MANUAL FOR SIMPLE WATER QUALITY ANALYSIS

Esther de Lange

International Water Tribunal

MANUAL FOR SIMPLE WATER QUALITY ANALYSIS

BY

ESTHER DE LANGE

IWT Foundation
Damrak 83-I, 1012 LN Amsterdam
The Netherlands

Hereby I want to thank all the people who have helped me with the production of the manual during my field trips to Chile, Ecuador, India, Kenya, the Philippines and Tanzania. I also want to show my gratitude to the Global Rivers Environmental Education Network (GREEN) in Ann Arbor, U.S.A., and the International Center of Water Studies (ICWS) in Amsterdam, the Netherlands, for their support.

Financial support to produce the manual is given by NOVIB, MISEREOR and BROT FÜR DIE WELT.

IWT Productions
Amsterdam, June 1994

Figures by Eveline de Lange
Edited by Nigel Harle
Layout by Eric Bijvoet
Design cover by Rob Koeze and Step Stevens

ISBN 90-70803-02-X

Table of Contents

Introduction

We all need water to survive, and it is important that, besides the amount of available water, the quality of the water we use meets with certain criteria. If those criteria are not met and water is polluted, it may no longer be usable for drinking, bathing, farming or industrial purposes. Also the plants and animals living in and around water need a certain water quality to survive and reproduce.

This manual explains important issues you may want to know when you have a water pollution problem. With this manual you will be able to find out whether water is polluted or not, and what type of pollution is occurring. Also you will be able to locate the source(s) of pollution. Concluding, many suggestions on how to reduce or solve water pollution problems are given.

This manual can be used by people without any specific knowledge about water quality, as well as by persons with an environmental or water quality background. It is intended especially for organizations and persons in developing countries, but it can also be used elsewhere.

Overview

The first chapter describes the different types of water, and the plants and animals living there. In Chapter 2 the most important types of water pollution, their possible sources and their possible effects are given. Everybody who wants to know more about water pollution should be acquainted with these chapters.

The Chapters 3 to 6 describe different methods of water quality analysis, ranging in level of difficulty, accuracy and equipment required.

Chapter 3 describes the Field Survey. The Field Survey uses colours, smells and land uses as indicators for water quality. To conduct a Field Survey no specific knowledge, training or equipment are needed.

With the results of a (properly conducted) Field Survey you will be able to make an inventory of all possible sources of pollution in an area, and make an assumption as to which type of pollution is occurring.

The Biological Survey, which is described in Chapter 4, uses bacteria, algae, large water plants, fish, vertebrates and small water animals as indicators for water quality. For these surveys little equipment is needed, and it can all be found or made at home. The Biological Survey does not require additional biological knowledge, except for the Pollution Tolerance Index; for which you need some extra knowledge about small water animals.

With the results of a (properly conducted) Biological Survey, you can prove the presence of pollution in a water, and you can estimate the pollution in terms of non-polluted, fair, moderate, or severely polluted. Biological indicators can tell a lot about the actual impact of pollution on a water, and about the long-term effects on the aquatic community.

Chapter 5 focuses on possible water contamination with disease-causing organisms (pathogens). This chapter consists of two parts. The first part discusses the Health Survey, which uses prevalent diseases and possible sources and routes of contamination as indicators for the presence of pathogens. The Health Survey is easy to conduct, and does not require any skills or equipment. Some extra knowledge about the occurrence and spread of diseases (besides what is explained this manual) may be helpful.

With the results of a (properly conducted) Health Survey you can make an inventory of the possible sources of pathogenic contamination, and an assumption as to the possible presence of pathogens.

The second part discusses a test to analyze water for the presence of F. Coli bacteria, which are indicative of the presence of pathogens. For this test training and laboratory equipment are needed.

(Properly conducted) F. Coli analysis can prove the presence of pathogens in water, and gives an estimation of the contamination in terms of uncontaminated, fair, moderate, or severely contaminated.

Chapter 6 discusses the analysis of a number of physical and chemical parameters that are indicative of water pollution. Sampling and preservation techniques are also explained, in case you want your sample to be analyzed by a professional laboratory. For these tests you need training and very specific equipment.

With the physical and chemical analysis discussed you can locate the source(s) of pollution and determine the dispersion pattern of pollution. Exact levels of pollutants, such as heavy metals and pesticides, can be obtained via the expertise of a professional laboratory.

Chapter 7 gives many practical suggestions about activities you can conduct to improve the water quality and quantity, at the household, community and a larger level.

Chapter 8 discusses a number of social and juridical activities you can conduct to reduce or stop problems caused by water pollution.

How to use the manual

If you use this manual, start by reading thoroughly Chapter 1 and 2. Acquaintance with these chapters is the first precondition to work with the manual.

Then continue with planning and conducting a Field Survey. The Field Survey must always be conducted first, before any of the other survey methods described. It is also very useful to regularly conduct Field Surveys in between the other survey methods and activities mentioned in the manual.

Then, depending on the local situation, your wishes and capacities, you can continue with the Biological Survey, the Health Survey and/or bacteriological test, and/or the physical and chemical analyses. The methods explained are complementary, but it is not necessary to conduct them all.

Conduct the bacteriological, physical and chemical tests only when you really need the information, because these are relatively expensive and require equipment and training.

After every survey method, even if you have only conducted the Field Survey, you can go to Chapter 7 and/or 8, to actually undertake actions to reduce or stop the water pollution problem.

The manual is mainly written in general terms, because it is meant to be useful in any developing country. However, every water has its own specific characteristics, and there are numerous types of water pollution. Thus problems in different areas are never identical. Therefore I encourage everybody to adapt the manual to the local situation as much as possible, leaving elements out that are not suitable, and adding new elements that are important in your particular case.

The manual deals with pollution problems in fresh waters only. It cannot be used for salt waters because the biology, physics and chemistry of salt water are quite different. However, the Field Survey discussed in Chapter 3, and the general ideas behind the Biological Survey and Health Survey, can be used to make another manual for salt water.

The described methods do not give information about the exact levels of pollutant(s) present. If you want to gather this type of information, you need more elaborate and more accurate chemical and physical tests, which are not discussed in this manual. However, the manual explains how you can send samples to a laboratory for further analysis (see Chapter 6).

Toxic substances like heavy metals and pesticides (see Chapter 2) can only be generally indicated with the methods discussed in this manual. It is not possible to determine which specific heavy metal or pesticide you are dealing with, nor the exact level. To obtain this type of information, you should send samples to a professional laboratory, as explained in Chapter 6.

Suggestions and comments

Please feel free to use this manual, and to share its contents with everybody who is interested. You can use the manual to make other materials about water pollution, that can be used by others then the people this manual is meant for (education materials for children, for example).

The manual is available in English, Spanish and French, and can be obtained via the IWT Foundation or via NOVIB (see addresses below).

If you have questions, suggestions and/or comments you can always write to the International Water Tribunal (IWT) Foundation.

Esther de Lange
June 1994

International Water Tribunal
Damrak 83-I
1012 LN Amsterdam
The Netherlands

NOVIB
Amaliastraat 7
2514 JC The Hague
The Netherlands

1 Facts about Water

This chapter describes some facts about water that are important to know when you look at the quality of the water. You will find short descriptions of different types of water, subdivided into standing and flowing waters. You will also find information about the plants and the animals living in the water, and how they are dependent upon one another.

1.1 The water cycle

The amount of water on earth always remains the same. As Figure 1 shows, water moves from the air to the earth and back into the air again. This is called the water cycle. Water in the air forms clouds, and falls to earth as rain or snow. On the earth water sinks into the soil, or flows overland as streams and rivers to lakes and oceans. The heat of the sun makes the water evaporate from the earth back into the air.

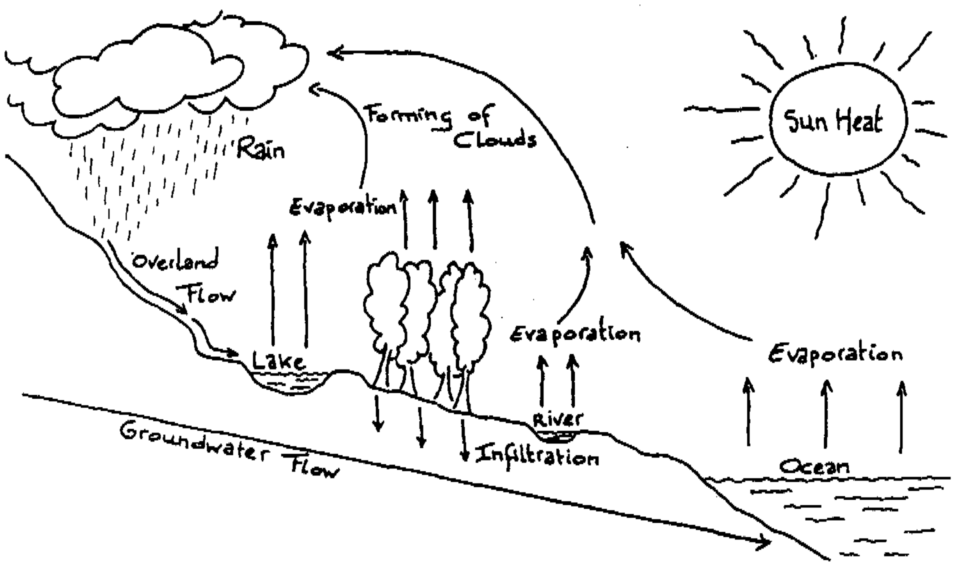


Figure 1: The water cycle

When it rains, part of the water sinks into the soil, and part flows over the land to a river or lake. Water sinking into the soil is called infiltration water, and water flowing over land is called run-off water.

Infiltration water is stored underground, and provides water to plants and trees when it is not raining. This water is called groundwater. Groundwater can also flow, especially in hilly and mountainous areas.

Run-off water carries soil away from the land into the water (which is called erosion), thereby carrying soil particles and all kinds of other substances to the receiving waters. Trees, bushes and plants reduce run-off water, thereby preventing erosion, because they hold the soil together with their roots, and they give the water the opportunity to sink into the soil.

1.2 A watershed

All the land that brings its groundwater and run-off water to one particular stream, river, pond or lake is called a watershed. Water is inseparable from the land through which it flows. Activities on the land in the watershed affect the water. For example, when a farmer uses pesticides on his field, the pesticides will enter a nearby river or lake after rain or via irrigation water, and will be carried downstream.

1.3 Different types of waters

There are many different types of waters. Because the velocity with which the water flows (stream velocity) plays an important role in the water quality, waters are often divided in standing and flowing waters. Examples of standing waters include ponds and lakes. Examples of flowing waters include streams, brooks and rivers.

Flowing waters

Flowing waters can have different origins. They may begin as a spring, from rainfall or snow-melt, as melt-water from a glacier, or as an outlet of a lake or a pond. Flowing waters generally start at higher altitudes as small streams or brooks. A stream is a small river. A brook is a stream originating from groundwater.

On their way to the sea (or to a lake), streams increase in flow and join with other streams. A branching network is established, much like the branches of a tree. Small streams become large rivers, and eventually they end up in a lake or an ocean. Usually, the stream velocity is higher in the upper part of the river. As the amount of water carried by the river increases, the river bed becomes wider, and the stream velocity becomes less. Rivers can become very big, like the Amazon in Brazil, the Congo in Zaire and the Ganges in India.

The stream velocity is very important for the water quality. When water is flowing, pollution is quickly dispersed and diluted, and incidental pollution can be flushed away completely.

Just like the air, water also contains oxygen. Oxygen is important for the animals and the plants living in the water, and also helps to break down certain types of pollution (see next chapter). The more oxygen the water contains, the better it is for the water quality. Cold water can contain more oxygen than warm water. Flowing water usually has more oxygen than standing water with the same temperature, due to increased exchange of oxygen with the air.

The stream velocity also influences the type of plants and animals that are able to live in the water. In fast-flowing rivers, the only plants and animals that can survive are those with special body parts, which prevent them from being flushed away.

The bottom materials (substrates) in flowing waters vary, depending on the stream velocity and the type of soil through which the water flows. Fast-flowing waters can carry small materials such as sand and silt, leaving only the very heavy boulders on the bottom (or bed). Thus fast-flowing waters have solid, stable beds. In slow-flowing streams these small soil particles settle down, which usually makes the bed soft (unstable) and shallow.

An estuary is the place where a river enters a sea or an ocean. Usually a river in an estuary has many tributaries (side-streams), and the river bed becomes wide and shallow because many eroded soil particles, that are carried by the river, settle down (sedimentation).

The water quality in an estuary can vary tremendously due to the tidal movement and the intrusion of salt water. At one location you can measure sea-water at high tide, while at low tide the water is only composed of water from the river. Because salt water is heavier than fresh water, salt water from the sea or ocean forms a tongue-shaped layer under the fresh water from the river. Therefore water quality in estuaries can also differ tremendously at various depths.

Standing waters

A lake is a body of standing water. A small lake with plants which have roots in the lake bottom, from one shore to the other, is called a pond. Wetlands are areas that are not deep enough to be called a lake (usually less than 2 metres), but are covered with water or have a wet soil at least part of the year. If the wetland supports shrubs and/or relatively large trees such as cypress and gum, it is called a swamp. If the wetland is treeless and is occupied by grasses, rushes and sedges, it is a marsh. Coastal wetlands are very important breeding grounds for many organisms living in and around the water.

The depth, the amount of nutrients and the residence time are the most important characteristics of lakes that influence the water quality.

In a deep lake, the upper layer of the water can become very warm, while at the bottom of the lake the water is still cold. Waters with different temperatures differ in weight: warm water is lighter then cold water. If there is a large temperature difference between the surface and the deeper water, the difference in weight between the upper and lower water is also large, and a barrier is created. The lake now has different water layers, which no longer mix easily with one another. This is called thermal stratification of a lake. Stratification can occur when lakes are deeper than 10 metres, but may also occur in shallower lakes. Besides depth this phenomenon is determined by the shape and the stability of the lake.

The establishment of these layers has important consequences for the lake and its life-forms. Since the upper and lower layer are separated from one another, there can be no exchange of oxygen between the two. As a result, the lower layer may lack oxygen during the periods when the water is layered, which eventually can lead to the death of most animals and plants. In many countries this occurs during the summer.

A lack of oxygen in the lower water layer also causes nutrients, which are present in the water bottom, to dissolve in the water. When the stratification ends, nutrients disperse also to the upper layer of the lake, where they serve as food for algae. Massive algal growth closes the circle of increasing eutrophication causing and caused by increasing organic pollution (see also Chapter 2).

The depth of the water and its clarity determine the amount of light which can penetrate the water. Water plants and algae need sunlight, and therefore do not grow in very deep or very unclear waters.

Nutrients are substances in the water which serve as food for plants. Lakes can be classified according to their concentrations of nutrients, varying from water with low nutrient concentrations (oligotrophic water) to water with high concentrations of nutrients (eutrophic water). Water with moderate nutrient pollution is called mesotrophic water.

Because lakes store the water they receive, they cannot be flushed clean quickly like a river. All materials which enter the lake remain there for a longer period, and thus concentrations slowly increase with time. The time which is needed to renew the complete water volume of a lake is called the residence time. This is calculated by measuring the volumes of all inflowing and outflowing waters (including respiration), and comparing them with the total volume of the lake in a certain time period. The longer the residence time, the more pollutants will accumulate in the lake.

1.4 The food web

Waters are full of life. Besides the fish and waterfowl we all know, they are home to many other types of plants and animals, varying from very small to quite big. All animals and plants living in the same area are dependent on one another. Together they form an ecosystem. Small plants serve as food for small fish, small fish are food for bigger fish, and bigger fish are eaten by birds and by people. When fish and birds die, their dead bodies are eaten by tiny organisms. This is called the food web, and is shown in Figure 2.

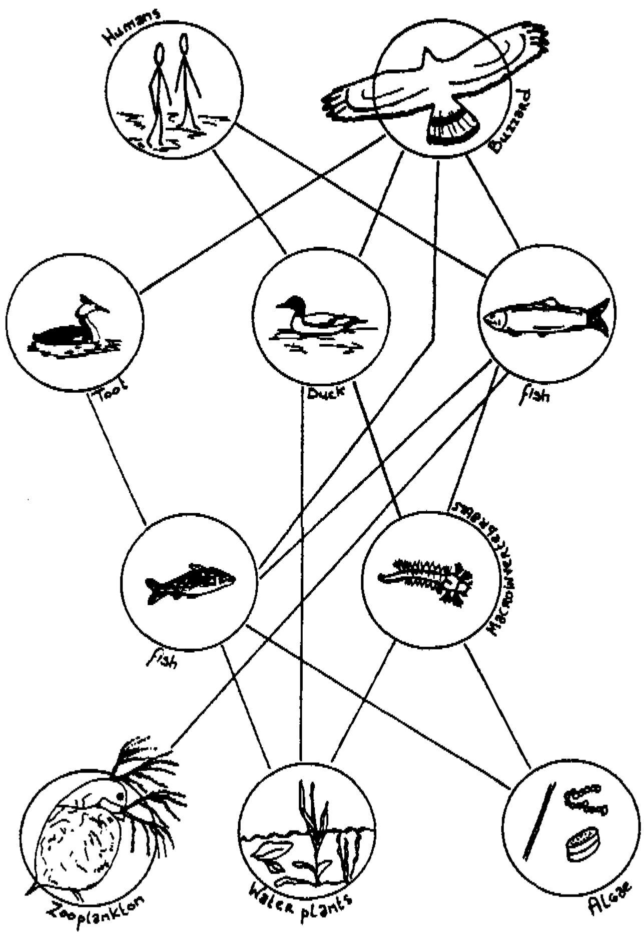


Figure 2: The food web

1.5 Plants living in the water

The number and types of plants in the water is determined largely by the amount of nutrients, the major food for plants. The amount of sunlight penetrating the water is also important, since no plant can grow without sunlight. Other factors determining the type and number of plants occurring are the depth of the water, the stream velocity, the type of bottom materials, and the temperature.

Plants are very important, because they produce oxygen in the water, which is essential for all organisms living there. They also serve as food for animals.

Algae

Algae are the smallest plants on earth. They have a very simple structure, without real stems and leaves. Algae can grow alone, or stuck together in strings or in balls. Most algae can only be seen with the aid of a microscope, but some can be seen with the naked eye. There are two types of algae: planktonic and benthic algae.

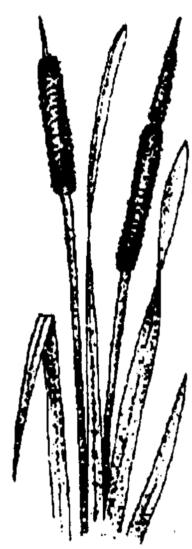
Planktonic algae are free-floating in the water, and unable to move by themselves. As individuals and in small amounts you can see them only with a microscope, but in huge amounts you can see them as a green, green-blue, brown or red colour in the water (algal blooms, like the red tide). Planktonic algae are typically found in ponds, lakes, slow-moving rivers and sometimes in pool areas of streams. They hardly occur in fast-flowing waters, because they are washed away.

Benthic algae are attached to rocks, submerged logs, the submerged bottom of boats, water plants or other objects. Certain attached algae can be recognized with the naked eye. Those forms are often referred to as pond moss or scum. Slick rocks are often due to algal growths. Attached algae are typically found in streams, rivers and around the edges of lakes.

Algae are very important, because they produce oxygen in the water, and because they serve as food for many other animals. In deep lakes they are often the major producers of oxygen. Too many algae limit the growth of water plants (because they use all the nutrients, and because they catch away all the sunlight falling on the water) and certain types of fish that need clear water. Too many algae may also cause problems for people, since the water can no longer be used for drinking (also not for animals) or irrigation water, for example.

Water plants

Similar to the plants on the land, there are also plants that live in water. There are different types of water plants. Some are attached to the bottom, while others float. Some plants have parts above the water, while others may be completely below the surface.



In shallow lakes water plants are often the main producers of oxygen. Water plants also provide food, breeding places and cover for aquatic insects, snails and fish. Water plants are eaten by many animals. In addition, waterfowl and other animals use water plants for homes and nests.

Water plants are effective in breaking the force of waves and with their roots they can hold the soil together, and thus reduce shoreline erosion. Plants like the water hyacinth can also take up nutrients and heavy metals from the water, thus forming a natural filter to clean the water (only when they are harvested occasionally, otherwise the nutrients and heavy metals re-enter the water). This is called a helophyte filter, and can be used to purify domestic waste water on a small scale, for example.

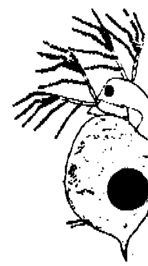
If there are too many water plants, they will be a problem for some of the animals living in the water, for example fish. They may also cause trouble when you want to use the water, for example for drinking, irrigation or industrial use.

1.6 Animals living in the water

The number and types of animals living in the water depend among others on the amount and type of food available. In general, small animals and plants are eaten by bigger animals. Whether a particular animal can live in a body of water also depends on the type of water.

Each animal also has a special type of area where it prefers to live. This area is called the habitat. Habitats have different characteristics (living conditions) that influence the distribution of animals, for instance dissolved oxygen, acidity and stream velocity. Some animals prefer deep water, other shallow water; some prefer flowing waters, others standing waters, etc.

Zooplankton



Zooplankton, just like planktonic algae, are tiny organisms, and most of them can be seen only with the microscope. Zooplankton organisms are able to move by themselves. They eat planktonic algae and bacteria, and serve as food for fish. The water flea is one of the largest zooplankton organisms, and can be seen with the naked eye.

Small water animals

Small water animals are about half to two centimetres in size. They are called macroinvertebrates. The term 'macro' refers to the fact that they can be seen with the naked eye. 'Invertebrate' means that the animal does not have a backbone. Many small water animals are 'benthic' macroinvertebrates. The term 'benthic' means bottom-dwelling and refers to organisms that live in, crawl on, or attach themselves to the bottom.

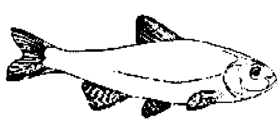
Most invertebrates are water insects or the 'children' of insects (the immature form of the insect, called nymph or larvae) Examples are stonefly nymphs, mayfly nymphs, caddisfly larvae, dragonfly nymphs and midge larvae.

Many of the flies and midges that live on the land spend the immature period of their lives in the water. The adult fly or midge lays her eggs in the water, for example on a leaf of a water plant. The larvae grows up in the water. As the larvae matures, it transforms into an adult fly or midge. It leaves the water and becomes the beautiful dragonfly or the stinging midge we all know.

Macroinvertebrates also include such animals as clams and mussels, crayfish, snails and aquatic worms. Most of the small water animals live in the water for more than a year.

Small water animals often go unnoticed because of their size and the place they live, but they are extremely important. They eat dead plants and animals, such as dead leaves and dead fish, thereby breaking the remainders down into very small particles. These particles, which include nutrients, again serve as food for the algae and water plants. Small water animals themselves are eaten by a lot of animals like fish, mammals and amphibians.

Big water animals



Vertebrates are the other animals living in the water. Most of them are bigger than the macroinvertebrates, and they have a backbone. Big water animals include fish, amphibians (salamanders, frogs, toads and sirens), reptiles (snakes, lizards and turtles), birds and mammals.

The presence of big water animals can tell you something about the health of the whole ecosystem in the water. Because they are on top of the food web, they are dependent on the health of a lot of other plants and animals for their survival. Therefore, water with large numbers of different kinds of animals most likely has a good quality.

Recommended literature

Water Watch, Kentucky Division of Water: "A field guide to Kentucky lakes and wetlands". Kentucky Natural Resources and Environmental Protection Cabinet, 18 Reilly Road, Frankfort, Kentucky 40601, U.S.A. 1985 (free of charge).

WETZEL, ROBERT G.: "Limnology". Michigan State University, Saunders College Publishing. Harcourt Brace Jovanovitch Inc., Orlando, Florida, U.S.A. Second edition, 1983.

2 Types of Water Pollution

We have the same amount of water on earth as we did millions of years ago, and through the water cycle (Figure 1) we continuously re-use that same water. Water which is used very often, can become easily polluted. Water is polluted when it harms the plants and animals living in the water, and when it can no longer be used as drinking water, as irrigation water, or for other purposes. This happens, for example, when garbage, wastes from industries, or sewage from cities and villages are discharged into the water.

Over the years the world's population is increasing, and we use more water for more purposes, increasing the water pollution. Also the nature of pollution is changing. We are making more artificial substances that are dangerous for the environment, and that are not biodegradable, meaning that they stay in the environment for a very long time.

The effects of pollution on the water depend first of all on the type of pollution. Different types of pollution and their effects on water quality are discussed in this chapter. The effects also depend on the amount of each pollutant, on the dilution and natural purification by the receiving water.

2.1 Sources of pollution

Water pollution can be caused by various human activities. The major sources of water pollution are industries, domestic wastes, farming activities, construction activities, mining, deforestation and oil-drilling. Sometimes water pollution occurs naturally, but the extent is usually much less than pollution caused by people.

Pollution can have two types of sources. This depends on how the pollution enters the water. *Point sources* are sources of pollution situated at one location, often a specific outlet (discharge) pipe. Factories and waste water treatment plants usually have discharge pipes leading directly to the water. Generally speaking, point sources are easy to locate.

Pollution from *non-point sources* does not come from one specific location. Instead, it comes from many small sources in a larger area. It is usually caused by water which flows overland to a river or lake, for example rainwater or irrigation water. As this water passes over the ground, it picks up pollutants and carries them into local waters. Non-point source pollution can also result from pollution in the air that 'falls' into the water or on the ground (atmospheric deposition). Non-point sources are more difficult to identify. For example, non-point source pollution can be caused by farming activities across an entire watershed, when the run-off water contains pesticides. Acid rain is also a form of non-point source pollution.

2.2 Types of water pollution

Table 1 gives the most important types of water pollution occurring in fresh water, and their major sources.

	industry	*farming*		*mining*	*domestic*	
		crops	*cattle*		*rural*	*urban*
suspended solids		x		x		(x)
organic waste	x		x		x	x
pathogens (faeces)			x		x	x
nutrients		x	x		x	x
pesticides		x				
heavy metals	x	x		x		(x)

Table 1: Types of water pollution and their major sources

Domestic wastes in rural areas consists of waste water and solid wastes (garbage) from households, and is often disposed directly into nearby waters or on the ground.

In urban areas domestic waste usually is disposed via a sewage system. Sewage discharge may also include effluents from industries and run-off water, and thus often contains all kinds of pollutants. Urban areas may have a sewage treatment plant. Sewage treatment plants often have effluents with high nutrient levels, low oxygen levels and some pathogenic bacteria. Solid wastes in urban areas are usually collected and stored in a dumping area, often located at a shore of a river or lake.

Suspended solids

Erosion is the wearing away of soil particles by wind or water. Every activity that disturbs the land causes soil to be washed into the water. Eroded soil that ends up in the water is called suspended solids. Farming, forestry, mining and unpaved roads are sources of suspended solids in rural areas. In urban areas, construction activities can contribute greatly to levels of suspended solids in water.

Flowing waters that are heavily loaded with suspended solids are very obvious because of their 'muddy' appearance. However, when the river reaches a standing water, the water loses speed and the suspended solids drop to the bottom and form a layer of sediment, a process called sedimentation. Therefore, lake water looks clear after you move some distance from the point where a muddy river enters. However, this does not mean that there is no sediment pollution in standing waters.

Toxic substances like heavy metals and pesticides have the tendency in water to stick to soil particles, and thus suspended solids can be contaminated (see also pesticides and heavy metals in this chapter). When suspended solids settle down in standing waters, the amount of heavy metals and pesticides in the water bottom slowly increases. Via animals that live in and near the water bottom the toxins will enter the food web, which can be very harmful for the ecosystem. Therefore water bottoms carrying heavy sediment loads are sometimes referred to as chemical time bombs.

Suspended solids block the penetration of sunlight. Especially algae and water plants, which need sunlight, will die when the water is very muddy. Of course this also affects the animals in the water, because they are dependent on algae and water plants for their survival.

Sediment on the water bottom can smother many small water animals. Those insects, which are a prime food supply for game fish, can be wiped out, adversely affecting the fish population. Game fish may give way to non-game fish or those fish whose existence does not rely on these small organisms.

An overload with sediments also fills in the stream bed, thereby reducing the channel capacity, which may result in floods.

Suspended solids can also destroy coral reefs, as it is taken to the sea. The corals die because it becomes smothered by the sediment.

If heavy loads of suspended solids are carried into a lake or a pond over a period of years, they can actually fill the basin and eventually turn it into a wetland, or even a dry land.

Organic wastes

Organic wastes are substances which originate from something that was once living. Examples include dead plants and animals, food left-overs, and also the faeces (excrement) of animals and people. You can find organic wastes in the discharges of factories (especially food-processing industries and pulp mills), in faeces from animals and people (watering and feeding places for animals, defecation places for people), and in garbage from households.

Organic wastes may be visible, causing dirty, cloudy-looking water. When the pollution is severe, you can smell faeces and/or an odour like rotten eggs.

Organic wastes cause several problems in the water. It makes the water unsuited for drinking. Organic wastes are eaten, and thus cleaned up, by bacteria living in the water. To do this, however, the bacteria need oxygen. When the organic pollution is severe, it causes a reduction and sometimes even a total lack of oxygen in the water. This is very serious, because the water plants, and most of the animals living in the water, can not survive without oxygen. Waters which are heavily polluted with organic wastes (like many rivers flowing through big cities) no longer have any plants and animals living in them: they are biologically dead.

