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Fresh Water

The Human Imperative

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Front cover: Life on the canals in Srinagar, India.
Back cover: The Sarvodaya Movement in Sri Lanka trains young women to manufacture, install, and maintain handpumps.

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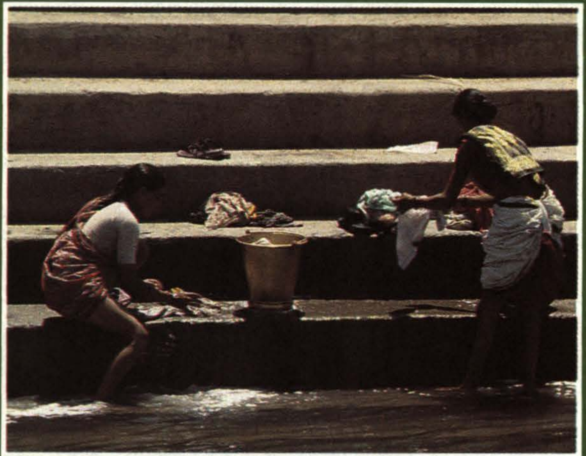


INTRODUCTION

The ancients revered water. In the age of innocence, earth, air, fire, and water were regarded as the four constituent elements. Mythology lent to them a richness of character and a range of mysterious attributes. During the intervening millennia, human settlements, human activities, and human festivals have all reflected the central role of fresh water.

Today, in the age of science, myths and mysteries are not in vogue. Neither, seemingly, is respect for water. Human indifference, human ignorance, and human greed combine globally to waste it, foul it, and divert it, thereby denying it to neighbours. There is probably no other commodity so treasured by some, while regarded with such indifference by others. International law, justice, and common sense all demand responsibility of the upstream actor. In terms of both quality and volume, persons downstream are entitled to be protected from despoliation and diversion. Yet poisonous wastes are dumped, sometimes into rivers and lakes, sometimes into the atmosphere, where they can cause acid rain, as if wholesome water is of no value and poison of no consequence. Destructive upstream activities, however, are not confined to water. Interference with normal catchment areas occurs all too frequently and broadly. Streams become destructive torrents.

Thus are the ancient natural cycles of rain and drought, providence and famine, and health and pestilence complicated and compounded by modern human activity. In these instances, there are limits to the compensating effectiveness of science and technology. Techniques may be refined for the conservation of water, for the recycling or disposal of wastes, and for the design of efficient handpumps. However, without an

Students from the Kakuyuni Primary School in Kenya are proud to explain to IDRC's President, Ivan L. Head, how they distributed 5000 seedlings as part of a local forestry project.

understanding of the need for their application, resources for their broad utilization, and a commitment by governments to wise policies, neither knowledge nor technology will be adequate.

The following pages are dedicated to water. The discussions of water-related issues are much broader, however, than the substance itself. Human attitudes, human knowledge, and human behaviour are regarded by the International Development Research Centre (IDRC) as ingredients central to any amelioration of water-related problems. In some instances, these characteristics may be better understood through sound research. In others, one can only hope that human beings will once more come to regard water with the respect shown it by societies in centuries past. In that regard, sadly, science and technology has been a negative influence. The incorrect assumption that science alone can overcome all problems has diminished the human race's earlier sense of humility and frailty and replaced it all too often with an entirely unjustified belief in its superiority.

Earth, air, fire, and water are as representative of the natural environment today as they were in prehistory. The Brundtland Commission has emphasized as sternly as any ancient gods that the very survival of the human race is dependent upon a wise stewardship of that environment.

In recent months, the Chairman of the Brundtland Commission transferred to IDRC all the original Commission archives. The Centre's library has assumed responsibility for the preservation and management of this important material. The information there recorded will encourage the Centre and direct its efforts. From the Commission's report, we trust, will come the stimulus to employ science and technology wisely and, in doing so, to live in balance with the world's water resources.

Ivan L. Head
President, IDRC

THE GLOBAL SUPPLY

Next to oxygen, fresh water is the most important substance for sustaining human life. Without it, people cannot survive more than about 3 days. Water accounts for 67% of human body weight and 90% of body volume.

Only 3% of the world's total water supply is fresh water; the rest is seawater. Much of the world's fresh water exists as glaciers and polar ice, sources that are largely unavailable for human use — the exception is the Inuit who cuts ice from a coastal iceberg and carts it home by snowmobile to be melted for drinking water. Similarly, much of the world's groundwater is locked away in deep rock formations, out of the reach of conventional human technology.

Although it makes up only a tiny fraction of the world's water, the planetary supply of accessible fresh water is more than enough to sustain the growing world population, which stood at 5.1 billion in November 1988. The problem for villagers, city dwellers, governments, and development agencies is to deliver this fresh water where it is needed, at an affordable price, and without degenerating its quality.

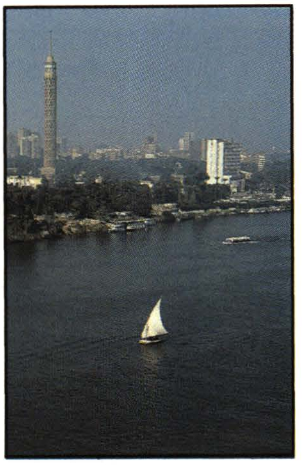
Hydrological Cycle

The principal supply mechanism of fresh water is the global hydrological cycle. Moisture from both the world's landmasses and seas evaporates, leaving any salts behind. Clouds then form and the moisture precipitates as rain or snow.

This water from the sky replenishes surficial reservoirs such as rivers and lakes, remoisturizes the soil, and recharges aquifers (underground layers of permeable soil or rock). Most of the precipitation returns to the sea directly through coastal groundwater flow or indirectly through seabound streams. Thus, the hydrological cycle is completed.

Human settlements and commerce have often appeared where fresh water was most accessible and plentiful. One of the cradles of civilization, for example, arose in the fertile plains between the Tigris and Euphrates rivers, in present-day Iraq. Its classical name, Mesopotamia, is derived from the Greek phrase for "between rivers." Likewise, Egyptian civilization developed along the fertile valley of the Nile River.

People also often settle in areas of fresh water deficit, in some cases to avoid disease. In parts of West Africa, for



Fountain of the pharaohs and source of agricultural fertility, the Nile is the world's longest river.

example, rural people have moved away from fertile areas to avoid river blindness, a parasitic disease transmitted by blackflies that breed in fast-flowing water. In Chile and Peru, it is the excellent maritime fishery that attracts people to the desert coast.

Water Wealth

The amount of water theoretically available for human use is far greater than what is available in practice. The gross and per-capita water "wealth" of various countries is shown in Table 1. Of course, population density, location, and year-to-year fluctuations in rainfall have a major bearing on a nation's "real" water wealth.

In areas where annual rainfall is low and highly variable (e.g., sub-Saharan Africa, Saudi Arabia, southern Iran, Pakistan, western India, southwestern United States, and northwestern Mexico), water shortages are common. In several areas of the African Sahel, which has suffered chronic debilitating drought, average annual rainfall has significantly declined in the past 20 years.

The annual global harvest of fresh water is estimated at between 2.6 and 3.5 trillion (10^{12}) m^3. The lesser value would be enough water to fill over one billion Olympic-size swimming pools! According to statistics compiled by the World Resources Institute and the International Institute for Environment and Development in Washington, DC, 73% of this total is devoted to crop irrigation, 21% goes to industry, and the remaining 6% is used for domestic and recreational needs such as drinking and washing.

These proportions vary from region to region depending on the economic base. Industries in Eastern

Table 1. Average annual availability of fresh water (surface and groundwater) in 20 selected countries.

Country	Total availability ($m^3 \times 10^9$)	Per-capita availability ($m^3 \times 10^3$)	Country	Total availability ($m^3 \times 10^9$)	Per-capita availability ($m^3 \times 10^3$)
Brazil	5190	36.7	Venezuela	856	46.9
USSR	4684	15.4	Malaysia	456	28.0
Canada	2901	111.7	Mexico	357	4.3
China	2800	2.6	Sudan	130	1.3
Indonesia	2530	14.7	Iran	118	2.5
USA	2478	10.2	Ethiopia	110	2.4
India	1850	2.4	Peru	40	1.9
Bangladesh	1357	12.7	Botswana	18	0.8
Burma	1082	28.0	Kenya	15	0.7
Colombia	1070	35.7	Saudi Arabia	2	0.2

Source: *World Resources 1987* — a report of the International Institute for Environment and Development and the World Resources Institute, Washington, DC, USA.

Europe, for example, account for up to 80% of the region's use of fresh water. By contrast, industry in Ghana accounts for only 3% of the country's total use of fresh water.

WATER FOR PEOPLE

Despite its small proportion of global water usage, fresh water for domestic purposes, especially for drinking, is a major concern of Third World countries and development agencies such as IDRC. The reason is simple: access to sufficient and reliable sources of clean water is crucial to public health and welfare.

In 1980, an estimated 1.8 billion people were exposed to waterborne diseases in the developing world. Every year, tens of millions of these people become ill with diarrhea, dysentery, cholera, typhoid, and other diseases. Children are particularly susceptible — in 1987 alone, some 4.5 million children died of diarrheal diseases. Many cases of disease and mortality could be prevented through a combination of improved water supplies and health education.

Although human beings need only about 5 L of water each day for cooking and drinking, according to the World Health Organization (WHO), good health and cleanliness demand a further 24 or 25 L. In fact, it is arguable that, for many of the world's poor, the first health requirement is not cleaner water but more water. Even water of questionable potability (because of high salt content, for example) may be sufficient for bathing and washing clothes, cooking utensils, and plates, thereby promoting health.

Daily trek in Kenya — a long way for a little water.

