South Pacific Regional Environment Programme

Training Unit D1

TIME

USE OF THIS UNIT

This unit treats several aspects of time that are pertinent to the environment, including the passage of time, how we measure or divide it up with a calendar, and the cycles things go through in time. Time is a subject that seems self-evident yet is difficult to understand across different cultures. If the leader and all the participants are from the same cultural background, this unit will be easier to cover (but perhaps less interesting) than if there are people from different cultures with different traditional conceptions of time.

The aspects of time presented in the text should be discussed carefully in the group to bring out the different ways of looking at time which affect how people understand the world around them. Then it will be easier to discuss the importance of time and cycles in the natural environment. Participants should try to think of as many local examples as possible from both their culture and their environment to illustrate these ideas.

(Unit written by A. L. Dahl)
[Revision 21/06/85]

TEXT

TIME

Time is one of the most important dimensions of the natural world. It includes how we measure what happens during the day, or with a calendar, and how we think about the past, present and future. Man's ways of thinking about time and measuring it vary greatly from culture to culture. This can make it very difficult to understand when people of different cultures discuss together, because we often do not understand how different our ideas of time may be. The words for time and the way time is expressed in each language can help to show how different these ideas are. If you try translating words for time from English into your local language, or vice versa, you may find some of these differences.

Some peoples did not think about the past and the future the way Europeans do, just as they did not separate themselves as individuals from their environment. The real or natural world and the mythical world of gods and ancestors were often merged together. The future was not planned for, it simply was there when certain signs appeared.

Measurement of time

Today most people measure time in years, months, weeks, days, hours, minutes and seconds, using printed calendars and clocks or watches. Yet most of our divisions of time are still related to natural astronomical events that repeat themselves regularly. Days are measured by the rising and setting of the sun, and are subdivided by the different positions of the sun into periods such as dawn, morning, noon, afternoon, sunset, evening and night. Months were originally related to the different phases of the moon, and in some places the lunar calendar is still more important that the solar calendar. Years are related to the different positions of the earth as it rotates around the sun. The changing position of the sun relative to the earth means that in any one place the angle of the sun is higher or lower, and the day length longer or shorter. This changes how much the sun heats the earth's surface, producing the seasons. These natural cycles were combined with cultural factors to produce the different calendars.

Time and the environment

Time is an important element of the environment because many natural events are linked with astronomical cycles. The seasons of the year are responsible for changes in temperature, weather and rainfall patterns, which in turn are related to growing seasons and times of dormancy in plants, as well as seasonal flowering, fruiting and animal reproduction.

The cycles of the moon drive the tides in the sea. The also have an important influence on many plants and animals both on the land and in the sea. Some plants and animals are known to reproduce once a month on a lunar cycle.

The cycles of day and night have an obvious influence on much biological behavior, including our own periods of waking and sleeping.

Understanding these natural and biological cycles can help both to explain why certain environmental features are as they are, and to improve our use and management of natural resources. The repeating patterns make it possible to predict and prepare for certain events, and any changes from the usual patterns can be a warning that we need to make adjustments. There are obvious examples in many aspects of life in the islands. Many crops such as yams are planted on an annual cycle, and the times for planting and harvesting are often associated with or indicated by natural phenomena. Similar phenomena are used in coastal fisheries to determine the best times to catch fish or the times to protect them so that they can reproduce. Certain weather patterns, such as times of drought or hurricanes, may also be predicted in this way.

In some island cultures, the calendar was not a separate dividing up of the year, but simply a series of responses to natural phenomena. The appearance of a star over the horizon, or the flowering of a particular tree in the forest, would signal that the time had come for a certain activity. Where environmental conditions vary from year to year, a calendar by association with natural biological events may be more responsive to changing environmental conditions that doing something at fixed dates in the solar calendar.

Collecting information about the role of time and various cycles in your local environment can help to make for better environmental management.

QUESTIONS .

How are the past, present and future viewed in your culture?

Was time measured during the day? How?

What are some examples of the influence of the moon?

Can you describe a traditional calendar?

South Pacific Regional Environment Programme

Training Unit D2

THE WEATHER

USE OF THIS UNIT

This unit discusses one of the most determining factors in any local environment, the weather, together with related problems of natural disasters. There should be no problem in getting into interesting discussions with the participants since most people have ideas on this subject. It is best not to criticize any ideas or theories expressed, since there are often good empirical observations or elements of truth in local folk wisdom even if these have not yet been validated scientifically.

If possible, bring in outside experts for discussions with the group. These could include a meteorologist from the local weather bureau, and perhaps an old man known for his ability to predict the weather.

EXERCISES

A visit to a local weather station would illustrate the different kinds of information collected on the weather, such as temperature, rainfall, hours of sunlight, wind speed and direction, atmospheric pressure, relative humidity, atmospheric conditions (with a weather balloon), and radar and satellite images.

(Unit written by A. L. Dahl)
[Revision 21/06/85]

TEXT

THE WEATHER

The weather is one of the most basic controlling influences on the environment. While we cannot (with rare exceptions) change or control the weather, we can understand it as it relates to our own local area and thus better plan the use and protection of the resources of the area.

The weather includes several things. The kinds of clouds and the amount of time they cover the sky determine the amount of sunlight there will be. Sunlight is important for the growth of plants, but too much sun under the wrong conditions can damage some plants or dry them out. Rainfall is another element of the weather that provides fresh-water for us and for all living things on the land. The amount of rain that falls, how hard it falls, whether it is concentrated in a few heavy showers or spread out in many light sprinkles, and whether there are long periods without rain are all important factors. (Precipitation in colder countries can also be frozen in the form of snow or hail, but this is seldom a problem in the Pacific Islands). Another aspect of the weather is the temperature, how high and how low it gets and how much it changes from day to night and season to season. The temperature is partly determined by where a place is on the earth's surface, and partly by the weather and the temperature of the winds and air masses that pass over. The winds are themselves part of the weather, with their strength, direction and distribution during the year all being significant.

The weather in any particular place is related to the general behavior of the air in the atmosphere, which involves patterns of circulation of warm and cold air masses around the world. The trade winds are an example of regular air movements related to global atmospheric circulation. The weather is also closely linked to the oceans. If the ocean is warmer than the air it will heat the adjacent air and if it is colder it will cool it. Since the air temperature changes more than the sea temperature, places near the ocean will have less extreme temperatures than places in the interior of continents. When the ocean is very warm, it can put so much energy into the atmosphere that is causes hurricanes or cyclones. The oceans also evaporate to provide much of the water vapour that goes to make clouds and eventually to fall as rain.

The land also has an effect on the weather. When the land heats up in the sun, it can warm the air and make it rise, bringing in sea breezes. If an island has mountains, the wind blowing across it must rise to go over the mountain. Rising air gets colder, which makes the clouds and rain so frequent over islands. The rain usually falls on the side of the island from which the wind comes, so that islands often have wet and dry sides. The land can also make the air colder at night, and of course the higher a place is on a mountain the colder it gets.

As a result of all these factors, each place has its own particular weather or microclimate, with some being more sheltered and others more open, some wetter and others drier. The weather in the bottom of a valley may be quite different from that at the top, and one side may be different from the other, depending on the orientation to the sun and the direction the

the prevailing winds. Even the nature of the land surface and whether it is covered by forest or other vegetation can have an influence. The weather recorded at the local weather station may thus not correspond very well to the weather on some other parts of the island. You may need to study your own weather in order to understand your particular microclimate.

Predicting the weather

One of the greatest problems with the weather is trying to predict what it will be. The weather goes through many kinds of changes, and even modern science is still far from understanding how or why they happen. We know that weather and climate can go through enormous changes over periods of tens or hundreds of thousands of years. At times in the past the world was more tropical than today; at other times there were ice ages with snow and ice over much of the land. These are not the kinds of changes that can concern us too much in our lifetimes. Then there are changes over several years or decades, some of which seem to be cyclical. A period of "good" years may be followed by "bad" years, and so on. Some changes may seem quite unusual or abnormal, as with the extreme "el Nino" of 1983 when the winds reversed across the central Pacific, the warm water went eastward, and unusual changes in weather were reported all around the world. The weather may be upset by some other factor; a severe volcanic eruption may blow so much dust into the upper atmosphere that it can go around the world and affect the weather for several years. For the first time, man has also reached the stage where he can have an effect on the weather. Some scientists fear that the increasing level of carbon dioxide in the air (from burning oil and coal and cutting forests) may cause the temperature to rise and the ice caps at the poles to start melting. This would change the weather everywhere and might cause the sea level to rise over a few hundred years, drowning many cities and island countries. However most changes in the weather are what might be called random variability. The weather changes because it is always changing, and whether the change in any one place is today, tomorrow or next week may be purely a matter of chance.

People who depend on the weather and who spend a lot of time outdoors learn to read the many signs in the environment that can help to tell what weather to expect. The kinds of clouds and the appearance of the sky, the waves and swells on the ocean, the behavior of seabirds and many other things can be used to tell what weather may be coming. This knowledge depends very much on each particular locality and so is best learned from someone who knows the area well.

Today modern scientific methods for weather prediction have greatly improved, drawing on reports from many other weather stations, radar, and satellite pictures that show all the cloud patterns on a big part of the earth from out in space. If you have access to such information, use it, but there is still much you can do to understand your local weather just as your ancestors did before.

Natural disasters

Some of the most important effects of the weather come from the natural disasters caused by very severe storms or droughts. A cyclonic storm (hurricane or typhoon) can blow houses apart, flatten trees and crops, flood land, smash coral reefs, and cause more erosion that ten years of normal rains. Some areas of the Pacific may have cyclones almost every year, and others only once in 50 or 100 years. It is often possible to collect information on what happened in previous storms, and even to look for lasting traces of storm damage such as rubble ridges along the reef or river flood crest levels. This information can be used to plan development so as to minimize the risk of storm damage.

Droughts, or long periods without rain, can be another form of natural disaster, with crops failing, livestock dying of thirst or starving for lack of forage, disease spreading through lack of hygiene, and in extreme cases people having to abandon their homes and islands. Areas subject to drought require careful advanced preparations, such as adequate (and properly maintained) water storage, emergency wells, and irrigation for crops if conditions permit.

Other natural disasters include earthquakes, volcanic eruptions and the resulting tsunamis (the giant waves sometimes caused by earthquakes or underwater landslides). If these are a risk in a local area, they can be planned for much as any other extreme environmental factor.

Average and extreme conditions

Two kinds of environmental conditions can be important for living organisms and thus for many development projects. Most things have normal requirements for the conditions they like best. A crop, for instance may grow best at a certain temperature, with a certain rainfall, weather pattern and seasonal variation. If conditions are not so ideal, it may still grow, but not quite so well. However, at some point, when the temperature is too high or too low, or it is too wet or too dry, or some combination of factors, the crop will be pushed beyond its limit and will die. Thus both the average conditions in the environment most of the time, and the occasional rare extreme factor, are important controls on the survival of plants and animals, and thus on development projects. The extreme conditions are often associated with natural disasters, so particular attention needs to paid to them in development planning. Understanding both the normal average conditions in the environment and the occasional limiting extremes can make the difference between success and failure.

QUESTIONS

What factors are used to describe the weather?

What is the weather like on your island?

Is it different from one side of the island to the other?

Can you think of places on your island with different microclimates?

Has the weather changed in the last few decades? How?

Is there someone in your village who can predict the weather?

What signs do you use to tell what the weather will be like?

What kinds of natural disasters is your area subject to?

Do people do anything to prepare for possible disasters?

Can you describe a natural disaster and its effects on the environment?

Why are both average and extreme conditions important?

South Pacific Regional Environment Programme

Training Unit D3

NUTRIENT CYCLES

USE OF THIS UNIT

Nutrients and the way they are cycled through living systems are one of the most critical factors in ecology. However, they cannot be seen and so are difficult to explain to someone with no knowledge of chemistry. This unit attempts to give the basic principles of nutrient cycling for people with no chemical background. The text should be explained carefully step by step, with discussion with the participants at each paragraph to ensure that the principles are clearly understood.

If a blackboard or other drawing board is available, the concept of the cycling of nutrients could be shown by drawing a diagram on the board while explaining it.

AUDIO-VISUAL SUPPORTS

An animated diagram showing nutrient cycling in a forest is included in the SPC film "Your Changing Island Environment".

(Unit written by A. L. Dahl)
[Revision 22/06/85]

TEXT

NUTRIENT CYCLES

All things are made up of tiny atoms (too small to see and hard even to imagine) which mix and join together to make the different substances like air, water, rock or the materials of which our body is made. The study of the many kinds of atoms, the ways they combine together and the substances they make is called chemistry, and is too complicated to explain here. What is important to understand is that there are different kinds of atoms, and that each substance or material is made up of specific combinations of these atoms. It usually takes energy to put atoms together in bigger and bigger combinations, like those we find in living things. Energy may be given up in the form of heat (as in a fire) when the atoms are separated again. However the atoms themselves are not changed in these normal chemical reactions; they just change their form, and they go through these combinations and changes over and over again indefinitely.

Cycles

For example, a tree may take in air through its leaves and water from the ground through its roots. Using energy from the sunlight, it breaks the water and air down to get carbon, oxygen and hydrogen atoms, and then puts these together first to make kinds of sugar and then to make wood. If the wood is burned, the atoms go back to the air as smoke, and the energy from the sun that held them together becomes the heat of the fire. The atoms that went back to the air may be taken up by another tree and used again. If some of the sugar made by the tree goes into a fruit, you could eat the fruit and your body would break down the sugar to give it energy (that is where your body heat comes from). The atoms from the sugar would be breathed out of your lungs as air. These are examples of cycles (meaning to go around in a circle) because something takes place or is used over and over again.

Cycles are an essential part of all natural systems and all living things. Growth and change and life itself involve taking in materials, using them in some way, and discarding them as other materials. Eating and breathing are obvious examples.

Nutrients

Many atoms are so common that their cycles do not matter much in managing the environment. However, some other atoms or chemicals are essential for life but are much harder to get in a form that can be used. These things that are needed as food are called nutrients, and if they are in short supply, plants and animals cannot grow the way they should.

The three nutrients that living things most often need but cannot always find enough of contain the atoms nitrogen (N), phosphorus (P) and potassium (K). Other things may also be needed, but less frequently or in smaller quantities. Only the most important nutrients are discussed here, but similar principles apply to the others.

Nitrogen occurs in air, but it cannot be used by most living things until it is "fixed" or attached to oxygen or hydrogen atoms. Phosphorus and potassium are found in some soil materials. Plants need these nutrients in order to grow, and if they cannot get them in the soil they will be stunted or even die. A plant suffering from the lack of a nutrient may have leaves that turn yellow or die at the edges, and may be shorter or weaker than healthy plants. If a soil is not too rich in nutrients, they will quickly be taken up and used by the plants, leaving the soil exhausted. However, when the plants die and decay, the nutrients go back into the soil where they can be used again, making a simple nutrient cycle.

Animals make the nutrient cycle more complicated. They must get their nutrients and energy from the plants they eat (or from eating animals that have eaten plants). When animals deposit their wastes or die, the nutrients in their bodies go back to the soil, but not necessarily in the same place where the plants grew. Thus nutrient cycles may involve the movement or transport of nutrients from one place to another.

It is important to understand the principles of these nutrient cycles, since respecting or managing them is an important part of keeping environmental resources productive, and ignoring them is a good way to fail in development efforts.

Nutrients in the environment

In most stable natural environments, the total quantity of nutrients stays the same as the nutrients cycle within the ecosystem. A productive ecosystem like a tropical forest or a coral reef is often able to build up quite high levels of nutrients over time. The long roots of forest trees reach down deep in the soil for nutrients which they bring up and add to the system. A large stock of nutrients is held in the vegetation and is quickly recycled if released. It is important to note that in such systems the reserve of nutrients is held in the plants and animals that make up the ecosystem, and not in the surrounding environment which may be quite poor. If the system of living things is damaged or destroyed, the nutrients that maintain its productivity may be lost very quickly.

Nitrogen is a special case, because it is made available as a nutrient by the biological activity of nitrogen fixation carried out by certain microbes and algae, sometimes in association with the roots of leguminous plants. It can also be lost as a nutrient when microbes break down nitrogen compounds. The fixing of nitrogen is a normal process in most natural systems, but when man disturbs or develops land, he usually destroys this capacity.

While the above description of nutrient cycles has focussed on the land, the same principles apply in the sea. Nutrients occur in seawater, although the amounts in tropical seas are very low except where they are added to the sea by runoff from the land. Nutrients are stocked in sea plants and animals, and are accumulated and recycled in productive systems like coral reefs.

Man's impact on nutrient cycles

It should now be clear that man's activities can easily create environmental problems by interfering with the nutrient cycles. Cutting, clearing or burning the vegetation releases the stock of nutrients, which may be washed away quickly by rain if there are not other plants to take them up. Dynamiting or poisoning the reef has the same effect. The mechanisms by which new nutrients are accumulated and recycled may also be destroyed.

In order to keep up the productivity of man-made systems like farming, it is necessary to add nutrients to the system, either by applying natural materials like compost or manure, or by adding chemical fertilizers of which nitrogen, phosphorus and potassium compounds are the most common. The careful management of nutrients is one of the most important aspects of agricultural development.

Most environmental problems concerning nutrients result from the lack of nutrients in agriculture or forestry production or when soils become degraded, but there can occasionally be problems of too much of some nutrients, particularly in rivers, lakes and lagoons. The excess nutrients may come from fertilizer washed off the land, or from human and animal wastes (high in nitrogen) or detergents (high in phosphorus). The runoff from fields, livestock areas, villages and towns may collect in the water, causing the rapid growth of algae or other aquatic plants which may smother more useful resources like the corals on a reef. The accumulated algae may eventually rot, using up the oxygen in the water, killing the fish and producing bad smells. Nitrogen compounds can also get into human water supplies, particularly ground water, where they can present a risk to human health.

QUESTIONS

What is a cycle?

Why are nutrient cycles important?

Where do nutrients come from?

How do animals participate in nutrient cycling?

Where are the nutrients in a tropical forest? in a coral reef?

What makes nitrogen compounds different from other nutrients?

What does man often do to nutrient cycles?

What can be done to maintain nutrients in agriculture?

Is it bad to have too much of some nutrients? Why?

South Pacific Regional Environment Programme

Training Unit D4

POPULATIONS

USE OF THIS UNIT

Principles concerning populations are important for understanding a number of environmental problems. This unit introduces the concept of populations, and explains the relationships between populations and the levels at which they feed through food chains. It then outlines the principles of island biogeography as related to island populations. Finally, it applies population concepts to problems of pest control. These topics usually generate considerable interest in a group. The discussion leader may want to develop his or her own additional examples, perhaps drawing on local cases.

It might be possible to find a local specialist in pest control in the agriculture department who could contribute to the discussion on that subject.

(Unit written by A. L. Dahl)
[Revision 21/06/85]

TEXT

POPULATIONS

Usually when we think of some species of plant or animal, we think of an individual of that species, but it would be more correct to think of the whole population, that is of all members of that species alive in one place at any one time. Individuals come and go, but it is the population that perpetuates the species. Old members of a population die, and new ones are born. The individuals making up a population may be totally different in several years from those there today, but the species continues.