Faeces

Faeces from animals and people contain many tiny organisms, for example bacteria, which can only be seen with a microscope. Some of them, however, can be very dangerous because they can cause diseases. Organisms that can cause diseases are called pathogens. When faeces end up in water (which often happens), the water becomes contaminated with those pathogens. People who drink this water can get sick. Faeces in water may be visible, or invisible when they are diluted.

For example diarrhoea, cholera, typhoid, dysentery, yellow fever (hepatitis), guinea-worm infection and bilharzia (schistosomiasis) are diseases which are caused by pathogens, mostly via our water. You can get sick if you drink contaminated water, and sometimes also when you stand or bath in contaminated water.

Nutrients

Nutrients are very small substances which cannot be seen with the naked eye. They serve as food for algae and water plants. The most important nutrients are nitrogen and phosphorus. Nutrients occur in (artificial) fertilizers and faeces from animals and people.

Unpolluted waters carry only small amounts of nutrients. When the amount of nutrients increases, some types of plants grow tremendously in number, while others can no longer survive. Then we speak of nutrient pollution, and more specifically of eutrophication.

Initially an increase in the amount of nutrients will result in an abundance of water plants, for example the water hyacinth. This can make water unsuitable for drinking, irrigation and industrial use for example.

Extensive nutrient pollution results in a dominance of algae. This can lead to algae blooms, giving the water a green, green-blue, brown or red colour. These algal blooms often make the water unsuitable for people, animals and water plants. The 'red tide', also an algal bloom, is toxic to animals like fish and shrimps.

Because algae and water plants are organic, their massive death causes oxygen depletion (see also organic wastes). Nutrient enrichment usually results in increased growth of plants and animals until the oxygen level becomes depleted.

High nitrate concentrations in drinking water can be toxic, especially to babies and old people. Nitrates block the breathing, eventually causing death through suffocation. This is also called the 'blue-baby syndrome'.

Pesticides and heavy metals

Pesticides and heavy metals are toxic substances. This means that they can be very dangerous to plants and animals living in the water, and even to people using water contaminated with these substances.

Pesticides are artificially made products, which kill certain types of plants (herbicides) or insects (insecticides). They are used by farmers to protect their crops against pests. The biggest disadvantage of pesticides is that they are not only harmful to the pest they are used against.

Pesticides are toxic substances that affect many plants, animals and even people. Pesticides are most harmful to people when they are exposed to pesticides directly, for example by spraying pesticides on a field. However, in this manual only the effects of pesticides that end up in the water will be discussed.

The term 'heavy metal' refers to a type of metallic element found on earth. Some common heavy metals include: aluminium (Al), arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), lead (Pb), manganese (Mn), mercury (Hg), nickel (Ni), silver (Ag) and zinc (Zn).

Heavy metals can be found in the soil and rocks of our earth. They can enter the water after volcanic eruptions and through the erosion of rocks, for example. You can therefore find low (background) levels of heavy metals in almost all waters.

However, human activities like mining and manufacturing processes, can cause very high levels of heavy metals in the water. Common uses of heavy metals in manufacturing include: lead and nickel in batteries, copper in textiles, silver in photographic film, and iron ore in steel production. Effluents from sewage (including effluents from industries) may carry high levels of heavy metals.

After heavy rains, urban run-off water carries elevated quantities of metals with it, for example lead from car exhaust, oil, and grease; zinc from motor oil and grease; and copper that has been worn off metal plating and brake linings.

Suspended solids eroded from croplands may carry copper, cadmium, and even uranium, which are both found in some phosphate fertilizers. Herbicides which are used to control weeds may contain arsenic or mercury.

Toxins like pesticides and heavy metals are known to have a wide range of harmful effects on organisms. They include cancer, loss of fertility, birth defects, blood disorders, genetic damage, hormonal and other chemical changes, disturbances in the central nervous system, damage to a number of organs and death. Often, it is very difficult to pinpoint the exact effects of toxins, because they are often present in complex mixtures, and toxins may also influence one another. Sometimes harmful effects appear only a long time after intoxication.

There are two important processes when toxins are consumed. One is bioaccumulation. When toxic substances enter the body of an animal, they usually stay there for a very long time. Toxins can be taken in directly from the water, or through the consumption of food containing toxins. Because toxins are only partly disposed of by the body, they can reach high levels, which are increasingly dangerous for the organism. Many organic pesticides and heavy metals bioaccumulate.

The second process is biomagnification. This term describes the increasing concentration of toxins as you move up the food web. Each animal accumulates the toxin load of all the creatures it has eaten. Animals at the top of the food web, such as eagles, and also people, are at risk of being exposed to high concentrations of toxic substances. For example, a particular toxin might be absorbed by a planktonic algae or consumed by a planktonic animal in levels that do not poison them. A minnow, however, eats thousands of these tiny plants and animals, each with its own small amount of the toxin. A bass or trout will eat hundreds of minnows, each with its amount of toxic substance gained from the thousands of pieces of plankton. Thus, the higher up this food chain you go, the more toxin you get with each bite. The substance has been 'bioaccumulated'. A person who eats only one meal of fish from a lake contaminated with bioaccumulating toxins may receive a higher dose of contaminants than someone who drinks the lake water his or her whole life.

Both bioaccumulation and biomagnification are slow pollution processes which are only visible when it is too late, when all the damage is already done.

2.3 Natural purification

Water has the capacity to purify pollution, as long as the degree of pollution is not very severe, and the pollutant is biodegradable.

Biodegradable means that a substance can be decomposed into its basic substances, that can be re-used for the growth of plants and animals. The decomposition of materials is done by bacteria and macroinvertebrates. Oxygen is used for the decomposition, and therefore the oxygen concentration in the water is a major factor determining the self-cleaning capacity of that water.

Temperature is also an important factor, since biological processes take place more rapidly when the temperature increases.

Besides decomposition by bacteria and macroinvertebrates, pollution is also reduced by physical and chemical processes in the water.

Recommended literature

WETZEL, ROBERT G.: "Limnology". Michigan State University, Saunders College Publishing, Harcourt Brace Jovanovitch Inc., Orlando, Florida, U.S.A. Second edition, 1983.

3 The Field Survey

When you experience or suspect water pollution which is problematic, it is good to know what kind of pollution you are dealing with, and where it is coming from. You should then start with a Field Survey. A Field Survey is very simple to conduct. It means that you examine the polluted water and the area where the water is coming from, just using your eyes, nose, and common sense.

A Field Survey involves looking at the different land-uses in the watershed, since the water quality is greatly influenced by activities on the land surrounding the water. You will also examine the water for strange colours and odours, since these may indicate water pollution. This chapter explains how you can conduct a Field Survey.

With the results of the Field Survey you will be able to describe the surveyed area in terms of possible pollution, and make an as complete as possible list of all potential sources of water pollution in the watershed. You will also have a good indication of what kind of water pollution you are dealing with. Although it is usually possible to see whether or not the pollution is severe, it is not feasible to be more precise about the amount and impact of the pollution.

A Field Survey is the proper way to prepare for a more elaborate study of the water quality. Therefore, it is the first step in this manual. You can also conduct Field Surveys before a pollution problem is suspected, for education purposes, as an early warning system, or to collect reference data, for example. It is very useful to conduct Field Surveys also between the other surveys and activities discussed in this manual.

3.1 Conducting a Field Survey

The Field Survey is very simple, and requires very little equipment: basically you need a clip-board, pencils, and the Field Survey Data Sheets nos. 1, 2 and 3 (see Appendix 1, 2 and 3). Boots reaching your hips, a camera and a compass, if available, are helpful.

The Field Survey involves three areas where you inspect the water for strange colours and smells, and list the present types of land-uses, using the Field Survey Data Sheets.

First you inspect the area in which you suspect or experience pollution. This is called the *surveyed area*, and can be a part of a river or lake, or a drinking water source. Following is an inspection of the complete water body in which the surveyed area is located, the complete lake or river, for example. Lastly you inspect the whole watershed in which the water body (and thus the surveyed area) is located, as complete as possible.

The Field Survey can be conducted walking overland or through the water, or by boat. It is best to use a combination, to be able to collect more information.

A camera is useful in documenting. Be sure to label all pictures with the proper location, date, time and photographer's name. You can also record a short description of the pictures taken. It may be helpful to have photographic stations where pictures are taken at various times of the year and over a period of several years. These will make slowly occurring changes more evident.

The Field Survey should be conducted by more than one person. Two or more persons will do a better job describing the characteristics of the area. If possible, form survey teams of people with diverse backgrounds. Include at least one local person in each team. Local people often know a lot about the land and the water, about its history, and its changes. Use one set of Field Survey Data Sheets for every small group of surveyors.

If possible, establish a good relationship with the landowner(s). Ask for permission to walk over private land before you conduct the survey, and try to involve land-owners in the survey.

3.2 Mapping of the area

During the Field Survey, you should draw at least two maps. One map (see Figure 3 as example) gives a detailed picture of the surveyed water. The second map should cover the whole watershed in which the surveyed water(s) is(are) located. This is called the general map of the area (see Figure 4). If you survey more areas, make a detailed map of each of them. For clarity, it may be advisable to draw also a map of the complete water body in which the surveyed water is located.

On each map, make a small box in a corner which states the name of the person drawing the map, the date, and the municipality or province of the area.

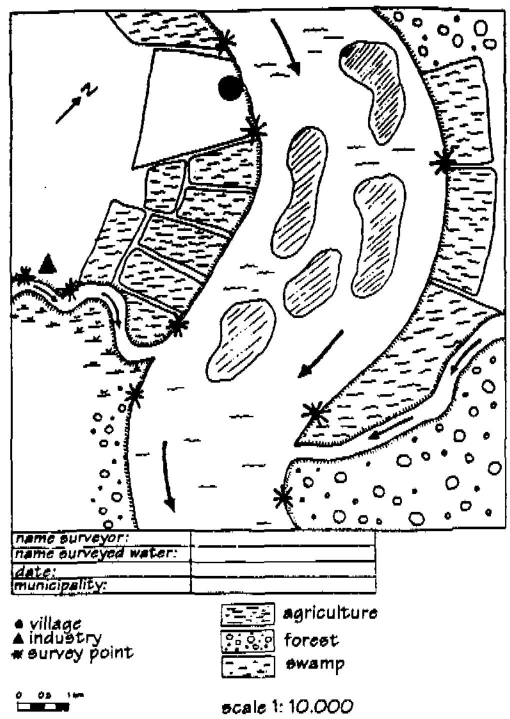


Figure 3: Map of the surveyed water

On the general map, also include the name of the watershed; on the detailed map, the name of the surveyed water.

Always mark the scale of the drawing and the 'legend' explaining the symbols you use. Always draw the direction(s) of the stream flow(s) and an arrow pointing north.

If possible, draw the boundaries of the areas belonging to national, regional or local administrative authorities (provinces, municipalities etc.), and altitude lines if the area is hilly or mountainous.

The following items should be drawn on each map: the boundaries of the watershed, all major waters and some of the major towns and cities within the watershed, the observation points of the Field Survey (name and number), different types of land- and water-use, and any structures in and around the water (for example islands, bridges, dams, weirs, locks). Mark the location of the surveyed water(s) on the general map (and on the map of the water body, if drawn).

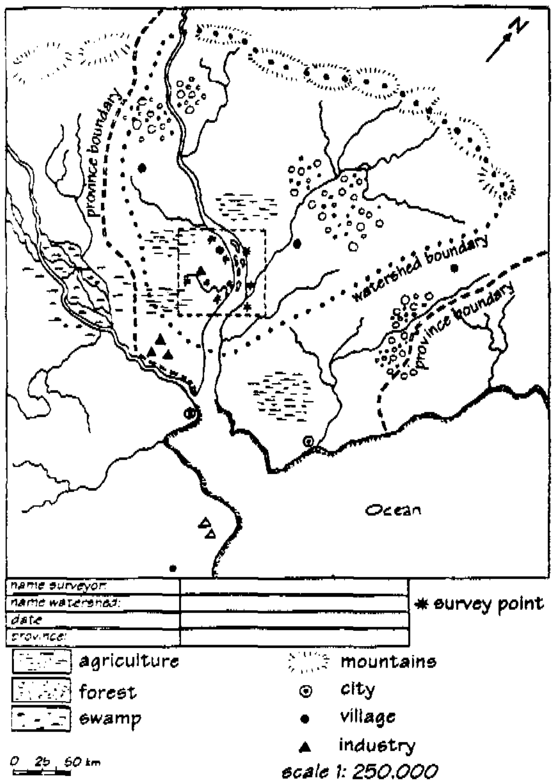


Figure 4: General map of the area

Besides drawing your own maps of the surveyed area, it is very helpful to make use of existing maps as well. This usually provides additional information, and helps to broaden the understanding of the area.

3.3 Location of the observation points

Observation points are locations within the surveyed area and the watershed of the surveyed area where you find indicators of pollution. Mark all observation points on your maps, number them and describe them on Field Survey Data Sheet no. 1.

To find out whether a certain site in a standing or a flowing water is polluted or not, examine this specific location. For example, you might want to know whether the site where people collect drinking water is polluted.

To identify the possible source(s) of pollution, use several observation points. The type of places you select will be different for standing and flowing waters.

When you are surveying a standing body of water, like a lake or a pond, ideally you should survey the complete water body and all inflowing waters. Pollution can enter the lake via overland run-off water, via groundwater, via inflowing waters like rivers and streams, or via atmospheric deposition. Be aware that it may also be a combination of sources. The amount of water flowing out of the lake (including evaporation), compared with the amount of inflowing water, gives you an idea of how much the pollution level increases in the lake.

When water pollution occurs in a stream or river, the best place to observe the effects is downstream of the suspected pollution source(s). The exact point downstream to survey varies. If the water flows very rapidly, you may have to make observations for some indicators at a distance downstream where the flow is slower. This is especially true when surveying possible effects or indicators of nutrients, because the effects of excessive nutrients often do not show in flowing waters until the stream velocity is low.

To locate the exact point of pollution, move upstream until you find water which does no longer show the indications of pollution. The distance you must move can vary greatly. Sometimes you will find a factory within 200 metres upstream of your surveyed water, but it is also possible that pollution is caused by farming, logging and/or mining activities somewhere far away, upstream in your watershed. Therefore it is recommended that you know what the complete watershed looks like, with a list of all potential pollution sources that is as complete as possible.

To describe the pollution in terms of impact, you can compare locations above and below the source of pollution. Use upstream observation point(s) which are obviously unpolluted as a reference.

3.4 The Field Survey Data Sheets

Of course it is very important that all the information you gather is documented and mapped very clearly. If you do not document properly, the data you have gathered cannot be used.

To record the information gathered during the Field Survey, use the Field Survey Data Sheets, which can be found in Appendix 1, 2 and 3. Discuss the data sheets before the survey starts with all participants, ensuring that all items are understood. Provide each team of surveyors with a set of data sheets, if possible together with a copy of an original map of (the section of) the water to be surveyed. Each team of surveyors should draw the maps as explained in Section 3.2.

As much as possible, try to adopt the Data Sheets to the local circumstances, eventual by adding other relevant items, and/or leaving irrelevant items out.

Do not write on the original Field Survey data sheets. Make copies and write on those.

The filling in of the Field Survey Data Sheets can never be done in an office!

3.5 What to do

1. Clearly write down the reason(s) why you want to conduct a Field Survey and, as comprehensive as possible, the goals you want to achieve.

2. Determine the area(s) you want to survey, which can be the area(s) where you experience or suspect pollution. Determine the complete water body and the watershed in which the surveyed area(s) is(are) located. If possible, use existing maps.

3. Form small groups of surveyors, composed of local people from the area (including land-owners), people from any involved organisation, and eventual other interested persons and experts.

4. Discuss with the participants the reason(s) and objectives of the Field Survey, the area(s) to be surveyed, and the Field Survey Data Sheets. Be sure that all other materials needed for the survey (for example a camera, a boat) are available and ready for use.

5. Start with walking and/or boating through the area you want to survey. Fill in the 'General data' and the 'Description of surveyed area' on Field Survey Data Sheet no. 1. Make a map of the surveyed area as described in Section 3.2.

6. Determine observation points in the surveyed area (see Section 3.3). Mark the observation points on the map, number them, and describe them on Field Survey Data Sheet no. 1.

7. Examine all current types of land use and their possible impacts in the surveyed area, using Field Survey Data Sheet no. 2. Mark all the land-uses you have found on your map. Again, use numbers or codes to highlight the areas of different land-uses on your map.

8. Inspect the water for unusual colours and/or smells. If you notice a strange colour and/or a strange smell, use Field Survey Data Sheet no. 3 to look for possible sources.

9. If you take pictures, write down the number, location, date and a short description on Field Survey Data Sheet no. 1.

10. When you want to survey more areas, conduct step 5 up to and including 9 for each area.

11. After you have examined the area(s) you want to survey, try to get an overview of the complete water body and the complete watershed in which the surveyed area(s) is(are) located. If you are surveying a flowing water, walk upstream and note all its tributaries (side-streams). Try to do the same walking downstream. When you are surveying a standing water, locate all in- and outflowing waters, and follow the inflowing waters upstream.

12. Fill in the 'Description of water body' and the 'Description of watershed' on Field Survey Data Sheet no. 1, and draw a map of the watershed (see Section 3.2). If needed draw a map of the water body.

13. Estimate the stream velocity of a flowing water by marking a distance of 10 metres on the shore, parallel to the water. Put a floating object in the water upstream of the marked strip. Registrate the number of seconds it takes your floating object to cover the marked distance. Calculate the stream velocity by dividing the number of meters covered by the amount of seconds (expressed in metres per second). Repeat this test at least 2 times and calculate the average stream velocity.

14. Determine observation points in the watershed (see Section 3.3). Mark the observation points on the map, number them, and describe them on Field Survey Data Sheet no. 1.

15. Again, use Field Survey Data Sheets nos. 2 and 3, when you make an inventory of the whole water body and the watershed. Try to be as comprehensive as possible.

16. After conducting the Field Survey, make an assessment as explained in Section 3.6.

3.6 Assessment

Once the survey is completed, you can use the information on the Field Survey Data Sheets to make a summary that describes the watershed and the surveyed area(s) in terms of possible pollution and all potential sources.

When the results of the Field Survey indicate pollution, there are various ways you can proceed. When you suspect that the pollution is related to diseases, you may want to conduct the Health Survey explained in

Chapter 5. The Health Survey can give you conclusive evidence on the presence of bacteriological pollution, and its source(s).

If you want to know more about the degree of pollution and its impacts on the environment, you may decide to conduct the Biological Survey. The Biological Survey is explained in Chapter 4.

When you want to detect precisely the distribution of industrial or sewage pollution, or when you want to know the exact level of oxygen in the water, you may conduct some physical and chemical analyses explained in Chapter 6. This chapter also explains what to do when you want a laboratory to analyze your water for heavy metals, pesticides or other toxins.

When the Field Survey gives enough information about the type of pollution occurring and its source(s), you may decide to read Chapter 7 and 8 and look for activities you can undertake to reduce the pollution problem.

Recommended literature

DICKMAN, M.: "Waterways walkabout". Biological Sciences Department, Brock University, St. Catharines, Ontario, Canada L2S 3A1. Second edition, 1992.

RERRELL, CHARLES R. and Dr. PATRICIA BYTNAR PERFETTI: "Water quality indicators guide: surface waters". Soil and Conservation Service, United States Department of Agriculture, Washington, D.C., 1991.

4 The Biological Survey

Because of their dynamics, rivers and streams are constantly changing. A section of water that is polluted today may be flushed clean next week. To a lesser extent, the same is true of ponds and lakes. Therefore, when you only look at the water itself (physical and chemical analysis, see Chapter 6), you may very well miss pollution problems that affected the water quality during a previous period.

However, pollution also effects the plants and animals living in the water. Those effects can be seen not only while pollution is occurring, but also some time after it has stopped, and are thus very good indicators of water pollution. Biological indicators also give a good picture of the long-term effects of pollution on the ecosystem.

The Biological Survey is very similar to the Field Survey discussed in Chapter 3. The only difference is that you do not investigate colours, odours and land uses, but the plants and animals living in and around the surveyed water(s).

The Biological Survey uses only the general types of plants and animals, because it has to be usable all over the world. However, one type of animal or plant actually consists of a big group of different species of this animal or plant, each species with its own special characteristics. For instance, there are more then 400 species of caddisflies, but the manual only talks about one caddisfly in general. The use of more specific indicator organisms will always give you more specific information.

With the results of a Biological Survey you will be able to determine the degree to which the water is polluted, ranging from unpolluted to fair, moderate and severe pollution. The results of a Biological Survey can give a strong indication of the type of pollution that is occurring and its source(s). However, physical and chemical analyses are needed to provide conclusive evidence.

With the Biological Survey you cannot detect pathogens (disease-causing organisms) in water. For this purpose you need to conduct the Health Survey explained in Chapter 5. Although the presence of toxic substances may be strongly indicated with the Biological Survey, it is not feasible to determine what types of toxin are present. Physical and chemical analyses are therefore also needed (see Chapter 6).

4.1 Biological indicators

In general there are two approaches to using plants and animals as indicators for water quality: the diversity of a given community of plants or animals, and the sensitivity of specific organisms to pollution.

(Bio)diversity

The number of different types of organisms found in a biological community is known as (bio)diversity. A high diversity means that there are many different types of organisms, and each type is occurring in low numbers. Low diversity means that there are only a few types of organisms, and each type is occurring in high numbers. In general, non-polluted waters have a high diversity, while polluted waters have a low diversity, or even no visible organisms at all. Thus, diversity can be used as an indicator of the degree of water pollution.

The manual explains the general use of the diversity of water plants and fish as indicators of the water quality. For macroinvertebrates (small water animals) the Sequential Comparison Index (SCI), which is based on the diversity of the macroinvertebrate community, can be used to calculate the degree of pollution (see also Section 4.11).

Sensitivity

Some organisms can survive in water that is polluted. These species are 'tolerant' to pollution. Others are very sensitive to changes in the water quality, and are 'intolerant' or 'sensitive' to pollution.

Organisms that are known to be either sensitive or tolerant to pollution can be used as indicators for the water quality. This chapter gives several types of bacteria, algae, fish and vertebrates that can be used as indicator organisms. The sensitivity of macroinvertebrates to pollution is used in the Pollution Tolerance Index (PTI) to describe the degree of water pollution.

In order to know whether the absence or presence of certain plants or animals indicates water pollution, you first of all have to know where and when these plants and animals occur naturally. In a given water body the absence of shrimps, which are sensitive to pollution, may only indicate pollution if the shrimps are normally present in this water. It is useless to look for bottom-dwelling small water animals on the surface of a deep lake, neither will you find large amounts of free-floating (planktonic) algae in a fast-flowing brook. Check the natural habitats of specific animals and plants by using the information in Chapter 1 and Appendix 6 and 7, and use additional literature sources if available.

You should also bear in mind that the absence of certain animals or plants may also be due to factors other then pollution. For example, when there are only a few types of fish present (low diversity), this may indicate pollution, but it may also be caused by overfishing. Similarly, the absence of water plants may be caused by pollution, but may also be due to seasonality, or the extreme shade from overhanging trees, for example.

4.2 Choosing biological survey points

During the Biological Survey you first of all may want to inspect the places where you expect water pollution, such as near an industrial waste discharge pipe, or in a water bordering on a banana plantation. Choose the biological survey points as close as possible to the suspected pollution source(s). The locations of such biological survey points can be determined with the findings of the Field Survey, and/or through other observations. Make use of the maps drawn during the Field Survey, and/or other maps.

After inspecting the sites with suspected water pollution, you should survey the water body in which the suspected pollution is occurring as thoroughly as possible. In this way you will obtain an overview of the water quality in the entire water body, enabling you to compare the degree of pollution at different sites, and helping you determine the source(s) of the pollution.

When inspecting a certain point source of pollution or disturbance in a flowing body of water, for example a factory or a large dam, you can compare biological survey points upstream and downstream of the source. Select two points upstream of the source, and three or four downstream, for example. When you are surveying a standing water, you can compare locations close to the pollution source or disturbance, and locations in an area where you do not expect there to be pollution effects, on the opposite shore of the lake, for example.

In cases where you do not suspect any particular pollution, your aim might also be to survey a water body to determine its biological quality. The ideal method would be to compare the water body to be surveyed with a similar water body that is clearly not polluted. In this case, you can use the non-polluted water as a reference or standard, and focus on the differences. However, the reference water must be very similar to the water you are surveying, and the survey methods identical, to make sure that any differences you find are due solely to pollution or disturbance. The habitat of the areas you intend to compare should be so similar that the plants or animals considered have the same types of factor influencing their presence. For example, it is useless to compare the upper stretch of a river (near the source) with an estuary. Important factors influencing the habitat of water organisms are the depth, the stream velocity and the type of bottom. Characteristics of the habitats of specific plants and animals are summarized in Chapter 1 and Appendix 6 and 7.

When you are surveying algae and water plants you should bear in mind the influence of overhanging trees, etc. Shade can result in great variation, even on two shores of the same water.

Bear in mind that locally modified sites, such as small impoundments and bridge areas, may also have local effects on the water quality.

Do not sample for macroinvertebrates shortly after heavy rainfall, unless you have specific reasons. This is because more animals will be washed away after such an event.

4.3 The Biological Survey Data Sheets

There are two Biological Survey Data Sheets, numbered 1 and 2, that can be found in Appendix 4 and 5. On the first data sheet general data about the survey and the surveyors should be filled in (at the start of the survey), together with a description of the water body (at the end of the survey).

On the second data sheet information about the different biological indicators can be written. After a short list of items describing the biological survey point, the data sheet lists the information on the various plants and animals that should be gathered when you decide to use that particular type of plant or animal as indicator. For the macroinvertebrates the calculation of the SCI and the PTI is given.

Use one copy of Biological Survey Data Sheet no. 1 for the complete Biological Survey. Use different copies of Biological Survey Data Sheet no. 2 to describe each biological survey point.

Besides the Biological Survey Data Sheets nos. 1 and 2, you need plain white paper to draw all the types of plants and animals you observe and use as an indicator.

4.4 Drawing plants and animals

It is very important that you make drawings of all types of plants and animals you observe during the Biological Survey. Make the drawings on plain white paper (not yet enclosed in this manual), and add this to the Biological Survey Data Sheet no. 2 of the corresponding survey point.

It is very important to make all drawings as accurate as possible, to be able to compare the findings of the various groups within on Biological Survey, and to compare results of different Biological Surveys (conducted in different waters, or in one water at different times).

On each drawing, write down the name of the person making the drawing, the date, and a description of the exact location where you have found the plant or animal (if possible with number and reference to a data sheet). Always describe the colours of the plant or animal, and mark the scale of the drawing.

When drawing plants, pay special attention to the number of leaves and if they are attached to the stem in a certain pattern. When flowers are present, pay attention to the number of petals, their shape, and the way they are attached to the plant.

When drawing animals, pay special attention to the shape of the body, the number of legs, the number and shape of the tail(s) and any projections.

4.5 What to do

1. Use the motivation and the conclusions of the Field Survey (and/or other findings) to write down the reason(s) why you want to conduct a Biological Survey, and the objectives you want to achieve.

2. As explained in Chapter 3, form small groups of participants with about 4 to 6 persons in each group. Discuss the reason(s) for and objectives of the Biological Survey, and explain how the data sheets should be used. Be sure that all the necessary sampling equipment is available and ready for use.

3. Based on the findings of the Field Survey and/or other observations, determine the biological survey points. Use the maps drawn during the Field Survey, and/or other maps to record the exact locations.

4. Copy Biological Survey Data Sheets nos. 1 and 2 (never write on the original). Use one copy of data sheet no. 1 for the entire survey. Use a new copy of data sheet no. 2 to describe each biological survey point.

5. Add sufficient plain paper to the manual to be able to make drawings of all types of animals and plants that you observe and use as indicators.

6. First inspect all the identified biological survey points. Fill in the 'General data' on data sheet no. 1. Use a new copy of the Biological Survey Data Sheet no. 2 for each biological survey point. Fill in the 'Description of biological survey point' and mark the exact location of the survey point on a map. Conduct step 6 up to and including 9 for each biological survey point you identify.

7. Estimate the stream velocity using the directions given in Section 3.5, and draw two small maps of each biological survey point: one top view and one cross section.

8. Regarding the bacteria, algae, large water plants and vertebrates, as explained in Sections 4.6 to 4.9, check the biological survey points

for their occurrence. Describe the site(s) and the nature of occurrence on the Biological Survey Data Sheet no. 2. Make accurate drawings (on separate plain paper) of all types of bacteria, algae and large water plants that you have observed, as explained in Section 4.4.

9. Regarding the fish, decide whether to only record visual observations of fish behaviour, or to catch fish for a more intensive study (see Section 4.10 for further explanation). Describe your method of survey and your findings on data sheet no. 2, and make accurate drawings of all types of fish that you have observed (see Section 4.4). Always collect as much as possible information from (local) authorities, universities and local fishermen about the occurrence of fish.

10. Regarding macroinvertebrates, use the methods explained in Section 4.11 to choose sampling locations to do the sampling. Describe the sampling area on data sheet no. 2. Make accurate drawings of all types of macroinvertebrates that you have observed (see Section 4.4), and calculate the SCI and PTI.

11. After inspecting all identified biological survey points, survey the complete water body as fully as possible. Determine other biological survey points (if necessary) with the aid of the suggestions given in Section 4.2. Again use new copies of data sheet no. 2 for each biological survey point you determine. Fill in the 'Description of water body' on data sheet no. 1.