A major constraint on water consumption is the distance to the source. In many Third World countries, women and children are the water bearers and must walk for several hours each day just to carry home 20–25 L of water, which is often contaminated. Generally, consumption increases as the water source gets closer. Studies of water collection in Africa, however, have shown that the equation is not altogether simple and that a plateau is reached. When the round-trip time drops below 30 min, water consumption levels off. It is only when water is installed right in the consumer's house or yard, making the collection time negligible, that another major boost in consumption occurs. All this simply underlines the tremendous investment that will be required to maximize the health benefits of improved water supply.

Table 2. Access (% of population) to safe drinking water (SDW) and sanitation (SS) in various developing countries.

Country	SDW	SS
Argentina	64	84
Bangladesh	41	4
Botswana	57	36
Burma	26	21
Guinea	17	13
Haiti	34	20
Indonesia	32	30
India	55	8
Iran	68	72
Kenya	28	45
Malaysia	79	72
Mexico	76	58
Peru	55	39
Rwanda	60	60
Saudi Arabia	91	82
Zambia	49	74

Source: *World Resources 1987* — a report of the International Institute for Environment and Development and the World Resources Institute, Washington, DC, USA.

Progress of the Water Decade

The United Nations declared the 1980s the International Drinking Water Supply and Sanitation Decade (the "Water Decade"). It did so because of the proven connection between water and health and the fact that so many people in the developing world were known to lack safe drinking water and proper sanitation.

Access to safe drinking water and sanitation (toilets and latrines) can vary greatly from one developing country to another (Table 2). United Nations data for 94 developing countries indicate that, by 1983, 74% of the urban population but only 39% of rural people had access to safe drinking water. As for access to sanitation facilities, the corresponding values were 52 and 14%.

According to one progress report on the Water Decade, the provision of urban water and sanitation kept pace with rapid population growth between 1980 and 1985 and, in the rural water-supply sector, real progress was achieved. In rural sanitation, however, developing countries lost ground. Needless to say, an enormous amount of work still needs to be done to ensure universal access to clean water and sanitation. It has been and will continue to be a priority of IDRC.

Ingredients of Adequate Supply

Ensuring an adequate supply and the proper use of potable water requires several general components:

- suitable technologies and materials for detecting, harvesting, storing, purifying, testing, and delivering water, as well as preventing contamination;
- trained personnel to apply these technologies and to install and maintain equipment;

- overall coordination of a country's water supply, including regular water monitoring and testing; and
- public cooperation, participation, and education regarding water and sanitation.

For developing countries, there are heavy financial and technical constraints to securing these components. Piped water is a good example. Although urban penetration is high in developing countries, many residents of slums and makeshift communities are not served at all. In rural areas, the cost of extending piped water is enormous. Until such service is possible, poor rural and urban communities around the world will have to rely on other sources such as wells equipped with handpumps. Tests to determine the water quality of existing wells are only sporadically, if ever, performed because of logistics and cost. Adding more wells to national inventories will place an increasing burden on government services.

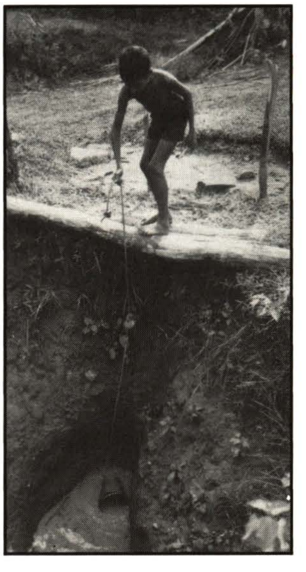
There is thus a growing perception that the job of delivering clean water to all the people of the developing world cannot be done singlehandedly by ministries of health. Even when they do have funds and personnel to cover hardware and installation costs, water programs rarely succeed without local support and participation. The end users of the technology, especially women, must be involved from the outset.

Increasingly, then, Third World governments and development agencies such as IDRC are turning to nongovernmental organizations (NGOs) and the intended beneficiaries to take on much of the responsibility, especially labour. Two IDRC-supported projects (in Egypt and Kenya) exemplify this trend.

A Personal Responsibility

Egyptian villages face serious health problems, especially diarrheal and parasitic diseases transmitted via contaminated drinking water. Pathogens thrive in an environment where drainage of wastewater from houses is inadequate and children defecate in the streets because latrines are designed with adults in mind. A 1982 study revealed that neither villagers nor local health personnel were well informed about environmental sanitation. A more recent study suggests that village women do not see the resolution of community problems as their personal responsibility.

An "action-research" project funded jointly by IDRC's Social Sciences and Health Sciences divisions is attempting to alter such attitudes and behaviour by directly involving villagers in environmental improvement. Social scientists from the Social Research Center of the



A polluted water source in Sri Lanka. Water improvement rarely succeeds without local support.

American University in Cairo are conducting this major study in two Egyptian villages. Their goal is to uncover shortcomings in the management of local water and sanitation programs and to include village women in the planning and maintenance of facilities.

The project calls for the training of village leaders and local health workers as communicators, each responsible for 30 households. Their job is to organize village women to discuss water problems and propose workable solutions.

People versus Schistosomiasis

In Kenya, another IDRC-supported study of two communities has recently demonstrated the power of grass-roots action. In this project, the health problem targeted by researchers from the Kenya Medical Research Institute was schistosomiasis, a waterborne parasitic disease common in irrigated areas of the tropics.

In one community (the study group), the infection rate was 91% among children and youths from 5 to 19 years of age. Health education was introduced and the villagers themselves constructed wells, bathhouses, and latrines, partly with their own money. In the second community, the infection rate was 64% in the same age group. This cluster of villages served as the control group; that is, there was no intervention program.

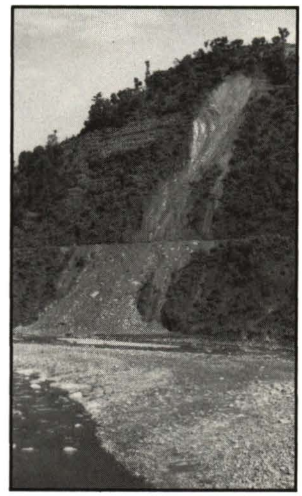
Both groups were eventually treated with drugs to bring the schistosomiasis infection rate to almost zero. A year later, the results were striking. The infection rate among children and youths in the study community was 41%; in the control group, the infection rate was 77%.

New bathhouse under construction at the Mwea irrigation scheme in Kenya. Villagers are determined to break the cycle of infection of the waterborne disease, schistosomiasis.

WATER FROM THE EARTH

IDRC set up its Earth Sciences Program 5 years ago as the flagship of its fledgling Cooperative Programs Division. As the divisional name suggested, the cooperative programs were created as a way of promoting research links between Canadian research scientists and their counterparts in the Third World. Since that time, other research programs have been added to the Division's portfolio. To reflect its strength in the various earth sciences such as hydrogeology, the Division changed its name to the Earth and Engineering Sciences Division.

From the very beginning of the Earth Sciences Program, water was identified as one of the most precious geological resources; therefore, it became a research priority. By mid-1988, some 25 research projects under the category of "water in the environment" were in progress. These projects include investigations of urban and rural groundwater resources, drinking water contamination, river pollution, soil erosion by runoff, riverbank erosion, glacial and snowmelt, the extraction of drinking water from coastal fog, and water basin management. This section describes a number of projects aimed at understanding the dynamics of water sources, particularly groundwater for drinking, as well as problems of contamination.



A landslide in Nepal — water and soil can be a dangerous mix.

Predicting the Mighty Indus

About 125 million people live in the Indus Basin, most of them in the dry, subtropical plains of Pakistan. The Indus River and its tributaries irrigate their fields, produce their electricity, and supply their cities with water. The glaciers and snow of the Himalayas are the sources of this great river system, and the rate at which they melt affects Pakistan's agriculture, industry, and, indeed, the quality of life.

As late as 1960, most of the waters of the Indus flowed unobstructed into the Indian Ocean. Since then, the river has been harnessed in large measure: a dam and irrigation systems have been completed under the direction of Pakistan's Water and Power Development Authority (WAPDA).

With such a large investment at stake, the nature and variability of stream flow from the mountains became a concern. In 1984, WAPDA engineers launched a major 3-year cooperative research project with Canadian hydrologists from Wilfrid Laurier University in Waterloo, Ontario. Their sophisticated weather-monitoring work in high-altitude areas of the Himalayas has led to a more detailed understanding of the dynamics of glacial and snowmelt.

This project is now complete and WAPDA is planning and discussing with IDRC a multimillion dollar implementation phase that would be funded by the Canadian International Development Agency (CIDA). Among other things, the follow-up project would create a network of high-altitude, weather-monitoring stations to ensure accurate prediction of river flow. As a result, Pakistan will become more adept at water conservation and the operation of reservoirs and irrigation systems.

Stab in the Dark

Very few developing countries are blessed with a snow-fed river like the Indus to quench their thirst and drive their economies. With only meager surface water resources, many countries rely heavily on subterranean water. In the absence of adequate financial resources or an understanding of local geological formations, drilling programs have often taken a "stab-in-the-dark" approach, with disappointing results. Proper hydrogeological studies, however, can help remove the guesswork from water prospecting.

Africa has a particularly difficult problem with its supply of fresh water, especially for human consumption. As one water expert put it, the continent has the "wrong geology for easily finding groundwater." The African shield possesses relatively few sedimentary basins with good groundwater, and most aquifers are small and intermittent or "discontinuous," making it difficult to site wells. Under the Earth Sciences Program, a number of studies are being conducted to improve the understanding of water-bearing formations and their natural recharging systems and to develop techniques for siting wells.

One of these projects focuses on the small East African country of Uganda. Only about 6% of the country's rural dwellers have access to an acceptably safe supply of water. The poor storage capacity of aquifers limits the availability of groundwater, especially in the northern and western areas. Also, in the dry season, surface water is often drastically reduced.

