as an early warning of threats to public health or the environment simply because specific toxic chemicals are not identified. For any given sample, the concentration of total organics may not be very high, but if a specific chemical, such as benzene or dioxin make up most of the sample, a substantial health risk could be overlooked.

Furthermore, the "sensitivity" of TOX or TOC tests is not very high when compared to tests that measure individual chemicals. In fact, testing for TOX and TOC requires 1,000 times MORE contamination than looking for specific chemicals because of the high detection limits of these indicators (Lee, 1983).

- **Priority Pollutants**
  Perhaps the best approach for testing water is to look for a group of chemicals called "priority pollutants". This list of 126 chemicals is useful in providing a broad range of chemicals likely to leak from a waste site. When you are just starting, it's best to look for more things and hope you don't find them, then to look for a few substances and hope you have picked the right ones. A complete list of priority pollutants is shown in Table 4.

In general, the priority pollutants consist of 111 organic chemicals and 15 metals, including

asbestos. The 111 organics are further divided into 5 groups: volatiles, base neutrals, acids, pesticides and PCBs. Table 4 shows which substances fall into these categories.

For each of these groups, it costs about the same to test for one compound as it does to measure for all of the compounds in that group. Therefore, you may want to consider looking at just volatile organics if these are the most likely contaminants in your water. You can always go back and do (or request) more testing depending on what you find. Or, you may decide that the volatiles are what you care most about and that's as far as you need to go.

One limitation to the priority pollutant list is that some chemicals are not included, such as formaldehyde, xylene, dibenzofuran, methyl ethyl ketone, aniline and many pesticides and herbicides. If you have reason to suspect a specific substance such as formaldehyde, then clearly it should be included in the test. No single test is perfect.

Who Should Do the Testing?
Before making any decisions about who should do the testing, you need to think about what you want to do with the results. Do you simply want to know what's in your well? Is it to provide the basis for legal action? Do you want the government to clean up the contaminated source or provide clean drinking water? Before any samples are taken, you should carefully define your (organization's) goals and objectives.

This also applies to government testing or testing that is done by consultants hired by the polluters. Be sure to ask them what their objectives are (it can differ from yours). Get yourself (via your organization) involved in the decision making process by which a sampling plan is designed and carried out. This is extremely important because what you look for, where you look and how hard you look are determined by the testing goals, which are spelled out in the sampling plan. If objectives are undefined or differ from yours, the same results can be interpreted

very differently. Keep this in mind as you read test results obtained from a government agency or industry-paid consultant. Everyone has their biases. Inadequate planning can lead to biased, meaningless or unreliable results.

So who should actually do the testing? Basically, there are 4 options:

- Do it yourself and send the sample to a lab.

- Hire someone to do it for you.

- Pressure the government to do it.

- Pressure the party responsible for the contamination to do it.

Which option is best depends on your individual circumstance. Mostly, it depends on who can give you what you want: a reliable test with believable results. If you test the water yourself, you run into a creditability problem. Your opponents can say you "spiked" the sample with cleaning fluids or other chemicals to "prove" that the contamination exists.

The only way to overcome this credibility gap is to have someone else test the water for you, but this will cost you money. Also, if you don't know what to look for, then the testing costs go up. Try to contact someone in the chemistry department at a local university or college. This could yield first-rate results with minimal expense.

If you do take the sample yourself, be careful not to contaminate yourself. You don't want to be foolish and get sick from handling contaminated soil, or by breathing contaminated air. Take proper precautions; talk with someone familiar with chemicals and sampling; wear protective gloves, boots or other clothing as needed.

In addition, you want to make sure that the sample is properly collected. As discussed later, making a mistake during collection can give you poor results. Again, consult someone who knows about sampling procedures. In particular, talk to the lab where you are going to send your sample. They will tell you what you need to do.

Quality assurance measures are also important. They increase reliability, accuracy and confidence in the results you get. Not surprisingly, they also increase costs. The most important factor in considering costs should be the consequence of being wrong.

Remember this when your local government tells you that they can't do any more tests because they have run out of money.

Your last options are to either pressure the responsible company or government to do the testing. Pressuring the responsible company leaves many open-ended questions about the quality and accuracy of data since it may be used against them in a court of law. Pressuring government has its advantages and disadvantages. The advantages are that it does not cost you anything and the results are credible. The disadvantages are the long wait for results, possible inexperience with testing methods and procedures, and lack of control over what is being done.

A useful exercise would be to make a list of advantages and disadvantages for each option. See the sample worksheet below.

- **Be Sure to Take Control From the Start**
  If someone else does the testing, you need to carefully monitor the testing and influence what is done. You can achieve this by knowing what you want and more importantly, asking for it. If you don't demand from the start what you want, you'll end up being victimized by those who may not want to find a problem or by those who want to minimize the extent of the problem.

  For example, if government agrees to test but only under their guidelines, here's what could happen. They take groundwater and drinking water samples and test for 5 chemicals at the parts per million (ppm) range. Their findings and conclusions read as follows: "The state has tested the water in your town, and found no evidence of contamination. Consequently, all further testing efforts will

Sample Worksheet

Pros	Cons
Have the water tested yourself. • You will get results immediately. • You have control. • You will have credibility with community. • You can choose sample locations and the type of analyses to do. **Hire someone to test it for you.** • You have control. • The results are credible. • A qualified person does the sampling. • They will help with interpretation of results. • Results can stand up in court. **Pressure the government to do it.** • No direct cost to you. • Test results will be "acceptable." • They can go after the responsible party.	**Have the water tested yourself.** • Costs money. • No good in court. • You might not know the best way to take a sample. • Government may not believe results. **Hire someone to test it for you.** • Very expensive. • Lab may have conflict of interest. **Pressure the government to do it.** • You have no control. • No trust is there. • You will have a long wait for results. • They may not have experience. • They often loose samples. • You may need outside help to interpret data. • They have no credibility with community.

be halted until a real need for further testing is clearly demonstrated."

In this instance, the state can now walk away saying we looked and didn't find anything. Why didn't they find anything? Perhaps because they looked for the wrong chemicals or they measured at levels to "high" to detect their presence. Meanwhile, you could have 100 parts per billion (1 part per billion is 1,000 times smaller than a part per million) of dioxin or cyanide in your water and the government is telling you nothing is there! This level of dioxin or cyanide in your water is still dangerous.

• **Split Samples**
When someone else is doing the testing a good way to keep "them honest" is to ask for a "split" sample. When someone comes to take a sample of soil, water and/or air, ask for duplicate samples - taken by the same person, from the same spot, placed in a similar container and sealed in the same way. If you want, you can have your sample tested and compare the results, or you can just say that you are going to do this and never actually test the sample. This is one way to keep whoever is doing the testing honest. Split samples really make people nervous because suddenly there is a way to double check the accuracy of the results.

• **Choosing a Lab**
If you decide to do the testing yourself, you will have to find a lab that can do the analysis. However, before choosing a lab, it's important to define the purpose of the testing. Knowing what you want to use the results for will determine what questions are asked and how they are answered. The lab must know

and understand your goals in order to define a sampling and analytical plan that will give you fruitful results.

An important factor in choosing a lab is its credentials. Can the lab deliver what you want– a result that will be technically valid and acceptable to government agencies. One way to assess a lab's credentials is to ask whether the lab is certified by the EPA. EPA operates a laboratory certification program for analyzing drinking water samples that is used to make sure that the level of any contaminants present in drinking water are in compliance with Safe Drinking Water Standards. Certified lab oratories must use EPA approved methods and successfully analyze either a set of performance samples for all regulated contaminants or a set of unknown samples (depending on the type of certification) at least annually, and pass an onsite evaluation at least once every 3 years (USEPA, 1997). In most instances, this certification program is managed at the state level by the state's environmental regulatory agency.

EPA lab certification does not apply to soil or air samples, nor to substances that are not regulated by the U.S. EPA Primary Drinking Water Standards (see Table 2). However, if a lab is certified by the EPA, it says a lot about its attitude toward accreditation and to acquiring a high standard of operation. In general, an EPA certified lab will produce high quality results that will be difficult for anyone to challenge. If a lab is not certified by the EPA, then you'll need to evaluate their methods and procedures much more carefully, or perhaps, not use them at all.

Another way to judge a lab is to ask if they use standardized testing methods such as those developed by EPA (see Laboratory Methods and Procedures in Chapter 3). The EPA has established standardized testing methods and procedures for labs that are contracted by the agency to use. These methods may not be the easiest, cheapest, or most current, but they are reliable, well documented, and well tested. They are generally considered to be the standards of the testing industry that are used by "everyone." Using these standardized testing methods allows the agency to compare results generated by different labs at different sites.

Another factor to consider is the lab's client listings. Who have they worked for? If their client list includes the company that's causing the contamination you're concerned about, then they're not a good candidate do any analyses for you. Similarly, if the majority of the clients that use the lab are private industry, they're not likely to want to do any analysis for you. This would be especially true if you are going to court or testifying at a hearing.

Other things to consider:

- Review the lab's experience in doing the specific analysis you want done.

- Examine the lab's educational experience as well as society memberships and participation.

- Find out whether the lab participates in inter-laboratory evaluations. This is where labs exchange samples or split the same sample and compare results as a way to evaluate the reliability and validity of their results.

- Evaluate the internal quality control/quality assurance procedures used by the lab.

- Find out how far away the lab is located. Ideally, a lab should be located close by and be available to work on an assignment when it is needed. Distance can affect communication primarily because of the cost of phone calls.

- Find out how quickly the lab can do the analysis. Generally, the faster you want the results, the more it's going to cost. Sometimes, quality is sacrificed in order to turn results around quickly. Also consider

going to a lab that's located out of state. An in-state lab will often work closely with the state regulatory agency and with most large polluters (they're the one's who have the money to pay for the testing).

Also consider going to a lab that's located out of state. An in-state lab will often work closely with the state regulatory agency and with most large polluters (they're the one's who have the money to pay for the testing).

As a result, a local lab may have a conflict of interest that makes it difficult for them to do any work for you. Often, they will simply not want to get involved in a situation that puts them on opposite sides of the state regulating agency or a larger corporate polluter.

Lastly, make sure the lab works with individuals. This means that they are set up to send you a

"sampling kit" that includes a bottle to collect your sample, instructions on how to collect the sample, preservatives to add to the sample if needed, and instructions on how to send the sample back to the lab for analysis. It's also the lab's responsibility to make clear the proper handling and use of containers.

In summary, deciding who should do the testing will depend on your individual circumstances and the funds available to you. Ultimately keep in mind who can give you reliable and accurate test results. You (as a community) will get the results you need through successful organizing efforts and by applying political pressure.

Now that we've talked about where you begin and taking control, let's look more carefully at what environmental testing is and how it is actually done.

If you decide to hire a laboratory, keep the following guidelines in mind:

- Establish your goals and intended uses before you contact the lab.

- Select a lab that can give you the results when you need them. If the lab is too busy then perhaps they won't give you the attention and guidance you'll need to get what you want.

- Examine the qualifications and credentials of the laboratory.

- Does the laboratory use standard EPA methods of analyses?

- What are the quality assurance and quality control measures used by the lab? Does the lab participate in an inter-laboratory quality control program? How often are duplicate samples analyzed? How often are inter-laboratory samples analyzed? Are split samples included in the protocols? (See Lab Methods and Procedures in Chapter 3).

Chapter 2

What is Environmental Testing?

Environmental testing simply defined is the collection of samples which when taken to a laboratory can tell you if chemicals are present. If chemicals are present, tests will determine what the levels or concentrations are. Samples can be collected from a variety of different "media" – water; which may be from groundwater, surface water or drinking water; air; soil or sediment. In the following chapters we will discuss each of these media, how samples are collected, and how they are analyzed. Once you know what chemicals are present, then you can begin to estimate the health risks and educate people about what they are being exposed to. This will help get people involved and with involved neighbors, you can force action from the politicians and the government.

Why is Environmental Testing Important?

- It provides evidence that contamination exists – there is benzene, trichloroethylene (TCE) or dioxin in your drinking water.

- It can tell you how far the contamination has spread and therefore who is immediately affected and who may be affected if nothing is done.

- It can give you a basis for evaluating potential health problems. If you know what you're exposed to, such as to PCBs, then you have a starting point for assessing health problems and risks. For example, PCBs are known to cause reproductive, liver and central nervous system disorders, so these would be some of the primary or "target" organ systems to investigate. However, since so little is known about most chemicals, this may only be a starting point.

- It can provide the basis for assessing potential risks posed by a contamination problem. Any sort of assessment of the risks posed by a situation is dependent upon having environmental exposure information. Without basic exposure data, risk assessments cannot be made. Risk assessments are themselves pretty risky depending on who's doing them (See Scientific Uncertainty in Chapter 3).

- It is needed to design an appropriate cleanup. You need to know where contaminants are and at what levels in order to determine how to clean them up.

How much testing you need depends on what questions you have and what your (organizational) goals are. Each situation is different and each requires its own set of decisions.

Mapping Your Community

It is important to think about how chemicals move through the environment to people. Scientists call this the routes or pathways of exposure. Is the chemical evaporating into the air? Is it getting into the groundwater? Is it leaking into a nearby creek? Is it in the soil where children play? Some pathways are very direct such as air exposures; others take more time such as migration through soil. In most instances, each of these pathways will exist. Which one presents the greatest threat depends on a number of factors.

Often, community exposures occur by more than one pathway. It's safe to say that if you're being exposed to a chemical present in the air, you are probably going to inhale it first, but because this chemical is landing in your yard, it may get into your drinking water, or it may get tracked into your home on your shoes. You may be exposed in other ways as well.

A good exercise to help you identify what routes of exposure exist in your situation is to make a map of your community. Indicate on your map what you know about the neighborhood, where the source of the problem(s) is and identify all possible pathways of exposure. For example, when you consider surface water, your map should indicate surface waterways that may exist in the neighborhood. Or, when you consider air exposures, what is the prevalent wind direction in relation to the source and those most affected?

Other factors include:

- What is the direction of groundwater flow?
- Who is on well water?
- Where are wells located?
- Who has access to the site?

Do not forget seasonal changes. In springtime water levels are higher while some streams and creeks only exist seasonally. Also, on your map you should include large farms, open fields where kids play, schools, hospitals, industrial plants, and just about any other feature you can imagine where people could be exposed to chemicals from the source. Once you have completed your map, you will have a good understanding of how people living in different areas of the neighborhood can be exposed to certain contaminants. Figure 1 shows a typical community map with important landmarks.

Figure 1: Community Map
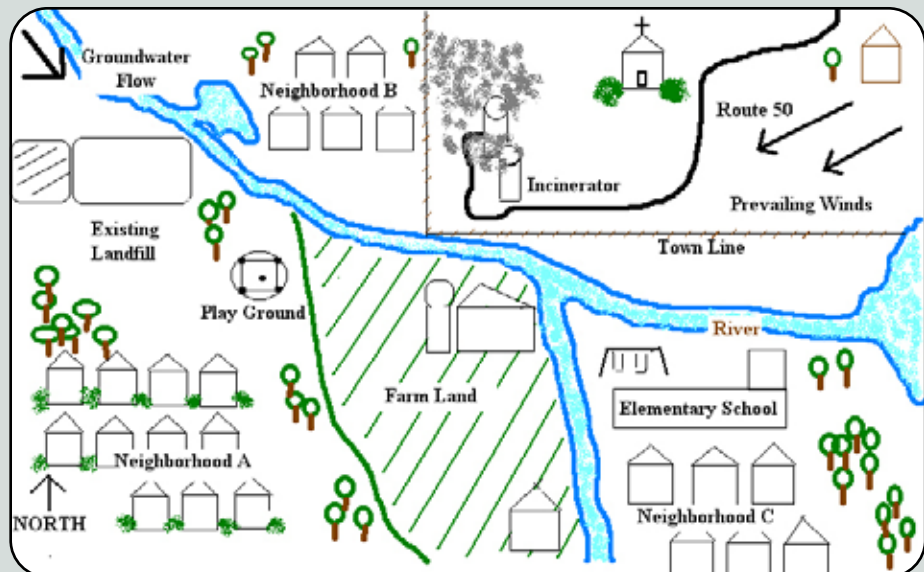
Chapter 3
Interpreting Results

The most difficult task of environmental testing is interpreting the results. Test data are difficult to interpret because scientists know little about what adverse health effects will result when a person is exposed to a chemical. Even less is known about what will happen when someone is exposed to a mixture of chemicals. Virtually all toxicity tests are done with animals exposed to a single chemical. Some data exists for chemicals that workers were exposed to while on the job. This information, however, is very limited. According to a report of the National Academy of Sciences, there is adequate information on toxicity for less than 10% of the chemicals in use (NAS, 1984).

This problem is further complicated by uncertainties about the exposures that a person has had that contribute to the overall impact on a person's health. A person who has been exposed to a mixture of chemicals, including benzene in their water, will not react in the same way to the same exposure of 5 ppm of benzene in their water as a person who has never been exposed to benzene before. There are also uncertainties about the way a sample was collected that impact how you interpret the results. As discussed later in this guidebook, if a sample is not collected properly, then the results are meaningless, regardless of the numbers. As a result, interpreting sampling data is a subjective act that depends on a scientist's understanding of toxicity and what levels he/she believes pose a risk.