12. After conducting the Biological Survey, make an assessment as explained in Section 4.12.

4.6 Bacteria

Sewage fungus, which is a type of bacterium (*Sphaerotilus natans*), is usually observed as slimy, cotton-wool-like plumes (usually white, grey or brown) clinging in long streamers to twigs or leaves, or attached to the water bottom. Sewage fungus is an indicator of organic pollution in flowing waters. For example, sewage fungus often appears in waters receiving wastes from paper mills, sugar refineries, canneries, breweries, alcohol refineries and municipal sewage pipes. If you find a growth of sewage fungus, move upstream until you find the source of organic pollution, usually not far away.

4.7 Algae

Natural occurrence

The presence of algae depends mainly on the amount of sunlight and the amount of nutrients available. The stream velocity determines whether benthic or planktonic algae occur.

Algae only occur in the upper part of the water body, where sunlight can still penetrate. Planktonic algae are free-floating in the upper layer of slow-moving or standing waters; benthic algae are usually attached to submerged substrates just below the water surface, and occur in flowing waters.

When there is enough sunlight, algal growth is usually limited by the amount of food (nutrients) available. In most waters, an increase in nutrients (coming from farmland or sewage, for example) will result in a larger algal population. Thus, the presence of a huge amount of algae usually indicates nutrient pollution.

Continuing nutrient pollution in standing waters can result in massive growth of planktonic algae, which is called an algal bloom. The massive death of these algae causes organic pollution and leads to serious oxygen depletion in the water, or even a total lack of oxygen.

Water that looks like pea soup contains blue-green algae. Many blue-green algae secrete toxins or foul-tasting substances. This makes blue-green algae most unattractive as food to other organisms, which allows them to grow unchecked by predators. Water containing many blue-green algae is unfit for drinking, both for animals and people.

Indicators

Good-quality waters have sparse to moderate amounts of algae. Waters with very little or no algae may be affected by toxic substances or may be located in areas with very low levels of nutrients. However, those findings can only be done with the aid of a microscope.

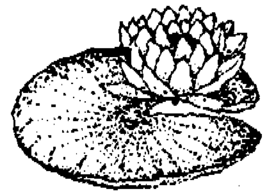
In flowing waters *benthic algae* (algae that are attached to a substrate), which can be seen with the naked eye, can be used as indicators of the water quality. Benthic algae that indicate pollution are usually known as pond scum and seaweed. There are also types of benthic algae that are sensitive to pollution and thus indicate clean water. Appendix 6 describes a number of benthic algae (which are visible with the naked eye) that are indicators of clean or polluted water.

Planktonic algae can be used as indicators of nutrient pollution in standing and slow-moving waters when they are present in huge amounts, since then they can be seen as a colouring of the water (algal bloom). Water may adopt a deeper colour of various shades of green, blue-green, red or brown, depending upon the type of algae present. Individual planktonic algae can only be seen with a microscope, and will therefore not be used as indicators in this manual.

Oxygen depletion, caused by the death of massive amounts of algae (organic pollution), is indicated by strange fish behaviour and fish kills (see also Section 4.9).

The process of nutrient enrichment, which is called eutrophication, has three different phases which can be easily recognized. When nutrient pollution is fair, there will be an abundance in the growth of large water plants. When the nutrient pollution becomes moderate, massive algal mats will be formed. Finally, when the nutrient pollution becomes severe, the water will be completely dominated by plants that live in the upper part of the water. When present, water plants with leaves floating on the surface will dominate. Otherwise blue-green, free-floating algae will dominate, giving the water a pea-soup appearance.

Natural occurrence



The kind and amount of water plants occurring depend on various factors, including the amount of sunlight, the stream velocity, the type of bottom, the amount of nutrients and the depth of the water. Most water plants occur in slow-moving or standing waters that are not very deep.

Sunlight is very important for plants. A reduction in sunlight can be caused by many factors, including heavy siltation, heavy algal growth, dense shading (for example by trees overhanging the water, or by water plants with leaves floating on the water surface), and of course the depth of water, since this limits the penetration of light.

Usually the depth of the water is the major factor determining the types of plants occurring. Different types of water plants form concentric bands in the water. The shallow region around the edge of the lake is colonized by plants that have their roots in the water bottom but most of their other parts above the water, like papyrus. Moving to the deeper area of the lake, the next band is formed by plants with floating or submerged leaves, with or without their roots in the water bottom, like the water hyacinth and the lotus. In the deepest water where light can still reach the bottom, you can find completely submerged plants, with or without their roots in the water bottom.

The best way to find out what type of water plants are naturally occurring in a certain area is to collect information about the historical occurrence of water plants in that area. Try to collect as much information as possible about the changes in the occurrence of water plants over time (from local people, for example), and list all possible reasons for the changes (change in water level, construction activities, water quality, for example).

Indicators

Slow-moving, relatively clear and shallow waters have the greatest amount of plant growth. When this type of water body has many different types of water plants (high diversity), it usually means it is not polluted.

When the diversity decreases during a certain period of time in an area of high diversity, this may indicate pollution. Bear in mind that besides water pollution, a reduction in diversity may also be caused by the change of season, by certain animals or people, or by a change in the water level or in stream velocity. Try to identify the possible causes of the reduction.

The dominance of only one type of water plant usually indicates high levels of nutrients. The water hyacinth (Eichhornia crassipes), for example, is a species of water plant that easily dominates other plants when nutrient pollution increases. An abundance of water hyacinth therefore usually indicates eutrophication.

When the water surface is completely covered with plants with floating leaves, this probably indicates a depletion of oxygen in the water, because oxygen can no longer be supplied from the air. The water quality is then probably poor.

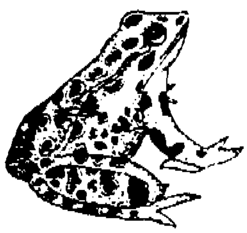
A huge amount of dead plants in the water, or an absence of water plants, indicates a depletion of oxygen, heavy sedimentation, or the presence of toxic substances. Of course it may also be due to a combination of pollutants.

When there is considerable sediment deposition, water plants may never reach full size and are not able to reproduce. Eventually an entire population of water plants may be smothered and die.

4.9 Vertebrates

The animals at the end points of the food web (see also Section 1.4 and Figure 2) are usually vertebrates (having a backbone). These animals, such as predatory fish, birds and mammals who eat fish, are dependent on all other organisms. When certain macroinvertebrates die out, for example, this will affect the larger animals that feed on these macroinvertebrates. Also, toxic substances ingested in small amounts by small animals can accumulate in the bodies of large animals to levels that are very harmful (see also Chapter 2, pesticides and heavy metals). These animals are therefore indicators of the health of the entire aquatic community. A historical record of the kinds and numbers of vertebrates living in a certain area is a very valuable indication of the water quality over a longer period.

Always record the vertebrates you see and/or hear, and ask local people what type of animals are occurring, and if there are any historical changes in the occurrence of the various animals.

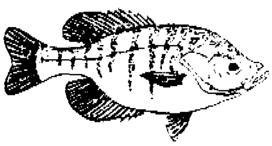


Reptiles and amphibians should be noted when seen and also when heard. Most frogs and toads have characteristic calls and can be identified by listening. Most frogs and toads are sensitive to pollution. For example, when a body of water becomes very acid (pH<4, see also Chapter 6), the eggs of frogs will shrivel.

Birds, of course, can be seen easily and can also be identified by songs or calls. The occurrence and diversity of fish-eating birds are indicators of the water quality. Birds are sensitive to toxins such as pesticides and heavy metals, which affects their fertility and weakens the shell of their eggs, for example, thus reducing their reproductivity.

4.10 Fish

Natural occurrence



Fish are usually present even in the smallest and all but the most polluted waters. The fish community generally includes a range of species that represents a variety of feeding (trophic) levels. These feeding levels include plant eaters, (herbivores), plankton eaters (planktivores), plant and animal eaters (omnivores), insect eaters (insectivores) and fish eaters (piscivores). A fish community in which one or more of these feeding levels are missing or severely reduced could indicate pollution or other impacts on the water.

The occurrence of fish species varies tremendously in different habitats all over the world. Many species are occurring only in one region of a particular country; there are even species that only occur in one part of one particular stream in a country. By consulting literature and/or experts (via the Ministry of Fishing or via a university, for example), check which types of fish occur in the specific waters of your country, and try to find out more about their habitat preferences and sensitivity to (different types of) pollution.

To find out what types of fish naturally occur in a given water body, especially ask local fishermen or other people. They may also be able to give you information about any historical changes that have occurred in the fish population.

> *Because of the abundance of common names (the same fish may even have different names in various regions of one country) and because many small, lesser known fish have no common names, it is important to be familiar with the scientific names of fish. The scientific name consists of two parts, the generic name (genus; plural genera, written with a capital) and the specific name (species, written with a small letter). For example, the scientific name of the large-mouth bass is Micropterus salmoides and the small-mouth bass is Micropterus dolomieui. The genus name Micropterus, which both share, shows a relationship between the two fish, while the species name, salmoides or dolomieui, shows each to be a unique type. Genera of fishes which have some characteristics in common are grouped into families. The genus Micropterus is placed in the sunfish family (Centrachidae) which also includes blue-gill and other sunfish (genus Lepomis) and crapples (genus Pomoxis).*

Indicators

Some fish are more tolerant to pollution than others. Fish that are sensitive to pollution include salmon, trout, and minnows such as goldfish.

Usually fish living close to silt and mud bottoms are more tolerant to organic pollution, since they are used to living in a habitat with less oxygen.

Predator fish that use their eyes for hunting, pike for example, need clear water, and thus are sensitive for pollution (organic matter, suspended solids and nutrients). Predator fish that do not hunt on site, such as the carp and bream, can survive in polluted waters.

Massive death of fish usually indicates a severe depletion of oxygen, which is caused by heavy organic pollution. Massive fish kills can also be caused by oil pollution or severe pollution with other toxic substances.

Fish swimming near the surface, gasping for air at the surface, slowing down in their movements, changing colour or swimming in circles (erratic swimming) may indicate the presence of toxic substances in the water.

Red sores or white cottony-like places on fish indicate the presence of disease. Several diseased fish in a given area may indicate the presence of toxic substances at levels not great enough to immediately kill the fish.

Damage to the organs of fish and tumours (which can be seen when you cut open the fish) are usually caused by toxic substances.

In all cases concerning toxic substances, you need to conduct chemical analysis to discover which types of substances are involved (see Chapter 6).

Methods of sampling

Fish may be collected by a variety of methods. It is most practical to use the knowledge and skills of local fishermen, when present. You can inquire about their fish catches, and/or ask them to catch fish for you.

For small- and medium-sized flowing waters, especially, the most practical way of catching fish yourself is to use a minnow seine (net) measuring about 1 by 1.5 metres. Fish sampling in riffles is most easily accomplished by collecting in a five or six square foot area at a time. One or two people should hold the net stationary, at an angle of 45° to the water in a downstream direction, with the bottom end of the seine on the water bottom. Another one or two individuals should move five or six feet upstream from the net, start disturbing the substrate with their feet, and slowly work towards the net. When the collectors reach the net, it should be lifted from the water and taken to shore. When seining standing waters, make short seine hauls, preferably starting near the middle of the lake and working towards the bank. The fish should be identified quickly and returned to the stream unharmed as soon as possible.

Specimens from a fish kill which may require laboratory analyses should be wrapped in aluminum foil, placed in a plastic bag, and deep frozen.

4.11 Macroinvertebrates

Macroinvertebrates (small water animals) are useful indicators because they are relatively immobile compared with fish, and thus cannot escape pollution. They are also sensitive to pollution. If the water is mildly to severely polluted, some types of animals will die. Since it usually takes some time for the normal community to fully recover once the pollution has stopped, you continue to see the effects for a long period.

Natural occurrence

Every type of macroinvertebrate has a preference for certain living conditions. For example, some prefer to live in fast- flowing rapids, while others are commonly found in standing waters. Besides stream velocity, the type of bottom is an important factor influencing the presence of macroinvertebrates. Benthic macroinvertebrates live close to the water bottom. Many benthic macroinvertebrates prefer to live on hard substrates like rocks, submerged stones, etc.

Many benthic macroinvertebrates live in so-called *riffle areas*. A riffle is a rapid in a flowing water. The optimum living area for small water animals is a riffle uniformly composed of any bottom material ranging in size from 30-centimetre stones ('cobbles') to 3-centimetre gravel. This provides a stable bottom. In addition, the constant flow of water provides a constant supply of food and oxygen. The deepest parts of very large rivers support few, if any, small water animals, because their silty bottom is unstable and most of it lacks oxygen (silt has a high organic content).

Streams with silt or mud bottoms (thus consisting of very small particles) support macroinvertebrates like tube-building worms, burrowing mayflies, blood worm midges, mussels and clams. Intermediate between cobble/gravel and mud/silt stream beds are sandy beds. Sandy bottoms support very few, if any, macroinvertebrates because shifting sands provide few stable surfaces to which organisms can attach themselves.

Appendix 7 lists the major types of macroinvertebrates occurring in fresh waters. Remember that, although correct, the descriptions and drawings are very general, and that in every water you will find deviations and exceptions.

Indicators

You can obtain a lot of information about the condition of the community of macroinvertebrates and about the water quality without identifying the animals. Simply by carefully sorting and grouping the animals that look alike, you can determine the number of types present, and thus the diversity.

If a good variety of types is present, with small numbers of each type observed or collected, the water probably is of good quality. A water body of poor quality will generally have only a few types, with large numbers of each.

The *Sequential Comparison Index (SCI)* indicates the diversity of a macroinvertebrate community by measuring the distribution of individuals among types of organisms. This measure is easy to use by people unfamiliar with the identification of macroinvertebrates. The SCI is based on the theory of runs. A new run begins each time an organism picked from a sample looks different from the ones picked before. To sort, use primarily body shape and number of legs and tails; secondary characteristics such as size and colour patterns may also be used.

$$SCI = \frac{\textit{number of runs}}{\textit{total number of organisms picked}}$$

The SCI ranges in value from 0 to 1, with the following water quality ratings:

0	- 0.3	*poor water quality*
0.3	- 0.6	*fair water quality*
0.6	- 1	*good water quality*

Appendix 7 lists the most important types (genera) of macroinvertebrates living in fresh waters. As mentioned earlier, one type of macroinvertebrate counts many different species as well. The best way to measure the diversity of a macroinvertebrate community is to count each species as a new run. However, since it can be quite complicated to distinguish the different species of one genus (you certainly need an elaborate determination key and a binocular), the SCI in this manual is restricted to the general types (genera) of macroinvertebrates.

The *Pollution Tolerance Index (PTI)* is based on a comparison between the number of pollution-tolerant macroinvertebrates in the water and the number of intolerant macroinvertebrates. With this method, you can distinguish excellent, good, fair and poor water quality. For this method, a determination key and some knowledge about the macroinvertebrates are required.

The ratio between pollution-tolerant and pollution-sensitive macroinvertebrates indicates the quality of a water. A large number of tolerant macroinvertebrates and a few, or no, intolerant macroinvertebrates means that the water is polluted.

The total number of macroinvertebrates may not change, however, if pollution-tolerant macroinvertebrates increase in number. Note that the presence of pollution-tolerant macroinvertebrates alone is not an indication of pollution, since they can also be found in unpolluted waters.

Macroinvertebrates are collected and identified by comparing them with the descriptions and drawings given in Appendix 7, and by using the identification sheet given in Figure 5. If they are available, you can also use other identification keys. The different types of macroinvertebrates are then divided into four groups, based on their tolerance to pollution. Each of the four groups is given an index value, with the least tolerant group having the highest value (see also Figure 5 and Biological Survey Data Sheet no. 2).

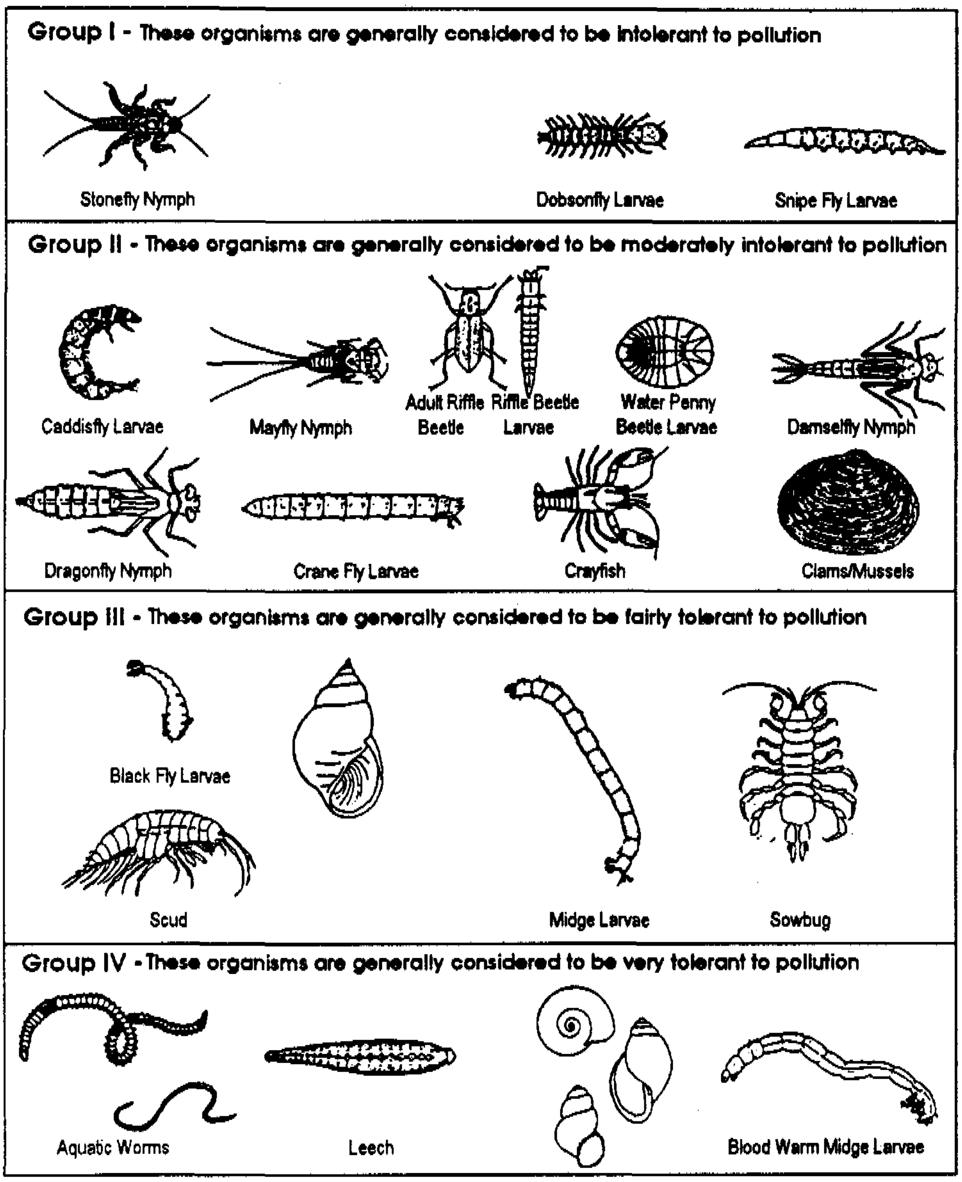


Figure 5: Identification sheet macroinvertebrates

A water quality value is determined by multiplying the number of types of macroinvertebrates in each group by the index value and adding the resulting three numbers together.

Calculate the Pollution Tolerance Index by multiplying the number of types of macroinvertebrates in each group by the index value for that group (1, 2, 3 or 4), and add the resulting four numbers. Then divide the total of all group scores by the total number of different types of macroinvertebrates found (see also Biological Survey Data Sheet no. 2).

Methods of sampling

You need the following things for sampling macroinvertebrates (see also Figure 6): a net, white trays (never place animals from different samples together in one tray), forceps, and the list of macroinvertebrates given in Appendix 7. Although not necessary, it is useful to have a soft brush to remove animals from stones etc, and a more elaborate identification key. If you want to collect macroinvertebrates for further study, a 70% alcohol solution, a number of small sample bottles and a pair of binoculars are required.

It is very important that everybody who conducts a Biological Survey always uses the same method of sampling, and always samples the same size in one location. This is the only way in which you can compare the results of different Biological Surveys with each other.

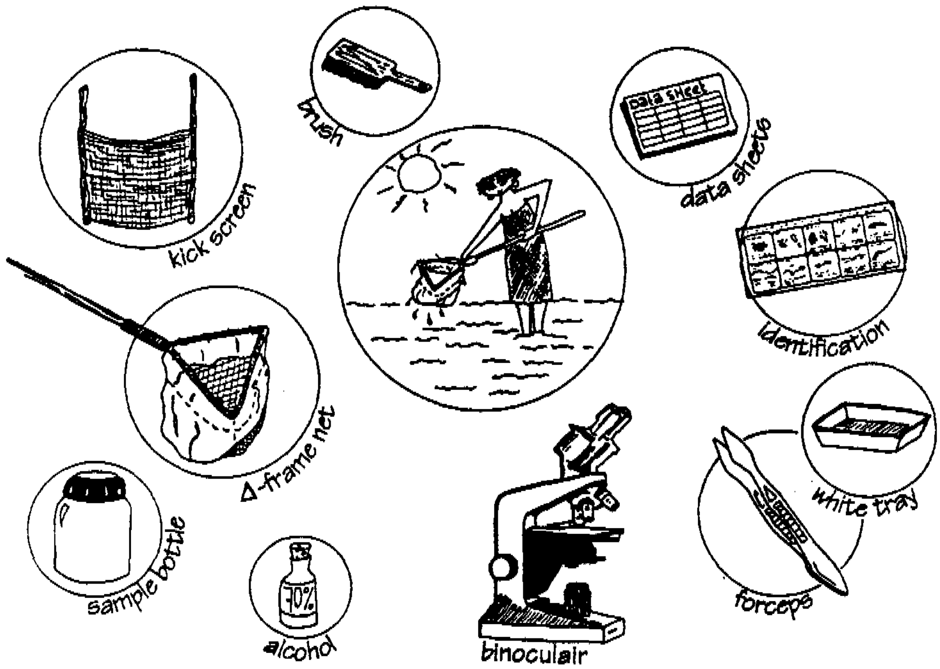


Figure 6: Sampling macroinvertebrates

For sampling you can use a Δ-frame net and/or a kick-screen net (Figure 6). A Δ-frame net is usually about 30 by 20 cm, with a depth of at least 40 cm and with a mesh of 0.5 mm. A kick-screen consists of a 1 by 1.5 or 2 metre piece of fibreglass screen or nylon netting with a 0.5 mm mesh, with two poles attached at the ends. A kick-screen can only be used in flowing waters.

Select sampling locations of approximately 1 square metre, with the help of the suggestions given in Section 4.2. You can also select a rectangular sampling site parallel to the shore of the water, of 1 to 4 meters long and approximately 0.5 meters width.

In flowing waters, always approach the sampling location from the downstream side so you do not disturb the area. Place the net on the bottom of the water at the downstream edge of the sampling area. Using your feet and/or hands, gently disturb the bottom in front of the net. Pick up all the rocks in the sampling area, and gently remove the attached animals in front of the net with your hand or with a soft brush.

In standing waters, you have to move your net around to catch the macroinvertebrates, since there is no current to automatically drive them into your net. Keep your net in contact with the bottom as much as possible.

In one sampling location, always try to sample as much as possible different habitats. Gently scrape animals from rocks, plants and other substrates, and pull your net through water plants when they are present.

The best way is to examine the animals in the field. Empty the contents of your net, with some of the sample water, into a white tray. Remove all large objects like leaves and stones, first checking whether any animals are attached. Never place animals from different sample locations in the same tray.

Analyze your sample using the methods described elsewhere in this section. After analyzing the sample, return the animals to the water where you found them.

If the analysis cannot be done in the field, you will have to kill the animals by conserving them before transport. Use forceps to place all animals in small bottles with a 70 to 80% alcohol solution. Isopropyl (rubbing) alcohol is a suitable preservative and can be purchased from any drug store. Only flat worms should be kept in water, since they will shrivel in alcohol. Write with pencil the date, place and sample number on two labels. Place one label on the outside of the bottle, and one label inside the bottle.

In most cases, sampling four times a year is sufficient to draw conclusions about the water quality. Choose different seasons for your sampling activities, so that you get a good picture of seasonal changes.

4.12 Assessment

Use the findings from the Biological Survey, together with those of the Field Survey, to arrive at an assessment of the type(s) of pollution occurring, and its source(s).

When you have detected pollution and its source(s), you can formulate suggestions to improve the water quality, as mentioned in Chapter 7 and 8.

If the information does not provide enough evidence on the type(s) and source(s) of pollution, and/or if you need scientific data, you can decide to do the physical and chemical analyses explained in Chapter 6.

If you have reason to suspect pathogenic contamination you might decide to conduct the Health Survey and possibly the bacteriological test described in Chapter 5.

Recommended literature

McDONALD, B., W. BORDEN and J. LATHROP: "Citizen stream monitoring, a manual for Illinois". Illinois Department of Energy and Natural Resources (ENR), Illinois, U.S.A. August 1990.

MITCHELL, MARK K. and WILLIAM B. STAPP: "Field manual for Water Quality Monitoring, an environmental education program for schools". Global Rivers Environmental Education Network (GREEN), 721 East Huron st., Ann Arbor, Michigan 48104, U.S.A. 7th Edition, 1992.

Water Watch, Kentucky Division of Water: "A field guide to Kentucky lakes and wetlands". Kentucky Natural Resources and Environmental Protection Cabinet, 18 Reilly Road, Frankfort, Kentucky 40601, U.S.A. 1985 (free of charge).

5 The Health Survey

Diseases are caused by tiny organisms such as bacteria and viruses, most of which are not visible with the naked eye. Disease-causing organisms in general are called pathogens. In developing countries many pathogens live in the water, or are transmitted by other organisms living in water (such as snails, for example). You can get sick from drinking water contaminated with pathogens, or from contact with contaminated water through the mouth, nose or ears, or through cuts in the skin.

Major diseases caused by pathogens in water include cholera, typhoid fever, paratyphoid fever, bacillary and amoebic dysentery, yellow fever (hepatitis), guinea-worm infections, bilharzia (schistosomiasis), gastroenteritis, tuberculosis, tape and nematode worms, and skin, eye and ear infections. A symptom of many of these diseases is diarrhoea, one of the leading causes of the death of children in developing countries. In some countries as much as 40% of the children younger than five years die of diarrhoea.

There are various methods for finding out whether a specific location or water source is contaminated with pathogens. You can conduct a Health Survey and/or a bacteriological analysis of the water. The ideal plan would be to conduct both. Both methods are discussed in this chapter.

Figure 7: Pathogens in water

With the results of the Health Survey you can estimate fairly accurately whether pathogenic contamination is present, and it gives you an overview of the possible sources of pathogenic contamination. Bacteriological analysis is the only way to really prove if the water is contaminated with pathogens, and it gives the exact level of contamination.

The Health Survey is similar to the Field Survey discussed in Chapter 3. One difference however is that the Health Survey is always prepared and conducted together with the local people that are using the water source you want to survey. They will provide you much of the information you need.

The Health Survey is easy to perform, and does not require any skills or equipment. Some knowledge about the occurrence and spreading of diseases (besides what is explained in this manual) can be very helpful. The performance of the bacteriological test requires both equipment and certain skills. The test is explained in this chapter, but you need some training before you can conduct it accurately.

Always start by conducting a Health Survey. If the Health Survey leads you to suspect pathogenic contamination, you can go straight to Chapter 7 to conduct activities to improve the water quality. If you want to know the exact level of contamination, or if you need the scientific data, you can conduct the bacteriological analysis after the Health Survey, and then proceed to Chapter 7.

5.1 Health Survey indicators

During the Health Survey you use three types of health indicators.

All the possible *sources of pathogenic contamination* are the first type of health indicators. Before you can conduct this part of the Health Survey, you should have some understanding about possible sources of pathogenic contamination. As also discussed in Chapter 2, the major source of pathogenic contamination is formed by the faeces from animals and from people, which occur in domestic waste. Domestic waste can be disposed via a sewage system (with or without a treatment plant), via a pit latrine or directly in the open air.

Sewage systems always discharge into a water body, with or without prior treatment. Since most sewage treatment plants do not have the capacity to eliminate pathogenic organisms, most of the waters receiving sewage discharge are contaminated with pathogens. The degree of pathogenic contamination depends on the concentration of pathogens in the sewage discharge water, and the amount of sewage discharge water compared to the volume of the receiving water. The smaller the volume of sewage water compared to the volume of receiving water, the quicker the pollution will be diluted.

When there is no sewage system present, people may either have pit latrines or open-air defecation areas. A pit latrine is a protected hole into which faeces fall (see also Section 7.4 and Figure 13). Pit latrines can prevent the spreading of pathogens when they are cleaned regularly and are closed for mosquitos and other animals. The distance between a pit latrine and a water source should be at least 10 metres, since groundwater usually flows (see also Section 1.1), and thus may carry pathogens from the latrine to the water source. When the water source is situated on a hill, pit latrines above the water source will most probably contaminate the water source with pathogens.

An open-air defecation area almost always means pathogenic contamination, because pathogens will always be distributed and carried to a water (via people, animals, rain water, etc.). The same is true for the areas where animals (wild or cattle) drop their faeces.

The second type of health indicators includes all possible *routes of pathogenic contamination* that can occur from the moment the water has been fetched from the source until it is being used. It has been proved that most of the pathogenic contamination occurs after the water has been fetched from the source. Contamination may occur when water jars, containers, ropes or hands are not clean, when flies and mosquitoes come into contact with the water, when pollution in the air enters the water, etc. For example, if you use a dirty jar to collect your drinking water, there is a big chance that your water will become contaminated. To get a complete overview of all possible routes of contamination, follow the water from the moment it is fetched from the source until the moment it is used.

