CWF
HOUSEHOLD
FILTER

Ethiopian Kale Heywet
Church
Development Programme
Tel 51-58-44
15-41-70
Addis Ababa

Samaritan's Purse
INTERNATIONAL † RELIEF

255.5-99 CW-17593

USING THE WATER FROM YOUR CWF ________ 49
Storage ________ *49*
Drinking ________ *50*
Cooking and Cleaning ________ *50*
Personal Hygiene ________ *50*
Potential for Improved Quality of Life ________ *51*
When Health Doesn't Improve ________ *52*

REFERENCES ________ 53

APPENDIX A: PRACTICAL APPLICATIONS ________ 54
Well Construction ________ *54*
Rainwater Capture and Storage ________ *55*
Privy (latrine) Planning ________ *55*

APPENDIX B: USEFUL EQUIVALENTS & FORMULAS ________ 57

TABLE OF CONTENTS

SAMARITAN'S PURSE GUIDE TO THE CANADIAN WATER FILTER — 8
- *Introduction* — 8
- *The Manual: A Work In Progress* — 8

THE WATER CYCLE — 9
- *Introduction* — 9
- *A Human Perspective: Our Place in the Water Cycle* — 11
  - Water Use — 11
  - Water Pollution — 12

DRINKING WATER QUALITY — 13
- *Physical Quality* — 14
  - Turbidity — 14
  - Color — 14
  - Taste and Odor — 15
  - Temperature — 15
- *Chemical Quality* — 15
- *Radioactive Quality* — 18
- *Biological Quality* — 18
  - Non-Pathogenic Organisms — 19
  - Pathogenic Organisms: Water-Related Disease — 19
    - Macro(visible)organisms — 21
    - Micro(invisible)organisms — 21

WATER SOURCES AND SOURCE PROTECTION — 22
- *Urban Supplies in the Developing World* — 22
- *Rural Supplies in the Developing World* — 24
  - Description and Evaluation — 25
    - Rainfall Capture — 25
    - Groundwater — 25
    - Surface Water — 26
  - Source Protection — 28

WATER PURIFICATION PROCESSES: DESCRIPTION AND EVALUATION — 29
- *Methods of Separation* — 29
- *Methods of Inactivation* — 29
- *Sand Filtration* — 30

THE CANADIAN WATER FILTER (CWF) — 30
- *Introduction* — 30
- *The Rules of Design and Use* — 31
- *Effectiveness, Appropriateness and Limitations* — 31

CONSTRUCTION OF A HOUSEHOLD CWF — 33
- *Concrete Model* — 33
  - Preparation — 33
  - Concrete Pour — 35
    - Preparing Concrete — 35
      - *Cost of Concrete* — 36
    - Pouring Concrete — 36
  - De-Molding — 37
  - Diffuser Plate and Filter Lid Construction — 38
  - Filter Installation — 39
    - Finding Gravel & Sand — 39
    - Sift & Clean — 40
      - *Sand Information* — 41
    - Installation of Sand and Gravel — 41
  - Operation — 42
  - Maintenance — 43
      - *Table for Recording Maintenance* — 44
  - Additional Operation and Maintenance — 44
    - Decommissioning the filter — 44
    - Moving the filter — 44
    - Repair — 44
- *The "Found" Filter* — 45
  - Preparation — 45

EVALUATION OF A CWF — 48
- *Flow Rate* — 48
- *Biological Layer* — 48
- *Physical Appearance* — 49
- *Water Quality Test: The Presence of Coliform* — 49

INTRODUCTION

This training workshop is designed to provide a basic understanding of the principles related to water quality and an expert understanding of the principles of design and construction of the Canadian Water Filter. *Most* of the concepts the workshop will cover are accessible to any person of any level of education, but the manual has been written with certain educational presumptions. The manual is not designed to be accessible to all people of all levels of education. It is a technical manual intended to transfer a body of expert knowledge to capable individuals. It is meant not to educate but to train individuals to educate. It is hoped that materials will soon accompany the manual, which will directly facilitate a process of public education and community participation. In the meantime, some of these considerations will be discussed in the practical component of the course.

Dr. David Manz developed the CWF design while at the University of Calgary. Samaritan's Purse is using the design with permission under specific guidelines. Essential to the agreement between Dr. Manz and Samaritan's Purse is the guideline to promote and maintain the integrity of the design as developed by Dr. Manz. This means that we have agreed not to alter the design of the CWF in such a way as will undermine its intended use or misrepresent the inventor. By the end of this course it will be clear why this guideline is essential, which alterations represent creativity, and which alterations represent departure from the CWF design. It is expected that all participants in the training workshop will understand, respect, and abide by this agreement.

THE MANUAL: A WORK IN PROGRESS

The manual is designed to be a *reference source* for a practical workshop. It cannot independently perform the task of transferring the CWF technology. Much of the technique required for producing and maintaining a CWF can only be gained through experience. As will become quickly evident in the workshop, there is much more to building this water filter than following a set of directions.

The manual also serves as a set of guidelines, a way to know if you have wandered to far away from the design principles, which make the CWF work. Much emphasis will be placed in upcoming pages on certain design principles. If the design principles are ignored not only will the filter you construct fail, it simply will not be a CWF.

The manual also provides the means of tracking filter construction cost and efficiency, filter performance, and filter maintenance in an effort to introduce some basic concepts of small-scale production. The more you invest in tracking methods and costs the more you will learn about the filters and the better you will be able to pass your experience on.

Finally, it is important to recognize that the manual is a *work in progress*. This is the first workshop it will be used in and it will likely see some significant revisions after this first run-through. Since it is a first edition we invite constructive remarks, suggestions, and insights into its accuracy, appropriateness, clarity, and content. Keep track of your remarks throughout the workshop for discussion at the end.

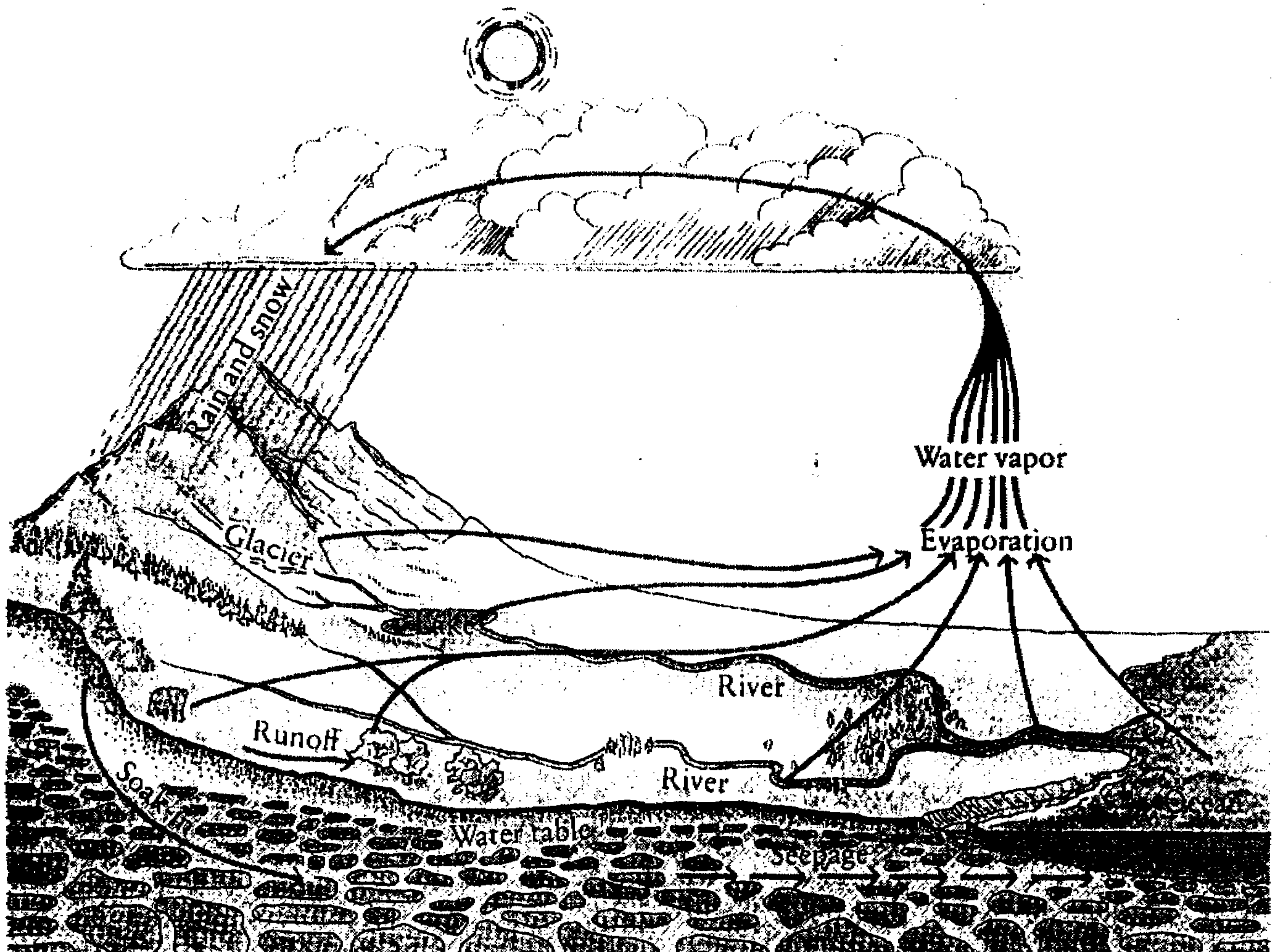
THE WATER CYCLE

INTRODUCTION

The water cycle is a continuous process powered by the sun in which water travels between the surface and atmosphere of the earth. Water evaporates from oceans, lakes, rivers, and on a smaller scale, from soil surfaces and the bodies of organisms. This water vapor accumulates, or condenses, in clouds and returns to the earth's surface by precipitation in the form of rain or snow.

By far the greatest amount of evaporation and precipitation takes place over the ocean, as it constitutes ¾ of the earth's surface. So, we often describe the water cycle with the ocean as a reference point. That is, we define the water cycle according to the movement of water into and out of the ocean. Water leaves the ocean by evaporation and, for the most part, returns directly by precipitation. Some of this water, however, falls upon land surfaces. This water flows over or through the ground (or evaporates) and returns to the ocean completing the cycle. So, with respect to the ocean the water cycle consists of two possible pathways. In one, water travels between ocean and atmosphere. In the other, water travels between ocean, atmosphere and land.

It is within this model of the water cycle that we can best examine the naturally occurring processes of filtration. In the ocean, water contains much more than H_2O molecules--most notably salt. In the process of evaporation, however, it is mostly only these H_20 molecules which vaporize and enter the atmosphere. When water evaporates from any surface, be it a lake or the leaf of a tree, this is true. So, the first method nature uses for purification is evaporation. When water vapor returns to the earth as rain or snow, it again combines with many other particles. As it flows down a hillside, for instance, it may combine with leaves, dirt and many unseen substances. Much of this water flows over land, eventually making its way to the ocean; we call this surface water. Some sinks into the ground (a process called percolation) and fills pockets of space in the earth's upper rock layer; we refer to this as groundwater. We call the level where this water collects the water table. As surface water seeps into the ground toward the water table the surrounding soil traps most of the particles (whether dirt, or unseen substances). The farther water travels through the ground, the cleaner it becomes.



The Water Cycle

Since water is present in all living organisms, we can define the water cycle according to the movement of water into and out of any living organism. However, if we included the entire living world in a model for the water cycle it would be immensely complicated and nearly impossible to comprehend. And yet, the two basic components of evaporation and precipitation do not sufficiently explain the multitude of change water, or bodies of water, may undergo within the water cycle. Rather than catalogue all the possible pathways water may take and the changes it may undergo, we will limit our focus to the role humanity plays in the water cycle.

A HUMAN PERSPECTIVE: OUR PLACE IN THE WATER CYCLE

Water Use

Of the earth's water, more than 99% is unavailable or unsuitable for beneficial human use because of its salinity or location. Oceans constitute about 97% of the earth's water, glaciers and ice caps about 2%. The fraction of a percent that *is* available for human use nonetheless represents a massive resource. For example, by the year 2000 world use of water is expected to reach 6000 km^3/yr, and yet the total average annual runoff *just* from rivers is approximately 48,000 km^3. On a global scale total water supply is not a problem; the problem is water's availability in the right place at the right time. Water's distribution between continents, between inhabited and uninhabited regions, and between geophysical locations varies greatly. Lakes and rivers constitute a volume of about 125,000 km^3, shallow groundwater (to 800m) a volume of 4 million km^3. Runoff in North America is half that of South America but still 20 times that of Australia. Nearly half off all runoff occurs in uninhabited or sparsely populated regions. [Botkin:372-73]

These factors of location and quality shape how humans enter into the water cycle. Our place in the water cycle is defined according to our effect on the availability, distribution, and quality of water. We derive our water supply from a variety of sources. Cities are generally served by central water plants which process water from major sources, such as a large rivers, lakes, or reservoirs and distribute the water through pipe systems. For the most part water is sufficiently treated for contamination before the distribution stage and is safe for drinking. However, the treatment process can fail and in many cases the distribution process contaminates processed water. In either case, the water may or may not be safe for drinking. Since, in this kind of supply system, consumers have no direct contact with the water source or the filtration process they are less likely to question the integrity of either. This lack of awareness is the hidden danger of the water supply in all cities, regardless of country, technology or wealth.

In rural settings, communities get their water from a variety of sources. Rain water basins, springs, rivers, lakes and wells are the most common. Sometimes water is piped from one of these sources into homes or to a community stand-post. Frequently, water is carried by pail from the source to its point of use. Rural consumers are generally in direct contact with their water source and are responsible for both the filtration and contamination of their water supply. Where there is no community water and sanitation program, collection and filtration are up to the individual. In this case, individuals exert the greatest amount of personal influence (good or bad) on the quality of their drinking water.

Regardless of where we live and the type of water supply that serves us, there are basic things we all need water for. Drinking, although it generally makes up the smallest percentage of our water use, is the most important to our good health. All the processes that go on in our body to support life and keep us healthy are dependent on water. We also need water for washing our bodies, clothes, household utensils, and food; for cooking; for irrigation and livestock. It is the most essential component of our life and all the life around us. Since water may contain harmful substances, which can cause sickness and even death, our drinking water needs to be clean and safe. We need to have *enough* water on hand to meet these basic needs. In determining or developing our water supply we should know the amount of water that is required to meet our basic needs. What is the distribution of water use in our own lives, our families, and our communities?

Our water supply *must* be able to meet our basic needs. In addition to these survival needs, industry requires a great deal of water to function. This water does not need to be of drinking quality, but it still needs to be relatively clean and safe. When we use contaminated water for irrigation, for example, the contaminants deposit on the crop and eventually find their way back to us.

In all our water use we alter its quality or composition in some way. The water we drink carries our body's waste products out with it. Water used for washing and irrigation carries soap, dirt, chemicals and fertilizers. When water leaves our lives it almost always carries something new, which it did not carry before. In some cases the natural filtration processes of the water cycle (evaporation and percolation) can amend these alterations. However, contamination frequently exceeds the capacity of these natural processes or it occurs after they have taken place. In many cases, by the time water returns to us through the cycle it is still contaminated. The water must then be filtered and sterilized. If we continue to use water in a contaminated cycle it will lead to sickness.

Water Pollution

Our use of water comprises only part of our place in the water cycle. Without even using water, we contribute massive amounts of pollution to the water supply and have a great impact on the quality of water throughout the entire water cycle. Oceans, lakes, rivers, rain, and groundwater are all affected by human pollution.

Surface waters, by acting as natural drainpipes for our communities, are a very common target for pollution. Sources of surface water pollution are usually described as either point or non-point. Point refers to a confined and singular source, such as a waste pipe from a home or an industrial plant. Non-point sources are pervasive and intermittent, such as city-street or agricultural run-off during heavy rain—they are difficult to control.

Groundwater is often polluted by fractured sewer lines, septic systems or latrines, landfills, and mining by-products. Very often, groundwater pollution is difficult to prevent or recognize because the source of contamination is not observable.

There are certain contaminants nature's filtration process cannot remove and others that it can. Either way, nature often cannot purify water in time to meet human demand. To keep pace with our needs, we usually must turn to additional means of purification.

DRINKING WATER QUALITY

For water to be beneficial for drinking it must be of a certain quality. We assess every glass of water we drink using our senses. We can observe color, turbidity, odor, taste, and temperature. These are physical characteristics. Although these observations may indicate the presence of undesirable substances, they cannot reveal the exact composition of water. To determine the exact qualities of any sample of drinking water requires scientific instrumentation and trained technicians. Unfortunately, these kinds of resources are often not available because they are costly. Even without the use of scientific instrumentation, we can come to some conclusions about the quality of our drinking water using our sensory observations along with an understanding of the water cycle and water sources.

Water quality is evaluated using physical, biological, chemical and radioactive criteria. The sum of all these criteria constitutes the overall quality of any water supply.

PHYSICAL QUALITY

As mentioned before, the physical qualities of water are things we can usually measure by our own senses with some degree of accuracy. Sophisticated equipment is available which can quantify physical characteristics into units of measurement. For the most part, however, our senses can tell us all we need to know. In general, if turbidity, color, taste and odor are not present and if water is cool the water has good physical qualities.

Turbidity

Turbidity is the degree of cloudiness in water due to the presence of sediment and other non-soluble particles. Particles that are held in water but do not dissolve are referred to as *suspended*. Natural and agricultural run-off is the primary contributor to turbid conditions in drinking water. Sediment consists of rock and mineral fragments, which range in size from 2mm to the finer particles of silt and clay. By volume it is the greatest water pollutant [Botkin:393]. In low amounts sediment is not harmful in and of itself although it obviously affects the taste and appearance of water. Sediment does, however, improve viability for microorganisms and can stimulate the growth of bacteria [WHO, 1993:124]. It does this by serving as attachment points for microbes and by shielding them from disinfecting chemicals, such as chlorine. The more turbid a water source, the more likely it is that significant populations of microorganisms are present. Since microorganisms are the primary source of water-related diseases, we must be wary of anything that contributes to their survivability. However, when water has a low or no turbidity it is not necessarily microbe free—particles are not necessary for microbe survival. In some instances the substance responsible for turbidity is itself harmful, such as non-soluble toxic chemicals.

Color

The color of drinking water is usually caused by the presence of colored organic matter found in soil. The presence of iron and other metals, either as natural impurities or as corrosion by-products, strongly influence color as well. Contamination by industrial waste may also effect color and color may therefore be the first indication of a hazardous situation. Color is particularly important to investigate when a substantial or sudden change takes place. [WHO, 1993:123]

A brown or orange color in water, not related to sediment, may be caused by iron (in the form of ferrous hydroxide) or by the source water having run over tree (not teal) leaves. When manganese present in water is exposed to air it turns black which may result in black stains on a basin or some similar effect. Likewise, blue-green stains in a basin signify the presence of copper in water usually caused by copper plumbing [Symons:18-19].

In most cases the element causing the color change is not present in high enough concentrations to pose a hazard to health.

Taste and Odor

Taste and odor arise from natural sources and biological processes, from contamination by chemicals, and from by-products of water treatment. They may also develop during storage or in the distribution process (from pipes). Both may indicate some form of pollution or a malfunction in water treatment or distribution. Therefore the cause of tastes and odors, especially when change is sudden and substantial, should be investigated [WHO, 1993:123].

Algae, which grow in many surface water sources, may cause unpleasant tastes and smells. The odor of rotten eggs is caused by hydrogen sulfide. Chlorine is usually present in treated water and has a distinct taste. In each of these instances, there is almost always no health threat. [Symons:17].

Temperature

Cool water is generally more palatable than warm water. High water temperature enhances the growth of microorganisms and may increase taste, odor, color, and corrosion problems [WHO, 1993:123-24].

CHEMICAL QUALITY

Abel Wolman, a famous water engineer, said water is $H_2O + X$ and that the *X* has occupied and preoccupied waterworks people for years. It will continue to occupy them plus toxicologists, physiologists, occasionally nutritionists, and from time to time health *faddists and "crackpots" for years to come* [Chanlett:79]. When *X* represents a necessary or beneficial element or mineral, such as sodium, there is no cause for alarm. In fact, this would contribute to a positive rating of water's chemical quality. When *X* represents a toxic chemical or a beneficial chemical, such as chlorine, in too high a concentration water's chemical quality becomes hazardous.

The chemical quality of drinking water is a significant issue in both rural and urban settings: rural because many agricultural products find their way into the water supply; urban because industry and domestic waste are major contributors to water pollution.

There are many toxic chemicals, which may find their way into the water sources. Some are naturally occurring, such as arsenic, radon, radium and selenium. Others are introduced to water sources through human industry. Nitrogen, phosphorus, and pesticides,

Selenium	0.01	Recognized occupational poison and cause of livestock poisoning where Se exceeds 3-4 mg/kg of food intake; high in soils and crops in some localities in north-central US	Definite symptoms of poisoning via water have been identified; trace amounts believed essential for nutrition; mild poisoning in man in high-Se areas observed.
Silver	0.05	To limit additions of silver for disinfection; silver retention causes argyria, the blue-gray discoloration of the skin, eyes, and mucous membranes.	Man retention data are based on therapeutic use of silver compounds; drinking water limit calculated from 1 g total of body burden which produces argyria.

This next table identifies chemicals for which the U.S. gives desirable limits [Chanlett:82].

Substance	***Conc mg/l***	***Reason included***
Alkyl benzene sulfonate (ABS)	0.5	A nonbiodegradable component of synthetic detergents which persists through ground percolation and sewage-and water-treatment processes; foaming usual at 1mg/l.
Arsenic	0.01	A desirable limit; rejection limit 5 times this amount.
Chloride	250	Proximate to salty taste threshold; sudden increases due to sewage.
Copper	1	Essential and beneficial for metabolism; taste threshold varies from 1 to 5 mg/l; limit prevents unpleasant taste.
Carbon chloroform extract (CCE)	0.2	CCE conc. Include part of the total organics in water, taste producers, toxicants, carcinogens and wastes; water at 0.2 limit is already of poor quality.
Cyanide	0.01	A desirable limit; rejection limit 20 times this.
Iron	0.3	Essential and beneficial for metabolism, but water cannot meet the 7-35 mg daily requirement; proximate taste threshold, 2mg/l;stains fixtures and white goods at 1mg/l
Manganese	0.05	Staining of white goods by MnO_2 deposits, off flavors in beverages; limit close to the attainable removal from most waters; probably an essential nutrient with 10 mg daily intake in food; toxic on inhalation.
Nitrate (as NO_3^-)	45	Private well waters with nitrates of 67-1,100 mg/l have produced methemoglobinemia in infants on milk formulated with such waters; no cases on public water service in US. Warn for infant formulas when nitrates exceed 45 mg/l.
Phenols	0.001	Reaction products of phenolic compounds with chlorine cause objectionable tastes and odors.
Sulfate	250	Laxative effect at 600-1,000 mg/l when magnesium and sodium are the cations.
Total dissolved solids	500	Taste and laxative effect the restraint; excess dissolved minerals in water result in poor brews of coffee.

for example, are a result of urban and agricultural runoff. Human pollution has effects on both surface and ground waters. Naturally occurring chemical contaminants are generally only present in groundwater supplies. [Symons:21-28]

The chemical quality of drinking water is so important because of the relationship it has to our health and the health of every living ecosystem, every system which requires water. We encounter health problems when the *X* in water is toxic. Chemicals are referred to as being in *solution*, rather than *suspension*, because they are dissolved in water. When water is ingested the *X* may be drawn out of solution and adsorbed through the digestive tract and into the bloodstream. In some cases, simple contact with the *X* in H_2O is harmful. The following table lists some of the toxic substances that are the basis for water supply rejection in the United States [Chanlett: 80-81].)

Substance	***Rejection Concen-tration (mg/l)***	***Reason for Inclusion***	***Comment***
Arsenic	0.05	Recognized poison; chronic effects, carcinogenic in some contacts, food intake contributory	Skin cancer high in areas of England with 12mg/l in drinking water. Not essential or beneficial.
Barium	1.0	Recognized toxic effects on heart, blood vessels, and nerves from accidental, experimental and therapeutic ingestion	Water standard derived from occupational exposure inhalation limit. Not essential or beneficial.
Cadmium	0.01	Acute Poisoning in man via foods, increased conc. in kidney and liver of rats on water with 0.1-10 mg/l	Individuals on water with average of 0.047 mg/l had no symptoms. Not essential or beneficial.
Chromium as hexavalent ion	0.05	Carcinogenic on inhalation; cumulative in rat tissue at level of 5 mg/l in drinking water; no toxic responses in rats for 1yr. At conc. Of 0.45-25 mg/l	No observed effect of single exam on family of 4 in 3 yr on water up to 1 mg/l. Not essential or beneficial.
Cyanide	0.2	50-60 mg fatal in single dose; 3-5 mg/day non-injurious; 10-mg single dose not injurious	Lethal to trout at 0.2 mg/l in 2 days; toxic limit for bluegill and sunfish close to 0.2 mg/l; chlorination converts cyanide to cyanogen chloride, which has 1/20 acute oral toxicity of cyanide.
Lead	0.05	Recognized poison with daily intakes with food, water, air, and inhaled tobacco smoke. Balance maintained at total intakes of about 0.3-0.4 mg/ day.	Intakes of 8-10 mg/l in water for several weeks are in the harmful range; poisoning reported from water varying from 0.04 to 1 or more mg/l; conc. As low as 0.1 mg/l is injurious to fish

Zinc	5	Essential and beneficial in metabolism with daily intake of 10-15 mg; emetic action ... at 675-2,280 mg/l; with zinc salts, milky at 30 mg/l and metallic tastes at 40 mg/l. Limit is below taste threshold.
Fluoride	0.7 0.9 1.2	Lower *Recommended limits in mg/l at 17.6-22.0 °C Optimum Upper

As the information in these tables demonstrates, the good chemical quality of water is not determined simply on the absence of all substances. As mentioned above, *X* can be beneficial. Some substances are toxic at any concentration, others have a range in which they are beneficial. Some substances, such as chloride, are part of water treatment processes while others are components of household wastes. The sources, toxic effects, and common concentrations of just these few substances could easily occupy a whole field of science. Measurement of many of these substances in any given water supply with any regularity is very costly and requires trained technicians and laboratory facilities. Money, trained technicians, and laboratories are in short supply, to say the least, in the rural countryside of the developing world.

In almost all cases the *X* in H_2O is impossible to observe using our natural senses. However, as we will discover when we discuss water sources, some clues about the chemical quality of water may be ascertained without laboratory analysis. We can make these educated guesses based on *peripheral* information, such as the history of a water supply, knowledge of contamination sources, and the typical characteristics of each water source. We must keep in mind, that this kind of guesswork is *very* limited, however helpful, and is not a suitable replacement for proper chemistry. Along side of nothing, however, it is a worthwhile resource.

Radioactive Quality

All exposure to and intake of radioactive substances are injurious. All uses of radioactive materials result in some small traces being released into the environment [Chanlett:87]. The presence of any radioactive substances in drinking water is not observable using our own senses. If a water source is known to have any radioactive content it should not be used.

Biological Quality

Water contains a diverse population of living organisms. The larger a body of water the greater and more diverse is its biological population. Most organisms present in water are *native* to the water environment but many are not. Some organisms are *visible* and others *invisible*, some are *harmful* and others *harmless*. The organisms of greatest concern in determining biological quality are those responsible for disease which are not naturally present in water and are spread by water use. Other organisms are a concern because they effect taste and odor.

⛏ Non-Pathogenic Organisms

Some organisms adversely effect water quality without being pathogenic (disease-causing). The presence of organisms in excessive numbers can result in changes in taste, odor, and appearance. The growth of certain organisms may also cause operational problems, such as clogging a well screen or pump. Others serve as indicators of the presence of harmful organisms. The following table is a catalogue of non-pathogenic organisms of concern in water quality. [Chanlett:77]

Organism	*Occurrence*	*Reason for concern*	*Comment*
Mold-like bacteria	In raw water impoundments; in distribution systems	Cause undesirable tastes and odors	Localized problem; spores pass filters
Algae	Raw water impoundments	Undesirable tastes and odors; reduce filter runs	Seasonal variations and "blooms"
Coliform	Surface waters and those receiving faeces	Measure of faecal contamination	The index for hygienic quality of water
Crustacea	Mostly in zone of recovery of polluted streams	Reduce filter run; may get to tap	Can transmit guinea worm larva
Faecal bacteria	Waters receiving human faeces	Indicates faecal contamination	Alternate to coliform index
Iron bacteria	Ground and surface water containing iron	Produces slimy often red growths; clogs well screens	Levels of 0.1-0.2mg/l of iron sufficient for growth

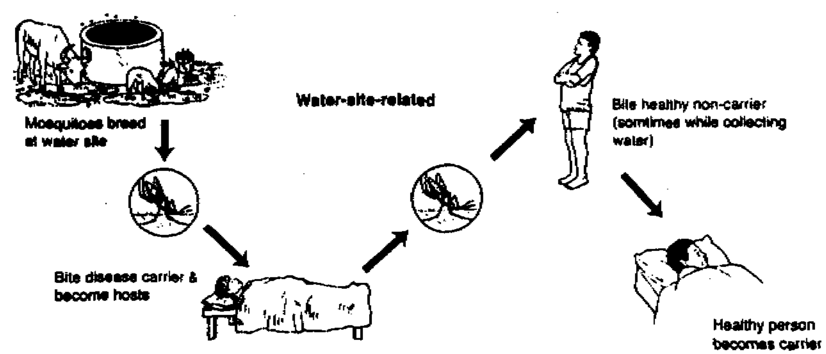
⛏ Pathogenic Organisms: Water-Related Disease

According to the World Health Organization(WHO), unsafe water is the cause of 5 million deaths and 500 million disabling diseases annually, worldwide [WHO, 1992]. Pathogenic microorganisms—disease causing germs not visible to the naked eye—are responsible for the majority of these diseases and deaths. In considering the pathogenic content of water, we will also discuss diseases that are related to water use and water collection

The following classification of water-related diseases is helpful in understanding the different pathways pathogenic (disease-causing) organisms may take in causing human infections. [Watt:28-29]

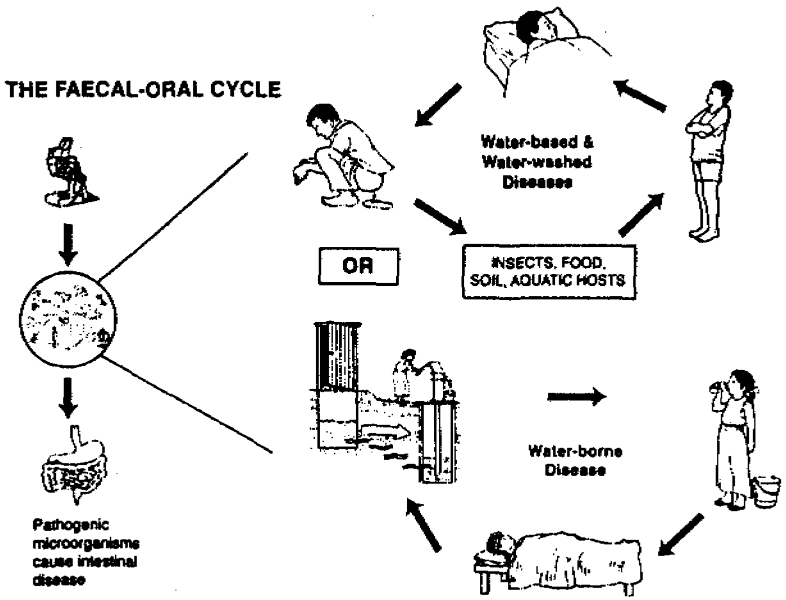
A) Waterborne diseases: those that may be *carried in water* and infect consumers. Includes cholera, dysentery, typhoid, and hepatitis. Almost always a result of faecal contamination.
B) Water-based(parasitic) diseases: where the organism causing the sickness spends part of its life cycle in an *aquatic host*—for instance, guinea worm, which is transmitted to humans though broken skin.
C) Water-washed(filth-borne) diseases: diseases whose incidence would be reduced if ample water were available for *washing and hygiene*. Examples include tropical ulcers, scabies, trachoma, and infantile diarrhea.
D) Water-site-related diseases: spreads by *insects* that breed in water and eventually become vectors for human diseases. Usually contracted while collecting or washing in surface waters. River blindness, malaria, and sleeping sickness come under this heading

WATER RELATED DISEASES



Some water-related diseases, primarily those responsible for acute diarrheas, will not be eliminated by clean water alone because so many other agents are responsible for their transmission (for example, food or flies). Most forms of transmission, however, share common sources. Most sources of contamination are related to sanitation standards. Some examples include misplaced human and animal excrement and cross-contamination of water pipes by sewer lines.

THE FAECAL-ORAL CYCLE



Insects, animals, and humans, which serve as storage areas or reservoirs for pathogenic organisms, are called vectors. All domestic animals (dogs, swine, cattle, horses, etc.) may harbor populations of pathogens in their intestinal tracts. This is also true for animal pests (mice and rats) and wild animals. Another significant vector related to water is the insect. Many surface waters, especially stagnant waters, and even storage tanks serve as breeding grounds for mosquitoes. Therefore, malaria is considered a water-related disease. In this case water has an *indirect* relationship with the disease, as water doesn't actually carry the disease-causing organism. It is also associated because water collection and bathing often require an individual to habit mosquito-breeding areas, exposing them to a bite by a mosquito vector.

The contamination of drinking water by human and animal excrement is the primary source of water-borne diseases. We call the transmission of disease by water, where the source for the disease-causing microorganism is excrement, the faecal-oral route of transmission. This refers to the cycle that can persist between our own excrement and oral ingestion. The faecal-oral route is not, however, dependent on water for its persistence. If after going to the bathroom an infected individual does not wash his or her hands, a microbe may be directly transmitted to another. This happens most often between parent and infant. This would is an example of a water-washed disease as washing would have eliminated the possibility of transmission by direct contact.

¤ ***Macro(visible)organisms***

Some of the organisms associated with water-related diseases are plainly visible without the use of a microscope. These include parasitic worms and insects that breed in the water environment. In the case of a parasitic worm (such as the tapeworm), eggs produced by the organism are ingested orally and then grow in the intestine. Other macroorganisms attach directly to the skin causing local epidermal infections and can, as with schistosomiasis, be absorbed into the blood stream and complete their lifecycle within.

¤ ***Micro(invisible)organisms***

Microorganisms, although invisible, represent the largest portion of agents responsible for water related diseases. The microbial content of natural waters varies greatly with location and with time. Rain and snow contain only small numbers of microorganisms. As water seeps through the soil it picks up significant numbers of microorganisms, but many of these are gradually removed as the water penetrates deeper toward the water table. Groundwater generally has the lowest microbial content, and deep groundwater is often nearly devoid of organisms. Surface waters, on the other hand, usually have large populations of microorganisms, derived from the soil (as runoff), human pollution, and the native biology growing in lakes and streams. Microorganisms native to natural waters are not pathogenic (have no disease potential in humans) and are harmless when consumed in small numbers. Pathogenic microbes found in surface or ground waters are usually not capable of growth in these environments, but have reached these waters as a result of contamination by human activity. [Brock: 408]

Pathogenic microorganisms transmitted by water usually grow and multiply in the intestinal tract and leave the body in the faeces. When faecal material is not sufficiently isolated from the environment it may enter into the water supply where many of its pathogenic microbes can survive. If the water is not properly treated, these pathogens may enter a new host when the water is consumed. Since water is consumed in such large quantities, it may be infectious even if it contains only small amounts of a pathogenic organism. With some bacteria only a few cells are necessary to cause infection [Brock: 410]. However, a portion of faecal matter the size of a fingernail could easily contain a few hundred million pathogenic microbes—a number more than sufficient to cause disease if ingested. This means that any individual, even taking into account massive dilution in water, may excrete enough pathogenic microbes in a day to infect hundreds of new individuals.

Once ingested, these pathogens lodge in the intestine and multiply, resulting in infection and disease. Disease may result from several different processes. In some cases a pathogen is absorbed into the blood stream from the intestinal tract. At this point it may travel to another organ system and attack its cell population, as with the hepatitis virus, which attacks the liver. The destruction of healthy cells on a microscopic level eventually has macroscopic manifestations, called symptoms. Symptoms may be fever, weakness, pain, or a combination of these or many others. Other pathogens are not adsorbed in the intestinal tract, but affect the physiology of the intestine. In this case the primary function of the intestine to adsorb water and nutrients from food into the body is blocked or hindered, usually resulting in diarrhea.

WATER SOURCES AND SOURCE PROTECTION

URBAN SUPPLIES IN THE DEVELOPING WORLD

In urban areas of the developing world more than 40 percent of the population does not have access to piped water—no piped water on the premises in which they live, no piped water at a public outlet. The sources available to them are vendors, rivers, local impoundments, and dug wells. The following tables are derived from a study performed by the World Health Organization. The first represents 75 developing countries (about 320 million people) in Latin America, Africa and Asia. [Chanlett: 71-73]

	URBAN POPULATION SUPPLIED			URBAN POPULATION NOT SUPPLIED(%)
Region	*From house connections(%)*	*From public outlets(%)*	*Total served(%)*	
Africa	34	30	64	36
Latin America	60	27	87	13
Asia	18	25	43	57
Total (75 countries)	33	26	59	41

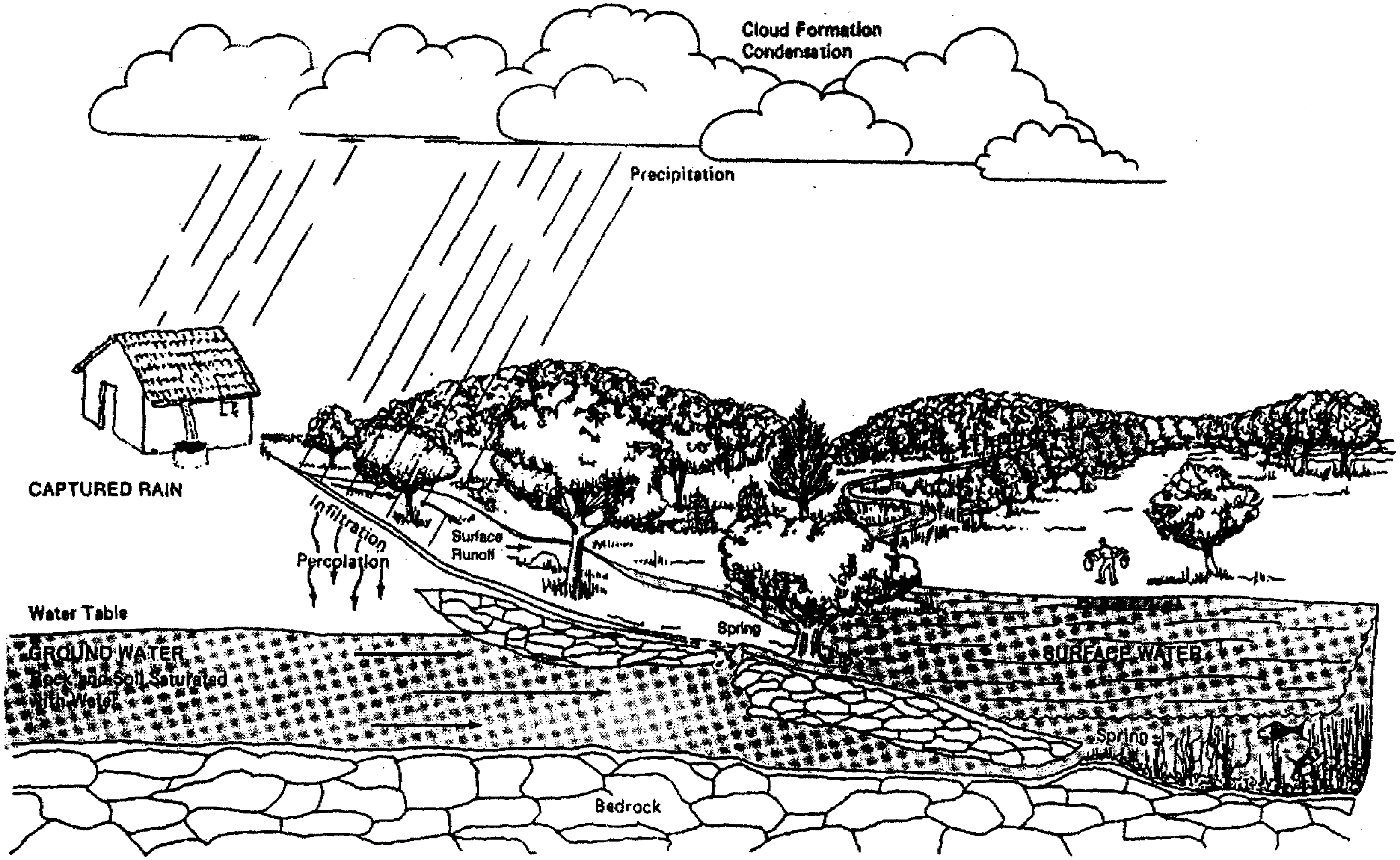
Since most of this piped water supply is intermittent (sometimes only 4-6hrs/day) people often store the water. Storage often negates any efforts made, up to that point, to provide water free of pathogenic organisms. For in storage any residual disinfectant dissipates and the water again becomes vulnerable to contamination. Moreover, once the distribution stops the pipe pressure created by the water ceases. The leak-rate of caste-iron pipes (laid with joints formed on site) is 100 to 500 gallons per day, per mile per inch of pipe diameter [Chanlett: 69]. When internal pressure ceases, contaminants are free to pass into the pipes through all these cracks. What is more, a negative pressure or vacuum may be created in the pipes causing a suction force that may draw in contaminants. This negative pressure is created when water distribution through the pipes is cut off and a connected draw is continued, or when individual connectors pump from the empty system and draw air rather than water..

This second table represents the urban water supply quality of 60 of the 75 countries. Only 12% or 7 of the 60 developing countries studied had "good" or "fair" water quality ratings; 88% were unsatisfactory or grossly unsatisfactory. [Chanlett: 73]

	Countries		Urban population	
Rating	***No.***	***% of total***	***No.***	***% of total***
Good	3	5	12, 080, 000	5
Fair	4	7	15, 020, 000	6
Unsatisfactory	33	55	121,040,000	49
Grossly unsatisfactory	20	33	97,100,000	40
Total	60	100	245,240,000	100

RURAL SUPPLIES IN THE DEVELOPING WORLD

We know from our discussion of the water cycle that all the freshwater available for human use arrives by rain. This rain may be captured and stored, runoff to the oceans, or seep into the ground. These three routes represent the three freshwater sources available to humankind.



WATER SOURCES

Description and Evaluation

¤ *Rainfall Capture*

Rainfall capture and storage produces water of high quality but usually variable quantity based on the rain cycle in any given climate. The impurities of captured rain are confined to the gases, vapors, and dust trapped during rainfall, and any substances washed from the capturing surface. In most cases, when a relatively clean capture surface is used, these impurities represent insignificant amounts. Biological and toxic pollutants are rarely present in detectable concentrations. Dissolved minerals are so low as to cause new users to describe cistern water as "flat". Quality deficiencies that may exist can be offset by wasting the first rainfall as flushing water, by providing particulate filters between the collecting surface and storage, and by disinfection.

Captured rain is an excellent alternative when surface and groundwater are seasonal or of low quality. In some cases it is used in conjunction with other sources. In areas of Southeast Asia the rain collection is part of a dual system of water use. It provides for immediate drinking and cooking needs. Bathing and laundering are done at the nearest stream or pond. Carrying the water from that point for cooking and drinking needs is postponed as long as the stored rain lasts through the dry spells. [Chanlett: 89-90]

Stored rainwater must be covered and should be stored in the shade. Covering keeps insects and animals out, both of which may carry disease, and keeps the water from becoming a mosquito breeding ground. Keeping the water in the shade and cool will hinder the growth of some microorganisms and prevent any sun-dependent biological growth (as algae). It is also very important to frequently clean and sanitize the storage containers.

¤ *Groundwater:*

Groundwater is of high biological and physical quality. The slow percolation and horizontal travel of water at only a few feet a day through the ground provides superb filtration removing all pathogenic forms, including viruses, and removing the causes of color, turbidity, and with a few exceptions, taste and odor. When it is a spring with gravity flow to the point of need or when it is a flowing well with sufficient pressure to pipe the water to the user without pumping, a groundwater source can even be convenient. In most cases, however, groundwater must be tapped into by boring or digging a well. Another attribute of a groundwater source is the ease and economy of protecting the withdrawal so that the high bacteriological and physical qualities are preserved.

¤ *Surface Water*

Surface water sources generally have the greatest ease of access and the highest degree of contamination. Its advantages and assets for water supply are:

- Easy access for shore and bank-located communities
- Quantity available can be observed and often predicted
- Impoundments can be used to even out flow variations
- Surface sources can be developed to provide large quantities of water for large populations

The deficits and limitations of surface water are:

- Rarely can it be used without treatment, a minimum being disinfection by chlorination
- Users below the point first use along a stream or river system must cope with all sorts of waste residuals from the point of first use
- On short stream stretches and from low volume impoundments there are flash changes in physical quality, particularly turbidity, requiring treatment adjustments
- Impoundments: subject to algae blooms, eutrophication, and stratification
- High quality water is usually very far from the largest population centers
- As quality goes down, the cost of treatment rises
- Difficult to protect because of exposure

The following table rates the various sources of water under usual conditions, prior to treatment. The ratings are as follows: "excellent, ready for use"; "good, not likely to require purposeful treatment"; "fair, likely to require purposeful treatment to attain drinking water quality"; "poor, with a few exceptions requires treatment to attain a high standard of quality". [Chanlett: 95, 97, 102]

Source	QUALITY FACTOR Bacteriological	Physical	Toxic Chemicals	Other chemicals	Hardness
Captured rain	Good	Good	Excellent	Excellent	Excellent
Groundwater	Exc	Exc	Exc	Fair	Poor
Surface water:					
Upland reservoir	Exc	Variable	Exc	Fair	Good
Lakes	Good	Good	Exc	Fair	Good
Rivers	Fair to Poor	Variable	Fair	Poor	Fair

This next table briefly accounts for the advantages and disadvantages of several water sources. [Brock: 409]

Source	*Advantages*	*Disadvantages*
Groundwater	Reliable supply, constant temperature	Limited quantity, water often hard
Dug well—shallow	Inexpensive	Undependable; easily contaminated
Drilled well—deep	More dependable, less contaminated	Expensive
Spring	Inexpensive	Often contaminated, water often hard, very limited supply
Surface Water	Inexpensive	Unreliable supply, temp varies, often contaminated
Rivers	Readily available	Often turbid
Lakes	Less turbid	Few good lakes
Reservoirs	Reliable supply	Expensive, excess algae growth
Captured rain	Soft water, uncontaminated	Unreliable supply, lack of storage
Cistern (under or above ground)	Easily polluted by runoff or catchment surface	Storage limited and expensive for large scale

We have discussed each of the sources, their advantages and disadvantages. In some cases they may be used in combination, in some cases there is only one useable supply. We now have the ability to generalize on the quality of water based on its source. Once our source or combination of sources is established the next step in attaining the highest quality drinking water is to protect the source.

Source Protection

In the rural setting we often passively rely on the protection supplied by nature's purification processes and do not take an active role in source protection. As we discussed above, nature's processes of filtration are almost always insufficient, mostly due to high loads of contamination, or futile because contamination occurs after purification. We must take the initiative of developing a system of our own to ensure our water is clean. The first step in this kind of system must be to protect and maintain the purity of the water source. The second step is to supplement natural filtration with our own devices.

The quality of our water, even when a filtration device is in place, is first and foremost related to source protection. Protection of the purity of our water sources has the greatest potential for improving water quality. Accepting methods of waste disposal and source protection because filtration systems will in the end render dirty water drinkable is self-destructive to the process of ensuring water quality.

All water sources are vulnerable to contamination, some more than others. Water contamination refers to a degradation of water quality as measured by biological, chemical, or physical criteria [Botkin: 390]. Sources are protected by blocking the entrance of contaminants into a water source and by isolating contaminants. Before contaminants can be blocked or isolated they must be identified. The most hazardous contaminants in the rural developing world are linked to human and animal feces. There is little skill involved in identifying sources of faecal contamination, but its isolation continues to be a significant obstacle. The isolation of contaminants is usually referred to as sanitation. The basic principles of sanitation are discussed further under "Privy Planning," in *Appendix A*.

Groundwater requires a high degree of protection because it is often used without chlorination or another disinfecting treatment. Wells must be located and constructed with their potential for contamination in mind. Waste disposal facilities must be a certain distance away. The well should preferably be capped. "Well Construction" in *Appendix A* considers in greater detail the basic principles of well design and protection.

WATER PURIFICATION PROCESSES: DESCRIPTION AND EVALUATION

For a long time we have recognized that the naturally occurring processes of filtration cannot keep pace with the great deal of waste we introduce into the environment. Over the last two centuries methods and technologies have been developed to treat and purify contaminated water. Of the technologies in use today, there are two main categories: those that *separate* contaminates from water and those that *inactivate* contaminates within water. This is meant to be a basic overview of modern filtration processes. Therefore it does not include all of the available technology. This section is intended to provide a reference point for evaluating the Canadian Water Filter.

METHODS OF SEPARATION

Filters that separate contaminants from water come in two basic designs. In one design water passes over an activated substance such as carbon or alumina. Certain contaminants adsorb to the molecules of this substance and water passes on. This is the basic design of many home filters in the developed world, such as the "Brita" filter. For the most part, these filters are intended to remove chlorine and other chemicals that affect taste.

Another method of separation is microfiltration. In this process water is forced by pressure or gravity through a filter which traps anything of a certain size and lets water pass through. A whole family of filters based on this principle exists. Some designs make use of ceramic candles, others of steel or cloth media with specifically sized holes. Some microfilters use a media with large holes to allow many substances other than water to pass through. These are often used in industry. For drinking water, a filter media is used with holes just large enough to let water through and still trap microorganisms and toxic molecules.

METHODS OF INACTIVATION

Another method for purifying water is to inactivate, or kill, any harmful biological content. Ultraviolet radiation and chemical disinfection are the most common means of inactivation. Ozone and chlorine are the most commonly used disinfecting chemicals. Chlorine is valued for it ability to remain in water throughout the distribution process for relatively long periods of time (referred to as a *residual effect*). Methods of inactivation are almost always used in conjunction with other filtration process because they have no effect on toxic chemicals or turbidity. In addition, turbidity interferes with chemical treatment by protecting microorganisms.

SAND FILTRATION

Sand filtration spans both of these categories because it involves, under certain designs, both separation and inactivation of harmful substances. When water is passes through a sand column, is acts as both a microfilter and an absorption surface. Some substances catch on the edges of the sand and some are trapped in the minute spaces between sand granules. In a slow sand filter, a biological layer develops on and within the top surface of the sand. This biofilm is predatory toward harmful biology in the water. Both the biofilm and the sand column have some ability to retain organic and inorganic toxicants. The Canadian Water Filter is based on the principles of slow sand filtration.

THE CANADIAN WATER FILTER (CWF)

Dr. David Manz teaching in Costa Rica

INTRODUCTION

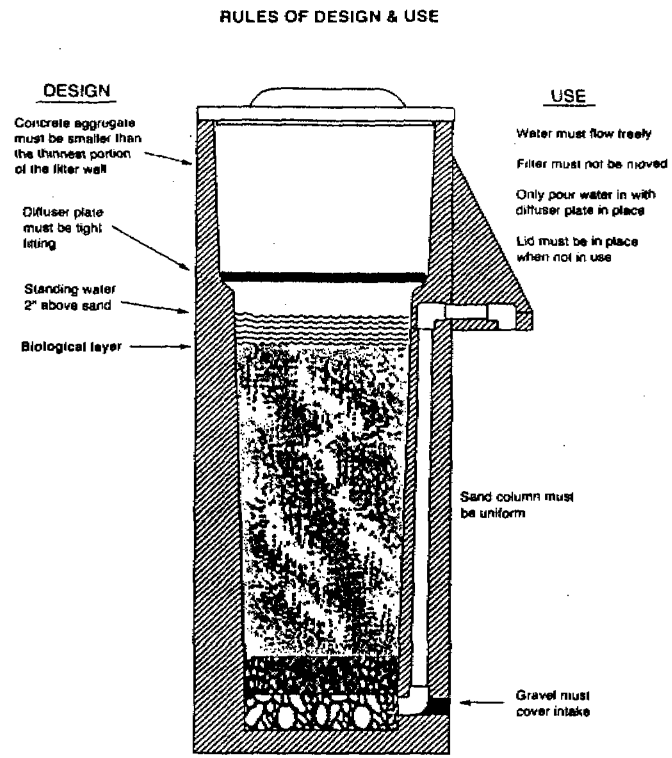
The CWF was invented and developed by Dr. David Manz, P. Eng., Ph.D. while at the University of Calgary. For many years slow and rapid sand filtration processes have been used in large-scale filtration plants to treat water supplies for larger populations. In some cases these sand filters are quite sophisticated and completely automated. They involve precise intake flow rates, pre-treatments such as flocculation, and back washing. All previous designs of slow and rapid sand filters required constant water flow for effective treatment and in most cases were used in conjunction with other treatments. By contrast the CWF is designed for household use, is simple, is effective on its own, and can be used intermittently. It requires no sophisticated technical expertise to build or maintain, uses materials available worldwide for minimal costs, and can easily last a lifetime. Most important, the CWF provides clean, safe, good tasting water.

The filtration processes employed by the CWF are the same as those discussed above in "Sand Filtration". Substances are *removed* from the water in the sand column either by adsorption or mechanical entrapment. The biological layer that forms on the upper surface of the sand column also consumes substances. What is unique about the CWF is its design to hold 5cm(2") of water above the top surface of the sand column while at rest. This allows the biological layer to be sustained in between use. Since the biological layer and the sand column are the two components that act as filters, they must be protected and maintained. If the sand column becomes clogged with fine silts, or the biological layer is disturbed, the filter will not produce quality water at an acceptable flow rate.

The CWF can be built from almost any plastic container over 80cm high, provided that the proper parts can be located. In addition, a steel mold has been designed to produce concrete filters. The top surface area size of the container determines the rate of filtration or flow—approximately 10 liters per minute per square meter. Household filters are designed to filter 1 to 3 liters of water per minute.

THE RULES OF DESIGN AND USE

In the construction, use, and maintenance of all CWF's, certain rules use must be followed for the filter to work properly. If they are not, it either will not yield and adequate flow rate or it will not yield clean, safe water. In the construction of any model, things cannot be assembled on a 'more or less' basis. Where specific directions are given, they must be followed. In using the CWF, care must be taken to preserve the integrity of the sand column and the biological layer. Performance of the filter must be monitored and when necessary, maintenance performed. This manual attempts to provide a rationale for all of the design criteria. These rules of design and use are summarized in the opposite diagram. The success of every filter is dependent on upholding these principles.



EFFECTIVENESS, APPROPRIATENESS AND LIMITATIONS

When constructed and used properly the CWF is exceptionally effective in removing nearly all water contaminants, especially those disease-causing microorganisms associated with the faecal-oral cycle discussed above. In principle, the more biology the water entering the CWF contains the more the biological layer (which feeds on these organisms) will grow and the higher the filter performance will be. In a recent study of 56 filters operating in Valle Menier, Nicaragua the CWF was shown to yield an average removal rate of faecal coliforms (bacteria indicating faecal contamination) of 97.00 percent, ranging from a low of 86.67% to a high of 100.00%.

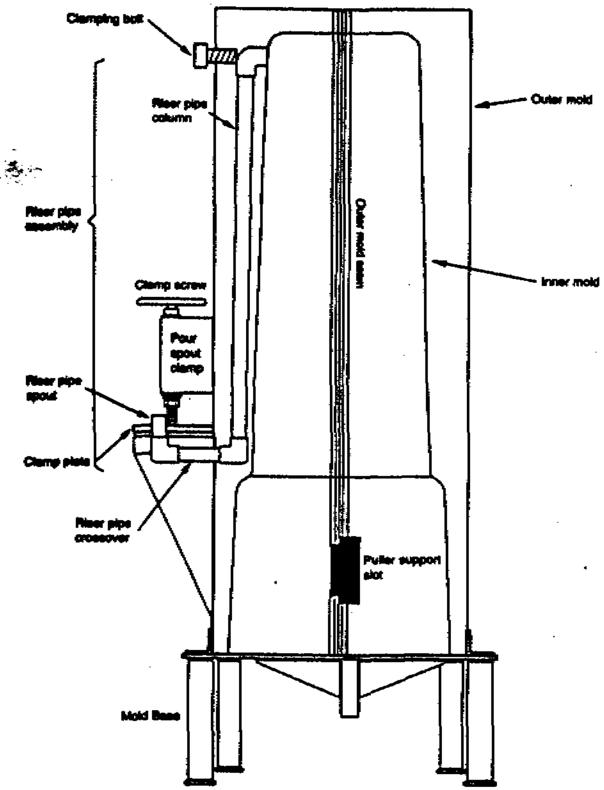
Some of the water sources within this community contain contamination in the range of 10, 000 fcb colonies/100mL. [Manz, Buzunis]

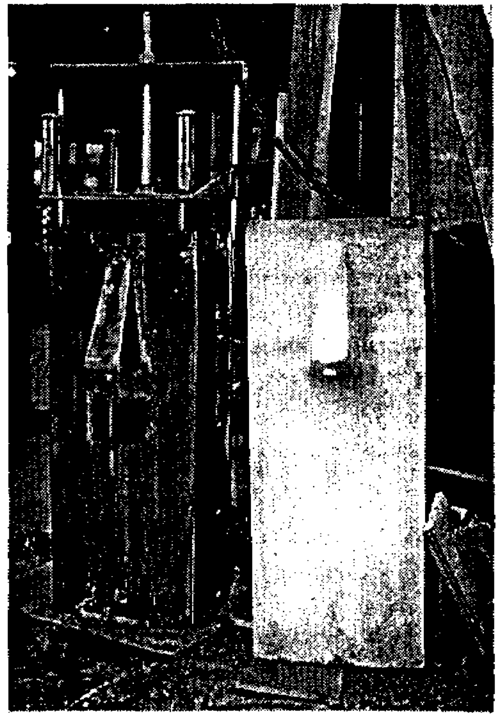
Unlike most modern methods of filtration, the CWF is not limited in the developing world by such things as high cost, lack of materials and lack of technical expertise. None of these things, which typically disable water projects of all types, apply to the CWF. The only limitation is the availability of *people* to teach the principles of use and construction and to organize the basic supplies required for construction. The technology of the CWF is appropriate anywhere, rural or urban, where the sources for drinking water is compromised or suspect.

The one significant limitation on the performance of the CWF, as with every filter design, is the turbidity of the source water. If the source water contains large amounts of fine silts and other fine particles not digestible by the biological layer, the sand column will eventually clog and the flow rate will decrease. Unlike any other filter design, however, when flow rate slows due to this clogging the quality of the filtered water is not compromised. When a microfiltration filter clogs, or when all the adsorption space on an activated carbon filter is occupied, these filters no longer provide safe, clean water. Moreover, in the absence of a regular testing program it is impossible to know with much certainty when these filters are working properly. When the flow rate of a CWF diminishes you know it is time to maintain the filter.

CONCRETE MODEL

The concrete model of the CWF is currently designed to be cast in a steel mold, although an aluminum mold is being developed. Steel molds and the technical drawings for their manufacture are available through Samaritan's Purse. When studying the following diagrams and instructions, take note of how each of the criteria for design and use are met.





PREPARATION

Materials

- tape measure / measuring stick
- pencil
- saw (to cut PVC)
- wrench set (for mold)
- lard (or other edible oil)
- PVC primer/cleaner
- PVC cement
- approx. 80cm(31in) ½"(13mm) PVC pipe

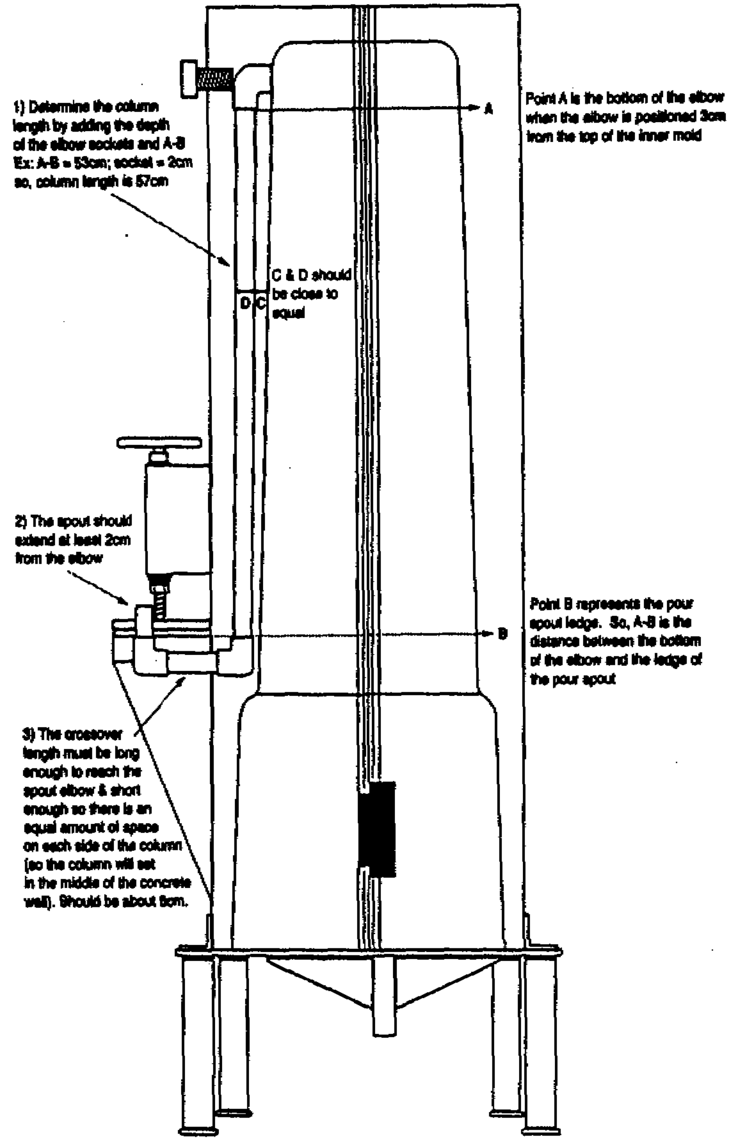
Study the diagram of the mold assembly and be familiar with each of its parts.

- ❑ Stand the fully assembled mold upright, base down.
- ❑ Determine the measurements for the three sections of the riser pipe assembly. See opposite diagram for method.
  - Column: cm / in.
  - Crossover: cm / in.
  - Spout: cm / in.

__Note__: this only needs to be done once, for the first filter cast in any given mold. So, write down the measurements here and note which mold they apply to.

- ❑ Obtain the following items for the riser pipe assembly: **cost/source**
  - (3) ½"(13mm) PVC elbows (all socket)
  - (1) riser pipe column [cm / in.] – ½" PVC pipe
  - (1) riser pipe crossover [cm / in.] – ½" PVC pipe
  - (1) riser pipe spout [cm / in.] – ½" PVC pipe
- ❑ Assemble the riser pipe and check for fit. If the fit is good, clean the connections with primer/cleaner and cement them together **__except__** the spout. Make sure the entire assembly is in line. Connect the spout but do not cement it so that it may be removed later.
- ❑ Disassemble the two halves of the outer mold and lie them on the ground. Using lard or another edible oil, generously coat every surface of the inner mold and the inside of the outer mold. Also grease the clamping bolt. If this is not done the concrete will stick to the molds and will be impossible to remove without damaging the filter.
- ❑ Leaving the outer mold flat on the ground, ensure the rubber gaskets are in place and reassemble the mold. The bolts need to be snug, but not excessively tight. You want to avoid causing the gaskets to bulge into the mold. Lift the outer mold over the inner mold and ensure puller-support slots line up. Tighten the base bolts well.
- ❑ Locate the riser pipe as shown in the previous diagrams and secure it to the surface of the inner mold using the clamping bolt.
- ❑ Check the mold assembly to ensure it is level.

Riser Pipe Assembly



CONCRETE POUR


Mixing Concrete

Materials

- cement, sand, gravel, water
- bucket
- shovel
- mixing tray/slab, or wheel barrel
- steel rod
- rubber mallet
- piece of wood (to use as a trowel)

PREPARING CONCRETE

If using pre-mix concrete, follow manufacturer's directions. If not the following proportions and suggestions should be followed. This is a precision casting, not a rough mix for sidewalk, or floor. That is why the recommended mix is rich in cement.

- ❑ Mix concrete using the following proportions:

1 unit volume of cement
1 unit of sand
1 unit gravel (1/2" - 3/4"; must not exceed 1")

- ❑ Mix in wheel-barrel or on any clean surface that can serve as a mixing tray. Spread the gravel on the mixing surface, then the sand evenly over the gravel, and then the cement evenly over the sand.
- ❑ Shovel all of it into a single pile on one side of the slab. Then turn the whole pile over again by shoveling it into a new pile on the other side of the slab. The whole pile has now been turned twice 'dry'.
- ❑ Flatten the pile, make a hollow at the top, and add water a little at a time. Turn the heap over twice as before, this time 'wet'.

Note: It is not possible to say how much water will be required as this depends on how moist the sand and gravel were before mixing. As a rough guide take a handful of the final mixture and squeeze it as hard as possible. If the consistency is right, it will just be possible (but only just) to squeeze a few drops of liquid out of the handful. Mixture should be the consistency of porridge. Remember it is always easier to add more water to a dry mixture than to add more cement, gravel and sand to one that is watery.

- ❑ Use the following table to keep tract of your concrete production—both the concrete mix and cost—for use in the future. In many cases, water, sand and gravel will not be purchased items, but ascribe to them a dollar value based on the time and work necessary to gather them.

Cost of Concrete

Component	*Source*	*Mix Ratio*	*Volume/ filter*	*Cost/ volume*	*Cost/ filter*	*Comments*
cement						
sand						
gravel						
water						
				Total cost/filter		

POURING CONCRETE

- Oil top portion of inner mold once more, since some of it will wear off as the concrete is poured.
- Pour 1/3 of the concrete into the steel mold. Thrust a steel rod in and out of concrete and pound outside of mold to ensure concrete fills all sections of the mold and to release any air bubbles (*see picture*). Repeat this procedure twice more, each time pouring a third of the concrete. Prior to completely filling the mold, oil the top portion of the inner mold, as some oil will have worn off in the pouring process.
- Level the top of the concrete surface using a short piece of wood.
- Adjust clamping bolt which holds the riser pipe against the inner mold so that there is enough pressure to hold the riser pipe in place without causing the outside mold to deflect on that side.
- Allow to cure for 24 hours. Letting it cure longer will result in the concrete sticking to the mold surface.

Setting the Mold Down

Removing the Inner Mold

DE-MOLDING

Material

- mold wrenches
- about 8 ounces of concrete
- pliers
- hammer
- scrap wood

Using the Puller Support

- ❑ Carefully turn mold right side up (inner mold legs up). Since the mold now has a great capacity to smash fingers, set a piece of wood down to avoid setting the mold flat on the ground (*see picture*). Avoid being crushed or pinned to the ground.
- ❑ Remove riser pipe clamping-bolt using wrench.
- ❑ Place puller-support in slots and screw in threaded rod. The rod only needs to be threaded the depth of the base nut. Once in place, hand tighten the floating nut against the puller-support crossbar (*see picture*).
- ❑ Remove base bolts(4).
- ❑ Using a wrench continue to tighten the floating nut against the crossbar to break the inner mold free. Raise it about 5 cm (2 in.). At this point the inner mold should be sufficiently loose for two people to lift it out by hand. If the inner mold sticks, raise it a little bit at a time using the puller-support, until it can be removed by hand. Set the inner mold aside.
- ❑ Remove the nuts(12) from bolts connecting the two sections of the outer mold.
- ❑ Remove the riser pipe spout (remember we didn't glue this); a pair of pliers may be needed for this. Remove the pour spout clamp plate and gasket.
- ❑ Starting with the rear outer mold section, use both hands to slowly pull back on the lip of the mold-stand and remove this section. Do not use a jerking motion, but pull evenly. If the mold does not budge, tap the connection edge (where the halves bolt together) using a piece of wood and some kind of hammer, alternating from one side to another. Be careful not to strike the concrete with the hammer and always use a piece of wood. Someone else should be pulling on the mold while another is tapping. Only tap until the section can be removed by hand.

- With all the above considerations and with careful attention to the pour spout, remove the front section of the mold.
- Using some concrete, patch the hole created by the clamping bolt, any cracks that appear, and any other significant imperfections in the concrete filter.
- Scrape the rough edges off the filter (the pour spout clamp plate works good). These usually occur at the top of the filter and along the two sides where the seam of the outer mold sections was. They are much easier to scrape off at this stage when the concrete is still curing.
- Keep filter wet and out of the sun for 2 to 3 days to allow the concrete to cure properly. If it cures too quickly due to sun exposure or a warm, dry wind, cracking may occur.
- Clean the mold sections and their parts.

Diffuser Basin Construction

Diffuser Plate and Filter Lid Construction

Materials

- drill & 1/8"(3mm) bit
- flat square of wood or plastic
- saw

- Measure and cut a piece of wood or plastic to fit **tightly** against the inner wall of the filter and rest on the interior ledge (approx. 11 ½"x11 ½"(30cmx30cm).
- Drill 1/8"(3mm) in. holes, approximately 2.5 cm (1 in.) apart, in a grid pattern over entire surface of the diffuser plate (*see picture*).
- Locate a large round rock to rest on top of the diffuser plate (so that only a few holes are covered) or two pieces of wood to wedge along the edges of the plate. This will prevent the diffuser plate from dislodging when water is poured in. **It is essential to the CWF design that water cannot skirt the edge of the diffuser plate or scour the surface of the sand and the biological layer.**
- Construct a lid to fit the top of the filter. A lid is essential to prevent debris and insects from entering and contaminating the filter. The lid should cover the filter at all times, except when adding water or performing maintenance. The lid may be made out of any material, but the following considerations must be met. The material used must be clean. The lid must not contain gaps that insects might pass through and should be secure and heavy enough so that young children cannot disturb it.

Materials

- clean Sand (course and fine)
- clean Gravel (1/2 in. to 1 in.)
- cleanest available water
- sifters
- water bucket
- large basin
- storage bucket or bag

FINDING GRAVEL & SAND

You are now ready to assemble the guts of the filter. All that is required for this is some sand and some gravel. However, the quality of these two simple materials is essential for the performance of the filter. The search for sand and gravel is sometimes as simple as going to a known crushing operation. Sand produced at a crushing operation has sharp edges (the best for trapping contaminants) and relatively clean. It is the best possible sand source. In the absence of a manufactured source, it is necessary to locate a natural hillside sand deposit. Do not be tempted in your search to use riverbed sand. Riverbed sand often contains the very contaminates you are trying to filter out. In addition, riverbed sand has rounded edges, which are the least effective in trapping contaminants. If you have no other choice (no other sand deposits in a 20km radius! and no means to deliver sand to the filter location) draw your sand from high in the riverbank where this no visible contamination, such as animal excrement. Beside the presence of natural deposits, sand and gravel is usually present in riverbeds. Finding a good sand source is often only a matter of using the correct word when asking around. In Laos, for example, only riverbed sand is referred to as "sand." If you are looking for the sand found at a crushing operation, you need to ask for "rock dust." Beside location, another good indication of sand quality is its smell. If your sand source carries a strong pungent smell, do not use it for your filter—save it for the concrete.

The sand and gravel used for the filter must be as pure, uniform and sterile as possible. At the place of filter installation these three characteristics are rarely met. Therefore, be prepared to do some exploring.

SIFT & CLEAN

Notes: Two sifters will be necessary if gravel is mixed with sand. If the correct sizes of gravel and sand have been purchased, then sifting will not be necessary.

- ❑ Locate your supplies close to a water supply.
- ❑ Calculate the ***ideal flow rate*** for your filter (see *Appendix B*).
- ❑ If gravel and sands are mixed, separate them using the appropriate sifters.
- ❑ To clean the gravel, simply rinse it in a tub with the cleanest available water. Set it aside in a clean container.

Notes: Cleaning the sand requires a little more precision. In order to end up with a uniform supply of sand, identical amounts of sand must be washed an identical number of times. Washing the sand removes dust, dirt, and some finer grades of sand. So, washing the ***same*** amount of sand the ***same*** number of times helps ensure the *same* amount of fine particles are removed while the same amount of larger particles remains: a uniform sand. It is necessary to remove these finer particles to yield an acceptable flow rate in the end. The dirt and finer sands drawn out with the water can give the water a cloudy appearance and a soupy consistency. If the washing water begins to come out clearer, the sand has probably undergone sufficient washing. The distinction between dirt and fine sands can only be learned by the experience of preparing a few filters. The only true test for the prepared sand is to install it into the filter and observe the resulting flow rate. The initial flow rate of the filter should be within 10% of the ***ideal flow rate*** for your filter. If the flow rate is too low, then the sand contains too many fine particles and requires more washing. This is just a matter of convenience; a low flow rate does not affect the filter's ability to clean your water. If the flow rate is too high, you have either washed the sand too much or the initial grade of the sand was too large. This is a matter of safety: the water is passing through too fast for the filter to be effective. If the flow rate is acceptable then the preparations were sufficient. Keep track of the necessary preparations for every sand source used, to eliminate future guesswork.

- ❑ Place between 4 and 6 equal size scoops of sand (choose a number and stick with it) into a basin. Fill with water, agitate and drain off. We suggest you start with 10 washes. Wash all samples of sand the same number of times.

Sand Information

Ideal Flow Rate for your filter:

Sand source	*Description of sand quality*	*Washes*	*Flow rate*	*Remarks(cost, time to prepare, amount sand per wash, etc)*

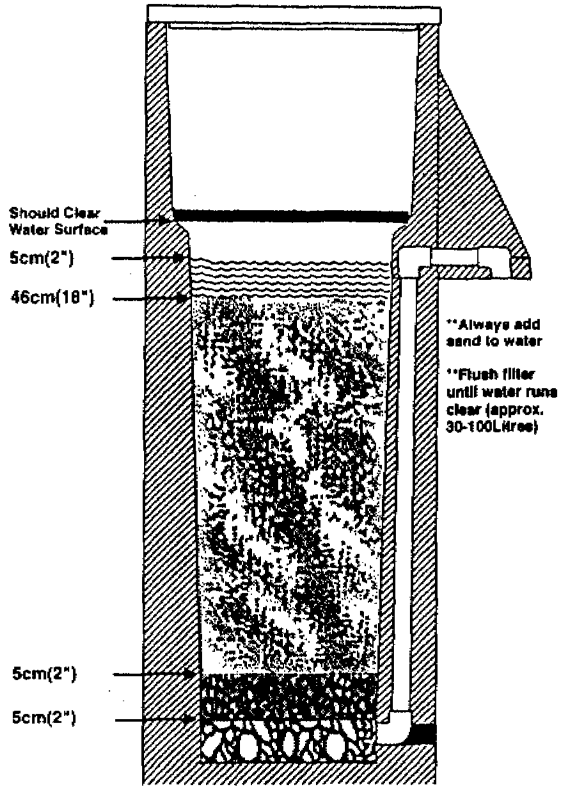
INSTALLATION OF SAND AND GRAVEL

- Locate the concrete filter into a home or area protected from weather, animals, and children. Once filled with sand and gravel the filter should not be moved. Movement will cause the sand to settle too tightly together, allowing less space for water to pass through which means a lower flow rate.
- Level the filter
- Pour course **gravel** into bottom of filter to a depth of 5cm (2 in.) and level.
- Add **water** to the filter such that the gravel is covered with approximately 10cm (4 in.) of water.
- Slowly add **course** sand into water to a depth of 5cm (2 in.) above course gravel. Level surface with hand.

Note: Always add sand to water. This will allow air in the sand to escape. Add water as necessary to ensure these conditions are maintained.

- Slowly add **fine** sand, making sure that the sand is added to water. The fine sand should be added until its top surface is approximately 5cm (2 in.) below the water when the water starts to drain from the filter. This will be about 46cm (18 in.) of fined sand. The installation of the filter media is complete.
- Place the diffuser plate on ledge inside the filter. If necessary , weight down with a large rounded rock or two tight fitting pieces of wood along the edges. **The diffuser plate must not be touching the surface of the water at resting level.**
- Flush the filter with water until the water runs clear (30-100L). When the filter is not in use there should be approximately 5cm (2 in.) of water on top of the sand.

Sand Installation



- Place lid on filter. The lid must always be replaced on filter after water is poured in.

The filter is now ready to use.

<u>Note</u>: The filter is not a water storage device. Water must always be allowed to flow freely from the filter; never stop up the spout to keep water from draining. Do not connect other devices to the spout—they may cause it to siphon.

OPERATION

- Place a clean pail or other suitable container under filter outlet.
- Remove the lid. Pour water into of filter and allow it to drain through. The diffuser plate must always be in place when filtering the water. Never pour water directly onto the sand layer. Replace the lid.
- Store filtered water in a clean container under seal.

<u>Notes</u>: The filter may require up to two or three weeks to reach optimum treatment potential for removal of bacteria and viruses; complete removal of parasites can be expected immediately. Periodically clean the filter spout with bleach. The filtered water can be disinfected using chorine. This is recommended in the two to three weeks required for the filter's biological layer to develop. The quantity of chlorine required is minimal as the water is free of turbidity. Methods of chlorination will be discussed in the workshop. The amount of chlorine added should be *just* sufficient so that there is a small *residual* amount after disinfection is complete. There should be no perceptible taste of chlorine in the water after this process.

- The filter should not be use as a storage device. Storing food in the container will attract insects such as cockroaches, ants and flies. These insects will not affect the filter's performance but some people find them offensive.
- Children should be discouraged from playing with or investigating the filter.
- Animals should not have access to the filter.

MAINTENANCE

Should the flow rate through the filter decrease to an unacceptable rate (around 20% below the ideal flow rate), it is time to maintain the filter.

- Remove the lid and diffuser plate.
- Lower the water level in the filter by scooping out water from the top of the filter with a small cup.
- Note the level of the sand.
- Scoop (but do not remove) a small hole in the sand with the cup. Scoop out the water until there is only wet sand visible.
- Remove approximately 2.5-5cm (1-2 in.) of sand and discard. Remember, the flow rate decreases as fine silts from the source water deposit in the sand column and as the biological layer thickens. The biological layer and silt deposits occupy only the top few inches of the sand column. That is why only the top few inches need replacement.
- Replace the diffuser plate.
- Pour water into filter until water begins to drain.
- Remove diffuser plate. Add fresh, clean sand such that the sand surface is 5cm (2 in.) below the water level. Level the sand surface.
- Replace diffuser plate and lid.

The filter is now ready for operation. Original performance characteristics can be expected to be completely restored within two to three days after maintenance has been performed.