One of the characteristics of life is that it reproduces itself. Since nothing lives forever, there is always a turnover of generations. In a stable population, the birth rate equals the death rate, and the total numbers do not change. If the death rate is higher than the birth rate, the population will get smaller and smaller until finally it becomes extinct. If the birth rate is higher than the death rate, the population will grow larger and larger until it finally reaches some limit that causes the births to decline or the deaths to increase.

Populations have the potential to grow very rapidly, in what is called a geometric progression. Suppose a couple (two parents) have four offspring before they die. If those two pairs each have four offspring, there will be eight, then in the next generation 16, then 32, 64, 128, 256, 512, 1024, 2048, 4096, 8192, 16384, 32768, 65536, 131072, etc. Note that four offspring is a very low number for most plants or animals; some species produce thousands or millions. The speed of population growth depends on the number of offspring per generation and the length of time between generations. If the above figures applied to a couple of human beings with 25 years between generations, it would take almost 400 years to reach a hundred thousand. (Many islanders do better than that, but few islands have room for 100,000 people). If the same figures were for cats breeding at two years of age, the pair of cats would reach 100,000 in a little over 30 years. Suppose a pair of flies manages to lay a thousand eggs in a two-week lifetime and they all survive; in six weeks there would be 250,000,000 flies. Obviously something must happen to limit those populations before they get so large. On the other hand, a green turtle that takes 40 years before being old enough to lay a hundred eggs of which only 2 survive to grow up will just succeed in replacing itself if it is lucky, and just a few adult turtles killed would mean the collapse and disappearance of the population.

Since most plants and animals produce many offspring, it is clear that few of those young survive to adulthood, yet some must succeed if the population is to continue. There are two principal reproduction strategies: producing many vulnerable young in the hope that a few survive; or producing a few young that are very strong and resistant, or that are protected by their parents until they are big enough to defend themselves. It is those that survive to reproduce that count, not the number that die along the way.

Clearly reproduction is the most vulnerable stage for the survival of of population or a species. Those that survive are generally the strongest or best suited to the environment, and the process permits the selection for the best qualities in the population. You can use the same principle to find and maintain the best varieties of crop plants or races of domesticated animals.

Food chains

One of the essential relationships between species is eating and being eaten. All of the food in island environments starts with plants, which use energy from the sun in order to grow. This plant life, whether in forests, grasslands or food gardens on the land, or mangroves, seagrasses, algae or plankton in the sea, is the starting point and first level of productivity for all island ecosystems. The amount of food produced by plants will determine how many fish and animals (and people if no food is imported) can live on an island. Anything that hurts plants will also affect the animals and reduce the size and productivity of the whole system.

Various animals (called herbivores) from caterpillars and snails to cows and dugongs feed on plants. Other animals (carnivores) eat them. Some animals (omnivores) like rats and men eat almost anything including plants and animals. A bird may eat caterpillars which eat leaves. A plant-eating snail may be eaten by a pig which you then eat for dinner. These are called food chains because the food energy passes along them from one organism to another like links in a chain.

A lot of energy is lost as it goes along a food chain. About nine tenths of an animal's food energy will be used up running around, eating and reproducing, and only about one tenth will go into making its body where it can become the food of the next animal up the food chain. This makes for a structure like a pyramid, with a large amount of plant energy at the bottom supporting ever smaller numbers of animals up the food chain. The animals at the top of the food chain need very large areas to support themselves It takes much more land to feed people with meat that with plant foods.

These food chains help to keep all the populations in an ecosystem in balance. The world is not overrun with flies because frogs, geckos, birds, spiders and many other things eat them. (One reason why there is a human population problem is that, apart from the rare crocodile or tiger, nothing eats us). The balance of populations along a food chain can be very complicated, and disturbing it in different places can create different kinds of imbalance with varying environmental effects. For instance, suppose there is a simple food chain with one kind of plant, one kind of plant-eating animal and one animal-eating animal. A reduction in the number of plants means a reduction in all the kinds of animals. Taking away the plant-eating animal will lead to a collapse in the number of animals that feed on it, but an increase in the number or size of the plants, since the animal is no longer there to feed on them and keep them under control. Killing the meat-eating animals at the top of the food chain will allow the plant-eating animals to get more common until they eat up all the plants and then starve to death themselves.

Real ecosystems are more complex than this, since there are many more kinds of organisms and more alternative kinds of food, but even then such imbalances can occur with population explosions or collapses. The crown-of-thorns starfish population explosions on coral reefs are an example well known in the region.

The linkages between species such as the examples given here of food chains and population control mechanisms can play an important part in environmental problems. The following classic example illustrates the unexpected consequence of an environmental action. A village was suffering from a plague of flies. The villagers sprayed an insecticide to control the flies. The dying flies loaded with insecticide moved more slowly, and were thus eaten by the geckos. The geckos in turn were affected by the poison and fell from the walls, where they fell easy prey to the village cats. The cats became sick from their poisoned food, and could not run fast enough to catch the rats. The result of trying to get rid of the flies was a population explosion of rats. Stories such as this show how difficult management of the environment can be.

Island populations

The problems of population numbers and controls are particularly important when the space available is limited, as it is on an island. There are special principles which are important to understanding why island populations are the way they are and how they came to be established.

All the Pacific Islands, except some continental islands, were created at some point by volcanoes rising from the sea floor. As they approached and then grew above the surface, coral reefs and other shallow sea life, and then land plants and animals, came to live on them. On some islands this may have happened more than once as the island submerged and reappeared. Once an island is available, a first few pioneering plants and animals get established. Gradually some more competitive ones arrive and push aside the early settlers. An equilibrium is finally established when the number of new arrivals is balanced by the number of extinctions, with the total number of species being related to the size of the island and its distance from other land areas. The populations on any island today are at one point in this series of successive stages, depending on how old the island is.

Crossing the sea is no easy matter for most organisms. Pioneer species have often developed special ways of crossing the ocean, such as floating seeds and salt-resistance. The coconut and many coastal plants are of this type. For other species transport to a new island is a rare and random event. Not only must the organism survive the long voyage in storm winds, on a drifting log, or stuck to a migrating bird's feathers, but for many species both sexes must arrive at the same time in order to reproduce and establish a population.

Island plants and animals may have come originally from a continent or from another island. A chain of islands may serve as stepping stones for the spread of a species. Organisms usually spread in the directions of winds and currents, and of the movements of migrating animals, or they may be transported during storms.

For a newly-arrived species, reaching a tiny speck of land in the vast sea is only the first step. New islands may present hostile conditions, while older islands have well-established communities against which the new arrival must compete. However, most islands have relatively few species, so there are often unfilled places waiting for new occupants. Even then, the small populations are still vulnerable to diseases, droughts, hurricanes, volcanic eruptions and other natural disasters. The smaller the island, the smaller the maximum possible population it can support and the easier it is for a calamity to wipe out a species. These continuing processes of the arrival and dying out of species are important contributors to the overall balance of life on an island.

Living on an island can have a number of effects on the evolution of the species concerned. Because most islands have fewer species on them, there is less competition and less danger of being eaten. The plants and animals may then lose their defenses and their ability to compete. In the case of continental islands, species present at the time of separation from a big continent may survive long after the parent populations have been driven to extinction by later more highly evolved forms. New Caledonia is an example of such an island, where long isolation without big plant-eating animals, and unusual soils toxic to later arrivals, permitted the survival of many primitive plants.

Sometimes an organism may reach an island and find many different places available with no competition; the species may then evolve rapidly into different forms to fill the available places. Charles Darwin described the classic example of the Galapagos finches. This is one reason why there may be many unusual species on an island. Small isolated island populations descended from single parents may also change slowly just because all the individuals are so closely related genetically; each island population may then develop its own distinct characteristics.

The result of these processes is a large number of distinctive and often unique species of plants and animals on islands. On some of the larger, more isolated islands, almost all the species may be unique to that island and found nowhere else on earth.

Pest control

Weeds, damaging insects, molds, diseases and other pests are often species that are able to multiply their populations rapidly. The principles concerning populations are therefore important in understanding how to control pests.

Natural systems are made up of many kinds of species mixed together, with each balancing and controlling the other. Man-made systems, however, such as agricultural fields or forest plantations, are usually large areas with just a single species. The pests which feed on our crops appreciate our providing them with so much food, and their populations multiply rapidly. A pigsty is an ideal nursery for flies, and the tender shoots in a vegetable garden could not be better for snails.

Some pests have natural enemies that keep their populations under control most of the time. When the pest is numerous, there is more food for the enemy, which will multiply and reduce the pest population to normal levels. Unfortunately, the pests have often reached the islands while their enemies have not, so pest problems can be more frequent and more severe here than elsewhere.

Controlling pes is a kind of population management. It is almost impossible to eliminate a pest population entirely; destroying pests gets more expensive as their numbers get smaller and more scattered. However, there are several ways to reduce pest populations to manageable levels. The simplest is to change the conditions so the pest has less food or has a harder time spreading. This means doing things like cleaning the pigsty to control flies, or spacing a crop with other resistant or repellant crops so that it is harder for a pest to spread.

A second method is to use biological controls, which means encouraging a natural enemy or finding and introducing a new enemy for the pest. Unfortunately it is hard to find an enemy that will not also attack other useful plants or animals, and in too many cases in the islands something introduced as a biological control has proven to be as much of a problem as the pest it was brought in to control. It is also possible to interfere with pest reproduction by releasing sterile males that keep the females from laying fertile eggs, or spreading sex attractant chemicals that confuse the males and keep them from finding the females. Biological controls are not always easy to use in islands and they require a great deal of research, so you should not try to introduce your own biological controls unless you use traditional controls that have already proven their worth locally.

If there are no alternatives available, then chemical controls may be necessary. This means using some kind of poison (a pesticide, insecticide, herbicide, fungicide, etc.) that kills the pest. Pesticides cost money, although they may be cheaper than the labour involved in other control methods. They have some other severe disadvantages:

1. A pesticide almost never kills all of the pests; a few will survive to come back when the pesticide is gone, so the poison may need to be applied again and again.

2. The pests that survive may develop a resistance to the pesticide, so that it may take more and more poison to kill them, and eventually the poison may no longer work at all.

3. The pesticide may kill more things than just the pest, such as the pest's natural enemies. If the enemies or biological controls have disappeared, then the pest may come back in even larger numbers than before. Other pests may also become a problem because the controls limiting their populations may be affected too.

4. Most pesticides are dangerous poisons for people too. They must be stored, handled and used with great care, following exactly the directions for their application, and using as little as possible. If pesticides are misused or an accident occurs, they can easily contaminate food or the environment, which can be particularly serious on a small island. If people are exposed to pesticides or become contaminated while using them, they may become sick or die.

It is therefore best to keep chemical pesticides as a last resort in case everything else fails, especially since islands are very vulnerable to pollution by chemicals.

Since pest control is basically population management, it is important to understand the population factors for each pest, such as its life cycle and reproductive strategy, in order to know when control may be easiest and most effective. Just as natural populations can be upset by interfering at a sensitive time such as reproduction, so can pest be managed more easily by attacking them when they are the most vulnerable.

QUESTIONS

What determines whether a population is stable, increasing or decreasing?

What factors influence the speed of population growth?

What are different ways that a species can ensure that some of their young survive to be adults? Can you think of some examples in animals or plants that you know?

Can you think of some examples of food chains in your local environment?

How big a garden does it take to feed you and your family for a whole year?

How do food chains help to control populations?

What are some of the special things about populations on islands?

Why do many island species have difficulty competing with introduced species?

Are many species on islands special or unique? Why? Can you think of some examples?

Why does something become a pest?

What are some ways of controlling pest populations?

Which methods of pest control do you think are best? Why?

South Pacific Regional Environment Programme

Training Unit D5

MICROBES

USE OF THIS UNIT

The subject covered in this unit on microbes is essential to understanding problems of disease and pollution, but it is difficult to explain because microbes cannot be seen without a microscope and the participants will thus not have had any direct personal experience on which to draw. Cover the material in the unit carefully. Then if possible try to arrange for a demonstration of microbial life as a practical exercise. A discussion of what has been observed in the exercises can then serve to review the basic points in the unit. Then discuss with the group what their new knowledge of the microbial world means in terms of their life in their own village or area. The participants must come to understand that microbes are everywhere around them carrying out essential ecological functions or ready to cause illness or environmental problems. They should try to think through how disease germs might be spread through their environment or through their daily activities. This awareness will be very useful in their environmental analyses.

EXERCISES

It is important to try to arrange some demonstrations of microbes so that the participants can associate the idea with something real that they have experienced. If it is possible to borrow or get access to a microscope (perhaps in a high school or college science laboratory, at the department of agriculture, or in a medical laboratory) then the participants can see microbes of different types moving or wiggling under the microscope. Simple preparations can be made of saliva or pond water to show bacteria and other tiny forms of life. The details of what is shown are less important than the demonstration that we are surrounded by living things we cannot see, but which are very important in our environment.

Other simple demonstrations can be arranged even if a microscope is not available. Mold can be grown on an old piece of bread or other spoiled food to demonstrate the actions of decomposers. A bottle of water to which a little bit of dry grass or other dead plants has been added can be left in front of a window for a few days; the water and the walls of the bottle should become clouded or coloured by algae or tiny animals. In this way, even though it is not possible to see individual microbes with the naked eye, it is possible to see them when many are grouped together.

(Unit written by A. L. Dahl)
[Revision 23/07/85]

TEXT

MICROBES

We know about large plants and animals like trees and horses, and small ones like grass and mice, and very small ones like mosses and ants, but there are many other living things even smaller then that, so small that we cannot see them with the naked eye. They are called microbes. This whole world of tiny living things is very important in the environment, so we must learn to understand, appreciate and respect them.

There are many kinds of microbes, and they are everywhere around us, in the soil, in the air, on our skins and even inside of us. Some microbes are tiny plants called algae that usually live in the water or on land. They make their food with energy from the sun just like bigger plants. When they are very numerous, they may colour the water green or brown, or they may appear as slimes or scums. The greenish black that often stains the outside of concrete buildings in the tropics comes from algae. Algae may be green, blue-green, brown, yellow-brown or even red or orange, like the alga that sometimes grows on the trunks of coconut palms near the sea.

There are also tiny animals or **protozoa** of many kinds that swim or crawl around and eat things like algae and other animals. Since most of them are colourless, they are hard to see without some kind of magnification.

The **bacteria** or germs are even smaller than the algae, and there are millions and millions of them everywhere. They live by dissolving and breaking down any kind of organic matter, which includes anything that is or was part of a living thing. Thus they break down anything that is dead, and sometimes they do not wait for it to be dead, which is often how things get sick. It is usually bacteria that cause milk to go sour or food to spoil. Even though a surface may look clean, it has bacteria on it unless it has been sterilized (made clean of all bacteria) by heating, boiling or the application of alcohol or an antiseptic (a chemical that kills bacteria).

Another important group of microbes are the fungi, which grow like plants but get their food by breaking down dead material. They include the molds and mildews which are responsible for rotting and decay. Mushrooms are the fruiting bodies of certain kinds of fungi.

There are three important kinds of activities that microbes carry out in the environment:

1. Decomposers

These microbes are an essential part of all ecosystems, because they decompose or break down dead material and keep it from accumulating. If something did not break down the dead leaves in a forest, they would pile up higher and higher until the trees were buried under them. When the decomposers break things down, they release the materials of which these things were made, particularly the nutrients, which are then available to be taken up by plant roots and used again. If the nutrients were not released, they would eventually all be tied up in dead material, and then nothing else

could grow. Sometimes the decomposers create a problem when they rot or spoil things faster than we would like.

2. Symbionts

Sometimes microbes are actually helpful to plants and animals in a relationship called symbiosis because each one helps the other. For instance, there are certain fungi in the soil which grow attached to the roots of trees and which help the tree to absorb water and nutrients from the soil. This help is so important for some trees that they cannot grow without their special fungus.

Only certain bacteria and blue-green algae are able to fix nitrogen from the air and make it available as a nutrient to plants. In certain plants like the legumes, the root have special swellings, called nodules where nitrogen-fixing bacteria can live under good conditions inside the roots and make nitrogen nutrients for the plant.

Animals like corals and giant clams have one-celled algae (tiny plants) living inside their bodies; the animals give the plants shelter and nutrients and expose them to the light, and the plants make food for the animals. Then there are animals like cows and termites that have special bacteria living in their stomachs to help them digest food in the grass and wood that they could not use otherwise.

3. Disease germs

There are always many kinds of microbes on and in our bodies, but most of them do not hurt us, and a few are even helpful. Unfortunately, some microbes are much more dangerous, and want to live off of us or of other living things before we are dead. Some may even try to kill us to get more food. As they multiply in our bodies they make us sick. Our bodies have some defenses against these disease germs, but sometimes they are not enough, and we need the help of medicines to overcome the germs and get well again. Antibiotics, for instance, are special poisons against microbes, just as insecticides are poisons against insects. Doctors sometimes must give us these strong medicines to help our body get rid of a dangerous disease germ, but they must be used with care or they can upset the body's balance in other ways.

Living with microbes

In thinking about the environment, we must remember that the microbes are always there even if we cannot see them. Often they are useful, but sometimes they are dangerous, and we must learn how to be careful and control them. Microbes that cause disease are often spread from one person to another, making many people sick. When a person is sick, there may be many disease germs in his mouth or in his wastes. If he sneezes on his hand, there will be germs on his hand. If he touches a child, the sickness could pass to the child; if he touches a loaf of bread, the germs could pass to anyone who eats the bread.

Suppose a person has been sick in the bush. An animal might pick up his germs and bring them back to the village. Pigs, rats, cockroaches and flies all may carry germs from dirty or unsanitary places and put them on food or in places where children play. This is why if a place is clean there is less chance of spreading sicknesses.

Germs are often spread through dirty or contaminated water. Imagine a bucket that everyone uses. It may be set on the ground where dirty pigs have been walking, or be used for washing dirty clothes or a sick babies' diapers, then it may be lowered into a well or cistern to get water for washing. The germs on the sides and bottom will get into the water, and then can be given to anyone drinking the water or eating food or from plates that have been washed in it. Since you cannot see germs, they may be there even if something looks clean.

There are things that can be done to control the harmful effects of germs or to keep them from spreading. Microbes are always waiting to break down anything that is lying around, like our food, for example. Since microbes usually grow faster when it is warm, food spoils faster (from attack by microbes) in warm weather. If the food is put in a cold place like a refrigerator, the microbes grow more slowly, and the food will keep several days. The colder it is, the longer the food can be kept without spoiling. In a very cold freezer, the microbes can hardly grow at all. In the same way, enough heat can kill microbes. Boiling water for 20 minutes will kill the germs in it, or in any food put in it. The food in cans does not spoil because the cans were heated in the cannery to kill all the microbes inside. Boiling baby bottles and nipples, and any water put inside them, will sterilize them and kill all the germs, since babies are still weak at fighting germs and get sick very easily.

There are also chemicals that can be used as disinfectants to kill microbes, including chlorine bleach, alcohol, and the antiseptics used to treat cuts and other injuries which might otherwise let microbes into the body. Washing with soap or detergent can reduce but not eliminate microbes. If someone is sick and there is a danger of contamination, then a disinfectant can be used to keep the germs from being spread.

QUESTIONS

Where are microbes found? Can you name some of the places?

What are some of the important kinds of microbes?

What do they do?

How do microbes contribute to nutrient cycles?

What happens to something that dies?

What would happen if there were no microbes?

What are some ways that microbes can be helpful?

Why are microbes sometimes dangerous or harmful?

How do medicines like antibiotics work?

What are some ways that germs or other harmful microbes can be spread in the house? in the village?

What can you do to keep microbes from spreading if someone in the house is sick?

South Pacific Regional Environment Programme

Training Unit D6

WATER POLLUTION

USE OF THIS UNIT

This unit explains why water pollution is one of the most dangerous and widespread environmental problems. It describes the different kinds of pollution and where they come from. Since the kinds of water pollution that are most important locally differ from place to place, the emphasis in this section should be put on those sources of water pollution that are the most significant locally. In the discussion of this unit, use local examples wherever possible. You may be able to get details of the water pollution problems in your country from local health, environmental, or port officials. You could also invite such people to meet with the group to discuss these problems.

EXERCISES

The group could be taken on a field trip to look at local examples of water pollution. They also could be assigned to go out individually or in small teams to identify as many different locations and sources of water pollution as possible. Then the group should discuss the origin of these pollution problems and what can be done about them.

If the government has a local water pollution monitoring programme, it might be possible to arrange for the group to go along and watch the samples being collected and analysed.

(Unit written by A. L. Dahl)
[Revision 25/07/85]

TEXT

WATER POLLUTION

Water is essential to all life, and living things are mostly made of water. This is because water is a very good solvent, which means that many kinds of materials can dissolve or wash away in it. Sea water is salty because salts are dissolved in it. The beverages we drink are water with something dissolved in it. When we wash something, the water dissolves and carries away the dirt. Because water is good at dissolving things, it also helps to transport them in dissolved form from one place to another.

These qualities which make water so useful also make it easy for water to be polluted, or made dirty with things that are dangerous or harmful. Often pollution comes from man-made substances or things produced by man's activities that prevent the water from being used naturally. Since nothing can live without water, anything that makes water unusable or dangerous is very serious, and can quickly lead to the death of people, plants or animals if other sources of clean water are not available.

Kinds and sources of water pollution

There are several kinds of water pollution that are important in the Pacific region. Each one comes from particular sources, and can be harmful in different ways.

Human wastes. Often water is contaminated with human wastes which may carry disease germs and parasites. Wherever people live, they must dispose of their wastes. In urban areas they may use water in toilets to carry these wastes away. Sometimes this water simply drains into a ditch, a stream or into the sea, carrying the pollution with it. More often the water carries the waste into a septic tank where the waste is digested by microbes and much of the pollution removed. Some large hotels and modern buildings have more complicated waste treatment plants to purify their wastes. Unfortunately septic tanks and treatment plants require maintenance to work well, and if this is neglected they also can release polluted water. This happens much too often in the Pacific.

In villages, there may be pit toilets or latrines, or people may simply take care of their needs in the bushes or on the beach. Rain or water runoff may carry these wastes into streams or the lagoon, or wash them down into the ground water where the pollution can get into wells and springs. Animal wastes may also carry disease germs which can get into water and pollute it.

These wastes not only carry diseases and other dangerous things, they also may be high in nitrogen nutrients. Too high a level of nutrients can make algae grow too fast in streams, lakes or lagoons, smothering other kinds of life and building up until they start to rot and kill the fish. If the nitrogen compounds get into drinking water, they can be turned into nitrites which have been linked to cancer in humans.

Washing water. Water is also used by people to bathe or shower in, to wash their clothes and dishes, and to clean their houses and work places. All that water has to go somewhere carrying all the dirt, germs, and soap, detergent or other cleaners. While such pollution is not as much of a health hazard as human wastes, it can still present some dangers. Detergents, for instance, contain phosphorus, which is another nutrient that can cause algae to grow too fast.

Storm water. Whenever there is a heavy rain, it washes the dust and dirt off the roofs and the streets. In towns and cities in particular, that dirt can contain pollutants such as oil spilled from cars and trucks, the poisonous metal lead from lead paints and the lead added to petrol (gasoline), and any other dangerous things that may have been spilled accidentally.

Sediments. Whenever erosion occurs on the land, whether from agriculture, construction, forestry or mining, the fine particles of the soil become pollution in the water. The water turns cloudy or turbid, so fish can no longer see far, and sunlight cannot reach the plants on the bottom that make food for everything else. As the fine particles settle out, they form sediment or mud on the bottom, smothering corals and plants, and covering up the hard surfaces of the reef or rock that such things need to attach to. The ecosystem changes from a stable and productive coral reef or lagoon ecosystem to a much less stable and productive soft bottom community.

Industrial wastes. Factories and industries often use water to wash away their wastes. Fruit and fish processing plants or canneries, sugar refineries, slaughterhouses, coconut oil or oil palm treatment plants, and breweries, among others, produce waste water with lots of organic material from the plants or animals that are processed. As this organic matter is attacked by microbes and decays in the water, it uses up the oxygen; the water and sludge may then turn black and smell bad, and all the fish and other animals will be killed.

The mining and smelting industries sometimes use very poisonous chemicals like mercury or cyanide in there treatment processes. If a metal like copper is mined, it may itself be poisonous. Since it is not possible to stop it from raining at a mine or smelter, or to prevent all accidents, there is always some small but possibly dangerous amount that gets into the water, and big accidental spills can also occur. Since these poisons do not break down, they can go on poisoning the environment for a long time.

Many other industries use chemicals that can be dangerous water pollutants. Not only can chemicals from photographic processors, laundries and dry cleaners, paint factories, metal working or plating companies, etc. be poisonous or harmful in themselves, but if they get into septic tanks, waste treatment plants, streams or lagoons they can also slow or stop the microbes that would otherwise break down and purify organic wastes, making other water pollution problems worse.

Oil pollution. We depend on oil, and oil products such as kerosene and petrol (gasoline), for much of the energy used in modern island life, as well as to keep motors and machines working properly. Unfortunately we cannot seem to help spilling some of it while we use it, and it can thus get into the water. Since oil products arrive in the islands by ship, the risks of oil spills are

greatest in the vulnerable lagoons, harbours and coastal waters, either in accidents while unloading the oil, in spills from storage tanks or facilities, or more rarely in the grounding of ships carrying oil.

While there are some poisons in oil that can dissolve in the water, the worst effects of oil pollution come from the fact that oil floats on top of the water, sticking to things along the shore and covering animals (like sea birds) that go in and out of the water. Oil can smother animals, mangrove roots, and other seashore life. If waves break the oil up into small globs, it may be eaten by fish and shellfish, giving them an oily taste. Since oil breaks down very slowly, it can take a long time for oil pollution to go away.

Agricultural runoff. Modern agriculture frequently requires chemicals such as fertilizers and pesticides. Unfortunately these do not always stay in the fields where they are needed, but may wash off with the rain into streams or the lagoon. The fertilizers like other nutrients can cause algae to grow too fast, while the pesticides and herbicides are poisons that can kill or weaken sensitive animals or plants even in very tiny amounts. Both can upset the balance of life in productive natural environments.

Plastics. Another kind of danger comes from the plastics, bottles, plastic bags, pieces of fishnet, etc., which get thrown in the sea. Such plastics break down very slowly or not at all, and meanwhile they drift around causing trouble. Fishnets may go on catching and killing fish long after their owners have lost them. Small bits of plastic may be eaten by fish which think they are food. Some turtles have been known to die from eating too many plastic bags thinking they are jellyfish. All the plastic things on the beaches look ugly and can hurt tourism.

Fresh water pollution

Some islands have fresh water running down from the mountains or collecting on their surface in streams, rivers and lakes. Since streams collect much of the rain that falls on the land, they receive the pollution that the rain picks up as it runs off the land and drains into them. This water is often used for drinking as well as for washing, bathing and swimming, so the pollution can hurt anyone who uses it. However, since this surface water is usually quickly replaced by new rainfall, stopping the sources of pollution can clean up the problem quickly.

The same is not true for ground water, which is the water that collects under the surface of the ground in spaces in the sand and rock. This fresh water comes from rainfall that seeps down into the ground, and it may be floating on top of the heavier sea water underneath all the islands. As the rain soaks into the ground, it may take with it any pollution on the surface or in the soil. Once this pollution gets into the ground water, it may stay there for years and years, since ground water may run off into the sea and be replaced only very slowly. Ground water is the most important fresh water resource on many islands, supplying wells, springs and water galleries. Pollution of this water can have a serious long-term effect on island resources, and can be expensive or impossible to correct.

Marine pollution

Pollution can reach the coastal waters of the marine environment either directly or by being carried down rivers or streams. Even though no one drinks sea water, it is used for fishing and recreation, and can thus be a direct threat to people who come in contact with it. Particular problems can come from big pollution accidents like shipping accidents or oil spills, which are rare but have occurred on a number of Pacific Islands. Sometimes the pollution is intentional, as when someone goes fishing with poisons (usually illegally).

There have been cases in the Pacific where marine pollution has had a serious effect on a whole lagoon or coastal area. In Kaneohe Bay, Hawaii, sewage from housing developments drained into a bay with some of the best coral reefs in Hawaii. The nutrients in the wastes so fertilized a kind of green bubble algae that it grew all over everything and smothered and killed the corals. The bay was an ugly mess. However, when a new sewage treatment system was put in to keep the pollution from going into the bay, most of the algae died off and the corals are now recovering. Another case was the cholera epidemic on Tarawa in Kiribati. The microbes that cause cholera were brought to the island by one sick person, who began to spread the disease to others. Their wastes got into the ground water and the lagoon, where the germs were collected by shellfish that were a popular local food. Many people got sick very quickly and a few died. The people had to stop eating food from the lagoon or using untreated well water, and an expensive waste treatment system had to be installed. Other islands have also had cholera epidemics spread by water pollution.

Dangers of water pollution

As shown in the case of Tarawa Lagoon, water pollution can kill people by spreading diseases. It can also cause poisonings, and make food like fish taste bad, or even be dangerous to eat. Some kinds of pollution in water may not be strong enough to hurt us immediately, but they may slowly collect in our bodies until there is enough poison to make us sick. since it happens slowly, we may not even know why we are sick. Water pollution is also ugly: oil and tar on the beaches; water a dirty brown or green colour; plastic litter. Such water pollution can be a threat to local people and damaging to the tourist industry.

Pollution also damages natural systems. It may hurt the productivity of mangroves, lagoons and coral reefs that are important island resources. It can upset the delicate balance between different kinds of life, as when excess nutrients encourage algae to grow.

Cleaning up water pollution

All wastes put in water that are not broken down along the way eventually find their way into the ocean, where they accumulate like the salt that makes sea water salty. Already some man-made pollutants from industrialized countries have contaminated all the world's oceans. Once a persistent pollutant is in the sea, it is almost impossible to remove, but because the oceans are so large, most such pollutants are diluted to the point that they are not a danger, at least at present. No one knows what effect

they may have in the long term. Since most of the pollutants made in the Pacific Islands will eventually break down, disposal in the oceans away from the coast may be a reasonable solution for the small quantities generated.

Fortunately, when water evaporates from the ocean to become the water vapour that makes clouds and rain, the pollutants stay behind. Unless the rain encounters air pollution (as in the case of the acid rain of Europe and North America) rain water is clean and pure, and it renews the fresh water supplies of the islands.

The best way to stop water pollution is to keep potential pollutants from getting into the water, or if the waste is the result of washing or some other use of water, to treat the water to remove the pollutants before it is released back into the natural environment. There are many ways to clean water, including filters of sand, or biological filters where microbes remove pollutants, or chemical additives to kill dangerous germs or to make chemical wastes turn solid and settle out of the water. Sand filters on water supplies, and septic tanks, waste digesters or oxidation ponds for human and animal wastes are relatively simple techniques that can even be used in village areas where water pollution is a problem.

QUESTIONS

Why is water so easily polluted?

How do human wastes become a source of water pollution?

How do nutrients in water become pollutants? Where do they come from?

What are some of the industrial wastes in your country that might pollute water?

What are the risks of oil pollution where you are?

What agricultural chemicals are used in your country that might become pollutants?

If there are streams in your country, are they safe to drink from?

Do many people suffer from diarrhoea in your village or town?

If ground water is used in your country, what are the risks that it could be polluted? Are there other water supplies you could use?

Do you see signs of pollution on your shorelines and beaches?

What steps are taken in your country to prevent water pollution?

What more needs to be done?