The third type of health indicators used in the Health Survey are the *occurrence*, at the time of the survey or in the past, *of diseases* that are spread by and via water. The occurrence of such diseases simply proves that the water is contaminated. Major diseases caused by pathogens in water are mentioned at the beginning of this chapter.

Note that the type of water source does not necessarily determine whether water is safe for drinking. Many people think that water from a tap or a well is always clean and safe, for example, which is absolutely not true!

5.2 The Health Survey Data Sheet

Copy the Health Survey Data Sheet, which can be found in Appendix 8, and use one copy for each water source or other location you survey for health indicators.

Most of the information you gather during the Health Survey should be given to you by the local people who are using the water source. Since every locality and every water source has its own, unique characteristics, you need to adapt the Health Survey Data Sheet to the local circumstances. Use all the items mentioned in the data sheet and in this chapter to formulate your own questions and items, and interview the local people who are using the water source.

After the general data and the description of the water source, the data sheet gives four possible sources of pathogenic contamination, namely: sewage discharge, latrines, open-air defecation areas and (defecation areas of) animals. Fill in details of the items present in your survey area, and don't forget to include any additional remarks needed to describe the situation.

Next, a number of possible routes of pathogenic contamination are given. Since possible routes of contamination vary tremendously depending on local conditions, this is absolutely not a complete and perfect list. Therefore adapt the mentioned items as much as possible to the local situation, and add as many as possible other routes of contamination you can think of.

The diseases that have occurred in the past year and/or are occurring at present can be listed in the last part of the data sheet. Use extra paper if there is not enough space to record your findings.

Finally you can write down the results of the bacteriological test, if it is conducted. See Section 5.5 and further for explanation of this item.

5.3 What to do

1. Prepare and conduct the Health Survey always together with the local people who are using the water source or water body that you want to survey.

2. Determine which water source(s) and/or water body(ies) you want to survey for pathogenic contamination. This can be determined with the help of the knowledge or wishes of the local people, the conclusions drawn from the Field Survey, and/or through other information or observations.

3. Write down the reasons why you want to conduct a Health Survey, and the objectives you hope to achieve. Discuss this with all participants of the Health Survey.

4. Use the Health Survey Data Sheet and the information given in this chapter to formulate questions and interview items which you need to gather all the necessary information. In this way, the setting of the interview and the questions are adapted to the local area and the people you want to survey. All participants of the Health Survey should be involved in adapting the data sheet to the local circumstances.

5. Before you start, ask the people you want to interview for the survey if they want to be interviewed, and explain the reasons for your curiosity. Explain to people if and how you can help them if they are suffering from contaminated water, and be careful not to make promises you cannot fulfil.

6. During the Health Survey, continually involve all people who use the water source (who are mostly the women!) and other local persons that are concerned. Share with them your observations, and alternate asking questions and making your own observations. When you interview people, always try to be as polite as possible.

7. Examine the water source and the surrounding area, and fill in the 'Description of water source'. Then check the presence of possible sources of faecal contamination, meaning the methods people use to get rid of their faeces, and the drinking (and thus defecating) areas for cattle and wild animals.

8. Together with the people who fetch and use the water (in most cases this will be women and children), list all the possible routes of pathogenic contamination after water has been fetched from the source.

9. Ask the people what they think about the quality of the source, and whether they know of any particular diseases that have occurred in the past year, or that are occurring now.

10. Use your adapted Health Survey Data Sheet to write down your findings and draw your conclusions.

11. If needed and possible, conduct the bacteriological test as described in the following paragraphs, and record the results also on the Health Survey Data Sheet.

5.4 Faecal coliform as indicator

If you want to analyze the water for pathogenic organisms, you can use faecal coliform (F. Coli) bacteria as an indicator. Faecal coliform bacteria by themselves do not cause diseases. They occur naturally in people's intestines, helping with the digestion of food. They are found in the faeces of people and warm-blooded animals (mammals).

F. Coli bacteria are no pathogens, but they are always found in large numbers when pathogens are present. In the intestines of sick people faecal coliform bacteria occur along with the pathogenic organisms. If there are many faecal coliform bacteria in the water (over 200 colonies/100 ml water sample), there is a very large chance that pathogenic organisms are also present.

Single faecal coliform bacteria cannot be seen without the aid of a microscope. However, within a few days, one bacterium can multiply into a big group (colony) of bacteria, which can be seen with the naked eye.

5.5 The bacteriological test

The bacteriological test is based on the principle that single bacteria multiply within a few days into colonies, if they have enough food and the right temperature. A few drops of the water to be tested are put a *special growth medium and stored in a stove for two days. The growth* medium contains all the food needed by the bacteria. The stove, which is called an incubator, remains constantly at the same temperature.

Each bacterium then grows into a colony that is visible with the naked eye and thus the amount of bacteria in the water can be calculated.

There are various types of tests to determine the presence of F. Coli bacteria. This manual only discusses the so-called *membrane filtration technique*, because with this method, when conducted properly, the level of contamination can be detected very accurately. However, this method cannot be used when water is very turbid (muddy). The technique (just like all others that are not discussed) requires some training, skill and understanding.

Because the bacteriological test takes at least 1 day to perform, the analysis always gives an indication of the water quality in a previous period.

5.6 Equipment

The equipment needed for the bacteriological test (see also Figure 8) includes: forceps, sample bottles, methyl or ethyl alcohol, a flame, distilled water, sterile filters, petri dishes, growth media, absorbent pads, a 10 or 20 ml syringe or pipette, a filtration system, an incubator and a sterilization unit.

Much of this equipment will have to be obtained from a special manufacturer. In Appendix 10 you can find names of addresses of a number of manufacturers. There you can buy all the equipment needed. Most manufacturers also supply a field kit for the bacteriological test, which is a small box containing most of the equipment needed to conduct the test (usually an incubator and sterilization unit are not included).

In many cases, it will be most practical to buy a kit to conduct the bacteriological analysis, since it offers most equipment in one set, and usually is has a manual as well. Bear in mind that there are different types of bacteriological tests, and a kit usually is only able to perform one type. Users-friendliness, expenses, availability of chemicals and the type of conclusions you can draw from the test are important factors to consider when you have to decide what field kit to buy.

In some cases it may be more advantageous to compose your own equipment, for example if you want to use it for other tests. Always first gather information about the different possibilities of equipment you can buy, and make your choice considering your needs and capacities.

Sampling bottles

For sampling and analyzing, glass bottles of at least 200 ml capacity with a ground-glass stopper or rubber-lined aluminium or plastic screw cap should be used.

Growth media

The growth medium needed for F. Coli bacteria must be obtained from a manufacturer. Manufacturers supply growth media that may be prepared from dehydrated powder, or growth media that can be used directly from pre-measured, ready-to-use glass ampoules. Ampoules are easier to use.

Absorbent pads

White absorbent pads are used to absorb the liquid growth media in the petri dish, and are available packed in dispenser tubes from manufacturers. There are also sterile disposable plastic petri dishes available with a nutrient pad already inserted and sterilized.

Petri dishes

Petri dishes are round and flat shaped boxes (like a tire of a car), and have a diameter of 9 cm. They are available from manufacturers.

Filtration system

A filtration system consists of a membrane through which the sample water is filtered. The sample water is put in a cylinder on top of the membrane, and sucked through the membrane by a syringe or other suction device. The bacteria are trapped on the membrane. There are different types of filtration systems, of which three are shown in Figure 8. You can obtain a filtration unit from a manufacturer. You can also make a filtration unit at home from tupperware (see also Figure 8), using tupperware mini-tumblers stuck to each other with a jelly-mould seal. Punch number 4 belt holes in both bottoms of the tupperware tumblers.

Incubator

An incubator is a special type of stove that always remains at exact the same temperature. It can be bought from a manufacturer. It is also possible to build one yourself (using warm water which is heated regularly via electricity), but it is very important that the temperature always remains stable and can be fixed at exactly 44.5 °C.

Sterilization

It is essential to sterilize all the equipment you use for the bacteriological test (sample bottles, pipettes and filtration system) before sampling and analyzing. Sterilization kills all micro-organisms, thus preventing any interference or disturbance of the test. This can be accomplished by using an autoclave, kept at 121 °C for 15 minutes.

You can also use a pressure cooker. The pressure cooker should run at 15 lbs per square inch gauge pressure to properly sterilize the equipment. Sterilization with a pressure cooker takes 20 minutes. If you live 600 metres above sea level or higher, increase the cooking time by 1 minute for every 300 metres above sea level.

You can also put your equipment in an oven at a temperature of 170 °C (± 10 °C) for at least 60 minutes. Plastic bottles and filtration units cannot be placed inside an oven, but can be placed in boiling water for 5 minutes.

Petri dishes, growth media, absorbent pads and filters are sterilized by the manufacturer and packaged.

Distilled water

Distilled water is water that purely consists of water molecules. It can be bought, or obtained by boiling water and collecting the water vapour that has evaporated. Be sure that all equipment you use for the distillation is properly sterilized.

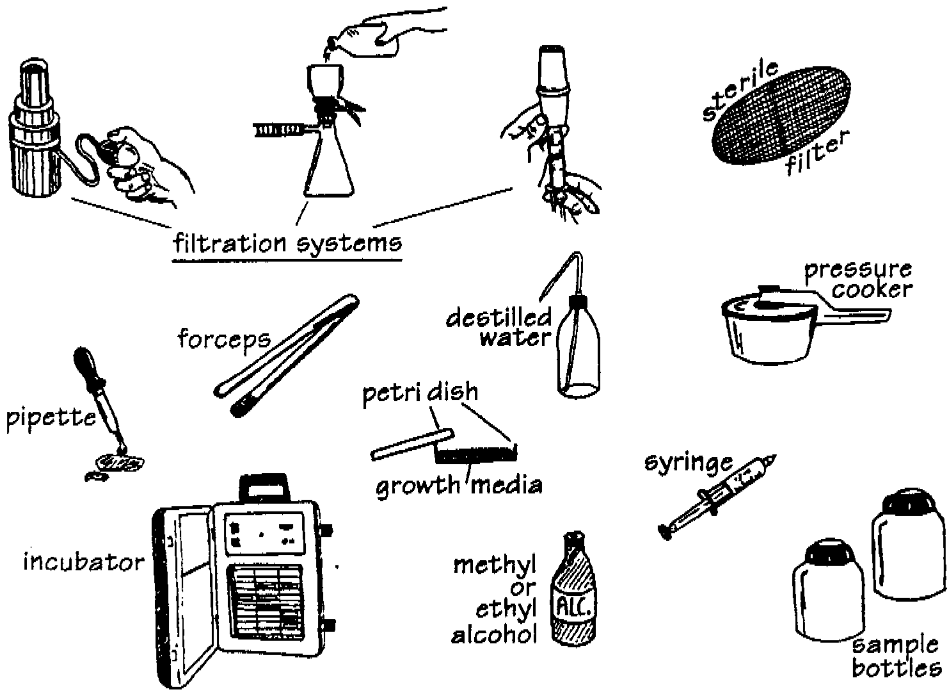


Figure 8: Analyzing F. Coli

5.7 What to do: the sampling

1. Sterilize all sample bottles carefully.
2. Select the sampling locations with the aid of the results from the Health Survey and/or other observations.
3. Remove the stopper or cap of each sample bottle just before sampling and avoid touching the inside of the cap.
4. Hold the bottle near its base and plunge it, with the opening downward, below the water surface. Then turn the bottle underwater into the current and away from you. If you cannot reach the water with your hand, use a stick or tie the bottle to a rope (hang a weight under the bottle).
5. Sample as close to point sources as possible, and always take a sample 30 cm below the surface or at mid-depth if the depth of the water is less than 30 cm.
6. Avoid sampling the water surface, because the surface film often contains greater numbers of faecal coliform bacteria than is representative of the water.
7. Also, avoid sampling the water bottom for the same reason, unless this is intended.
8. When taking samples, leave some space in the sample bottle (a few centimetres), to allow mixing of the sample before pipetting.
9. Write down on the label of every sample bottle the date, time and sample location.
10. Ideally, all samples should be tested within one hour of collection, and anyway within 6 hours. During transport keep the samples cool with ice between 4 and 10 °C, but not frozen.

11. If the water to be sampled is likely to contain chlorine or other disinfectants, then 0.1 ml of 1.8% solution of sodium thiosulphate ($Na_2S_2O_3.5H_2O$) per 100 ml of bottle capacity should be added, before or immediately after sampling has taken place.

5.8 What to do: the analysis

1. Sterilize the forceps by dipping them in alcohol and burning the alcohol off with a flame. Do not place the hot forceps back in the alcohol.

2. Place an absorbent pad, using the sterilized forceps, in a presterilized petri dish. Be careful not to touch the pad or the inside of the petri disk with your fingers.

3. Place the growth medium on the absorbent pad. Put the top on the petri dish and set aside.

4. Sterilize the forceps again, and place a sterile filter paper on top of the membrane of the filtration system, with the grid side up. Make sure the filter lies completely flat with no wrinkles.

5. Determine the desired volume of water (in ml) to be tested. When counts of bacteria are expected to be high the sample must be diluted. The ideal number of faecal coliform colonies is 20 to 60 on a petri dish. Always dilute the sample water with distilled water. Make about 3 different dilutions of one sample.

6. Adjust the filtration system. Before taking a sample, use the pipette or syringe to rinse the filtration system with a small amount of distilled water. Add the water through the hole in the top of the system.

7. Fill the pipette or the syringe with the desired volume of sample water, shown by the volume markings on the side.

8. Place the pipette or syringe in the hole on top of the filtration system, and release the water sample into the funnel.

9. Use the suction pump or the syringe to draw all the sample through the filter, and rinse the filtration unit with distilled water to make sure all the bacteria end up on the filtration paper.

10. Carefully remove the filtration paper with sterilized forceps, and slide the filter into the petri dish, with the grid side up. Petri dishes should be incubated within 30 minutes after filtration of the sample. Be sure to record the date, site and volume of the sample on the petri dish.

11. Put the petri dish inverted in the incubator. If you are using a water bath, enclose the petri dish in a waterproof bag (avoid leakage) and put it into the water bath. The dishes may also be sealed with waterproof tape (freezer tape) to avoid leakage. Incubate for 24 hours (± 2 hours) at 44.5 °C. (± 0.25 °C). Petri dishes should be inverted during incubation to avoid condensation. Please wash your hands after the test.

12. After incubation, carefully count the bacterial colonies on the filter. You might want several people to verify the bacterial count. Each bluish spot is counted as one faecal coliform colony. Cream or grey-coloured colonies are non-faecal coliform. Faecal coliform colonies should be examined within 20 minutes to avoid colour changes that occur with time.

13. From the results from the Health Survey and bacteriological test you can draw your conclusions about the occurrence of pathogenic contamination. Check your findings with the accepted water quality standards for coliform bacteria, which can be found in Appendix 13..

Recommended literature

DUKTA, B.J. and A.H. EL-SHAARAWI: "Use of simple, inexpensive microbiological water quality tests, results of a three-continent, eight-country research project". IDRC, P.O. Box 8500, Ottawa, Canada K1G 3H9, 1990.

LLOYD BARRY, and RICHARD HELMER: "Surveillance of drinking water quality in rural areas". WHO and UNEP, 1991.

NDUKA OKAFOR: "Aquatic and waste microbiology, A textbook for microbiologists, hydrobiologists, general biologists, sanitary engineers and public health workers". Fourth Dimension Publishers, 1985.

WHO: "Guidelines for drinking-water quality, Volume 3. Drinking-water quality control in small-community supplies". Geneva, 1985.

6 Physical and Chemical Analysis

The biological parameters discussed in the previous chapters involve all living beings that describe and influence the quality of a body of water. Physical and chemical parameters concern all non-living factors describing and influencing the water quality.

Water contains many substances (constituent parts) that cannot be seen with the naked eye or even with a normal microscope. In chemistry these constituent parts are called molecules and ions. Examples include the nutrients phosphorus and nitrogen (see Section 2.2), which can occur in many forms such as phosphate, nitrate and ammonium. Chloride occurs in water as an ion, and can be used to kill pathogenic organisms (a process know as disinfection). Heavy metals are ions that usually are found attached to soil particles in the water. Physical and chemical analysis focus on the presence of these constituent parts.

Physical parameters are for example the temperature, clarity and acidity of the water in question. Chemical parameters are for instance dissolved oxygen, nutrients, heavy metals and pesticides.

By using physical and chemical analysis you can determine the exact levels of specific pollutants in water. For instance, you can measure the concentrations of phosphorus and nitrogen, measure the concentration of heavy metals or pesticides in water, or measure the level of dissolved oxygen. Only chemical analysis can conclusively proof the presence of a specific pollutant.

Biological parameters usually tell you much more about the actual impact of pollution on a water, and about the long-term effects on the aquatic community.

Since water quality is determined by both biological and non-biological factors, it is best to combine biological with physical and chemical analysis to gain a complete understanding of the water quality in a certain area.

In this chapter the relevance of some basic physical and chemical parameters is explained, and suggestions are given about various analysis equipment. With the guide parameters discussed, you can always locate point sources of pollution. The location of non-point sources is more difficult (as explained in Section 2.1), but also possible. With the temperature and dissolved oxygen test, the effects of organic pollution can be exactly measured.

To determine exactly which type of pollutant(s) is (are) occurring, for example the type(s) of heavy metals or pesticides, you should send water samples to a professional laboratory. An explanation of what to do in this case is given.

6.1 Sampling

Samples should be collected very carefully, since the accuracy of the results is primarily determined by the accuracy of the sampling. Some general considerations regarding sampling are given below first. Specific requirements for individual parameters are discussed in the corresponding paragraphs.

Equipment

The type of equipment used depends on the parameter that is to be analyzed. Usually you need some general equipment that can be used for every test, such as sample bottles, a funnel, pipettes or syringes, glass beakers, etc.

Besides the general glassware, certain specific equipment is required for each parameter. The equipment you need depends on the type of test you want to conduct, and usually there are different tests for a given parameter. For example, you can measure acidity with indicator paper, a colour comparator, a pH meter or a pH probe. The tests usually differ in user-friendliness, accuracy and expenses. Information and equipment can be obtained from manufacturers of water quality testing equipment, such as those listed in Appendix 10.

Some manufacturers also supply a water quality field testing kit, which is a box containing all the equipment required to conduct a series of tests. One advantage of a kit is that you have all the equipment you need in one set. Of course you have to decide whether the tests offered in the kit meet your requirements. Expenses and accuracy differ from kit to kit. Usually kits are supplied with a manual.

Always consider safety precautions when you are working with chemicals (protect your hands and eyes), and carefully dispose of the chemicals after use. Don't flush through the toilet!

This manual is restricted to tests that are easy to conduct and can be done in the field. Before you choose a type of test and the corresponding equipment, always check first what degree of accuracy is required in your research, the expenses you can afford to buy equipment, and how much knowledge and skills are required to operate the equipment. If you buy a meter or probe, always check if a calibration method is enclosed.

Also check whether the chemicals (also called reagents) that are part of the test are easy to obtain and not too expensive. This is especially important if you plan to buy a testing kit, because such kits often use tests that are designed by the manufacturer and do not use standardized equipment. The chemicals needed might only be available through the manufacturer. If it turns out that you cannot buy the reagents that you need for your tests or that they are very expensive, it means you can use the kit only until you run out of reagents.

Time of sampling

Pollution and the measured parameters usually change over time. First of all, sources of pollution can be continuous or discontinuous. For instance, pesticides are only disposed of during the growth season in which they are used, and industries may discharge continuously or only at certain times.

The parameters you measure may also change daily and/or with the season. The concentration of dissolved oxygen is always lower during the night then during the day, for example (see Section 6.7). Temperature is one of the parameters that changes both daily and seasonally.

It is therefore very important to choose the right time to conduct the sampling, and to always record the sampling date and time on the Data Sheet for Physical and Chemical Analysis, which can be found in Appendix 9. A proper comparison of different water samples can only be made when the sampling times and dates correspond.

To obtain more information about yearly changes in the water quality in a certain water, it is useful to take more samples at the same location at different times, for instance during the different seasons of a year.

Sampling locations

If the pollution comes from a point source, you should take samples as close as possible to the source. These samples are compared with samples taken upstream of the source (if the water is flowing), or so far from the source that no influence of the pollution can be measured (standing waters).

If pollution is caused by non-point sources, it should be checked in which stretch of the water body the pollution occurs, thus locating the source of pollution. If you want to prove that pollution is coming from a certain non-point source, you should make sure that all other possible sources are excluded from suspicion. Sampling locations should be located in such a way that all other sources are excluded or quantified.

When you want to take a sample that is representative of a water body, you should avoid sampling close to the shore or impoundments (dams, etc.). If there is no boat available, sampling from a bridge can be very practical. In flowing waters a rule of thumb is to sample midway across the water and about 10 cm below the surface. Standing waters should be sampled at their deepest point or, when this is unknown, in the middle, also 10 cm below the surface.

Fill in the items that describe the sampling location on the Data Sheet Physical and Chemical Analysis (see Appendix 9).

Guide parameters

If the exact location of a source is not known, this can be determined with the guide parameters temperature, pH, conductivity and, if necessary, oxygen. When one or more of these parameters suddenly change in value, this usually indicates the presence of pollution. As you move closer to the source, the deviation of one or more of these parameters increases.

Methods of sampling

Always make sure the equipment you use is clean, and thus cannot contaminate the sample. When you use a meter, always check the battery, and calibrate the meter before each reading.

Protect yourself against possible hazardous effects from pollution, especially when sampling industrial waste water or sewage discharge.

Always label the sample bottles and write down the name of the sampler, the date, number and name of sampling location, any preservation techniques used and the parameter for which the water is to be analyzed. Fill in the corresponding items on the data sheet.

It is strongly recommended to test all the parameters discussed in this chapter in the field. However, if this is not possible, there are techniques to preserve the samples for a certain period of time. Appendix 11 lists a number of preservation techniques for different parameters.

To improve the accuracy of the measurements, it is strongly advisable always to take samples in duplicate (two identical samples), and calculate the average measurement.

Sending samples to a laboratory

If you plan to send your sample(s) to a professional laboratory, consult the laboratory on choice and number of parameters, choice of sampling equipment, preparation of sample bottles, method(s) of preservation, quality control requirements, analysis control and reporting method.

Give background information about the types of sample (for example if the sample consists of reference water, concentrated effluent or polluted water), the pH, temperature, conductivity and the time of sampling. To ensure objectiveness, do not give information about (possible) sources of pollution. Fill in the corresponding items on the data sheet.

The laboratory has to perform standardized analysis methods, including an internal quality control to ensure their accuracy. External standards from such official bodies as the U.S. Environmental Protection Agency (EPA), the European Commission (EC) or the World Health Organisation (WHO) can also be used to perform an external quality control. These external standards are certified samples with known levels of the pollutants to be analyzed. These samples are analyzed regularly during the analysis of other samples to check whether the performed analyses are accurate. It is also possible to take samples in duplicate (two identical samples), and offer the second sample to another laboratory for a second opinion.

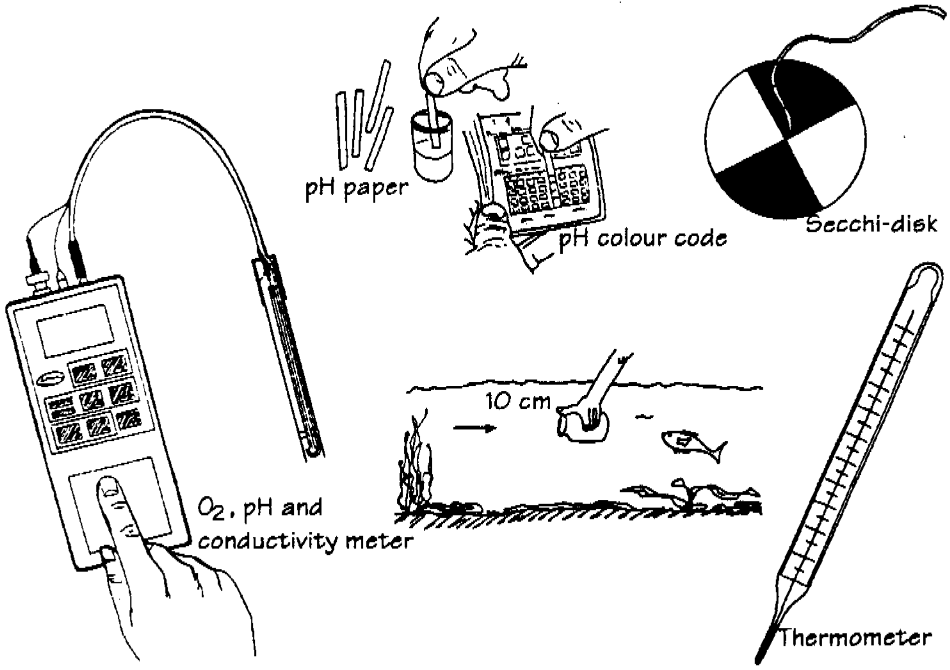


Figure 9: Physical and chemical analysis

6.2 Colour and odour

Clean water is almost without colour (bear in mind that this does not mean that colourless water is always clean and safe!). To detect the colour of a water, pour some water into a glass beaker and hold it in front of a piece of white paper or other white background. If you find blended colours you should mention the dominant colour first, for instance blue-green when blue is stronger then green. To detect whether the water has any odour, fill a glass beaker and smell. Record your findings on the data sheet (Appendix 9). For further information about colours and odours, see also Chapter 3 and Appendix 3.

6.3 Temperature

The temperature of the water is normally determined by factors such as the type of the source (groundwater is usually colder then surface water, for example), the distance from the source, the depth of the water and the shade. The temperature has natural daily and seasonal changes.

A temperature increase induced by people (also called thermal pollution) may be caused by industries that use water to cool machinery, such as nuclear power plants, and by urban run-off water. It can also be caused by the cutting down of trees that used to shade the water. Suspended solids also increase the water temperature, since they absorb the heat of the sun (see also Section 6.4).

Cooling-water from industries is usually discharged via a pipe different from the one used for waste water, and thus does not necessarily contain other pollutants. However, the cooling-water discharge pipe is never very far from the waste discharge pipe.

The water temperature is important for the water quality. It influences the amount of oxygen that can be dissolved in the water (cool water can hold more oxygen than warm water; see also Section 6.7) and it affects the growth rate of all water organisms. Temperature preferences among water organisms vary widely, but all organisms can tolerate slow, seasonal changes better than rapid changes. Thermal stress and shock can occur when the temperature changes by more then 1 or 2 °C in 24 hours. If this occurs, whole populations can be wiped out.

Measurement

The temperature can be measured with an alcohol-toluene, mercury-filled or dial thermometer. Some meters, such as conductivity and dissolved oxygen meters, may also have a temperature-measuring facility (see also Figure 9).

Always measure the temperature at the same location where you measure other parameters, also when you collect samples from different depths. Keep the thermometer 10 cm below the water surface for approximately 2 minutes (until it is steady). Record your findings on the data sheet.

To measure the temperature at great depths, attach the thermometer to a measured stick, or sample water from this depth and measure the temperature immediately after you have brought the sample water to the surface.

When you put the thermometer in a beaker or bottle with sample water, rinse the thermometer first by pouring a portion of the sample water over it.

Because the water temperature is often a good indicator of point source pollution, repeat the temperature measurement as soon as possible about 1 km upstream or away from the sampling location, record your findings and calculate the temperature difference. Rapid temperature changes in a section of the water body indicate pollution.

When comparing the water temperature at two different sites, it is important to match as closely as possible the physical conditions at these sites, such as stream velocity, amount of sunlight reaching the water and depth. To reduce errors, use the same thermometer at all sites.

In waters over 10 metres deep, it is important to measure the temperature at different depths, because stratification can occur (see also Section 1.3), which has many implications for the water quality. A temperature profile is measured simultaneously with the level of dissolved oxygen; see Section 6.7.

The temperature can be expressed in degrees Celsius (°C) or degrees Fahrenheit (°F). In official documents, the temperature should always be given in degrees Celsius. The conversion factors can be found in Appendix 12.

6.4 Visibility (turbidity)

Turbidity is the opposite of clarity. It is due to the presence of suspended solids (see also Section 2.2) and can be seen as a colouring of the water, ranging from nearly white and yellowish to brown, as well as green or red from algal blooms. During the rainy season and during or just after a storm event, turbidity levels are usually higher then normal.

Turbidity can also be expressed in terms of visibility, which will be the focus of the manual in this chapter.

Elevated turbidity levels can cause a variety of problems for people, plants and animals (see also Section 2.2). Water is no longer suitable for drinking, and irrigation systems may become blocked, for example.

High turbidity stimulates the growth of bacteria and can protect pathogens from the effects of disinfection. When water is being disinfected, therefore, the turbidity must always be low.

Water plants and animals are also affected by increasing turbidity. Turbidity reduces the amount of light penetrating the water, making it more difficult for algae and large water plants to survive. Without algae and large water plants, the level of dissolved oxygen falls drastically (see also Section 4.7 and 4.8).

Since suspended solids absorb the heat of sunlight, turbidity raises the temperature. This decreases the level of dissolved oxygen (see Section 6.7).

Suspended solids may clog the gills of fish, reduce their growth rates and decrease their resistance to disease. When suspended solids settle on the water bottom (sedimentation), they can smother the eggs of fish and other animals and the benthic macroinvertebrates.

Measurement

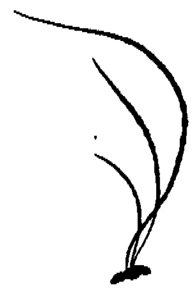
Visibility can be measured with a Secchi disk. A Secchi disk is a weighted circular disk with a diameter of 20 centimetres, a thickness of 1 or 2 cm and four alternating black and white sections painted on the surface (see Figure 9). The disk is attached to a measured line that is marked off in metres, divided into tenths of a metre. A Secchi disk can be obtained from a manufacturer or can be made at home.