Note: The sand removed from the filter does not constitute any kind of biohazard unless the water being filtered constitutes a biohazard in which case it should not be used for potable water purposes. The sand removed does contain a variety of biology but nothing more unusual than that found in the water source.

Table for Recording Maintenance

Water source	*Time between maintenance*	*Time to maintain*	*Remarks(appearance of biofilm, removed sand, etc.)*

ADDITIONAL OPERATION AND MAINTENANCE

DECOMMISSIONING THE FILTER

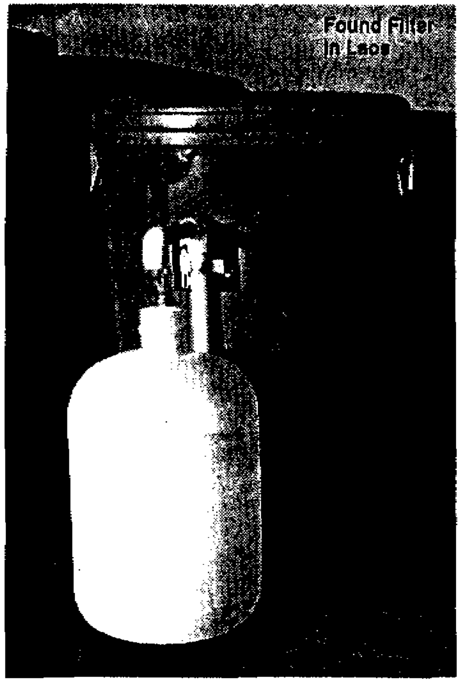
Remove the sand and gravel layers separately and store for future use, if desired. Pushing the filter onto its side to drain will cause mixing of the sand and gravel and possible damage to the concrete shell. This method of draining should not be used.

MOVING THE FILTER

The filter is not portable. It should not be moved once it is filled with sand and gravel. If the filter must be moved, remove the sand and gravel as described above. The original sand and gravel may be re-used. Re-install the filter in a new location as described in the installation instructions.

REPAIR

Concrete may develop cracks with time, and with some cracks leaking water. Repair these by draining the water and removing the sand and gravel (which can be re-used, if desired). Patch cracked areas with a layer of fine concrete mortar. Re-install the filter as described in the installation instructions.



THE "FOUND" FILTER

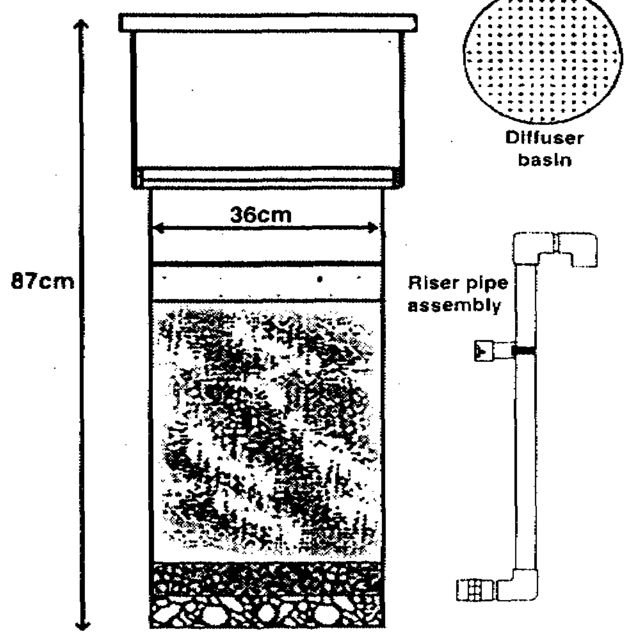
The essential principle of the "Found" Filter is that it is constructed out of materials *found* in local markets on location. The "Found" Filter allows the builder to develop innovative ways to meet the design criteria of the CWF. Even for the CWF, there are 'many different ways to skin a cat,' but at the end of the day your design must obey the CWF rules of design.

PREPARATION

Materials

- tape measure / measuring stick
- pencil
- saw (to cut PVC)
- 123 cm (48") PVC ¾" or ½"pipe
- various PVC parts
- filter body: plastic container w/lid
- diffuser plate or basin(no deeper than 6")
- PVC primer/cleaner
- PVC cement
- silicone sealant

The Ideal Found Filter



Study the diagram of the ideal found filter and be familiar with each of its parts.

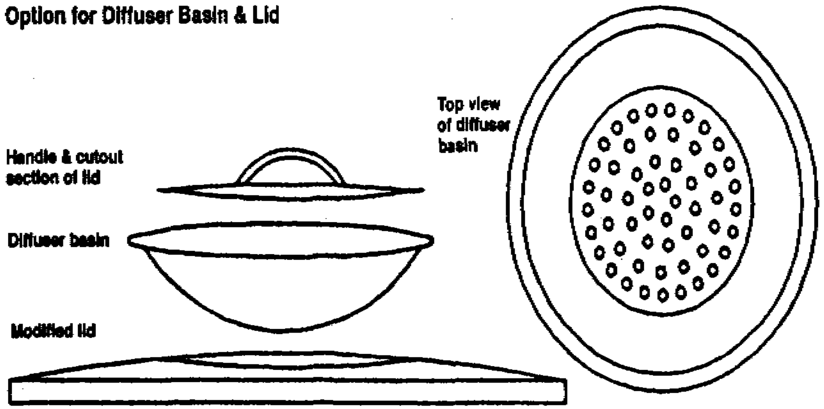
- ☐ Obtain a round, thick-walled plastic container and lid that can be used as the *filter shell* and *lid*. The ideal dimensions for the container are 87cm (34in) in height with and inside diameter of 36cm (14in). Unless the plastic is very thick, a square container will not work because the sides will deflect and the sand column will shift during installation. The container needs to be clean and free of any hazardous materials. If it is suspected that the container was once used to store any kind of hazardous material, it should not be used.

<u>*Note*</u>: It is necessary to find a filter very near to the ideal dimensions to allow for a filtering column over 30cm(12in) in diameter.

- ☐ Construct a diffuser plate following the instructions for the concrete model. **<u>Or</u>** obtain a suitable plastic basin that can be used as the *diffuser basin*. The basin must be small enough to fit inside the filter but large enough to rest on the filter's top edge. If the basin is too small to fit on the top edge of the filter, cut a hole in the lid such that the basin can fit within the lid(see diagram). Use the cutout section of the shell lid as a lid for the basin. The lid should be no greater than 15cm (6") in depth.

- ☐ Drill/cut holes into the bottom of the diffuser basin. The hole should be 3mm (1/8") in diameter and spaced 2.5cm (1in) apart in a grid pattern. Holes larger than this will allow the water to pass through the diffuser basin too quickly, causing disturbance to the top sand layer. As with every CWF water must not skirt the diffuser level(plate or basin) or scour the biological layer. If a suitable diffuser level cannot be found to fit the filter shell, then the shell is worthless.

Option for Diffuser Basin & Lid



Diffuser Basin Construction

☐ Obtain or prepare the following items for the riser pipe assembly: <u>cost/source</u>

Note: Either ¾" or ½" PVC may be used in the following instructions

¾" PVC pipe connector (socket/female thread)

(1)	PVC pipe connector (socket/male thread)	
(3)	PVC 90-degree elbows (all socket)	
(2)	PVC pipe caps	
(1)	pipe strap	
(1)	screw or nut and bolt	
(1)	riser pipe column	[49cm (19")] – PVC pipe
(1)	riser pipe pick-up	[38cm (15")] – PVC pipe
(3)	connection sections	[5cm (2")] – PVC pipe
(1)	PVC primer/cleaner	
(1)	PVC cement	
(1)	silicone sealant	
(1)	Teflon tape	

☐ Attach PVC elbows to both ends of the riser pipe column, so that the open ends face opposite directions.

☐ Using a connection section attach the third elbow to one end of the riser pipe column.

can see gaps in the layer, be sure the resting water level is not in contact with the diffuser plate and that the diffuser plate is functioning properly. There should be no other reason under normal use why the layer should have gaps.

PHYSICAL APPEARANCE

The appearance of the filter, including its location, is also important to its effectiveness in delivering clean water. All the considerations discussed above for locating the filter should be followed. If the filter has cracks which are below the resting water level and they are leaking, your flow-rate will likely decrease. These cracks should be patched. Techniques for patching the concrete filter will be discussed in the workshop.

WATER QUALITY TEST: THE PRESENCE OF COLIFORM

A relatively simple and inexpensive laboratory test may be performed on the filter water to determine its ability to remove faecally related microorganisms. This is a very helpful addition to the basic visual inspections in evaluating the performance of a CWF in the field. A faecal coliform bacterium (fcb) is a harmless microorganism that is naturally present in the intestinal track. Since it is always in faecal matter it serves as an indicator of the presence of faeces but not necessarily any particular pathogen. It is generally recognized that 200 cells of fcb per 100 mL of water at the *source* (before filtration) is the maximum when this water is intended to be used for drinking purposes. After filtration it is recommended that no fcb is present. In the developing world this is rarely the case. There are some simple and inexpensive fcb test kits available. They will be discussed in the workshop.

USING THE WATER FROM YOUR CWF

STORAGE

Once water is filtered it must be properly stored to preserve its quality. If water is stored in an open container it again becomes vulnerable to contamination by humans, animals and insects. Water should be stored in a clean container with a tight fitting lid, out of the sun. Water should be poured out of the container before it is used; water should not be used in the container. If a ladle or some other dipping device is used to draw water from the container, it should be frequently cleaned and also protected from contamination. The container itself should be frequently cleaned. The general goal is to keep anything that might be contaminated out of contact with the storage container and the water it contains.

DRINKING

The primary purpose of the CWF is to provide clean and safe drinking water. A great deal of disease-causing microorganisms are transmitted from person to person by drinking water. Using the CWF eliminates microorganisms from our drinking water. Therefore, it is necessary to drink only filtered water if we hope the CWF to have an impact on our health. If on some days we drink filtered water, and on other days we do not, our health will not improve. We must be dedicated to drinking only filtered water. This means that when we travel, go to work, or visit our family we carry filtered water with us. Sometimes this requires a bit of planning, so be aware of how much water you typically consume each day. If access to filtered water is impossibility then use your knowledge of water sources, quality, and contamination in selecting the best possible drinking water. The best possible drinking water will often have to suffice.

COOKING AND CLEANING

The things we eat and the utensils we prepare our foods with all have the capability of transmitting disease-causing microorganisms. If we use contaminated water to cook and clean with, these contaminates will end up in us. Filtered water should be used for all cooking and food preparation. This includes water used to clean fruits and vegetables and even water we expect to reach boiling temperatures. Filtered water should be used to clean any surfaces used in food preparation including eating utensils. Cooking and cleaning are often the largest loophole in the wall against the spread of water-related diseases. We often regard drinking filtered water as the only defense necessary. This simply is not true. If we commit to drinking filtered water, and fail to cook and clean with it, we will not have a significant impact on our health.

PERSONAL HYGIENE

Effective personal and community hygiene are essential to breaking the cycle of water-related disease. If we take the proper steps towards eliminating filth-borne or water-washed diseases, such as washing our hands after going to the bathroom and before eating, and yet do not use clean water in the process we only defeat our purpose. Clean, safe water must be used in maintaining our own cleanliness. If we use disease-ridden water to wash faecal matter from our hands, we have made no progress. Filtered water should be used in washing our entire bodies. If this is not possible then filtered water should be used to clean our head, hands, teeth and wounds.

Potential for Improved Quality of Life

Not enough emphasis can be given to the fact that the CWF is only effective in improving the health of our families and communities when it is partnered with proper sanitation and hygiene. When this partnership is established, the cycle that persists between faecally excreted pathogenic organisms and oral ingestion can be eliminated. Diseases that are spread epidemically by water supply can be completely prevented. The greatest killer of infants in the developing world can become a thing of the past. Water, which is so crucial to our lives, is also responsible for million of deaths each year. Clean water and effective sanitation can turn this around. The CWF can provide clean water for families, communities, villages, churches, schools, and cities. There are few limits for its application. However, there is every limitation on its effectiveness to improve individual and community health. It must be used in conjunction with good sanitation and hygiene practices.

In most cases this partnership simply is not a reality. In these circumstances two key points should be made. The first is that no matter how poor sanitary conditions are they can be improved. Source protection, public hygiene education, and the isolation of excrement require very little money in most cases. What they do require is time, commitment, and a few people willing to lead efforts in their communities. Leadership within the communities is so essential because change of hygiene practices is often in conflict with cultural or behavioral practices. When it is in conflict and there is no leadership from within the community to resolve the conflict, new behavior will almost always fall a distant second to cultural practices that have often been in place for thousands of years.

The second key point when partnership is not a reality is that everything must be done to maximize the use of the CWF. Filtered water should be used as much as possible in every circumstance imaginable, and the filter should be diligently maintained. Use filtered water for cooking, cleaning, bathing, drinking, even for livestock. Do everything possible to ensure the CWF is doing everything it can for you. The CWF makes no great or incredible claims to improve health. That is entirely up to the user. What the CWF can do is provide clean and safe water for a lifetime.

When Health Doesn't Improve

When the health of people using the CWF does not improve, all we can do is ask questions.

What do you and don't you use filtered water for? Does your whole family use it? Do you use it when you are away from your home? How do you store your water?

Is your filter in good condition? Are there leaks? What is the flow rate? Does the biological layer appear disturbed?

What are the sanitary conditions in your household? your community? Where do you go to the bathroom?