Some of the uncertainties and lack of information that make interpretation of test data difficult are listed below.

- Uncertainty and inconsistencies with sampling methods and procedures.

- Uncertainty and inconsistencies in laboratory methods and procedures.

- Uncertainty about how long exposure has been occurring.

- Uncertainty about the level of past exposure.

- Uncertainty about the number of substances a person has been exposed to.

- Uncertainty about effects from exposure to "small" amounts of chemical mixtures.

- Standards only exist for a small number of substances.

• All existing standards are established on the basis of exposure to a single substance and often times only for a single health outcome such as cancer. Synergistic or additive effects caused by simultaneous exposures to more than one substance are scientifically justifiable, but no none knows how to set standards which consider this.

• Cumulative exposures over time are not considered.

Measuring Chemicals

One of the most confusing aspects of test results are the labels – parts per million (ppm), milligrams per liter (mg/1), milligrams per kilogram (mg/kg) or milligrams per cubic meter (mg/m³). Each of these units is a measure of how much of a chemical is present (the milligrams) in a standard volume, which differs depending on whether you're in air (m³), water (liters) or soil (kg).

Visualize this by taking a standard container like a gallon milk jug. Fill it with water. Now add two ounces of salt. What you have in the milk carton is 2 ounces of salt per gallon of water. Since scientists use the metric system, the 2 ounces per gallon of water can be converted to milligrams per liter (mg/L).

A standard volume is used so that comparisons can be made between one water sample and another. Otherwise, you would be comparing apples and oranges. The standard volume differs for different media. Liquids (water) are measured differently than solids (soil), which are different from gases (air). This is because the amount of space each takes up is different for the same weight. Take one pound of dirt and one pound of water. Could you put them both in the same size container? Would they both fill the gallon milk carton to the same level? No, they wouldn't. Neither would one pound of air. Each would take up a different volume.

Air measurements are more complicated because you need to know the molecular weight (MW) of the chemical to convert an air reading of 50 mg/m³ to ppm. To do this you would use a chemistry book

So What Do the Results Mean?

Scientists know so little about what it means to be exposed to low level mixtures of toxic chemicals that interpretations become very subjective. However, whenever you find a scientist hedging on the meaning of the results, ask a simple question: Would you live there? Or, would you drink this water? Or, would you let your children play there? It helps put things in perspective.

to look up the MW, and plug the numbers into this formula:

$$PPM = 25/MW \ (mg/m^3)$$

Whenever you get test data back with unit measures that you don't understand, ask to have the numbers converted to something familiar like ppm or ppb. Or, whenever possible, ask in advance to have all numbers reported in those units. The lab will do whenever you ask. For them, making conversions is easy. A chart to help make some common conversions is shown in Table 5.

You want to avoid being confused by test results given in different or unusual units. Keep one step ahead of your opposition by requesting/demanding common and simple units of measure.

How Toxic is Toxic?

When you do get results back, industry and government often minimize the results by saying that the levels are insignificant, equal to a needle in the haystack or comparable to a grain of sand on a beach. Is this really true? Can these "experts" be right? Is 11 parts per million of benzene really harmless? Let's look at this more closely.

One part per million of a substance means that there is one milligram of that substance for every kilogram of body weight. For example, for an adult

weighing 130 pounds (or 59 kilograms), a dose of 1 ppm equals 59 milligrams (59 mg/59 kg). Consider this in terms of a common aspirin. The average aspirin tablet contains 325 milligrams of active ingredient. Two tablets would be approximately the equivalent of 11 ppm in a 130-pound adult. We get 11 ppm from the following equation:

$$325mg \times 2 = 650\ mg$$
$$650\ mg/59\ kg = 11ppm$$

This dosage can stop pain and reduce fever. While 11 ppm may seem insignificant in a ton of hay, it could mean a lot in the human body!

Remember, doctors do not (or seldom) recommend that you take even one aspirin every day, and you do not give the same amount of aspirin to an infant as you would give to an adult. More importantly, aspirin is dangerous if you take two as frequently as you would drink a glass of water or take a breath of air, which is the amount of exposure we are talking about in cases of contamination.

In addition, all chemicals are not equally toxic. Some chemicals, like dioxin, are very dangerous even at the parts per billion level. So the situation is more complicated than government or industry experts may want you to believe.

Depending on the substance, 11ppm could be very significant – even dangerous – and certainly not "just a needle in a haystack. Despite these limitations, judgments can be made. But to make good judgments, you need as much information as possible.

Sampling Methods and Procedures

Before looking at what the numbers mean, look at how the samples were collected and analyzed to see if things were done correctly. If the data is no good, then it doesn't matter what the numbers are. Sampling methods and procedures describe how, why, when, and where the sample was taken.

We've listed some general questions that apply to all samples that you may want to ask about the testing to help you understand how the samples were collected. The answers will help you evaluate how

useful the data you have is. Specific questions relating to groundwater, surface water, air, and soil testing are included in subsequent chapters.

General questions that apply to all types of samples:

- How many samples are there?
- Where are the samples located?
- How far from the source of contamination is each sample?
- Are they properly located to "catch" the contaminants?
- What are the actual collection methods and procedures used in the field?
- What laboratory methods and procedures are going to be used?
- What chemicals are being looked for and why (see Chapter 1)?
- What are the "limits of detection" for each substance?
- What quality control measures will be used?
- Where are the samples going to be analyzed?
- How long will it take for the samples to be analyzed?

The answers to each of these questions can influence the interpretation of the test results. For some factors, this is common sense. For example, if there are only two samples taken from around a 50-acre landfill, you need more samples. If the samples are located upstream or outside of a contamination plume, then more samples will need to be taken.

Another example is the placement of groundwater monitoring wells. It is easy to completely miss a "plume" of contamination or to just catch the edge of a plume by placing wells in the wrong place or by not screening at the right depths. This difficulty was vividly described in a review by hydrogeologist Don Cherry, formerly of the Princeton University Water Resource Program:

"Imagine that we cannot see the sky, we cannot tell the direction or velocity of the wind, and we ask: Is the factory (with its thousands of little chimneys) polluting the air? That is our groundwater-monitoring problem—at it's easiest. It is made more difficult because the geological properties of the soil vary with depth and direction, and this variation is unknown and uncertain. When we look up in the sky, we observe the spatial variation of the pollutants. If we could look up only through a small tube or telescope, then the information we gathered from the one sighting might not be representative of what we would see if we looked everywhere. The small tube into the sky is like our groundwater monitoring well: the data we gather may not tell us too much about what is occurring in other nearby locations."

Another way to look at this problem is through illustrations. Figure 2 and Figure 3 show examples of how incorrectly placed monitoring wells can completely miss a plume. Figure 4 shows how a monitoring well should be placed.

Figure 2: Incorrectly Placed Monitoring Wells 1.

Monitoring wells placed in the direction of natural groundwater flow may not be effective if contaminants are captured by the cone of influence of a nearby production well.
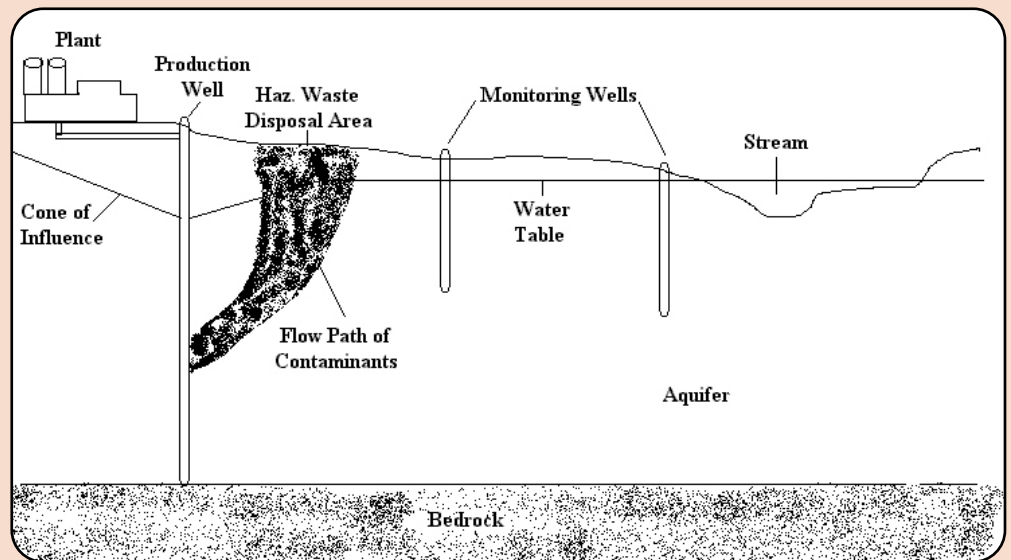

Figure 3: Incorrectly Placed Monitoring Wells 2.

Monitoring wells placed in the upper part of an aquifer may not detect contamination moving through a lower section of an aquifer.
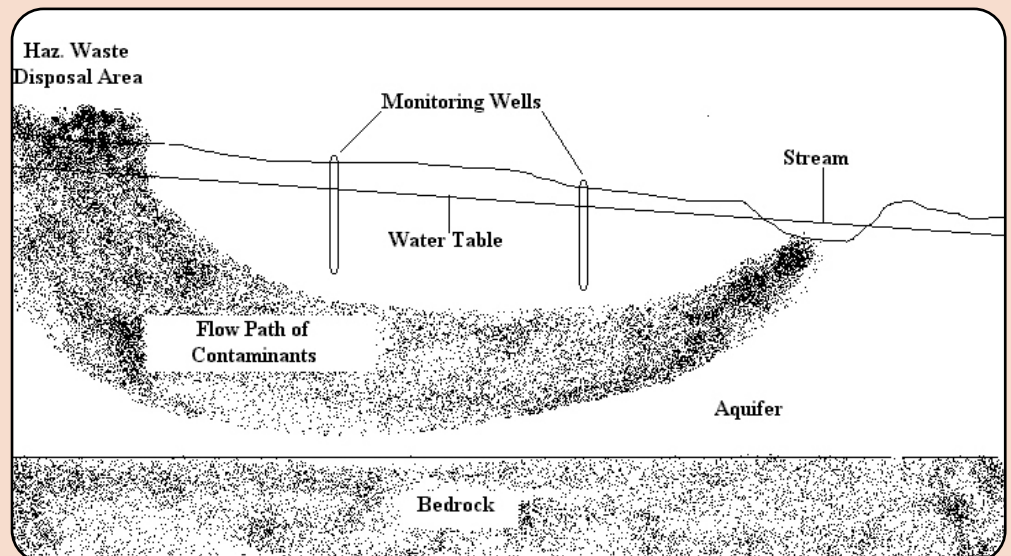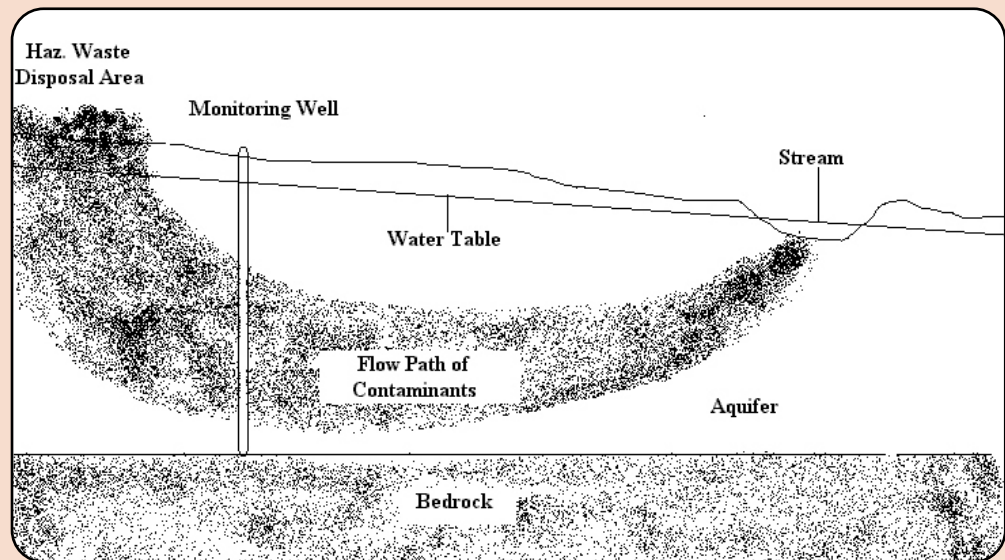
Figure 4: *Correctly Placed Monitoring Wells.*

Furthermore, there must be enough wells to define the edge of a plume. The federal government's requirements of only 3 wells, one upstream and two downstream, are mostly inadequate for assessing groundwater movement, or to provide any warning that a site is leaking. Most permit applications require between 4-20 detection wells, while in some cases as many as 40, 50 (Illinois) or even 100 (New Jersey) wells have been required (OTA, 1984). Selecting the right number of wells depends on the size of the site, the depth(s) to the water table(s) and the amount and extent of contamination.

These examples show how sampling procedures can influence test results. Poorly selected sample locations will result in poor results. If you don't ask questions, you may never realize that the results you were given were the direct result of poor sampling procedures.

Laboratory Methods and Procedures

Laboratory or analytical methods and procedures are also important. If the lab uses incorrect methods or does not look for the "right" chemicals, then nothing will show up, even if something is there. The major responsibility of the laboratory is to ensure that the results obtained are "real" and not artifacts of laboratory or sampling errors. This is ensured by using quality control (QC) and quality assurance (QA)

procedures. Key elements of such programs, applicable to all testing include:

- Splitting a number of samples and separately analyzing them and comparing the results.

- Splitting a number of samples and sending the split samples to a different lab for analyses and comparing the results.

- Collecting a field "blank", or sample, in the field duplicating the exact procedures used to collect the sample without actually taking a sample.

- Numbering samples in the field so that the lab doesn't know which are actual samples and which are field blanks.

- Mixing in "trip" blanks which do not undergo the field procedures but which accompany the sample from the point of collection to the laboratory.

- Replicating analyses on the samples to ensure consistency of the results.

Data from monitoring and sampling programs cannot be evaluated and interpreted with confidence unless adequate quality assurance (QA) methods and procedures have been included in the initial sampling plan. Adequate QA requires the identification and quantification of all sources of error at each step of the

sampling plan. A properly designed QA plan will ensure that proper analytical techniques are used so that the resulting data will be of acceptable quality (Csuros, 1994).

Limits of Detection

An important issue when testing for chemicals is to define the limits of detection. The detection limit is the lowest level of a substance that can be detected in a sample. The lower the detection limits of a sample, the more likely you are to identify if contamination is present. If the detection limits are too high, then the lab will report that "nothing was found" in the sample. This may actually be true. Or, it may not be accurate if the detection limits are too high to identify if specific chemicals are present in a sample. A good lab will state on the original lab report whether specific substances were identified at levels below the detection limits. However, this is not often reported to the public. The best way to know is to get a copy of the original lab report.

The cost of analyzing a sample using low detection limits is substantially greater than analyzing a sample using higher detection limits. Detection limits are generally determined in advance of the testing (based on how much the client is willing to pay). Often, the limit is the same across a group of substances such as volatile organic compounds, semi-volatile organic substances, or PCBs. Detection limits should remain constant for the same substance analyzed for in different samples.

There are no specific requirements for what detection level to use in analyzing water samples. There are, however, several guidelines that can be used. First, the EPA has defined detection limits that labs participating in the Drinking Water Certification Program must use (see discussion from Choosing A Lab in Chapter 1). These labs must achieve detection limits of 0.5 micrograms per liter (ug/L) or 0.5 parts per billion (ppb) for volatile organic compounds (VOCs) in drinking water (USEPA, 1997). Detection limits for semi-volatile organic compounds (SOCs) vary from 0.01 ppb for endrin and ethyenedibromide (EDB) to 9.0 ppb for endothall. For metals, the

detection limits vary from 0.4 ppb for mercury and thallium to 400 ppb for barium (USEPA, 1997).

A second option is to use the detection limits that EPA contract laboratories must use for testing done at Superfund sites. The EPA Contract Laboratory Program (CLP) has defined specific "quantification limits" for testing done in soil and water at Superfund sites (USEPA, 1989 and 2003). In this case, the agency has defined two detection limits: one for low level contamination and another for a higher level of contamination. The CLP quantification limits used to detect low level contamination are very similar to those used by the EPA's drinking water program. For VOCs, most CLP detection limits are 0.5 ug/Liter or ppb in water and 10 micrograms per kilogram (ug/kg) also equal to ppb in soil (USEPA, 2003). For SOCs, most CLP detection limits are 5 ug/L in water and 330 ug/kg in soil. A complete list of the CLP detection limits for both soil and water can be found on the Internet at: http://www.epa.gov/superfund/programs/clp/target.html.

If you find out that a lab has used the higher contamination detection limits, ask them why they did this. These higher values should only be used when there is clear evidence that contamination levels are very high. Even at Superfund sites, which include the worst contaminated sites in the country, this is not always appropriate. Whenever investigating a site where you are trying to define the extent of contamination, it's always best to use the lower detection limits. This ensures that if any contamination is present, it will be found. If the higher levels are used, contamination may be present that is not detected by the testing.

If these detection limits are not available to you, another option is use no more than 20% of the EPA Primary Drinking Water Standard as a guideline. This is a rough approximation that will give you some idea of whether the detection limits that were used are too high. One problem with this approach is that there are standards for only a small number of substances (see Table 2). Often, industry will set the detection limits at the Drinking Water Standard, which is too high.

Further complications arise when several chemicals are mixed together, as is almost always the case at dumpsites. The ability to detect a specific chemical by a given test procedure is usually reduced. This is called "analytical interference" and usually results in raising the detection limits.

Standardized Test Methods

In order to ensure consistency, and accuracy in comparing data collected at different times or from different places, EPA has established standardized test methods that they use for all their testing. They require all agency contractors to use these standardized test methods as well. These methods have generally been adopted by state and local governments along with private industries.

- **EPA Test Methods**
  The EPA has developed a series of environmental test methods that they routinely use. These methods provide a standardized set of reliable, sensitive, chemical-specific methods that use quality control and quality assurance methods and procedures that are well documented and traceable (USEPA, 1989). Specific methods have been developed for testing different media. A very simplified version of the set of test methods that apply to soil, air and water is shown below:

  - Soil and Solid Waste - SW-846 Methods (USEPA, 2002)

  - Organics in Water and Wastewater - the EPA 600 series (USEPA, 2002a)

  - Organics in Drinking Water - the EPA 500 series (USEPA, 2002a)

  - Toxic Organic Compounds in Air – the TO series (USEPA, 2002b)

  Each of these general categories include many different test methods. Both the 500 and 600 series include literally hundreds of different test methods. Some of these methods are defined by substance, others by medium, and still others by analytical instruments. The identification and numbering system

used by the EPA is very complicated and difficult to follow.

The use of these methods is not legally required. They are offered as guidelines to help companies, local government agencies, and others identify appropriate methods to use in order to analyze for different substances in different media. Find out if a lab is using any of these methods. If they're not, ask why not. If they are, then at least you know they're using a standardized reliable method. However, just because a lab uses EPA test methods does not guarantee that the results you get will be accurate. Never accept results at face value.

An index of EPA's test methods was created in the late 1980's to improve access to these methods and to help the public identify the right methods to use in different circumstances. This index can search for methods by their designated number, chemical or method description, or by the date a particular method was published. The most recent version of this index can be downloaded from the EPA New England Region 1 website at: http://www.epa.gov/region01/oarm/index.html Another useful resource available online is the Key to Obtaining Sources of EPA Test Methods, which can be found at: http://www.epa.gov/epahome/index/key.htm This key gives a basic outline of air, water and solid waste test methods.

- **EPA's Contract Laboratory Program**
  Although there's no law that requires labs to use specific test methods, the EPA has identified specific analytical methods that they want to use when they do their own testing. These methods are defined for laboratories participating in the EPA's Contract Laboratory Program (CLP). This program was started in 1980 because the EPA needed to be sure that they could use the environmental testing data they were generating at contaminated sites in a court of law.

The EPA typically cleans up contaminated sites using federal funds and tries to recover the cost

of the cleanup from the companies who were responsible for the contamination. This is especially true at federal Superfund sites, the worst contaminated sites in the country. The CLP filled the need for legally defensible analytical results supported by a high level of quality assurance and documentation (USEPA, 1989). Only data generated by a CLP lab can be used in the quantitative risk assessment used by the EPA to assess the public health and environmental risks posed by a Superfund site.

Laboratories apply to the EPA to become a CLP lab. These labs must meet stringent requirements for laboratory space and practices, instrumentation, personnel training, and quality control, and must successfully analyze performance evaluation samples (USEPA, 2002c). Once certified, these labs are routinely used by the agency to do testing at Superfund sites. The EPA maintains a list of labs that are currently certified as CLP labs. The list is available from the EPA and is on the internet at http://www.epa.gov/superfund/programs/clp/download/lablist.pdf

- **ASTM Test Methods**
  The American Society for Testing and Materials (ASTM) International provides standards for testing that are used for a range of activities including manufacturing, procurement and regulatory procedures. ASTM's standards have been accepted and used around the world for over 100 years. Although these standards are voluntary, they are often a source of guidance for private labs and for government agencies alike. The major limitation to ASTM methods is that they are developed by a consensus of a large and diverse group of industry workers, government officials, engineers, and scientists. The result is the development of methods that adhere to the lowest common denominator, which often results in standards that are not very stringent (ASTM, 2001).

Scientific Uncertainty

As incredulous as it may seem, scientists know very little about health effects caused by exposures to small amounts of chemicals. Even less is known about what happens when you are exposed to more than one chemical at a time. This is primarily because most of what we know about toxic effects comes from animal studies. Some evidence comes from occupational exposures such as: mesothelioma from workers exposed to asbestos (NTP, 2002), angiosarcomas in workers exposed to vinyl chloride (NTP, 2002), and reduced reproduction rates in females exposed to dichlorobromopropane (Schettler, 1999).

Animal experimentation is not the ideal model of human response to chemicals, but it is the best we have. Even animal data sheds little light on the toxicity of most chemicals. Of the estimated 87,000 chemicals in use today, the majority lack basic toxicity testing according to the EPA (USEPA, 1998). For those tested, data on important health effects such as reproductive, neurological, developmental, and immunological effects are lacking at best, and non existent in most cases. An EPA review of 2,863 of the most commonly used chemicals found no toxicity information available for 43% of the substances and a complete set of toxicity data for only 7% (USEPA, 1998a).

Other uncertainties include the lack of understanding of the toxic effects caused by exposure to more than one substance (synergistic effects), the lack of data on cumulative effects (effects caused by continuous exposures to both individual and multiple chemicals over time), the lack of information on a person's individual exposures that contribute to a person's overall body burden that may predispose a person to vulnerability, difficulties in detecting health damages before problems are fully developed, lack of understanding of environmental fate and transport processes that contribute to human exposures (how the chemicals move in the environment) and the lack of understanding of how our body functions convert exposures into disease (biological mechanisms of action).

There are also uncertainties in the many models used to bridge information gaps. For example, mathematical

models are often used to estimate risks in people exposed to low doses of chemicals. These models use data from experiments where animals are exposed to very high levels. Models are also used to construct past exposures such as estimating what exposures were 10 years ago for people drinking contaminated groundwater based on data collected today, and to predict the future, such as estimating how far a contaminated plume will travel in the next year. These models are only as good as the information that is put into them, which is necessarily incomplete due to the many factors discussed above. If the data entered into a model is garbage, then the estimates that you get out of them will be equally worthless.

In order to compensate for these many uncertainties, "conservative" estimates or judgments of risk should be made. In this case, conservative means making decisions or judgments that protect public health and the environment in the absence of better knowledge. Conversely, government officials often act "conservatively" to protect other interests, such as their jobs or local industry by making statements such as "we have no evidence" or "we can't be sure" or "we simply don't know." In each case, the result is inaction. If this decision is wrong, the consequences are damage to the environment, continued exposures, and people becoming ill (if they aren't already). On the other hand, if the government goes the other direction, and is wrong, the only consequence is money spent on cleanup or assessment that could have been spent on other problems. What is more important, money or people's health? History has made it clear what is important to government and industry.

Currently, governments and industry use risk assessment methods to address these uncertainties. There are two key elements to any risk assessment, exposure and effects. However, there are many uncertainties in collecting data in both these areas. To compensate, "worst case" exposure conditions are often defined and subsequence risks are estimated. The idea being that a worst case overcomes these uncertainties by providing added protection. If the worst-case risk is "acceptable", then the "real" risk is even lower.

The danger with risk assessment is that the numbers begin to take on a life of their own. They produce a numerical estimate, which implies a precision that is not justified by the data and the many assumptions used in the process. Once you get a number, people tend to forget the assumptions and uncertainties and start accepting the numbers as "real". Often the worst case is challenged as being too unrealistic and the assumptions are altered to more closely reflect actual conditions. The further you go from the worst case, the less you can compensate for the uncertainties; the reason for selecting the worst case in the first place.

There's another way to look at these scientific uncertainties that's gaining favor and support in many grassroots communities. This is the application of the precautionary principle. People are beginning to realize that scientific uncertainty should be cause for caution, not for plunging ahead until all scientific questions can be answered. Industry and government often argue that we should not set stricter standards until we find out exactly what level of benzene in drinking water is unsafe. They would have us wait until we have eliminated all scientific uncertainty and have the "bodies in the street" as proof of the dangers of benzene exposure. The precautionary principle would have us act before such tragedies occur and if necessary to err on the side of caution, because such errors are less costly in the long run.

Instead of asking how much damage or harm we will tolerate (which is the approach taken by risk assessment), the precautionary principle asks how to reduce or eliminate hazards, and it considers all possible means for achieving that goal, including scrapping the proposed activity. It also shifts the burden of proof. Proponents of an activity have to prove that their activity will not cause undue harm to human health or the environment (REHW, 1999).

One way to include a precautionary approach to decision-making is conduct an "Alternatives Assessment." This approach calls for examining the pros and cons of a full range of options and for answering several questions that are quite different

from the questions asked in a risk assessment. The questions raised in an Alternatives Assessment are:

- How much damage is possible from this practice, chemical or technology?

- Is the proposed activity necessary or needed?

- Is the proposed activity ethical?

- What will be the cumulative effect on the environment and on humans at this location?

- Are there less damaging ways to accomplish the same thing?

An Alternatives Assessment is also extraordinarily democratic. It is simple, allows all sectors of society to participate, challenges and involves people's creativity and innovation, and calls for industry and government agencies to explore in a public forum, on paper and in understandable language, the options for causing the least possible environmental damage. This approach places responsibility on those who diminish, pollute, extract, and degrade to think publicly about alternative ways they can behave, and shows industries and agencies how they can avoid activities that may later cost industry and the public enormous amounts of money to mitigate (if even possible), and it encourages industries and agencies to consider processes that are forward–looking (O'Brien, 2000).

One of the underlying principles of an alternatives assessment is that understanding and acknowledging that there are alternatives is an essential and powerful step towards creating change. Alternatives assessments bring new questions and possibilities to discussions about risk, and allows decision makers to consider a wider range of options — including taking precautionary steps to completely avoid risks instead of just managing them.

In the absence of clean-cut scientific answers, government interests are very different than the community's. Therefore, it's up to the community, to you, to protect your own health and welfare. You can't leave it to government.

Uncertainties About Exposures

An area where there are many uncertainties is the understanding of exposure. In order to assess health damage, you need to know how much of a chemical a person has been exposed to. This is called the dose. To determine the dose (D), you would multiply the concentration (C) of the chemical that you are exposed to by how long exposure occurred (T). This can be expressed in the formula $D = C \times T$. In most instances, these factors are difficult, if not impossible to determine. Do you know how long your water has been contaminated? Or what chemicals were in it? Did the levels change over time? Most people do not know this information.

Sometimes, estimates of past exposures are made using models. In Hardemann County, TN, scientists hired by lawyers representing local citizens developed a model, which predicted exposure levels as far back as 10 years. Using this model, the researchers were able to estimate concentration levels in the drinking water 10 years ago and were, therefore, able to approximate the total dose certain residents received. They then used these numbers to confirm the health damages that residents had reported. Similar estimates have been made in other communities (Harris, 1983).

This example is extremely rare because it's very expensive to undertake research of this type, it takes time to develop, and because there is often insufficient data to develop a model. As discussed above, a model is only as good as the data you have to put into it – garbage in, garbage out.

Even when using an elaborate model, you're left with a "best estimate". This may be sufficient to decide whether to continue to drink the water or not, but it will likely not be enough to estimate long-term risks.

Existing Standards

The most often used way to evaluate sampling data is to compare the results to federal standards. The problem is that there are few federal standards that are

applicable to evaluating exposures at contaminated sites. The only standards that you can use are those that apply to drinking water. There are no standards at all for soil and sediment. For air, there are six standards (see Table 6), but these substances are not what you would look for at a contaminated site. They are traditional urban air pollutants - ozone, sulfur dioxide, particulates, nitrogen dioxide, carbon monoxide, and lead. Only lead is likely to be found at a contaminated site. But even with lead, the air standard is based on a quarterly average value. At contaminated sites, you are trying to identity current exposures and evaluate risks based on those exposures.

For drinking water, the EPA has established standards for microorganisms, disinfection byproducts, disinfectants, some organic chemicals, inorganics, metals, and radionuclides. These standards, referred to as "primary" drinking water standards are shown in Table 2. The EPA has also established "secondary" standards, as shown in Table 3. The primary standards are intended to ensure the quality of drinking water for public water systems while the secondary standards address the "aesthetic qualities" of water (does it look and taste good).

The Primary Drinking Water Standards, established under the Safe Drinking Water Act (SDWA) of 1974 and amended in 1986 and 1996, are described as "maximum contaminant levels" (MCLs). MCLs measure the highest level of a contaminant allowed in drinking water and are enforceable by law. MCLs apply only to water systems that service at least twenty-five households daily, at least 60 days out of the year. Therefore, these standards do not legally apply to rural areas where residents obtain their water from individual wells. However, these federal standards can still be used to evaluate the risks that exist in individual wells.

In 1986, Congress passed an amendment to the SDWA that included determining "maximum contaminant level goals" (MCLGs). The EPA was charged with determining the highest level of a drinking water contaminant that would be allowed in drinking water if adverse health effects were the only factors to consider.

This level, the MCLG, was defined as the ideal "goal" for setting a drinking water standard. However, this level did not take into consideration the economic impact of achieving this goal. Industry argued that the MCLGs were too low and that it would cost "billions" to reduce contaminants in drinking water to below the MCLGs. In fact, the MCLGs for all chemicals that cause cancer in either people or in animal studies is zero. As a result, the EPA backed off the MCLG values and set the legally enforceable drinking water standards at the maximum contaminant level or the MCL. The MCLs are all higher, some substantially, than the MCLGs.

In addition to the fact that the MCLs are not based on providing the maximum protection from adverse health effects, there are other limitations. They are derived using standard risk assessment approaches that have many problems including the fact that they are based on exposure to a single chemical, not to multiple substances as often occurs; they fail to consider cumulative and synergistic effects; they fail to consider individual susceptibility, especially in children; they fail to recognize that some chemicals only cause their damage during critical periods of development or reproduction; and they focus on cancer alone when a substance has been found to cause cancer in animal studies or in people, but other adverse effects are not considered. There are also only a limited number of MCLs. Currently EPA has set MCLs for 7 microorganisms, 3 disinfectants, 4 disinfectant by-products, 16 inorganic chemicals (mostly metals), 53 organic chemicals, and 4 radionuclides (see Table 2).

It is important to keep the MCL values in proper perspective. If contaminant levels exceed the MCLs, then the water cannot be used for drinking. But, this does not mean that values below the MCL are "safe" or inconsequential. Exposure to chemicals found at levels below the MCL still poses some health risks. What those risks are depend on the levels of the chemicals, how many chemicals you are exposed to,

how long you are exposed to them, and individual susceptibility, which varies widely from person to person.

As discussed above, a few standards exist for the air. In 1990, the Clean Air Act (CAA) was amended to require the EPA to set National Ambient Air Quality Standards for pollutants that were considered harmful to the public's health and the environment. Like the Safe Drinking Water Act, there are primary and secondary standards. The primary standards set limits to protect health while the secondary standards protect public welfare and the aesthetic value of the air around us. There are six major air pollutants, known as "criteria pollutants," that have been given standards. Table 6 lists these pollutants and their standards.

Chapter 4

Groundwater Testing

The most common route of chemical movement is through groundwater. Some of the ways groundwater can become contaminated are shown in Figure 5.

Figure 5: *Sources of Groundwater Contamination*
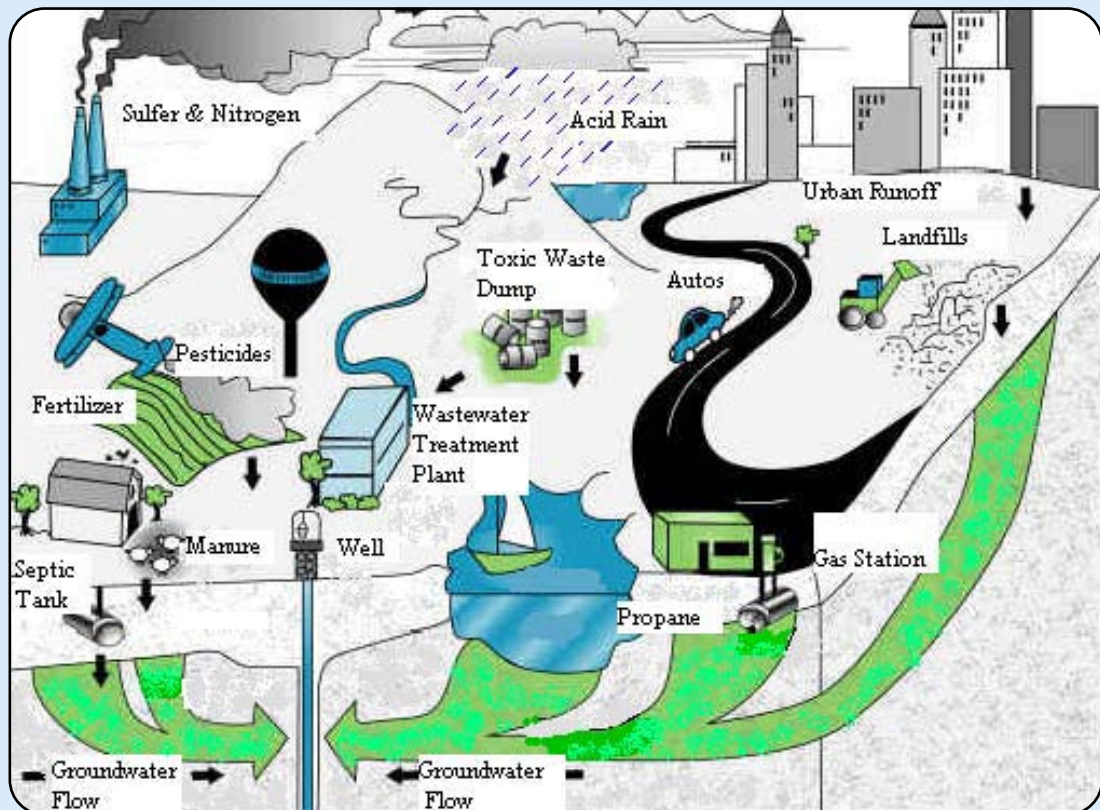
(Source: The Groundwater Foundation, 2000)

What is Groundwater?

There are a great many definitions of groundwater, most are confusing and complex. Simply put, groundwater is water moving through soil and rock. Depending on the makeup of the soil, there may be more than one depth where water moves. Each of these "layers" defines a water table. If it is relatively close to the surface (less than 50') it is generally considered an "upper groundwater table". If it is deeper (more than 50') then it is generally considered a "deep groundwater table".

These water tables can be separated by "confining" soil layers or areas of soil such as clay that are less permeable and prevent the easy passage of water from one layer to another. Water that "sits" above this confining layer is considered to be "perched" if it doesn't move very much.

Water also moves in an aquifer or a body of water trapped in deep rock formations. Aquifers are an excellent source of clean drinking water for metropolitan areas and larger rural communities. Once an aquifer has been contaminated though, very little can be done to "clean" it up. Only time can do this by flushing it out and diluting it with clean water. This process, depending on

the amount of contamination, may take hundreds of years.

As much as groundwater is separated by confining layers, so are aquifers. The uppermost aquifer is "unconfined" (above the first confining layer) and is replenished directly by rainfall. This aquifer also feeds the groundwater tables. Deeper aquifers are "confined" and are replenished by deep "artesian" wells (see Figure 6).

Movement of Contaminants in Groundwater

Contaminant movement though soil primarily depends on the makeup of the soil and the influence of existing water conditions. In general, contaminants move as a "plume" until they reach a point of discharge – a lake, river stream or until the pollutants adhere or attach to the soil.

Pollutants will travel at different rates in groundwater (see Figure 7). Contaminants that are not very soluble in water will move only a short distance over a long period of time. Contaminants that are highly soluble in water will move with the groundwater and eventually get into nearby rivers and streams. Certain materials such as bacteria, radioactive materials, most metals, and certain chemicals including dioxin, adhere to soil

Figure 6: *Types of Aquifers*
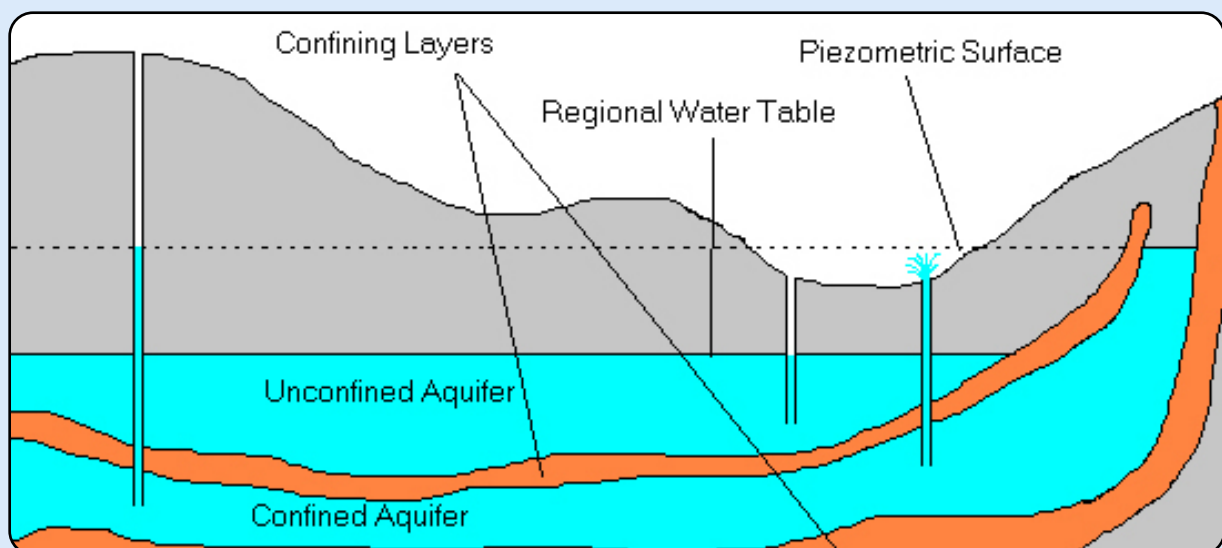
(Source: Chadwick, 2002)

Figure 7: *Plume of Contamination*
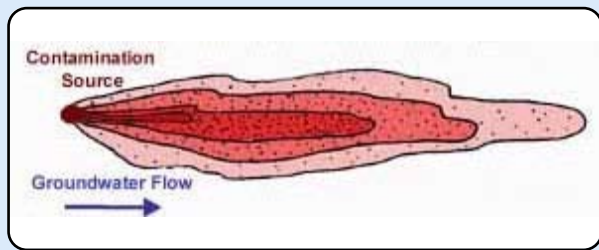
(Source: Fetter, 1994)

through physical-chemical reactions that result in slower movement through the groundwater.

The extent to which a contaminant plume moves outward instead of downward depends on the amount of water in the soil. If there is not a lot of water in the soil, this region is considered unsaturated, and the movement will be more outward (in the vertical plane). If the soil holds a lot of water, it may be saturated or near saturation. Then, the movement will be more downward towards a point of discharge such as a lake, stream or river. A secondary factor is the permeability of the soil. If the soils are highly permeable such as sand or gravel, then water movement will tend to move downward due to the pull of gravity.

In subsurface soil where there is no water, that is, in soil above the water table, some contaminants will move through the soil by evaporation. Volatile chemicals can travel through the pore spaces in the soil above the water table, through the area known as the "vadose zone." This movement, called vapor phase transport, depends mostly on the makeup of the soil. Volatile chemicals can move fairly easily through porous soil, such as sand or loam. They move less easily though clay or rock. These gases will continue to travel through the soil until they are released into the air or until they come in contact with water where they become dissolved depending on their solubility.

Movement of Organic Chemicals:
Non-Aqueous Phase Liquids (NAPLs) Chemicals that contaminate groundwater generally enter the soil as a liquid with differing degrees of solubility in water. Liquids that are highly soluble will be diluted quickly

in the water; some are not very soluble and remain concentrated; and others are partially soluble in water. This latter group is called non-aqueous phase liquids or "NAPLs." Their movement in groundwater is not well understood and thus is not easily predictable. This is a problem because NAPLs, which are only partially soluble in water have been found to travel large distances, which would not be expected based on their solubility alone. This is also a problem when trying to define an effective cleanup plan.

NAPLs include petroleum hydrocarbons and the most common contaminants of groundwater - volatile organic compounds or VOCs. VOCs include chlorinated solvents such as trichloroethylene and methylene chloride that are more dense than water, therefore they are called dense NAPLs or DNAPLs. Other DNAPLs include coal tars, polynuclear aromatic hydrocarbons (PAHs), and transformer oils that include mixtures of PCBs. Petroleum hydrocarbons are less dense than water and are thus called Light NAPLs or LNAPLs. Migration in groundwater depends on whether the substance dissolves in water, or is carried as a DNAPL or LNAPL (NRC, 1994).

Figure 8 shows a typical DNAPL groundwater contamination source such as a leaking storage tank of a chlorinated solvent. As the chemical leaks into the soil, it can either dissolve in the groundwater, evaporate into the soil above the water table or remain as an undissolved "slug." When the solvent reaches the water table, its downward movement is slowed somewhat by the resistance of the water. However, if the amount of the solvent is sufficiently large, it will continue to move downward displacing the water.

In the saturated zone, some of the DNAPL will dissolve in the groundwater that passes through the plume (see Figure 8). More of the DNAPL plume will continue to migrate downward through the vadose zone where some of VOCs will evaporate. The rest will continue to move downward (pulled by gravity) until it hits an impermeable barrier that stops

the downward flow. When the plume hits this barrier, it will begin to spread laterally creating a "liquid pool" of contamination on the surface of the impermeable barrier (NRC, 1994).

With different contaminants such as petroleum hydrocarbons (LNAPLs), you see a different pattern of movement. As this type of contaminant plume passes through the vadose or unsaturated zone, it will behave similarly to the DNAPL plume. Volatile

components will evaporate out of the plume and be trapped in the pose spaces of the soil. However, as the plume continues to move downward, it will spread laterally, forming a "layer" floating on top of the water table. This plume will then travel in the general direction of the groundwater flow. If the direction of groundwater changes, such as due to seasonal fluctuations or the influence of pumping wells, then the LNAPL plume will also move with these

Figure 8: *Typical DNAPL Groundwater Contamination Source*

This diagram represents DNAPL migration through the subsurface. As the diagram indicates, some DNAPL remains as an entrapped residual in the soils (indicated by the dark shading), some migrates as a separate fluid phase (indicated by the black areas), some dissolves in the ground water to create plumes (indicated by the light shading), and some vaporizes into the gas in the soil pores (indicated by the white areas).
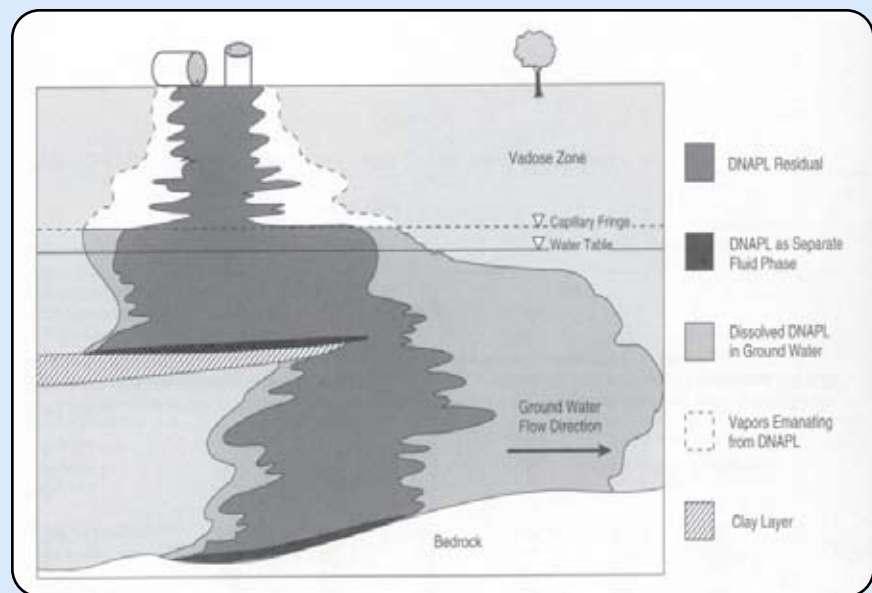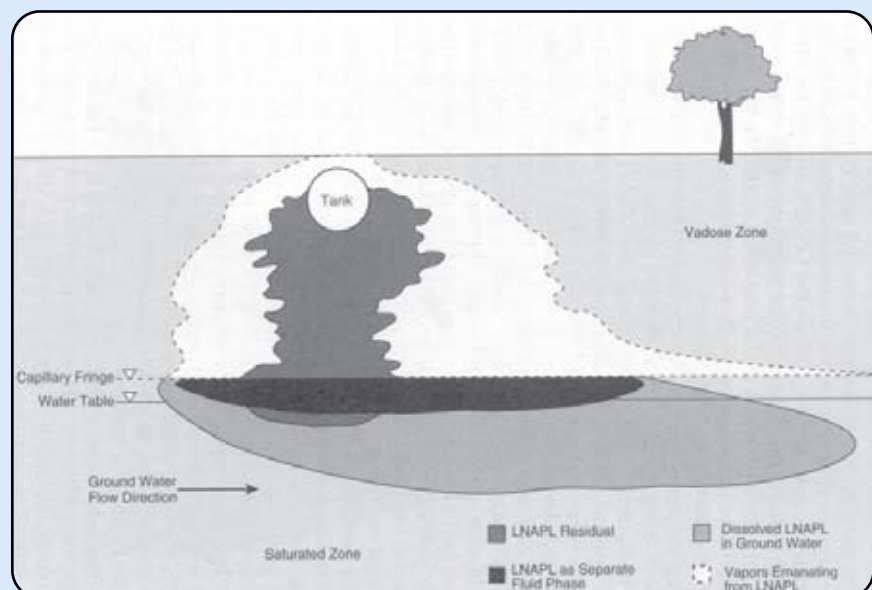

Figure 9: *LNAPL Plume*

This diagram represents LNAPL transport through the subsurface. As the diagram indicates, some LNAPL remains entrapped in the soil pores, some remains as a separate fluid phase near the spill source and on top of the water table, some vaporizes into the soil pores, and some dissolves in the ground water to form a plume.

(Source: NRC, 1994)

directional changes and further spread the contaminant plume. This scenario is shown in Figure 9.

Contaminants can thus move either through the groundwater or the soil depending on the properties of the substance and chemical and physical characteristics of the site. In many situations, you may see different components of a plume separating and moving at different rates and in some cases different directions. In almost all cases, you will see the contaminants moving through both the soil and the groundwater, though predominantly through one or the other.

What Factors Influence How Contaminants Move Through Groundwater?

There are a large number of factors that affect how contaminants move through groundwater. A number of these are listed in Table 7. In a practical sense, there are two basic factors: the make-up of the soil and directional rate of groundwater flow. Soils made up of sand or gravel are highly permeable to water movement. Soils such as silt or loam are less permeable while clay or rock are even less permeable. Often, there are mixtures of all of these elements, which makes predictions of groundwater movement extremely difficult. In essence, the soil make-up presents barriers or obstacles to water movement, forcing the direction and rate of groundwater flow.

Groundwater movement is complicated by cracks or "fractures" in bedrock or clay, and by "lenses", or layers of sand or gravel. Sand lenses and bedrock fractures create areas of less permeable soil. These factors provide a "preferential" route of movement for water altering what the "experts" would predict. Fractures or sand lenses must be identified if groundwater movement is to be properly understood.

Sand lenses and bedrock fractures are extremely hard to find without drilling a lot of holes in the ground. Even then, they're easy to miss. Yet, these factors are commonly found. For example, at Love Canal, engineers familiar with the local geology completely missed the presence of "swales" or streambeds that had dried up years before and had later been backfilled. The backfilled materials were extremely

porous and those portions of the swale, which crossed the canal provided a relatively easy path for movement of chemical leachate from the landfill. Those homes built on these old swales were found to have the second highest number of health problems among the Love Canal families (following those families living directly next to the canal).

Another interesting observation that came out of Love Canal was finding "desiccation cracks" in the stiff clays below the site. Originally the engineers designing the cleanup project predicted that the stiff clay layer, which sat 12-25 feet below the surface, would confine the upper groundwater table and thus keep the chemicals from moving downward. So they designed a collection system to sit just above this clay layer. When they dug into the soil, they found the stiff clay to be full of cracks from normal drying of the clay. What surprised everyone, except the community people who took nothing for granted, was that the cracks were lined with chemicals, which clearly had moved downward through the entire "impermeable" stiff clay to depths ranging from depths of 12-25 feet! In this case, the experts were wrong and the collection system had to be lowered.

Groundwater Testing

The key elements of groundwater testing are knowing about the soils and determining the rate and direction of groundwater flow. It is rare when useful information on these factors is available prior to the discovery of a contamination problem. In cases where information is available, it is often very general in nature and usually not site specific.

So where do you begin? What do you need to know? You begin by asking for all available "hydrogeological" reports on the site. These reports should include the following information that you will need:

- Identification of the source of contamination and the nature of the chemicals entering the groundwater.
- A description of the soils and geology of the site, all the way to bedrock usually described on test-boring logs (see Figure 10).

- The depth of the water table.

- Location of existing monitoring wells.

- Well records showing how the wells were installed, the depth of screens if present and related information.

- Water quality data- results of samples collected from wells, including what was found and the concentrations.

- Sampling procedures and methods – how the samples were taken, stored and shipped to the laboratory for analyses.

- A topographical map helps in determining probable direction of groundwater flow and in locating probable discharge areas such as surface waters and springs.

This data should describe whether the site lies over an aquifer, the depth to the water table(s), the general direction and rate of groundwater flow, and the existing water quality. When certain information is unavailable, you need to organize your community to request/demand additional tests. The less information, the greater the uncertainties and the harder it becomes to predict groundwater movement and to adequately assess groundwater contamination.

Much of this information is highly technical in nature and you will likely need to call on the assistance of a groundwater specialist – a hydrogeologist. The information listed above is what your scientist will need to help you. Obtain it before you make your contact. This can save you a lot of time and money.

Once you have this basic information, you will be in a position to give this information to someone who is knowledgeable, who can:

- Interpret results available from existing wells.

- Decide whether new wells need to be installed.

- Determine whether the existing information is sufficient to answer your questions about the extent and severity of the contamination levels.

- Design a sampling plan to address unanswered questions.

Sampling Methods & Procedures
Soil Borings
Before any wells are installed, test wells are drilled to provide basic information on the soils and water conditions at the site. The number and depths of these borings vary depending on the specific hydrogeological conditions and the size of the site. As a general rule of thumb, at least 6-10 borings (depending on the size of the site) are drilled to a depth of at least 50 feet. If this test-drilling program is not conducted, then the depths and the location of the monitoring wells may not properly selected. If it isn't done, ask why not. Ask how they know the wells are in the right place. And when you get your answers, be sure to get the data, which supports their statements.

Piezometer Installation
A piezometer is a device that is used to obtain water level measurements before a permanent monitoring well is installed. It is installed much like a monitoring well, but is much smaller and does not provide samples for analysis like a monitoring well. Piezometers are useful because they provide information that can be used to determine the rate and direction of ground water flow. If time allows, water levels should be recorded over an extended period in order to get an accurate reading of where groundwater is flowing since levels can change seasonally and from year to year, (Wilson, 1995).

Monitoring Well Installation
Once preliminary measures have been taken, a monitoring well is ready for installation. The well drilling itself is done by either "hollow" or solid stem augers which are shaped and work like a screw driven into wood. The wood tailings or soil is pushed to the opening of the hole by the turning action of the screw. The auger is driven or turned by a pump that is either air or oil cooled. Hollow stem augers are used to collect soil samples. Inside the auger is a metal tube, open on both ends, which "captures" the soil, intact, as the auger is driven down. The samples are then

used to describe the soil at different depths on a "log" sheet, a sample of which is shown on Figure 10.

Boring logs provide important information about a site. General information typically found on a boring log should include the project name, location, date started and completed, drilling method, sampling equipment used and names of people involved in the drilling. In addition, the following information should be in a boring log:

- Description of the soils

- Grain size

- Vertical extent of the different soil zones

- Moisture content

- Color

- Depth of borehole

Figure 10: Sample Test Boring Log (Source: Cumberland Geotechnical Consultants, Inc., 2003)
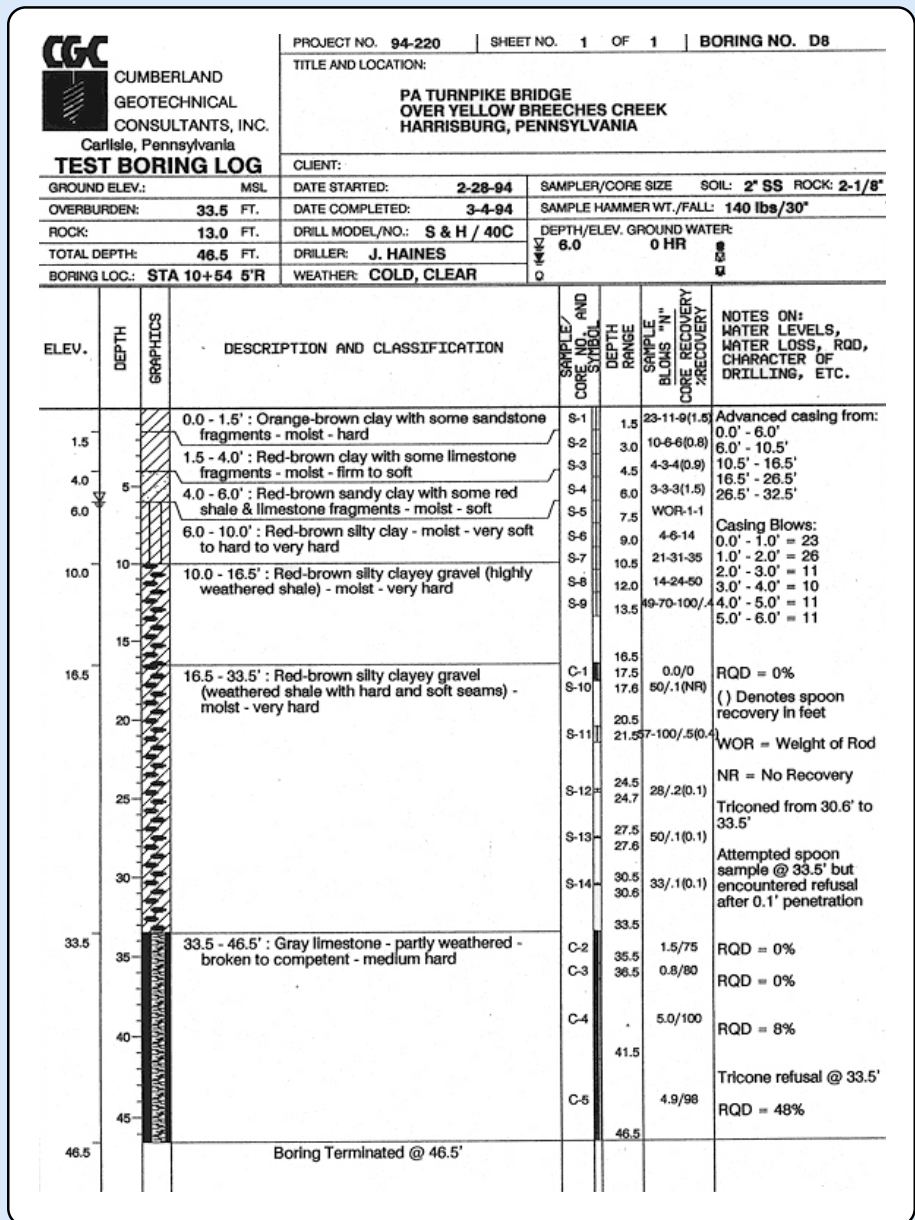
• Depth, location and identification of any contaminants encountered

• Depth to water table

After the hole is drilled to the desired depth, the monitoring well is placed in the hole. A typical well is shown on Figure 11. The well consists of PVC pipe, often in 20 foot pieces that are joined together and sealed by screws. Once the entire well length is installed, the area surrounding the well is backfilled. First with sand and then with a clay material called bentonite, which swells in contact with water creating a seal around the well.

Very often the well is placed at the top of a confining layer (which prevents downward water movement) and screened just above this layer. For example, if the first confining layer is 50 feet down, then the well

Figure 11: *Typical Monitoring Well (Source: Environmental Advantage, Inc., 2002)*
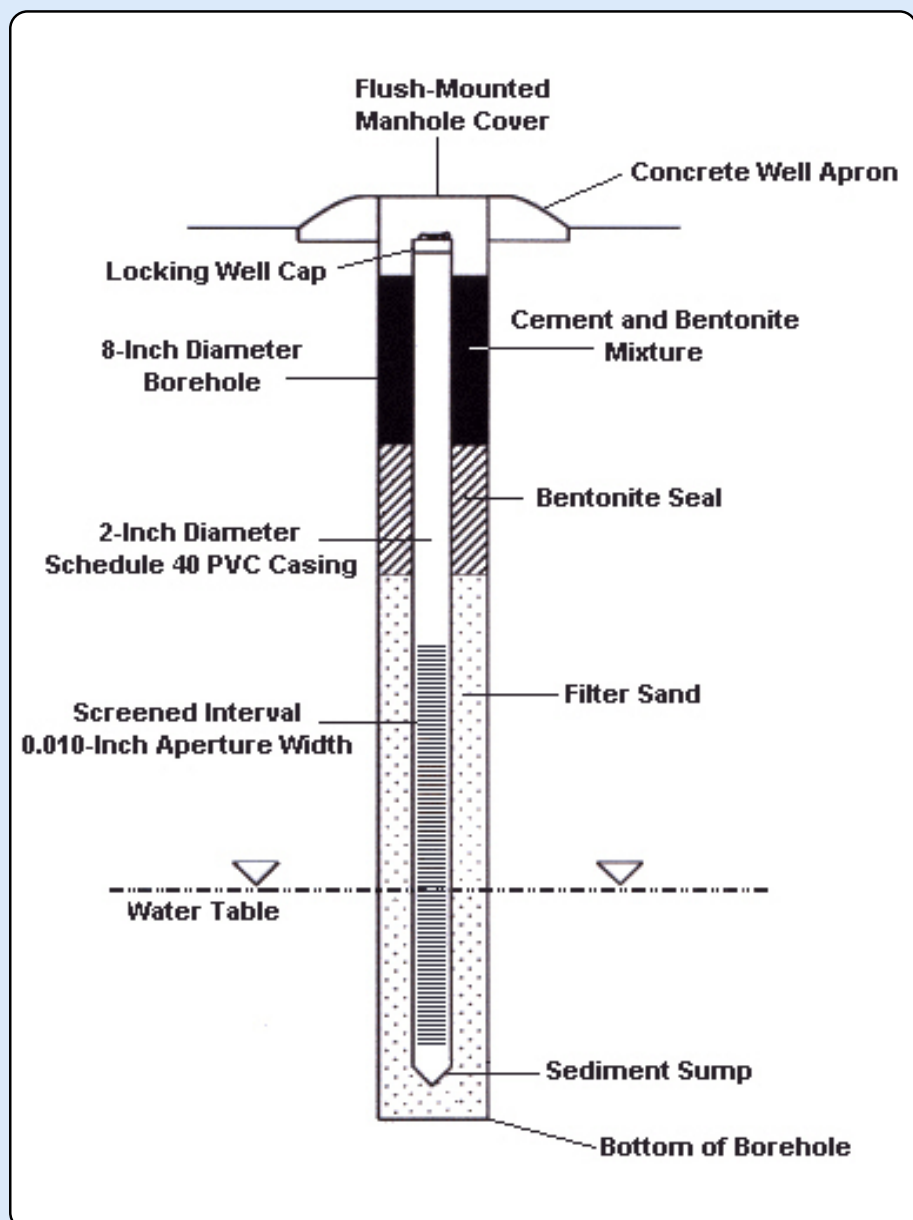
would be installed to 50 feet, screened for the bottom 20 feet, backfilled with sand for the bottom 30 feet, then 10-15 feet of bentonite and the top portion of the well backfilled with cement.

The next step is to clean the water in the well by removing soil, sediment or other debris. This is called "well development". Finally, the riser, or portion of the well visible above ground, is encased with a steel cap and a lock to prevent tampering. All of these steps are important. If anything has been left out, it may influence the quality of the data collected from the well.

How the water is collected from a well can influence what is found. Generally three to five volumes of water are "bailed" or emptied from a well. This process rids the well of stagnant water, which is not representative of the actual groundwater. In addition, water samples are often filtered in the field using a 0.45 um filter to take out sediment or particles in the water.

The sample should be placed in a glass jar or container and filled to the brim. If there is any airspace in the jar, then any volatile chemicals in the sample will escape into this airspace and will be lost when the jar is opened. The jars should

then be shipped to the lab and refrigerated until they can be analyzed (usually within 7 days).

Questions To Ask About Groundwater Monitoring Wells:

- How deep are the monitoring wells?
- How deep is the water table? For example, at what depth does the groundwater enter the well?
- Where are they screened?
- Are the wells going to collect water from the same water table the contaminants are in?
- Are proper well construction materials being used?
- Are the wells sealed against surface water contamination, or from water from different zones?
- Are proper well completion methods being used such as development, maintenance and protection against vandalism?
- Are the background wells located in clean water? Are they in the same water table as the contaminants?

Chapter 5

Surface Water Testing

Surface waters are lakes, ponds, streams and rivers. In general, surface waters receive their water from rain, snow, groundwater and overland runoff. Some surface waters are temporary, existing only following heavy rains or snow melts in the springtime. Others such as small streams and creeks may be seasonal, existing only in times of high water.

Some of the ways surface streams become contaminated include direct discharge by an industrial plant, direct dumping, discharge from contaminated groundwater, settling of air pollutants, runoff from contaminated areas, and joining with other waterways that are contaminated.

Surface waters are commonly contaminated by landfill "seeps". Seeps are leachate streams which leak from landfills due to gravity, landfill construction, or landscape design. Seeps most often occur on the side of a hill or in a low-lying ravine, which is fed by groundwater.

Surface waters are important because many serve as a drinking water source for densely populated urban areas. Rivers are also a source of food. Fish and shellfish cannot be eaten if they contain high levels of contaminants. Furthermore, contaminated water restricts the usefulness of the water, which limits swimming, boating and other recreational uses. Use of the water in food processing is also eliminated since water contaminated with chemicals such as PCBs cannot be used in many processes, which leave residues in food or containers.

The concentration of chemicals in surface water depends on the amount of leachate, which gets into the water, and the rate of flow of the water. The faster the flows, the more dilution that occurs and the less likely you are to find anything. For this reason, it is not uncommon for a state agency to test a stream or river located near a landfill, find nothing and claim that the site poses no risks. This, of course, is false since the water is simply diluting the chemicals and the test methods are not detecting them.

Surface water samples can identify contaminants released from a point source such as a pipe or landfill located near a surface water body, like a stream. Measurements should be taken downstream from the point where the contaminants are entering a stream. "Control" samples that are not contaminated should be taken from locations upstream of the point

source. Several duplicate samples should then be collected and analyzed.

The equipment used to sample surface waters is very basic, consisting of a sample container, usually glass, which is dipped into the water and filled. Care must be taken to fill the bottle so that there is no air in the container. If there is, then any volatile contaminants will escape into that air space and will be lost when the container is opened.

The sample itself is generally taken from the center of a stream or river, at mid-depth (about half way between the surface and the bottom of the water "column"). Inlets or stagnant areas may actually contain higher amounts of contaminants and are recommended for testing as "hot spots" when available.

For lakes or ponds, EPA recommends sampling only at the top of the water, although the mid depth and bottom can also contain contaminants. This is especially true of the bottom sediments. Chemicals that are largely insoluble in water, like PCBs or dioxin, will settle out in the sediment. Such contaminants remain in sediments for long periods of time. To

get a complete picture of contamination that has occurred, the sediment should be sampled.

The importance of sediment sampling can be demonstrated very easily by placing salt in a glass of water. Some of the salt will dissolve, but most of it will settle out in the bottom of the glass. Thus in many cases, the sediment will also need to be tested. Fish, plants and other aquatic life are other measures of environmental quality, which could also be measured.

Questions To Ask About Surface Water Sampling:

- Where are the samples being taken – at the edge of a body of water or in the middle?

- At what depth are the samples going to be taken?

- Are multiple samples going to be taken from different locations from the point source?

- Are the samples going to be taken upstream and downstream?

- Are sediment samples going to be taken?

- What is the temperature of the water at the time of sampling?

Chapter 6

Air Testing

Exposure through the air is the most direct way for people to be exposed to hazardous wastes. Air exposures can occur by breathing chemicals that evaporate directly into the air or by breathing dust that contains toxic chemicals.

The goal of an air testing program needs to be established before any testing is done. Typical objectives include identifying hot spots, monitoring remedial work, or assessing soil releases. Often, the interest and demands of the local community dictate whether any air testing is done at all. Otherwise, it is unlikely that the air will be tested.

Chemicals that evaporate into the air can come from contaminated open pits, ponds or lagoons, barrels stored out in the open, failing landfill operations, waste treatment operations, wastes exposed during cleanup actions, accidents, spills and other releases. Gas vents from municipal landfills are another source of air contamination. Dusts can be generated from contaminated soil from any of these sources.

Air testing is difficult to assess, primarily because of the extreme variability in air readings and the unreliability of the small number of samples, which are generally taken. These factors make air readings of limited value in assessing environmental contamination levels.

Factors which influence measured air levels include:

- Different volatilization rates – different chemicals evaporate at different rates.

- Temperature – volatilization is greater on hot days than it is on cold days.

- Wind speed – the greater the wind movement, the greater the degree of volatilization. As the wind disperses the contaminant, more contaminant is released into the air.

- Humidity – the moisture content of the air will influence volatility and the amount of contaminants that will be collected during sampling. Combined with a lack of wind movement, humid conditions will cause chemicals evaporating from a site to remain near that site's surface.

Another factor, which influences the reliability of air tests, is the lag time in getting the results. For example, when air samples are taken during cleanup

actions, the results are generally not available until the following day or sometime the next week. Thus, if toxic chemicals were present, you would only find out AFTER some period of time. Consequently, air testing is not a good way to measure daily cleanup risks unless a direct reading instrument is used.

Air contaminant levels from residential homes are also frequently dismissed. For example, when tricholoethylene (TCE) is found in a home, the government usually claims it comes from nail polish remover, or that the dioxin comes from a wood stove. The "blame the victim" syndrome is used all the time. If you want to have your home air tested, be sure not to fall into this trap and take everything, cleaning soaps, paint cans, nail polish and so on out of your home 24 hours BEFORE the testing. And make sure you show whoever's doing the sampling that nothing is there and make him/her write it down in their log.

Air Reading Instruments

There are a number of different air reading instruments: those that are direct, which give a reading on the spot and those that are indirect, which collect air on an absorbing material which is sent to a lab for analysis.

Direct reading methods use instruments such as the organic vapor analyzer (VOA) and direct reading cholorimetric tubes. In general, these instruments are insensitive to small concentrations and for the most part, are only useful as a qualitative guide to what is in the air. In other words, they can only tell you if something is in the air or not. A VOA can tell you if volatile chemicals are present, but you can't use it to determine actual concentration levels. The reasons for this include:

- Low sensitivity – these instruments can't detect small quantities.

- The need for constant calibration. Calilbration is the "tuning" of the instrument. If this is not done, the entire test is invalid. Reliability and accuracy are dependent on proper calibration.

- Wind, temperature, movement (often the instrument is hand held), humidity and other environmental influences.

Indirect reading methods are much more accurate and reliable. Generally, indirect reading instruments include the gas chromatograph (GC) and the infrared spectrophotometer (IR). With these instruments a sample is collected in the field, sealed and delivered to a laboratory for analysis. Figure 12 shows a diagram of the stages used in "capturing or collecting a sample". As shown, the ambient air is drawn through a collection device (usually a tenex or poropac absorbing tube for volatile organics) and trapped or fixed on the absorbing material. The volume of air pulled through the collecting device is also recorded. This measurement is critical, since the concentration is determined by knowing how much chemical is present per volume of air sampled. The collection tube is then sent to a lab for analysis.

Figure 12: Sample Collection Process
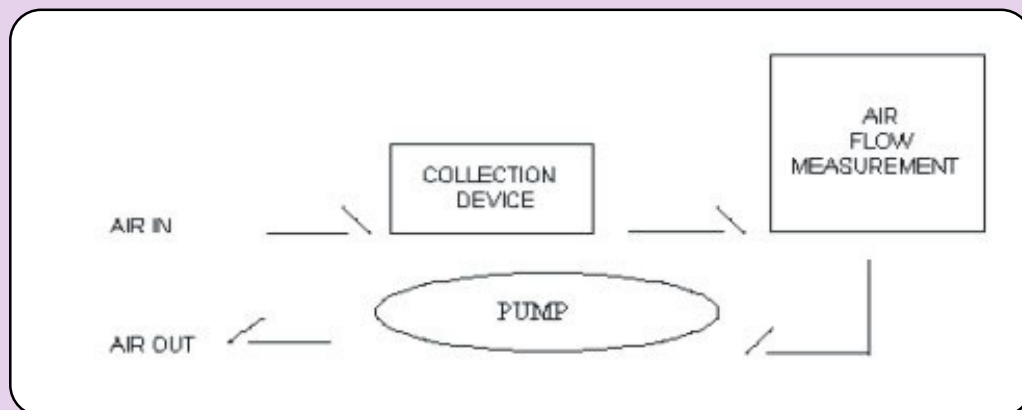
How long an air sample is taken is very important. If the sampling time is too short, then you don't have a representative sample of what is in the air. Because air levels are so variable, too short a sampling period can result in missing contaminants that could be present. Proper sampling times will vary between 2 to 4 hours, depending on the concentration of the contaminants in the air.

On the other hand, sampling too long can produce other problems. If a sample is collected over a long period of time, the phenomenon of "breakthrough" can occur. Breakthrough occurs when the absorbing material is saturated and can no longer absorb contaminants. When the absorbing material is saturated, the contaminants pass through the tube and are not collected. The end result is a measurement that reveals a lower contaminant level than what actually exists. To compensate for this, two tubes are used in sequence so that if the first becomes saturated, the second one picks up the contaminants.

Remember, if someone wants the sample to show less chemicals than are really there, they can conduct the tests for too short or too long a period to altar the readings.

In some instances, indirect methods of testing can be set up in the field. Continuous Emission Monitoring (see section below) is an example of an indirect method developed for use in the field. If this is done, the air sample is drawn directly into an analytical instrument, usually a gas chromatograph. Doing this provides a result within a matter of minutes. It is not common, however, since the number of chemicals that can be measured is limited (primarily to VOCs) and it is very expensive.

Continuous Emissions Monitoring

Continuous Emissions Monitoring, also known as CEM, is the continuous measurement of pollutants emitted into the air from stack gases released by industrial plants and incinerators (USEPA, 2003a). CEM systems can be installed in the emissions stack of an industrial plant or incinerator or in an open air fixed monitoring station. They are designed with a detection probe in either the stack or in the open

air that collects samples of the air. A computer then calculates the concentration of specific substances, primarily volatile organic compounds (VOCs), almost immediately. This type of testing is referred to as "real time" testing because the sample does not have to be sent to a lab to be analyzed. Instead, you can find out what contaminants are present in a sample within minutes of when the sample was taken.

A CEM device can provide valuable information for communities concerned about air emissions from an incinerator or other point source if they can get access to the raw test results quickly. The residents of Winona, TX had hoped to do just this. The local grassroots community group, Mothers Organized to Stop Environmental Sins (MOSES), succeeded in forcing Gibraltar Chemical Resources, Inc, a hazardous waste treatment, storage, and disposal facility, to install CEM ambient air monitors to test the air for toxic releases from the plant. The monitoring system used a Fourier Transform Infrared, or FTIR, spectrometer to collect air samples from air monitoring stations placed around the perimeter of the facility. MOSES had opposed the facility for years because they felt that the emissions from the plant caused adverse health effects in area residents.

The facility operated two commercial hazardous waste injection wells, a solvent recovery facility, and a hazardous waste fuel blending operation all of which released volatile organic chemicals into air of the surrounding community. After years of struggle, the state finally agreed to require the CEM. However, the CEM system never worked to the group's advantage.

The monitors were placed in such a way that they did not give accurate readings and they were never operated properly. The community was not given the results of Gilbralter's emissions in a timely manner and when they did receive them, the group felt that they were whitewashed to make the company look good.

Despite these setbacks, MOSES persisted and succeeded in shutting down Gibralter through their

community organizing efforts. They created so much awareness of the problems created by the company that the state was forced to pay attention to them. They were also able to settle multiple lawsuits outside of court. Eventually, the company closed its doors in 1997 when it could no longer keep up with the group's activities and the many lawsuits filed against them.

The Bucket Brigade

Since 1994 communities across the nation have been using a simple, low-cost, and credible method of air sampling that uses a bucket to take a grab sample of the air. This method of community based air sampling was developed by Communities for a Better Environment (CBE) in California in order to put information about air quality in the hands of citizens (Susag, 1999.) Communities who use this method are called "Bucket Brigades." This method allows for communities to be in control of when and where they want air samples to be taken. It also promotes a sense of community involvement and helps get government agencies to pay attention and respond to community concerns. The buckets are designed so that they can obtain the same measurements as the EPA or any other regulatory agency, only they are maintained and operated by people who are directly being affected by contaminants in their air.

The buckets are 5 gallon round plastic buckets with bags inside that are able to take a "grab" sample of the outside air and capture any contaminants present in the air at the time. A small vacuum sucks air from outside of the bucket and fills a sampling bag inside the bucket.

The bag is removed and sent off to a lab for analysis. The most commonly requested tests include those for VOC's and inorganic chemicals, and those for sulfur compounds. There are limitations to the bucket, however. Buckets can only test for gases, not for particulate matter such as heavy metals and toxins that attach themselves to particles. They are also not able to measure for acid rain or radiation. For more information about bucket brigades you can obtain

a manual on how to start your own Bucket Brigade from Communities for a Better Environment. CBE can be found online at: http://www.cbecal.org.

Epa Testing Methods

The EPA uses several different methods to test air quality. For example, the Emission Measurement Center (EMC) is responsible for developing methods for measuring air pollution emissions from stationary sources. As with all EPA test methods, these methods have been designated numbers. They range from 1 to 300. Numbers between 1 and 100 are for Performance Specifications for the New Source Performance Standards, method numbers in the 100 series are for the National Emission Standards for Hazardous Air Pollutants (NESHAPs) and the method numbers in the 200 series are example State Implementation Plans (SIPs). The EMC does not deal with other air pollution methods (USEPA, 2002d).

Some testing methods are categorized according to the compounds they analyze. The Ambient Monitoring Technology Information Center has five different categories of testing for air quality that are not included in the EMC's list of methods. Some of these include tests for toxic organic compounds. This set of tests are known as the TO Series and range from TO-01 to TO-17 (USEPA, 2002d).

Understanding how these test methods are numbered and who develops them is not so important. Knowing that the EPA does indeed have methods for testing is more important so that you are able to question whether or not an EPA test method is being used to test your water, air or soil. As mentioned earlier in Chapter 3 under Laboratory Methods and Procedures, each method is numbered and can be found in an index, by using this index you can identify specific test numbers for specific contaminants.

Ambient Air Monitoring and the Clean Air Act
In 1990, an Ambient Air Monitoring Program was created as a result of amendments made to the

federal Clean Air Act. This is an EPA program but is carried out by state and local agencies. The purpose of the program is to collect air quality samples for the following reasons:

- To monitor compliance/progress towards meeting ambient air quality standards (see Table 6)

- To activate emergency control procedures to help prevent air pollution episodes

- To observe pollution trends

- To provide a data base in order to conduct research

There are four basic categories of monitoring stations throughout the nation. These include State and Local Air Monitoring Stations (SLAMS), National Air Monitoring Stations (NAMS), Special Purpose Monitoring Stations to measure criteria pollutants, and Photochemical Assessment Monitoring Stations (PAMS) to measure ozone precursors.

Questions To Ask About Air Testing:

Air levels are extremely difficult to measure and even harder to interpret. If you have air results you want to interpret or if you decide you want to know what's in your air, here is what you should ask to start off:

- What is the direction of air movement or the direction of prevailing winds? If you sample up wind from a source of pollution, you'll never find anything.

- Where are the sample locations in relation to the chemicals?

- What is the duration of the air sample – for how long is the sample going to be taken?

- What is the air temperature and time of year? There is more volatilization of chemicals when it is hot outside than when it is cold. Cold weather can reduce contribution to air and limit the likelihood of getting results.

- What is the humidity at the time of sampling?

- How many samples are going to be taken?

- What are the sampling methods and procedures?

- What are the analytical methods and procedures?

- For how long is the sample going to be taken?

- What is the sampling rate?

- What kinds of collecting/capturing devices are going to be used?

- Are these devices saturated? Is there going to be any "break-through" occurring? If not how do you know?

Chapter 7

Soil Testing

The most common contaminated environmental medium is soil. Testing is important because:

- People can come in direction contact with soil.

- All other media can be contaminated indirectly by contaminated soil (see section on Cross Media Contamination).

- If not addressed, contaminated soil will contribute to contamination of other media.

Signs of soil contamination can be visually obvious. Areas that are scorched, discolored or where no vegetation grows indicate that something is wrong with the soil. Wild vegetation will grow almost anywhere, unless there are poisons in the ground. Change in pH content in the soil is another measure that indicates something is wrong. pH measures the amount of acid in soil. Normal soil pH would range between 6.5 and 7.5. If your soil is outside of this range, then something may be wrong.

You should go out and survey your community. Look at where the vegetation has died, where bare spots exist. Are chemicals surfacing? With this information in hand, you can request testing in areas that are clearly questionable. Otherwise, tests may be taken in the wrong places and will produce results that show little or no soil contamination.

Samples can be collected in one of two ways: either as a grab sample or as a composite sample. Grab samples are taken from a single location in a single "grab" activity. Composite samples are more complex. In this method of sampling, a location is identified and 4 or 5 grab samples are collected from a uniform distance around a selected location.

These satellite samples are collected from around the center of the initial sample location. Usually this distance is a foot or two, but it can be 5, 10, or even more feet depending in the number of sampling locations. These 4 or 5 grab samples are then combined into a single "composite" sample, which is analyzed as a single sample and considered to come from only a single location.

The difference between these two methods is obvious. With the grab sample you have a small sample from a single location. This sample could be very informative if you have a good idea of where the contamination is. If you don't, then a grab sample

might not be very helpful since you may miss the contamination altogether. The composite sample has the advantage of collecting more samples and mixing them together. This increases the chances of finding contamination. However, if contamination is found using a composite sampling approach, the actual contamination levels in the field will be much higher than recorded in the sample because the sample was mixed which diluted areas of higher contamination with areas of lower or even no contamination. This may not be a factor if the soil is evenly contaminated across the entire area being sampled (though this is rare).

Soil samples are usually collected with a stainless steel scoop or hand towel and collected in clean glass jars. Split spoon augers are used to collect subsurface soil samples. Samples should be kept cool until analyzed because, like water samples, volatile chemicals present in the soil will eventually volatilize and be lost when the jar is opened. EPA generally recommends holding times of no greater than 14 days prior to analysis (USEPA, 1996).

The TCLP Test
One method commonly used to measure contamination in soil is the "Toxic Characteristic Leaching Procedure" or the TCLP test. This test was developed by the EPA, originally as the Extraction Procedure or EP Toxicity test in 1980 (USEPA, 1990). The TCLP test was adopted in 1990 and is considered an improvement over the original test because it added 25 organic substances to the list of toxicconstituents that can be evaluated by the test. The test was designed to simulate the movement of chemicals (leachate) through the soil of a landfill.

This is done by gathering a sample of the soil or waste being tested and placing it in a mixing vessel. A liquid that is slightly acidic is added and the container is agitated to mix the liquid with the waste. The water mixes with contaminants in the soil and generates a "leachate" which is collected as an "extract" from the bottom of the container. This leachate is then analyzed for a list of 39 substances. For each of these substances, EPA

has set a regulatory limit as shown in Table 7. If any of the substances in the soil sample exceed the TCPL regulatory limit, then the sample is considered to have failed the test. This sample would then be considered to a "TC waste" (ie a hazardous waste) and is subject to all Resource Conservation and Recovery Act (RCRA) hazardous waste requirements (USEPA, 1990).

This test has become popular as a way to determine if contamination in soil poses any risks. The use of the TCLP test for this purpose is completely inappropriate. If you are trying to determine the extent of contamination and the degree of risks pose by that contamination, the test must determine the actual amount of contamination present. The TCLP does not do this. Instead, the TCLP test, like its predecessor the EP Toxicity test, tells you the amount of select contaminants that will leach out of a sample of soil or waste. The difference between a TCLP test and a direct soil sample analyzed to identify what chemicals are present in the soil can be substantial. The TCLP test largely underestimates the presence of contamination, perhaps by as much as 100 or 1,000 fold.

The TCLP test has also been criticized for being generic in that it only simulates one set of conditions. In real world situations, there are a wide range of conditions that exist at landfills that are not accurately reflected by the TCLP test. While industry and government see advantages and convenience in this quick and easy test, community groups have been frustrated by the use of this test which does not provide information on the amount of specific chemicals present in a sample.

Soil Cleanup Guidelines
There are no federal standards that define what level of contamination in soil is "safe" or that define what risk will result from a specific contamination level in soil. So how do you evaluate risks and decide how much cleanup is needed? This is not easy and is open to much debate and controversy. For metals, such as lead or arsenic, the contaminant level is generally compared to "background" levels of the same met-

als that can be found by testing areas where there is no contamination. Each of the heavy metals occurs "naturally" in the environment and by measuring for metals in areas away from the site, you should be able to determine a background value for metals. These values would then be compared to metal levels found on a contaminated site.

With organic chemicals, such as trichloroethylene, benzene, or methylene chloride, there are no "naturally" occurring levels, so there is no "background level" for these substances. Therefore, many community activists argue that these substances should be cleaned up to a zero level. However, most government agencies do not accept this premise. Their main argument is that it costs too much to completely restore soil to "pristine" levels and that general pollution and contamination from other sources in the area means that you would likely be cleaning up a site to levels that would be below the rest of the community.

So what do you do? While the federal government has not adopted any set of soil cleanup standards, many states have set cleanup goals that can be used as a guideline for evaluating the risks posed by contaminated soil. CHEJ reviewed a number of state and federal cleanup and residential soil standards to identify those that are most protective. We found that the New York State Soil Cleanup Objectives were generally lower than all others. These values consider not only the impact on human health, but also the impact on fish and groundwater quality. A summary of values of the NY state soil cleanup objectives is shown in Table 8.

Several Regional EPA offices have developed their own cleanup guidelines. Two that are commonly used are the Region 3 Risk Based Concentration Values (http://www.epa.gov/reg3hwmd/riskmenu.htm) and the Region 9 Preliminary Remediation Goals (http://www.epa.gov/region09/waste/sfund/prg/).
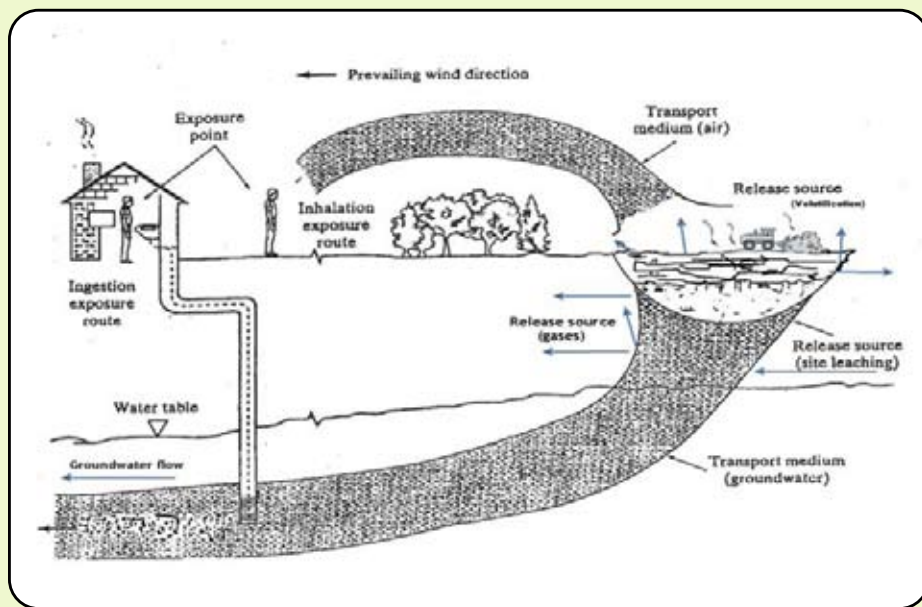
Figure 13: *Cross Media Contamination*

Common ways for exposures to occur at a contamination site:
Ground water: drinking water, showers, evaporation to soil and air
Surface water: recreational (swimming/bathing), animals, runoff to soil, evaporation
Soil: direct contact (yards, playgrounds), gardens, evaporation and dust to air
Air: prevailing winds and dust to soil and water

Both these values are similar and both are substantially higher than the NY state values though they are both more current and more "acceptable" to government agencies.

Cross Media Contamination

Contamination of one medium can often lead to cross contamination of other media. This occurs most often with soil as shown in Figure 13. Subsurface soil contamination can lead directly to contamination of 1) groundwater as soluble soil contaminants leach into groundwater; 2) ambient air as volatile contaminants evaporate out of the soil into the air; and 3) surface water as leachate from contaminated soil seeps into surface waters. Subsurface soil contamination can also lead to contamination of other medium indirectly when volatile chemicals pass through clean soil into basements where people can then breathe the fumes and when soluble substances move through groundwater and discharge into surface waters (see Table 9).

Questions To Ask About Soil Testing:

- Is the sample a composite or grab sample?

- What is the depth of the sample?

- What is the temperature and humidity at the time of sampling?

- How quickly will the sample be analyzed after it has been collected?

- Was the sample kept on ice from the time it was collected until the time it was analyzed?

Chapter 8

Conclusion

In summary, there are many factors that influence environmental testing results. Before you can interpret test results, you have to know if the data is any good. By asking about sampling and laboratory methods and procedures, which chemicals were tested, and detection limits you should be able to figure out how good the data is. There are no easy answers or perfect environmental tests, despite what government says. It is your job to organize the people in your community to force the government to give you accurate and reliable test results. You have the right to know what chemicals are in your community.

Hopefully this guidebook will help you to understand what you should look for when you are testing your water, air or soil and has emphasized the importance of asking the right questions so that you are able to interpret test results. This guidebook is only meant to give you an overview of several different types of environmental testing, and should only be used as a tool to gain a basic understanding of the issues that were addressed. If you are in need of more assistance with interpreting results or if you need more information about certain types of test methods and procedures, please do not hesitate to contact the Center for Health, Environment and Justice.

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Appendix

Table 1: General Pollution Parameters For Evaluating Groundwater and Drinking Water

5-Day Biological Oxygen Demand (BOD)

Chemical Oxygen Demand (COD)

Total Organic Carbon (TOC)

Total Suspended Solids (TSS)

Total Dissolved Solids

pH

Acidity

Alkalinity

Hardness

Color

Oil and Grease

Total Phosphorous

Total Nitrogen

Nitrogen

Ammonia

Sulfates

Chlorine

Chloride

Table 2: U.S. EPA Primary Drinking Water Standards

Microorganisms	MCLG[1] (mg/L)[2]	MCL or TT[1] (mg/L)[2]	Potential Health Effects from Ingestion of Water	Sources of Contaminant in Drinking Water
Cryptosporidium	zero	TT [3]	Gastrointestinal illness (e.g., diarrhea, vomiting, cramps)	Human and fecal animal waste
Giardia lamblia	zero	TT[3]	Gastrointestinal illness (e.g., diarrhea, vomiting, cramps)	Human and animal fecal waste
Heterotrophic plate count	n/a	TT[3]	HPC has no health effects; it is an analytic method used to measure the variety of bacteria that are common in water. The lower the concentration of bacteria in drinking water, the better maintained the water system is.	HPC measures a range of bacteria that are naturally present in the environment
Legionella	zero	TT[3]	Legionnaire's Disease, a type of pneumonia	Found naturally in water; multiplies in heating systems
Total Coliforms (including fecal coliform and *E. Coli*)	zero	5.0%[4]	Not a health threat in itself; it is used to indicate whether other potentially harmful bacteria may be present[5]	Coliforms are naturally present in the environment; as well as feces; fecal coliforms and *E. coli* only come from human and animal fecal waste.
Turbidity	n/a	TT[3]	Turbidity is a measure of the cloudiness of water. It is used to indicate water quality and filtration effectiveness (e.g., whether disease-causing organisms are present). Higher turbidity levels are often associated with higher levels of disease-causing microorganisms such as viruses, parasites and some bacteria. These organisms can cause symptoms such as nausea, cramps, diarrhea, and associated headaches.	Soil runoff
Viruses (enteric)	zero	TT[3]	Gastrointestinal illness (e.g., diarrhea, vomiting, cramps)	Human and animal fecal waste

Disinfection Byproducts	MCLG[1] (mg/L)[2]	MCL or TT[1] (mg/L)[2]	Potential Health Effects from Ingestion of Water	Sources of Contaminant in Drinking Water
Bromate	zero	0.010	Increased risk of cancer	Byproduct of drinking water disinfection
Chlorite	0.8	1.0	Anemia; infants & young children: nervous system effects	Byproduct of drinking water disinfection
Haloacetic acids (HAA5)	n/a[6]	0.060	Increased risk of cancer	Byproduct of drinking water disinfection
Total Trihalomethanes (TTHMs)	none[7] ---------- n/a[6]	0.10 ---------- 0.080	Liver, kidney or central nervous system problems; increased risk of cancer	Byproduct of drinking water disinfection

Disinfectants	MRDL[1] (mg/L)[2]	MRDL[1] (mg/L)[2]	Potential Health Effects from Ingestion of Water	Sources of Contaminant in Drinking Water
Chloramines (as Cl_2)	MRDLG=4[1]	MRDL=4.0[1]	Eye/nose irritation; stomach discomfort, anemia	Water additive used to control microbes
Chlorine (as Cl_2)	MRDLG=4[1]	MRDL=4.0[1]	Eye/nose irritation; stomach discomfort	Water additive used to control microbes
Chlorine dioxide (as ClO_2)	MRDLG=0.8[1]	MRDL=0.8[1]	Anemia; infants & young children: nervous system effects	Water additive used to control microbes

Inorganic Chemicals	MCLG[1] (mg/L)[2]	MCL or TT[1] (mg/L)[2]	Potential Health Effects from Ingestion of Water	Sources of Contaminant in Drinking Water
Antimony	0.006	0.006	Increase in blood cholesterol; decrease in blood sugar	Discharge from petroleum refineries; fire retardants; ceramics; electronics; solder
Arsenic	0[7]	0.010 as of 01/23/06	Skin damage or problems with circulatory systems, and may have increased risk of getting cancer	Erosion of natural deposits; runoff from orchards, runoff from glass & electronicsproduction wastes
Asbestos (fiber >10 micrometers)	7 million fibers per liter	7 MFL	Increased risk of developing benign intestinal polyps	Decay of asbestos cement in water mains; erosion of natural deposits
Barium	2	2	Increase in blood pressure	Discharge of drilling wastes; discharge from metal refineries; erosion of natural deposits
Beryllium	0.004	0.004	Intestinal lesions	Discharge from metal refineries and coal-burning factories; discharge from electrical, aerospace, and defense industries
Cadmium	0.005	0.005	Kidney damage	Corrosion of galvanized pipes; erosion of natural deposits; discharge from metal refineries; runoff from waste batteries and paints
Chromium (total)	0.1	0.1	Allergic dermatitis	Discharge from steel and pulp mills; erosion of natural deposits
Copper	1.3	TT[8]; Action Level=1.3	Short term exposure: Gastrointestinal distress Long term exposure: Liver or kidney damage People with Wilson's Disease should consult their personal doctor if the amount of copper in their water exceeds the action level	Corrosion of household plumbing systems; erosion of natural deposits
Cyanide (as free cyanide)	0.2	0.2	Nerve damage or thyroid problems	Discharge from steel/metal factories; discharge from plastic and fertilizer factories
Fluoride	4.0	4.0	Bone disease (pain and tenderness of the bones); Children may get mottled teeth	Water additive which promotes strong teeth; erosion of natural deposits; discharge from fertilizer and aluminum factories
Lead	zero	TT[8]; Action Level=0.015	Infants and children: Delays in physical or mental development; children could show slight deficits in attention span and learning abilities Adults: Kidney problems; high blood pressure	Corrosion of household plumbing systems; erosion of natural deposits
Mercury (inorganic)	0.002	0.002	Kidney damage	Erosion of natural deposits; discharge from refineries and factories; runoff from landfills and croplands
Nitrate (measured as Nitrogen)	10	10	Infants below the age of six months who drink water containing nitrate in excess of the MCL could become seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue-baby syndrome.	Runoff from fertilizer use; leaching from septic tanks, sewage; erosion of natural deposits

Nitrite (measured as Nitrogen)	1	1	Infants below the age of six months who drink water containing nitrite in excess of the MCL could become seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue-baby syndrome.	Runoff from fertilizer use; leaching from septic tanks, sewage; erosion of natural deposits
Selenium	0.05	0.05	Hair or fingernail loss; numbness in fingers or toes; circulatory problems	Discharge from petroleum refineries; erosion of natural deposits; discharge from mines
Thallium	0.0005	0.002	Hair loss; changes in blood; kidney, intestine, or liver problems	Leaching from ore-processing sites; discharge from electronics, glass, and drug factories

Organic Chemicals	MCLG[1] (mg/L)[2]	MCL or TT[1] (mg/L)[2]	Potential Health Effects from Ingestion of Water	Sources of Contaminant in Drinking Water
Acrylamide	zero	TT[9]	Nervous system or blood problems; increased risk of cancer	Added to water during sewage/wastewater treatment
Alachlor	zero	0.002	Eye, liver, kidney or spleen problems; anemia; increased risk of cancer	Runoff from herbicide used on row crops
Atrazine	0.003	0.003	Cardiovascular system or reproductive problems	Runoff from herbicide used on row crops
Benzene	zero	0.005	Anemia; decrease in blood platelets; increased risk of cancer	Discharge from factories; leaching from gas storage tanks and landfills
Benzo(a)pyrene (PAHs)	zero	0.0002	Reproductive difficulties; increased risk of cancer	Leaching from linings of water storage tanks and distribution lines
Carbofuran	0.04	0.04	Problems with blood, nervous system, or reproductive system	Leaching of soil fumigant used on rice and alfalfa
Carbon tetrachloride	zero	0.005	Liver problems; increased risk of cancer	Discharge from chemical plants and other industrial activities
Chlordane	zero	0.002	Liver or nervous system problems; increased risk of cancer	Residue of banned termiticide
Chlorobenzene	0.1	0.1	Liver or kidney problems	Discharge from chemical and agricultural chemical factories
2,4-D	0.07	0.07	Kidney, liver, or adrenal gland problems	Runoff from herbicide used on row crops
Dalapon	0.2	0.2	Minor kidney changes	Runoff from herbicide used on rights of way
1,2-Dibromo-3-chloropropane (DBCP)	zero	0.0002	Reproductive difficulties; increased risk of cancer	Runoff/leaching from soil fumigant used on soybeans, cotton, pineapples, and orchards
o-Dichlorobenzene	0.6	0.6	Liver, kidney, or circulatory system problems	Discharge from industrial chemical factories
p-Dichlorobenzene	0.075	0.075	Anemia; liver, kidney or spleen damage; changes in blood	Discharge from industrial chemical factories
1,2-Dichloroethane	zero	0.005	Increased risk of cancer	Discharge from industrial chemical factories
1,1-Dichloroethylene	0.007	0.007	Liver problems	Discharge from industrial chemical factories
cis-1,2-Dichloroethylene	0.07	0.07	Liver problems	Discharge from industrial chemical factories
trans-1,2-Dichloroethylene	0.1	0.1	Liver problems	Discharge from industrial chemical factories

Dichloromethane	zero	0.005	Liver problems; increased risk of cancer	Discharge from drug and chemical factories
1,2-Dichloropropane	zero	0.005	Increased risk of cancer	Discharge from industrial chemical factories
Di(2-ethylhexyl) adipate	0.4	0.4	General toxic effects or reproductive difficulties	Discharge from chemical factories
Di(2-ethylhexyl) phthalate	zero	0.006	Reproductive difficulties; liver problems; increased risk of cancer	Discharge from rubber and chemical factories
Dinoseb	0.007	0.007	Reproductive difficulties	Runoff from herbicide used on soybeans and vegetables
Dioxin (2,3,7,8-TCDD)	zero	0.00000003	Reproductive difficulties; increased risk of cancer	Emissions from waste incineration and other combustion; discharge from chemical factories
Diquat	0.02	0.02	Cataracts	Runoff from herbicide use
Endothall	0.1	0.1	Stomach and intestinal problems	Runoff from herbicide use
Endrin	0.002	0.002	Liver problems	Residue of banned insecticide
Epichlorohydrin	zero	TT[9]	Increased cancer risk, and over a long period of time, stomach problems	Discharge from industrial chemical factories; an impurity of some water treatment chemicals
Ethylbenzene	0.7	0.7	Liver or kidneys problems	Discharge from petroleum refineries
Ethylene dibromide	zero	0.00005	Problems with liver, stomach, reproductive system, or kidneys; increased risk of cancer	Discharge from petroleum refineries
Glyphosate	0.7	0.7	Kidney problems; reproductive difficulties	Runoff from herbicide use
Heptachlor	zero	0.0004	Liver damage; increased risk of cancer	Residue of banned termiticide
Heptachlor epoxide	zero	0.0002	Liver damage; increased risk of cancer	Breakdown of heptachlor
Hexachlorobenzene	zero	0.001	Liver or kidney problems; reproductive difficulties; increased risk of cancer	Discharge from metal refineries and agricultural chemical factories
Hexachlorocyclopentadiene	0.05	0.05	Kidney or stomach problems	Discharge from chemical factories
Lindane	0.0002	0.0002	Liver or kidney problems	Runoff/leaching from insecticide used on cattle, lumber, gardens
Methoxychlor	0.04	0.04	Reproductive difficulties	Runoff/leaching from insecticide used on fruits, vegetables, alfalfa, livestock
Oxamyl (Vydate)	0.2	0.2	Slight nervous system effects	Runoff/leaching from insecticide used on apples, potatoes, and tomatoes
Polychlorinated biphenyls (PCBs)	zero	0.0005	Skin changes; thymus gland problems; immune deficiencies; reproductive or nervous system difficulties; increased risk of cancer	Runoff from landfills; discharge of waste chemicals
Pentachlorophenol	zero	0.001	Liver or kidney problems; increased cancer risk	Discharge from wood preserving factories
Picloram	0.5	0.5	Liver problems	Herbicide runoff
Simazine	0.004	0.004	Problems with blood	Herbicide runoff
Styrene	0.1	0.1	Liver, kidney, or circulatory system problems	Discharge from rubber and plastic factories; leaching from landfills
Tetrachloroethylene	zero	0.005	Liver problems; increased risk of cancer	Discharge from factories and dry cleaners

Toluene	1	1	Nervous system, kidney, or liver problems	Discharge from petroleum factories
Toxaphene	zero	0.003	Kidney, liver, or thyroid problems; increased risk of cancer	Runoff/leaching from insecticide used on cotton and cattle
2,4,5-TP (Silvex)	0.05	0.05	Liver problems	Residue of banned herbicide
1,2,4-Trichlorobenzene	0.07	0.07	Changes in adrenal glands	Discharge from textile finishing factories
1,1,1-Trichloroethane	0.20	0.2	Liver, nervous system, or circulatory problems	Discharge from metal degreasing sites and other factories
1,1,2-Trichloroethane	0.003	0.005	Liver, kidney, or immune system problems	Discharge from industrial chemical factories
Trichloroethylene	zero	0.005	Liver problems; increased risk of cancer	Discharge from metal degreasing sites and other factories
Vinyl chloride	zero	0.002	Increased risk of cancer	Leaching from PVC pipes; discharge from plastic factories
Xylenes (total)	10	10	Nervous system damage	Discharge from petroleum factories; discharge from chemical factories

Radionuclides	MCLG[1] (mg/L)[2]	MCL or TT[1] (mg/L)[2]	Potential Health Effects from Ingestion of Water	Sources of Contaminant in Drinking Water
Alpha particles	none[7] ---------- zero	15 picocuries per Liter (pCi/L)	Increased risk of cancer	Erosion of natural deposits of certain minerals that are radioactive and may emit a form of radiation known as alpha radiation
Beta particles and photon emitters	none[7] ---------- zero	4 millirems per year	Increased risk of cancer	Decay of natural and man-made deposits of certain minerals that are radioactive and may emit forms of radiation known as photons and beta radiation
Radium 226 and Radium 228 (combined)	none[7] ---------- zero	5 pCi/L	Increased risk of cancer	Erosion of natural deposits
Uranium	zero	30 ug/L as of 12/08/03	Increased risk of cancer, kidney toxicity	Erosion of natural deposits

Notes

[1] Definitions:

Maximum Contaminant Level (MCL) - The highest level of a contaminant that is allowed in drinking water. MCLs are set as close to MCLGs as feasible using the best available treatment technology and taking cost into consideration. MCLs are enforceable standards.

Maximum Contaminant Level Goal (MCLG) - The level of a contaminant in drinking water below which there is no known or expected risk to health. MCLGs allow for a margin of safety and are non-enforceable public health goals.

Maximum Residual Disinfectant Level (MRDL) - The highest level of a disinfectant allowed in drinking water. There is convincing evidence that addition of a disinfectant is necessary for control of microbial contaminants.

Maximum Residual Disinfectant Level Goal (MRDLG) - The level of a drinking water disinfectant below which there is no known or expected risk to health. MRDLGs do not reflect the benefits of the use of disinfectants to control microbial contaminants.

Treatment Technique - A required process intended to reduce the level of a contaminant in drinking water.

[2] Units are in milligrams per liter (mg/L) unless otherwise noted. Milligrams per liter are equivalent to parts per million.

[3] EPA's surface water treatment rules require systems using surface water or ground water under the direct influence of surface water to (1) disinfect their water, and (2) filter their water or meet criteria for avoiding filtration so that the following contaminants are controlled at the following levels:

- Cryptosporidium (as of1/1/02 for systems serving >10,000 and 1/14/05 for systems serving <10,000) 99% removal.
- *Giardia lamblia:* 99.9% removal/inactivation
- Viruses: 99.99% removal/inactivation
- *Legionella:* No limit, but EPA believes that if *Giardia* and viruses are removed/inactivated, *Legionella* will also be controlled.
- Turbidity: At no time can turbidity (cloudiness of water) go above 5 nephelolometric turbidity units (NTU); systems that filter must ensure that the turbidity go no higher than 1 NTU (0.5 NTU for conventional or direct filtration) in at least 95% of the daily samples in any month. As of January 1, 2002, turbidity may never exceed 1 NTU, and must not exceed 0.3 NTU in 95% of daily samples in any month.
- HPC: No more than 500 bacterial colonies per milliliter.
- Long Term 1 Enhanced Surface Water Treatment (Effective Date: January 14, 2005); Surface water systems or (GWUDI) systems serving fewer than 10,000 people must comply with the applicable Long Term 1 Enhanced Surface Water Treatment Rule provisions (e.g. turbidity standards, individual filter monitoring, Cryptosporidium removal requirements, updated watershed control requirements for unfiltered systems).
- Filter Backwash Recycling; The Filter Backwash Recycling Rule requires systems that recycle to return specific recycle flows through all processes of the system's existing conventional or direct filtration system or at an alternate location approved by the state.

[4] more than 5.0% samples total coliform-positive in a month. (For water systems that collect fewer than 40 routine samples per month, no more than one sample can be total coliform-positive per month.) Every sample that has total coliform must be analyzed for either fecal coliforms or *E. coli* if two consecutive TC-positive samples, and one is also positive for *E.coli* fecal coliforms, system has an acute MCL violation.

[5] Fecal coliform and *E. coli* are bacteria whose presence indicates that the water may be contaminated with human or animal wastes. Disease-causing microbes (pathogens) in these wastes can cause diarrhea, cramps, nausea, headaches, or other symptoms. These pathogens may pose a special health risk for infants, young children, and people with severely compromised immune systems.

[6] Although there is no collective MCLG for this contaminant group, there are individual MCLGs for some of the individual contaminants:

- Trihalomethanes: bromodichloromethane (zero); bromoform (zero); dibromochloromethane (0.06 mg/L). Chloroform is regulated with this group but has no MCLG.
- Haloacetic acids: dichloroacetic acid (zero); trichloroacetic acid (0.3 mg/L). Monochloroacetic acid, bromoacetic acid, and dibromoacetic acid are regulated with this group but have no MCLGs.

[7] MCLGs were not established before the 1986 Amendments to the Safe Drinking Water Act. Therefore, there is no MCLG for this contaminant.

[8] Lead and copper are regulated by a Treatment Technique that requires systems to control the corrosiveness of their water. If more than 10% of tap water samples exceed the action level, water systems must take additional steps. For copper, the action level is 1.3 mg/L, and for lead is 0.015 mg/L.

[9] Each water system must certify, in writing, to the state (using third-party or manufacturer's certification) that when acrylamide and epichlorohydrin are used in drinking water systems, the combination (or product) of dose and monomer level does not exceed the levels specified, as follows:

- Acrylamide = 0.05% dosed at 1 mg/L (or equivalent)
- Epichlorohydrin = 0.01% dosed at 20 mg/L (or equivalent)

(Source: U.S. EPA, 2002e)

Table 3: U.S. EPA Secondary Drinking Water Standards

Contaminant	Secondary MCL	Noticeable Effects above the Secondary MCL
Aluminum	0.05 to 0.2 mg/L*	colored water
Chloride	250 mg/L	salty taste
Color	15 color units	visible tint
Copper	1.0 mg/L	metallic taste; blue-green staining
Corrosivity	Non-corrosive	metallic taste; corroded pipes/ fixtures staining
Fluoride	2.0 mg/L	tooth discoloration
Foaming agents	0.5 mg/L	frothy, cloudy; bitter taste; odor
Iron	0.3 mg/L	rusty color; sediment; metallic taste; reddish or orange staining
Manganese	0.05 mg/L	black to brown color; black staining; bitter metallic taste
Odor	3 TON (threshold odor number)	"rotten-egg", musty or chemical smell
pH	6.5 - 8.5	*low pH:* bitter metallic taste; corrosion *high pH:* slippery feel; soda taste; deposits
Silver	0.1 mg/L	skin discoloration; graying of the white part of the eye
Sulfate	250 mg/L	salty taste
Total Dissolved Solids (TDS)	500 mg/L	hardness; deposits; colored water; staining; salty taste
Zinc	5 mg/L	metallic taste
* mg/L is milligrams of substance per liter of water		

MCL = Maximum Contaminant Level

(Source: U.S. EPA, 2002e)

Table 4: Priority Pollutants for Testing Water

Extractable Volatile Organic Compounds (VOCs)

Acrolein
Acrylonitrile
Benzene
Bromodichloromethane
Bromoform
Bromomehtane (methyl bromide)
Carbon tetrachloride
Chloroethane
2-Chloroehtylvinyl ether
Chloroform
Chloromethane
Dibromochloromethane
1,1-Dichloroethane
1,2-Dchloroethane
Trans-1,2-Dichloroethane
1,1-Dichloroethene
1,2-Dichloropropene
Ethyl Benzene
Methylene Chloride (dichloromethane)
1,1,2,2-Tetrachloroethane
Tetrachloroethylene
Toluene
1,1,1-Trichloroethane
1,1,2-Trichloroethane
Trichloroethylene
Vinyl Chloride

Base Neutral Extractable Organic Compounds (Semi-volatile)

Anthracene
Acenaphthene
Acenaphthylene
Benzidine
Benzo(a)anthracene
Benzo(b)fluoranthene
Benzo(k)fluoranthene
Benzo(a)pyrene
Benzo(ghi)perylene
Bezyl butyl phthalate
Bis (2-chlorethoxy) methane
Bis (2-chloroethyl) ether
Bis (2-chloro-isopropyl) ether
Bis (2-ethlhexyl) phthalate
4-Bromophenyl phenyl ether
2-Chloronaphthalene
4-Chlorophenyl phenyl ether
Chrysene
Dibenzo(a,h)anthracene
1,2-Dichlorobenzene
1,3-Dichlorobenzene
1,4-Dichlorobenzene
3,3'-Dichlorobenzidine
Diethyl phthalate
Di-n-butylphthalate
Diethlyl phthalate
Di-n-butylphthalate
Dimethyl phthalate
2,4-Dinitrotoluene
2,6-Dinitrotoluene
Di-n-octylphthalate
1,2-Diphenlhydrazine
Fluorene
Hexachlorobenzene (HCB)
Hexachlorobutadiene
Hexachloroethane
Hexachlorocyclopentadiene (HCCP)
Indeno(1,2,3-cd)pyrene
Isophorone
Naphthalene
Nitrobenzene
N-Nitrosodimethylamine
N-Nitrosodiphenylamine
N-Nitrosopyrrolidine
Phenanthrene
Pyrene
1,2-Trichlorobenzene

Phenols (Acids)

4-Chloro-3-methylphenol
2-Chlorophenol
2,4-Dichlorophenol
2,4-Dimethylphenol
2,4-Dinitrophenol
2-Methyl-4,6-Dinitrophenol
2-Nitrophenol
4-Nitrophenol
Pentachlorophenol
Phenol
2,4,6-Trichlorophenol

Pesticides and Metabolites

Aldrin
Alpha-BHC
Beta-BHC
Gamma-BHC (Lindane)
Delta-BHC
Chlordane
4,4'-DD (P,P'-DDD)
4,4'-DDE (P,P'-DDE)
4,4'-DDT (P,P'-DDT)
Dieldrin
Endosulfan I (alpha)
Endosulfan II (beta)
Endosulfan sulfate
Endrin
Endrin aldehyde
Heptachlor
Heptachlor epoxide
TCDD (dioxin)
Toxaphene

PCBs

PCB-1242 (aroclor 1242)
PCB-1254 (aroclor 1254)
PCB-1221 (aroclor 1221)
PCB-1232 (aroclor 1232)
PCB-1248 (aroclor 1248)
PCB-1260 (aroclor 1260)
PCB-1016 (aroclor 1016)

Metals

Antimony
Arsenic
Asbestos
Beryllium
Cadmium
Chromium
Copper
Cyanide
Lead
Mercury
Nickel
Selenium
Silver
Thallium
Zinc

Table 5: Common Conversions and Measurements

m = cubic meter
kg = kilogram = 2.2 pounds (lbs)
g = gram = 0.001 kilograms
mg = milligram = 0.001 grams
ug = microgram = 0.000001 grams
ng = nanogram = 0.000000001 grams
ppm = parts per million
ppb = parts per billion
ppt = parts per trillion

mg/kg = milligrams per kilogram
mg/l = milligrams per liter
ug/kg = micrograms per kilogram
ug/l = micrograms per liter
mg/m = milligrams per cubic meter
ug/m = micrograms per cubic meter

one part per million

for water: 1 mg/l = 1 milligram per liter of water
for soil: 1 mg/kg = 1 milligram per kilogram of soil
for air: 1 mg/m = varies with substance

one part per billion

for water: 1 ug/l = 1 microgram per liter of water
for soil: 1 ug/kg = 1 microgram per kilogram of soil
for air: 1 ug/m = varies with substance

one part per trillion

for water: 1 ng/l = 1 nanogram per liter of water
for soil: 1 ng/kg = 1 nanogram per kilogram of soil
for air: 1 ng/m = varies with substance

Water and Air Temperature

If a temperature is given in degrees Celsius, use the following equation to convert to degrees Fahrenheit (this is only an approximation): $^{o}F = ((9/5 \times {}^{o}C) + 32)$

If a temperature is given in degrees Fahrenheit, use the following equation to convert to degrees Celsius (this is only an approximation): $^{o}C = (5/9) \times (^{o}F - 32)$

Table 6: National Ambient Air Quality Standards
(Also known as Criteria Pollutants)

POLLUTANT	STANDARD VALUE *		STANDARD TYPE
Carbon Monoxide (CO)			
8-hour Average	9 ppm	(10 mg/m^3)	Primary
1-hour Average	35 ppm	(40 mg/m^3)	Primary
Nitrogen Dioxide (NO$_2$)			
Annual Arithmetic Mean	0.053 ppm	(100 µg/m^3)	Primary & Secondary
Ozone (O$_3$)			
1-hour Average	0.12 ppm	(235 µg/m^3)	Primary & Secondary
8-hour Average	0.08 ppm	(157 µg/m^3)	Primary & Secondary
Lead (Pb)			
Quarterly Average	1.5 µg/m^3		Primary & Secondary
Particulate (PM 10) *Particles with diameters of 10 micrometers or less*			
Annual Arithmetic Mean	50 µg/m^3		Primary & Secondary
24-hour Average	150 µg/m^3		Primary & Secondary
Particulate (PM 2.5) *Particles with diameters of 2.5 micrometers or less*			
Annual Arithmetic Mean	15 µg/m^3		Primary & Secondary
24-hour Average	65 µg/m^3		Primary & Secondary
Sulfur Dioxide (SO$_2$)			
Annual Arithmetic Mean	0.030 ppm	(80 µg/m^3)	Primary
24-hour Average	0.14 ppm	(365 µg/m^3)	Primary
3-hour Average	0.50 ppm	(1300 µg/m^3)	Secondary

*Parenthetical value is an approximately equivalent concentration.

(Source: U.S. EPA, 2002f)

Table 7: Toxicity Characteristic Constituents and Regulatory Levels

Constituent	Regulatory Level (mg/L)
Arsenic	5.0
Barium	100.0
Benzene	0.5
Cadmium	1.0
Carbon tetrachloride	0.5
Chlordane	0.03
Chlorobenzene	100.00
Chloroform	6.0
Chromium	5.0
o-Cresol	200.00
m-Cresol	200.00
p-Cresol	200.00
Cresol	200.00
2,4-D	10.00
1,4-Dichlorobenzene	7.5
1,2-Dichloroethane	0.5
1,1-Dichloroethylene	0.7
2,4-Dintotoluene	0.13
Endrin	0.02
Heptachlor (and its hydroxide)	0.008
Hexachlorobenzene	0.13
Hexachloro-1,3-butadiene	0.5
Hexachloroethane	3.0
Lead	5.0
Lindane	0.4
Mercury	0.2
Methoxychlor	10.0
Methyl ethyl ketone	200.00
Nitrobenzene	2.0
Pentachlorophenol	100.00
Pyridine	5.0
Selenium	1.0
Silver	5.0
Tetrachloroethylene	0.7
Toxaphene	0.5
Trichloroethylene	0.5
2,4,5-Trichlorophenol	400.00
2,4,6-Trichlorophenol	2.0
2,4,5-TP (Silvex)	1.0
Vinyl Chloride	0.2

Table 8: New York State Recommended Soil Cleanup Objectives for Chemicals Commonly Found at Contaminated Sites

Volatile Organic Contaminants

Contaminant	Recommended Soil Cleanup Objective (mg/kg or ppm)
Acetone	0.2
Benzene	0.06
Benzoic Acid	2.7
2-Butanone	0.3
Carbon Tetrachloride	0.6
Chlorobenzene	1.7
Chloroform	0.3
1,2-Dichlorobenzene	7.9
1,3-Dichlorobenzene	1.6
1,2-Dichloroethane	0.1
Methylene Chloride	0.1
Tetrachloroethene	1.4
Toluene	1.5
Vinyl Chloride	0.2
Xylenes	1.2

Semi-Volatile Organic Contaminants

Contaminant	Recommended Soil Cleanup Objective (mg/kg or ppm)
Acenaphthene	50.0
Antracene	50.0
Benzo(a)anthracene	0.224
Butylbenzylphthalate	50.0
Chrysene	0.4
2-Chlorophenol	0.8
Dibenzofuran	6.2
Fluorene	50.0
Hexachlorobenzene	0.41
2-Methylphenol	0.100
Naphthalene	13.0
Nitrobenzene	0.200
Pentachlorophenol	1.0
Phenol	0.03
Pyrene	50.0

Organic Pesticides/Herbicides and PCBs

Contaminant	Recommended Soil Cleanup Objective (mg/kg or ppm)
Aldrin	0.041
alpha-BHC	0.11
Chlordane	0.54
4,4'-DDT	2.1
Dieldrin	0.044
gamma-BHC (Lindane)	0.06
Heptachlor	0.10
Heptachlor Epoxide	0.02
Parathion	1.2
PCBs	1.0 (surface); 10 (subsurface)

Heavy Metals

Contaminants	Recommended Soil Cleanup Objective (mg/kg or ppm)
Arsenic	7.5
Cadmium	1
Chromium	10
Iron	2,000
Mercury	0.1
Nickel	13
Selenium	2
Zinc	20

Note: This is a partial list of 126 substances prepared by the NYSDEC

(Source: NYSDEC, 1994)

Table 9: Factors Influencing How Contaminants Move Through Soil

METEOROLOGIC	PEDOLOGIC	GEOLOGIC	HYDROLOGIC
Precipitation Average Annual Form Distribution	**Physical Properties** Texture Grain Size Grain Size Distribution Porosity Hydraulic Conductivity Infiltration Rate Runoff Coefficient Unified Soil Classification Atterberg Limits Thickness	**Geomorphic Setting** Active Landforms Inactive Landforms	**Surface Water** Distance Type Quality
Severe Weather	**Chemical Properties** pH Ion Exchange	**Topographic Settings** Slope Erosion Potential	**Ground Water** Depth Fluctuation Flow Rate Transmissivity Recharge Aquifer Distribution Quality
Evaporation Depth to Water Table Vegetation		**Bedrock Setting** Rock Type Depth to Bedrock Structure Weathering Porosity Hydraulic Conductivity Infiltration Rate Runoff Coefficient pH Ion Exchange	
Temperature			

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