The Secchi disk is used to measure how deep a person can see into the water. Lower it into the water by the measured line until you lose sight of the sharp boundaries between the black and white sections. Make sure the Secchi disk is lowered in a straight line and that you observe from vertically above the Secchi disk. Then raise the disk until you can see the boundaries sharply again. Move the disk up and down a few times until you have found the exact maximum depth at which the sharp bounda-

Appendix

6 List of Algae

Clean water algae



Lemanea

Lemanea has short, dark olive green to black strings (2.5 to 15 cm). The strings are stiff and not branched, and can be attached to the water bottom, rocks, submerged logs, plants or other surfaces. Lemanea occurs in turbulent waters, and is typically found in flowing waters and around lake margins.

Rhizoclonium

Rhizoclonium has generally long, silky, green strings (to 60 cm), that form a tough algal mass. The stings are without knobs and not branched, and can be attached to the water bottom, rocks, submerged logs, plants or other surfaces. Rhizoclonium is typically found in flowing waters and around lake margins.

Diatoms

Diatoms exist in different forms. One type lives in slimy colonies and has a golden to brown colour. The individual plants cannot be seen. These diatoms are attached or loosely associated with their substrate and often grow on mud. They are typically found in standing or very slow moving waters, and also in springs and seeps.

Another type has a golden-brown to dark brown colour. The diatoms live in slimy colonies forming rock slick. They are attached to water plants or other surfaces, and are typically found in flowing waters and around lake margins.

The third type is a planktonic algae that colours the water yellow-green to yellow-brown as it is uniformly distributed in the water column. The individual algae are mostly microscopic, free-floating, and do not form surface scums. These diatoms are typically found in standing and slow-moving waters.

Oedogonium

This algae has unbranched strings, forming mats or attached or loosely associated with various surfaces like submerged wood, sticks, weeds and grass stems. Oedogonium does not grow from bottom mud. It can be found in standing or very slow-moving waters. It also grows on the walls of reservoirs.

Batrachospermum

Batrachospermum is commonly found in or below springs. It is dark olive-green to black in colour and characterized by compact, gelatinous (slimy) masses. It grows attached to any substrate.

Another type of Batrachospermum is compact, slimy and with an olive green to reddish-purple colour. The strings are branched and imbedded in a jelly-like mass. This Batrachospermum can be frequently found in springs or in the outflow of springs, in running waters or on shorelines. It also grows on the walls of reservoirs.

Cladophora

Cladophora is dark-green to brownish-green in colour. The strings are bushy and rough, and are often long (sometimes 90 to 120 cm). The strings are attached or loosely associated with substrate, but not attached to submerged wood or growing from bottom mud. Cladophora is found in standing or very slowly moving waters.

Cladophora can also occur as a dark green to brownish-green rough, bushy mass. The strings are branched and attached to the water bottom, rocks, submerged logs, plants or other surfaces. This type is typically found in turbulent waters, flowing waters and around lake margins.

Another type of Cladophora has a green to brownish-green colour. This Cladophora forms algal maths of long, branched and bushy, rough strings. The strings can be attached to the water bottom, rocks, submerged logs, plants or other surfaces. It can be found in nutrient enriched streams and lakes, and often occurs in very fast-flowing waters.

Euglena (viridus)

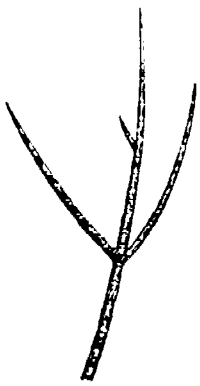
Euglena is a planktonic (free-floating) algae and forms dark green (sometimes reddish) surface scums or appears as "chopped grass" in the water. The individual algae are smaller than 2 mm and do not have roots. Euglena is typically found in slow-moving and standing waters.

Spirogyra

Spirogyra can be bright green to yellowish, consisting of floating stringy mats, often accumulating near lake shores and in coves, but may cover the entire surface of a lake or a pond. The strings are silky, unbranched, slippery, and the ends are curling if held up. The strings are attached or loosely associated with substrate, but not attached to submerged wood nor growing from bottom mud. Spirogyra is common in limestone areas, and typically found in standing or very slowly moving waters.

Another type of Spirogyra is brilliant green, free-floating or loosely attached to substrate, very slippery, and often forms mats which contain trapped bubbles of oxygen.

Stigeoclonium

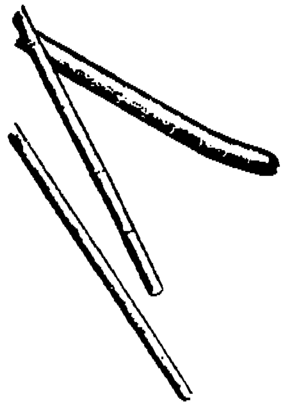


Stigeoclonium forms a slimy, bright green algal mass. The branched strings can be attached to the water bottom, rocks, submerged logs, water plants or other surfaces. Stigeoclonium is typically found in turbulent waters, in flowing waters and around lake margins.

Another type of Stigeoclonium forms brilliant green, soft, slimy masses, The long, branched strings are embedded in a jelly-like mass, and can be attached to the water bottom, rocks, submerged logs, water plants or other surfaces. Stigeoclonium is typically found in flowing waters and around lake margins.

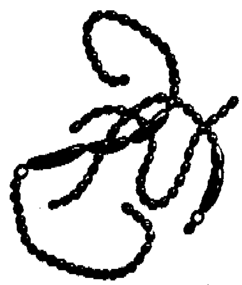
Blue-green algae

There are different types of blue-green algae. One type occurs as a mass without strings, like a tough membranaceous paper-like sheet, consisting of slimy colonies. The colour is green to olive green. The individual plants often cannot be seen. It can be attached or loosely associated with substrate, often on mud. It can be found in springs and seeps, in standing or very slowly moving waters (e.g. Lyngbya).



Another type of blue-green algae is blue-green, olive or black, and forms round, slimy, jelly-like colonies. The individual plants often cannot be seen. It can be attached or loosely associated with substrate, often on mud. It can be found in springs and seeps, in standing or very slowly moving waters (e.g. Oscillatoria).

There are also dark green to black colonies of blue-green algae, consisting of free-floating stringy, velvety mats that are easy to separate. The mats often accumulate near lake shores and in coves, but may cover the entire surface of a lake or pond, accumulating at the water surface, forming blooms (surface scums). It is typically found in slow-moving and standing waters (e.g. Phormidium).



The light green or blue-green scum resembling 'pea soup' is also a blue-green algae. The individual plants smaller than 2 mm, without roots. They are free-floating and accumulate at the water surface forming blooms (surface scums), or appear as 'chopped grass' in the water. This type of blue-green algae is typically found in slow-moving and standing waters (e.g. Anabaena).

Free-floating, light blue-green to pea soup colour blue-green (planktonic) algae are distributed in the upper few feet of the water, not forming surface scums. This type of blue-green algae is typically found in standing and slow-moving waters (e.g. Anabaena).

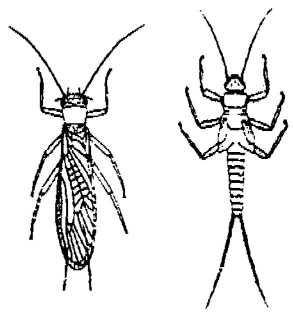
Appendix

7 List of Macroinvertebrates

This appendix gives the major types of macroinvertebrates occurring in fresh waters. Bear in mind that both the descriptions and the drawings are very general, and that there are many deviations possible (concerning colour, size, and the shape of certain body parts, for example). Although this list of macroinvertebrates generally is applicable worldwide, not all macroinvertebrates are occurring in all parts of the world. Therefore always adapt the descriptions and drawings to the local circumstances in your country.

Macroinvertebrates dominant in clean waters

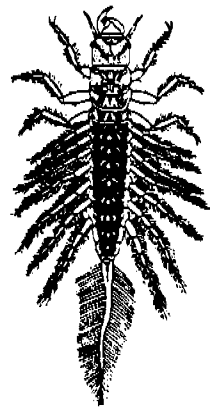
Stonefly larvae *(Plecoptera)*



Stonefly larvae have long legs consisting of three parts, each with two small hooks, and two tails extending from the back part. Stonefly larvae are usually grey-brown, but can also be brightly coloured, ranging from tan, brown or gold to a glossy black. Some even appear to be clad in an armour, beautifully decorated in yellows and deep browns. Their length varies, but is up to 2.5 centimetres.

Generally, these insects are slow-moving, living in protected areas in debris, leaves, sand or gravel, or under stones. Usually stonefly larvae are found in cold, flowing waters that have a lot of oxygen. They are most abundant in brooks with a gravel or stone bottom. A few types live in standing waters. They are very sensitive to pollution, especially oxygen depletion.

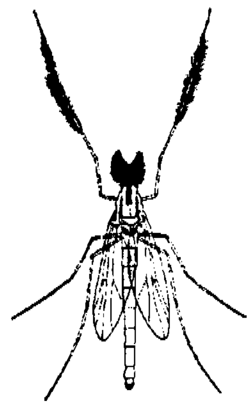
Dobsonfly larvae *(Megaloptera)*



These insects are quite striking while in the larval stage. They have strongly developed jaws and a hairy tail. Their big, long bodies are thick-skinned, and are often dull-coloured yellow, brown and tan. The larvae of the dobsonfly are called hellgrammites and are known as a fine fish bait. Their length is from 3 centimetres up to 7.5 centimetres.

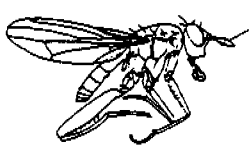
They are most often found crawling on the bottom or buried in the mud of lakes and wetlands. Depending on the type, you can find them in all kinds of waters, both standing and flowing.

Snipe fly larvae *(Diptera Athericidae)*

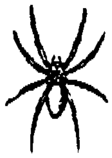


The larvae of snipe flies have an elongated, cylindrical, slightly flattened bodies, with the abdomen shaped like a cone. They have two fringed tails at the end of the abdomen. The colour varies, and the length is up to 1.2 centimetres.

Snipe fly larvae only live on the bottom of very clean, flowing waters.



Water spider *(Argyroneta aquatica)*



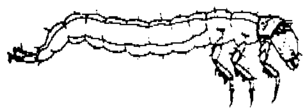
You can find the water spider, which looks just like a normal spider, in clear, standing waters, with a lot of water plants and a lot of oxygen. The spider brings oxygen bells from the surface to her web, where it forms a clock-like bubble. The spider stays most of the time in this clock, and breaths via the air bell. When the spider swims, the hairy body is covered with a layer of oxygen, which gives a silvery appearance. The water spider is intolerant to pollution.

Macroinvertebrates dominant in moderate polluted waters

Caddisfly larvae *(Trichoptera)*

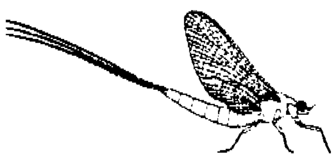
The adult caddisfly is a type of moth. The caddisfly larvae are characterized by a cylindrical body, with three pairs of legs attached to the front side of the body, just behind the head. There are two small hooks extending from the back part.

The larvae of caddisflies are known for their construction of hollow cases that they either carry with them or attach to rocks. The best way to find them is to look on the bottom of shallow waters for a moving piece of debris. When you look closely, you will see the dark head of a caddisfly poking out. The hollow cylindrical cases are composed of grains of sand, small pieces of leaves, grass, bark and twigs. There are also various types of caddisfly larvae that live without a case. A number of stream or river types actually construct complex nets for the purpose of trapping food from the moving water. The length of the larvae can be up to 2.5 centimetres.

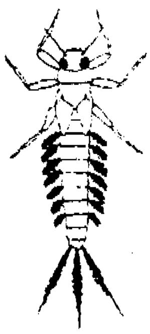


Most types of caddisfly larvae live in clear, flowing waters, but some others occur in standing waters. Caddisfly larvae living in flowing waters are very sensitive to pollution, especially oxygen depletion. The types living in standing waters can tolerate a minor amount of pollution.

Mayfly nymphs *(Ephemeroptera)*

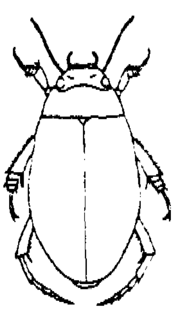


Mayfly nymphs are very similar in shape to stonefly larvae. However, they usually have three tails (sometimes two), and have one hook at the end of their legs. Their antennae are relatively short. Their colour varies from green or brown to grey, but is usually black. Their total length is up to 2.5 centimetres.



They can be found climbing on submerged plants or crawling along or ploughing their way through the bottom. Mayfly nymphs occur in all types of freshwater where the oxygen supply is good, but mostly in clear and flowing waters. Most types prefer clean water. The adults of some types of mayfly (*Hexagenia*, for example) emerge simultaneously from the water, when they have matured, forming a dark cloud of mayflies.

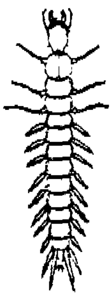
Beetle larvae and adults *(Coleoptera)*



Beetles are the largest group of insects living in water. Adult beetles are easily recognised, but the larvae can be confused with other animals. Beetle larvae are totally different from the adults, and vary greatly in their appearance. Some are able to swim, while others crawl or walk. Beetle larvae are usually found in the same areas as the adult beetles.

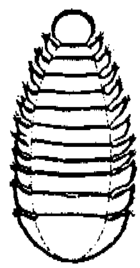
Many adult water beetles rely on oxygen from the air for their breathing. They either store air under their wing covers, or capture air bubbles on the fine hairs that cover their legs and stomach area. Different types of beetles can be found in both standing and flowing waters. Adults are usually located in shallow areas on plants or debris. Many are found clinging to sticks or logs.

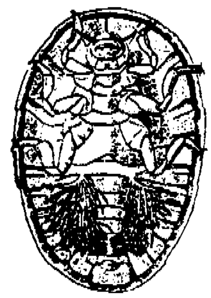
One of the most visible beetles on the surface can be seen swimming around in groups, helter-skelter in circular movements. It looks as if it is writing. This is the whirly-gig beetle *(Gyrinidae)*. The whirly-gig beetle lives in fairly nutrient-rich water, without further pollution. It is usually found in standing waters.



The riffle beetles can be found in small streams, often among stones and underwater moss. The larvae of the riffle beetle resemble a small torpedo, with circular stripes or rings around its body. Their body is pointed at both ends, and the rear end has a 'fuzzy' mass. Their colour is usually greyish; their length is less than 1.5 centimetres.

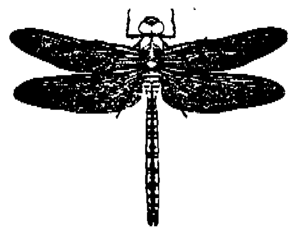
The larvae of the water penny beetle *(Psephenidae)* are very flat and usually lives attached to rocks in very clean, fast-flowing waters. Their size is approximately 4.5 to 6 mm.



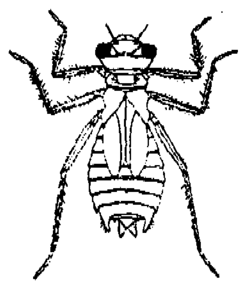


In general, adult beetles are tolerant of a wide variety of pollutants. However, the larvae have more critical water quality requirements. They occur both in standing and flowing waters.

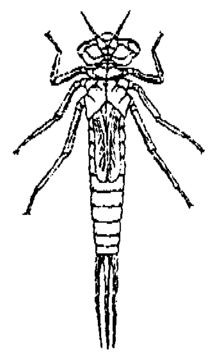
Dragonfly nymphs *(Odonata Anisoptera)* and damselfly nymphs *(Odonata Zygoptera)*



The adult dragonflies and damselflies are very well known aquatic insects. They have long, slender bodies, with four big, strong wings. Their great ball-shaped eyes are very striking. Everyone can see them flitting and playing around bodies of water.
The aquatic nymphs have a very distinct spoon-shaped food-gathering device that folds back underneath the head. It can be as long as one-fourth the size of the body. When a prey approaches, this device is suddenly extended, grabbing the prey and bringing it to the mouth.



The damselfly nymph has three paddle-like tails (actually gills), located at the rear. It has three pairs of legs positioned near the front of the body, and two large eyes on top of the head. The colour ranges from green or brown to black. Some nymphs are robust, while others are slender. Their length is up to 5 centimetres.
The damselfly nymphs are usually very active and live mostly among water plants. They tolerate a little pollution.



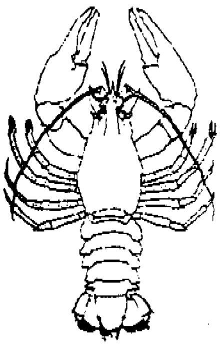
Dragonfly nymphs vary in shape, but most have robust, elongated or spider-like bodies, and algae may grow on their backs. They have three pairs of legs positioned near the front of the body, and two large eyes at the sides of the head. A pair of small wings begins to develop on the back. They have their gills hidden in the rear of the body, which looks like a small pyramid. The colour can be brown or black, but is often green. The length is up to 5 centimetres.
The dragonfly nymphs live hidden in the mud bottom, or among water plants, and are usually slow-moving.

Dragonfly and damselfly larvae prefer slow-moving or standing waters. They are commonly found on submerged plants, and in the shallow areas of lakes and streams.

Crane fly larvae *(Diptera Tipulidae)*

Crane fly larvae *(Tipulidae)* look very worm-like, are thick-skinned, and brownish-green to somewhat transparent or whitish in colour. They are pointed or rounded at one end, and have a set of disk-like spiracles at the other. Their length is up to 7.5 centimetres. The larvae occur in clumps of moss, in silt and among leaves on the bottom of shallow standing and flowing waters.

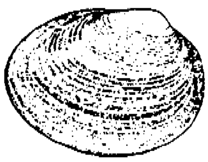
Crayfish *(Crustacea Astacidea)*



Crayfish are among the largest of the invertebrates you will collect. Crayfish resemble tiny lobsters, and have four pairs of walking legs and a pair of pincers. Their colour can be brown, green, reddish or black. Their length is up to 15 centimetres.
Usually they hide in the stream banks or under rocks and logs. Most crayfish are burrowers and are rarely seen during the day, although you may find them under rocks or logs. At night, by using a flashlight, you can find them crawling on the bottom. Crayfish can be found in both standing and flowing waters, and if the proper habitat and food are available, they can become extremely numerous. They are also relatively pollution-tolerant.

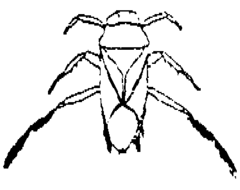
Mussels and clams *(Bivalvia)*

Mussels are characterized by having shells consisting of two halves connected by an elastic hinge. Mussels are large (up to 20 centimetres in diameter), robust, thick- or thin-shelled, and usually dark in colour. Clams are small (the size of a fingernail, no more than 1 centimetre in diameter), and are light-coloured.

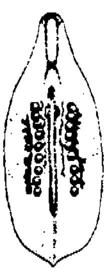


Most mussels prefer sand and gravel bottom areas. Clams have less stringent requirements, being found on all types of bottoms. Both are found partially or completely buried in sand, gravel or mud bottoms, usually in water less than 2 metres deep. Mud bottoms contain different types from sand bottoms, so heavy siltation, as occurs in many reservoirs, will wipe out sand-living types. Both occur in standing and flowing waters, with a slight preference to flowing waters.
Mussels and clams are difficult to see in lakes. Perhaps the easiest way to find them is to look for their shells at the water's edge where they are commonly left by muskrats and raccoons. Check around places where muskrats live, especially.

Water boatman *(Hemiptera Notonectidae)*



The water boatman has long, flattened hind legs, similar to peddles, that they use to dart about in the water. They use only their hind legs to propel themselves through the water, giving them the appearance of rowing along. Often they are swimming upside-down, because their carry air bubbles to breath. Their colour is usually dark grey, brown and black. It has a small shield on its back.
The water boatman is truly aquatic and remains in or on the water as adult, except to fly to other waters. They can be found in the shallow, slow-moving sections of streams and rivers, and in ponds and lakes. They are fairly intolerant of pollution.



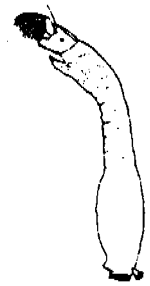
Flat worms *(Plathelminthes)*

Flat worms can be between 0.5 to 4 cm when they are stretched. Flatworms live their whole life in water. They are commonly found both in standing and flowing waters. They do not like the sunlight, so they can be found beneath rocks, logs or dead leaves. They are more active at night then during the day. Flat worms move like snails, but smaller types can also swim.

The flat worm is sensitive to organic pollution, but they like to live in water with moderate nutrient pollution. They need water with a lot of oxygen, usually fast flowing water. Some types can survive a short period with very little oxygen.

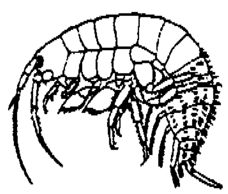
Macroinvertebrates dominant in fairly polluted waters

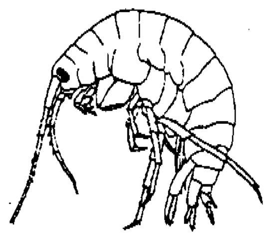
Black fly larvae *(Diptera Simuliidae)*



Black fly larvae *(Simuliidae)* are small and worm-like, with a kind of small ball at one end. When they are out of the water, they fold themselves in half while wiggling. Their colour varies from green and brown to grey, but is usually black. Their length is up to 0.8 centimetres. They live on a solid substrate, often piled up in the current of brooks and rivers. You can also find them in the overflow of ponds.

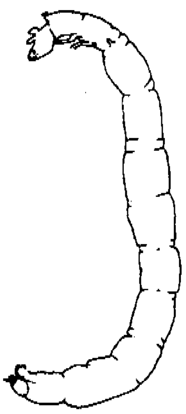
Scuds *(Crustacea Amphipoda)*





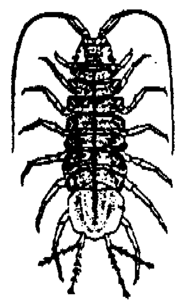
Scuds are also referred to as side-swimmers. They have extremely flattened sides, and are usually curled into a half-moon shape. Their body colour can be creamy white or brown, but is usually grey. Most of them are very small, but some can reach 1.5 centimetres in length. They move about by skittering on their sides and flexing their entire body.
You will most often find them hiding in plants or under debris in most, preferably shallow, waters. They are common and widespread, occurring in a wide variety of standing and flowing waters. They are moderately intolerant of pollution.

Midge larvae *(Diptera Chironomidae)*



Midge larvae *(Chironomidae)* are extremely small and thin. They look worm-like and wiggle intensely when out of the water. Their colour varies from gold or brown to green, but they tend to be black. Their length is usually less than 1.5 centimetres. They occur in almost all types of waters, even salt water. They live in the silt bottom, on solid substrates, or on water plants.

Sowbugs *(Crustacea Asellidae)*

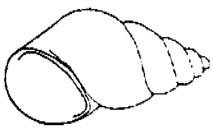


Sowbugs, commonly called pill bugs, resemble their terrestrial cousins, somewhat flattened. They have seven pairs of legs, extending on either side. Their colour varies; usually it is grey, but sometimes brown. Their length is less than 2.5 centimetres. They seldom inhabit open waters, but instead remain hidden under rocks, plants and debris. They are typical inhabitants of small- to medium-sized streams and standing waters. Standing and slow-flowing waters contain the most types of sowbugs. They are moderately intolerant of pollution.

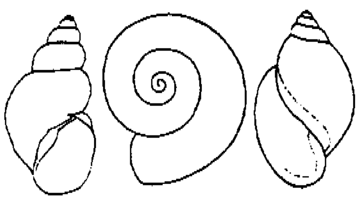
Snails *(Mollusca Gastropoda)*

Snails are familiar to most people and can be found in almost any type of water, standing or flowing. They creep over the bottom and crawl about on plants growing in shallow waters, usually less than 2 metres deep. They have a variety of shapes and sizes, but most have a coiled shell and a muscular foot. The foot sticks out of the shell, and is used for movement. As they move about, they form irregular shaped tracks in the sediment. Some types are quite intolerant to pollution, while others are tolerant, but none can withstand very acidic waters.

There are two types of snails, namely snails with gills *(Prosobranchia)* and lung snails *(Pulmonata)*. Snails with gills are dependent on the level of oxygen in the water, and thus are sensitive to oxygen depletion. Lung snails can obtain oxygen straight from the air, and therefore are able to live in waters with little or no oxygen.

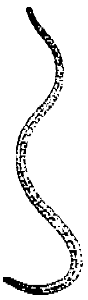


Snails with gills always have a shutoff valve at the opening of their shell. Also, almost all snails with gills are right-handed. Right-handed snails are identified by their swirling shell opening on the right-hand side (when the point of the shell is straight up in the air and the opening faces you).



Lung snails never have a shutoff valve, and can be either left- or right-handed, or flat. Left-handed snails are identified by the fact that the shell opening is on the left-hand side (when the point is straight up and the opening faces you). Flat snails have shells that look like ram's horns.

Macroinvertebrates dominant in severely polluted waters



Aquatic worms *(Oligochaeta)*

Aquatic worms look like worms that live in the soil, although they are thinner. Their body length varies from a few millimetres to 30 centimetres. Their colour is reddish, brown or grey. Usually the skin of the worms is transparent, so you can see the veins of the worm. Many worms have a two bunches of hair, on each of its rings.
Aquatic worms usually live on and in the bottom, both in standing and flowing waters. They like bottoms of silt, sand, larger-size sediments, dead plant materials and water plants. Sometimes they may even live on other animals, for example on crayfish. Often you will find aquatic worms in huge numbers, with their heads in the sediment, and their bottom part whirling around. On silt they form colonies which look like red spots.
Because aquatic worms live in silty bottoms, they are adapted to low oxygen levels. They can survive in strongly polluted water.

Leeches *(Hirudinea)*

Leeches have the worst reputation of all macroinvertebrates, because they are parasitic and some types attack livestock and people. However, they can be quite beautiful, with bright colours and unique patterns over the length of their body. Their colour can be green, black, brown or grey, and white, yellow, blue or red spots can occur. Their length is up to 13 centimetres. Leeches look like worms, but they do not have hair on their skin. They have two suction disks at the belly side, one on the front and one on the back side of the body.
Leeches can live in any water body, standing or flowing, although they are found in larger numbers in standing waters. They prefer shallow waters with a lot of water plants. Usually you will find leeches on the underside of rocks and stones (stable materials). In general, leeches are active during the night.
Most types can tolerate pollution, but few can live in strongly acidic waters. Most leeches can live several days without oxygen, which makes them indicative of moderately to strongly polluted waters.

Appendix

8 Health Survey Data Sheet

Copy this data sheet and give one copy to each small group of participants conducting the Health Survey. Use one data sheet to describe one surveyed water source. Write additional comments to describe the source on the back of the paper.

General data

Date:

Surveyors' name(s):

Name province/municipality:

Name, address organisation:

Surveyed water source:
(name and location)

Number of people using the water source:

Pictures taken :
(numbers and short description)

People being interviewed:

Name	male/female	age	city/village	remarks
--				
--				
--				
--				
--				
--				
--				
--				
--				
--				
--				

Description of water source

Type of water source:
(well, spring, river, stream, brook, lake, rain, other)

Function(s) the water is used for:
(drinking, washing, bathing, irrigation, animals, other)

Colour of the water: Odour of the water:

Taste of the water:

Clarity of the water:
(clear, moderate, fair or severely turbid)

Other remarks:

Possible sources of faecal contamination

A) Sewage system

Is there a sewage system present:

Number of connected households:

Distance between the sewage discharge point and the water source:
(overland and through the water, if possible)

Is the water receiving sewage discharge connected with the water source via surface water:

If the connection is a flowing water, what is the direction of the flow:

Other remarks:

B) Latrines

Are there latrines present:

Name of owner	*distance towater source*	*type of latrine*	*frequency of cleaning*	*cover present*
--				
--				
--				
--				
--				

Number, names and distances to sources of latrines that are situated higher in altitude than the water source:

Other remarks:

C) Open-air defecating areas

Are there people defecating in the open air:

Number of people using such area(s):

Distance to water source:

Distance to other water bodies:

Other remarks:

D) Cattle and wild animals

Is the water source used by animals:
(number and type)

Are there other drinking places for animals:

Description location	*Type & number of users*	*Distance to water source*	*Connection with water source*

--

--

--

--

--

Other remarks:

Possible routes of faecal contamination

Is the water source protected:

If yes, how:
(fence, cover, soak-away drain, platform, other)

Do water collectors clean jars before use:

Is the jar covered during transportation of water:

Is drinking water kept in separate jar at home:

If yes, is the drinking water jar cleaned before use:

Is drinking water being boiled:

Is drinking water stored:

If yes, how long:

Are other purification methods used:

If yes, describe materials, method and number of users:

Other routes of faecal contamination occurring:

--

--

--

Diseases experienced

Diseases that have occurred and/or are still occurring

Name of sick person	*Age*	*Type of disease*	*Period of illness*	*Remarks*
--				
--				
--				
--				
--				
--				
--				
--				

Other remarks:

Results of bacteriological test

Sample number	*Sample location*	*F. Coli counts*
--		
--		
--		
--		
--		
--		
--		
--		
--		

Any time delay between sampling and analysis:

Other remarks:

Appendix

9 Data Sheet
Physical and Chemical Analysis

Copy this data sheet and use one copy for each sampling location. Write additional comments on the back of the paper.