In basic terms, the geological structure of the northern region consists of a substratum of crystalline "basement" rocks covered by a discontinuous mantle of weathered bedrock. Water is contained in fractures of the basement rocks or in the overlying weathered bedrock. Because of the discontinuity of these shallow aquifers and their meager storage capacity, drilling has often resulted in wells that are dry or have low yields. Between 1930 and 1980, some 6000 water boreholes were drilled in Uganda. A 1981 survey indicated, however, that as many as 70% of these water sources had ceased to function. It is estimated that between 10 000 and 20 000 new boreholes are needed to ensure a safe, reliable water supply to Uganda's rural citizens.

In 1980, coinciding with the beginning of the UN Water Decade, the United Nations Children's Fund (UNICEF) began providing assistance to the Ugandan government to rehabilitate existing wells and drill new ones. The drilling started in 1984. To date, water yields have been low, with about one in five boreholes turning out to be dry. Despite less than spectacular results, drilling operations do provide a favourable context in which to investigate the factors that make a geological formation more or less likely to yield adequately and recharge sufficiently.

In 1985, a Ugandan–Canadian research team of hydrogeologists, funded by IDRC, teamed up with UNICEF to take advantage of the window of opportunity afforded by the drilling program. The Canadian team is led by two scientists: an experienced private consultant in the area of hydrogeology and a professor of geology from the University of Toronto. The Ugandan team is composed of an engineer and a hydrogeologist from the Water Development Department of Uganda's Ministry of Lands, Mineral and Water Resources.

Under this cooperative project, the researchers are "logging" each borehole for its geological and geophysical characteristics. They are also conducting tests to determine the permeability of the rocks they encounter. This provides information about the rock formation's water-carrying capacity. Furthermore, the age of the groundwater — and, hence, the renewability of each aquifer — is determined by sophisticated testing of water

The West African nation Burkina Faso is prone to drought and water shortages. Here, the White Volta has been reduced to an overgrown puddle.

samples for the presence of specific chemical isotopes. (The rates of decay of certain isotopes are well known, making them useful for dating.)

The resulting data will enable the researchers to prepare a conceptual model of the study area's overall hydrological system. This, in turn, will allow planners and engineers to predict how the system will behave under various rainfall and pumping conditions. At a more immediately practical level, the project will produce a hydrogeological map and set of criteria to guide engineers, water supply planners, and development agencies in the siting of wells.

In the drought-prone Sahel, 4000 km west of Uganda, lies the landlocked nation of Burkina Faso. Its climate, geography, and geology have combined to give it chronic water shortages worse than those of Uganda. The availability of surface water is minimal and boreholes are an important source of water for small towns and villages. The success rate for drilling boreholes of low output (less than 5 m^3 of water per hour) is about 70% ; for larger wells, however, this value plummets to 15%. Under such nebulous conditions, drilling is a gamble.

To help turn water prospecting into a more precise exercise, scientists from the Université du Québec à Chicoutimi are collaborating, with IDRC funding, with African counterparts from the Institut des sciences de la nature, part of the Université de Ouagadougou. Like the Ugandans, they are attempting to establish what geological conditions lead to a high yield of water.

A third project, in neighbouring Niger, with similar objectives and approach, is being conducted as a collaborative venture between the Département de géologie of the Université de Niamey in Niger and the Laboratoire de géochimie isotopique et de géochronologie of the Université du Québec à Montréal. A separate grant from IDRC's Fellowships and Awards Division is also allowing a young Canadian researcher on the team to complete his PhD thesis in geology.

In all three of these groundwater projects, the African researchers have had the benefit of working with Canadian experts in hydrogeology and related research methods.

Living Close to Your Water Supply

Whether you reside in a long-established city of the North or a mushrooming metropolis of the Third World, environmental degradation seems to go hand in hand with industrialization and urban living. In Latin America, many important rivers run through cities and industrial areas. Not surprisingly, these rivers easily become polluted with

Learning proper hygiene in Thailand.

untreated domestic and industrial wastes, as well as farm chemicals.

People living along these rivers sometimes have no choice but to drink untreated water. In urban areas, contaminants sometimes enter the drinking water system as a result of negative pressure in pipes during water cuts. Urban water is usually treated for organic wastes but not for chemicals. How does this situation affect public health and which segments of the population are most at risk?

An international team of epidemiologists, toxicologists, chemists, and physicians is currently trying to answer this question. With backing from IDRC's Health Sciences Division, they are studying human exposure to heavy metals and pesticides. The people being studied in Bolivia, Chile, Colombia, Ecuador, Peru, and Venezuela all live along polluted rivers.

The researchers have taken blood, urine, and hair samples for analysis and have physically examined the subjects. The resulting data are being correlated with other factors such as proximity to the pollution source and level of income. In essence, the researchers are providing a scientific snapshot of the public health side of the contamination problem. They hope their results will motivate national authorities to monitor river pollution better and to pass related legislation.

The developing world has numerous "megacities" whose water supplies are threatened not only with contamination but also with overexploitation. Bangkok, Cairo, Dakar, Mexico City, and São Paulo are some of the better known examples.

Urban populations often grow faster than the rate at which basic services such as water and electricity can be installed. As the ring of suburban neighbourhoods, including slums and squatter settlements, expands around the city core, there is a scramble to find new sources of water. More often than not, the solution is to drill new wells to tap aquifers, usually in an uncoordinated fashion. Without a proper understanding of the underlying geology of the area, this haphazard development of groundwater supplies leads to a number of serious problems: contamination from domestic and industrial sources, sinking land (or soil subsidence), and, in the case of coastal cities, saltwater intrusion.

Surface water (from streams, rivers, lakes, and reservoirs) is more easily polluted than groundwater but can be cleaned up relatively quickly. Groundwater, however, may be adversely affected for decades once contaminants have found their way into the hydrogeological system. In the case of saltwater intrusion, correcting the problem is very costly and, sometimes, the situation is irreversible. Likewise, land subsidence caused by overpumping of groundwater from an aquifer is probably irreversible.

IDRC's Earth Sciences Program supports a large network of urban hydrogeology projects around the world aimed at helping large cities to better manage their groundwater resources. The main focus of the network is the burgeoning cities of Latin America; however, clusters of projects are also under way or being developed in Africa and Asia. In Latin America, an estimated 100 million people live in large cities; only half of them have access to clean water. IDRC is currently supporting urban groundwater research in Mexico City, in São Paulo, Brazil, and in Montevideo, Uruguay. Proposals from several other countries are also under consideration.

The Sinking City

Mexico City offers perhaps the most dramatic example of the water supply issues and solutions facing city residents and water supply specialists. With a population of 18 million, Mexico's capital is already the world's largest city and is expected to grow to more than 25 million by the year 2000. This places, and will continue to place, enormous demands on the groundwater resources of the Valley of Mexico in which the city is located.

Overpumping of the Valley's aquifers has led to serious soil subsidence since the 1940s. As surface aquifers are depleted, water in the overlying clays is also sucked out. The lowered groundwater pressure results in the compression of the clays, a slow process called "consolidation." This, in turn, causes the gradual sinking of land at the surface.

On such an unstable base, city buildings begin to settle, often unevenly, public water mains and sewers crack, and natural drainage patterns are altered. Add to this the otherwise unrelated geological fact that Mexico City lies in an earthquake zone. The result is a recipe for disaster, as demonstrated by the catastrophic earthquake of 1985 in which thousands of people died or were injured and thousands of buildings were destroyed. It is sadly ironic that several libraries and archives containing important information on the hydrogeology of the Valley of Mexico were destroyed in this earthquake.

In 1985, before the earthquake, a research team from the Instituto de Geofísica of the Universidad Nacional Autónoma de México and the Groundwater Research Institute of the University of Waterloo in Canada had been studying the city's groundwater resources. From available records, it was assumed that only 30% of the city's water came from aquifers, with the rest drawn from surface sources. It was also thought that beneath the city there were two relatively thin aquifers, with clay in between, and that the recharge rates were insufficient to allow continued expansion of the water supply. The prospect of the world's largest city running out of water was indeed alarming and spurred the Mexican and Canadian scientists to joint action.

Following the 1985 earthquake, the government decided to find out more about the geology of the Valley and, therefore, arranged to have the State petroleum corporation, PEMEX, drill a number of wells, some as deep as 3000 m. The IDRC-supported research team had already begun its work and was thus in an excellent position to use these wells to learn more about the city's aquifers.

Recent findings of the project are dramatic. Happily, they paint an optimistic picture of Mexico City's future prospects with regard to water supply. The disturbing news uncovered by the researchers is that Mexico City has been far more reliant on groundwater resources than previously admitted. This probably accounts for the severity of the subsidence problem. The researchers found that 93% of the city's water supply, not 30%, is coming from aquifers.

The good news is that the underground water-bearing structures appear much larger than previously thought. Observations indicate that, rather than two thin aquifers near the surface, there is really one very large aquifer under the city. At places it extends down some 2000 m, with the lower part being composed of a thick layer of sediment and volcanic rocks. There is also evidence of water circulation at even lower levels.

These findings imply that by drilling deeper wells, Mexico City could tap a large and hitherto unexploited source of groundwater. This would help ensure the water needs of the growing population for decades to come and stop the overexploitation of the shallower section of the aquifer. Also, because of the depth of the source, the water would be better protected from industrial pollution.

There is one more piece of good news. The researchers also found that the compressible clays mentioned earlier occur only near the surface. Thus, exploitation of deeper wells would prevent further land subsidence.

These preliminary findings are most encouraging. Further research will be needed, however, to provide a new mathematical model of the Valley of Mexico's hydrological system. This will help to put the management of Mexico City's water supply on a sounder footing.

A girl fetches water for her family in a shanty town of Santiago, Chile.

The Dynamics of Contamination

In São Paulo, Brazil, other researchers from the University of Waterloo's Groundwater Research Institute are working with the Instituto de Geociências of the Universidade de São Paulo to observe groundwater pollution caused by waste-disposal sites. The electrical properties of contaminated water differ from those of uncontaminated water. Using this phenomenon to their advantage, the Waterloo scientists earlier pioneered the development of relatively inexpensive geophysical techniques for detecting and tracking water pollutants.

Working with the Brazilians, the University of Waterloo research team is applying the new methods to the São Paulo environment. New knowledge of the effects of contaminants on groundwater quality should make for better waste management in one of the developing world's most industrialized and polluted cities. The ultimate beneficiaries of this research will be the 7 million residents of São Paulo (half the population) who depend on local wells for their drinking water.

Some 1500 km to the southwest of São Paulo, the industrial, coastal city of Montevideo, Uruguay, is also becoming increasingly reliant on aquifer water; farm soil erosion has severely cut the amount of water available from reservoirs in the Santa Lucia River basin. However, overuse of the groundwater has caused the water table to drop and salt water is beginning to contaminate groundwater. IDRC-financed researchers have been studying Montevideo's aquifers and sources of contamination, with a view to controlling the water table and water quality.

In West Africa, researchers in Senegal and Benin have also been investigating the intrusion of salt water, as well as other problems of urban aquifers. In Tanzania, IDRC's Health Sciences and Earth and Engineering Sciences divisions are supporting the Ardhi Institute in its investigation of water pollution in the capital city of Dar es Salaam. Researchers there recently began a 2-year study of the link between pit latrines and the contamination of groundwater and piped water.

Delivery and storage

Structures for conveying and storing water are among the most enduring and impressive engineering feats of pre-Christian civilization. The Roman aqueducts and baths, the irrigation "tanks" of ancient Sri Lanka, the deep wells of the Valley of the Nile, and the cisterns of Carthage are but a few examples. However, despite the marvels of both ancient and 20th-century civil engineering, much of humanity continues to rely on very simple water technologies. Wells, either hand dug or mechanically drilled or excavated, are a major source of water for household use. A simple bucket attached to a rope or pole often serves as the vessel of collection. The tedious, backbreaking job of drawing and transporting water usually falls to women and children and may take several hours of walking per day.

The Handpump Option

The Third World has millions of village wells. For convenience of access, many are left uncovered, exposing them to contamination from people, farm animals, and

Senagalese women drawing water. An uncovered well is a threat to water potability.

WHAT IS IDRC?

The International Development Research Centre (IDRC) is a corporation created by the Parliament of Canada in 1970 to stimulate and support scientific and technical research by developing countries for their own benefit. Although IDRC is funded entirely by the Canadian Parliament, to which it reports annually, its operations are guided by an international 21-member Board of Governors. Under the IDRC Act, the chairman, the vice-chairman, and 9 other governors must be Canadian citizens; in practice, 7 of the remaining 10 governors are from developing countries.

The Centre's programs help developing countries to build the scientific competence of their institutions and their researchers so that these countries can work to solve their own problems. Opportunities are given to researchers to broaden their experience through practical work assignments or advanced studies.

IDRC emphasizes the role of the scientist in international development and encourages Third World countries to draw on the talent of their own scientific communities. Building a strong local base for future research is an important objective of most IDRC-supported work. Research projects are identified, designed, conducted, and managed by developing-country researchers in their own countries, to meet their own priorities.

IDRC helps to create and supports international research networks through which developing countries can learn from each other, share common experiences, and conduct similarly designed studies in areas of mutual concern. It also promotes cooperation between developing-country researchers and their counterparts in Canada through so-called cooperative projects.

Cooperative Projects

Most of IDRC's funds support research conceived, managed, and carried out by Third World scientists. The Centre also supports collaboration between scientists in developing countries and their counterparts in Canada — whether academic, governmental, or private. Cooperative projects can be in any of the research areas supported by IDRC, provided there is recognized Canadian expertise in that area.

Research Programs

Agriculture, Food and Nutrition Sciences — In this group of related sciences, emphasis is on farming systems, social forestry in arid and semi-arid lands, and aquaculture. Specific areas of support by the Agriculture, Food and Nutrition Sciences Division include previously neglected food sources such as root crops, food legumes, and oilseeds; agroforestry (growing trees and crops together); multiple cropping systems; improvement of pasturelands; use of nonconventional feeds for animals; fish and shellfish farming; postproduction systems for the preservation, processing, and distribution of food crops, fruit, and fish; and the economics of small-scale farm production and marketing.

Health Sciences — The support of the Health Sciences Division is concentrated in three broad areas of applied research: health and the community, health systems, and health and the environment.

Social Sciences — Research supported by the Social Sciences Division is designed to improve understanding of the social and economic issues related to international development, permitting researchers and policymakers to formulate policy options in several thematic areas. These include education, population and women's issues, urban policy, rural development, resource management, environment, energy, economics, science and technology policy, and public policy.

Earth and Engineering Sciences — The Earth and Engineering Sciences Division supports research in three main areas. One program aims at helping small- and medium-scale enterprises in developing countries create jobs. The Earth Sciences Program focuses on hydrology, hydrogeology, geotechnics, and small-scale mining technologies. Shelter is the theme of a third program supporting research using local resources to develop improved, low-cost construction materials and techniques.

Information Sciences — Support given by the Information Sciences Division helps developing countries to establish regional and national information systems and improve library infrastructures at these levels; participate in international information networks; create specialized information centres (serving a region or the world) on development-related subjects; strengthen sectoral information programs, especially in agriculture, health, population, industry, the environment, cartography, and social issues; and develop information tools and methods. The Division's computer systems group provides internal services and distributes MINISIS, a bibliographic software package designed by IDRC, to developing countries. In addition, a library and micrographics unit serve IDRC staff, the Canadian development community, and IDRC-supported projects.

Communications — The aim of the Communications Division is to strengthen the ability of research institutions in developing countries to prepare and disseminate scientific and technical information, particularly on projects supported by IDRC. Services provided by the Division include the publication and dissemination of the results of IDRC-supported research via print and film media, public affairs, and translation.

Fellowships and Awards — The Fellowships and Awards Division funds the training of junior and senior Third World scientists, managers, and planners working in sectors covered by IDRC's program divisions. Preference is given to individuals from the least-developed countries and the emphasis is on professional upgrading rather than basic training. In addition, the Division supports practical, nondegree group training to improve technical, research, and administrative skills of individuals. A portion of the Division's funds is also used to encourage the involvement of young Canadian researchers in scientific areas of concern to IDRC and to expose them to the problems of the developing world. These doctoral students are posted to a Third World country for studies, research, or placement.

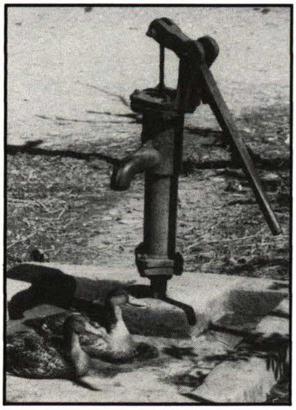
Funding and Selection of Projects

Each program division channels funds to institutions in developing countries (government departments, universities, research centres, etc.), to international and regional institutions, and to Canadian institutions. The recipient is expected to pay a portion of the costs.

All projects are reviewed by IDRC's professional staff and assessed in light of factors such as

- Development priority: Is the proposal consistent with national or regional development goals?
- Regional applicability: Are the research findings likely to be applicable in developing countries or regions other than the one in which the research takes place?
- Usefulness: Will the research help close gaps in living standards or lessen the imbalance in development between rural and urban areas?
- Local resources: Will the project make full use of local resources and research workers from the region?
- Training: Will the project result in better trained and more experienced researchers and more effective research institutions?
- Research area: Does the research fall within IDRC's areas of concentration?

When IDRC agrees to support a project, it enters into an agreement with the developing-country institution. The agreement stipulates the project's purpose, research methods, payments, and schedule for research and progress reports.



Duck soup? Just add water . . . but don't let the critters contaminate the well.

debris. In recent decades, however, imported electric or diesel-driven pumps and handpumps have improved the rural water scene, making water collection more efficient and reducing the risk of contamination.

Unfortunately, these cast-iron imports haven't stood up well to daily village use. A handpump designed for light use in Japan or Canada, for example, will not long survive the punishment from 50 Ethiopian families drawing water all day long. As a result, rusty, broken-down pumps, abandoned for lack of money to buy spare parts, are a common sight in the rural localities of developing countries.

Mechanically speaking, handpumps are simple. One might think, then, that designing the "ideal" Third World handpump (one that can be manufactured in the country or region and operated and maintained by villagers) would be fairly easy. This is not so. The simplicity of a successful technology often masks the complexity of thought and research that went into its design. An appropriate handpump must accommodate many factors: the users' ability to pay, local availability of manufacturing materials, repair skills, local beliefs and practices, aesthetic preferences, the number of users, and even the local weather. In this sense, there is no one handpump ideally suited to all countries.

For 12 years now, IDRC's Health Sciences Division has been backing the development of various models of a "simple" handpump that take the needs of users squarely into account. The pump's below-ground components are made largely of polyvinyl chloride (PVC) plastic, which is strong, light, and widely available in the developing world. In addition, PVC plastic doesn't rust or make the water taste bad. Based on an early prototype from the University of Waterloo in Ontario, Canada, several PVC handpump designs have been, or are being, tested in 13 countries in Asia, Africa, and Latin America. Two are now being mass produced in Malaysia and Sri Lanka, and thousands of the pumps have been installed.

In terms of engineering and design, the Malaysian UNIMADE series of handpumps is the most mature in the IDRC-sponsored global network. The latest model, the UNIMADE D series, is the fourth generation of pumps to emerge from the University of Malaya in Kuala Lumpur.

Two recently approved handpump projects are particularly noteworthy. Firstly, in China, the Academy of Agricultural Mechanization Sciences has been given an IDRC grant to investigate the feasibility of large-scale manufacture of the UNIMADE pumps. Secondly, in Sri Lanka, an NGO called Sarvodaya is expanding its IDRC-supported handpump program into other dry areas of the country. Sarvodaya designed the highly successful SL5 handpump and has trained teams of young women to manufacture, install, and repair it. Under the new phase of work (supported by IDRC and CIDA), Sarvodaya is training a new group of female pump technicians. In addition, two Sarvodaya technicians visited the pump project in China to learn low-cost drilling techniques.

International Crossroads

In May 1988, a milestone was reached on the long road toward the emergence in the developing world of mature, truly indigenous, handpump technologies. A new research and training centre, geared toward dissemination of handpump manufacturing technology, opened at the University of Malaya. IDRC is funding its first 3 years of operation.

From manufacture to maintenance, the Sarvodaya pump has been a success story in Sri Lanka.

This regional centre of excellence services the technical needs of water-supply specialists and handpump manufacturers from the government, the private sector, and NGOs. As these people are dispersed around the developing world, IDRC's Information Sciences Division has agreed to support the testing and evaluation of a "telematics" network to ensure good communications. This computer-based system would enable the training centre and its clients to exchange technical information, including graphics. Complementing this information network is a newsletter called *Waternet News*. The Malaysian engineer who perfected the PVC UNIMADE handpump and heads the new centre has a vision of a self-sustaining international network of handpump projects in place when IDRC funding ends in a few years.

Another promising pumping technology supported by IDRC is a robust device called the hydraulic ram, or "hydram." With only two moving parts, it is a simple technology dating back 200 years. A hydram pump runs on renewable energy: the kinetic energy produced by the flow of a stream to a lower level. As the water moves through the hydram, a small portion of the flow is diverted through a pipe to a higher level.

Some hydrams installed in East Africa have been operating for more than 50 years. However, modern commercial models are costly and there has been a growing trend to design smaller, lighter, less expensive hydrams that can be manufactured in developing countries.

With IDRC support, research teams in Uganda and Tanzania are collaborating in this area. They have taken inventories of hydram pumps in their respective countries and, armed with hydrological and topographical maps, have identified continuously flowing streams suitable for new installations. A computer model of hydram performance is being developed to help design new hydrams that can be manufactured locally at a low cost. Village leaders will be invited to see the new designs in action at a demonstration and test site near Entebbe, Uganda.

IDRC is also supporting the development of a simple, but highly experimental, solar, liquid-piston pump at the University of Science and Technology in Kumasi, Ghana (see boxed section). If successful, this technology could help Ghana to harness its plentiful solar energy, thereby lessening the country's dependence on electricity and fossil fuels.

The liquid-piston pump has an important advantage over the conventional solid-piston pump: there is no need for the pump cylinder to be precision machined. This means that small local machine shops should be able to fabricate the device quite easily. A major challenge for the researchers is to design solar collectors efficient enough to run the pump.

Rural schools and hospitals require a good supply of safe water and stand to benefit from the introduction of

Solar-Powered, Liquid-Piston Pump

A prototype "liquid-piston pump," powered by the sun's energy, is being designed by researchers in Ghana, West Africa. It works on the principle that a fluid (in this case, freon) can produce useful mechanical energy when it is repeatedly vapourized and condensed.

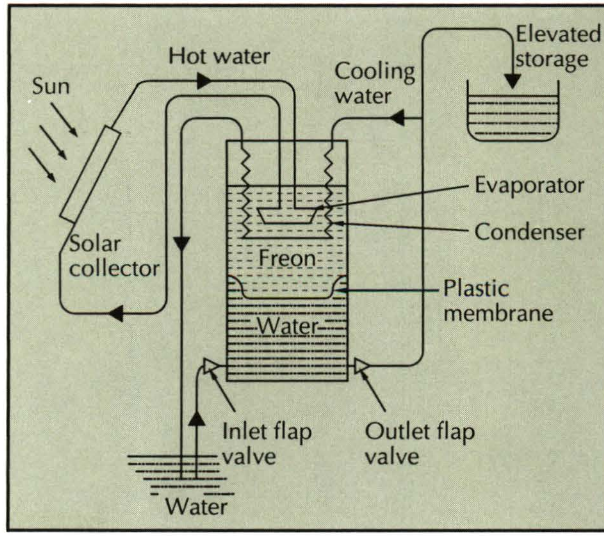
The pump consists of a cylinder separated into an upper and lower chamber by a flexible plastic membrane. The top chamber is filled with freon, a liquid that vapourizes at a lower temperature than water. Immersed in the freon are an evaporator coil that circulates hot water and a condenser coil for cooler water. A solar collector powers the system by heating the water in the evaporator coil. The lower chamber houses the water being pumped. It has one flap valve to let water flow in from the supply and another to let the water flow out to the elevated storage container.

Here's how one cycle of the pump works:

1. The solar collector heats the water in the condenser coil, causing it to circulate naturally.
2. The liquid freon warms up and begins to evaporate and expand.
3. As the chamber pressure increases, the flexible plastic membrane moves downward, forcing water in the lower chamber to flow through the outlet flap valve (the intake valve remains closed).
4. When the level of liquid freon drops below the bottom of the evaporator coil, evaporation ceases.
5. Meanwhile, cool water flowing through the condenser coil causes the freon to begin condensing back into liquid.
6. As the chamber pressure decreases, the membrane moves upwards, drawing water from the main supply through the inlet valve (outlet valve remains closed).

The cycle repeats itself over and over, giving rise to an undulating movement of the membrane and a flow of water to the storage tank (see diagram opposite).

the solar, liquid-piston pump. It could be used to pump groundwater or collected rainwater into raised storage tanks. This would prevent contamination of the water and allow gravity feed to buildings.



An experimental pump for raising water to a storage tank.

Wind, Sun, and Water

The Health Sciences Division of IDRC is funding a project on wind-powered pumps in Panama. The research team is examining the technical performance and social acceptability of a low-cost, locally designed model. Before promoting the technology, the researchers want to be certain that it is indeed appropriate for local communities.

Senegal is a hot, sunny country with low rainfall. Often, rural people don't have enough water for either agriculture or household use. At present, about 20 deep wells in the country are equipped with solar-powered electric pumps, a technology intended to mechanize the rural water supply without having to resort to expensive diesel power. Unfortunately, only a few of these pumps are still working. This is because rural users weren't adequately consulted and there wasn't a proper repair and maintenance plan drawn up in advance.

To improve the chances of success of such technology, Senegalese energy researchers are designing guidelines and procedures for the correct siting and installation of solar pumps. These guidelines will ensure that both social and technical factors are properly assessed before decisions are made. The project is jointly funded by IDRC's Agriculture, Food and Nutrition Sciences and Health Sciences divisions.

Rainwater and Cement

In many countries, the water table is too deep for simple handpumps to be effective. Rainwater catchment sometimes offers an attractive alternative. Compared with surface water or water from shallow wells, rainwater is relatively free of chemical and microbiological contaminants, making it safe to drink. The roof and gutter from which the rainwater is collected and the container in which it is stored, however, must be kept clean.

Over the years, IDRC has funded a number of research projects on rainwater catchment in Africa and Asia. A recently completed project on the island of Capiz in the Philippines demonstrated that ferrocement — wire mesh covered with thin layers of mortar — is an excellent,

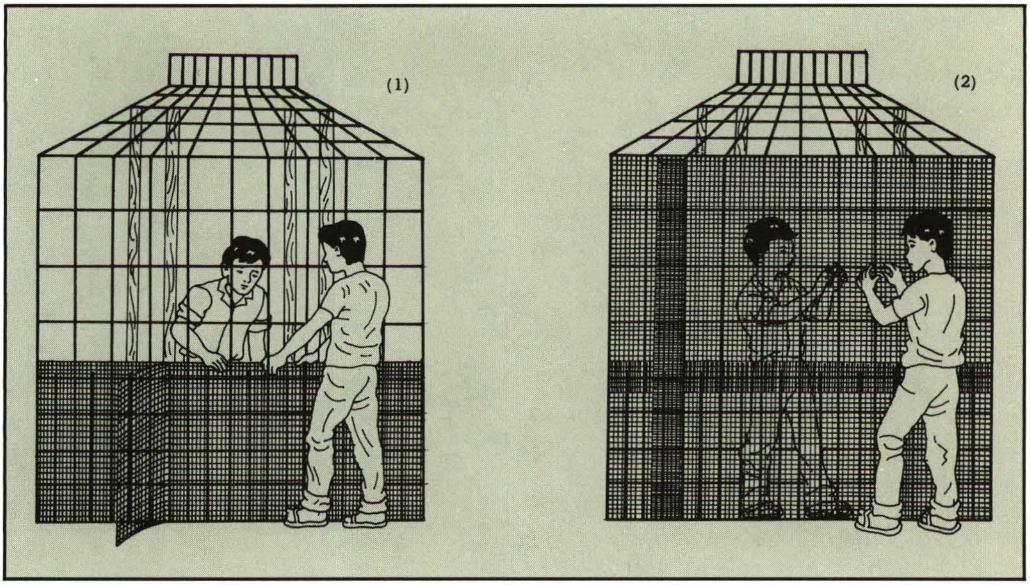


Illustration from an IDRC-sponsored Philippine manual on the construction of ferrocement rainwater tanks.

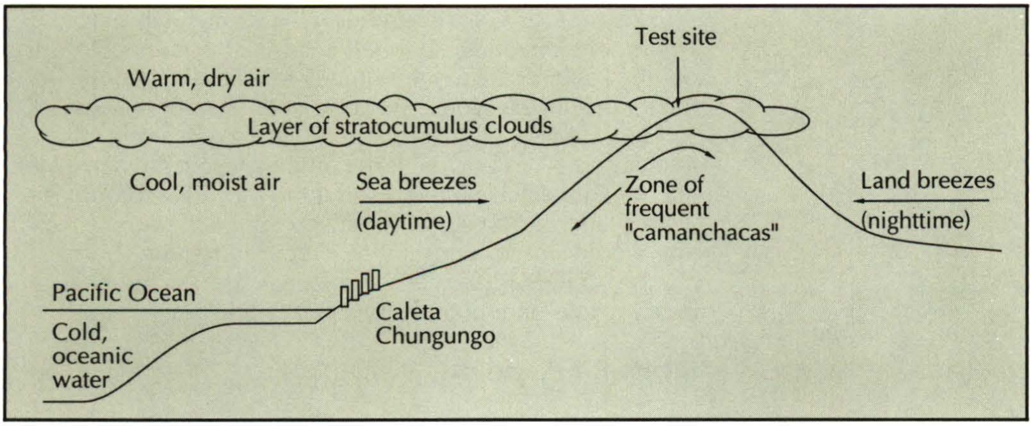
inexpensive technology for building rainwater cisterns. The Capiz Development Foundation, Inc., a community-based NGO, pioneered the use of ferrocement rainwater tanks in the Philippines. The Foundation is now preparing to disseminate this technology to other islands in the archipelago and to other Asian countries. Negotiations are under way with CIDA for the creation of a major ferrocement training centre in Capiz for this purpose.

IDRC's Communications and Health Sciences divisions jointly followed up on the success of the Capiz project. They supported the design and production of an illustrated manual on the construction and maintenance of ferrocement rainwater tanks. The work was carried out by Kabalikat Ng Pamilyang Pilipino, a local NGO in the Philippines with communications expertise. Along with posters and brochures promoting the technology, the manual was published in the Tagalog and Ilonggo languages.

Despite rainwater's good reputation as potable water, there is a risk of contamination during collection and storage. The materials used to construct the rain gutters, collection roof, and storage containers, for example, may adversely affect water quality. The University of Khon Kaen in Thailand has received an IDRC grant to look into this and other factors that lead to bacteriological and chemical contamination of collected rainwater.

Harvesting Coastal Fog

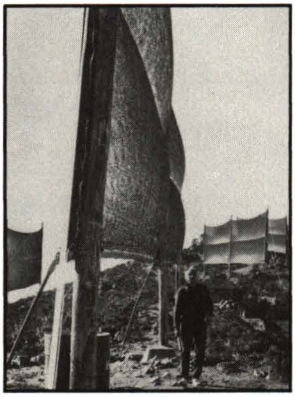
Like rain, fog is atmospheric moisture with good potential as a source of potable water. Ironically, the mountainous desert coast of Chile and Peru, where it almost



Fog harvesting on the Chilean coast.

never rains, is marked by heavy daily fogs that blow in off the Pacific Ocean. Here, a team of Chilean and Canadian researchers has made significant progress in tapping this novel water resource. Many tiny fishing villages in this region lack an adequate supply of drinking water. In the Chilean village of Caleta Chungungo, for example, villagers pay dearly to have springwater, often contaminated, trucked in once a week from 50 km away.

The research team, supported by IDRC's Earth and Engineering Sciences Division, is encouraged by their studies of the potential water harvest from the "camanchacas," as the fogs are called. On the mountain slopes just outside of Caleta Chungungo, the scientists have installed giant nylon nets, 12 m long by 4 m high, to extract water. Results to date show that the village water supply could be increased eightfold and cost as little as one-fifth that of trucked-in water. Even though the researchers are still busy with experiments, villagers are already tapping the new source in an informal way. Their supply of water has considerably improved as a result.



Exploiting geography: nylon nets extract water from the "camanchacas." — Courtesy R.S. Schemenauer.

Testing and Treatment

In pursuit of the goals of the United Nations Water Decade, rural communities around the world are working with governments, NGOs, and other development agencies to install new wells, pumps, and springwater- and rainwater-collection systems, and to upgrade old systems. All this effort will be wasted, however, unless these water sources are protected from contamination.

Few Third World countries have enough lab space, equipment, chemical supplies, or trained personnel to carry out the sophisticated water-quality tests routinely done in the industrialized world. Because of this, it often takes a serious outbreak of waterborne disease to push officials into action — an approach not unlike closing the barn door after the horse has bolted. Even if the technical resources were available, expeditious transport of water samples to labs would still be a constraint. Furthermore, the sheer number of individual wells and other water points to be tested would undoubtedly overtax facilities.

Stringent Standards

For a variety of reasons, developing countries have difficulty meeting international standards for the microbiological and chemical quality of water. If they were adhered to, many water sources that rural people depend on would have to be closed down. For example, in a

Some Major Waterborne Diseases

Cholera is a highly infectious and sometimes fatal waterborne disease. Marked by diarrhea and other gastrointestinal symptoms and caused by *Vibrio cholerae* bacteria, its incubation period varies but is normally 3 days. Cholera is widely endemic in South and Southeast Asia.

Typhoid fever is also highly infectious and sometimes fatal. This waterborne disease is marked by fever, diarrhea, headache, intestinal inflammation, and pinkish spots on the abdomen and is caused by *Salmonella typhi* bacteria. The long incubation period of several weeks sometimes makes it difficult to pinpoint the source and time of infection. An infected person may remain a carrier even after recovery.

Bacillary dysentery, also called shigellosis, is caused by members of the *Shigella* family of bacteria. Marked by acute or chronic inflammation of the colon and with an incubation period of 4 days or less, this disease is a major cause of death among young or feeble people where sanitation is inadequate.

Amebic dysentery can cause diarrhea or constipation and is rarely fatal. Infected people lose their appetite and have abdominal discomfort, with blood and mucous in the feces. Caused by single-celled organisms, or protozoa, called *Entamoeba histolytica*, which form cysts for protection, this waterborne disease may persist as the victim continues to act as a carrier for years by excreting the microorganism in the feces.

Poliomyelitis, known simply as polio, is a crippling, waterborne disease caused by a virus. Symptoms of polio include fever, headache, gastrointestinal disturbance, and stiffness of the neck and back. The disease attacks the central nervous system causing paralysis of the lower limbs; it has a normal incubation period 1–2 weeks. Children from 1 to 16 years of age are more susceptible than youths and adults.

Infectious hepatitis, a highly infectious and sometimes fatal waterborne disease, is also caused by a virus. The symptoms of this disease are fever, nausea, loss of appetite, vomiting, fatigue, headache, restlessness, and mental confusion; infectious hepatitis sometimes results in a coma. The liver becomes enlarged and the skin and whites of the eyes become yellowish. With an incubation period of usually a little more than 3 weeks, infectious hepatitis has several modes of transmission, including consumption of contaminated water and food.

water-quality survey conducted a few years ago in the Cochabamba District of Bolivia, 60% of water samples collected from rural water sources failed to meet bacteriological standards.

The microbiological quality of water is normally determined by testing for a group of organisms known as coliforms. In particular, the presence of fecal coliforms — bacteria normally found in the bowels and excrement of human beings and other animals — is like a red flag to the public health authority. They signal the possibility that the water may also contain disease-causing organisms (see box on waterborne diseases). Standard tests for detecting coliforms are based on relatively sophisticated and expensive technology, often requiring water samples to be incubated for a long period. A new faster, simpler, and less expensive test is now being developed with IDRC support and with the developing world in mind.

Water turbidity, or cloudiness, caused by the presence of sediment, also has a bearing on potability, although indirect. Minute suspended particles can act as shelters for bacteria and viruses, making them hard to detect and resistant to disinfectants such as chlorine.

Appropriate Test Kit

With the help of the respected National Water Research Institute (NWRI), part of Canada's Ministry of the Environment, a new bacteriological test kit is being developed by a network of researchers in Brazil, Chile, Egypt, Malaysia, Morocco, Peru, the Republic of Singapore, and Thailand. Rather than zeroing in on the coliforms, the new test kit identifies the presence and quantity of coliphages. These organisms accompany and prey on coliforms. The beauty of this technology is that it requires neither sophisticated equipment nor a laboratory.

Health ministries take note, this water-test kit is simple, fast, and cheap. — Courtesy The Citizen, *Ottawa, Canada.*

The researchers are also formulating a more realistic water-classification system that considers sanitary conditions at the source. The system will allow water authorities to rank water sources according to their public health risk. The ranking — perhaps on a scale of 1 to 4 — would combine the results of coliphage tests with sanitary factors observed directly at the sites (e.g., whether village wells are properly sealed or located far enough from latrines).

Water-supply specialists have cited cases in developing countries where well-intentioned health departments surveyed rural water quality by conducting traditional microbiological tests. The results were recorded manually on laboratory forms and then left to collect dust in government offices. Failure to do the necessary data analysis and follow up wasn't due to a lack of interest or resources, but to the sheer volume of the data. The new coliphage test kit promises to provide developing countries with a large and rich new pool of such information. What, then, can be done to avoid the "dusty data" syndrome? What can governments do to ensure that the new data ultimately result in better quality water for villagers?

A Malaysian research team drawn from the government's Department of the Environment and the University of Malaya is currently working with Canada's NWRI to solve this problem with the help of microcomputers. This work is supported jointly by IDRC's Health Sciences and Information Sciences divisions. The aim of this highly innovative data-management project is to produce a user-friendly, low-cost software package for developing-country agencies that monitor water quality. It is based on existing software called RAISON, developed and written by NWRI for monitoring acid rain in Canada.

The adapted system will allow users to keep track of all coliphage test results and will generate maps and computer reports on various characteristics of a country's water supply. Built into the software will be a mathematical model to quickly rank water sources according to the "risk"-classification system previously mentioned. This will make the system particularly powerful.

This project promises to give Malaysian authorities ready access to timely information on the many rural water sources in the country. They will be able to identify "hot spots" requiring decontamination or protection as well as decide where maintenance should be carried out and new water systems installed. If successful, the system will be disseminated to other interested countries.

Low-Cost Purification

When it comes to the treatment of water to ensure potability, centralized, piped water systems in cities have the advantage of economy of scale. In rural areas, however, a single water source such as a well or stream may serve only a small village or just a few families. In this environment, standard disinfection methods such as boiling or chlorination may be too time consuming, too expensive, or at odds with local customs.

In recent years, IDRC has funded many research efforts to develop alternative water-treatment methods tailored to local needs. It has long been known, for example, that ultraviolet (UV) radiation can kill bacteria in drinking water. Disinfection units that use UV lamps are commercially available in industrialized countries, but are too expensive for developing countries. Researchers in Thailand and Lebanon have received IDRC grants to investigate the use of natural UV light from the sun to disinfect water.

In India, water-related diseases are responsible for an estimated 80% of public health problems. An inexpensive water-treatment method could help turn this situation around. The Indian Institute of Technology in Kanpur has shown that the ash produced by burning rice husks (an abundant waste product on Indian rice farms) can be mixed with cement and water to produce inexpensive water filters. IDRC is currently funding a project with the Tata Research Development and Design Centre in Pune, India, to design and test such filters for household use. The results of this work will be of interest to other rice-producing countries.

The Institute has also been given funds to investigate, in cooperation with the University of Ottawa, the use of bituminous coal in household water filters. Earlier tests indicated that the coal has good potential for eliminating disease-causing bacteria and viruses from water.

Other water-treatment methods being investigated with support from IDRC's Health Sciences Division include sand filtration in Thailand and hypochlorinators for village use in Bolivia. Researchers in India are also experimenting with an extract from seeds of the Theythancottai tree as a means of removing suspended solids in water by coagulation.

Finally, the development in Botswana of small-scale solar stills for removing salt from borehole water in the Kalahari Desert should be mentioned. Isolated communities in that dry country have only a fraction of the fresh water they need for good health and comfort. Borehole water is often saline and, if regularly drunk, causes serious health problems.

A research team at the Rural Industries Innovation Centre (RIIC) in Botswana designed and built small greenhouselike structures made of glass and fiberglass.

Assembling solar stills in the Kalahari Desert of Botswana.

Saline water is placed in the fiberglass base of the still and is heated by the strong desert sun. The water evaporates and then condenses on the glass covers. The distilled potable water slides down the glass into a collection trough and flows into a storage vessel. Meanwhile, the salt remains behind in the base of the still. The success of this project in remote villages of Botswana has prompted requests to RIIC from other African countries to disseminate the technology.

Freshwater hazards

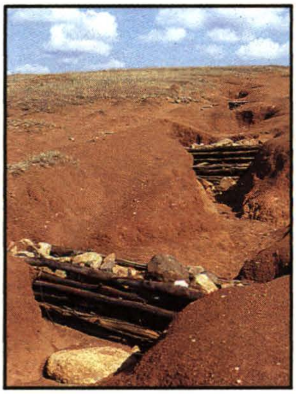
Water in motion is a mighty force that can literally move mountains. Among its most dramatic manifestations — those hazardous to human life and property — are flash floods, mud slides, and soil erosion. The natural flow of water over land and the resulting transport of soil to lower ground or even to the sea are part of the natural geological evolution of our planet. Around the world, however, soil erosion has been accelerated by human activity, with devastating consequences. Growth of human and animal populations, destructive cropping and grazing practices, and deforestation through logging are some interrelated causes.

China, with over 1 billion people, is still largely an agricultural nation. Some areas are seriously threatened by soil erosion, a problem that has concerned the government since the late 1950s and has been acted on with some success. Soil erosion reduces agricultural productivity and undermines port development and the navigation of river channels because of siltation. It also causes rivers to spill over their banks resulting in life-threatening floods.

South China's hilly Guangdong Province has been particularly hard hit. About one-third of the province's 110 counties have eroded areas larger than 100 km^2. Many countermeasures have been tried: e.g., the planting of trees and other vegetation, the building of check dams and water-diversion channels, and the use of terraces. In some cases, interventions are working; in others, they aren't. The root of the problem is a lack of scientific understanding of how these actions reduce the effects of erosion.

IDRC's Earth and Engineering Sciences Division is supporting a major project in Guandong Province to investigate soil erosion. Scientists from the Institute of

Geography in Guangzhou, China, and from the University of Toronto in Canada are examining its causes and its biophysical and socioeconomic impact. The joint research program calls for the monitoring of rainfall, soil moisture, groundwater, overland flow, and other erosion-related factors. The impact of current erosion-control measures will also be evaluated. The most significant outcome of this work will be recommendations for improved land management.



Stone-and-log barriers against erosion in Swaziland.

Getting the Most out of Radar

The Chinese province of Gansu is frequently hit by flash floods and hailstorms that badly damage the wheat, corn, and millet crops. Recognizing the problem, the Lanzhou Institute has been using standard weather radar technology to study the structure and distribution of these surprise meteorological events so that they can be predicted. The radars, however, are not equipped with digital recording and computer analysis systems. Such systems would enhance the tracking of cloud formations and, in turn, improve the speed and accuracy of storm and flood predictions.

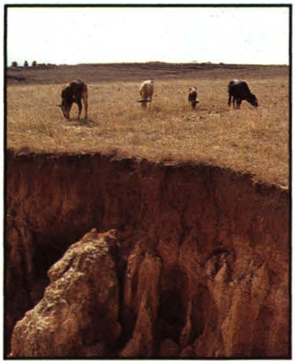
A joint IDRC project between the Lanzhou Institute and McGill University in Montréal is giving the Chinese an opportunity to enhance their radar system and develop the necessary expertise in computer-assisted analysis. This will improve the forecasting not only of damaging storms but also of rainfall in general. As a result, water-resource management, especially for irrigation, should also improve.

Recently, IDRC's Information Sciences Division agreed to fund a major flood-related project in South China. The grant will enable the Laboratory of Resources and Environment Information System to set up a geographic data base on the Donting Lake Region, a fertile agricultural area that is highly susceptible to flooding. The computerized system will contain topographical, meteorological, and hydrological data, as well as maps and information about the availability of relief materials. The project staff will develop a method for updating the information using remote-sensing techniques and data. In the future, when floods strike, this computerized system will help improve the efficiency of damage control and management. Another highly practical outcome of the project will be the production of a regional atlas containing about 70 thematic maps.

Gashes in the Mountain

The erosion problems of the tiny mountain kingdom of Swaziland, in Southern Africa, are similar to those of

Dongas, or gullies, carry sediment to lower ground, where it clogs rivers and streams.



Cause and effect: overgrazing and erosion.

South China. The flow of water across degraded slopes has slashed huge gullies into the landscape. These "dongas" are largely the result of human activity. Farmers clear and cultivate the land and then leave their cattle (often too many) to graze. With much of the plant cover gone, the fragile soil is easily washed away. Aquifers lose their water through the dongas and, because of the increased runoff, don't recharge as quickly. This lessens the amount of potable groundwater available for local villagers. Downstream, the sediment clogs streams, rivers, and culverts, and weakens the foundations of roads and bridges.

A Swazi–Canadian team of researchers is now examining in more detail the causes of dongas and how the water regime of the area is affected. They hope to identify remedial actions that will halt this disturbing deterioration of Swaziland's ecosystem.

Finally, IDRC is supporting a joint Bolivian–Canadian effort to understand a perplexing and serious flooding problem in Bolivia. The high-altitude "altiplano" region of Bolivia has a subtropical, semi-arid climate with highly irregular annual rainfall. In the past three decades, rainfall variation has become extreme, with periods of intense and frequent rainfall as well as periods of drought. This climatic shift is causing serious flooding in the drainage basin of the altiplano — a densely populated mining and agricultural area. The water levels of the Desaguadero River and lakes Titicaca and Poopo have risen and two new lakes have been created since 1960. In recent years, floods have damaged large tracts of farmland, destroyed thousands of houses, and forced the evacuation of whole communities.

Unfortunately, in the absence of a scientific understanding of the area's changing hydrological system, it is impossible to design effective antiflood measures or strategies of water conservation and management. With IDRC support, scientists from Laval University in Quebec, Canada, are working with their counterparts at the Universidad Mayor de San Andrés in La Paz and the

Universidad Tecnólogica de Oruro to provide this information and propose concrete measures to control flooding. This kind of pioneering scientific work is a necessary first step in rehabilitating the lands along the Desaguagero River. Without it, the area will remain at the mercy of this bewildering change in climate and geography.

INFORMATION FOR SPECIALISTS

Scientific and technical knowledge is not static. True, the broad conceptual models, or "paradigms," that direct day-to-day research may change only once in a generation. However, there is a constant accretion of results from those paradigms: new puzzles, corrections of theory, novel applications, technical innovations, and warnings of blind alleys along the perilous path to knowledge.

Organizing and making those results accessible — especially the innovations — is the job of the information scientist. Without up-to-date information, wheels get reinvented and blind alleys disappoint yet another unwitting water engineer or handpump designer. The chronic water supply "emergency" of the developing world begs for quick access to information on proven, appropriate technologies.

Networking in Latin America

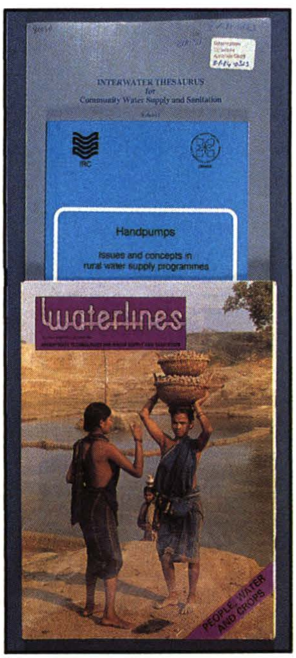
Well before the beginning of the UN Water Decade, IDRC's Information Sciences Division was busy playing the role of international midwife in the creation of information centres and networks to serve the needs of water specialists. In the mid-1970s, the Division supported the design, establishment, and operation of the Latin American Network on Information and Documentation in Sanitary Engineering and Environmental Sciences (REPIDISCA). With headquarters at the Centro Panamericano de Ingeniería Sanitaria y Ciencias del Ambiente (CEPIS) in Lima, Peru, this network now has 135 collaborating member centres in 14 countries of Latin America and the Caribbean. The centres identify and select documents such as books, journals, technical reports, theses, working documents, research findings, and presentations to congresses. They describe and analyze the content of each item and submit the information to the network's bibliographical data base. REPIDISCA is a good example of effective information sharing at the regional level, and efforts are under way to replicate the concept in Africa and Asia.

With REPIDISCA fully operational, IDRC's direct support has ended. At the national level, however, IDRC continues to provide assistance to information bodies wishing to join the regional network. Such projects are being conducted in Argentina, Guatemala, Nicaragua, and Peru.

African and Asian countries are also beginning to use information networking in the area of water and sanitation. In West Africa, for example, IDRC is supporting the documentation centre of the Comité interafricain d'études hydrauliques (CIEH), based in Burkina Faso. In addition to strengthening the centre's operations, the project will set up a water and sanitation information system to serve other countries in West and Central Africa.

The Asian Alliance of Appropriate Technology Practitioners (APPROTECH), based in the Philippines, has 38 member NGOs in eight countries. All are involved in grass-roots development work and are in need of access to pertinent information on the provision of water and sanitation. APPROTECH has received an IDRC grant to set up an information system to fill this need. Information produced by Alliance members is being collected, organized, and disseminated. The project will also produce a directory of the network's water and sanitation projects, a registry of experts, and a bibliography of appropriate technology.

In Sri Lanka, NGOs also play an important role in community water projects. An IDRC grant to the National Water Supply and Drainage Board is being used to set up a water and sanitation documentation centre. This centre will serve as the information hub of a country-wide network of NGO field-workers, university personnel, and government workers. A similar project at the governmental level is under way in Indonesia.



Some publications on water supported by IDRC.

Key Water Words

One of the most recent fruits of IDRC-supported labour is the *Interwater Thesaurus*. Published in 1988 by the International Reference Centre for Community Water Supply and Sanitation (IRC) in the Netherlands, it provides a structured, multilingual list of key words used to index and classify documents on rural water supply and sanitation. This publication will undoubtedly be of use to water-information specialists around the world and will ensure consistency in the processing and recording of new documents. IRC, in cooperation with IDRC, has also published *Handpumps: issues and concepts in rural water* *supply programmes*. This publication (IRC Technical Paper No. 25) covers several aspects of water supply and stresses community involvement in all project phases.

Finally, IDRC continues to provide funds for the publication of *Waterlines*, a quarterly magazine on appropriate technologies for water supply and sanitation. Published by Intermediate Technology Publications Ltd., in London, U.K., it is aimed at professional and technical personnel in developing countries. The most recent grant will support the publication until the end of the Water Decade and permit it to develop a marketing strategy to ensure its survival in the 1990s.

The Information Sciences Division is now reviewing its water and sanitation information program. This will ensure that, for the rest of the Water Decade and beyond, its assistance is carefully coordinated with the efforts of other international agencies.

CONCLUSIONS

Water is among the most important of the raw materials of life. It can also be a destructive and terrifying force beyond human control. The quest for an adequate quantity and quality of fresh water and for ways to tame its natural might is a human imperative, a permanent preoccupation.

Students gather to learn pump technology in Ethiopia.

The explosive growth in world population and the industrialization of the 20th century have put increasing demands and ecological pressure on our water supply. It is becoming increasingly difficult to protect water from the hustle and bustle of daily human activity, especially in the large cities of the developing world. This reality demands the application of ordered thinking and practical solutions — in short, research and development.

For 18 years, IDRC has supported and promoted the work of scientists and technologists in developing countries; much of this work has focused on the role of fresh water in people's day-to-day lives. In some cases, Canadians have worked in partnership with these men and women. New knowledge and expertise have been created, and an arsenal of cost-effective, appropriate water technologies is slowly being established.

The UN Water Decade will soon be over. Although its optimistic goals will not have been fully achieved, tangible progress has been made. For millions of people, the Decade has meant that fresh water is now a safe and reliable resource rather than a chronic health hazard. In the global context, IDRC's contribution has been modest but significant. It has helped put the pursuit of the human imperative on a more scientific footing.

Books and films

The following books and films are on water-related issues. Produced by IDRC's Communications Division, they can be obtained by contacting the Head Office (IDRC, P.O. Box 8500, Ottawa, Ont., Canada K1G 3H9) or any of the regional offices of IDRC (see back cover). IDRC films may be purchased or borrowed and publications are distributed free of charge to developing countries and at a nominal charge to the developed world. IDRC publications are also available in microfiche form.

Books

Evaluating health impact: water supply, sanitation, and hygiene education — J. Briscoe, R.G. Feachem, and M.M. Rahaman, 1986, 80 p., IDRC-248e, $8.00

To set priorities and allocate funds rationally, health authorities in developing countries need to know what impact water and sanitation programs have on health. This monograph, sponsored jointly by UNICEF and IDRC, summarizes the results of a 1983 workshop in Bangladesh hosted by the International Centre for Diarrhoeal Disease Research. The meeting addressed several topics: e.g., the conditions under which health impact evaluations should be undertaken, indicators for measuring health impact, study designs, and how results can be interpreted.

Laboratory and field testing of handpumps — Goh Sing Yau, 1985, 138 p., IDRC-TS51e, $10.00

This publication describes laboratory and field-testing protocols for polyethylene and PVC pumps. A mathematical analysis of the reciprocating pump, a method of optimizing the design of valve assemblies, two computer programs for data aquisition and processing, and standard field survey forms are included.

Women's issues in water and sanitation: attempts to address an age-old challenge — 1985, 104 p., IDRC-236e, $12.00

This book reports on an international seminar held in Manila, Philippines, in September 1984. It discusses the problems and constraints that have limited the participation of women in water and sanitation activities. Areas for future research and ways to enhance the role of women in water and sanitations are identified.

Films

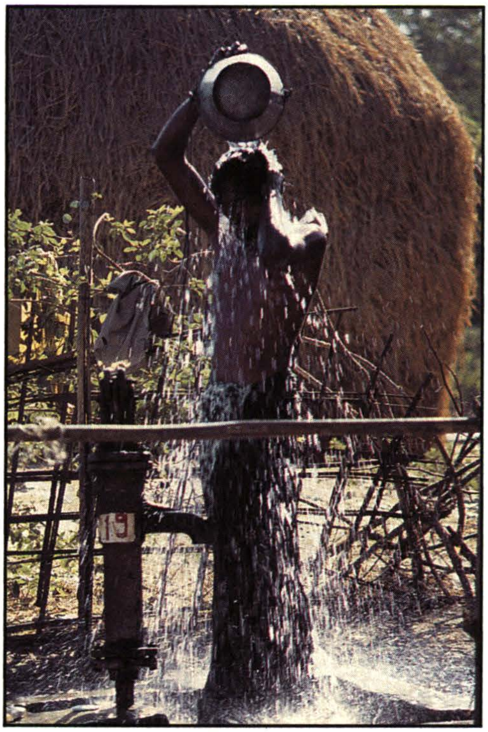
A handle on health — 1986, 27 min, IDRC, available in 16-mm and video (NTSC and PAL)

Thousands of people in the developing world die each day for lack of clean water and proper sanitation. Women and children spend hours each day bringing home water that is often contaminated. This film shows how simple, durable handpumps can be designed, tested, and manufactured locally to provide clean water and employment opportunities, and to eliminate dependency on expensive foreign pumps and pump components. The film also shows how women, the primary drawers of water, can take control of the water-delivery system and its maintenance.

Prescription for health: clean water, hygiene, sanitation — 1983, 23 min, IDRC, available in 16-mm and video (NTSC, PAL, and SECAM)

In developing countries, waterborne diseases such as cholera, typhoid, and dysentery kill thousands every day. Children are the most frequent victims. Even when a source of drinking water is safe, polluted surroundings and lack of hygiene may contaminate the water, causing disease to spread. This film was shot on location in Bangladesh, Kenya, the Philippines, Sri Lanka, and

Thailand. Extensive animation has been used to illustrate clearly the path of disease and to unify the film's message for audiences of diverse cultural backgrounds. Produced in collaboration with the World Health Organization and Oxfam, *Prescription for health* is aimed primarily at health-care workers and water and sanitation engineers and technicians in developing countries. It is a prime source of information for policymakers. A user's guide is available in cases where the film is to be shown for health-education purposes in the developing world.



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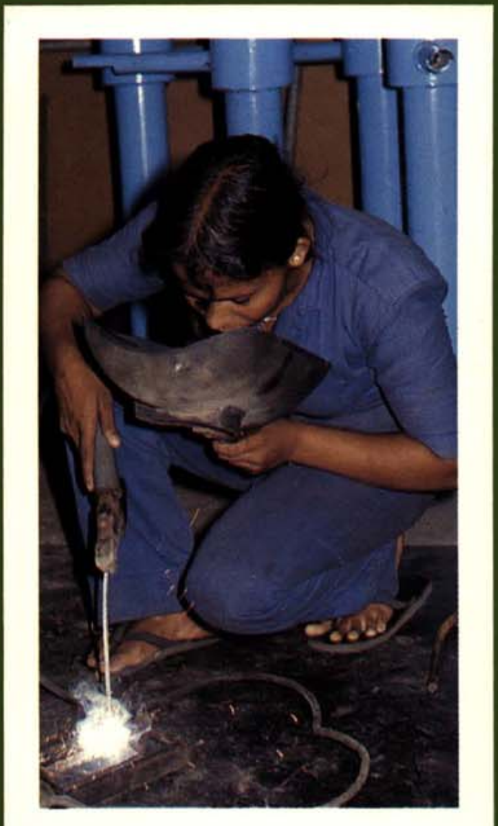

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