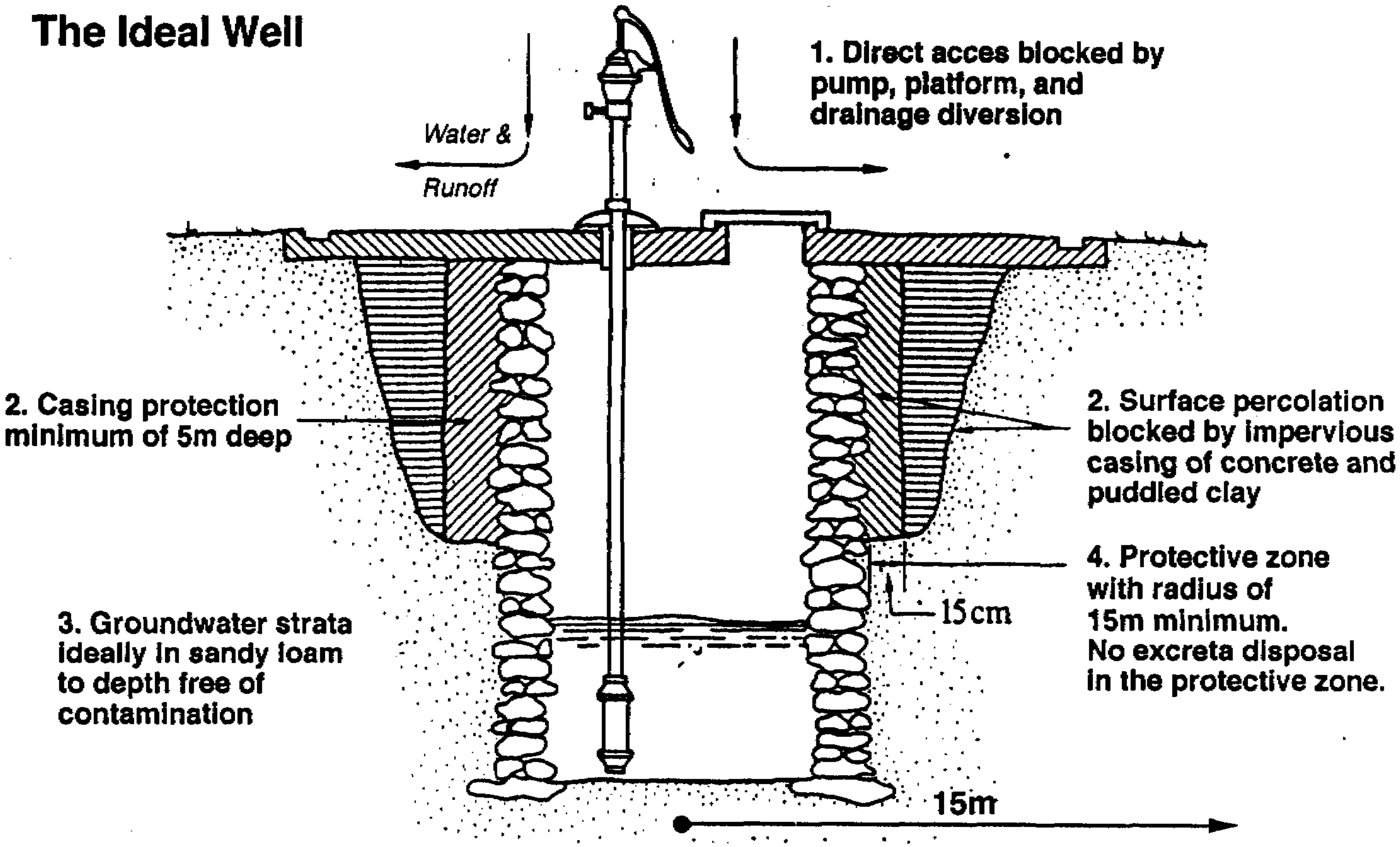
Questions can be grouped into two categories. One group of questions attempts to determine the effectiveness of the CWF in the life of and individual, family or community. Another group of questions is designed to reveal anything that might undermine the filtration process. The kinds of questions which should be asked ought to be evident to you based on what you have learned in this course. Making sense of the answers is often complicated and requires a certain expertise, such as that held by a public health authority, physician or epidemiologist. In some cases, the answers to these question point to obvious problems and solutions, such as the lack of latrines in a community, or the improper construction and use of a CWF.

REFERENCES

[1] Botkin, Daniel B.; Keller, Edward A. Environmental Studies. Merrill Publishing: Toronto, 1987.
[2] Brock, T.; Brock, K.; Ward, D. Basic Microbiology. Prentice-Hall: New Jersey, 1986.
[3] Chanlett, Emil T. Environmental Protection. McGraw-Hill: New York, 1973.
[4] Dixey, Frank. Water Supply. Allen and Unwin: London, 1950.
[5] Manz, David. Household Slow Sand Filters. Davnor Water Treatment: Calgary, 1996.
[6] Manz, David; Buzunis, B.J. Nicaragua Community Scale Household Filter Project. University of Calgary, Dept. of civil Engineering: Calgary, 1995.
[7] Symons, James M. Plain Talk About Drinking Water. AWWA: United States, 1992.
[8] Watt, S.B.; Wood, W.E. Hand Dug Wells. Intermediate Technology: London, 1976.
[9] WHO. Guideline for Drinking Water Quality. World Health Organization: Geneva, 1993.
[10] WHO. Our Planet, Our Health. World Health Organization: Geneva, 1992.

WELL CONSTRUCTION

As discussed above, groundwater is most often the best choice for a water supply. Well construction can be accomplished by hand or by machine. Some excellent resources on well construction are named in "Further Readings." Since machine-bored wells are very expensive, hand dug wells are usually the only option in developing countries. All the details and considerations which should accompany a guide to constructing wells exceed the scope of this manual. However a diagram which outlines the basic principles of a hand-dug well has been included. [Chanlett:91]



RAINWATER CAPTURE AND STORAGE

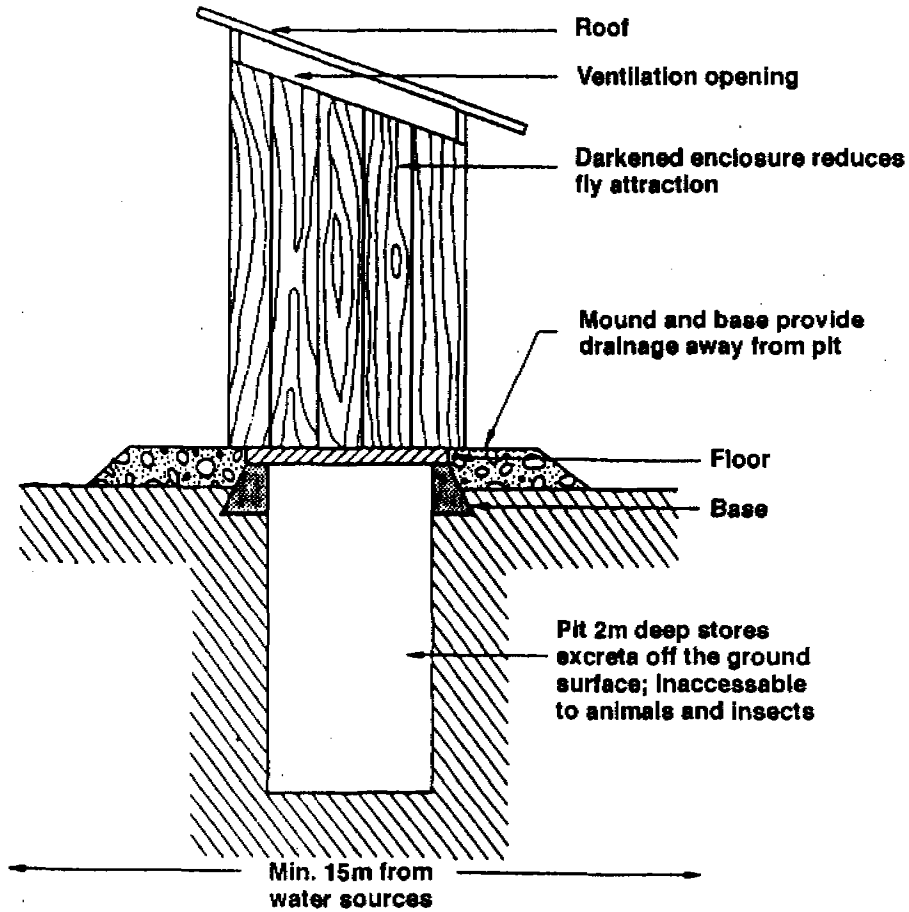
Rainwater capture by catchment surfaces is a significant source of water in many developing countries. In most cases it is used in conjunction with other sources. In some cases, it is the only available water source. When contamination of ground and surface water is prevalent and uncontrollable, and when rainfall is consistent or at least substantial, rainwater can be developing into a primary water source. Most of the literature that discusses rainwater as a water source regards it as a community project. It seems the only way to properly develop catchment surfaces and storage facilities is on a large scale, which would require community participation and investment. Channeling water off a thatch roof and into a barrel simply will not meet the needs of a family throughout the dry season. Storage containers and catchment surfaces must be built on a large scale for rainwater to be a primary or even significant water source. This kind of development extends the purpose of this manual but is available. Resources are listed under "Further Reading."

PRIVY (LATRINE) PLANNING

Eliminating the oral-faecal cycle is, in theory, simple: isolate excrement so that it comes into contact with nothing but itself. In practice, however, this is not so simple. For it means no one in the community may defecate in the open bush; all must use a properly constructed privy. It means insects, birds, livestock and all other creatures cannot come in contact with human excrement, and that humans not come in contact with disease-carrying animal wastes. It means water must be used to wash after defecating and before eating. It means that water, in the form of runoff, cannot come in contact with excrement. It means we must filter at least our cooking and drinking water. Often it means we must use purified water to bath in. It means we must not only control these sanitation practices in our own communities, but also those which effect us because they are upstream or because their sanitation practices have implications for surrounding communities. Since a small amount of excrement contains massive populations of pathogenic microorganisms, even the smallest loopholes in managing human and animal waste can have large-scale repercussions. The oral-faecal transmission of disease is indeed a difficult cycle to permanently interrupt.

Using clean water to meet all our basic needs is but one critical element in a sanitation program aimed at eliminating the oral-faecal cycle. Although it is this element which serves as the backbone for creating this manual and using the CWF, to eliminate the cycle of disease perpetuated by our own feces, we must add the elements of personal and community hygiene along with excrement isolation.

Construction and use of a pit privy or latrine is one of the most effective and affordable solutions to the problem of the oral-faecal cycle. It is estimated that "at least 2 billion rural people have yet to take this personal step of health protection by isolating their own excreta so it cannot re-infect them with roundworms, hookworms, flatworms, protozoa, bacteria, and viruses" [Chanlett:139]. Detailed instructions on the design, construction, and use of latrines, along with cultural and behavioral considerations are available from many local and international organizations. Such instructions go beyond the scope of this manual but we have included a diagram that identifies the basic design principles of a pit latrine [Chanlett:140].



The privy should be located so that ground-water supplies are "upstream" or above the privy and as far as possible from personal residence and the water supply (at least 15 meters).

APPENDIX B: USEFUL EQUIVALENTS & FORMULAS

Ideal Flow Rate (per minute)

10litres / meter^2 = 1L / 1000centimeter^2 = 1L / 155inches^2

Area

$A_{(square)}$ = length × width
$A_{(circle)} = \pi \times$ radius^2
1 cm^2 = 0.155 in^2
[radius = ½ diameter]

Volume

$V_{(square)}$ = length × width × height
$V_{(cylinder)}$ = height × π × radius^2 (where π = 3.14)

1 Imperial gallon = 1.2(6/5) US gallon
1 Imp gallon = 4.55 L = 0.16 ft^3
1 L = 0.22 Imp gallons = 61.02 in^3
1 cm^3 = 0.061 in^3

1 US gallon = 0.83(5/6) Imp gallon
1 ft^3 = 28.32 L = 6.23 Imp gallons
1ft^3 = 1728 in^3

Length

1 in = 2.54 cm

1 cm = 0.39 in

Weight

1 pound = 0.45 kilograms

1 kg = 2.21 lb

Sample Problems

What is the volume of 20 L of water in ft^3 and in^3?
20 L × 1 ft^3/28.32 L = 0.71ft^3
0.71 ft^3 × 1728 in^3/1ft^3 = 1227 in^3

What must the height of a cube be to hold 20 L of water if the length and width are 12 inches? of a cylinder if the radius is 6 inches?

$V_{(20\ L)} = 1227\ in^3$

$V_{(square)} = l \times w \times h$

$1227\ in^3 = 12in \times 12in \times h$

$8.52\ inches = h$

$V_{(cylinder)} = \pi \times r^2 \times h$

$1227\ in^3 = 3.14 \times (6in)^2 \times h$

$10.85\ inches = h$

What is the ideal flow rate for a square CWF with a square edge sand surface of 12 inches? for a round CWF with a sand surface radius of 6 inches?

$A_{(square)} = 12in \times 12in = 144in^2$

$IFR = 1\ L(min)/155in^2 \times 144in^2 = 0.93\ L(min)$

$A_{(circle)} = 3.14 \times (6in)^2 = 113in^2$

$IFR = 1\ L(min)/155in^2 \times 113in^2 = 0.73\ L(min)$