General data

Name of person(s) sampling:

Name, address of organisation:

Date and time of sampling:

Weather conditions:

Pictures taken:
(number, location, date and short description)

Description sampling location

Type of water sampled:
(brook, stream, river, lake, pond, reservoir, estuary, other)

Location:
(number, name, reference to map(s), reference to other survey(s))

Method of sampling:
(from the shore, from a bridge, by boat, other)

Distance to shore:

Water plants and animals present:

Point source(s) present:
(discharge pipe, inflowing water, other)

Possible non-point source(s) present:
(types of land use, other)

Type of sample water:
(reference water, concentrated discharge water, polluted water, other)

Physical and chemical parameters

Colour:

Odour:

Temperature

Water temperature sample location: °C

Water temperature reference location: °C

Temperature difference reference and sample location: °C

Distance reference and sample location: m or km

Turbidity/visibility

Secchi disk reading: m

Stream velocity and flow

Stream velocity water body: m/s
(estimated average)

Flow water body: m^3/s
(estimated average)

Flow point source: m^3/s
(estimated average)

Acidity (pH)

pH:

Method used:

Dissolved oxygen

Depth (m)	Temperature (°C)	DO (mg/l)
--		
--		
--		
--		
--		

BOD_5: mg/l

Temperature at time of sampling: °C

Conductivity

Conductivity: µS/cm

Temperature: °C

Samples send to laboratory

Number/code of sample bottle(s)	pH	Temperature (°C)	Conductivity (µS/cm)
--			
--			
--			
--			
--			

Name, address laboratory:

Name contact person:

Appendix

10 List of manufactures of water quality testing equipment

Hach

Serving United States, Canada, Latin America, the Carribean, the Pacific, Australia and the Far East:

Hach Chemical Company	Tel:	+1(800)227 4224
World Headquarters	*(for calls from U.S.)*	
P.O. Box 389	Tel:	+1(303)669 3050
Loveland	*(calls from other countries)*	
Colorado 80539	Fax:	+1(303)669 2932
U.S.A.	Telex:	160840

Serving Europe, Africa, the Middle East and Near East:

Hach Europe S.A./N.V.	Tel:	+32(81)445 381
Chausseu U Namur 1	Fax:	+32(81)441 300
5150 Floreffoix	Telex:	59027
Belgium		

LaMotte

LaMotte Chemical Products Company	Tel:	+1(410)778 3100
P.O. Box 329	Fax:	+1(410)778 6394
Chestertown		
Maryland 21620		
U.S.A.		

Merck

Frankfurter Str. 250	Tel:	+49(6151)720
64271 Darmstadt	Fax:	+49(6151)722 000
Germany	Telex:	419 280

Millipore

Millipore Intertech Inc.	Tel:	+1(617)275 9200
P.O. Box 255	Fax:	+1(617)275 5550
Bedford	Telex:	92 3457
Massachusetts 01730		
U.S.A.		

Oxfam

DelAgua		
The Robens Institute	Tel:	+44(483)259 203
University of Surrey	Fax:	+44(483)503 517
Guildford GU2 5XH	Telex:	859331 UNIVSY G
United Kingdom		

Appendix

11 Recommended water sample preservation techniques

Parameter	*Container*[1]	*Sample Vol (ml)*	*Preservative*	*Storage time*
Total organic carbon	P, G	100	H_2SO_4 to pH<2 4 °C	1-2 dy
Total inorganic carbon	P, G	100	Air seal 4 °C	0[2]
Chlorine demand	P, G		None	0
Aluminium (Al)	P, G	100-200*	NHO_3 to pH<2	6 mo
Arsenic (As)	P, G		NHO_3 to pH<2	6 mo
Cadmium (Cd)	P, G	100-200*	NHO_3 to pH<2	6 mo
Calcium (Ca)	P, G	100-200*	NHO_3 to pH<2	6 mo
Chromium (Cr)	P, G	100-200*	NHO_3 to pH<2	6 mo
Copper (Cu)	P, G	100-200*	NHO_3 to pH<2	6 mo
Iron (Fe)	P, G	100-200*	NHO_3 to pH<2	6 mo
Lead (Pb)	P, G	100-200*	NHO_3 to pH<2	6 mo
Magnesium (Mg)	P, G	100*	NHO_3 to pH<2	6 mo
Manganese (Mn)	P, G	100-200*	NHO_3 to pH<2	6 mo
Mercury (Hg)	G	500	NHO_3 to pH<2	2 wk
Nickel (Ni)	P, G	100-200*	NHO_3 to pH<2	6 mo
Selenium (Se)	P, G		NHO_3 to pH<2	90 dy
Zinc (Zn)	P, G	100-200*	NHO_3 to pH<2	6 mo
Ammonia-nitrogen	P, G		H_2SO_4 to pH<2 4 °C	24 hr
Nitrate-nitrogen	P, G		H_2SO_4 to pH<2 4 °C	24 hr
Nitrite-nitrogen	P, G		H_2SO_4 to pH<2 4 °C	24 hr
Organic-nitrogen	P, G		H_2SO_4 to pH<2 4 °C	24 hr
Total Kjeldah nitrogen	P, G		H_2SO_4 to pH<2 4 °C	24 hr
Oil and grease	G		H_2SO_4 or HCl to pH<2 4 °C	24 hr
BOD	P, G	300	4 °C	6 hr
COD	P, G	200	H_2SO_4 to pH<2 4 °C	7 dy

[1] P = plastic; G = glass.

[2] One reference indicates TIC may be preserved for 3 months in a sealed bottle with $HgCl_2$ (W.S. WONG, "Deep Sea Research", 1970).

Parameter	*Container*[3]	*Sample Vol (ml)*	*Preservative*	*Storage time*
PCB's	G	2 l	4 °C	
Organochlorine pesticides	G	1 l	4 °C	
Chlorinated phenoxy acid herbicides	G	1 l	H_2SO_4 to pH<2 4 °C	
Organophosphates and carbamates	G	1 l	H_2SO_4 to pH<3 10 g Na_2SO_4	
Phenolics	G	500	0.1-1.0 g $CuSO_4$ H_3PO_4 to pH<4 4 °C	24 hr
Soluble reactive	P, G		Filter 4 °C	24 hr
Total phosphorus	P, G		4 °C	7 dy
Redox potential	P, G	100	None	None
pH	P, G	100	4 °C	6 hr
Total solids	P, G	200**	4 °C	7 dy
Volatile solids	P, G	200**	4 °C	7 dy
Sulfides	P, G		2 ml ZnOAc	24 hr
Polynucleated aromatic hydrocarbons	G			

* Sample can be used for other metal analyses.

** Sample can be used for total solids and volatile solids.

Source: PLUMB, RUSSELL H. Jr.: "Procedures for handling and chemical analysis of sediment and water samples". U.S. Environmental Protection Agency. Published b Environmental Laboratory, U.S. Army Engineer Waterways Experiment Station, P.O. Box 631, Vicksburg, Mississippi 39180, U.S.A.

[3] P = plastic; G = glass.

Appendix

12 Conversion Factors

Multiply	*by*	*To obtain*
acres	43560	square feet
acres	4047	square meters
acres	0.404687	hectare
centimeters	0.3947	inches
centimeters/sec	0.03281	feet/sec
cubic centimeters	0.06102	cubic inches
cubic centimeters	0.001	Liter
cubic centimeter	1.0	milliliter
cubic feet	0.0283	cubic meters
cubic feet/s	448.831	gallons/min
cubic meter	1000.0	Liters
cubic meter	264	gallons
fathom	1.828804	meter
fathoms	6.0	feet
feet	30.48	centimeters
gallons (U.S. liquid)	3785.0	cubic centimeters
gallons	0.1337	cubic feet
gallons	8.33	pounds-water
grams	1000	milligrams
grams	0.03527	ounces (avdp)
grams/Liter	1000.0	parts/million (ppm)
hectare	2.47	acres
inches	2.540	centimeters
kilograms	2.205	pounds
knots	6080	feet/hr
knots	18532	kilometers/hr
knots	1.0	nautical miles/hr
knots	1.689	feet/sec
league	3.0	miles (approx.)
Liters	1000.0	cubic centimeters
Liters	0.03531	cubic feet
Liters	0.2642	gallons (U.S. liq)
meters	3281	feet
miles (U.S. statute)	1.609347	kilometers
miles (nautical)	6080.27	feet
miles (nautical)	1.853	kilometers
miles (nautical)	1.1516	miles (statute)
milligrams/Liter	1.0	parts/million (ppm)
ounces	28.349527	grams
ounces (fluid)	0.02957	Liters
parts/thousand (ppt)	1000.0	parts/million (ppm)
pounds (mass)	0.4536	kilograms
pounds of water	0.01602	cubic feet
pounds/square feet	4.882	kg/square meter
square centimeters	0.1550	square inches
square meters	10.76	square feet
square miles	2.589998	square kilometers

$$°C = \frac{(°F - 32.0)}{1.80} \qquad °F = (°C \times 1.80) + 32.0$$

Gas	*Multiply ppm to obtain µg/m³*	*Multiply µg/m³ to obtain ppm*
Ammonia (NH_3)	696	14.40×10^{-4}
Hydrogen fluoride (HF)	818	12.20×10^{-4}
Carbon monoxide (CO)	1150	8.73×10^{-4}
Ethylene (CH_2:CH_2)	1150	8.72×10^{-4}
Nitric oxide (NO)	1230	8.15×10^{-4}
Hydrogen sulfide (H_2S)	1390	7.18×10^{-4}
Hydrogen chloride (HCl)	1490	6.71×10^{-4}
Fluorine (F_2)	1550	6.44×10^{-4}
Nitrogen dioxide (NO_2)	1880	5.32×10^{-4}
Ozone (O_3)	1960	5.10×10^{-4}
Sulfur dioxide (SO_2)	2620	3.82×10^{-4}
Chlorine (Cl_2)	2900	3.45×10^{-4}

Appendix

13 Water quality standards WHO and EPA

To determine whether water is good or bad, test results must be compared to some form of water quality standards. The quality of a water should always be interpreted in relation with the intended use of the water. For example, the perfect balance of water chemistry that assures a sparking clear, sanitary swimming pool would not be acceptable as drinking water and would be a deadly environment for many fish larvae.

Thus, usually water quality parameters have different guideline or standard values, related to the water use. Another example are the widely different levels of faecal coliform bacteria that are considered acceptable:

Faecal coliform Standards (in colonies per 100 ml):

Drinking water	0 FC
Total body contact (swimming)	200 FC
Partial body contact (boating)	1000 FC
Treated sewage effluent	not the exceed 200 FC

This appendix lists the health-based Water Quality Guidelines formulated by the World Health Organisation (WHO, 1992), and some of the Quality Criteria for Water formulated by the U.S. Environmental Protection Agency (EPA, 1979).

The drinking-water guideline values formulated by the WHO represent the level (a concentration or a number) of a constituent that ensures an aesthetically pleasing water and does not result in any significant risk to the health of the consumer. The quality of water defined by the guideline values is such that it is suitable for human consumption and for all usual domestic purposes, including personal hygiene.

Concerning heavy metals, the recommended guideline values for human health are based upon the amount of toxin a person can withstand before becoming ill. Standards are derived from chronic toxicity tests on rats and other mammals.

The Quality Criteria for Water formulated by the EPA represent the level of a constituent that does not result in any harmful effect of the constituent on the aquatic ecosystem.

In developing countries national drinking-water standards based on the WHO guidelines may differ from the WHO guidelines due to a variety of local geographical, socioeconomic, dietary and industrial conditions. Similarly, the guideline values given have often to be considered as long-term goals rather than rigid standards that have to be complied with at all times and in all supply systems.

World Health Organisation (WHO)
November 1992

Parameter	Guideline Value (GV)	Remarks
Arsenic	0.01 mg/l (P)[1]	
Cadmium	0.003 mg/l	
Chromium	0.05 mg/l (P)	
Copper	2 mg/l (P)	ATO[2]
Cyanide	0.07 mg/l	
Fluoride	1.5 mg/l	Climatic conditions, volume of water consumed and intake from other sources should be considered when setting national standards
Lead	0.01 mg/l	
Manganese	0.5 mg/l (P)	ATO
Mercury (total)	0.001 mg/l	
Nickel	0.02 mg/l	
Selenium	0.01 mg/l	
Uranium		NAD[3]
Nitrate (NO_3)	50 mg/l	The sum of the ratio of the concentration of each to their respective GV should not exceed 1
Nitrite (NO_2)	3 mg/l	
Total hardness	500 mg/l	(as $CaCO_3$)
E. Coli bacteria	Not detectable in any 100 ml sample	
F. Coli bacteria	Not detectable in any 100 ml sample	
Chlorine	5 mg/l	ATO. For effective disinfection free chlorine residual 0.5 mg/l after at least 30 minutes contact time at pH ≤ 8.0

Aesthetic quality values

Aluminium	0.2 mg/l	
Ammonia	1.5 mg/l	
Chloride	250 mg/l	
Colour	15 TCU	
Copper	1 mg/l	
Hydrogen sulfide	0.05 mg/l	
Iron	0.3 mg/l	
Manganese	0.10 mg/l	
Dissolved oxygen	-	No GV set
pH	6.5 - 8.5	
Sulfate	250 mg/l	
Taste and odour	-	Should be acceptable
Temperature	-	Should be acceptable
Suspended solids	1000 mg/l	

Turbidity	5 NTU	For effective disinfection ≤ 1 NTU
Zinc	3 mg/l	
Pesticides		
Alachlor	20 μg/l	For 10^{-5} excess risk
Aldicarbl	10 μg/	
Aldrin/dieldrin	0.03 μg/l	
Atrazine	2 μg/l	
Bentazon	30 μg/l	
Carbofuran	5 μg/l	
Chlordane	0.2 μg/l	
Chlortoluron	30 μg/l	
DDT	2 μg/l	
1,2-dibromo-3-chloro-propane	1 μ g/l	For 10^{-5} excess risk
2,4-D	30 μg/l	
1,2-dichloropropane	20 μg/l (P)	
1,3-dichloropropane		NAD
1,3-dichloropropene	20 μg/l	For 10^{-5} excess risk
ethylene dibromide		NAD
Heptachlor and hepta-chlor epoxide	0.03 μg/l	
Hexachlorobenzene	1 μg/l	For 10^{-5} excess risk
Isoproturon	9 μg/l	
Lindane	2 μg/l	
MCPA	2 μg/l	
Methoxychlor	20 μg/l	
Metolachlor	10 μg/l	
Molinate	6 μg/l	
Pendimethalin	20 μg/l	
Pentachlorophenol	9 μg/l (P)	
Permethrin	20 μg/l	
Propanil	20 μg/l	
Pyridate	100 μg/l	
Simazine	2 μg/l	
Trifluralin	20 μg/l	
Dichlorprop	100 μg/l	
2,4-DB	90 μg/l	
2,4,5-T	9 μg/l	
Silvex	9 μg/l	
Mecoprop	10 μg/l	
MCPB		NAD

Source: "Revision of the WHO guidelines for drinking-water quality", World Health Organisation Geneva 1992. Report of the final task group meeting Geneva, Switzerland, 21-25 September 1992.

Parameter	*Quality criterium*	*Remarks*
Ammonia	0.02 mg/l	For freshwater aquatic life
Cadmium	10 µg/l	For domestic water supply (health)
Chlorine	2.0 µg/l	For salmonoid fish
	10.0 µg/l	For other freshwater and marine organisms
F. Coli bacteria	≤ 200 per 100 ml	For bathing waters
	≤ 14 MPN per 100 ml	Shellfish harvesting waters
Copper	1.0 mg/l	For domestic water supply (welfare)
Cyanide	5.0 µg.l	For freshwater and marine aquatic life and wildlife
Iron	0.3 mg/l	For domestic water supply (welfare)
	1.0 mg/l	For freshwater aquatic life
Lead	50 µg/l	For domestic water supply (health)
Mercury	2.0 µg/l	For domestic water supply (health)
	0.05 µg/l	For freshwater aquatic life and wildlife
	0.10 µg/l	For marine aquatic life
Nitrogen (nitrates and nitrites)	10 mg/l	For domestic water supply (health)
Dissolved oxygen	5.0 mg/l	For fish populations
pH	5 - 9	For domestic water supply (welfare)
	6.5 - 9.0	For freshwater aquatic life
	6.5 - 8.5	Marine aquatic life (not more than 0.2 units outside normally occurring range)
Phosphorus (elemental)	0.10 µg/l	For marine or estuarine waters
Hydrogen sulfide	2 µg/l	For freshwater and marine aquatic life
Zinc	5 mg/l	For domestic water supply (welfare)

Source: "Quality criteria for water", by Russell E. Train, 1979. U.S. Environmental Protection Agency, Washington D.C.

---

[1](P) - Provisional guideline value. This term is used for constituents for which there is some evidence of a potential hazard but where the available health effects information is limited, and/or where an uncertainty factor greater than 1000 is used in the derivation of the tolerable daily intake (TDI).

[2]ATO - Concentrations of a substance at or below the health-based guideline value may affect the appearance, taste or odour of the water.

[3]NAD - No adequate data to recommend a health-based guideline value.

Appendix

14 List of juridical organisations

Atty. Ma. Paz Luna
Haribon
340 Villamor st., Pinaglabanan
San Juan, Metro Manila
Tel: +63(2)704 316
Fax: +63(2)631 2061.

Friends of the Earth International (network)

Secretariat:
FOE International
P.O. Box 19199
1000 GD Amsterdam
Tel: +31(20)622 1366
Fax: +31(20)627 5287

International Union for the Conservation of Nature (network)

IUCN International
Avenue du Mont Blanc
CH - 1196 Gland
Switzerland
Tel: +41(22)999 0001
Fax: +41(22)999 0002

World Wildlife Fund (network)

WWF International
CH-1196 Gland
Switzerland
Tel: +41(22)364 9111
Fax: +41(22)364 5468

WWF India
Center for Environmental Law
172-B Lodi Estate
New Delhi - 110003
Tel: +91(11)469 7721 or 461 6532
Fax: +91(11)462 6837

➔

E-LAW also gives juridical and environmental advise to persons and organisations in countries other then mentioned below.

Australia
Suite 82, 280 Pitt Street.
Sydney NSW 2000
Tel: +61(2)261 3599
Fax: +61(2)267 7548
E-Mail: elawoz@peg.apc.org

Ecuador
Dra. Marcela Enriquez V
Dr. Byron Real Lopez
P.O. Box 17-12-309
Tel: +593(2)221 791
Fax: +593(2)225 029
E-Mail: elaw@cordavi.ec

Indonesia
Jalan Diponegoro no. 74
Jakarta 10320
Tel: (62 21)310 1755
Fax: (62 21)330 140
E-Mail: elawjakarta@igc.org

Japan
T-Y Building 3-18-11 Hongo
Bunkyo-ku, Tokyo 113
Tel: +81(3)3813 6544
Fax: +81(3)3814 0252
E-Mail: elawjapan@igc.org

Peru
Manuel Ganzalez Olaechea 349
San Isidro, Lima 27
Tel: +51(14)411 737
E-Mail: elawperu@igc.org

Sri Lanka
29, Siripa Road
Colombo 5
Tel: +94(1)588 804/582 439
Fax: +94(1)588 804
E-Mail: e-law-sl@ef.org.ac.lk

Philippines
Soute 901, Richbelt Tower
17 Annapolis Street, Greenhills
San Juan, Metro Manila
Tel: +63(2)722 7180/722 6884
Fax: +63(2)722 7119
E-Mail: elawmanila@igc.org

Maleisia
87 Jalan Cantonment
10250 Pulau Pinang
Tel: +60(4)373 713
Fax: +60(4)368 106
E-Mail: twn@igc.org

United States
1877 Garden Av.
Eugene, OR 97403
Tel: +1(503)687 8454
Fax: +1(503)687 0535
E-Mail: elaweugene@igc.org

Appendix

15 Glossary

Algae - the smallest plants on earth, without real stems and leaves, growing mainly in water or in damp locations. Can be subdivided into planktonic algae (free-floating) and benthic algae (attached to substrate).

Atmospheric deposition - Air pollution that is deposited in surface water or on the ground.

Aquifer - water-carrying layer in the ground, holding groundwater.

Bacteria - very small organisms, which cannot be seen with the naked eye, but which play an important role in nature. Some bacteria living in the water break down organic matter, thereby consuming oxygen. Several types of bacteria that are spread via the water can cause diseases.

Bioaccumulation - the accumulation of toxins like heavy metals and pesticides in certain organs of animals.

Biodegradable - material that can be decomposed in a natural way, mostly by bacteria.

Biological pest control - the control of pests (insects, for example) without using unnatural, toxic substances.

Biomagnification - the increase in concentration of toxins like heavy metals and pesticides as you move up the food web.

Concentration - a measure of the amount of a constituent (substance) in a given volume of solution. This can be expressed in several ways, for instance percentage, milligrams per litre (mg/l), parts per million (ppm), etc.

Distilled water - water that only contains water molecules, without any other constituents (substances).

Diversity (biodiversity) - the number of different types of organisms in a biological community (ecosystem).

Ecosystem - a system of interrelated organisms and their non-biological (physical and chemical) environment.

Eutrophication - the enrichment of water with nutrients, mainly phosphorus and nitrogen compounds, which stimulates the growth of algae and large water plants.

Erosion - the wearing away of land surface by wind or water. Erosion can occur naturally or through land-use activities such as clearing for timber, development, road building and farming.

Gill - body part of animals like fish and some snails, for example, that filters dissolved oxygen from the water. Comparable with lungs, which filter oxygen from the air.

Groundwater - the supply of water found beneath the earth's surface.

Habitat - the area in which an plant or an animal naturally occurs.

Impoundment - a dam, dike, flood gate or other barrier, confining a body of water.

Larvae - the immature form of an insect.

MacroInvertebrate - a small animal without a backbone that can be seen with the naked eye.

Non-point-source pollution - pollution from any diffuse source. Generally initiated by run-off water from urban, forestry, agricultural and construction land uses.

Nutrients - very small constituents (substances), mainly nitrogen and phosphorus, not visible with the naked eye, that serve as food for algae and large water plants.

Nymph - the immature form of an insect.

Organic farming - farming methods that use only natural substances like organic fertilizers rather than unnatural, toxic substances such as artificial fertilizers and pesticides.

Organic waste - substances which originate from something that was once living.

Organism - a living being: a plant, an animal or a human being.

Pathogens - disease-causing organisms, for example certain bacteria, viruses, amoebae and worms.

Pesticides - artificially made products that kill certain types of plants or insects, and thus are used to protect crops.

Point-source pollution - pollution from any single identifiable source, a pipe, a pit or a ship, for example.

Pollutant - any substance introduced into the environment that adversely affects the usefulness of a resource.

Residence time - the time that is needed to renew the complete water volume of a lake.

Run-off water - water from rain, snow melt or irrigation that flows over land towards a water body.

Sample - a representative portion of a system, for example a part of a water body.

Sediment - soil, sand and minerals which are washed from land into water, usually after rain, and has settled on the substrate as new bottom material.

Sedimentation - the settling down of suspended solids on the bottom of a water, caused by the reduction of the stream flow.

Silt - very small soil particles, smaller than sand, which can be suspended in water, or settled on the bottom of slow-flowing or standing waters.

Slow sand filtration - the cleaning of water by sending it through a bed of sand.

Source - the beginning or origin, for example the origin of a river, or the origin of pollution.

Sterilization - the killing of all disease-causing organisms.

Substrate - bottom material of a water body.

Suspended solids - eroded soil particles, sand, silt or minerals for example, that are washed from land into water, usually after rain.

Thermal stratification - separation of the surface and bottom water of a standing water into distinct layers, due to differences in temperature.

Vertebrates - animals with a backbone, which can be seen with the naked eye, such as birds, reptiles, mammals and fishes.

Virus - a disease-causing organism, not visible with the naked eye.

Water plant - plant that lives completely or partly in the water. This can be an algae or a large water plant.

Watershed - all the land that serves as a drainage for a specific stream, river, pond or lake; also called catchment area or drainage area.

Zooplankton - tiny animals living in the water. Most types can only be seen with a microscope.

ries are clearly visible. This depth is the Secchi disk reading. Precision can be to the nearest centimetre.

The disk cannot be used in very shallow or very fast-flowing waters. In the latter case it tends to swing with the current or rotate, which prevents accurate measurement. In such a situation it may be helpful to attach a heavy object under the disk before lowering it into the water.

There also exist meters which measure the turbidity, which can be obtained from a manufacturer (see Appendix 10). They are expensive, but most accurate. Usually, however, visibility can be measured sufficiently accurately with a Secchi disk.

Officially turbidity is expressed in NTUs (Nephelometer Turbidity Units) or JTUs (Jackson Turbidity Units). With the Secchi disk the visibility is measured, which is expressed in metres.

6.5 Stream velocity and flow

The *stream velocity* is defined as the distance water moves in 1 second (the speed at which the water flows). The *stream flow* is defined as the volume of water that passes a certain cross-section of a river in one second. In general, the stream velocity and flow vary according to the size of the river or stream (amount of water), the shape of the river bed and the slope of the river or stream.

Stream velocity is an important feature to know since it determines how much oxygen diffuses into the water (reaeration, see also Section 6.7), the erosion and sedimentation pattern in the water and the occurrence of water plants and animals. It also determines how quickly pollution is flushed away in a flowing water, and how can it accumulate in a standing water (residence time; see Section 1.3). When the pollution comes from a point source, such as a discharge pipe from a factory, you need to know the flow to calculate the amount of pollution discharged.

The concentration of a pollutant or constituent is a measure of the amount of the constituent that occurs in 1 litre of water (or other solvent). The absolute amount of constituent that passes through a river or accumulates in a lake over a certain time period, is called the load. The load is calculated by multiplying the flow with the concentration, and is expressed in mass unit per time unit, kg/s or kg/day for example.

$$\textit{Load (kg/s or kg/day)} = \textit{flow } (m^3/s) \times \textit{concentration (mg/l)}$$

Measurement

To measure the stream velocity you need a marked rope at least 5 metres long, a watch with a second hand, a floating object and a landing net. The floating object should not be too big or too light, since then its speed may be influenced by the wind.

Mark off a distance of at least 5 metres along the shore. Put the floating object in the main flow of the water upstream of the marked strip. Record the number of seconds it takes your floating object to cover the marked distance. Scoop the floating object out of the water. Calculate the stream velocity by dividing the number of metres covered (the length of the marked strip) by the number of seconds you have recorded (the stream velocity is expressed in m/s). Repeat this test at least 2 times and calculate the average stream velocity. Record your findings on the data sheet.

$$Stream\ velocity\ (m/s) = \frac{meters\ covered\ (m)}{seconds\ needed\ (s)}$$

To estimate the flow you need the same equipment as for the stream velocity. In the case of a small discharge pipe you also need an empty bottle with a known volume (a soft-drinks bottle, for example), a funnel and gloves to protect your hands.

Imagine a straight line from one shore to the other, which is the width of the river (or stream). Estimate the length of this line, by using the marked rope or a map. Divide the imagined line across the river into 4 to 10 sections, depending on the width of the river. Tie a heavy object to the marked rope. At every section along the imagined line, lower the heavy object until it reaches the bottom, and record the depth of the water you find (you can also use a measuring stick). Calculate the average depth of the river. The width multiplied by the average depth gives the sectional plane of the river (at your measuring point). Estimate the flow by multiplying the stream velocity by the sectional plane (width x depth) of the river. Record your findings on the data sheet.

$$Sectional\ plane\ (m^2) = width\ (m) \times average\ depth\ (m)$$

$$Flow\ (m^3/s) = stream\ velocity\ (m/s) \times sectional\ plane\ (m^2)$$

If the flow is small enough to be caught with a funnel, you can use an empty bottle with a known volume (for example a 1 litre soft-drinks bottle) and a funnel. You can also use a bucket. Record the time needed to fill the bottle or bucket. Do this test 3 times and calculate the average. Avoid direct skin contact with water from discharge pipes; always use gloves or something else to protect yourself.

6.6 Acidity (pH)

The acidity of water is expressed as pH, and can vary from 0 to 14. Neutral water has a pH of 7. Acidic water has a pH below 7, basic water has a pH above 7. Everyday examples of basic substances are bleach (pH 12), ammonia (pH 11), baking soda (pH 8.5) and seawater (pH 8). Acidic substances include orange juice (pH 5.5), Cola (pH 4), vinegar (pH 3), lemon juice (pH 2) and battery acid (pH 1).

Alkalinity or acid neutralizing capacity, refers to the ability of a water to resist changes in pH by neutralizing acid input. The higher the alkalinity, the greater the ability of the water to neutralize acids. The procedure of measuring alkalinity involves monitoring the changes in pH of a water sample as an acid is dripped into it.

Most natural waters have a pH from 6 to 9, and most natural surface waters are slightly basic (pH of 7.5 to 8). Glades and bogs are usually acid. In glades and bogs where peat moss (Sphagnum) grows, the pH is usually between 4.0 and 5.0. Waters in sandy areas also have acidic water. Waters on clay ground and fenland are usually basic.

Generally domestic sewage water is basic, while industrial waste may be acidic or basic. Because the pH of industrial and domestic waste water is usually different from the pH of the receiving water, sudden changes in acidity often indicate this type of pollution.

The pH value naturally varies daily and seasonally, mainly due to the activity of algae and large water plants. At night water is slightly acidic, while during the day the pH value increases.

Plants and animals usually have a preference for a specific acidity and will not survive if the acidity deviates very much. Some organisms are more tolerant to pH changes, while others are very sensitive.

Changes in the pH of a water can also affect the water quality indirectly, for example because toxic metals that are trapped in sediment are released into the water at lower pH levels (see also Section 2.2).

