# ENVIRONMENTALLY SOUND SMALL-SCALE WATER PROJECTS

## GUIDELINES FOR PLANNING

BY

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COORDINATION IN DEVELOPMENT
VOLUNTEERS IN TECHNICAL ASSISTANCE



Cover design and illustrations by Susann Foster Brown

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## PREFACE

This is the second volume of the Guidelines for Planning series. The first volume, Environmentally Sound Small Scale Agricultural Projects, was jointly published in 1979 by VITA and The Mohonk Trust. The remainder of the series is being produced by CODEL and published jointly by VITA and CODEL. The booklets can be ordered from VITA.

This booklet has been written for community development workers in developing countries who are not technicians in the area of water resources. It is meant to serve as a general guide when planning environmentally sound small-scale water projects, that is, projects which protect and conserve natural resources in a manner which allows sustainable development to take place. Sources of more detailed and specific information are listed in the text.

CODEL is grateful to members of the CODEL Environment and Development Committee who have supported this effort and commented on the material:

**Father John Joe Braun, Missionaries of Africa, Committee Chairperson**
**Ms. Elizabeth Enloe, Church World Service**
**Mr. George Gerardi, Attorney at Law**
**Mr. George Mahaffey, The Peace Corps**
**Dr. Ragnar Overby, The World Bank**
**Ms. Agnes Pall, International Division, YMCA**
**Mr. C. Anthony Pryor, Center for Integrative Development**
**Mr. A. Keith Smiley, Mohonk Consultations on the Earth's Ecosystem**

**Pastor Charles Fluegel, a former Committee member, deserves special thanks for his thoughtful, practical contributions. In addition, two other former members of the Committee should be recognized for their involvement in the project: Miss Marion Morey and Mr. Michael Hayes.**

**CODEL is pleased to publish a booklet written by Dr. Gus Tillman whose environmental training, expertise and overseas experience make him a unique resource to the development community. Dr. Tillman also serves on the CODEL Committee.**

**Special appreciation is reserved for Mr. Philip W. Quigg for his invaluable editorial and technical expertise.**

**Several persons reviewed the draft manuscript: Dr. John**

M. Kalbermatten, Mr. James H. Patric, Dr. Daniel A. Okun, Mr. R. Paul Chakroff, Ms. Marilyn S. Chakroff and Dr. Patricia Rosenfield. In addition, the book was reviewed by VITA volunteers and AID personnel, among them Ms. Molly Kux, AID Office of Forestry, Environment and Natural Resources.

Ms. Kux and Mr. Albert Printz, AID Environmental Coordinator, have been a constant source of support for the Environment and Development Program and especially the publication series. We are also appreciative of the continuing support of the AID Office of Private and Voluntary Cooperation.

We welcome comments from readers of the book; a questionnaire is enclosed for your convenience. Please share your reactions with us.

Rev. Boyd Lowry, CODEL
Ms. Carol Roever, CODEL
Ms. Helen L. Vukasin, CODEL

## ABOUT CODEL

**Coordination in Development (CODEL) is a private, not-for-profit consortium of 38 development agencies working in developing countries. CODEL funds community development activities which are locally initiated and ecumenically implemented. These activities include health, agricultural and career training projects, among others.**

**The Environment and Development Program of CODEL serves the private and voluntary development community by providing workshops, information and materials designed to document the urgency, feasibility and potential of an approach to small-scale development which stresses the interdependence of human and natural resources. This booklet is one of several materials developed under the Program to assist development workers in taking the physical environment into account during project planning, implementation and evaluation. For more information, contact CODEL at 475 Riverside Dr., Room 1842, New York, NY 10115 USA.**

## ABOUT VITA

**Volunteers in Technical Assistance (VITA) is a private nonprofit international development organization. It makes available to individuals and groups in developing countries a variety of information and technical resources aimed at fostering self-sufficiency--needs assessment and**

program development support; by-mail and on-site consulting services; information systems training. VITA promotes the use of appropriate small-scale technologies, especially in the area of renewable energy. VITA's extensive documentation center and worldwide roster of volunteer technical experts enable it to respond to thousands of technical inquiries each year. It also publishes a quarterly newsletter and a variety of technical manuals and bulletins. For more information, contact VITA at 1815 North Lynn Street, Suite 200, Arlington, VA 2209 USA.

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## AUTHOR'S NOTE

### Users, Uses and Mea Culpa

This manual is written for all those who are planning, implementing, or responsible for a water project to benefit small segments of the world's urban or rural poor. Depending on the reader's level of expertise, the manual may be criticized for over-simplification of complex topics or for being too technical. It is meant to provide a beginning for ecological analysis and a reference to the necessary technical materials. The manual is best suited as an initial guide for planning and discussion with community leaders.

**In using this manual, it is hoped that the development worker will read the section which applies to the proposed project and then select one or more technical references from the bibliography. The worker may then write to the distributors (Appendix II) to obtain a copy of the relevant references.**

**The author acknowledges with thanks the fine editorial work of Philip Quigg as well as assistance from Julie Morgan and typist Phyllis Haight of the Cary Arboretum. References listed in Appendix I were invaluable. The author accepts all responsibility for technical sins of commission and omission.**

**G.T., Millbrook, New York**
**1981**

**1. WATER - USERS AND USES <see image>**

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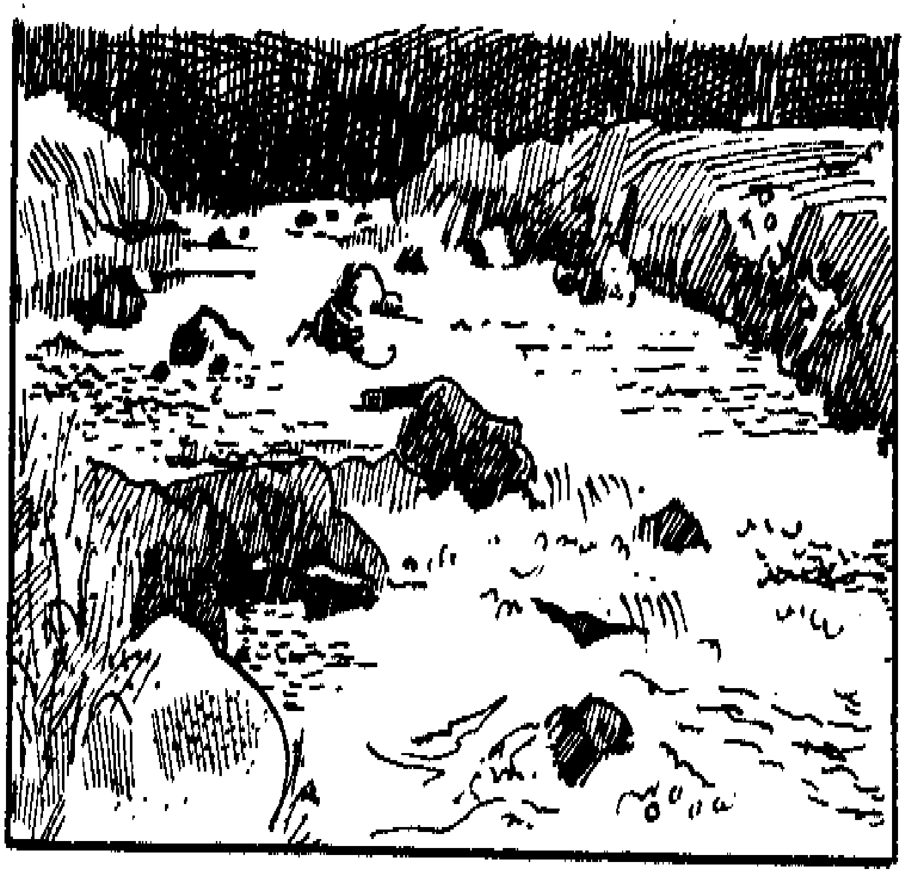

**"The greatest problem in communication is the illusion that it has been achieved."**

**Anonymous**

**Our planet contains an estimated 336 million cubic miles of water. However, nearly 95% of this prodigious supply**

is saltwater contained in the oceans and seas which cover two-thirds of the earth's surface. Of the 5% that is freshwater, all but 1% is frozen in polar ice caps or vast northern glaciers. The remaining 3.36 million cubic miles, which is at least theoretically available for human use, is distributed approximately as follows:

Ground water 98.55%
Lakes 1.0
Soil (between particles) 0.2
Rivers and streams 0.1
Atmospheric vapor 0.1
Biological (in plant and
animal tissue) 0.05

If freshwater supplies were uncontaminated and equally distributed around the globe, there would be little need for water development projects and even less need for this development manual. However, common sense and numerous global studies tell us that water supplies are neither uncontaminated, nor equally distributed; therein lies the need for water development projects. According to a recent global survey of 91 countries conducted by the World Health Organization (WHO), 86% of the rural populations (1.11 thousand million people) are without "reasonable access to safe water." By region, the numbers and percentages of rural people without reasonable access to safe

**water are as follows:**

**Africa 136.0 million 89%**
**Americas 92.1 million 76%**
**Eastern Mediterranean 139.5 million 82%**
**Europe 23.3 million 56%**
**Southeast Asia 661.7 million 91%**
**Western Pacific 59.0 million 79%**
**All regions 1,111.6 million 86%**

**(after Feachem, 1977)**

**In view of these staggering statistics, the World Health Assembly set a seemingly modest target at the start of the last decade: to give 25% of the rural populations of developing nations reasonable access to safe water by 1980. However, just to maintain 1971 levels, world population growth would require new water supplies for 297 million additional people since the start of the decade. In spite of the intensive and costly efforts to increase safe water supplies, it is likely that a larger percentage of rural people lack access to safe water in 1980 than in 1971. To gain ground, water development efforts will have to increase in quantity and improve in quality. Therein lies the principal need and purpose of this manual.**

**It is not always possible to obtain the professional studies and analyses that might be desired. New water-related**

**projects are increasingly being developed to meet pressing local needs in agriculture and health without benefit of professional scientific or engineering advice. Small-scale projects are initiated, planned and often implemented by highly motivated, experienced development workers, who have insufficient technical skills and experience in water resource development. Given ideal conditions, field workers can develop the necessary expertise to plan and implement small-scale water projects. But realistically, assignments are short-term, needs are at crisis point, available experts are overworked on large-scale projects and literature is so difficult to obtain it might as well be on the moon.**

**To address this reality, this manual was prepared as a guide or aid in planning and executing environmentally sound small-scale water resource projects. It is not intended to replace technical literature or professional advice when available, but to serve as a helpful substitute when those sources of information are unobtainable or as a guide to topics on which further information may be needed. Through a discussion of the environmental factors which relate to water development and use, the manual encourages the incorporation of environmental considerations into water development planning to increase the probability of long-term project sustainability.**

## WHO SHOULD USE THIS MANUAL?

**Anyone who must plan, review, supervise or implement small-scale water resource projects and:**

*** has limited experience in water resource technology or minimal access to technical experts**

*** wishes to learn more about the environmental relationships that affect water resource projects**

*** must prepare or review a report on the environmental aspects of water development projects**

*** must prepare a training program on small-scale water development projects.**

**WHAT DOES THE MANUAL PROVIDE?**

*** Basic ecological principles which relate to water resource development**

*** A guide for planning small-scale water projects**

*** Suggestions for low-cost techniques to avoid adverse impacts of water development**

*** Basic information and resources for planning and implementing projects in water supply, water conservation,**

water distribution systems, waste-water treatment, agriculture, energy and public health.

## ECOLOGY AND THE ENVIRONMENT

Today the terms ecology and environment often are used interchangeably, but they are not the same. Quite simply, ecology is the study of the relationships and interactions of the living and non-living parts of our surroundings. The living parts include plants, animals and one-celled organisms (e.g., bacteria and algae), while weather, soil, rocks, energy, topography and water are some of the nonliving elements in our surroundings. All these factors are interrelated, mostly in ways which we do not fully understand, although many of the major relationships have been defined by ecologists. We have learned that it is impossible to alter one part of our surroundings without producing changes in some other components. Since a water development project will alter major parts of a particular ecologic system, we know that other parts will change. Through sound planning and implementation, we can try to ensure that changes will not produce severe negative effects.

Environment is an even simpler term to define because it can be used interchangeably with surroundings, if one keeps in mind that surroundings are all-inclusive, involving all living and non-living parts. Within this definition, it is proper to include man and the social and cultural activities associated with humans. It is clear from the definitions that ecology is the study of environment; therefore these are not interchangeable terms and will not be used in this manual as though they were.

The natural environment is a term used to describe systems which have evolved over millions of years, approaching a harmonious, or perhaps, dynamic balance. In natural systems, water cycles, soil fertility and plant-animal relationships tend to be stable and predictable, although often upset by natural catastrophes such as earthquakes, floods, volcanic eruptions or lightning-induced fires. Man, who has the ability to alter significant parts of a system, produces artificial environments such as cities, farms and lakes. The new environments contain many benefits to be sure, but also may create many unfavorable conditions: increased disease, contaminated water supplies, deforestation, desertification and eroded soils. Recently, through ecology, we have learned that if artificial environments can be made to function more like natural environments, they tend to be more stable and predictable. Therefore, it is in our best interest to understand the functioning of a natural system so that the conditions ensuring stability and long-lasting benefits can be preserved, at least in part, in man-devised projects. Scientists often identify smaller units within the natural system called ecosystems. See section on "Ecosystems" in

# Chapter 2.

## 2. WATER AND ENVIRONMENT <see image>

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**". . .For in the wilderness shall waters break out and streams in the desert."**

The Bible

The primary goal of water resource development is to provide safe and reliable water supplies for human use. This may involve the development of a new water source, expansion of an existing source, improvements in collection and delivery, or methods of water conservation. In some cases, water quantity may be adequate, but inferior quality requires a plan for purification or improved sanitation. In addition to developing potable water supplies for human consumption and hygiene, communities often want more water for agriculture or manufacturing to increase employment opportunities and improve the standard of living.

Even where water development projects are implemented with the best intentions, unforeseen environmental factors can produce negative effects, often outweighing the benefits of the project. Dramatic increases in water-related disease, loss of soil fertility, increased erosion and changes in the hydrologic balance are some of the adverse side effects of poorly planned water projects. Determining the possible positive and negative effects may be the most important task faced by planners of small-scale water projects. Through the selection of an alternate technique or a minor modification of a proposed project, many of the unwanted consequences can be either reduced or avoided altogether. An understanding of basic ecological concepts and an awareness of environmental relationships can help planners to judge the direction and magnitude of environmental changes that various alternatives might cause and to assess the positive and negative effects of the possible options.

It is in tropical regions, where most of the developing countries are located, that we find the greatest inequities in water distribution. The extensive arid and semiarid regions of the tropics are plagued not only by inadequate rainfall for crops, but also are subject to extreme variations of rainfall from season to season and from year to year. When rainfall is normal, it is often restricted to brief intervals during the year--not long enough for plant growing seasons. In the past, such lands were sparsely occupied, usually by nomadic tribesmen who moved their families and livestock from place to place to find seasonal water and vegetation. Rising populations of people and domestic animals have put intense pressure on these small, seasonal sources, often resulting in their destruction through overuse.

On the other hand, moist tropical areas receive amounts of rainfall far in excess of that required for plant growth. The excess water moves over or through the soil to form immense tropical rivers such as the Amazon, Niger, Congo, Mekong and Nile. The enormity of these river systems illustrates the unequal distribution of freshwater: one river, the Amazon, discharges approximately 20% of the world's runoff of freshwater. This overabundance of water can create serious problems, as we will see, if the natural vegetation is altered for development purposes.

In both arid and moist regions, increased human activities have produced changes in natural water cycles, some yielding obvious agricultural or industrial benefits while others have caused serious unforeseen consequences and increased human suffering.

MAJOR SOURCES OF WATER FOR DEVELOPMENT PROJECTS

* Precipitation, in the form of rain or snow, cannot yet be effectively controlled by man. Water resource projects must be designed to accommodate the wide range of annual as well as seasonal precipitation.

* Surface waters are the most obvious source of freshwater that can be tapped. Lakes, ponds, rivers, streams, reservoirs and catchments are examples of surface water sources.

* Ground water refers to the subsurface supplies fed by precipitation and surface water. It is a major reservoir for freshwater. Ground water supplies contained in aquifers are relatively stable unless influenced by man's activities. When ground water is within 3 meters of the land surface, it may move upwards, against gravity, through small soil pores

by a process known as capillary action. It thus becomes available to shallow rooted plants, such as most agricultural crops. In some areas, or during periods of excessive rainfall, ground water may be at or near the surface, flooding the root zone and killing most plants. Ground water may also be held in pockets far down in the earth's crust and can be reached only by drilling deep wells through rock.
A shallow pocket is also an aquifer. Some aquifers, such as those found in northern Africa, often contain huge volumes of water but were covered in an earlier geological time with impervious rock layers which do not permit recharge from surface sources. These "fossil water" aquifers have remained in place for thousands of years and since they cannot be replenished by natural means, they must be considered non-renewable resources.

The upper level of the ground water is called the water table and how far it is beneath the surface of the land is as important to consider in water development projects as the volume of ground water itself. The height of the water table will change with the seasons and the amount of rainfall. The relationships of water table, ground water, surface water, geologic features and precipitation are shown in Figure 1.

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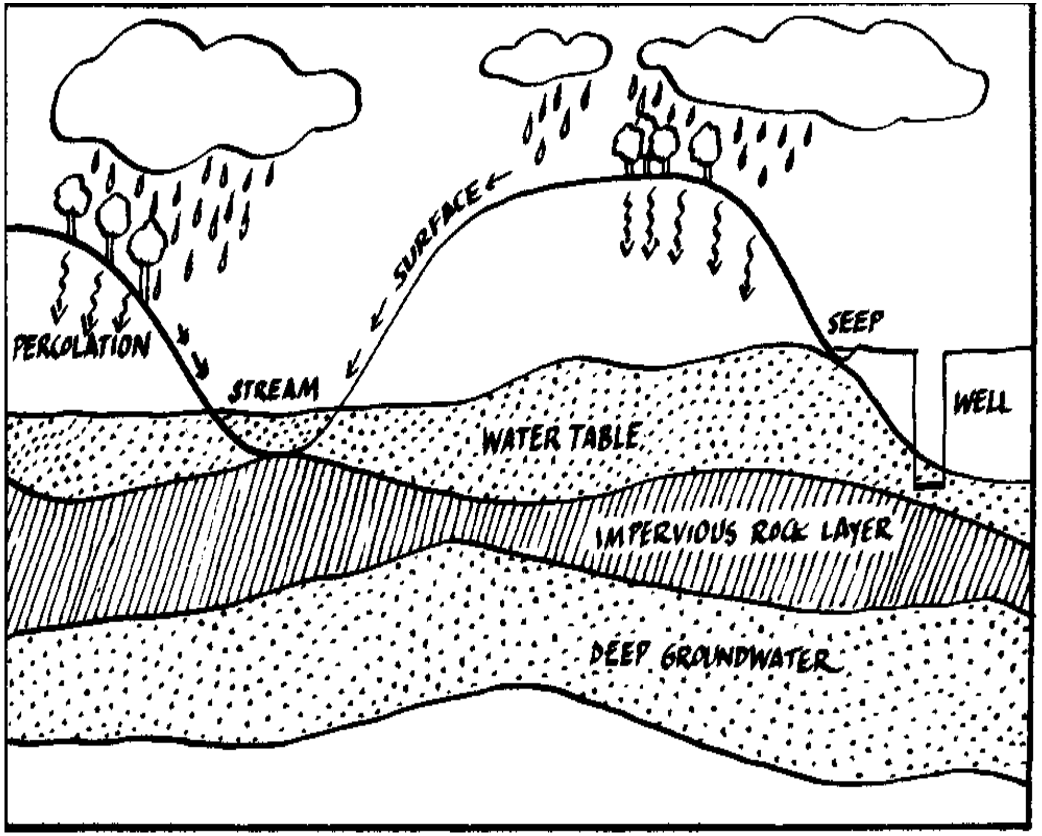


Figure 1. Ground Water and Water Table

* Distillation and condensation are minor and expensive sources of freshwater. Distillation and condensation of a saline water supply will produce freshwater, but require a large amount of energy. Some small, solar-powered stills can provide supplemental water for domestic use with inexpensive

**materials. Natural condensation of water vapor (dew) is a minor source of water for plants, but has little or no potential for human use.**

**THE HYDROLOGIC CYCLE**

**The movement of water from earth surfaces to the atmosphere and back to the earth is called the hydrologic cycle. It is the basis for all water development projects, large and small, and a firm understanding of the basic process and its vagaries are important to water resource planning.**

**The hydrologic cycle involves evaporation, transpiration (emission of water vapor from the leaves of plants), condensation, cloud formation, precipitation, surface runoff, water storage and percolation (Figure 2). These processes**

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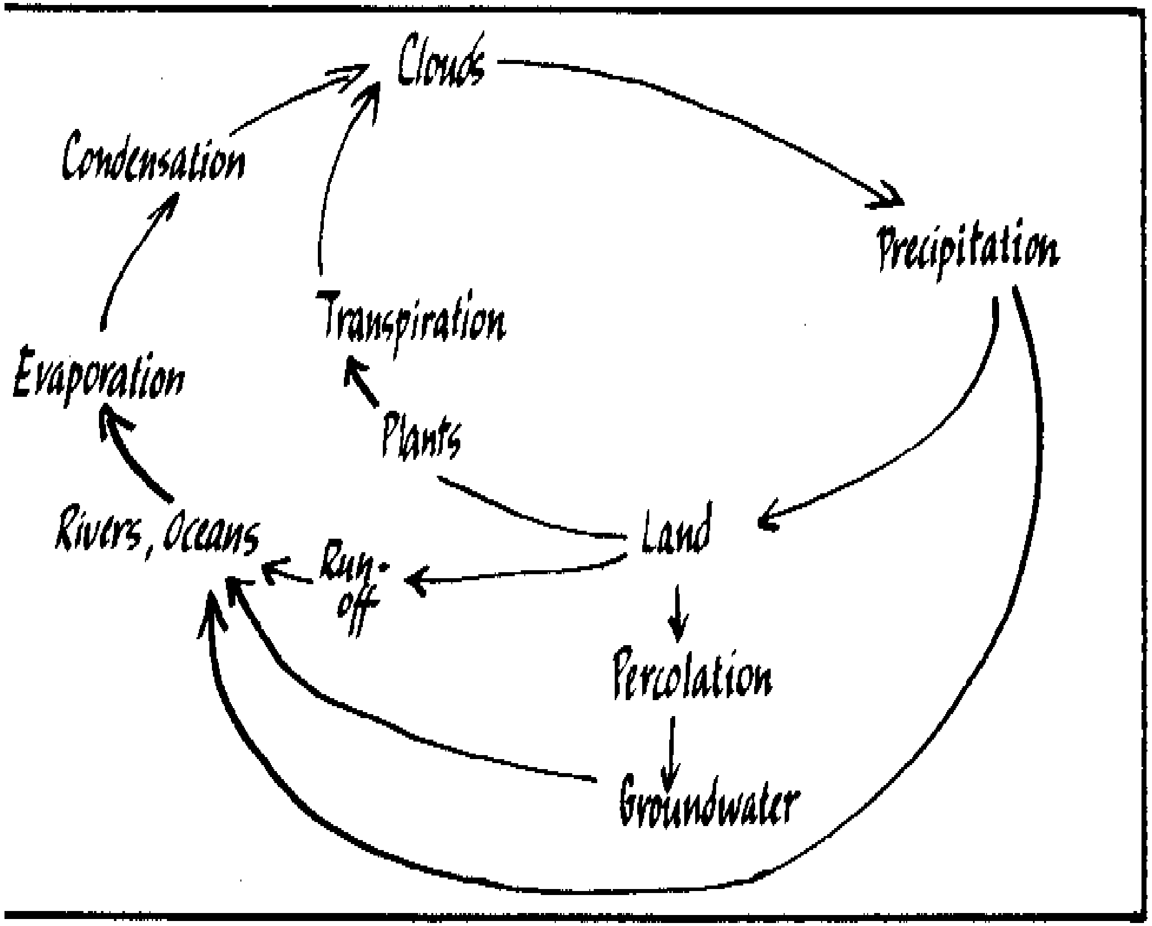


Figure 2. The Hydrologic Cycle

in turn affect the patterns, practices, quantity and quality of human life. Most water development projects seek to make minor local changes in the natural cycle so as to provide additional human benefits in the form of additional water supplies or water movement. Alteration of the hydrologic cycle does not involve changes in the basic processes, but rather in their rates or volumes.

When sunlight strikes a water surface, whether it be an ocean, a river or saturated land, the water molecules get warmer and begin to move faster. As the movement increases, some molecules break away from the liquid surface and move into the atmosphere as a gas, in this case, water vapor. This process is known as evaporation and is responsible for most of the water vapor in the atmosphere.
Most of the global water evaporation takes place over the oceans which comprise nearly 70% of the surface area of the earth. When water and other liquids are evaporated from land or water surfaces, the larger and slower molecules, such as salts and metals, are left behind.

Transpiration is the second major contributor of atmospheric water vapor and it too is powered by energy from sunlight. Water absorbed by plant root systems is passed internally to the upper portions of the plant. In the green portions of the plant, principally the leaves, some water is used for photosynthesis, but most of the water is passed through small pores or openings in the leaves. At the leaf surface, the sunlight causes the water to change to a vapor which then rises into the atmosphere as it is heated. The amount of water moved by transpiration is amazing; for instance, one hectare of corn can transpire 37,850 liters (10,000 gal.) per day or 1,900,000 liters (500,000 gal.) per growing season. A single mature tree may transpire up to 378 liters (100 gal.) per day. In areas where soil moisture is excessive, plants are often used, along with artificial drains, to remove the excess moisture in the soil.

In analyzing moisture loss or water requirements for agriculture, evaporation and transpiration figures are combined as evapotranspiration losses. Since both processes are directly affected by temperature, relative humidity, wind and available water, the rate of evapotranspiration loss is an important indicator of the climate of the area. More commonly, the climatic factors can be used to estimate the evapotranspiration loss for proposed agricultural projects.

Condensation of water vapor in the atmosphere produces the various cloud formations that will eventually lead to precipitation. The vapor gradually cools as it rises, and eventually its molecules strike small particles, such as dust, in the atmosphere and condense to form clouds. The moisture laden clouds may cool further by passing over a mountain range or by meeting a cold air mass. The sudden cooling further compacts the water molecules into droplets of water that fall as rain or in frozen form such as snow or sleet. Topography, cloud altitude and prevailing wind direction all contribute to the uneven distribution of precipitation. Some areas, such as the windward slopes of coastal mountains, may receive over 3000 mm per year while the other side of the same mountains may not record any precipitation for an entire year.

Most soils, especially if covered with vegetation, absorb water and only the excess becomes part of the surface runoff. But if all or parts of the soil are even slightly impervious to water due to rock cover, soil compaction or baking, runoff will be heavy.

Surface water will either flow to the oceans, seep into the ground water, or evaporate. Because surface water is so precious in most countries, it may be used for several human activities before it reaches the ocean. For instance, surface water could pass through a hydroelectric generator, flow on to an irrigated field, pass through an industrial cooling system or be used for sewage removal for a riverside city. Each use would have effects on water quality and minor effects on parts of the hydrologic cycle by increasing or decreasing the rate of evaporation or percolation.

Rapid or uncontrolled surface runoff can produce flooding, land slides and serious erosion. Even on a lesser scale, runoff can have deleterious environmental effects. As it moves across the land, the water picks up soil particles and organic materials important to soil fertility. Their removal from agricultural land decreases productivity. Of course, if the particles of topsoil are deposited on downstream agricultural areas, those lands are improved. However, the soil particles are usually transported to water courses and are carried as suspended solids until deposited as sediments in slow-moving bodies of water, such as reservoirs, lakes or oceans. Although this may enrich aquatic systems, it represents a serious loss to agriculture.

Water falling on vegetation is more likely to remain in place than water which strikes bare soil. The plant material not only dissipates the force of the rainwater but also impedes surface flow. Vegetation allows more time for the soil to absorb the rainwater and also improves the soil structure so that it can absorb more water at a faster rate.

Once absorbed into the soil, the water can percolate down to aquifers in rock or gravel, or strike an impervious rock layer and move horizontally as a subsurface or ground water flow. Some of the subsurface water will be taken up by plants. The rest, if untapped by wells, will either remain as ground water or eventually feed into streams or rivers, becoming a part of the surface water system. Since subsurface flows are more leisurely than surface flows, the water remains available for human use for longer periods.

In spite of the seemingly incredible amount of plants and animals in the world, only a miniscule fraction of the total freshwater supply is held in plant and animal tissue and can be disregarded in planning for water resource development.

This oversimplified explanation of the hydrologic cycle indicates major areas for analysis before implementing a water development project. It suggests where water is likely to be found and is the basis for determining the best methods to develop and protect the source.

## ECOLOGICAL CONCEPTS IMPORTANT FOR WATER RESOURCE DEVELOPMENT

Development implies change for the better--a change from existing conditions or resource use to a system that is safer or more productive; in other words, producing more benefits for a larger number of people. Development involves the alteration of resources or imposes a different strategy for using the resources available. By understanding ecological principles, developers can increase the probability of success, i.e., there will be more positive than negative effects.

### Ecosystems

Since a study of ecological systems can be so all encompassing, the shorthand term "ecosystem" was coined to define the smaller units which ecologists choose to study. Thus, a scientist may study a forest of several thousand hectares or a decaying log and yet investigate principles and concepts common to both systems. The term allows the scientist to place recognizable boundaries on the area of investigation to fit the needs of research objectives.

As with many scientific terms, "ecosystem" has been widely and often used erroneously and now has a much broader meaning. Generally, the term applies to an area of homogeneity of one particular part of the natural system, such as type of vegetation, amount of rainfall, topography or physical feature. Further, ecosystems can be classified as natural or artificial. In natural ecosystems, man is not the dominant factor and changes tend to be minor unless some catastrophic event occurs. In studies of natural ecosystems, scientists have found dynamic balances achieved through constant minor adjustments within the system. These balances ensure relative stability in plant and animal populations, minor fluctuations in water movement, and nutrient inputs nearly equal to nutrient losses.
If more had been known about the reasons for stability and productivity of the natural ecosystems, the artificial ecosystems created by man might have been a lot more productive.

The biological bases of any ecosystem consist of three major groups: producers, consumers and decomposers. The ecosystem producers are the green plants, whether algae, grasses, trees or weeds. By the process of photosynthesis, plants combine carbon dioxide and water in the presence of sunlight (for energy) to produce carbohydrates (sugars and starches) and release oxygen as a by-product. Using the carbohydrates for energy, the plants can take other nutrients from the environment to produce fatty acids, protein and vitamins, forming the energy and nutritional base for the other biological parts of the ecosystem. The goal of many water development projects is to supply water essential to these producers.

The consumers in the ecosystem are animals, including man, which eat plants or other animals. In order to produce energy, consumers must combine food with oxygen, releasing small amounts of carbon dioxide and water in the process. Animals use the energy for heat, growth, movement, and the production of more complex chemical compounds, such as fats and proteins, which are important in storing energy, building new tissue or transmitting genetic materials to offspring. Consumers require additional supplies of water to construct new tissue to transport various chemical compounds within the body, and to regulate internal temperature.

Plants cannot absorb nutrients unless they are in very simple chemical forms. For instance, the roots of a forest tree cannot use the nutrients in a dead animal's tissue unless the complex carbohydrates, fats and proteins are broken down into simpler molecules which contain carbon, nitrogen, potassium, calcium and phosphate.

Decomposers, mainly bacteria and fungi, break down the large molecules in dead plant and animal tissues or wastes into the simpler forms that can be used by plants. These microscopic organisms play a vital role in the ecosystem, for without their presence, the producers would not be able to construct new tissues. Water development projects, whether for agriculture or sanitation, must rely on viable populations of decomposers to continue the recycling of nutrients through the ecosystem.

The role of plants and animals in an ecosystem is not limited to production, consumption and decomposition. There are many other functions such as soil protection, water retention, microclimate modification, pollination and seed dispersal, just to name a few. So when someone wishes to alter a part of an ecosystem to make it more productive (or less hostile) for man, it is necessary to examine aspects other than productivity.

**WHAT HAPPENS WHEN NATURAL SYSTEMS ARE ALTERED?**

The dominant natural feature of most land ecosystems is the plant cover or vegetation. The type and density of the vegetation influences soil structure and content, water movement, nutrient balance, type and abundance of animal populations and microclimate. When the native plant cover is removed or changed for development, each of these areas can be affected. For instance:

* If vegetation is removed, wind can blow away soil particles and organic matter in the topsoil, thereby removing the most fertile part of the soil.

* The combined action of wind and sun on exposed soil increases evaporation, often causing the soil to become dry and brittle, less likely to be suitable for agriculture.

* Soil particles with attached nutrients, as we have noted, may be dislodged by hard rainfall striking the ground rather than plant leaves. Runoff carries the soil particles and nutrients from the land, where they are needed to maintain soil fertility, to waterways where they are not needed. As silt and sediments, they may clog water courses, kill fish, increase flooding and fill reservoirs.

* Nutrients carried into the waterways may increase the growth of algae or waterweeds, rendering the water unfit for desirable animals, but more suitable for animals that transmit diseases (vectors). The nutrients may also make the surface water less desirable for human consumption.

* Protection from flooding is reduced when covering vegetation is removed. Plants maintain soil porosity

which helps the soil absorb water. In addition, the roots and stems retard the flow of surface water. With the vegetation removed, water does not percolate easily into the soil if the terrain is not level, but tends to run over the surface in sheets or rivulets, increasing soil erosion and the danger of flooding in downstream areas.

* Traditional sources of wood, fruits, medicines and cooking herbs may be lost if the native vegetation is removed or replaced by agricultural crops.

* Diversity of animal life is decreased. Animals which depend upon natural plants for food or shelter will be forced to move if the vegetation is removed by man. These animals are often replaced by animals that live all too comfortably with domestic crops or livestock--basically agricultural pests. The animal population may decrease the number of different species, but increase the number of individuals, which may be the unwanted types.

There are, of course, many other effects on the environment when natural ecosystems are altered; it would be impossible to make a complete list. Some changes are complex and difficult to predict; others are rather straightforward. In water resource planning, we obviously want to

**capitalize on the changes which are beneficial and minimize those changes which are detrimental. Each water development project will cause changes (environmental impacts) and proper planning involves an analysis of these impacts before the project is implemented. The following chapters should help development workers plan and implement water resource projects within an environmental framework that identifies impacts of alternative schemes and helps to ensure the selection of the most appropriate option.**

**3. WATER AND HEALTH <see image>**

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**"Where water goes, disease follows in its wake."**

**Anonymous**

**Small-scale water development projects are intended to improve the quality of the human environment. Most health-related projects are designed to provide potable water, safe excreta disposal, or water for agriculture to improve nutrition. If well-planned and well-designed, the**

projects are successful and the people benefit. However, if planning is haphazard and designs are incomplete, there is a strong possibility that disease may increase. In many cases, a water project may bring about a decrease in one type of disease but cause an increase in a more severe type. This unfortunate outcome is most common in projects designed to improve local agriculture or to provide additional energy through the use of water.

POSSIBLE EFFECTS OF WATER DEVELOPMENT PROJECTS ON HUMAN HEALTH

* Water carries microscopic organisms that can cause disease in humans and livestock. The microscopic organisms include bacteria, viruses, fungi and single-celled protozoans.

* Water provides an environment necessary for the development of many animals (e.g., snails and insects) that transmit diseases. These animals, called vectors, rarely cause sickness directly but instead carry the microscopic organisms that cause serious illness. Flies and mosquitoes, especially, help to pass germs from sick people to healthy people, thereby spreading the disease. In many cases, the insect spends only a part of its life or life cycle in water, but can transmit disease to humans without their direct contact with infected water supplies.

* Water sources can provide suitable environments for animals that are extremely common parasites of humans. These parasites, which can be single-celled organisms, flat worms or round worms, are responsible for the world's most common diseases, causing massive expenditures for medical care and treatment as well as terrible suffering. Schistosomiasis, filariasis and amoebic dysentery are common examples of parasitic diseases. Table 1 lists some of the major water-related diseases.

* Water from polluting industries or agriculture can carry toxic chemicals that cause grave illnesses or death if the water is used for human consumption.

* Health is affected by the amount of water available for personal hygiene: washing clothes, bathing and washing of utensils and household items. If supplies are limited, personal hygiene is often neglected. A safe supply of water for personal use is essential to good health.

* Water is directly and indirectly related to proper nutrition. Each adult must have a water intake of at least 6 liters per day to maintain adequate body fluids. In addition, agricultural produce requires water for survival and growth. If water supplies are not sufficient, agricultural production will

**decline and adversely affect nutrition.**

**TABLE 1**

**WATER AND HEALTH**

| Disease | Infectious Agent | Role of Water |
|---|---|---|
| Schistosomiasis (Bilharziasis) | Helminth worm | Direct Transmission/ skin penetration |
| Diarrhea/enteritis | Symptom of many agents | Direct Transmission/ ingestion |
| Hepatitis (Infectious) | Virus | Direct Transmission/ ingestion |
| Cholera | Bacteria | Direct Transmission/ ingestion |
| Typhoid Fever | Bacteria | Direct Transmission/ ingestion |
| Ascariasis | Helminth worm | Direct Transmission/ ingestion |

**Dracontiasis Helminth worm Direct Transmission/ ingestion**

**Amoebic Dysentery Protozoa Occasional Transmission**

**Bacillary Dysentery Bacteria Occasional ingestion**

**Malaria Mosquito Vector habitat**

**Filariasis Mosquito Vector habitat**

**Onchocerciasis Black Fly Vector habitat**

**Yellow Fever Mosquito Vector habitat**

**Flukes Helminth worm Habitat of intermediate host**

**COMMON WATER-RELATED DISEASE AND CONTROL**

**Of the diseases listed in Table 1, four specific diseases and one general category of disease are especially significant in terms of their total incidence, their widespread**

**distribution and their long-term impacts on human populations as shown below.**

**TABLE 2**

**ESTIMATED WORLD-WIDE PREVALENCE OF CERTAIN DISEASES RELATED TO WATER RESOURCE DEVELOPMENT**

| Disease | Prevalence |
|---|---|
| Schistosomiasis (Bilharziasis) | 200,000,000 |
| Filariasis | 200,000,000 |
| Onchocerciasis | 40,000,000 |
| Malaria | 25,000,000 |
| Enteric Disease | Unknown |

**(after McJunkin, 1975)**

**Schistosomiasis**

**This disease, also known as Bilharziasis, is caused by worms which spend a part of their lives in snails before**

**infecting humans. There are three species of the schistosomes which cause disease throughout the tropical and subtropical parts of the globe. Schistosoma mansoni is found in central and southwest Africa and is increasing in eastern and northern South America. S. haematobium <see figure 4> is**

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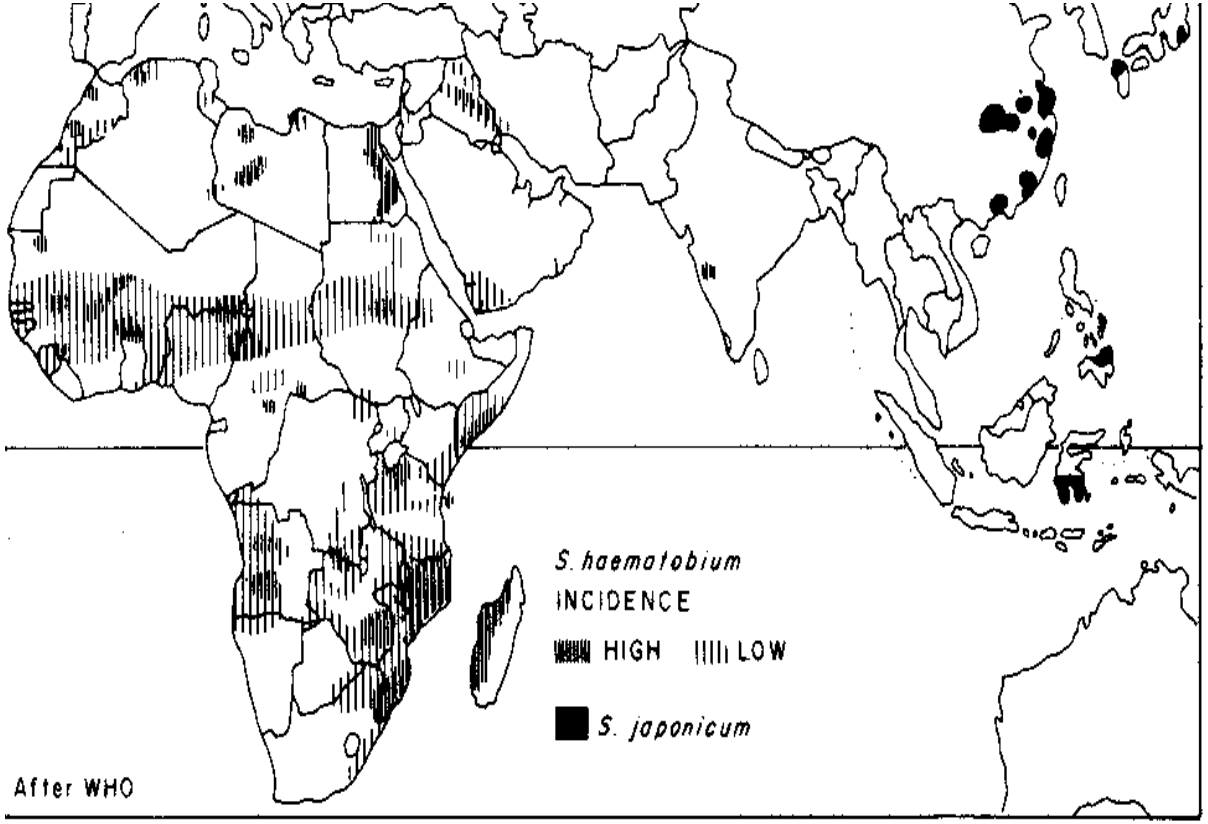


Figure 4. World Distribution of S. haematobium and S. japonicum (after McJunkin, 1975)

found throughout Africa, in many areas overlapping with S. mansoni. <see figure 3> S. japonicum <see figure 4> is

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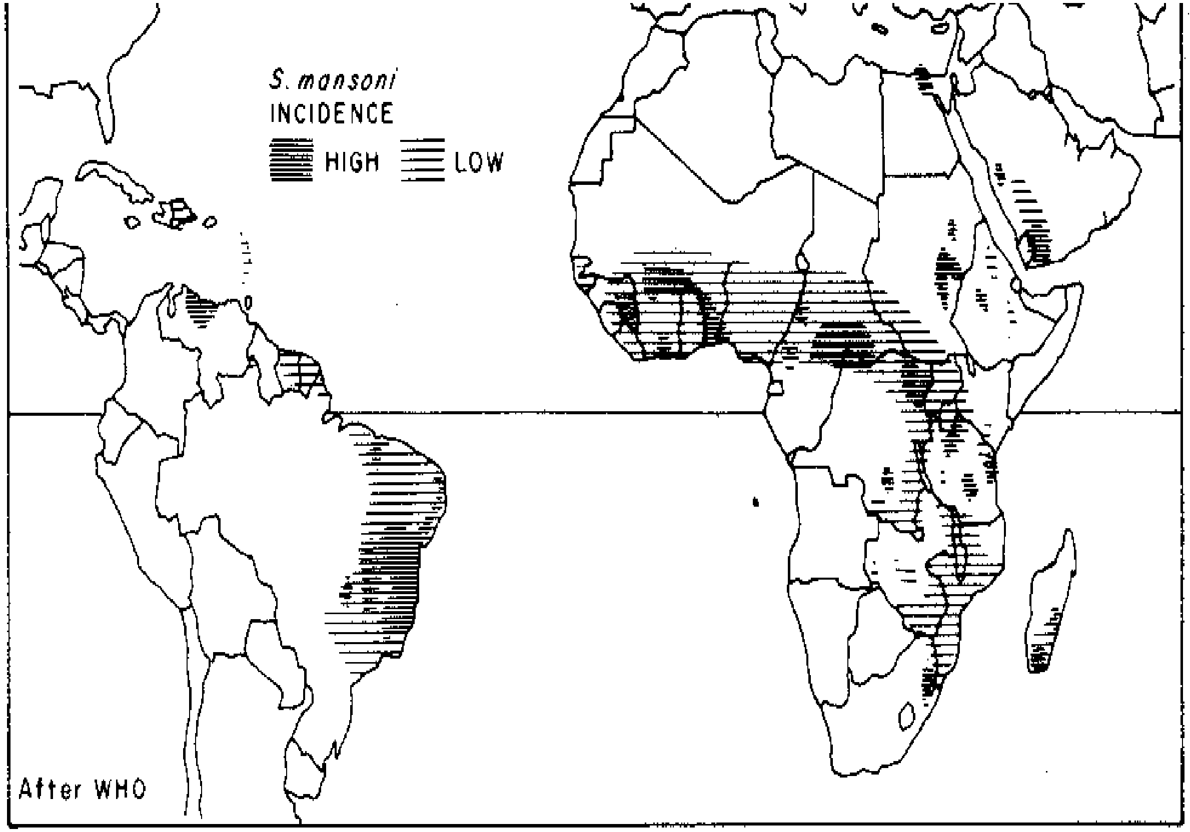


Figure 3. World Distribution of S. mansoni

(after, McJunkin, 1975)

restricted to parts of Asia.

Like most intestinal worms (helminths) schistosomes require two different hosts during their lifetime. The adult worms, 7 to 26 mm long, live either in the intestines (S. mansoni and S. japonicum) <see figures 3 & 4> or in the bladder (S. haematobium) of man or other animals. After mating, the female lays eggs that are passed out of the human body in

**feces or urine. To survive, the eggs must reach water within a month and, if successful, the eggs hatch into small swimming larvae called miracidia. These larvae must penetrate the skin of certain species of freshwater snails within 24 hours or die. Once inside the snail, each miracidium reproduces asexually, producing thousands of larvae called cercariae. These forked tailed larvae leave the snail and swim about vigorously, searching for a suitable host. Man is the principal host for S. mansoni and S. haematobium, although infections of S. mansoni have been reported in baboons, dogs, cattle, rodents and other small mammals. In S. japonicum, the non-human hosts play a more important role. If the cercariae do not find a host within 72 hours, they perish; but if they make contact with human skin, they quickly penetrate and enter the blood stream of their new host. After reaching the liver via the blood vessels, the larvae mature into adult worms; they mate and migrate to veins in the intestinal or urinary tract where they may live for years, constantly producing new eggs. (Figure 5.)**

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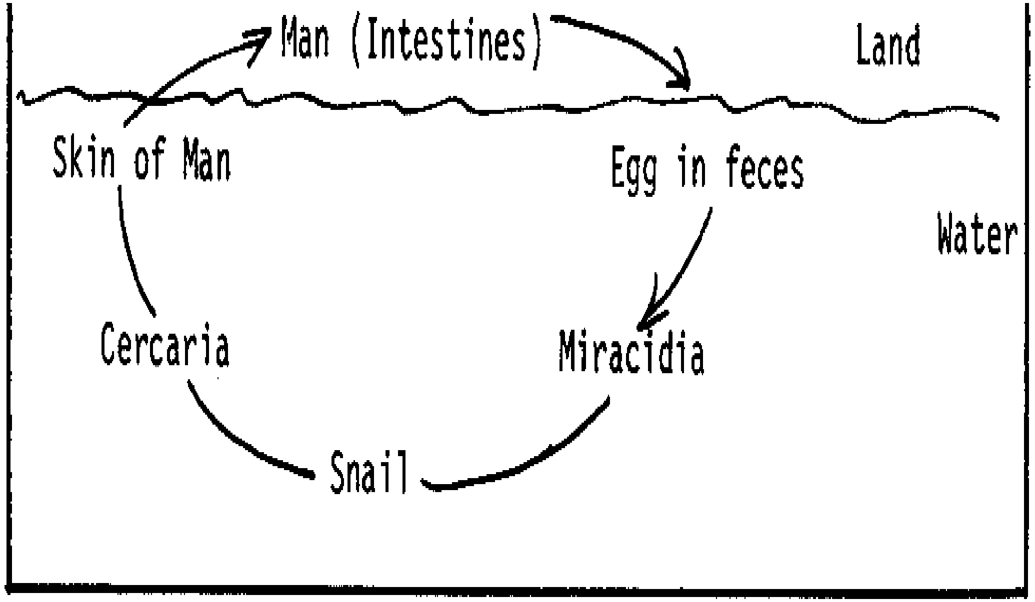


Figure 5. Life Cycle of Schistosoma mansoni

The symptoms of schistosomiasis caused by S. mansoni and S. japonicum are very similar. After infection, a skin rash may appear, diarrhea is common and the liver may enlarge. The diarrhea continues and the abdomen enlarges and is painful when the adult worms begin to lay eggs.

In S. haematobium, the bladder becomes infected, producing internal lesions which usually result in bloody urine. Diarrhea or dysentery is not common with S. haematobium.

Medicines for treating schistosomiasis are expensive and often cause undesirable side effects. The disease is more debilitating than deadly, although severe infection can cause death. The weakened physical condition of the victim also increases the susceptibility to other diseases.

Filariasis

The parasitic roundworms (nematodes) which cause filariasis also require two hosts. The adult worms live and reproduce within human lymphatic tissue, a part of the circulatory system. The female worm produces smaller worms called microfilariae which may be ingested by blood-sucking mosquitoes. In the mosquito the larvae undergo changes until they reach an infective stage. As the mosquitoes feed on another human, the larvae pass into the host's circulatory system where they move to lymphatic tissue and there develop to maturity.

The symptoms of filariasis consist of painful swellings of the lymphatic glands under the arm and especially of the groin, genitals and thighs. If the infection is extreme, grotesque enlargements of the breasts, genitals or lower extremities may occur. This condition, called elephantiasis, is severely debilitating, as well as disfiguring.

**The role of water in the spread of filariasis is to provide breeding habitat for the many types of mosquitoes which are capable of transmitting the disease. Unlike the conditions for schistosomiasis, direct human contact with water is not necessary. Because so many kinds of mosquitoes carry the disease, it is widespread in all tropical regions (Figure 6). As with schistosomiasis, the disease**

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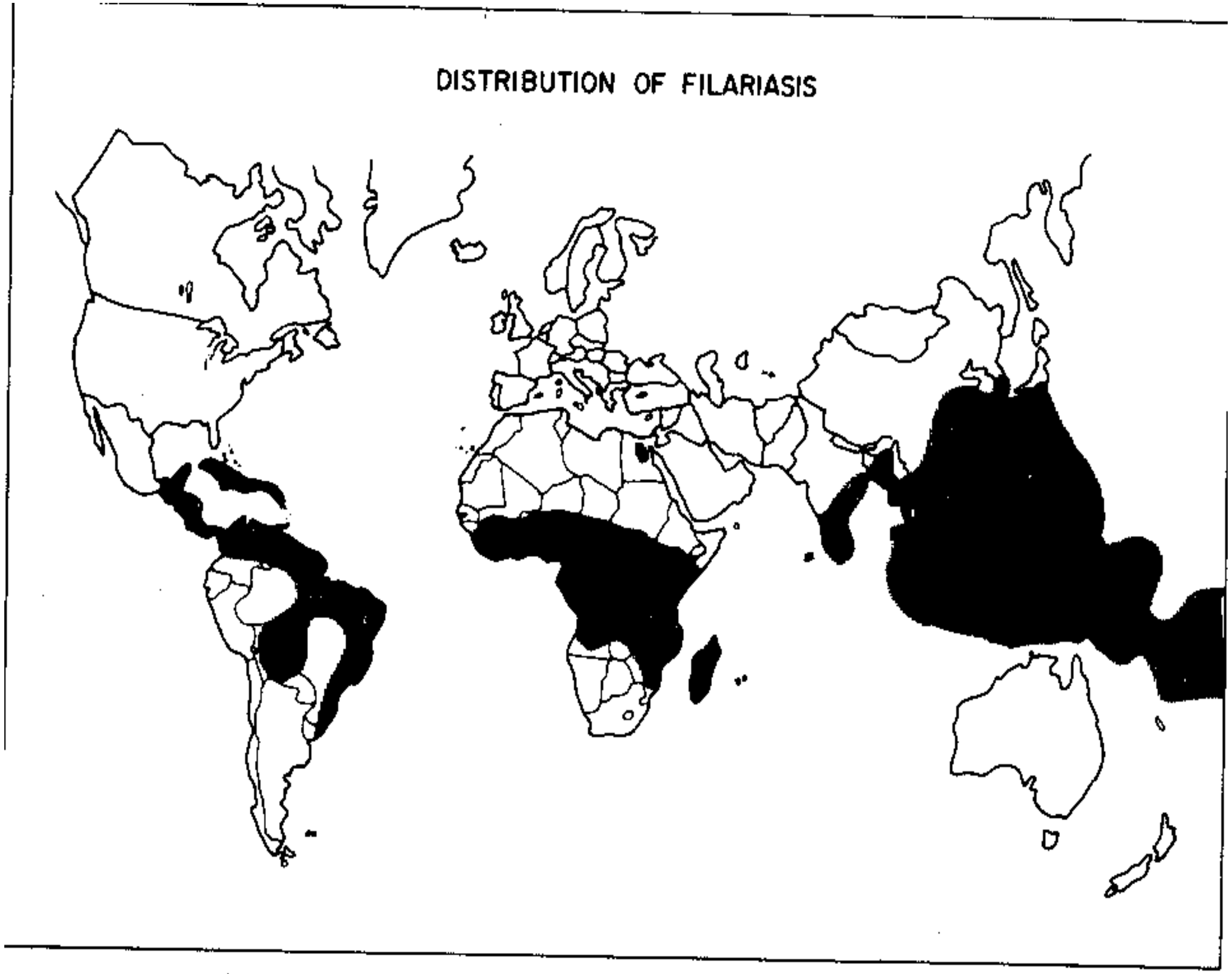


Figure 6. World Distribution of Filariasis (after McJunkin, 1975)

does not respond well to medical treatment except in minor infections.

**Onchocerciasis**

**This disease, commonly called River Blindness, is caused by another nematode, transmitted by the bite of a black fly. It is most common in Africa (Figure 7), although it**

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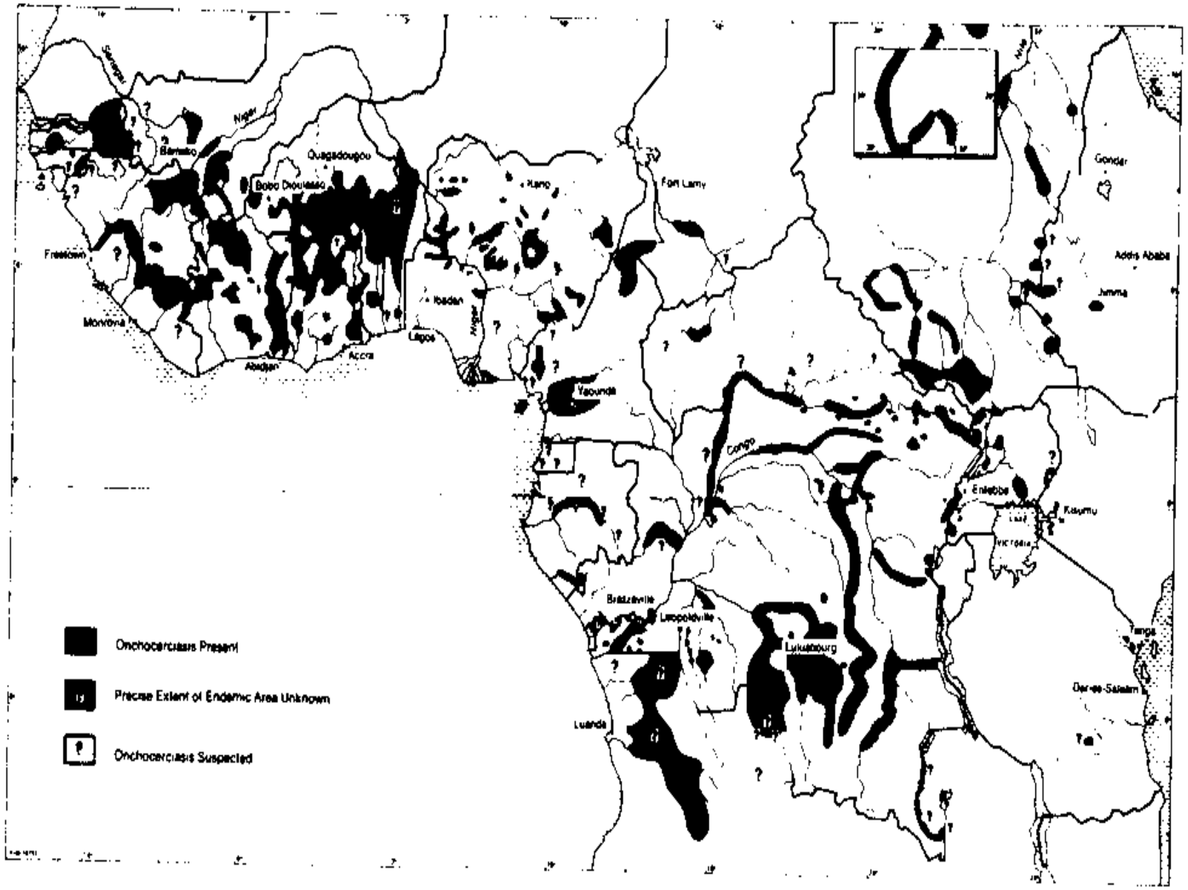


Figure 7. Distribution of Onchocerciasis in Africa (after McJunkin, 1975)

is found in parts of Central and South America. The adult worms live just beneath the skin of humans, where the female produces microfilariae. When a certain species of black fly (Simulium sp.) bites an infected human, some of the microfilariae go into the fly where they develop into infective larvae. As the fly bites another human, the larvae enter the blood vessels in the skin to complete the life cycle.

At first the worms produce a severe itching of the skin; later, thickening and loss of pigmentation in the infected areas are common symptoms. The severity of the disease increases when the worms reach the eye, where they can and often do cause blindness. In some areas, more than 10% of the population may be infected by this terrible disease which does not respond well to present-day medicines.

Malaria

The parasite responsible for this widespread tropical disease is a one-celled organism (protozoan) from the genus Plasmodium (Figure 8). Four different species of

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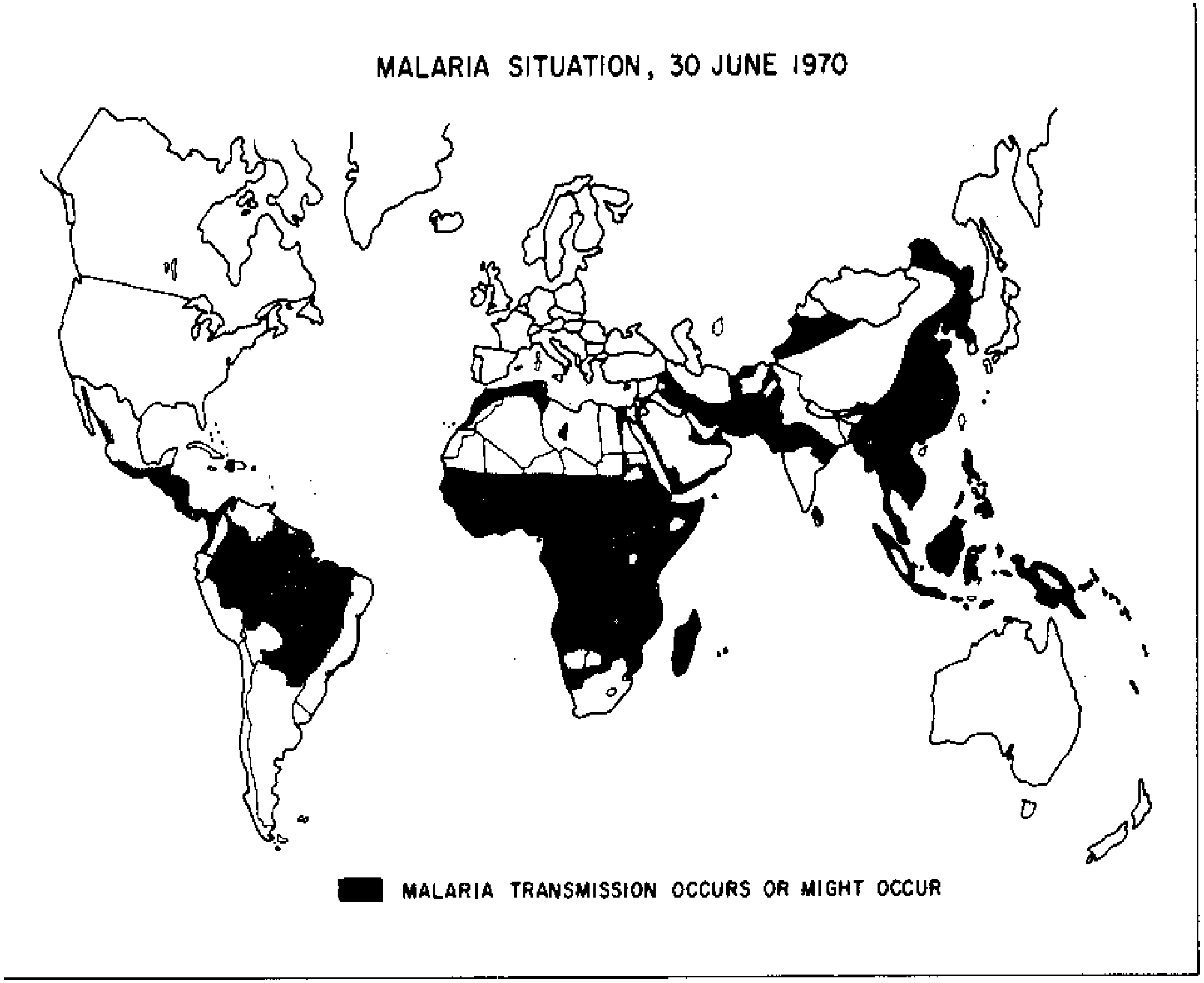


Figure 8. World Malaria Situation
(after McJunkin, 1975)

**this parasite (Plasmodium falciparum, P. vivax, P. ovale and P. malariae) cause different types of malaria, differing in severity and timing of the malarial fevers**

they produce.

The parasite is introduced into a human bloodstream through the bite of an infected mosquito, commonly one of the many species of Anopheles. The parasite multiplies in the liver and the blood stream of the human host, eventually invading the red blood cells. After being taken into a mosquito during a blood-meal, some of the parasites reproduce and become infective. Lodged in the mosquito's salivary glands, they can be injected into a human on the next blood-meal.

The symptoms of the disease are recurrent fevers and chills plus abdominal enlargement. The disease does respond well to several modern and classic medicines such as quinine and atabrine. Other medicines have been discovered that can prevent the development of the parasite, but weekly treatment is required. However, recently, there have been reports of more virulent forms of malaria that do not respond to normal treatment or to prophylactic measures.

## Enteric Disease

More for the sake of simplicity than precision in medical terminology, several actual diseases are lumped together here under the general term "enteric disease." Caused by a variety of pathogenic microorganisms (viruses, bacteria, protozoans), the diseases share common characteristics in that they all involve intestinal disorders resulting from ingestion of water contaminated by human excreta. The severity of the disease depends on the type of infection, ranging from the high mortality rates of cholera and typhoid to the less serious but debilitating diarrheal diseases. Bacillary and amoebic dysentery, gastroenteritis, enteroviral and rotaviral are also included.

Symptoms vary with the specific diseases, but all involve degrees of diarrhea, abdominal pain and fever. As we would expect for such a broad category, the duration of the symptoms is variable, as is the method of treatment. What is uniform and important to the community worker is the high rate of infection. Some experts estimate that as much as 90% of all people living in tropical rural areas suffer from some type of enteric disease.

## DISEASE PREVENTION IN WATER PROJECTS

Since most water-related diseases do not respond well even to expensive modern medicines and since treatment in any case can produce side effects, the best way to control the diseases is to prevent their spread through water improvement projects. Table 3 shows the potential for disease control through various types of common improvement projects. To control disease one needs to know a good deal about it and how it is transmitted. For instance, if the disease is caused by a parasite transmitted by a non-human vector, it is helpful to know the complete life cycle of the parasite, the biology of the vector, and the most likely points of contact between humans and the vector. Within this complex arrangement, weak points in the transmission cycle can be identified and the environment altered to make disease transmission less likely.

**TABLE 3**

**PERCENTAGE REDUCTION OF DISEASE BY WATER IMPROVEMENT**

| Disease | Estimated reduction by water improvement (%) |
| --- | --- |
| Cholera | 90 |
| Typhoid | 80 |
| Hepatitis (Infectious) | 10? |
| Bacillary Dysentery | 50 |
| Amoebic Dysentery | 50 |
| Gastroenteritis | 50 |
| Scabies | 80 |
| Yaws | 70 |
| Leprosy | 50 |
| Diarrheal Diseases | 50 |
| Ascariasis | 40 |
| Schistosomiasis | 60 |
| Guinea worm | 100 |
| Sleeping sickness | 80 |
| Onchocerciasis | 20? |

**Yellow Fever 20?**

**(after Bradley in Feachem, 1977)**

**Schistosomiasis Prevention**

*** Dual water systems are an excellent, although expensive means to limit snail-human contacts. Except in the case of fishermen and irrigators, the most frequent human contact with water in rural villages involves fetching domestic supplies for drinking and cooking, bathing, washing clothes and recreational bathing, all of which may risk exposure to schistosomiasis. If one water supply is developed solely for drinking, cooking and washing while the other system is kept for agriculture or waste disposal, infection is less likely to occur. This may be quite simple in the moist tropics where new water supplies can be easily found. In fact, in moist tropics, catchments and cisterns can be developed so that potable water can be collected with each rainfall and protected until used. In more arid regions, new tubewell techniques and inexpensive polyvinyl chloride (PVC) pipes are providing uncontaminated water for village use.**

* Eliminate snail habitat. Although the different snail vectors prefer slightly different habitats, they all like stagnant or sluggish water. Therefore, removing sediment and waterweeds and increasing the rate of flow in waterways will help control snail populations.

Unlined canals or channels are more likely to harbor snails than those lined with concrete, plastic or any other material. The lining prevents burrowing, eliminates plant growth and improves flow velocities. Pipes or covered conduits are the best but most expensive means of eliminating snail habitats.

* Efficient drainage. Snails can breed in small areas of standing water, such as seeps from unlined canals, clogged ditches or borrow pits (places where earth has been excavated for use elsewhere) . Improving the drainage of these areas will reduce the habitat available to the snail.

* Physical barriers between likely snail environments and human activity reduce the chance for infection. If fences or distance separates necessary but slow-moving ditches or drains from village compounds, humans--especially children--are not as likely to use the water for recreation or bathing

or to defecate or urinate into the water channels.

* Improve sanitation. If the eggs of the schistosomes do not reach water, the cycle can be interrupted. Improved sanitation can reduce the number of eggs in snail-infested water. Simple latrines and waste treatment eliminate a large percentage of the helminth ovi reaching water bodies--though not all.

* Several molluscicides have been developed for snail control and, if properly used, can be effective. If the chemicals are applied to water with high snail populations just before the main breeding period, they are quite efficient. Since molluscicides are expensive and their effects on other organisms are not fully known, their use should be restricted to those times and sites of high snail densities and at concentration specified on the container label.

Chemical control with natural products is another possibility. For instance, in Ethiopia, an astute observer noted that downstream from a riverbank, much used for laundering, there were relatively few snails. Investigation revealed that a local berry used for soap, and appropriately named soapberry (Phytolaca deocodandra), contained a chemical lethal to snails. This area of research has been

**sadly neglected, but it holds some promise if only development workers and scientists could spare the time to pursue field studies.**

*** Biological control is a preferred alternative. In some places it is possible to introduce snails that eat the schistosome snails, but do not carry schistosomiasis. However, this type of program involves trained people who are familiar with the biology of the different snail species. Also, there has been encouraging research showing that some species of marsh flies have larvae that eat snails. The marsh fly does not bite humans and, so far as is known, does not carry any human diseases. Other research has found certain species of fish which eat snails and could be introduced into snail habitats. Development of a biological control program would require support from a technical assistance organization or a local university.**

**Control of schistosomiasis depends on the use of all the available techniques. Successful control based on a single method is very unlikely or, at best, temporary. Nor is it likely that a complete, comprehensive control program can be instituted at once. The development worker must select options that are possible and implement them as best he can--more than likely, one step at a time. Above all, care should be taken to see that a new project does not increase the disease through poor planning.**

**Onchocerciasis Prevention**

**Control of onchocerciasis or River Blindness is a frustrating problem. The disease does not respond well to medical or chemical treatment, nor is it easily controlled by environmental changes. The black fly vector breeds in swift, turbulent water, such as waterfalls or rapids. Moreover, the insect is a strong flyer, capable of traveling more than 50 km from its breeding site. The disease is not affected by improved sanitation or health education programs. The only control programs involve resettlement or application of chemicals. Where the disease is prevalent:**

*** Avoid project designs that will create breeding sites for black flies, such as fast, open spillways or turbulent sluiceways.**

*** Remove fast, turbulent waters where possible, through the construction of small impoundments or barriers.**

*** Use insecticides on critical areas during periods of black fly breeding or seasonal human use.**

*** Insofar as possible, provide protection from black fly bites. Mosquito netting or settlement at**

breezy sites may reduce incidence of the disease.

Malaria and Filariasis Prevention

Measures for effectively controlling malaria and filariasis in water development projects depend on elimination of mosquito breeding sites. Mosquito larvae require stagnant water in which to mature. Extremely small areas will suffice as breeding habitats--a discarded food can or an abandoned tire.

* Uncovered standing water should be eliminated around living and work areas. This is especially true in the moist tropics where frequent rains can produce small but persistent pools that provide ideal conditions for mosquito breeding. Artificial containers, such as abandoned pails, barrels or pots should not be left to accumulate water.

* Ditches and drains should be maintained to permit constant water flow. Waterweeds provide excellent mosquito habitat. Community efforts are required to remove waterweeds from small water bodies, ditches and drains.

* In arid regions, all water storage devices should be kept covered to restrict egg-laying by adult mosquitoes. An inventory of potential mosquito

breeding sites will almost always reveal exposed standing water which could be easily covered, drained or deepened to deny additional breeding grounds.

* Chemical control measures work best when the chemicals can be directed at the larvae. Larvicides are less toxic to other animals and, when mixed with oil, can be applied as a thin film over breeding surfaces. Pesticides for adult mosquito control are relatively toxic, more persistent and more costly. These chemicals should only be applied to homes and public buildings at rates and concentrations listed on container labels. These insecticides are too costly and polluting to use outdoors. Coordinated programs of larvicide sprays on breeding sites and periodic spraying in dwellings have been effective in controlling malaria in many communities.

## Enteric Disease Prevention

The key to control of enteric disease is the disruption of the fecal-oral route of contamination. This requires improvements in domestic water supply and human excreta disposal.

* Implementing dual water systems, one for safe

domestic water and the other for non-potable uses, is a preferred method. Ground water from deep wells or boreholes is usually safer to drink than surface water. If surface water or shallow dug wells are used for domestic water, disinfection or filtration systems should be instituted (as described below).

* Excreta disposal methods should be developed to reduce or eliminate fecal contamination of domestic water. This does not necessarily mean the use of an expensive sewerage system--merely the control of human waste disposal at sites where potable water must be protected.

* Education programs are essential in the control of enteric diseases. If people can be convinced that these diseases have causes that can be corrected and need not be a natural condition of life, they will avail themselves of water supplies and sanitary measures to reduce enteric infections. Without an education program and community support, projects are not likely to be effective.

Whether the project involves domestic or agricultural water supplies or the development of community sanitary stations, the project should be planned so as to avoid increasing the level of disease in the community, and preferably to reduce it. Wherever possible, the project should have as an objective the reduction of a prevalent water-related disease by a certain percentage or within a certain age group. Given the constraints of time and budget, this may not be realistic where irrigation is the primary objective. Often the development worker can only hope to maintain existing disease levels while anticipating longer-term community health benefits from better nutrition, higher standards of living or reduced workloads.

## WATER PURIFICATION

Water for drinking and cooking can be improved at relatively little cost and with great benefit to health. An accurate but inexpensive chlorinator is the most effective method for killing water-borne pathogens, but may not be available or cost-realistic in remote, sparsely populated areas. In these situations, no other single process can equal the improvements in the physical, chemical and biological quality of surface water produced by a slow sand or biological filter. These simple and inexpensive systems do not require chemicals, energy or excessive maintenance. Ideally, surface water supplies should receive both filtration and accurately measured chlorination while sub-surface waters require only chlorination. The slow sand filter is encouraged since it can be constructed from locally available material by local labor and the quality of the water supply is significantly improved.

**The essential parts of a slow sand filter are: 1) a water-tight container (a 55 gallon barrel--200 liters--is a good size); 2) a small amount of gravel; and 3) washed sand (Figure 9).**

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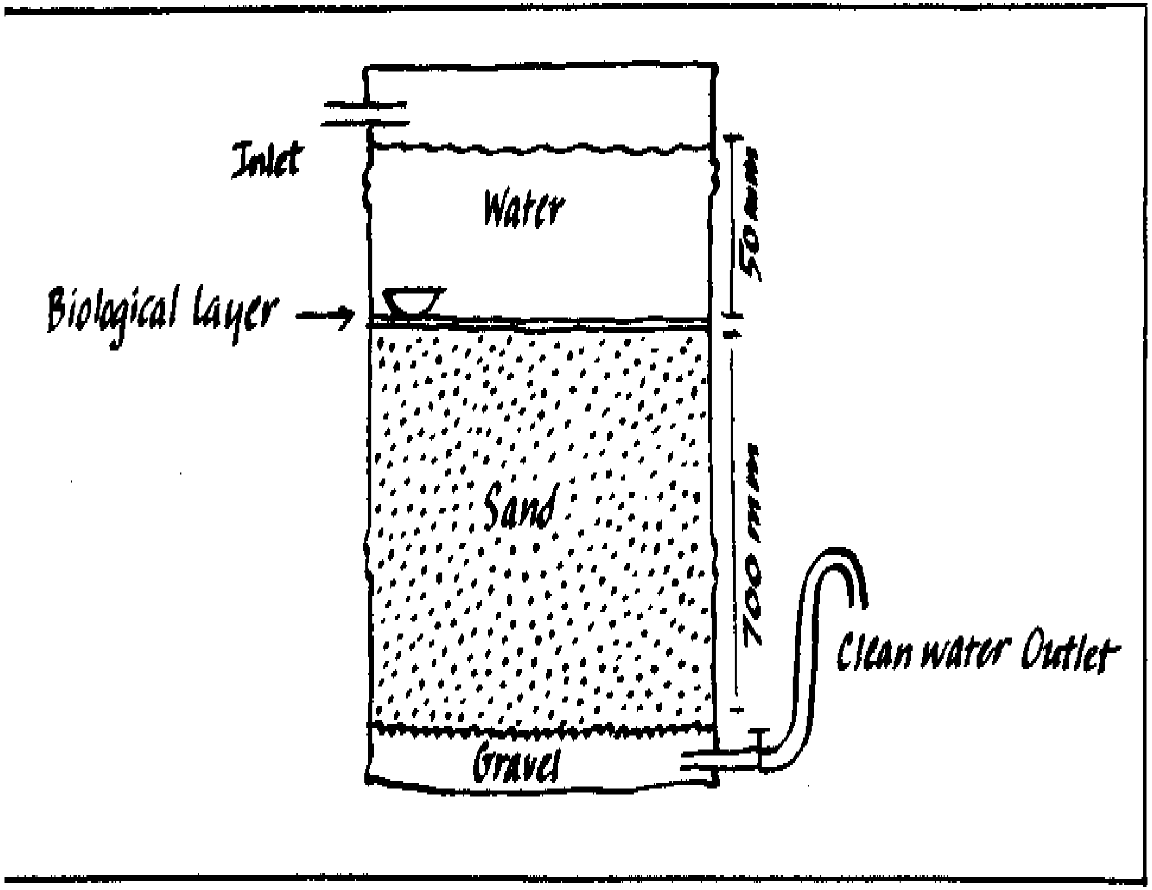


Figure 9. Slow Sand Filter

(after Cairncross & Feachem)

**After making sure that the container or drum did not carry highly toxic chemicals, it should be thoroughly scrubbed and disinfected with bleaching powder. A 5 cm layer of clean gravel should be placed on the bottom of the drum,**

**covering the perforated outlet pipe. A 70-75 cm layer of clean sand is placed over the gravel, leaving 10-15 cm to the top of the drum. The raw water inlet pipe enters the filter near the top. A flat rock or small dish placed under the inlet will prevent disturbance to the sand layer. Simple valves for the inlet and outlet pipes plus a top cover complete the filter and it is ready to deliver filtered water at rates of up to 1 liter per minute. The filter will not be completely effective until the biological layer becomes fully active, which takes a few days.**

**The biological layer is a thin film of algae, bacteria and other microorganisms that develops on top of the sand and is very important in the purification process. The microorganisms break down organic matter in the water and strain out much of the inorganic particles. As the water moves through the sand, other microorganisms continue to remove impurities. By the time water reaches the gravel and the perforated outlet, over 99% of the bacteria and schistosome larvae will have been removed if the filter has been properly maintained.**

**Fortunately, maintenance is a simple task. When water flow at the outlet is noticeably reduced, it is time to clean the biological layer. After allowing the water to drop below the level of the sand, the biological layer, plus a few millimeters of sand, are removed. That is the extent of the frequent maintenance (every 2-4 weeks). When more than half of the sand has been removed, it is**

**necessary to replace the sand and gravel with freshly washed materials. This may be necessary once or twice a year.**

**The slow sand filter can be further improved by two other inexpensive additions: a settling container and an aerator. The settling container can be another drum, placed so that water must enter it before passing to the filter. The suspended solids in the water held in the first drum settle out before reaching the filter. The absence of suspended materials prolongs the useful life of the biological layer in the filter, thereby cutting down on maintenance.**

**During filtration, oxygen is removed from the water by the microoganisms in the filter. Water tastes better when it has oxygen, so an aerator can be added to the filtration system. Water coming out the drain can be aerated by passing it over an inclined plane or series of cascades (steps) into a storage container. Or the water can be passed over built-in weirs as in Figure 10.**

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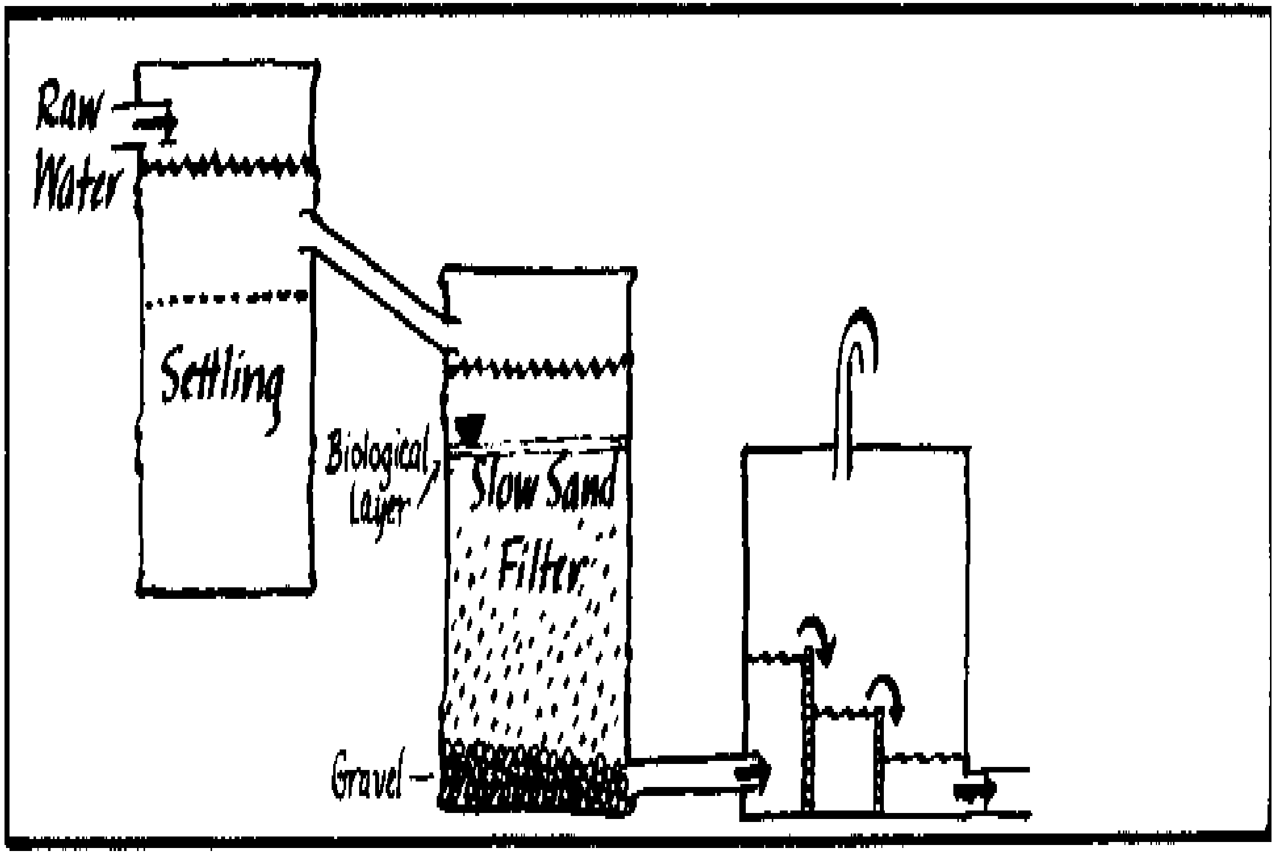


Figure 10. Settlement, Filtration, Aeration System

**Another method of purifying domestic water supplies is disinfection. The two most common methods are boiling and**

chlorination. Boiling for 20 minutes does destroy most pathogens but alters the taste of water and uses large amounts of fuel, which is often in very short supply.

Chlorination is effective and relatively inexpensive. Chlorine solutions can be prepared from bleaching powder or high-test hypochlorite. To maintain the chemicals' effectiveness, both forms should be stored in a cool, dark place in non-corrosive containers. Stock solutions can be made by adding 40 grams of bleaching powder or 15 grams of high-test hypochlorite or 150 ml of liquid bleach to one liter of water. These stock solutions can then be used to disinfect drinking water by adding three drops of any one of the solutions for each liter of water to be disinfected. If the organic material in the water is high enough to color the water, the dosage should be doubled. The water should be mixed and allowed to stand for 30 minutes before use.

Simple chlorinators can be devised from local materials to purify well water.

a. Single pot chlorinator (Figure 11). A 12-15 liter

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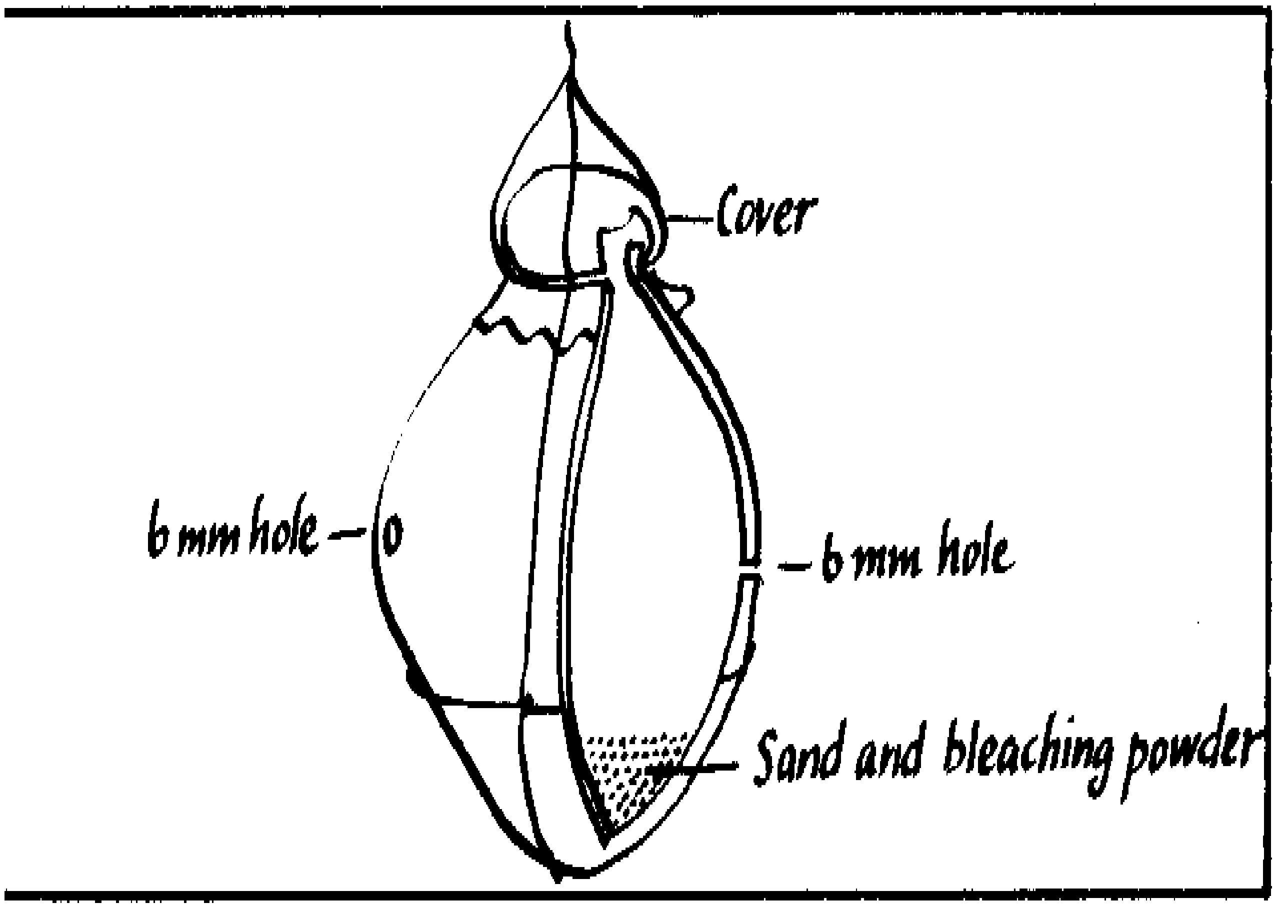


Figure 11. Single Pot Chlorinator

(after Rajagopalan and Schiffman)

earthen pot with two 6 mm holes is filled with a mixture of 1.5 kg bleaching powder and 3 kg coarse sand. After the top has been fitted with a

**water-tight cover (rubber or polyethelene), it is suspended 1 meter below the low water level of the well. The chlorinator will disinfect a well which yields up to 1200 liters per day for seven days.**

**Another version of this can be made with a large coconut, split horizontally and hollowed out. Three .5 cm holes are burned or bored midway down the lower portion of the shell. A plastic bag with 1 kg each of sand and bleaching powder is sealed and two .8 cm holes are made near the top. The bag is placed in the coconut and the halves are closed with twine. The shell is hung 30 cm below water level and can disinfect yields up to 90 liters per day for about 3 weeks.**

**b. Double pot chlorinator (Figure 12). This type,**

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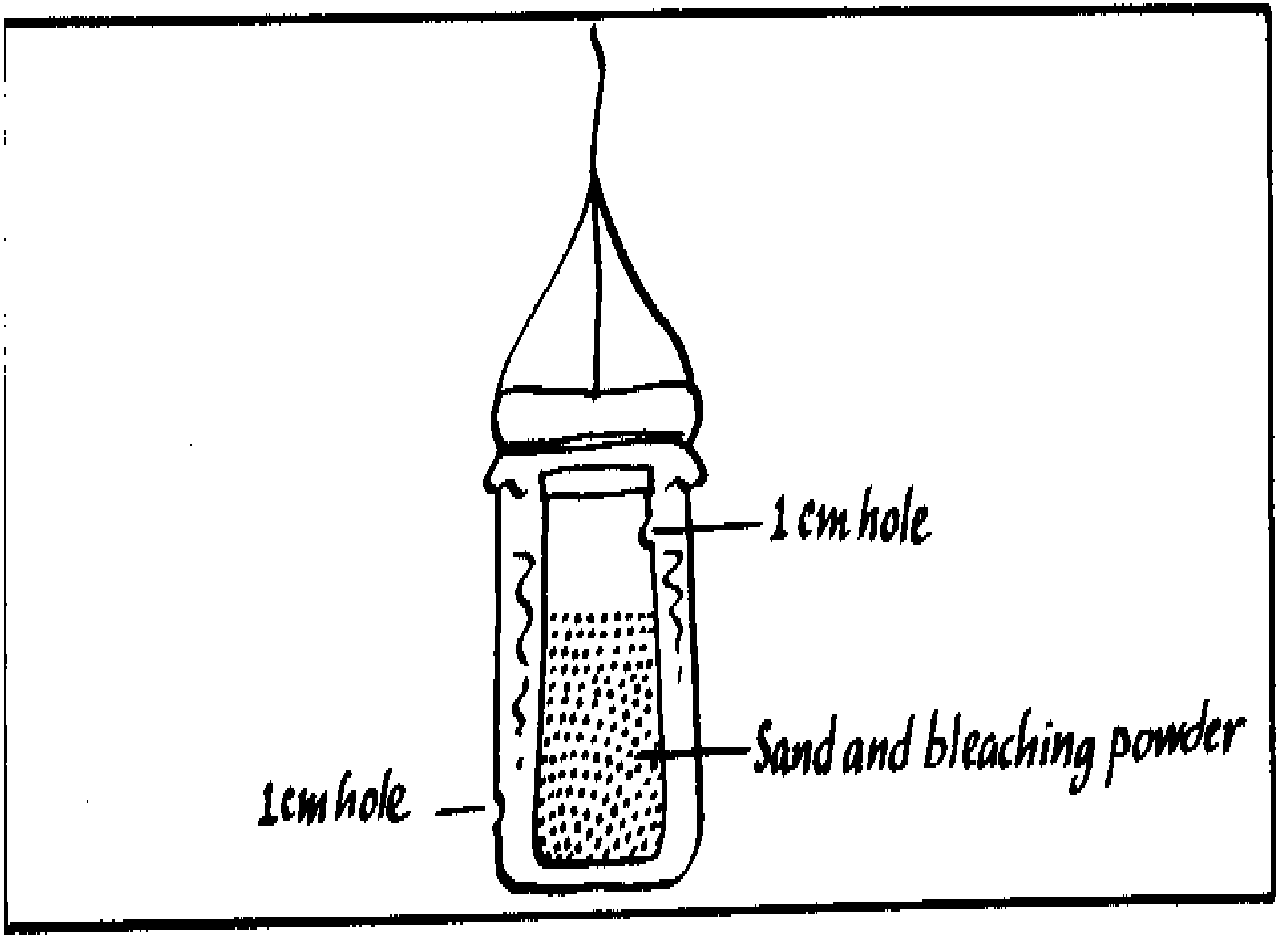


Figure 12. Double Pot Chlorinator

**which is more effective for a longer period, consists of a container filled with a 1 kg of bleaching powder and 2 kg of sand placed inside a second**

**container. The inner container should have a 1 cm diameter hole approximately 3 cm above the sand-bleaching powder mixture. The larger container should have a water-tight cover and a 1 cm diameter hole about 4 cm above the bottom. The chlorinator is placed 1 meter beneath the water surface. Most family wells (under 5000 liters) can be disinfected for 2-3 weeks with this chlorinator.**

**Table 4 provides guidelines for the amounts of chlorine in alternate substances which could be used to disinfect large amounts of water for domestic use. Remember, these are guidelines for water with "average" amounts of organic material and tests would have to be done to determine if the amount is correct for a specific water supply.**

**TABLE 4.**

**AMOUNTS OF CHLORINE NEEDED TO DISINFECT DRINKING WATER**

**Water Bleaching High Strength Liquid Bleach**
**PLUS Powder OR Calcium OR (5% Sodium**
**Hypochlorite Hypochloride)**

**1 cubic meters 2.3 grams 1 grams 14 milliliters**
**1.2 PLUS 3 OR 1.2 OR 17**
**1.5 3.5 1.5 21**
**2 5 2 28**

| | | | |
|---|---|---|---|
| 2.5 | 6 | 2.5 | 35 |
| 3 | 7 | 3 | 42 |
| 4 | 9 | 4 | 56 |
| 5 | 12 | 5 | 70 |
| 6 | 14 | 6 | 84 |
| 7 | 16 | 7 | 98 |
| 8 | 19 | 8 | 110 |
| 10 | 23 | 10 | 140 |
| 12 | 28 | 12 | 170 |
| 15 | 35 | 15 | 210 |
| 20 | 50 | 20 | 280 |
| 30 | 70 | 30 | 420 |
| 40 | 90 | 40 | 560 |
| 50 | 120 | 50 | 700 |
| 60 | 140 | 60 | 840 |
| 70 | 160 | 70 | 980 |
| 80 | 190 | 80 | 1100 |
| 100 | 230 | 100 | 1400 |
| 120 | 280 | 120 | 1700 |
| 150 | 350 | 150 | 2100 |
| 200 | 470 | 200 | 2800 |
| 250 | 580 | 250 | 3500 |
| 300 | 700 | 300 | 4200 |
| 400 | 940 | 400 | 5600 |
| 500 | 1170 | 500 | 7000 |

**(after Ram 1979)**

**Neither the simple filter nor the primitive chlorinators will make the drinking water absolutely safe for drinking, since even the most modern systems cannot totally eliminate the transmission of water-borne disease. However, these simple devices will make the water safer at low cost and, to the world's rural poor, these are the most important considerations.**

**For projects in larger villages with more resources, planners may select low-cost chlorinators which are available and are much safer. These new chlorinators are reliable, durable and require minimum attention for operation and maintenance.**

**The decision as to which water treatment system is most appropriate will depend on the number of people to be served by each unit and the amount of funds available.**

**4. ENHANCEMENT, DEVELOPMENT AND PROTECTION <see image>**

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**"Water is the driver of life."**

**Leonardo da Vinci**

**The goal of water projects is most often to increase the**

amount of water available to a community. The supply can be increased in several ways:

1. Make more efficient use of existing water supplies. In most existing systems, a large amount of water is wasted through unwise use or poor methods of collection.

2. Improve water delivery systems to reduce water losses through evaporation or seepage.

3. Enlarge existing sources.

4. Develop new sources of water.

5. Protect watersheds and other sources of water in order to maximize water output and avoid wide fluctuations.

The list given here is arranged in order of priority for the community worker but not strictly by environmental preference. The fifth alternative is the most ecologically sound approach to water management. Water projects have a better chance of gaining community support if the benefits are immediate and apparent. Watershed protection or improvement projects are long term; benefits are indistinct or accrue to future generations. Therefore, these projects are less likely to receive enthusiastic support unless an education program can persuade the

**community of their present importance and future value.**

**The first three alternatives receive high priority because: 1) community benefits are immediate and apparent; 2) investment is relatively low; 3) environmental impacts are not significant; and 4) cultural adjustments are minimized.**

**When there are deficiencies in community water supplies, marked either by insufficiency or high rates of waterborne disease, the first reaction is generally to locate and exploit a new source of water without first considering improvement of the existing system. For economic, social and environmental reasons, community workers should reject proposals for new sources until the first three alternatives (above), either singly or in combination, are judged to be insufficient or unsound. Indeed, all alternatives should be examined before selecting the best method for increasing the water supply to meet the desired objectives.**

## CALCULATING AND USING WATER CAPACITY AND CONSUMPTION

**The first step in the process is to calculate the water requirements of the community and measure the capacity of the existing system.**

**In small villages with a limited number of water sources, such as community wells or standpipes, actual water**

consumption can be measured by recording the amount of water taken from each source over a period of two or three days. From these data, annual water use can be estimated. It is important to remember that if water is made more readily available, annual consumption is likely to increase. Another method is to employ minimum standards for domestic water use proposed by various international organizations. For instance, UNICEF recommends a daily per capita minimum of 38 liters for drinking, cooking and bathing. This figure multiplied by the community population would provide an estimate for domestic water requirements. For agricultural or commercial water supplies, estimates can be gained from the technical literature or from technical advisors, if available.

Evaluating the capacity of the existing system requires a little field work and investigation. Each community water source should be mapped and notes taken on capacity and quality, as well as the type of use for each source, e.g., drinking, washing or agriculture. The yield of the spring can be determined by measuring the time required to fill a container of a given volume. Yields from wells can be measured by bailing or pumping a given volume after marking the initial water level. The time required for the well to return to the original level is then used to calculate the yield per unit of time. The volume of water in a stream or channel can be estimated by measuring the cross-section area of the water flow and calculating the water velocity by timing a float along a measured distance.

**VITA's Village Technology Handbook and Peter Stern's excellent reference, Small-Scale Irrigation, (see Appendix I) provide assessment methods for each water source.**

**Planners should not overlook the educational opportunities in the mapping and measuring exercises. Local teachers could use the occasion for teaching math, public health or mapping. Student involvement will also increase the level of community participation, since the students can be expected to relate their experiences and lessons to their parents.**

**Of course, account must be taken of seasonal variation in the water sources. Village elders can provide the necessary information for this adjustment to the estimate. The elders will know which wells run dry and for how long and can describe the low water flows of streams and channels during the dry seasons. Unless storage facilities are available, the dry season capacity should be used in evaluating the project alternatives.**

**If community water supplies are greater than water requirements, as is often the case in tropical moist areas, then the real question may be how to protect the water from pollution or how to use it wisely. If the wet season capacity exceeds community requirements and there is a shortage in the dry season, then the best water development project may be some type of storage system so as**

to use the yearly water supply more efficiently.

In arid regions, the maximum seasonal water supply may be adequate or barely adequate; for the rest of the year outputs may fall well below minimum requirements. If minimum consumption requires more than a 100% increase in water supplies, it is likely that new sources will be needed. Otherwise, the objective may be achieved through a water conservation program, improving delivery or storage systems, or enlarging existing sources. In fact, these three alternatives are productive even if the development of new sources is ultimately necessary.

COMMUNITY WATER CONSERVATION PROGRAM

The most obvious waste of water is from a source that runs constantly whether in use or not. Water is also wasted when the flow cannot be constrained to conform to the rate at which containers or conduits can be filled. Water sources should be equipped with devices, such as valves or reduction pipes, that can vary the flow and force of water being delivered.

Excessive use of water is most common in agriculture, where farmers tend to put out more water than livestock require or to irrigate with larger quantities than are needed by the plants for optimal production.

Evaporation and seepage losses can be reduced to provide more available water. Exposed water surfaces, whether in reservoirs or ditches, lose huge quantities of water. Covers for water storage units or ditches can reduce evaporation up to 50%. By digging reservoirs and ditches deeper, more water can be moved or stored with less surface area exposed to evaporation. Seepage can also account for immense losses. Dug wells, springs or unlined irrigation canals allow water to seep into the soil. Lining with impervious materials like concrete or rocks can reduce the loss substantially. If pipes rather than open unlined canals are used, the water that can be delivered is effectively doubled simply by reducing losses. In addition, lined canals or closed pipes do not provide good habitat for snails and mosquitoes.

Conversion to closed water systems can be programmed over several years as labor, materials and funds are available. Each section of open canal or storage system that can be covered or lined will reduce water losses, until the system has been completely converted.

IMPROVED DELIVERY OR STORAGE SYSTEMS

Often, the water supply for a community would be adequate if it were evenly distributed over the year. Where it is not, improved storage systems can capture more water when it is available, for times when it is scarce.

The construction of enclosed water storage containers or cisterns can be quite effective. The Village Technology Handbook provides construction details for several types. Cisterns require a collection area or catchment to gather water during the wet season. A common method, used in the Caribbean, is to collect rain from the roof, allowing it to drain into a covered tank (Figure 13). Later the water

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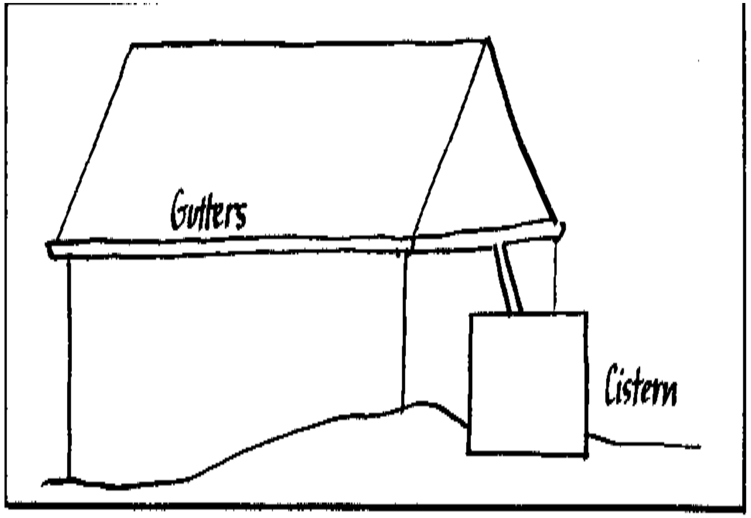


Figure 13. Cistern with Roof Catchment

can be purified with small amounts of chlorine.

Catchments for agricultural cisterns were a common practice in the arid Middle East. Channels or furrows were placed along barren hills leading to large cisterns or open reservoirs at the base of the hill. Surface water running off the hill was diverted by the water channels into the reservoir or cistern (Figure 14). This practice,

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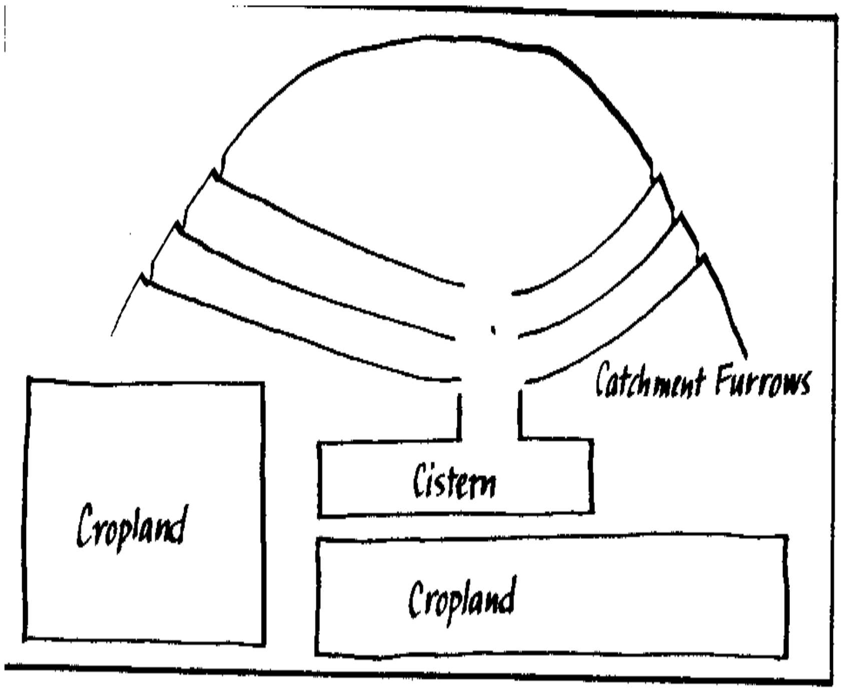


Figure 14. Catchment on Barren Hill

over 2,000 years old, is being reintroduced in Israel with excellent results. During the dry season, the catchment can be improved by compacting the furrows or lining the catchment channels with rocks, concrete or plastic membranes. Asphaltic concrete has been applied to entire catchment areas, so as to capture even more of the precious water. The National Academy of Sciences devotes an entire chapter in its book More Water for Arid Lands to domestic and agricultural catchments. (See Appendix I.)

In all types of storage systems, closed cisterns are preferred to open reservoirs. By enclosing the storage tank, evaporation and seepage losses are kept at a minimum and the tanks do not provide breeding habitat for snails or mosquitoes. The cisterns should be placed as close as possible to the point of use to minimize the expense and complexity of delivery systems. In community systems, the roof area of several houses can feed into one cistern, thereby reducing the costs of construction.

Often, safe water is available to a community only at considerable distances, requiring the women and children to walk many kilometers several times per day to secure household supplies. If the burden becomes too great, they may turn to a source that is unsafe, but nearer by. Improving the delivery system is always an expensive task unless local labor and materials can be used. The advantages of lining or piping are apparent, but heretofore the high cost of concrete, fiberglass or polyvinyl chloride (PVC) has been prohibitive. Recent improvement and transfer of PVC technology provides exciting new possibilities. In countries where the technology is available, the light and flexible PVC pipe is relatively inexpensive and adaptable to' rural conditions. Many community systems have been built with PVC pipe using local labor to dig trenches and to transport the durable piping.

Obviously, there are prerequisites to piped water systems. Unless the water source is at a higher elevation than the village, expensive pumps are necessary. The pipe must be buried, since sunlight makes the material very brittle. Unfortunately, rodents seem to be attracted to PVC, often gnawing small holes in the pipe. Frequent inspection and repair of the system is therefore necessary. The use of PVC is expected to increase as more developing countries acquire the pipe-making facilities.

Concrete is more commonly used for linings or conduits in developing countries. The advantages of concrete are that it can be cast on-site and local labor can easily develop the necessary construction skills. The Village Technology Handbook provides technical information plus designs for forms and molds that can be used for casting linings or conduits for water supply systems.

Concrete lining permits construction of narrow and deep canals with higher water velocity to reduce mosquito and snail breeding and less surface area to minimize evaporation. Water flow is more easily regulated in pipes or lined canals so less water is wasted through uncontrolled flows. Seepage losses in both situations are virtually eliminated.

In tropical moist areas, wood conduits may be used to carry water. Bamboo makes excellent piping, where small water volumes are handled. The villagers will know how to remove the internal barriers in the bamboo. The ends can be shaved or widened to form water-tight connections, once wrapped with tarred rope. The bamboo is light, sturdy and somewhat flexible--a good piping material for bringing water from spring or cistern to a dwelling or central square.

ENLARGING EXISTING SOURCES

Any water source unattended for a number of years has been reduced in efficiency and capacity by the addition of debris and sediments. Dug wells and tube wells slowly fill in as walls erode. As these wells are cleaned, they can also be enlarged either in depth or diameter. With lined wells, or tube wells with casings, increasing the diameter is not recommended, since the lining would have to be removed. However, the well can be enlarged below the lining or casing and, unless there is impervious rock layer, can be dug deeper.

Open reservoirs and surface-water cisterns accumulate sediments and require periodic cleaning. The reservoirs can be enlarged during cleaning by removing more material both in and around the reservoir. Care should be taken not to disrupt any impervious layer or to exceed the water volume that can safely be held back by the dam or barrier.

**DEVELOPING NEW WATER SOURCES**

**If all the alternatives for improving existing sources have been explored and a community is still short of water, the search for new sources should be undertaken with recognition that the easy or obvious may have already been done; new sources may be harder to find or more expensive to develop. Some possibilities--such as cisterns--have been discussed under the heading of improvements. The most likely new source will be various kinds of wells.**

*** In rural areas, dug wells are a very common method of providing new water. If lining materials such as concrete or masonry are available, dug wells are inexpensive and durable. Wells 1.5 meters in diameter can be dug by two men, and sections of the concrete casing can be cast in place. After the first section is cast, the well-diggers merely remove soil beneath the casing and, as it is lowered, new sections are cast on top until the well goes below the dry season water table.**

**Linings are recommended for dug wells to prolong well life and to reduce contamination. The casing or lining should rise at least one meter above ground level. This prevents small children and animals from falling into the well and also reduces**

the amount of contaminated water spilling back from the ground surface.

Ideally, the well should be covered and water removed by some type of hand pump, rather than expensive and hard-to-repair motorized pumps. Realistically, however, in many remote areas even hand pumps create insurmountable repair problems and the most feasible well design incorporates simple bucket mechanisms. The bucket should be a part of the well so that people do not use their own containers, which may be contaminated, to dip water. Several bucket designs, including self-tipping varieties, are available in appropriate technology literature.

* In areas of soft soils, sand or limestone, bored wells can be made with hand-powered borers or augers. If and when water-bearing layers are penetrated, small diameter pipes with strainers are sunk into the bore hole and a pump is attached. The well should be capped to prevent contamination. The Village Technology Handbook offers directions on how to construct simple boring equipment and advice on techniques. The book also has technical designs for concrete tile machines to make well casings. Bore or tube wells are commonly used for domestic and agricultural water supplies. If soils are favorable and the boring equipment is available, the bored wells are an environmentally

**sound source of water, providing non-motorized and easily maintained pumps can be used.**

*** Driven wells are made by driving a well-point (a pointed strainer) into soft or sandy soils. The well is driven by pounding pipes (with a special cap) connected to the perforated well-point until water-bearing layers are reached. The pipes provide a well casing as they are driven into the ground. The driven wells require a special pump and this may produce maintenance problems.**

**A problem common to all types of wells is seepage of contaminated water back into the source. Even the best casings cannot prevent all seepage, so methods to reduce spillage or seepage must be devised. Wells should be surrounded by sloping concrete aprons with drainage furrows. Water spilled at the well will then be directed away rather than back toward the casing. Trenches of loose gravel around the edge of the apron will eliminate puddles which encourage snail or insect breeding. Layers of clay mixed with water puddled around the casing will also reduce seepage into the well (Figures 15 and 16).**

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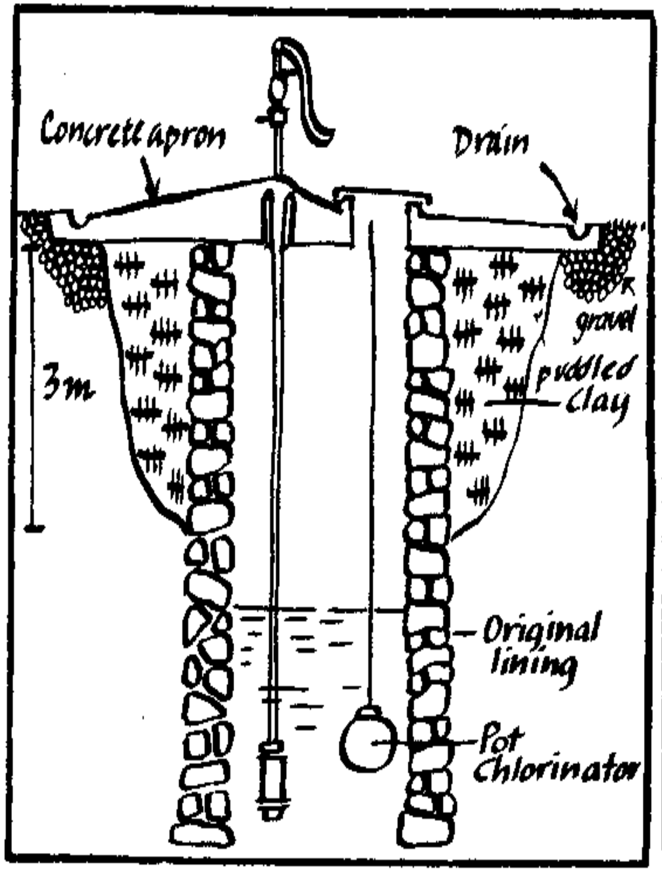


Figure 15. Well with Pump (after Wagner & Lanoix)

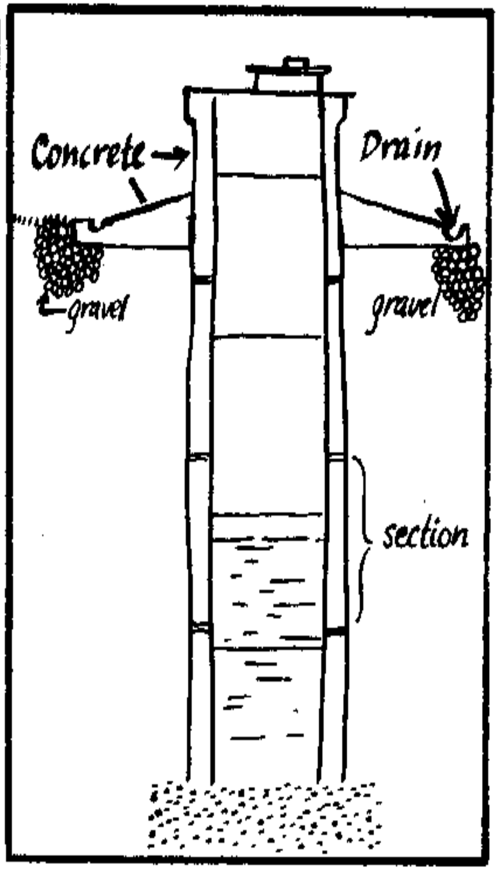


Figure 16. Well with Wall (after Rajagopalan & Shiffman)

**To keep livestock away from wells, water should be carried by conduits to troughs or holding tanks**

some distance away. Gravel beneath and around the trough and tanks eliminates standing water.

People can also be encouraged to do laundry or bathe away from the well by the addition of a cement laundry or bathing pads 20-25 meters from the well. Gravel drains should also be included in these areas.

* Sand reservoirs can be constructed in arid regions to provide new sources of water. A low barrier (approximately 1 meter) can be built across seasonal streams. If the sediment load of the stream is sand, it will settle behind the barrier. The dam can be raised in one meter increments for the next 3-4 years, if topography permits. Water will remain in the spaces between the sand grains and can be tapped with driven wells (Figure 17). Sand

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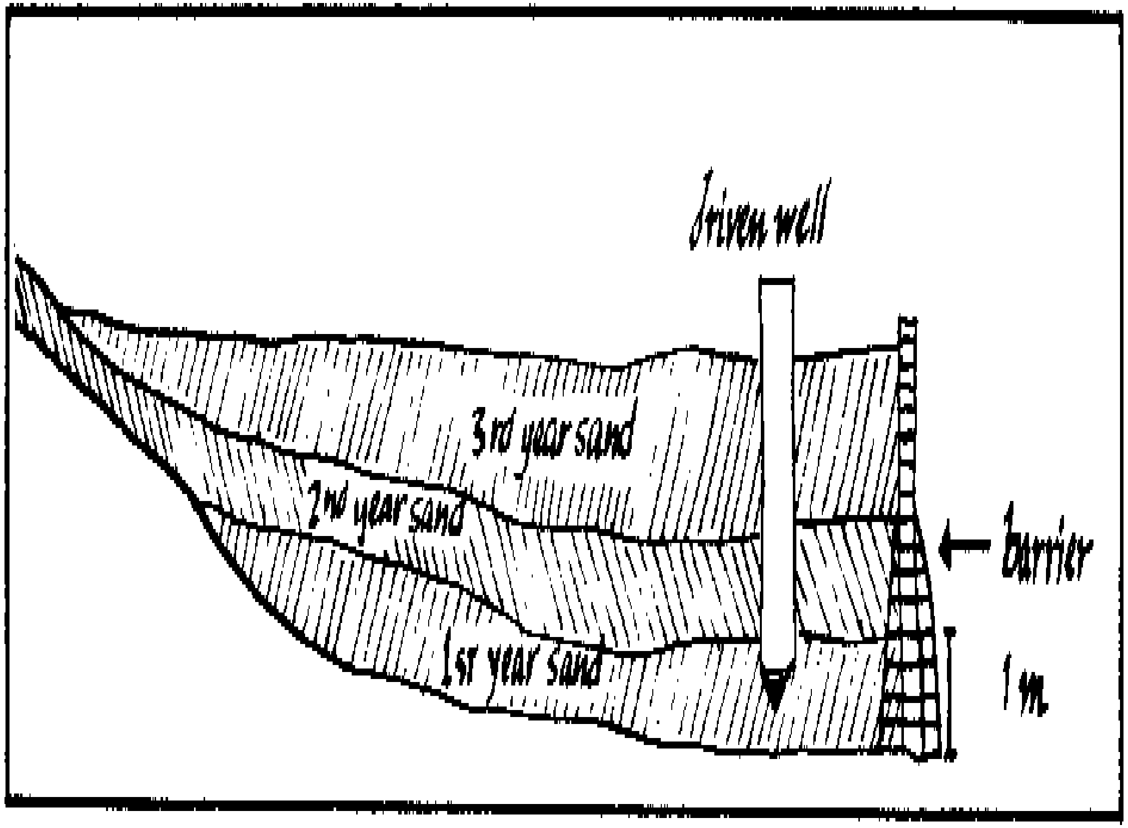


Figure 17. Cross Section of Sand Reservoir

reservoirs can hold a great deal of water without excessive loss from evaporation and they do not provide habitats for disease vectors.

* Open reservoirs are not a preferred alternative in

**arid zones because evaporation is excessive and health risks are serious. However, open catchments can serve as temporary livestock watering areas. Also, open reservoirs can be useful in recharging aquifers in order to raise the water table and thereby refill dug wells.**

**PROTECTING WATER SUPPLIES**

**Once water sources are developed, they should be protected from damage by humans and animals. Burying pipes or building fences around wells can be helpful. The value of these protective measures can easily be demonstrated. However, protection of the watershed is often neglected because the value is not readily apparent. Watershed protection is a long-term investment that only gradually improves the water supply. It is difficult to see that many current water problems are the result of poor watershed management in the not-so-distant past.**

**If, in arid regions, surface water is allowed to escape as surface runoff before it can be utilized, a major loss has occurred. Natural ecosystems prevent excessive runoff and erosion by providing a vegetation buffer between rain and soil. In order to maintain this natural protection, plant cover must be retained in water collection areas or areas adjacent to water supplies. The vegetation can consist of a mixture of grasses, shrubs and trees. The first step in**

developing this protection is through reforestation projects. Young trees can be planted and tended until roots reach deeper water layers. As the trees begin to bind the soil and provide shade, other types of plants may be introduced artificially or naturally, until a complete mixture of grasses, shrubs and trees is established, providing three plant layers of soil protection.

Water development projects should include strategies for protection by some form of plant cover in the watershed. The first step is education designed to convince the community of the necessity of protecting water sources with plants. If the community does not understand or appreciate the need, the project will fail.

In order to protect watersheds it is not necessary to create inviolate preserves, but rather a management area. Plants or wood products can be harvested as long as the natural rate of replacement is equal to or greater than the amount harvested. However, the management area should be well-defined and should receive higher levels of protection than areas that do not contribute to the water supply.

On watersheds unprotected by vegetation, development of water resources must begin with afforestation, whether with quick-growing trees or other kinds of plants. The species of trees to be planted can be selected with the advice of government forestry experts. However, trees should be selected on the basis of utility to the community as well as characteristics of quick growth for watershed protection. For instance, fruit or nut trees can perhaps be planted to supplement food supply or develop a cash crop. If fuel is scarce, trees can be selected for their value as firewood. The key to the success of tree planting is maintenance of their future growth. It will not suffice to plant hundreds of trees and fail to monitor their progress or provide them with some degree of protection. Even if properly planted, most trees wil not survive unless they receive added care for a few years. Seedling trees are vulnerable to damage by animals and are susceptible to drought until the root systems become established. A tree planting program must include provisions for temporary protection from animals with barriers or fencing and may need supplemental water for at least two years. If the community supports the project, "tree guardians" can be appointed to care for the trees and to supply small amounts of water when the symptoms of drying become apparent.

The rewards of a well-executed watershed management program are not dramatic. Unless records are kept, the improvements are so subtle that villagers will not see the results nor remember the conditions before the project began. Like most environmental change, increments are small and spread over long periods but they can produce significant results. Efforts to protect watersheds are one of the best investments for the future.

**OPERATION AND MAINTENANCE**

**Improving or creating water supplies is gratifying, but is only one-half of the project. Unless provisions are made to ensure effective maintenance, the water supply may quickly return to pre-project levels yet be expected to fulfill an increased demand. Plans and organization for operation and maintenance should be established before the project begins. Community support and acceptance of responsibility for the project are as crucial to maintenance as to development. Water development projects in which villagers were assigned or elected as titled caretakers or watchmen trained in operation and maintenance have had great success. A community organization to "care for the water" can benefit water projects. Effective water projects will involve development of new skills and experience in working with metals, masonry, pumps and in preventative maintenance where appropriate. This will contribute to sustaining the project after the departure of the development team.**

**Local technology should be the basis of the project. If the project depends on outside skills or foreign parts, it will be only as good as the availability of those goods or services. Before accepting a pump or other mechanical device, make sure the replacement parts are available and repairs can be made by members of the community.**

Increasing or improving water supplies is a difficult and expensive task. The United Nations' goal of providing safe water for everyone by 1990 seems out of reach. But to relieve the daily lives of those people to whom 38 liters per day would be a luxury is an achievement not to be measured in numbers alone. Small steps in water development taken in thousands of villages are far more effective than gigantic projects at a few sites.

## 5. SANITATION AND WASTE TREATMENT <see image>

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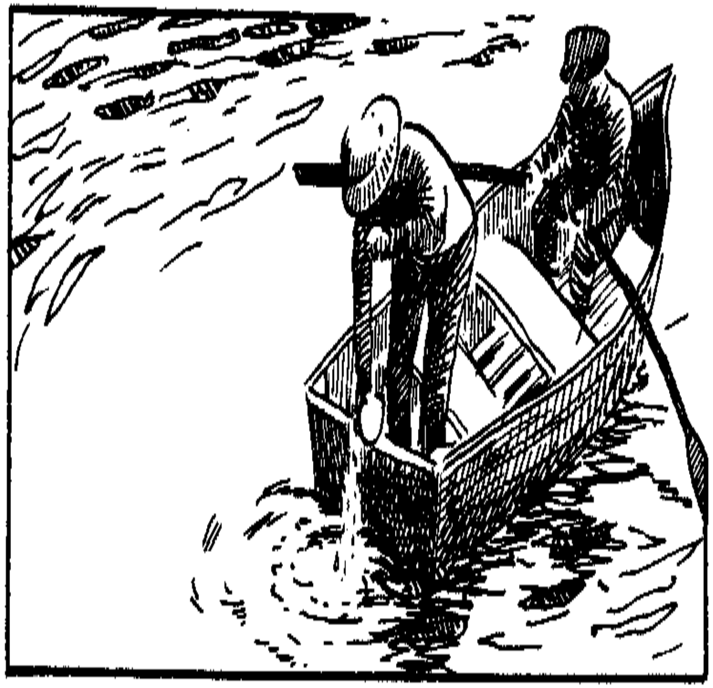

**"In many instances, it is a question of life or death, not speak of human dignity and self-respect. One cannot teach a child to read if he is debilitated by diarrhea, or expect a man to take a great interest in improving his shelter if he has to wade through his own, his neighbors' and his animals' filth."**

**Grava**

**In all of the nations of the world, one common problem is adequate sanitary waste collection and excreta disposal. However, excreta should be regarded as a resource rather than a waste. In many parts of the world, human excreta is regarded as a valuable commodity, carefully collected and sold for fish farming or agriculture. However, many health hazards are associated with these practices. In other areas, human excreta and other organic wastes are used to provide domestic energy supplies while satisfying the seven performance criteria of Wagner and Lanoix.**

**The problems of collection and disposal are particularly far from being solved in developing nations. Improvements in excreta disposal are essential in order to raise levels of public health. Small-scale waste disposal technology has lagged behind the recent advances in water supply.**

**Yet, both technologies are equally important, for if water supply is increased and sanitation is not improved, the new water supply provides a vehicle for the further spread of disease. Often the typical response to waste disposal problems is to apply industrialized technology which is expensive and wasteful of natural resources. Water-borne sewer or septic systems, which work well in temperate zone industrial nations, are often inappropriate in tropical areas. Fortunately some efforts have been made recently to determine which small-scale disposal technologies are cost-effective for the rural tropics.**

**OBJECTIVES FOR EXCRETA DISPOSAL SYSTEMS**

**The 1958 World Health Organization publication by Wagner and Lanoix (Appendix I) is still the best source of information on the disposal of human wastes in developing countries, although the Village Technology Handbook offers many of the same designs and recommendations. Wagner and Lanoix offer seven rather stringent criteria for any excreta disposal system:**

*** The system should be simple and inexpensive in construction and operation**

*** Handling of fresh excreta should be kept to a strict minimum**

* Excreta should not be accessible to flies or animals

* Contamination of wells and springs should be prevented

* Pollution of surface water should be safeguarded against

* The surface soil should not be contaminated

* There should be freedom from odors or unsightly conditions.

These criteria have been listed in order of priority, although some may disagree with the arrangement. Surprisingly, if some of the conditions can be met, the others fall into place or are met at least in part. In addition to these criteria, the system must be culturally acceptable and supported by the community. The collection, storage and treatment of the water must not be incompatible with local customs or religious practices.

BASIC WASTE DISPOSAL METHODS

The many methods of waste disposal are all variants of three basic types:

* Removal, where excreta is collected and transported, either manually or automatically to a discharge site or a central facility for further processing. A common method in urban areas.

* Infiltration, or the absorption and dispersion of waste materials into soil or ground water. Common in rural areas and a source of serious contamination.

* Destruction, where excreta and other wastes are converted into useful and harmless substances.

The relationship of the three methods is diagramed in Figure 18.

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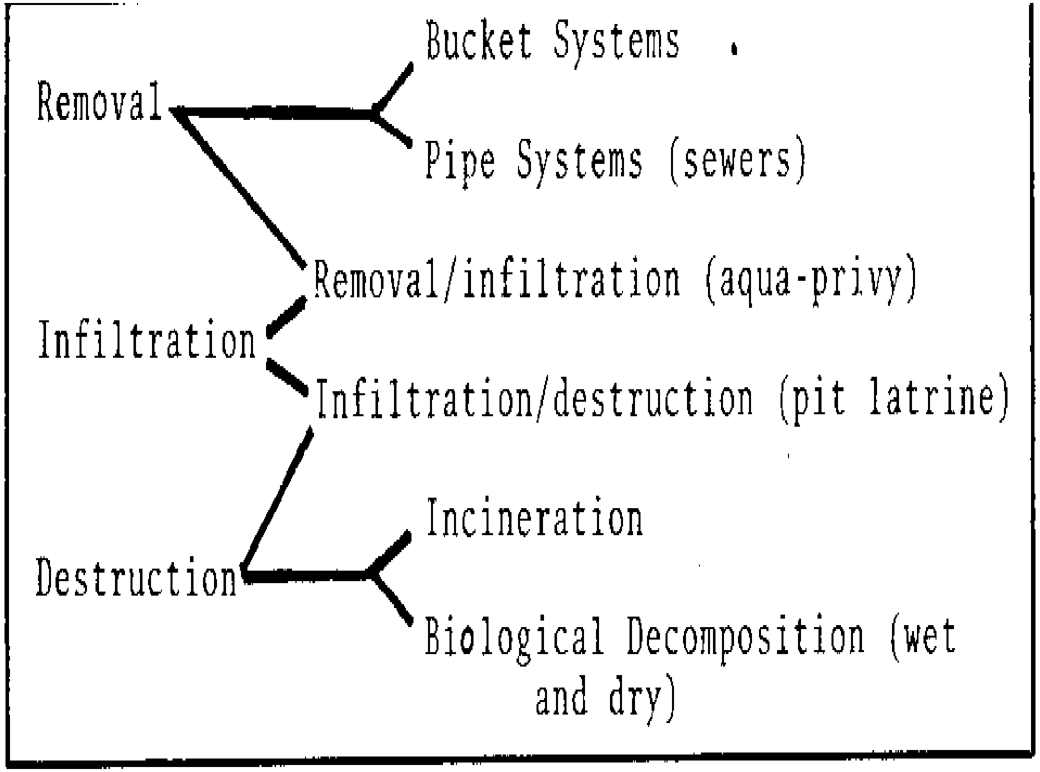


**Figure 18. Classification of Disposal System (after Winblad)**

Other than bucket latrines, the most common excreta disposal systems are combinations of the three basic methods.
Using combinations of new and old techniques may be the best approach in designing small-scale village sanitary systems, because one method is not likely to meet economic, social and environmental criteria for an entire village.
A slight difference in soil texture, ground water

or proximity to surface water or cropland in one location can make a method less suitable than it might be at another location.

Removal systems with pipes or conduits for human wastes are generally too costly for rural projects. In urban areas, where large sewer mains are available for connection, piped systems may be very appropriate. Sewer systems are capital intensive and require large volumes of water for operation, rendering them less suitable for arid regions.

Removal by bucket is a common and viable option for excreta disposal. This is especially true in villages and cities near agricultural areas where human excreta, or night soil, has been traditionally used to fertilize croplands. In many Asian communities, collectors pay householders for the wastes which are then transported in tank trucks or push-cart vaults to farm areas and sold to farmers. The system is inexpensive and does not require water; but it may create health hazards from handling or exposure to flies and also is odorous. In the best of the bucket systems, the bucket is routinely cleaned and tarred or disinfected and equipped with a tight-fitting vermin-proof cover.

In more urbanized areas, a ventilated vault may replace the bucket. The vault is pumped out by a vacuum truck and the excreta taken to a central site for treatment or directly into the country to be sold to farmers. The system is an improvement over buckets in that handling and odors are reduced.

The chemical toilet is also a modification of the bucket latrine. Bacteria-killing chemicals, such as formaldehyde, are added to the bucket to reduce odors and handling hazards. The initial cost of the chemical toilet is low but depends on a constant supply of expensive chemicals. Furthermore, the chemicals may cause environmental harm at disposal sites by killing fish and vegetation. The chemicals also destroy natural bacteria in the excreta and delay the decomposition process. The chemical toilet is not recommended as a means for excreta disposal in rural areas.

The aqua-privy (Figure 19), a removal/infiltration technique,

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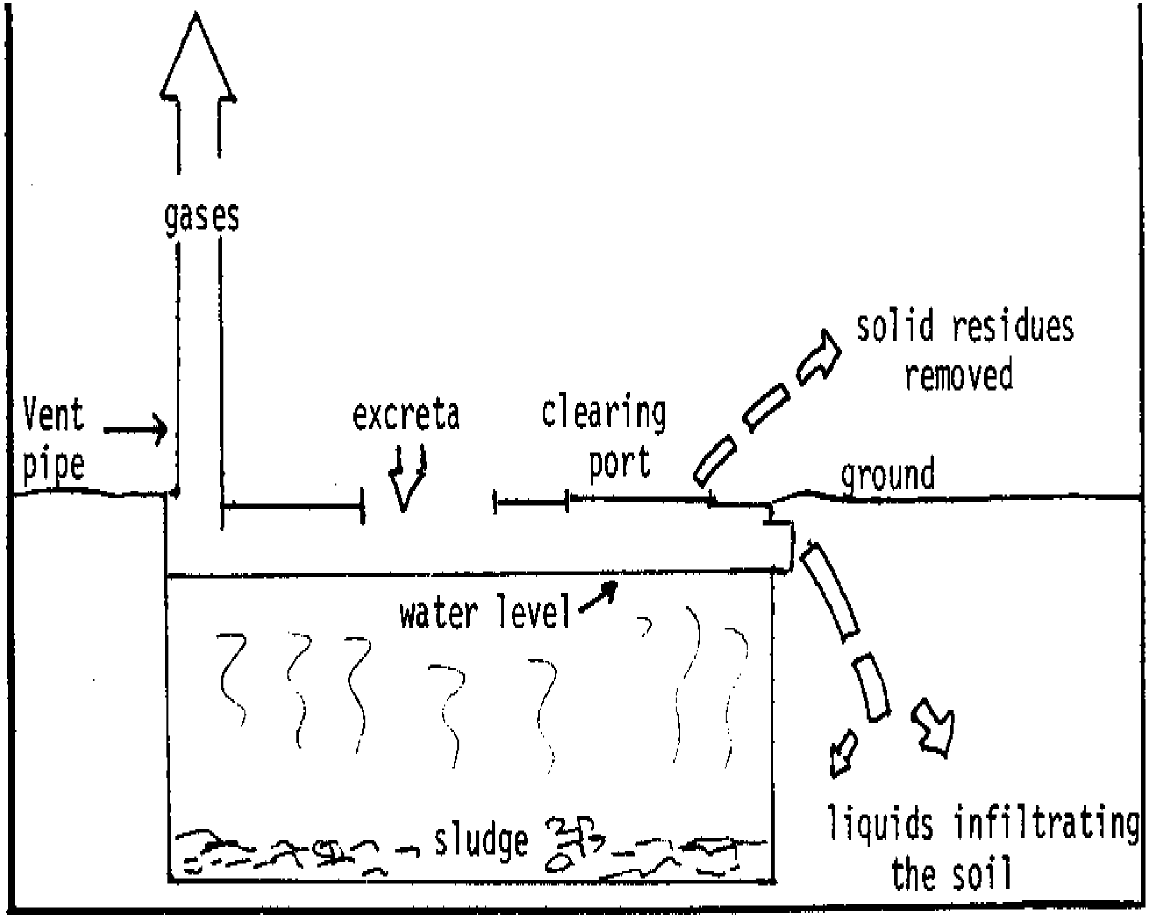


Figure 19. The Aqua-Privy

eliminates some of the problems of bucket latrines but at increasing cost. The unit consists of a watertight vault or tank in which water is kept at a constant level by an overflow drain. Waste material, dropped beneath the surface of the water, is decomposed by anaerobic

**bacteria (bacteria that do not require oxygen), which are normally present in fecal material. The resulting sludge must periodically be removed (by pumping or vacuum truck). If the sludge is not exposed to fresh pathogens for three weeks, it can be spread on croplands with little health risk. The overflow liquids, mostly urine and contaminated water, infiltrate the soil and may introduce pathogens, so aqua-privies should not be located within 15-20 meters of a well or other domestic water source. The soil surrounding the aqua-privy should be permeable to allow rapid percolation of the effluent. To prevent too heavy concentration of the effluent, units should be at least 15 meters apart.**

**The reduction of health hazards and odor may be worth the increased cost of the aqua-privy, if construction material is locally available. Unless vents and other openings are screened or covered, insects can use the water for breeding. The vents are necessary because anaerobic decomposition does produce a combustible gas. The vents should not be placed near open flames and should extend at least two meters high. In some systems, the gas can be captured for domestic cooking and heating.**

**The septic tank is another removal/infiltration approach, direct from the temperate industrialized areas (Figure 20).**

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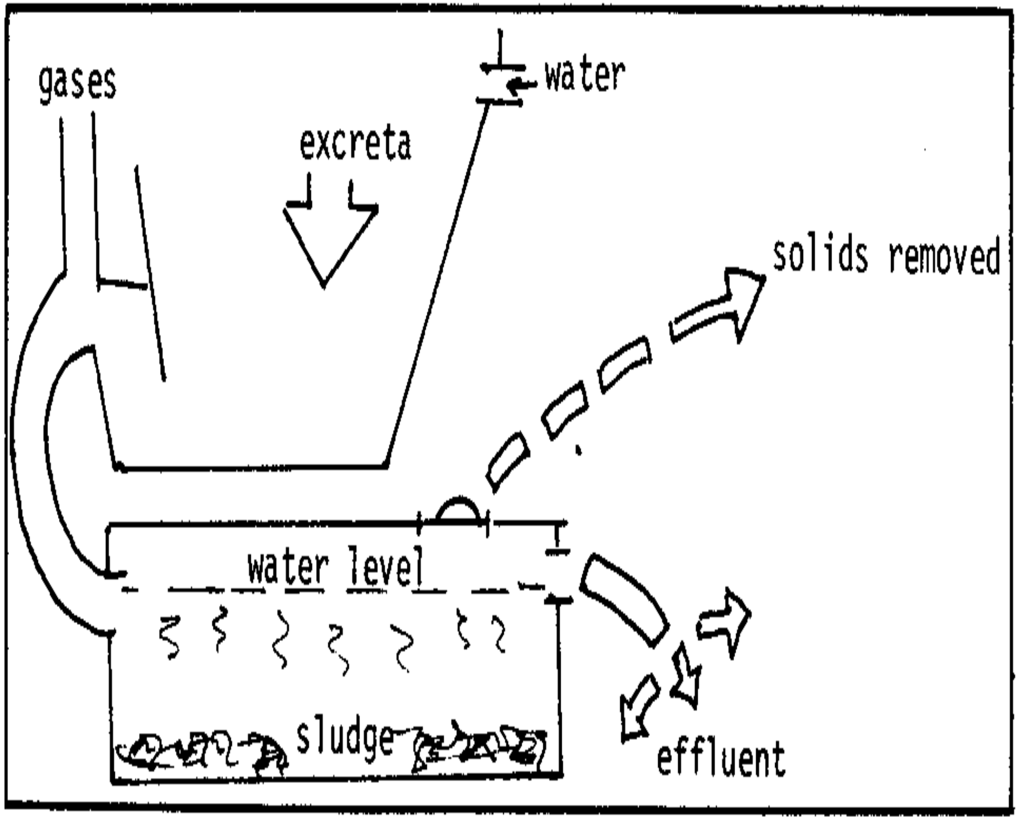


Figure 20. Septic System

In this system, water is added to the excreta before entering the infiltration tank. Effluent infiltrates the soil by way of an overflow drain which can go directly into the soil or be directed to a soakage pit or filter drains. Solids are retained in the tank and slowly decompose anaerobically. The residue, or sludge, must be removed when the tank becomes filled with solid material. It is much the same as an aqua-privy, except for much

**higher water consumption, a serious disadvantage in arid regions. The septic tank requires permeable soil or an extensive drain field of gravel and pipes. In areas of high water tables or impermeable soils, the effluent may rise to the surface, providing breeding habitat for disease vectors.**

**The pit latrine, which may be nothing more than a hole in the ground, is commonly used as a temporary waste disposal method or as the first step in the development of village sanitary systems. With improvements, the pit latrine can be less temporary and more sanitary.**

**This cheap and simple latrine consists of a hole or trench, often covered by a plate or slab. Liquid wastes seep off into the soil and the solids accumulate, slowly decomposing, until the pit is filled. Thereafter, a new pit is dug and the old one is covered with earth.**

**Designs for the latrine slab can be found in Village Technology Handbook and the publication by Wagner and**