Measurement

Samples should be taken away from the shore and about 10 cm under the water surface, just like oxygen samples. The pH should be measured in the field, or otherwise the sample should be kept in the dark and in ice, and should be analyzed as soon as possible. Record your findings on the data sheet.

There are three basic measurement techniques that can be used to measure the acidity in the field, namely pH indicator papers, liquid pH indicators, and portable pH electrodes (probes) and meters (see Figure 9). Liquid pH indicators are easy to use, but relatively prone to inaccuracies and difficult to use in turbid water. The indicator papers and meters are very easy to use, but vary in accuracy and expense. The pH indicator paper is the cheapest and least accurate, but sufficient for most indicative sampling programmes. Meters and electrodes are much more expensive, but worth buying if used frequently. All equipment can be obtained through manufacturers (see Appendix 10).

It is important to bear in mind that for every unit change on the (logarithmic) pH scale, there is a tenfold change in how acid or basic the water is. In other words, pH 6 is ten times more acidic than pH 7; pH 5 is one hundred times more acidic than pH 7.

6.7 Oxygen

Oxygen is as essential to aquatic life as it is to life on land. Without oxygen, a water would be an aquatic desert without fish, plants or insects. For this reason, many experts consider dissolved oxygen to be the most important parameter used to characterize water quality.

The amount of oxygen in water is called the dissolved oxygen (DO) concentration, and is influenced by the water temperature. The colder the water, the more oxygen it can hold, because gases like oxygen are more easily dissolved in cool water.

Oxygen naturally moves (diffuses) from the air into the water. Agitation of the water surface by winds and waves (at riffles and waterfalls, for example) enhances this diffusion process, which is called reaeration.

Algae and large water plants, just like any other plant, produce oxygen as a by-product of photosynthesis. This is the transformation of heat (energy) from sunlight into energy that can be used by the plant. But algae and water plants also use oxygen for respiration.

Respiration occurs all the time, but photosynthesis occurs only in the presence of light. Consequently, a water that has a large population of algae or large water plants can experience a great fluctuation in dissolved oxygen concentration during a 24-hour period.

Bacteria that decompose organic matter use oxygen from the water. The amount of oxygen required to decompose organic matter is called the biological oxygen demand (BOD). When the BOD exceeds the available dissolved oxygen (DO), the DO in the water is reduced or depleted. This is very harmful for the water organisms, it can even cause fish kills. In normal, healthy streams the addition and removal of oxygen are generally balanced.

The chemical oxygen demand (COD) is the amount of dissolved oxygen that is reduced by chemical reactions in the water.

The amount of dissolved oxygen plays an important role in determining the type of organisms that live in the water. Some organisms need consistently high dissolved oxygen concentrations to survive, while others are more tolerant of low or fluctuating concentrations of dissolved oxygen. Waters with a consistently high level of dissolved oxygen are usually considered healthy and stable aquatic ecosystems capable of supporting many different kinds of aquatic organisms.

Lakes can become stratified into two layers (see also Section 1.3). The upper layer is warmer and contains algae and large water plants because sunlight can penetrate the water. The lower layer is cold and dark. Because these layers do not mix, the lower layer is cut off from the supply of oxygen via the atmosphere and oxygen produced by plants. Consequently, oxygen can become depleted at the bottom, especially if there is a lot of organic matter that is decomposed by bacteria. Therefore, it is important to determine the temperature and the level of dissolved oxygen at different depths in a lake when characterizing dissolved oxygen conditions. Significant temperature differences at different depths indicate stratification.

In addition to its impact on living organisms, a lack of oxygen can also have profound effects on water chemistry and eutrophication. For example, phosphorus (a nutrient) can be released from bottom sediments when there is a reduction in the oxygen level, and thus enhance eutrophication.

Measurement

Always sample away from the shore and below the water surface, and always determine the temperature of the sample (location) at the same time. Record the temperature on the sample bottle and on the data sheet. Try not to agitate your sample, since this will increase the level of dissolved oxygen. Make sure that there are no air bubbles in the sample bottle. The test should be run immediately after sampling, or otherwise preservation techniques should be applied (see Appendix 11).

Dissolved oxygen can be measured by means of chemical analysis, for example using the Winkler titration method, or with a DO meter or probe (see Figure 9). A field testing kit usually provides a titration method. A DO meter or probe is more expensive in the short term (in the long term the reagents for the chemical methods will also cost you a lot of money), but is much easier to use and less prone to inaccuracies. A DO meter can usually measure some other parameters as well (like temperature and conductivity).

The level of dissolved oxygen in a lake is best characterized by making a dissolved oxygen profile (measurements from the surface to the bottom at set intervals), and a temperature profile measured at the same intervals.

The biochemical oxygen demand (BOD) is measured by using one light (normal) and one dark sample bottle. A sample bottle can be darkened with electricity tape or with aluminium foil. Take samples with the two bottles at the same location and depth. Analyze the level of dissolved oxygen in the light bottle immediately after sampling. Store the dark bottle at 20 °C in a dark place. Determine the level of dissolved oxygen after 5 days. If the water contains high levels of organic matter, it might be necessary to dilute the sample water (with distilled water) and/or to calculate the BOD after 2 or 3 days in stead of 5.

The BOD_5 = DO in light bottle (mg / l) - DO in dark bottle after 5 days (mg / l).

6.8 Conductivity

Conductivity is an expression of a water's ability to conduct an electric current. The conductivity depends on the concentration of dissolved salts (ions) in solution. The conductivity is influenced by the temperature of the water.

Conductivity influences the occurrence of plants and animals in the water. Some types of organisms are sensitive to increased conductivity, while others are more tolerant.

Conductivity is one of the guide parameters, which means that changes in the conductivity of a sample may indicate pollution. Generally spoken higher conductivity means more pollution.

Measurement

Conductivity should be measured in the field. If this is not possible, a measurement should be carried out as soon as possible, since the conductivity of a water sample may change with time.

It is important to measure the temperature of the sample while measuring its conductivity. Several instruments automatically compensate for temperature. If this is not the case, the temperature at the time of measurement should also be recorded on the data sheet.

Conductivity can be measured with a meter, which is supplied by many manufacturers (see Figure 9). Some instruments are cheap and often a little fragile for field use so its worth paying a little extra for a good model.

Usually the conductivity is expressed in µS/cm (microsiemens per centimetre).

6.9 Heavy metals and pesticides

Both heavy metals and toxic organic compounds (pesticides) are very harmful to human beings, animals and plants (see also Section 2.2). If you find a noticeable absence or low diversity of aquatic organisms, especially benthic macroinvertebrates, but the physical and chemical tests do not reveal any water quality problem, the water may be contaminated with heavy metals or pesticides.

If you want to be sure if and what kind of pesticides or heavy metals are present in a water and/or water bottom, you will have to send a sample (one or more) to a professional laboratory that can conduct the analysis. The equipment is too expensive and the analysis too difficult to be conducted by somebody who is not a professional in this field.

Check universities, governmental agencies and private institutions for possibilities of having samples be analyzed. Use the suggestions given in Section 6.1 and Appendix 11 to take samples, preserve them and send them to a laboratory.

6.10 Water quality monitoring

To obtain a complete picture of the water quality of a water body, it is important to conduct measurements over long periods of time (several years), to detect changes in an ecosystem (both the water and the surrounding lands). This is called monitoring. Data can be used to establish baseline conditions, to determine trends in the water quality, or to identify current and emerging problems.

Monitoring can be done by collecting data at different points in one water body, to compare the water quality at different stages (for example along the length of a river). The river may be less healthy as it passes through farmlands than where it passes through upstream forested areas, for example, due to the run-off of fertilizers and pesticides.

You can also compare similar water bodies (for example streams of comparable size and origin), if one is polluted and one is in a healthy condition. By making use of a reference water body, it is possible to prove the influence of pollution and to formulate local biological water quality classifications.

A precondition for properly conducting a monitoring programme is the existence of a *'leading agency'* that is responsible for the institutional development of the programme. Objectives should be identified, and the parameters to be measured and methods to be used should be determined beforehand. The parameters and methods used depend very much on the available funds and the knowledge of the people participating in the monitoring programme. When setting up a community-based monitoring programme, it is important to develop local monitoring methods that can be used at the community level.

For detailed information about the setting up of a water quality monitoring programme, please read the recommended literature. Unfortunately this subject cannot be discussed in this manual.

Recommended literature

Campbell, G. and S. Wildberger: "The monitor's handbook". LaMotte Company, P.O. Box 329, Chestertown, Maryland 21620, U.S.A., 1992 (free of charge).

Ellett, Kathleen K.: "An introduction to water quality monitoring using volunteers. A handbook for coordinators", second edition 1993. Alliance for the Chesapeake Bay, Inc. 6600 York road, Baltimore, Maryland 21212, U.S.A. (free of charge).

HUTTON, L.G.: "Field testing of water in developing countries". WEDC, Dept. of Civil Engineering, University of Technology, Loughborough LE11 3TU, United Kingdom, 1983.

MITCHELL, MARK K. and WILLIAM B. STAPP: "Field manual for Water Quality Monitoring, an environmental education program for schools". Global Rivers Environmental Education Network (GREEN), 721 East Huron st., Ann Arbor, Michigan 48104, U.S.A. 7th Edition, 1992.

SIMPSON, J.T.: "Volunteer lake monitoring: a methods manual", U.S. Environmental Protection Agency, 1991. Office of Wetlands, Oceans and Watersheds. Assessment & Watershed Protection Division (WH-553), 401 M Street S.W., Washington, D.C. 20460, U.S.A. (free of charge).

U.S. Environmental Protection Agency: "Volunteer water monitoring: a guide for state managers". Office of Water Regulations and Standards, Assessment and Watershed, Protecion Division (WH-553), 401 M Street S.W., Washington, D.C. 20460, U.S.A. (free of charge), 1990.

WHO and UNEP: "Guidelines for drinking-water quality, Volume 1. Recommendations". Geneva, 1984.

WHO and UNEP: "Guidelines for drinking-water quality, Volume 2. Health criteria and other supporting information". Geneva, 1984.

7 Activities to Improve your Water

The previous chapters helped you find out what kind of water pollution is occurring in your water source or watershed, and what is causing this pollution. This chapter gives you suggestions on how you can improve the quality and the availability of your water.

Every person on earth has the right to a sufficient supply of clean and safe water. Governments have a responsibility to take care of the supply of water. In principle, when you have a water problem, you can go to the government and ask for help.

However, in practice the situation is often different. People in the government might not have the time to help you, or they might lack the equipment or money which is needed. Therefore one advice is not to wait until your government helps you. There are many things you can do yourself, and together with the people of your community, to improve your water situation. As soon as you understand your water problem, you can work on doing something about it.

This chapter explains various activities which help you to obtain cleaner and safer water for drinking and other uses. Suggestions to increase the amount of available water are also given. Finally a number of land-use practices to reduce erosion are explained. Many of the items mentioned in the text are shown in the various figures.

7.1 Improving drinking water at home

Use one and the same jar, preferably earthenware, only for drinking water. Always use the same container to remove water from the jar. Keep the jar closed.

Clean this earthenware jar very carefully with soap and clean water before you fill it with drinking water.

Store drinking water for two days or more in an earthenware jar, in a cool and dark place, before drinking it. After two days most of the dirt will have settled down on the bottom and, more importantly, most of the disease-causing organisms will have died. Any unpleasant smell can be easily removed by a quick boil. Any layer of dirt on the water surface can be removed by pouring the water through a clean, tightly woven cloth.

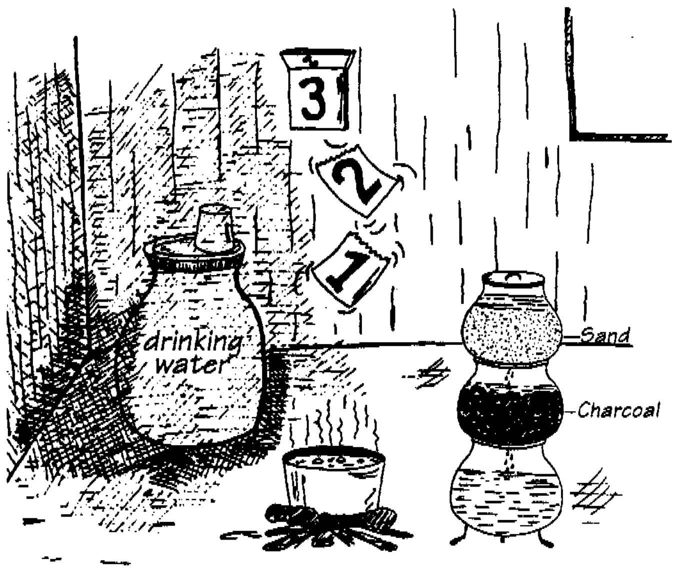


Figure 10: Water at home

If you have not stored the drinking water for two days or more, boil it for ten minutes before you drink it. This kills all the pathogens present in the water. If you have only a little firewood, at least boil the water for the children, the elderly and the sick.

Clean all your water jars and containers very carefully with soap before you use them.

When you fetch water from a well, share only one bucket and rope with everybody who uses the well. Clean the bucket and rope carefully with soap before use.

Figure 11: cleaning water utilities

Prevent dust and dirt getting into the water while it is being transported from the source to your home, for example by covering the jar.

If the water looks muddy or dirty, you can pour it through a clean, tightly woven cloth which you tie up around the opening of the jar. This method gives less clean and safe water then storing or boiling water, but it removes insects, plant debris, other coarser impurities and pathogenic eggs and worms from the water. Clean the cloth in boiling water after each time you use it, and put it away in a clean box before the next use.

To clean visibly or invisibly polluted water, you can pour it through a so called 'three-pot system' (see also Figure 10). With this *slow sand filtration* method, almost all the pollution can be removed. The three-pot system consists of three earthenware jars on top of each other. The upper two jars have a small hole (diameter about 1 cm) in the bottom. Fill the upper jar one third or one fourth with sand having a diameter of 0.2 to 0.4 mm. Fill the middle jar one third or one fourth with sand having a diameter of 0.6 to 0.8 mm. Pour your water into the upper jar. It will slowly drip via the middle jar into the lowest jar, while the pollution sticks to the sand. When the sand becomes visibly dirty, you should renew or clean it.

You can also purify water with the aid of the ashes of burned plants, certain seeds or certain vegetables. Ashes from any kind of plant can be used, but many people in Asia, Africa and Latin America often use the ashes of millet stalks, firewood, coconut shells and paddy husk.

Sieve two milk cups of ash (each containing 127 g) and add them to a jar with 50 litres of raw water. Stir the water for 30 minutes with a stick.

An example of purifying seeds are the seeds of the Moringa tree. This tree is native in central and south India, but also widely distributed throughout southeast Asia, Africa, the West Indies and Latin America. In many countries, parts of the tree are used as medicine. In central and south

India and east Africa It is used as a food stuff, roasted like peanuts or with the green pods prepared as curries.

Many species of the Moringa tree are known to have purifying capacities, for example Moringa oleifera, Moringa peregrina and Moringa stenopetala. Remove the wings and seed coat and crush the white kernel material to powder just before use. Mix the powder with a small amount of already clarified water in a tea glass for about 5 minutes. Pour the suspension through a tea strainer onto the raw water in a jar. Slowly stir the water with a stick for 10 to 15 minutes. Use the water after 1 hour or later. Use 3 seeds for 4 litres of water.

Vegetables which can purify water include broad beans (Faba vulgaris) or haricot beans (Phaseolus vulgaris). Clean the seeds of husk and dust, and carefully remove the seed coat. Crush the kernel material and use the same method as with the Moringa seeds. Use 23 or 24 beans for 40 litres of water.

7.2 Selecting and protecting your water source

Always remember that water coming from a tap or a pump is not necessarily clean and safe. In particular, the water may contain pathogens which can cause diseases. Even clear water having a good taste is not always free from pollution.

The best way to obtain clean and safe water is to select the place where you fetch your water very carefully. Water sources consisting of groundwater, like wells and springs, are usually cleaner and safer than sources from surface waters, such as rivers and lakes.

Select a water source which is not used by other people and animals, or only minimally. Sources hidden in rocks are usually cleaner and safer to use. Try to avoid using water which smells or looks dirty.

In India and Iran there are people who use goldfish (Carassius auratus) as a warning system for water pollution. The goldfish are kept in the water source, and as soon as they slow down their movements, change colour or die, the people know that the source is no longer safe to use.

> ***Water sources***
>
> *Water can be used for many purposes. The place where people fetch water is called a water source. Water sources can be divided into groundwater and surface water sources. Groundwater sources are water-carrying layers in the ground (aquifers) and springs. Surface water sources are rivers, streams, lakes, and ponds, and also collected rainwater.*
>
> *Ultimately, all water sources are fed by the rainfall falling in the watershed. The routes the water takes and the time the water requires to reach a water source greatly affects the amount of water available during the different seasons, as well as the type and degree of pollution.*
>
> *Groundwater sources are more protected against pollution than surface water sources, and thus usually provide cleaner and safer water. Groundwater sources are also affected more slowly by pollution than surface water sources, because water moving through the ground takes more time to reach a source than water moving over the surface. Because groundwater moves very slowly, the link between a source problem and its cause may be more difficult to find. For instance, pollution affecting a well may have been caused years before it is experienced.*

Surface water sources

Fetch water (at least drinking water) early in the morning, when the source is least disturbed by other people and animals.

Fetch drinking water upstream of communities, industries, and other land-based activities that can pollute the water.

Fetch water in an area where the water is deep and the bottom stable, like a rock or cobble bottom. Avoid taking water from along the shores of a lake.

If possible, always dig a hole on the shore of the water body and fetch water from the hole in stead of directly from the water body. Take care that the water from the water body cannot flow overland into the hole. The sand of the shore serves as a filter to trap any pollution (see also Figure 12).

Plant trees on the shores of water bodies. Branches shading the water reduce the evaporation of water. Trees and shrubs should also be planted further away from the water body, because they help water to drain into the soil, prevent erosion of the soil, and attract rain to the area.

Groundwater sources

Protect your water source against animals. Build a fence around the source and organize a special drinking place for animals downstream and downhill from your water source.

Construct a small platform around the water source (preferably of concrete), a soak-away drain of approximately two metres, and a cover to prevent the inflow of polluted water back into the water source (see Figure 14).

Do not build pit latrines (toilets) within 10 metres from your water source. If the source is located on a hill, do not build latrines above the source.

Do not use the land within fifty metres of the water source for farming or storage of pesticides and fertilizers.

Clean the well thoroughly with soap and clean water at the end of every dry season.

7.3 Collecting rainwater

If you lack water during the dry season, you can build a big vessel beside your house, and collect the rainwater that falls on your roof (see Figure 14). Bigger rainwater collection systems can supply more households, even up to a whole community. In Nigeria there are communities that store 50 jars of rainwater, each with a capacity of 50 litres, for their water supply during the dry season.

Vessels for rainwater collection can be made of various materials, and can have different sizes, depending on the materials and money available, and the capacity required. At the end of this chapter titles of publications are given that clearly explain how to build different types of vessels. You will also find some names and addresses of organizations that can give good advice on this issue. Contact any of these if you want to build a rainwater vessel and need help.

Any roof is suitable for rainwater collection, except roofs made of asbestos, because asbestos can cause diseases and even death to people and animals. Asbestos is light grey, and looks like a mixture of metal and hard board. If you are not sure whether you have an asbestos roof, check with an expert, for example at the Ministry of Housing or the Ministry of Health.

7.4 Protecting and improving community health

Use different places for collecting drinking water, bathing and swimming, washing clothes, and letting animals drink.

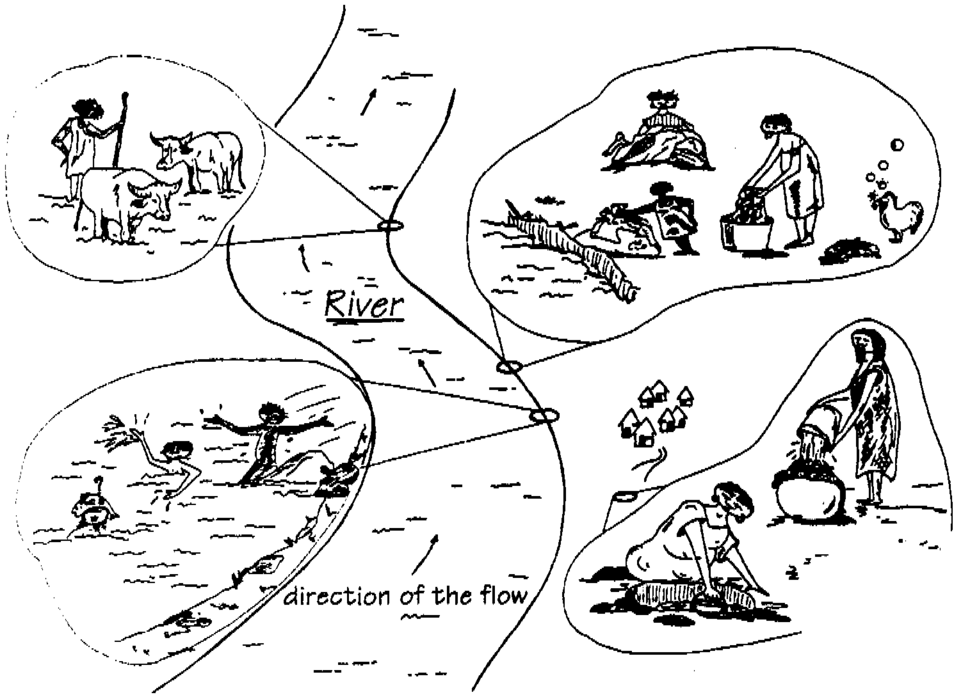


Figure 12: Seperating water functions

When you use a river or a stream as your water source, collect drinking water as far as possible upstream. Second furthest upstream, determine a place for bathing and swimming. Downstream from this area, locate a place for washing clothes. Drinking places for animals must always be furthest downstream.

Sanitation is very important. Open-air defecation or improper latrines can cause very dangerous diseases. Always keep in mind that: faeces should not contaminate the groundwater or surface water, should not pollute the soil, should not be accessible to flies, rodents, or other animals, and should not create a nuisance due to odour or unsightly appearance.

Collect garbage and dispose of it properly. Separate organic waste (anything which was once living) from other waste (such as cans, plastics, paper etc). Dig one hole for organic waste, and one for the other waste. Neither of the holes should be near the water, especially not near a water source. You can reuse organic waste as fertilizer for the soil.

Build proper pit latrines. A pit latrine is simply a protected hole in the ground into which faeces fall (see Figure 13). It has a squatting plate or riser with a hole, a cement lining, and a ventilation pipe with a fly screen. When the pit is filled to within one meter of the surface, the cement lining and the squatting plate are removed and the pit is filled up with soil. A new pit is then dug nearby. Never built pit latrines close to or uphill from a water source.

Improve people's understanding of the possible sources of disease, and the different ways people can become infected (see also next chapter).

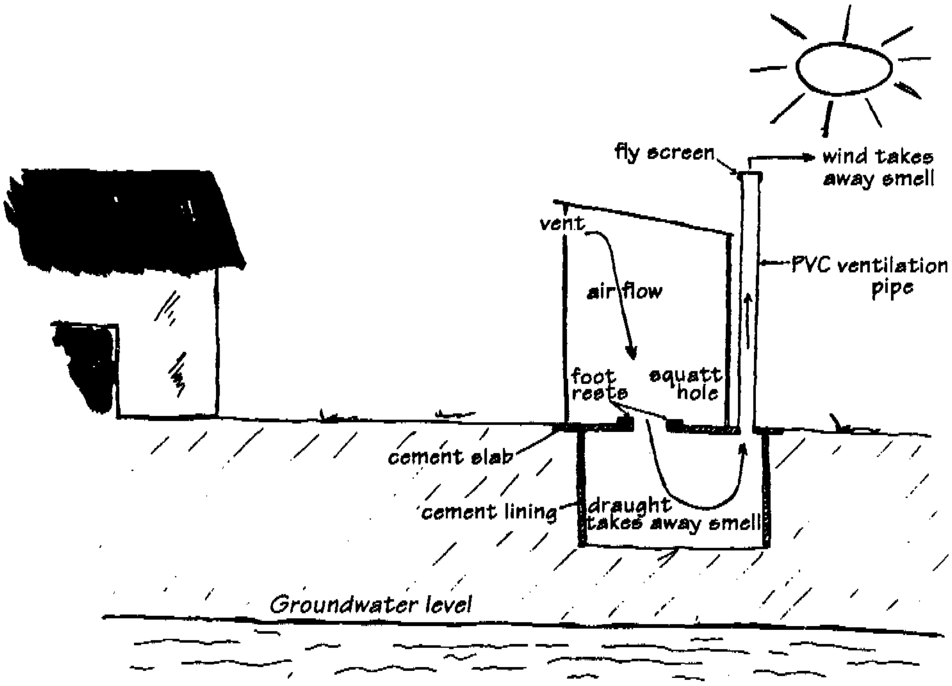


Figure 13: Building a pit latrine

7.5 Protecting your watershed against erosion

Plant trees up to 9 km above and away from your water source, and up to 600 metres from the shores of all water bodies. Use fast-growing trees which supply firewood, or trees that supply fruits. You can also plant Moringa trees, the seeds of which can be used to purify water (see Section 7.1). Be careful to avoid trees that consume huge amounts of water, like the eucalyptus. Avoid planting trees which do not belong in the area, or are not commonly found there. Trees help water to soak into the ground, prevent erosion of the soil, and attract rain to the area. Ask your Ministry of Forestry for advice. In most countries this ministry also provides free seedlings.

Plant trees and shrubs especially on slopes, since these areas are very sensitive to erosion. Never leave a hill bare and barren.

Plough farmland on slopes in horizontal patterns along the altitude lines. Also try to build terraces for farmlands on slopes (see Figure 14).

In the open field, you can lay lines of stones along the altitude lines, to reduce the speed of overland run-off water during the rainy season, and thus reduce erosion.

Try to ensure that the soil is covered with plants most of the time, to prevent drying out of the land (groundwater) and erosion. For example, you can do this by using crops growing very close to one another, by planting different crops mixed together, by planting a new (different) crop after the harvest, and/or by providing a cover of plants between crop seasons, for example by leaving plant residues after the harvest.

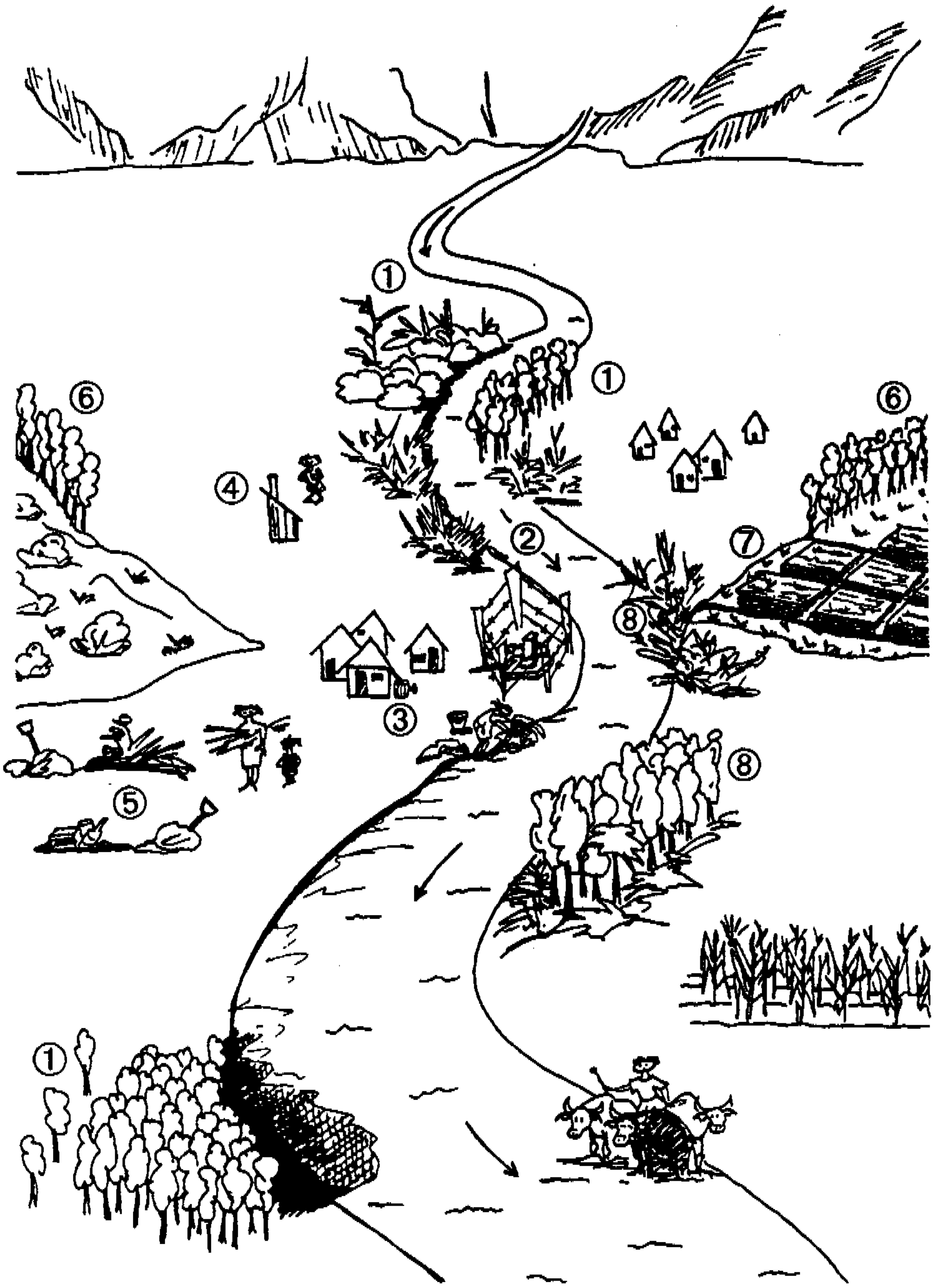


Figure 14: Improving water in your community

1. Plant trees on the shores of water bodies as well as further away
2. Protect your water source
3. Collect rainwater
4. Built proper pit latrines
5. Collect garbage and dispose of it properly
6. Plant trees and shrubs on barren hills
7. Plough hills in horizontal patterns
8. Create a forested buffer between farmland and water bodies

7.6 Alternative farming to reduce pollution

As much as possible, convert to *organic farming* methods. This means reducing the use of pesticides and inorganic (artificial) fertilizers, and replacing them with natural fertilizers, such as manure, and *biological* methods of *pest control.*

Create forested buffers between farmlands and surface waters to reduce water polluted with pesticides and fertilizers flowing overland to the surface water.

Biological methods of pest control include control by natural enemies, and control by using plants (garlic for example). Physical or mechanical control methods can also be used, such as blocking holes created by pests, producing continuous sounds to disturb the mating of pests, and catching rats. You can also leave rice at the corners of each field: birds eat this up and therefore do not attack the crop, and consequently eat the worms around.

Dispose of fertilizer and pesticide containers properly: keep containers out of water bodies, sinkholes, creeks, and other places close to water bodies.

Recommended literature

JAHN, SAMIA AL AZHARIA: "Traditional water purification in tropical developing countries, existing methods and potential application". Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH, P.O. Box 5180, D-6236 Eschborn 1, Germany, 1981.

JAHN, SAMIA AL AZHARIA: "Proper use of African natural coagulants for rural water supplies". Research in the Sudan and a guide for new projects. Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH, P.O. Box 5180, D-6236 Eschborn 1, Germany, 1986.

MANN, H.T. and D. WILLIAMSON: "Water treatment and sanitation, a handbook of simple methods for rural areas in developing countries". Intermediate Technology Publications, 1986.

NDUKA OKAFOR: "Aquatic and waste microbiology, A textbook for microbiologists, hydrobiologists, general biologists, sanitary engineers and public health workers". Fourth Dimension Publishers, 1985.

OXFAM publications, among others manuals for water storage, water pumping, well digging, water distribution and water filtration. Oxfam Publications, 274 Banbury Road, Oxford OX2 7DZ, United Kingdom.

SCHULZ, CHRISTOPHER R. and DANIEL A. OKUN: "Surface water treatment for communities in developing countries". Department of Environmental Sciences and Engineering, School of Public Health, University of North Carolina at chapel Hill, Intermediate Technology Publications, 1984.

HASSE, ROLF: "Rainwater reservoirs above ground structures for roof catchment. Most common rainwater tanks in comparison and construction. Manual". Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH, P.O. Box 5180, D-6236 Eschborn 1, Germany.

LEE, MICHAEL D. and JAN TEUN VISSCHER: "Water harvesting. A guide for planners and project managers". 30 Technical Paper Series. IRC and DANIDA, 1992. International Water and Sanitation Centre (IRC), P.O. Box 93190, 2509 AD The Hague, The Netherlands.

8 Community Organizing and Legal Actions

Chapter 7 has given suggestions on how to obtain clean and safe water, and how to protect and increase the amount of water in your area. However, when pollution occurs in huge amounts over a long period of time, you may find it can be very difficult to do something about the pollution yourself. For example, it may be very difficult to reduce or stop pollution from a big factory or large-scale mining activities, or from a hospital or the sewage outflow from a city.

If you face these types of water pollution problems, there are still activities you can undertake to try to improve the situation. The activities discussed in this chapter are: organizing your community, setting up a campaign, and conducting legal actions. The chapter closes with some last suggestions.

Although this manual focuses primarily on water quality problems, the suggestions given in this chapter can also be used in relation with other then environmental issues.

8.1 Community organizing

It is important to know that a group of people together stands much stronger than one person alone. Because of this, people often organize themselves in a group. Workers may organize a union to improve their salaries and working conditions, farmers may work together in groups on each other's fields to reduce the work load, and women may organize a day-care centre to take care of one another's children.

Very often water pollution affects more than one person. A whole community may have problems with the water, sometimes even several communities along the same lake or river, or in the same watershed.

The first thing to do is to bring all the people who are affected by the pollution, and others who are interested, together in one group. You can start with the people in your own community (which can be a village, a small town or a quarter of a city). This is called community organizing. When the people in your own community are organized, you can expand to other communities who are also affected by the water pollution.

Be sure to involve all persons affected by the pollution, and involve both the men and the women. Appoint one person (male or female) to be the chairperson of the organization. This person can, for example, be the spokesperson of the community. Sometimes you need to appoint other persons as well, for example a treasurer if the organization has money, or a contact person for the press if you are often in communication with them.

Share together the pollution and other experienced problems, and discuss the possible cause(s). To this end you can conduct any of the surveys explained in this manual and use the results, combined with other available information. Use the experience of the people in the group. Fishermen, for example, usually know very well where and how often a factory is discharging pollution into their fishing waters.

After you have identified the pollution problem(s) and its source(s), you can think about solutions. Practical suggestions for activities to improve the water quality and quantity at the household, community and watershed level are given in Chapter 7.

In cases where the activities explained in Chapter 7 are insufficient to solve the problem(s), you should talk with the person(s) responsible for the pollution, and pressure them to reduce or stop the pollution, and compensate for the damage it has caused. This may be the president of a factory or a mining company, or the mayor of a village or city that is polluting your water with sewage. Try to come to an agreement that satisfies all persons involved. Always put agreements and appointments down on paper. Official documents should always be signed by all parties involved.

It is often the case that people who are responsible for pollution are not very willing to spend time and money on reducing or stopping the pollution. When this happens, you have to undertake further actions to increase pressure, for example by starting a campaign or conducting legal actions. Bear in mind that a group that wants to put pressure should be very strongly organized.

8.2 Setting up a campaign

A campaign is a series of activities that expose an issue to many people, and that pressures the responsible person(s) to do something about the problems the issue is causing. Always try to set up a campaign as a group, consisting of one or more communities suffering from pollution, for example.

If possible, contact an environmental or other organization that has experience with organizing campaigns, to give suggestions and to help with your activities. Usually you will find such organizations in the capital or other bigger cities.

There are many activities that can be part of a campaign. Few of them are mentioned below:

- Make a *petition* and offer it to person(s) responsible for the pollution. In a petition you can describe the problems experienced. Write down clearly why you think that the person(s) you are giving the petition should do something about the pollution (try to prove his or her responsibility). Mention the wishes (and/or demands) of the group (for example concerning cleaning up existing pollution and rehabilitating the area) and present solutions and alternatives. The petition should be signed by as many people as possible: by the people affected by the pollution and other concerned persons.

- Expose the pollution problems via the *media*: in newspapers, on the radio and/or on television. The media can be a big support to your campaign, because it means that many people will learn about the pollution and the problems it is causing. This pressures the person(s) responsible for the pollution to do something about it. Besides the local press in your area, it is usually very useful to contact the national press as well.

- Try to talk to *politicians* at the local, regional and national level, like the mayor, the governor and members of congress. Inform them of the pollution problem(s) and your campaign, and ask for their support (this is called lobbying). This is very important, since politicians often have some power to reduce or even stop pollution.

- Organize a *rally* to attract broad attention to the pollution problem(s). Usually, a rally in a big city, preferably the capital, is most effective. If the participants of the rally live elsewhere, you need to organize transportation and eventually lodging. Make huge billboards and streamers and walk a certain route. You can walk to the office of the company or institution responsible for the pollution and offer a petition, for example. You can also invite guest speakers to talk about the issue and the wishes of the campaigners. Always try to involve the press.

- If the responsible organization(s) or person(s) is (are) foreigners, like many mining companies, big factories and oil companies, it can be helpful to seek *international support* from the press, environmental and other groups in those countries as well.

- If the problem is caused by what is called a *development aid project*, for example the construction of a big dam, the financier(s) of this project is (are) the most important responsible person(s) to address. Financiers can be national and/or international governments, banks or private organizations.

- Organize *training and education* activities for the affected people, for example about environmental and/or health aspects, or about how to conduct any of the suggestions given in Chapter 7. Two groups of people are very important in this respect, namely children and women.

Our children are our future, and it is very important that they learn how to protect our environment, and specifically our water. You can contact an (environmental) organization in your country that has developed environmental education programmes. Discuss with teachers from schools the possibility for setting up an environmental programme, for example a special week where different classes learn about the environment and/or water.

8.3 Women and water

Women are usually the ones who deal most with water. In most developing countries they fetch the water (when there is no tap), take care of the cooking, wash clothes and in many countries they also have some cattle-raising and farming activities. Thus, women are most directly concerned with water pollution.

It is very important that women are very well informed about the different types of water pollution and its possible harmful effects, especially on health. Since many women have not been able to go to school, especially in rural areas, it is very important to organize training and education about these aspects for them.

Many of the suggestions given in Chapter 7 can be put into practice by women. You can organize a training session on how to built your own three-pot system, for example, or on how to protect your water source.

It may happen that men are not very willing to cooperate with activities meant specially for women. However, not only for the sake of women, but also for their own sake and that of their children, it is very important to involve the women in all activities concerning water and organise training sessions if needed.

It can be very helpful to start a special women's organization. Many issues and problems are strongly related to the position of women in their society. A women's organization is more capable of attending to women's issues. This is very important, since in many countries the social and economical situation of the women is still much worse than that of the men.

8.4 Legislation

The government of each country has made rules about the organization of the state (politics), about relations among citizens, and about relations between citizens and the state. In these rules people's rights and obligations of what to do and what not to do are written, for example. In this way, it is declared that it is forbidden to kill somebody, and many countries ruled that every child should be able to go to school.

These rules are written down in different types of laws, together called legislation. Laws are made to ensure that everything in a country runs well. Each country has many rules about water, focused on the different functions the water fulfils, for example rules concerning water used for transportation, hydropower, industrial use, agriculture, drinking, fishing and recreation. Many rules only describe the function of water, but rules about the amount (quantity) and/or the quality of the water usually also exist. In many countries water quality standards (similar to the standards given in Appendix 13) are formulated, for example.

All the laws concerning water are scattered over different ministries, depending on the function the water fulfils. For example the Ministry of Mining, the Ministry of Agriculture and the Ministry of Health all make their own water laws.

Often water bodies are not restricted to one country. A river may flow through different countries, or different countries may border on the same lake or sea, for example. Besides their national legislation, therefore, it is important that countries make international agreements about the regulation of water use or water pollution, for example. Such agreements often are called conventions.

8.5 Conducting legal actions

Usually there are rules restricting or forbidding the pollution of water. If somebody does not follow these rules without permission from the government, that person is breaking the law. If it is proven that a case of pollution is against the law, the organization(s) or person(s) responsible for the pollution will be punished, for example by paying a fine, enforcements to stop or reduce the pollution, or by cleaning up the mess.

Conducting legal actions means checking whether the pollution you have found is against the law. If you want to conduct any legal action, it is very important to contact an organization which is able to give you juridical assistance, since a lot of professional knowledge about legislation is needed to undertake juridical actions. In Appendix 14 you will find a number of names and addresses of organizations that can give you legal advice and assistance.

You can undertake legal actions either as an individual or as an organization that is recognized as a legal body in your country. This means that if you want to start a legal action with a group of people, a community for example, it is absolutely essential that the group is officially registered as an organization (such as a foundation, union, etc.).

Especially for legal actions, but also when you organize a campaign, it is very important that the information you gather about the pollution problem is accurate and based on conclusive evidence. Thus always gather information very carefully and document it clearly.

8.6 Types of legal action

There are different types of legal action you can undertake to stop or reduce pollution. You can either check administrative procedures or bring a case before a court. In this section these types of action are explained in general terms, not specifically for any country in particular.

It may be possible to undertake a combination of various legal actions on the same issue at the same time. Always first make a thorough inventory of your possibilities and chances with the help of an experienced organization or person before you decide what action(s) to conduct.

1. Checking the water administration

When a factory starts its operations, for example, or when a big dam is to be constructed, there are a number of procedures which have to be followed. In many countries the company involved must make a study of the environmental effects (impacts) of the factory or the new construction project. This is called an Environmental Impact Assessment (E.I.A.). If permission is given to build the factory or dam, it is agreed that the pollution or disturbance it causes will not exceed pre-determined levels. There is a government department, generally called the water administration, that checks whether those prescriptions are met.

As an individual or recognized organization the first opportunity to become involved in the process is supposed to be when the E.I.A. is conducted, at opportunities set up for public comment. If the E.I.A. has already been conducted, you can check whether all the prescribed procedures were followed before the factory started its operations or before construction took place. Lastly, you can also check whether the pollution you have found is allowed according to the permit or concession.

Actually, in this way you are checking the government agency that is supposed to check the pollution. This is called checking administrative procedures. When you find any deviations in the execution of the administrative procedures, you can request the water administration to bring up a case before court on the issue.

In theory, administrative procedures are the easiest of all legal actions to conduct, because you do not start up a juridical procedure yourself (instead you ask the water administration to do so), and you therefore do not need a lawyer. However, in practice it can be very difficult to gather all the necessary information. Although in most countries the information of an E.I.A. should be freely accessible to anybody, in many countries government agencies and companies are not very happy about people checking their activities, and therefore withhold information.

2. Bringing a case before court

If you have suffered personal damage from pollution and the organization(s) or person(s) responsible is(are) not willing to pay for the damage and/or restore the damage, you can bring a charge against this organization(s) or person(s). This can occur, for instance, when somebody has used violence against you or destroyed your property, or when you are personally affected by pollution. You have to prove that you suffer damage, that the damage is caused by the pollution (and not by something else), and what organization(s) or person(s) are responsible. If, after hearing the case, the judge believes that you are telling the truth and that the accused party is guilty, you have won your case and the responsible organization(s) or person(s) is (are) obliged to pay for the damage. Depending on the case, the responsible person can also be forced to stop or reduce the pollution, to restore the damage and/or to clean up the mess.

You can bring a case before court either as an individual or as a recognized legal body (organization). If you act as an organisation, there should be a clear relation to the objectives and activities of the organisation and the case you are presenting.

3. A public action

If pollution does not affect you personally or as a group, for example when it affects an area which is not your property (a public stream or a lake), you can bring a charge against the organization(s) or people(s) responsible through a public action. In this way you try to protect the environment (nature) that has become the victim. In practice it is often very difficult to win this type of case, because in many cases it is very difficult to exactly determine what damage or changes in the environment are caused by what particular pollution. Especially in countries where environmental law is relatively new, there might not be enough experience with this type of case.

8.7 Final suggestions

Water pollution problems and water legislation can vary tremendously in different countries all over the world, and in different areas within one country. It is therefore impossible to write down all the activities you can do to reduce or eliminate a pollution problem in only one manual. For more suggestions you can always try to contact other organizations and people with similar experiences.

Always try to adapt the suggestions mentioned in this manual, as well as suggestions obtained elsewhere, as much as possible to your own situation.

Appendix

1 ____________ Field Survey Data Sheet 1

General Description

Make copies of the Field Survey Data Sheets nos. 1, 2 and 3, and give one copy to every group of participants conducting the Field Survey. Write additional comments needed to describe the surveyed water on the back of the paper.

General data

Date:

Surveyors' name(s):

Name province/municipality:

Name, address organisation:

Description of surveyed area

Name of surveyed water:

Type of water surveyed:
(brook, stream, river, lake, pond, reservoir, estuary, other)

Size of area surveyed:
(measured or estimated)

Type(s) of land-use present:

--

--

--

--

--

--

--

--

--

--

--

--

--

--

--

--

--

--

Description of water body

Total size of water body:
(measured or estimated)

Type(s) of land-use present:

If water is standing

Number and names of inflowing waters:

Number and names of outflowing waters:

If water is flowing

Source of the river:

Stream velocity:
(estimated m/s)

Surveyed area in upper, middle or lower part of the stream/river:

Number and names of tributaries:

Description of watershed

Name of watershed
(subwatershed if applicable):

Size of watershed:
(estimated length and width)

Number and names of major water bodies in watershed
(streams, rivers, ponds, wetlands, lakes, other):

--

--

--

--

--

Type(s) of land-use present:

--

--

--

--

--

--

--

Observation points

(number and description)

Surveyed area:

--

--

--

--

--

--

--

--

Watershed:

--

--

--

--

--

--

--

--

Pictures taken:

(number, location, date and short description)

--

--

--

--

--

--

--

Appendix

2 Field Survey Data Sheet 2

Land-use indicators of water pollution

Check all land-uses you listed down in Field Survey Data Sheet no. 1 for potential indicators of water pollution, using one or more observation points for each land-use activity. 'OP' stands for observation point.

Forest

→ check for sediments (cloudy or muddy water) from erosion caused by logging, road-building or mining.

	OP	*OP*	*OP*
Name & number OP:			
Forest area (ha or km^2):			
Logging present:			
Mining present:			
Road-building present:			
Clarity of the water:			
Other:			

Farmland *(cattle and crops)*

→ look for faeces of animals in the water. Check watering places for cattle, and use your nose. Also look out for erosion from farming practices, which is indicated by a brown, muddy appearance of the water. The presence of nutrients (from fertilizers) is indicated by a green colour of the water. Pesticides are indicated by the presence of pesticide containers, and by an acrid (sharp) odour. You can also ask farmers if and what kind of fertilizers and pesticides they are using.

	OP	*OP*	*OP*
Name & number OP:			
Farmland area (ha or km^2):			
Type(s) of crop:			
Pesticide containers:			
Kind(s) of cattle:			
Number of cattle:			
Animal faeces in water:			
Colour of water:			
Odour of water:			
Information from farmers:			
Other:			

Industries

→ keep an eye out for colour changes. A green colour indicates nutrient enrichment (algae). An acrid (sharp) odour indicates industrial pollution in general. A dark red, purple, blue or black colour of the water may indicate organic dye pollution from leather tanning or clothing manufacture. Organic pollution may be indicated by a muddy, sludge bottom, sometimes dark, muddy water, and the smell of rotten eggs.

	OP	OP	OP
Name & number OP:			
Type of industry(ies):			
Colour of water:			
Odour of water:			
Clarity of water:			
Type of bottom:			
Other:			

Domestic waste water with sewage system
(treatment plants, discharge pipes or other)

→ look for organic pollution indicated by a muddy, sludge bottom, and a smell like rotten eggs. Dark, muddy water may be caused by sediments and/or organic pollution. Sewage can also carry nutrients, indicated by a green colour, and many other sorts of pollution including metals (such as lead), salts, chemicals and oil. Oil can be seen as a multi-coloured reflection on the water.

	OP	OP	OP
Name & number OP:			
Name village, city:			
Number of inhabitants:			
Discharge pipe(s) present:			
Colour of water:			
Odour of water:			
Type of bottom:			
Clarity of water:			
Other:			

Domestic waste water without sewage system

→ check what people use for defecating. Open areas or open latrines may indicate diseases. Check what people do with the waste water from their households. Soaps can be seen as white water, sometimes with white scum.

	OP	OP	OP
Name & number OP:			
Name village, city:			
Number of inhabitants:			
Way of defecating:			

Colour of water:			
Odour of water:			
Other:			

Solid waste *(garbage)*

→ check for garbage that is thrown into the water. Organic pollution may be visible as a dark colour, a muddy, sludge bottom, and in severe cases a rotten-egg smell. A multi-coloured reflection on the water surface indicates oil.

	OP	*OP*	*OP*
Name & number OP:			
Size dumping area:			
Colour of water:			
Odour of water:			
Trash present:			
Type of bottom:			
Other:			

Mining

→ check for sediments, indicated by a brownish, muddy colour of the water. A yellowish-orange deposit may be present on the bottom, due to a high iron content. Methods of mining include open-pit, bulk and tunnel mining, for example.

	OP	*OP*	*OP*
Name & number OP:			
Mining area (ha or km²):			
Type(s) of ore:			
Method(s) of mining:			
Clarity of the water:			
Colour of bottom:			
Other:			

Fish ponds

→ check for excessive use of pesticides and fertilizers. The presence of nutrients (from fertilizers) is indicated by a green colour of the water. Pesticides may be indicated by the presence of pesticide containers, and by an acrid (sharp) odour. You can also ask farmers if and what kind of fertilizers and pesticides they are using.

	OP	*OP*	*OP*
Name & number OP:			
Kind of fish bred:			
Size fish pond(s):			

Colour of water:			
Pesticide containers:			
Odour of water:			
Information from farmers:			
Other:			

Construction

→ land-disturbing activities such as the building of houses and roads cause erosion, so watch for cloudy or muddy water.

	OP	*OP*	*OP*
Name & number OP:			
House building present:			
Road building present:			
Clarity of water:			
Other:			

Appendix

3 Field Survey Data Sheet 3

Colours and odours with unidentified sources

Green, green-blue, brown or red

→ indicates the growth of algae which is stimulated by nutrient pollution. This can lead to and algal bloom, which may appear as pea-soup, for example. Nutrient pollution can be caused by domestic waste or fertilizers.

	OP	OP	OP
Name & number OP:			
Colour of water:			
Farmland present:			
Type(s) of crop:			
Fertilizer used:			
Watering places cattle:			
Cities or villages present:			
Domestic waste present:			
Specific findings:			

Orange-red

→ can be caused by acidic mine drainage or oil-well run-off. The colour is due to an iron compound in such areas. Iron also occurs naturally.

	OP	OP	OP
Name & number OP:			
Mining drainage present:			
Drilling present:			
Industries present:			
Specific findings:			

Light to dark brown

→ is due to suspended sediments in the water, which gives a muddy or cloudy appearance. Erosion can be caused by mining, farming, run-off from urban areas, unpaved roads and construction activities.

	OP	OP	OP
Name & number OP:			
Mining present:			
Farming present:			
Urban areas present:			
Unpaved roads present:			

Construction activities:			
Specific findings:			

Blue

→ can indicate the presence of copper. Copper can give skin irritations. Tea smells funny after boiling. Fish may die. Copper is used as a pesticide. Pesticides may be indicated by the presence of pesticide containers, and by an acrid (sharp) odour. You can also ask farmers if and what kind of pesticides they are using.

	OP	*OP*	*OP*
Name & number OP:			
Pesticide containers:			
Information from farmers:			
Odour of water:			
Specific findings:			

A shiny layer after leaving the water for 6 to 8 hours

→ this indicates the presence of iron. This can be experienced in households.

	OP	*OP*	*OP*
Name & number OP:			
Name village, city:			
Name household:			
Specific findings:			

A multi-coloured reflection

→ indicates oil floating on the water. Oil pollution can be caused by oil drilling and mining activities, wastes from ships, service stations and garages or car dumps.

	OP	*OP*	*OP*
Name & number OP:			
Drainage from mining:			
Oil drilling present:			
Oil waste from ships:			
Service stations present:			
Garage/car dump present:			
Specific findings:			

White deposits along banks

→ may indicate salt (brine) pollution caused by oil-well operations.

	OP	OP	OP
Name & number OP:			
Oil drilling present:			
Specific findings:			

Dark reds, purple, blues, blacks

→ indicates organic dye pollution from leather tanning or clothing manufacture.

	OP	OP	OP
Name & number OP:			
Leather industry present:			
Specific findings:			

Odours with unidentified sources

Rotten-egg odour

→ may indicate organic pollution, and can be caused by domestic wastes or industries.

	OP	OP	OP
Name & number OP:			
Industry (ies) present:			
Domestic waste present:			
Garbage dumps present:			
Specific findings			

Musky odour

→ may indicate the presence of sewage discharge, or livestock waste, decaying algae or other conditions.

	OP	OP	OP
Name & number OP:			
Sewage discharge present:			
Cattle faeces present:			
Dead algae present:			
Specific findings:			

Acrid (bitter) smell

→ may indicate the presence of industrial or pesticide pollution.

	OP	OP	OP
Name & number OP:			
Industry(ies) present:			

Farmland present:			
Use of pesticides:			
Specific findings:			

Chlorine smell

→ may mean that a sewage treatment plant or chemical industry is over-chlorinating its effluent.

	OP	*OP*	*OP*
Name & number OP:			
Sewage treatment plant:			
Industry(ies) present:			
Specific findings:			

Foaming (scums)

→ when white, and more than 3 inches high, foam is generally due to soap (detergents). Foam can also originate from decaying algae, indicating nutrient pollution.

	OP	*OP*	*OP*
Name & number OP:			
Washing areas:			
Sewage discharge:			
Farmland present:			
Specific findings:			

Appendix

4 Biological Survey Data Sheet 1

General Description

Make copies of the Field Survey Data Sheets nos. 1, 2 and 3, and give one copy to every group of participants conducting the Field Survey. Write additional comments needed to describe the surveyed water on the back of the paper.

General data

Date:

Surveyors' name(s):

Name province/municipality:

Name, address organisation:

Pictures taken :
(numbers and descriptions)

Reference(s) to Field Survey Data Sheets:

Description of water body

Type of water body surveyed:
(brook, stream, river, lake, pond, other)

Location:
(reference to map(s), reference to other survey(s), name)

Total size of water body:
(standing water in m^2 or km^2, flowing water length and width in m or km)

Appendix

5 ______ Biological Survey Data Sheet 2

Biological Indicators

Make copies of the Field Survey Data Sheets nos. 1, 2 and 3, and give one copy to every group of participants conducting the Field Survey. Write additional comments needed to describe the surveyed water on the back of the paper.

Description of biological survey point

Location:
(name, number, reference to map(s), reference to Field Survey, short description)

Length and width: by m

Depth of water: m

Stream velocity: m/s *(estimated, see Section 3.5)*

Description of the shore:
(height, slope)

Description of bottom materials:
(dead leaves, silt, sand, mud, rocks, boulders, other)

Colour water bottom:

Map of top view of biological survey point:
(including bottom types, plants and animals present)

Map of cross section of biological survey point:
(including bottom types, plants and animals present)

Bacteria

Sewage fungus *(Sphaerotilus natans)*

Description of exact location:
(type of substrate, submerged or above water, other)

Estimated amount (volume in cm^3 or dm^3):

Reference to drawing:

Possible source(s) of organic pollution:
(sewage system, food processing industries, paper mills, other, with short description of location)

--

--

--

--

--

--

--

--

Other remarks:

Algae

Planktonic algae present
Colour of the water:

Clarity of the water:
(clear, moderate, fair or severely turbid)

Presence of dead algae:
(foam present, type of odour)

Other remarks:

Benthic algae present
(See also Appendix 6)

	Type 1	Type 2	Type 3	Type 4
Name				
Colour				
Size (cm)				
% Coverage *(estimated)*				
Floating or submerged				
Type of substrate				
Reference to drawing				
Other remarks				
Indicating clean or polluted water				
Sources used other then Appendix 6:				

Water plants

Types (if possible names) of water plants present:
(floating, submerged completely or partly, roots in bottom or loose in the water, with estimated number of occurrence and reference to drawing)

--

--

Estimated number of types of plants present: in m^2

Estimated total number of plants present: in m^2

Estimated diversity:
(high, moderate, low)

% Cover of water surface with floating leaves:
(estimated)

Estimated number of dead plants present: in m^2

Historical changes in occurrence of plants:

Other remarks:

Vertebrates

Description of vertebrates seen or heard:
(location, name, number, male/female, time and date of recording, reference to drawing)

Birds:
(waterfowl and other)

--

--

Reptiles and amphibians:

--

--

Mammals:

--

--

Historical changes in occurrence:

Other remarks:

Fish

Methods of survey:
(visual observation, sampling by fishermen or by yourself, source(s) of information)

Method of sampling:
(equipment, actions)

Size of the sampled area: m^2

Kinds of fish occurring in water:
(name, if possible local and scientific, reference to drawing, if possible feeding level)

--

--

--

Historical changes in fish population:

Presence of dead fish (kinds and numbers):

Presence of fish swimming erratically (kinds and numbers):

Presence of sick fish (specify symptoms):

Other remarks:

Literature and persons used for information:

Macroinvertebrates

Method of sampling:
(equipment, actions)

Size of the sampled area: m^2

Kinds and numbers of animals brought back:
(names, reference to drawings)

Description of the sampled area:
(type of bottom, depth)

Weather conditions at time of sampling:

Weather conditions previous period:

Other remarks:

Score rating of the Sequential Comparison Index (SCI)

$$SCI = \frac{\text{number of runs}}{\text{total number of macroinvertebrates picked}} =$$

0 - 0.3 poor water quality
0.3 - 0.6 fair water quality
0.6 - 1 good water quality

Sample Location		
Number	*Description*	*SCI*

Score rating of the Pollution Tolerance Index (PTI)

Group 1	*Group 2*	*Group 3*	*Group 4*
Stonefly	Caddisfly	Black fly	worms
Dobsonfly	Mayfly	Midge	leeches
Snipe fly	Riffle beetles	Sowbug	lung snails
	Damselfly	Scud	blood-worm
	Dragonfly	snails with gills	midge
	Crayfish		
	Crane Fly		
	Clam/Mussel		
Number of Types × 1 = (*a*)	Number of Types × 2 = (*b*)	Number of Types × 3 = (*c*)	Number of Types × 4 = (*d*)

$(a) + (b) + (c) + (d) =$

$$\frac{\text{Total of all group scores}}{\text{Total number of different types}} =$$

Pollution Tolerance Index			**Water Quality**
1	-	2.0	excellent
2.1	-	2.5	good
2.6	-	3.5	fair
	over	3.5	poor

Sample Location		
Number	*Description*	*PTI*

References to the drawings: