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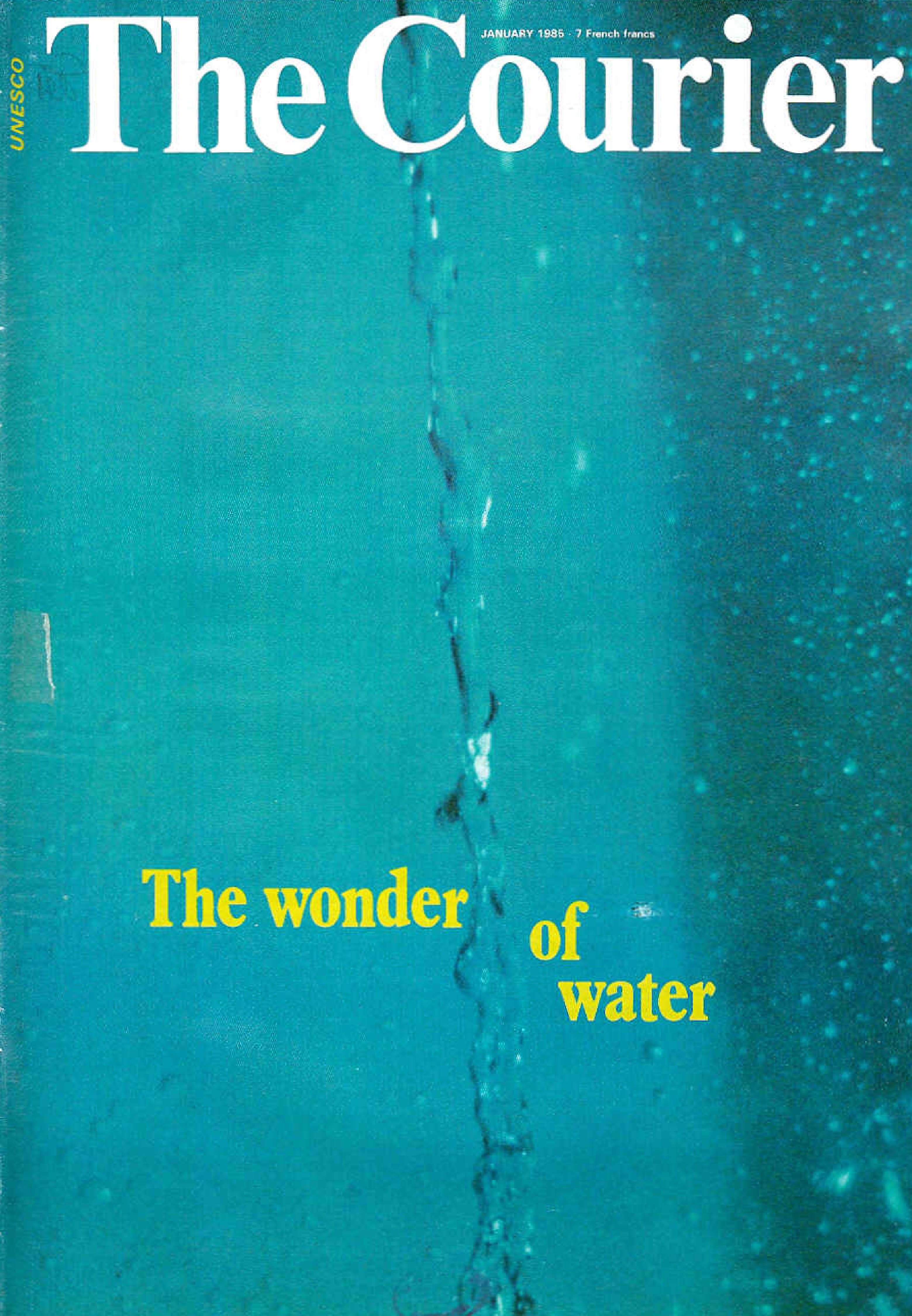

The wonder of water

A message to world youth

IN 1979 the General Assembly of the United Nations designated 1985 as International Youth Year.

The main purpose of this Year, dedicated to participation, development and peace, is to inform world opinion about the situation, needs and aspirations of young people. It also aims to strengthen co-operation in the search for solutions to questions concerning young people and in the launching of joint youth action programmes, and to associate young people in studying and solving problems of social, economic and cultural development and of world peace.

In 1983 Unesco's General Conference decided that the Organization should play as full a part as possible in the celebration of International Youth Year. Young people form a considerable and ever-increasing proportion of the world population. Inevitably they are concerned by all the problems arising from the present and future of humanity. None of the major questions of our time can be answered without the active involvement of young people.

Young people constitute 45 per cent of the world's population today and their numbers are continuing to grow. There were 730 million fifteen- to twenty-four-year-olds in 1975, and this figure should rise to 1,180 million by the year 2000—an increase of 60 per cent in twenty-five years.

If the role and impact of youth in national life vary from country to country, young people in many cases share a number of common preoccupations, fears and aspirations.

In many countries young people are particularly exposed to such problems as unemployment, hunger, delinquency, drugs, violence and racism, all of which are rooted in the tensions and uncertainties of today. But young people are also endowed with imagination, enthusiasm, and courage, qualities which may contribute to the changes which prove necessary; they stand at the meeting-point of continuity and change, tradition and progress.

The different groups of young people must have the opportunity to participate fully in all aspects of the economic, political, educational, cultural, and scientific life of the society in which they live, and to exercise freely in it the qualities which are theirs.

Unesco, which places action in favour of young people at the heart of its programmes, notably those concerned with education and training, is making its contribution to the achievement of this goal.

Unesco's efforts in this field are focussed on three main objectives: stimulating research on young people in the different world regions; promoting the diffusion and exchange of information about and for young people; contributing to the formulation of policies and the application of programmes which will encourage the participation of young people in all aspects of the life of societies.

The *Unesco Courier* will publish in the coming months a number devoted to young people in which these themes will be covered and an opportunity will be given to many young people to tell us in their own words about their successes of today and their hopes for tomorrow.

A.M. M'Bow

Amadou-Mahtar M'Bow
Director-General of Unesco

UNESCO The Courier
A window open on the world

Editorial

COVERING more than seventy per cent of the surface of the globe, water is the most common substance on earth. It is in the air we breathe and in the ground we walk on. It fills the oceans, rivers and lakes. It is the source and sustainer of life without which neither plant nor animal nor man could live.

Every living thing consists mostly of water. A human being is about 65 per cent water, an elephant about 70 per cent, a potato about 80 per cent and a tomato an amazing 95 per cent.

The wonder of water does not end there. It is both our slave and our master. It helps to regulate the global climate, and with its tremendous force it shapes the earth, at times destroying man's puny constructions. We use it for bathing, cooking and recreation. It carries away our wastes and irrigates our fields and, when taken from certain sources, has unequalled therapeutic properties. It is an inexhaustible, self-renewing resource.

The benison of water is not evenly distributed. Although clean fresh water is vital for life and for health, over half the people in the Third World do not have clean water to drink and three-quarters of them have no sanitation, yet more than three-quarters of human illness is related to lack of clean drinking water and sanitation.

This is why, in November 1980, the General Assembly of the United Nations declared the *International Drinking Water Supply and Sanitation Decade (1981-1990)*, whose target is "Clean Water and Adequate Sanitation for All by 1990".

Unesco's involvement in water problems goes back to 1950 when it launched a programme of research on the world's arid zones. The purpose of its current *International Hydrological Programme* (IHP) is to develop a scientific basis for the rational management of water resources and to help find solutions to specific water problems in countries with varying geographical conditions and levels of technological and economic development.

Badly managed, water, or the lack of it, can be a destroyer. Ill-conceived irrigation schemes can ruin agricultural land as effectively as drought and desertification, the two great scourges now affecting huge areas of Africa. Bad land-use practices, such as overgrazing and deforestation, can make water a prime agent of erosion. Bad industrial practices can turn rivers into sewers and "the gentle rain from heaven" into an acid-bearing blight that can kill a lake and destroy a forest.

There is as much water on earth today as there has ever been or ever will be. We must look after it.

Cover: Photo *Unesco Courier*

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38th year

Emblem of the International Drinking Water Supply and Sanitation Decade, 1981 to 1990.

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WATER

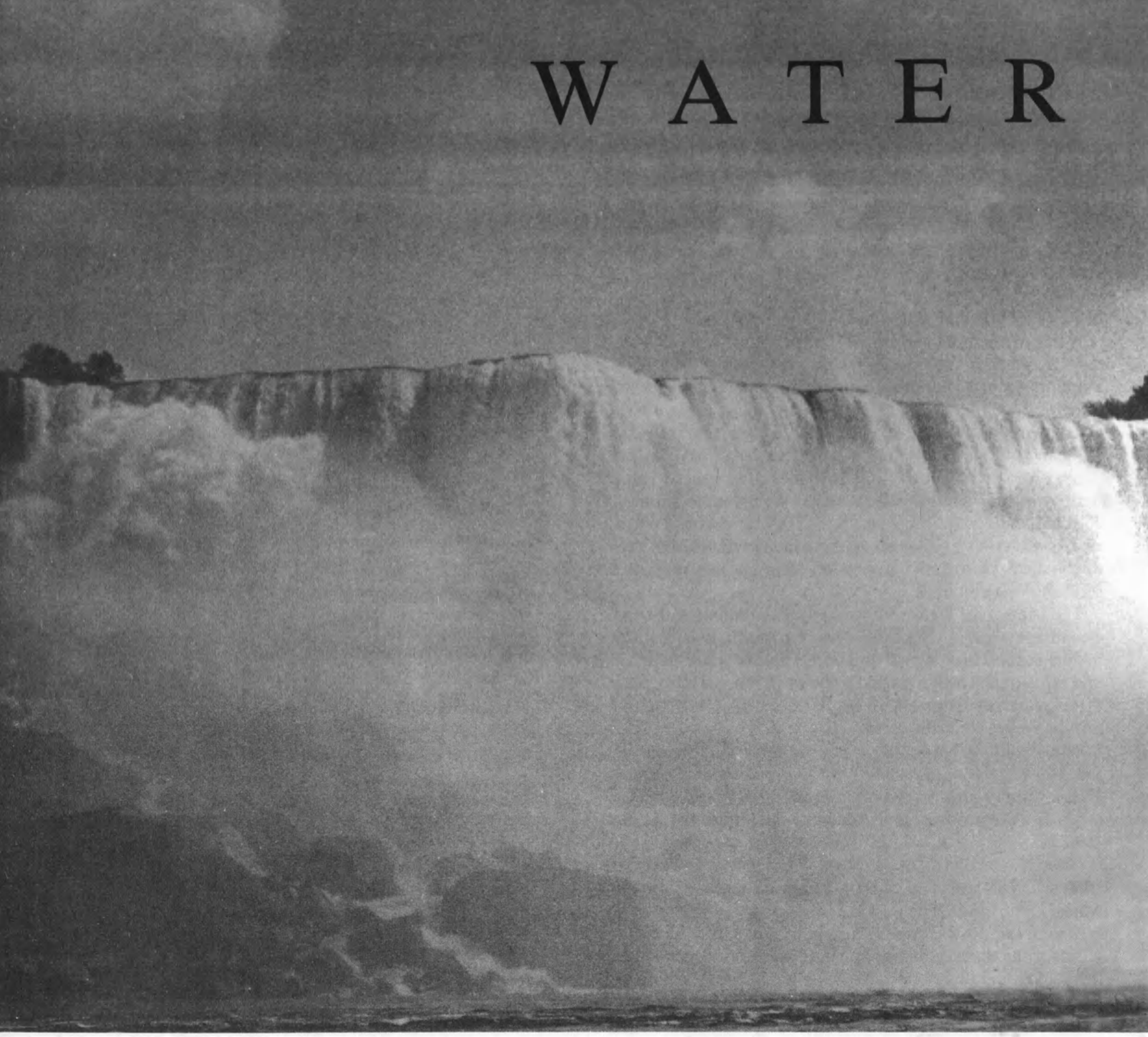


Photo Dominique Roger, Unesco

One of the natural wonders of South America, the Iguacu Falls are situated on a stretch of the Rio Iguacu forming the boundary between Brazil and Argentina. The horseshoe-shaped falls are over 4 km wide (4 times wider than Niagara in North America). During the rainy season from November to March the flow rate may reach 12,740 cubic metres per second. The Falls derive their name from a Guarani Indian word meaning "great water".

THE Earth is a sphere covered with a humid envelope, the hydrosphere, which comprises the oceans, the seas, and all other water resources. It was in the oceans that life appeared and took shape. But the extremely complex mechanism of life on our planet today cannot function without fresh water or, more precisely, without the very small proportion of water that is renewed each year in the water cycle through evaporation, precipitation, infiltration and runoff (that part of precipitation that flows toward streams on the ground surface or within the soil).

As part of this great natural movement (see drawing page 7), some 120,000 km³ of water reaches the continents as rainfall; this is only 1 per cent of total surface runoff water and 0.001 per cent of underground water. This water is today the essential source of life on our planet: it humidifies the plant layer of the soil, which is indispensable for agriculture; it conserves the forests and promotes their expansion; it completes the underground reserves whicl provide drinking water for almost one fiftl of the world's population.

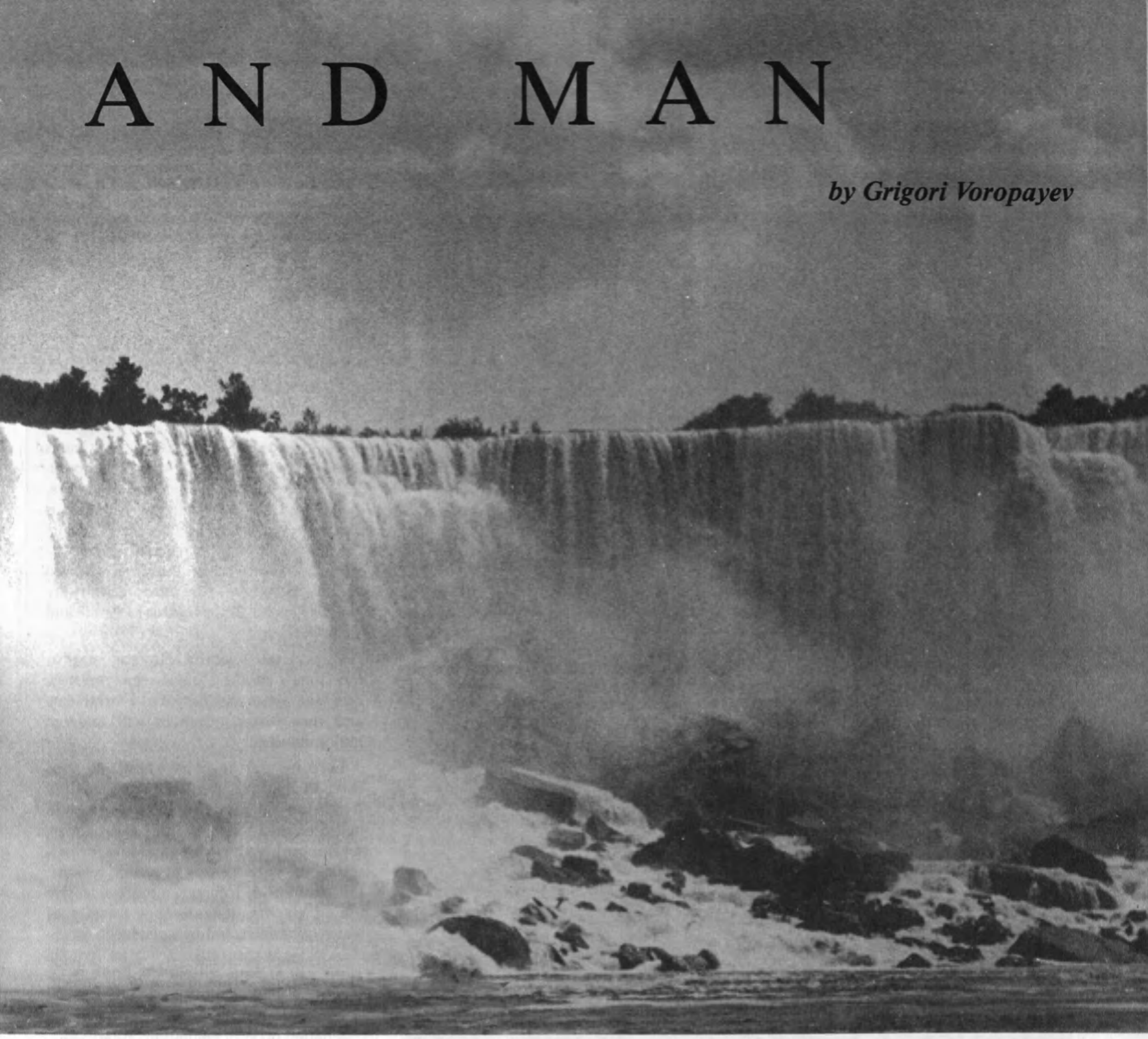
A large proportion of precipitation, som 40 per cent, constitutes the hydrographica network which controls the biologica equilibrium of lakes, seas and oceans, an influences world economic activity. Rive water provides the habitat of edible fish an is an important link in the biological chai of certain sea and river fish such a sturgeon, salmon and eel.

Deltas and estuaries formed by rive mouths, river systems, lakes, marshes an fresh water reservoirs all provide importan habitats for a large number of anima species necessary for human needs.

River water runoff constitutes annuall some 50,000 km³, or a little more than 0. per cent of the total fresh water of th planet. But its geographical distribution i unequal: it is mainly concentrated in th northern hemisphere, and in one-third o

AND MAN

by Grigori Voropayev



the hottest continental zones there are few or no rivers.

The birth of civilizations, population growth, increased production in all fields, from agriculture to advanced electronics, would be impossible without fresh water. While many countries have been notably successful in developing techniques for the desalinization, purification and re-utilization of used water, world consumption of river water continues to increase each year. Since the beginning of the twentieth century consumption of fresh water has risen more than sevenfold and now stands at almost 3,000 km³ per year. In the next twenty or thirty years the figure is expected to rise by at least 50 per cent.

Where the river network is insignificant, notably in the world's arid zones, the main existing watercourses are already or soon will be fully exploited in order to satisfy economic needs. This is the case of such rivers as the Nile, the Tigris, the Colorado, the Syrdarya, the Chu, the Amu Darya, and many other rivers in Australia, India, Mexico, Africa and elsewhere. In these regions the provision of drinking water and the development of irrigation are major problems.

The unequal distribution of river runoff on the different continents has a considerable impact on the water supply. Its annual volume per head of population is some tens of thousands of cubic metres for Oceania, South America and North America, but only a few thousand cubic metres in the case of Europe and Asia. The gap is even bigger in countries and regions where the annual volume per head is no more than several hundred cubic metres, which in practice makes it impossible to supply the population with drinking water or to establish modern hygiene facilities. For people living in these regions, water supply is a vital question which mobilizes all their efforts.

However, in spite of these major difficulties, the problem would be easier to solve if the natural mechanism of the water cycle remained constant. Unfortunately this is not the case. Man's economic activities modify the water cycle by influencing the hydrological regime, as well as water reserves and quality. The release of sulphur compounds into the atmosphere leads to the formation of "acid rain" which modifies the acidity of the aquatic environment, has a harmful effect on all forms of life and restrains the development of vegetation.

Intensive urbanization has an impact on evaporation and infiltration, modifies the runoff regime and the chemical composition of the water, and loads it with pollutants that are in many cases toxic. In some regions the catchment basins of rivers have already been and continue to be transformed by human activity.

The consequence is a drop in Spring flooding and flooding caused by rainfall. The area of naturally irrigated land is reduced, while the salinity of the water in- ▶

Photo © Limnological Institute of the Siberian Section of the USSR Academy of Sciences.

Lake Baikal, in the southern part of eastern Siberia, is the world's deepest lake and a unique living museum of aquatic plant and animal life. Some 25 million years old, it contains about one fifth of the fresh water on the Earth's surface, and is 636 km long with an average width of 48 km. Its area is 31,500 sq km. More than 300 rivers flow into the lake. Most of the outflow is through the Angara river which flows out from the southwest coast of the lake, shown in photo.

Below, a mangrove swamp in El Salvador. The mangrove is a tropical tree that flourishes in estuaries and swamps where fresh water mixes with the salty ocean and no other tree can grow. As it grows it sends down roots from its branches. Mangrove swamps were once considered wastelands, but their environmental importance and their economic potential are now recognized. Their leafy canopies and maze of roots constitute unique ecosystems sheltering an astonishing array of bird, insect and marine life. They are also an important source of timber, fuel, fisheries, fertilizer and other products. In collaboration with the International Council of Scientific Unions (ICSU), Unesco is conducting a research and training programme to promote the rational utilization and conservation of mangrove ecosystems in different parts of the world.

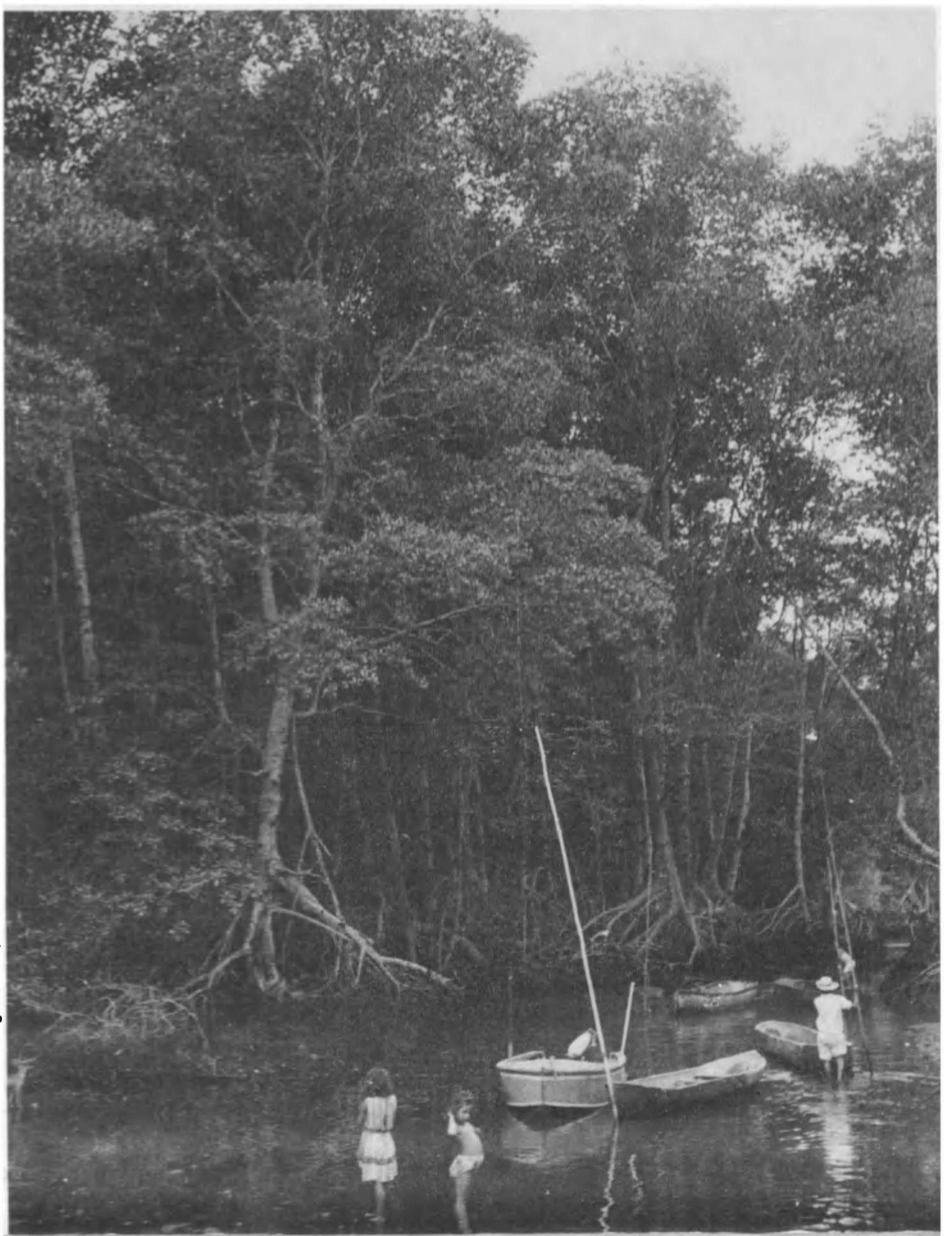


Photo T. Burgers. FAO, Rome

▶ creases in the river mouths. Many streams and rivers disappear forever. As a consequence of the construction of reservoirs, sluices and tapping facilities, river flow is diminished, water quality is radically changed, and the exchange of water between land and sea is accordingly slowed down. Effects on the environment are negative, especially as regards humidity and air temperature.

If, as certain scientific data now suggest, the climate of the globe is changing, the heat and water balance of the continents and their water resources will undergo major changes.

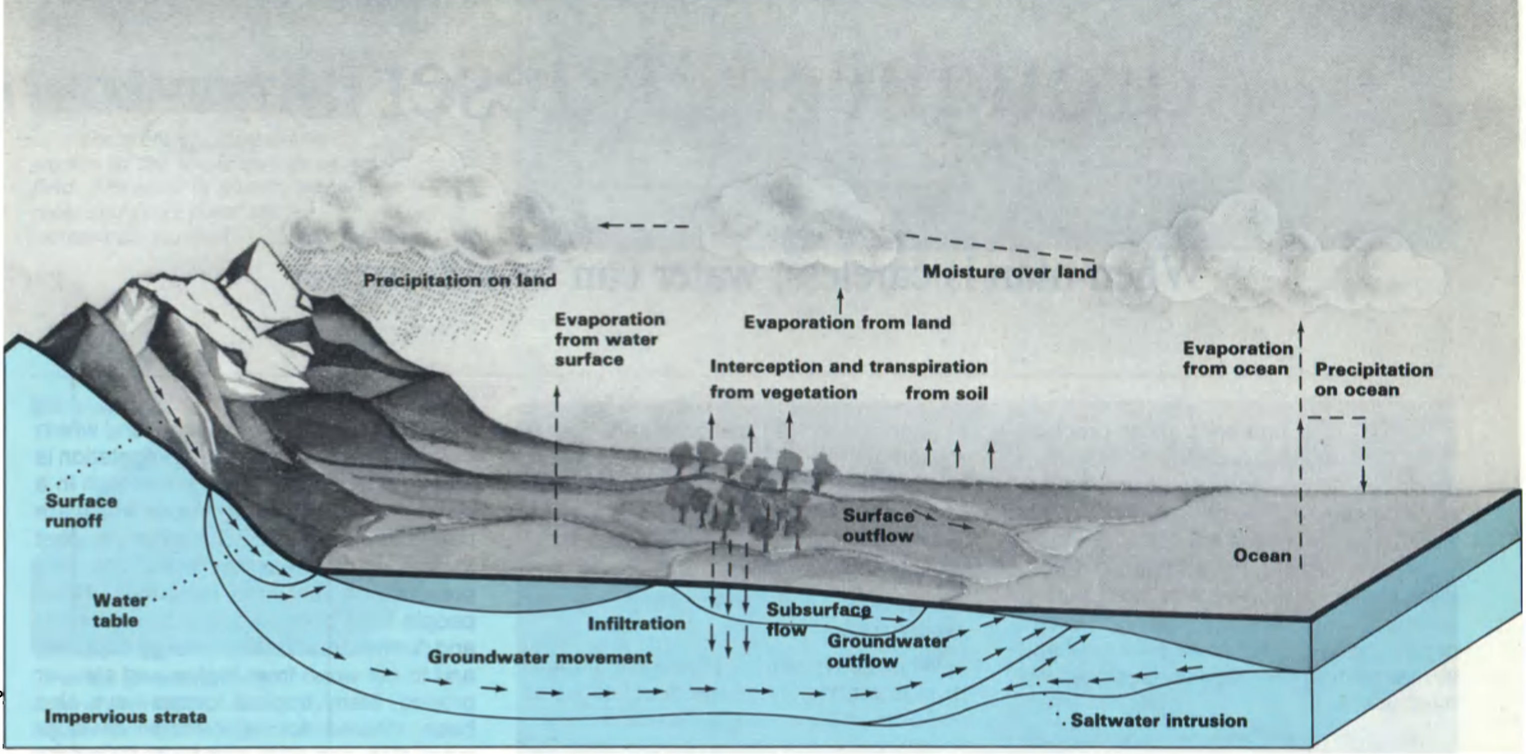
In recent years there have been major efforts to improve domestic and industrial fresh water supplies. In addition to progress in techniques for desalting sea water, several projects have been mooted for offsetting the water penury of certain regions: the transport of icebergs, a more extensive use of glaciers, long-distance transfer of water by tankers and by aqueducts.

Successes achieved so far provide grounds for a certain degree of optimism. But massive efforts will be required to solve these regional water supply problems, and ultimately these are bound to affect the geographical distribution of population and industries.

We live at a time when progress in the Earth sciences is such that environmental change can be foreseen and this knowledge can provide the scientific basis for a strategy for the utilization of natural resources and notably for the wise management of the hydrological regime and water resources as the most important and effective lever for modifying natural processes. It is for the world scientific community to unite in the search for a solution to this urgent problem. ■

GRIGORI VOROPAYEV, *of the Soviet Union, is a corresponding member of the USSR Academy of Sciences and director of its Institute of Hydrology. A member of the USSR National Committee for Unesco's International Hydrological Programme, he is the author of some 170 books and studies on problems of water including a monograph on the* Physical and Geographical Principles of Water Supply in Agriculture.

Nature's water wheel



Drawing Unesco Courier

OUR earth has been called the Water Planet, and with good reason. If it were not for the pervading presence of water on earth, the life forms that we know simply would not be here. Some very simple organisms can exist without air, but none can do so without water.

If this globe on which we all reside were not 150 million kilometres from our sun, the earth would not have its present mixture of gaseous, liquid, and solid moisture. Calculations show that if the earth were located closer than 134 million kilometres from the sun, our water would be boiled away. On the other hand, should the orbit of the earth have turned out to be more than 166 million kilometres out from the sun, the Ice Age of the earth would have been without end.

So things happen as they do because our solar system's thermonuclear fireball is located where it is. The sun is just the right distance to keep the earth's "water wheel" (the "hydrological cycle" as scientists call it) in constant motion.

The sun lifts water from the surface of the ocean—as well as from fresh water lakes, reservoirs, and streams. Additional significant amounts of moisture are obtained from the surfaces of plant leaves through a process called transpiration.

These masses of moisture, invisible unless temperature conditions are such that clouds form, move over the oceans and land. When lifted by mountain ranges—or when they come in contact with cooler air masses—the water molecules coalesce, and can no longer be supported aloft. Rain, hail, or snow then takes place.

If the precipitation falls upon relatively impermeable soil, the water may flow over the land as a small rivulet. But if the surface of the soil is quite porous, or with thick vegetation which softens the blows of the falling drops, there will be more infiltration and less direct runoff.

Once water begins to infiltrate the soil surface, its rate of movement drastically decreases. If the soil is tightly compacted or contains much clay, the water may move hardly at all. In such an instance, the water may be hundreds of years in reaching what is called the groundwater table—that area of the ground which is saturated with water.

It should be noted that the area between the surface of the soil and the top of the groundwater—called the unsaturated zone—is of major importance to vegetation. If it were not for this region which contains some water, along with oxygen, most plants could not exist.

The moisture which reaches the groundwater is not permanently removed from the water which is circulating in the world-wide hydrological cycle. The groundwater will move, however slowly, back towards the ocean. It may reach a lake where it may be lifted skyward. It may come to the surface in a spring where it joins the overland movement of a stream. When the stream does reach the river/ocean interface, the hydrological cycle may be said to have been completed.

In fact, of course, the cycle continues. The earth is still operating with its original supply of water which is still essentially undiminished. The molecules of water in Archimedes' bath are still floating around in some ocean, lake, stream, or aquifer.

It is estimated that approximately 505,000 km³ of ocean water is evaporated annually. However, about 458,000 km³, is of no use to us as it precipitates back into the oceans. Only about 47,000 km³ is carried far enough to precipitate over the land. It is only this water that is available to us for our multiple domestic, agricultural and industrial uses. In reality, the total annual precipitation over the land is much more than that; it is of the order of 119,000 km³, the balance of 72,000 km³, comes from water permanently retained as moisture by the atmosphere, soil and vegetation in a never-ending cycle of evaporation from ground and water surfaces, transpiration from vegetation, and precipitation from the atmosphere. The excess of about 47,000 km³ of water carried over from the evaporation of the oceans returns to the oceans as rivers and groundwater runoff. ■

This text and those on pages 25 to 28 are adapted from the booklet Water and the City, *published by Unesco within the framework of the International Hydrological Programme and written by Gunnar Lindh, professor of water resource engineering at the Lund Institute of Technology, University of Lund, Sweden.*

Erosion, drought and deserts

When man is careless, water can be a destroyer

SOIL is a country's most precious natural resource, aptly described as "the bridge between the inanimate and the living". It consists of weathered and decomposed bedrock, water, air, organic material formed from plant and animal decay, and thousands of different life forms, mainly micro-organisms and insects. All play their part in maintaining the complex ecology of a healthy soil.

Although soil erosion does occur naturally, the process is slow. Man has increased the rate of natural erosion by at least 2.5 times and, over the centuries, has destroyed an estimated 2,000 million hectares of land. There is good evidence that past civilizations, in the Mediterranean and in Central America, collapsed as a result of soil erosion following the cutting of forests on steep slopes and other destructive practices.

Soil erosion occurs primarily when land is exposed to the action of wind and rain. Unprotected by a cover of vegetation, and the binding action of roots, each raindrop hits the naked soil with the impact of a bullet. Soil particles are loosened, washed down the slope of the land, and either end up in the valley below or are washed out to sea by streams and rivers.

Water erosion is the commonest form of erosion. It is causing massive damage in nearly all developing countries. It is found where steep land is being unwisely farmed and where gently sloping land is left exposed to the effects of heavy rain for any length of time.

Worldwide, about 25,000 million tonnes of soil are being washed away each year, ending up in the rivers and finally the oceans. According to a study carried out by the Food and Agriculture Organization of the United Nations (FAO) and the United Nations Environment Programme (UNEP) an estimated 11.6 per cent of Africa north of the equator and 17.1 per cent of the Near East are subject to water erosion. So are 90 million of India's 297 million hectares.

Water erosion causes two sets of problems: an "on-site" loss of agricultural productivity; and a downstream movement of sediment, causing flooding, a loss of river navigability and the silting up of reservoirs.

While heavy rainfall, prolonged drought or high winds may be the direct cause of soil erosion, they are not the real problem. A landscape can remain stable under all these conditions, whether it is in a natural state or being sensibly farmed. Erosion occurs when farming practices are used which fail to take account of the ease with which soils can be washed or blown away.

For example, over-stocking and over-grazing have caused untold damage in much of Africa and Asia in the past few decades. In arid areas, soil is compacted around water holes, the vegetation is stripped and dies, and erosion sets in. Too often the land ends up as desert, the intimate result of soil erosion and degradation. If erosion is the sickness of a land, desertification is its death.

Today, desertification is threatening about 3,200 million hectares of land; the livelihoods of the 700 million people who depend on that land are at stake.

About 30 per cent of the world's exploitable soils are still under shifting cultivation in Africa, Asia and Latin America. The technique is practised by more than 30 million people in Africa alone. Formerly, this use of land served to conserve fertility, as it allowed a long fallow period during which soil fertility would build up to its previous level. Today, population pressure and the struggle for improved yields are cutting the fallow period back to virtually nothing. Under such conditions, the forest soils soon lose their fertility and begin to erode. Essentially, this is because the land is being farmed beyond its capability.

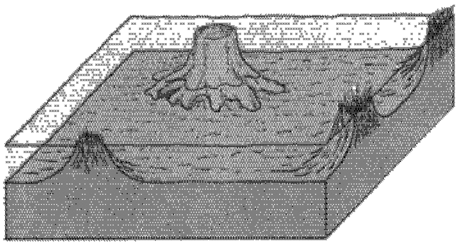
Nearly always, it is exposed land which erodes while land covered in vegetation is stable. The process often starts high in a watershed, on the steep slopes which are traditionally forested. But over the past few decades, there has been mounting pressure on fuelwood resources. Rural people have been forced to travel further and further to find their energy supplies, and to cut wood from higher and steeper ground. Many tropical forests have also been cleared for agricultural development. Between 1975 and 1980, 37 million hectares of forest were destroyed in Africa, 12.2 million in Asia and 18.4 million in Central and South America.

In some countries, an increasingly critical balance of payments situation has forced governments to plant more and more cash crops. If no more arable land is available, the new crops have to be planted in marginal land, previously pasture, which is brought under the plough for the first time. Much of the thin soil may be lost in the first heavy rain which occurs when the field surface is still bare. During a short storm in the United Republic of Tanzania a few years ago, scientists found that a field they were studying lost 5 centimetres of topsoil over its whole surface in just a few hours; rills had cut down to a depth of 15 centimetres.

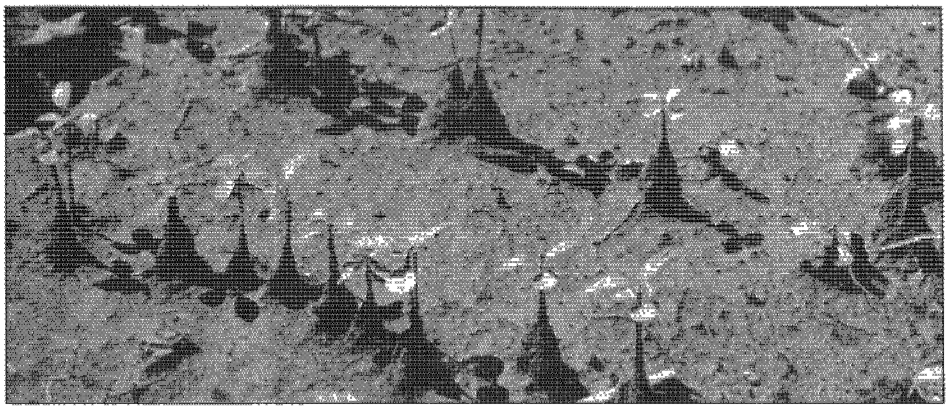
The problems of soil conservation are closely connected to those of rural development and rural poverty. A farmer who has to struggle to grow even enough food to feed his family cannot devote weeks or months to terracing his land or learning new farming techniques. It follows that successful rural development is an essential precursor to eliminating soil erosion. ■

Text, drawings and photos adapted from Protect and Produce: soil conservation for development, *published by the Food and Agriculture Organization of the United Nations.*

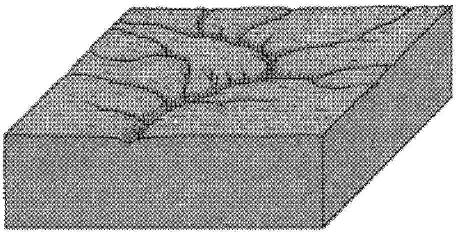
Sheet erosion...



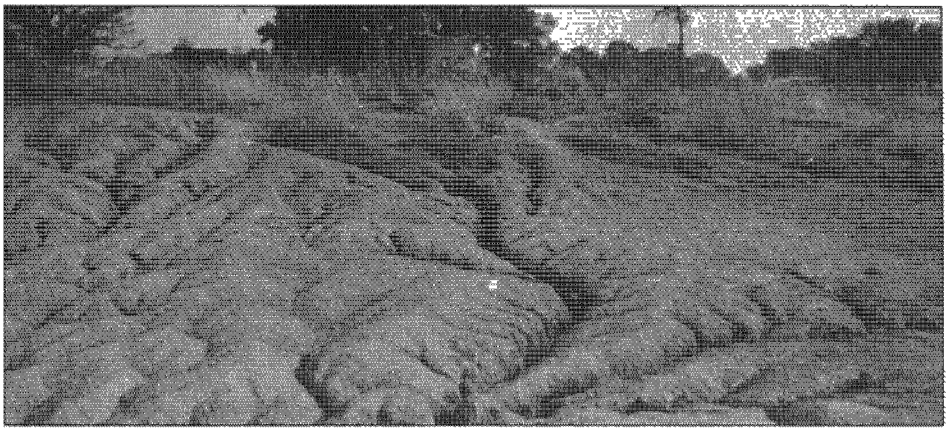
... is the more or less uniform erosion of the whole surface of a field. The roots of plants, tree roots and fence posts are increasingly exposed



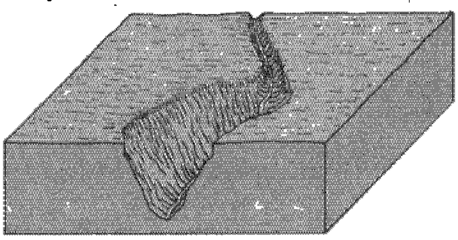
Rill erosion...



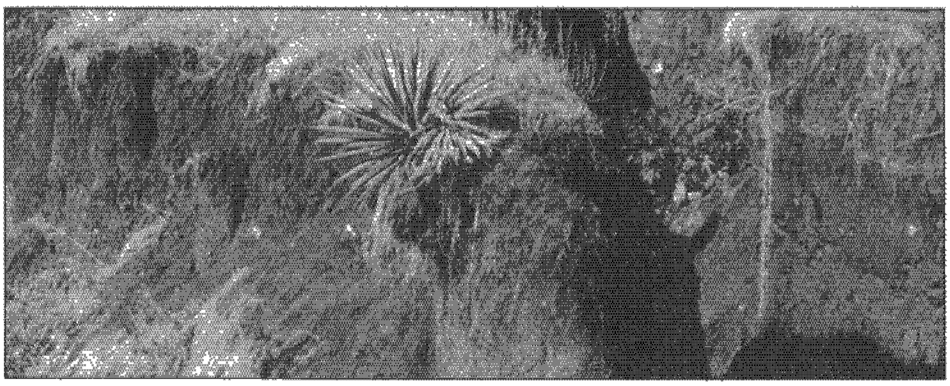
... is the accentuation of natural depressions caused by surface run-off. While normal cultivation often hides the damage, much fertile soil is still lost



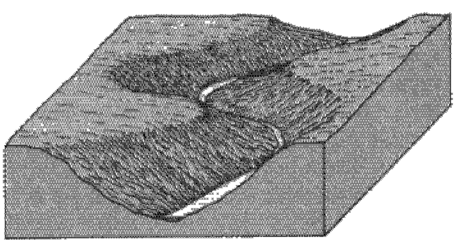
Gully erosion...



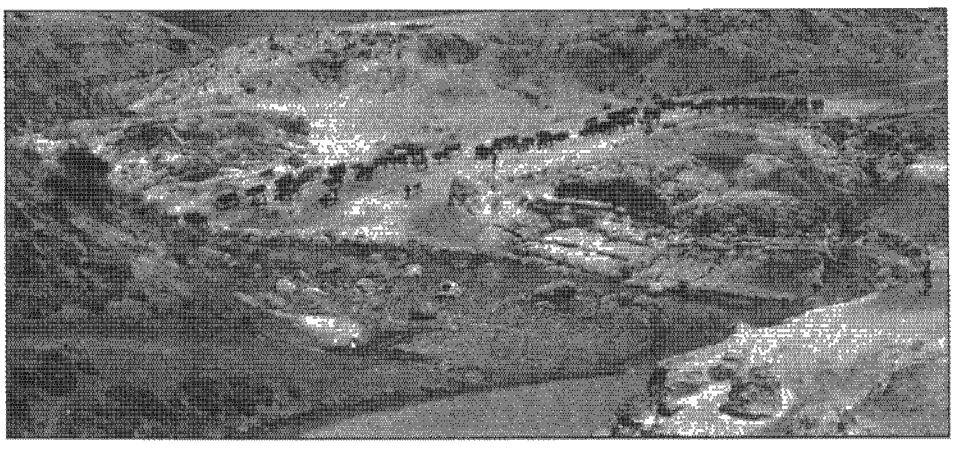
... causes deep fissures in otherwise cultivable land. If left unchecked, gullies eat their way progressively back into the hill



Streambank erosion...



... converts deep, fast-flowing streams into wide and sluggish meandering watercourses with extensive mud banks. It can cause serious loss of cultivable land



Drought over Africa

The eleven worst-stricken countries

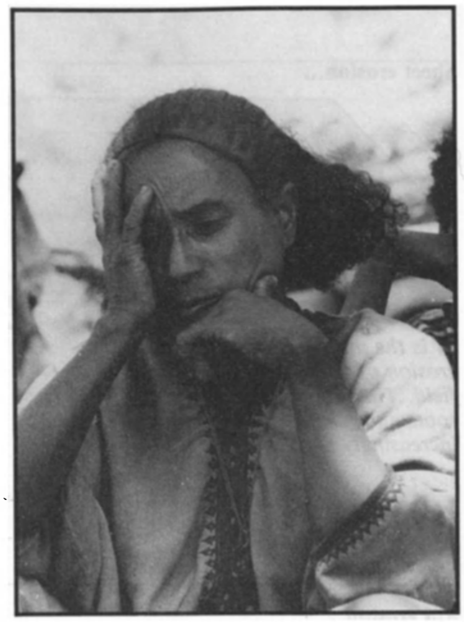


Photo T. Page, World Food Programme

Ghana

Most affected provinces: upper and northern regions.

Ghana, almost self-sufficient in cereal production ten years ago, is today facing a severe economic and financial crisis aggravated by the recent prolonged drought.

The marked deterioration of agricultural production compounded by the non-availability of transport and fuel, the poor road network, the lack of storage facilities, and reduced purchasing power has had immediate impacts on the nutritional status of mothers and children.

The infant mortality rate, which was steadily diminishing, is now on the increase throughout the country and especially in the north.

Food shortage is especially dramatic in the northern part, since a serious logistic problem has to be overcome to facilitate food distribution in this region.

Burkina Faso

Most affected regions: the northern part of the country (Sahel region).

Burkina Faso, formerly Upper Volta, the fifth poorest country in the world with one of the highest infant mortality rates, has been seriously affected by drought and desertification ever since 1968. The lowest recorded rainfall for 30 years was registered in 1981 when about one-third of the country's livestock was lost due to drought. 1983 was another peak drought year, especially in the northern part of the country where the harvest failed completely.

In a country where the health and nutrition status of children and mothers is normally already very poor, the present drought renders them even more vulnerable to communicable and parasitical diseases as malnutrition increases.

Large-scale imports of basic foodstuffs, which have become an annual feature of the country's battle for survival, were again needed in 1984 to meet the food shortages. Seeds for the next planting season will also be required.

Mauritania

Most affected provinces: nine regions (out of a total of 12).

The drought situation, which has existed for over ten years, became particularly serious in the course of 1983. In certain localities, rainfall levels were the lowest in 70 years. The Senegal River rose only to 10% of its normal rainy-season level, thus preventing water-recession agriculture, and the losses of animals and grazing land have been massive.

Difficulties in the supply of milk and meat are foreseen due to the present large-scale sale of livestock at low prices. Current cereal production is estimated at 15,000 tons (against 61,000 tons in 1981/1982), which represents only 6% of consumption.

Severe cases of malnutrition are already recorded in some areas (numerous cases of vitamin deficiency, especially scurvy and anaemia).

Zimbabwe

Most affected regions: all eight provinces (the outskirts of the country more than the centre).

According to government estimates, malnourished children total 464,200, and only 244,400 are currently assisted.

Zimbabwe is suffering the third year of a drought which is the worst in living memory. No surplus food is currently available and the situation is not expected to improve with the next harvest. The maize shortfall over the next 15 months, entirely due to the drought, is estimated at 838,000 tons.

Amongst the vulnerable groups, the health condition is often very serious.

Drought relief programmes are being coordinated by the Zimbabwe government and include the distribution of basic food rations and supplementary feeding programmes.

Ethiopia

Most affected regions: Wollo, Gondar, Eritrea, and Tigre.

Number of affected persons: 5,200,000 out of a total population of 32,395,000

The percentage of those under the age of 15 affected varies from 37 to 68% in different regions. In addition, about 2.2 million displaced people need assistance. Several administrative regions have not had rain for three consecutive crop seasons. The most affected regions are all in northern Ethiopia.

Serious food shortages are also occurring in other administrative regions of Ethiopia. Some 52,950 people in the region of Bale, 278,830 in the region of Hararghe, and 35,250 in the region of Gojjam require immediate assistance; 122,000 in the Soha region, 2,530 in Arussi, 79,880 in Gemu-Goffa are likely to require assistance. 165,040 nomads in the Sidamo administrative region are also in dire need of assistance. In addition, some 221,610 displaced persons in the Gondar, Hararghe, Bale and Sidamo regions require immediate assistance.

Mozambique

Most affected regions: Gaza, Inhambane, Maputo, Tete, Zambezia, Sofala, Manica.

Number of affected persons: 4,700,000.

Mozambique has been experiencing severe drought for the past four years, with an aggravation of the situation in 1982 and 1983. Gaza, Inhambane, and Maputo are considered to be the most seriously affected. FAO estimates that 4.7 million people, especially in rural areas, are affected, including 1.8 million in the southern provinces alone. Moreover, the Maputo province was struck by a cyclone at the end of January 1984 and more than half of the population was affected by the complete loss of summer crops.

The cereal imports required by the country at large are estimated at 600,000 tons as opposed to 300,000 tons in normal years.

Photo Maggie Murray-Lee, UNICEF

Photo Jacques Danois, UNICEF

Photo Norbert Engel, UNICEF

Chad

Most affected provinces: Kanem, Biltine, Batha.

Number of displaced and affected persons needing emergency assistance: Kanem, 200,000; Biltine, 50,000; Batha, 50,000; the majority are women and children.

The situation is catastrophic due to 17 years of internal conflict, a decade of drought, lack of adequate administrative structure, and a very poor internal communication network.

Chad is presently totally dependent on international food aid for its survival. The *Comité Inter-Etats de Lutte contre la Sécheresse au Sahel* (CILSS) estimates that the structural food deficit in Chad is 15,000 metric tons a year. The Ministry of Natural Calamities estimated the net food deficit for 1983/1984 at 107,557 tons.

The most severely affected groups are women and children. They are facing serious malnutrition and illnesses caused by nutritional deficiencies and lack of drinking water (scabies, malaria, measles, intestinal infections, tuberculosis).

Niger

Most affected provinces: Zinder and Diffa.

Number of affected children: 23,800.

Niger, which has a large external debt, is like other Sahelian nations facing the consequences of uncertain rainfall. In 1983 and 1984 persistent drought severely affected certain pockets of the population, especially in the areas of Zinder and Diffa in the south-east.

On the other hand, in some other parts of the country, harvests were more or less satisfactory. Although some food stocks are available, many households in both rural and peri-urban areas do not have the purchasing power to buy them.

Mali

Most affected provinces: all the Sahelian zone of the country (Gao and Timbuktu regions).

Number of affected persons: 2,500,000 of whom 1,100,000 are children under the age of 15 and 500,000 under the age of five. These figures exclude migrants from neighbouring countries, as their present number is difficult to evaluate.

Chronic drought has affected the Sahelian region of Mali (two-thirds of the country) since 1969. The severe drought of 1968-1974, with the peak year of 1973, drastically reduced livestock levels. There was some improvement between 1976 and 1978, but since 1980 the recurrence of serious drought conditions has again resulted in a drop in food production and the herd level.

The situation worsened in 1983; the rainfall throughout the country has never been so poor and the level of the rivers is the lowest recorded this century. Most of the lakes are now dried up.

Many of the water points where sedentary and nomadic people are now concentrated are not equipped to cope with the increased numbers. This creates a spreading ground for diseases and epidemics and puts the children in particular at high risk, all the more because the areas severely affected by the drought are also seriously under-equipped in the social and health fields.

It is feared that the catastrophic death toll of 1973—when 90% of the children under the age of five died in the camps that had been set up—will recur if no urgent action is taken to rehabilitate the health and nutrition conditions.

Texts adapted from Ideas Forum, *UNICEF. As we go to press, new and higher figures for the numbers of people affected are being quoted. Some authorities now estimate the figure for Ethiopia, for example, to be as high as 7,000,000.*

Senegal

Most affected provinces: the river region, the north, and the Louga and Linguere regions.

Number of affected persons: 1,100,000 among whom 500,000 in the most vulnerable group (children, pregnant and nursing mothers).

Senegal has been suffering over the last 15 years, and especially for the last seven years, from a severe drought that has seriously affected the population and the local economy. Drought conditions drive cultivators and nomads towards the towns, which are totally unable to support them.

The 1983 rainy season was particularly poor and the harvest available for consumption in 1983/1984 was estimated at half the normal annual production. The cereal deficit itself was estimated at 370,000 tons.

Angola

Most affected provinces: central and southern provinces.

Number of affected and displaced persons: 1,000,000.

The drought began in 1980/1982 in the central and southern provinces. More than 260,000 people are affected and among these almost 80% are women and children.

A succession of dry seasons has considerably reduced food production, and the decline in the price of oil, coffee, and diamonds on the world market has also considerably reduced export earnings at a time when large-scale importation of food is necessary.

In addition to the deteriorating economic situation, the political and military conflict has displaced and affected many more people.

Heavy rains during February and March 1984 had disastrous effects on the road conditions, housing, sanitation, and crops as floods washed away seeds and young plants.

Today in Angola, one-third of the children die before their fifth birthday. ■

The menace of desert advance

by Mohamed Skouri

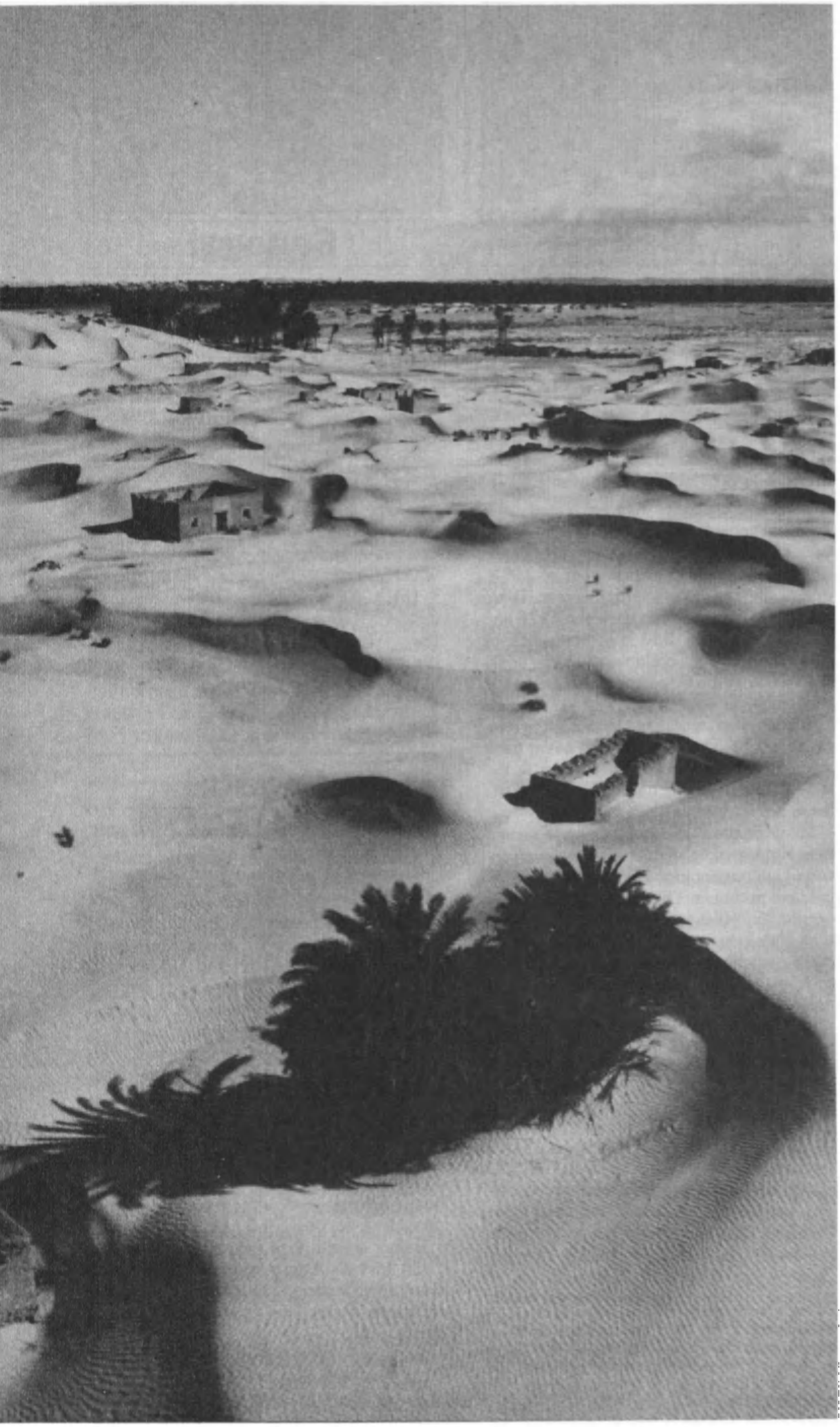


Photo Michaelangelo Durazzo © ANA, Paris

FOR the past twenty years, areas on the fringe of the Sahara have suffered from profound disturbances which have drastically changed the facts of desertification. In addition to the persistence of the drought, these areas have undergone substantial socio-economic and ecological changes which have even increased the severity of the problem.

Although scientific knowledge about near-desert environments has made enormous progress, a great deal still has to be done on the practical level to arrive at solutions which are adapted to the ecological and socio-economic conditions prevailing there.

Research must therefore aim not only at broadening knowledge and at improving the methods of exploiting natural resources but also at taking greater account of the characteristics of these resources in relation to technological development and to changes in socio-economic conditions.

It was with just such things in mind that Unesco launched its major international programme on Man and the Biosphere (MAB). The goal of this programme, which started operations early in the 1970s, is to promote a new approach to research on natural environments, studying the impact of human activities on natural resources in order to identify the best ways of using those resources. As well as leading to an improvement of methods, this programme has contributed to the launching of pilot projects embracing research, training and demonstration activities and closely involving the people concerned, researchers, extension workers and decision-makers.

In preparation for a special meeting held in Nairobi in April/May 1984 to make a general assessment of progress in the implementation of the Plan of Action to combat desertification, Unesco was requested to update three case-studies concerning Chile, Niger and Tunisia which were initially prepared for the 1977 United Nations Conference on Desertification.

The study on Niger provides a typical example of the way MAB works.

Updating the case-study shows that of the two main causes of desertification, that is, the prolonged drought and increasing human and animal pressure, either could have been the main one. However, the fact that there are instances of serious deterioration in sparsely inhabited regions means that the initial cause of the process was the inadequate rainfall. There is reason to believe that if, in 1970, human and animal pressure on the natural environment had been less

Each year 21 million hectares of once productive land are rendered useless for farming and a further 6 million hectares are reduced to desert. Left, the abandoned village of Douz, Tunisia, has been almost completely swallowed up by encroaching sand dunes.

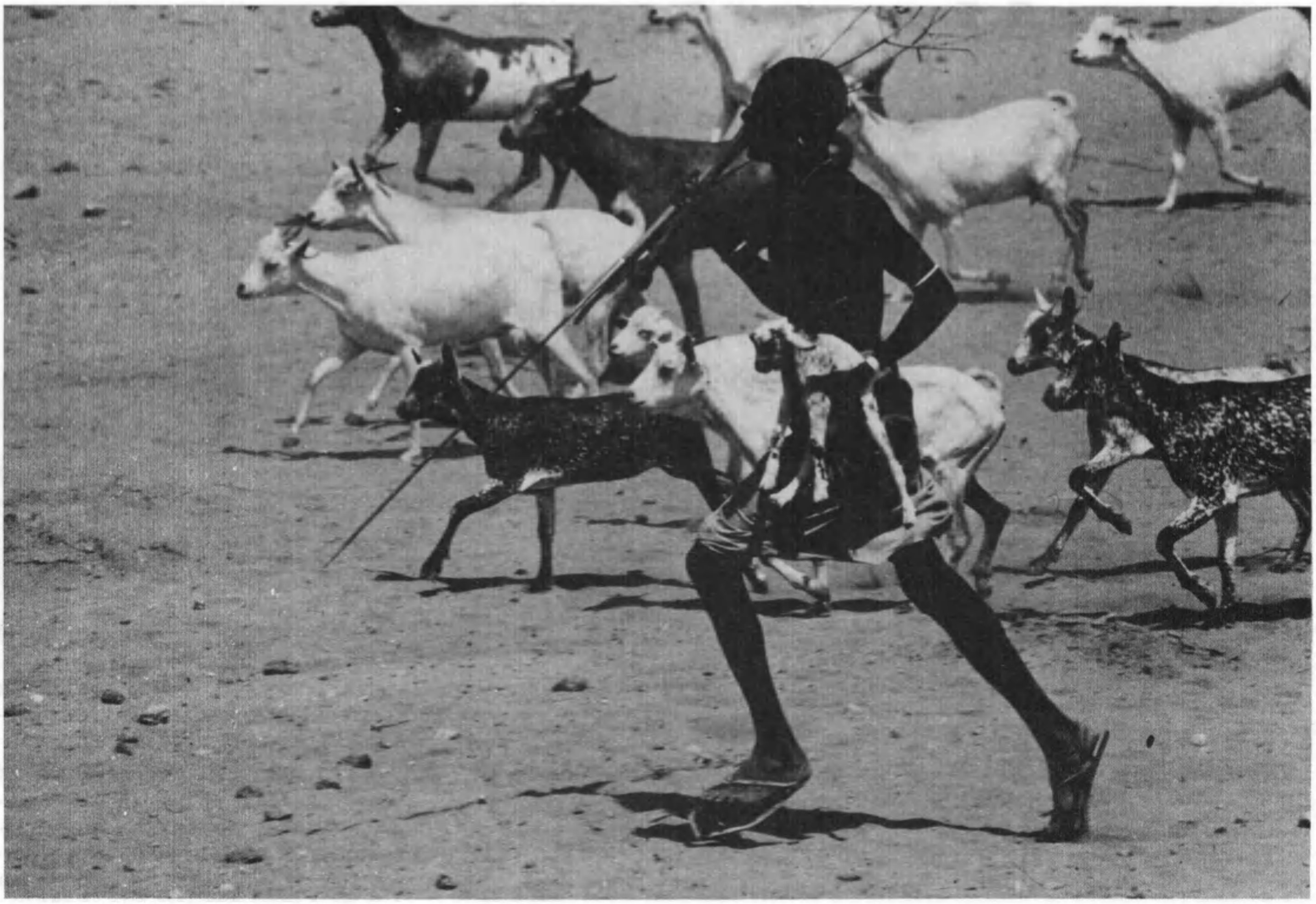


Photo Amos Schliack © ANA, Paris

With the smell of water in their nostrils, a flock of goats races towards a water hole across rangeland badly eroded by overgrazing in Kenya.

severe, the effects of the drought would have been neither as swift nor as dramatic, but they would have existed in a more localized fashion.

By 1983, despite a rise in rainfall since 1977, the vegetation had not yet returned to its pre-drought level, either in quantity or in quality. This was certainly due to the fact that the rains during these "good years" were neither abundant enough nor sufficiently well distributed to make up for the heavy toll of the long years of previous deficits, and also because human and animal pressure on pastoral areas had outpaced regeneration. When the crisis began during the 1970s, the pastoral load was eased as the people fled and was eased even more towards the end as animals died after depleting all the fodder. After the exceptional drought, the return of Peul cattle herds, the livestock replenishment policy and the rapid increase of small livestock has led to a rapid reconstitution of herds, though previous numbers have not yet been attained.

The responsibility of man, whose action is coupled with the effects of the climate, is beyond doubt. However, the impact of man is localized since the destruction of the vegetation through direct felling, through grazing or trampling by herds, and even through bush fires, never affected the entire environment as climatic change did. In the absence of man, his herds and/or his crops, the shortage of rainfall would have had nearly identical effects, outside areas of heavy concentration. Overgrazing is not responsible for the alarming regression of the *Commiphora africana,* a shrub whose leaves are eaten by goats and camels, but the prolonged drought and the wind. On the other hand, overfelling of forest for firewood is quite independent of climatic variability.

The greatest source of concern for the future is now the effects of the regression of the plant cover. When inadequately covered, the land is exposed to the ravages of the sun, water and wind. The lack of plant matter reduces the formation of humus so that a chain reaction is likely to be triggered off which would make the possibility of any true "recovery" of the biological environment very unlikely.

The reduction of plant biomass and the concomitant dwindling of plant formations leave the soil bare and reduce obstacles to the winds. Denuded surfaces have increased significantly and, in addition, wind abrasion is affecting larger areas, which in turn are increasingly difficult for vegetation to reconquer. The now-frequent, violent, sand-laden winds are surely a sign of a worsening of environmental disintegration.

In the final analysis, it is very hard to provide a categorical countrywide response to the question: "Has desertification increased or diminished in northwest Niger since 1977?" In fact, according to the sector or factor under consideration, one can give opposite replies. Plant cover in the Sahel is constantly undergoing change and quite frequently, to complicate observation, the herbaceous layer does not develop at the same rate as the tree layer, or growth on sandy soils is not the same as growth on clay soils. Faced with these non-synchronous changes, it is rather difficult to express an overall opinion on trends in 1984. On the other hand, views are unanimous about the causes described above and this makes it possible to build a strategy on solid bases.

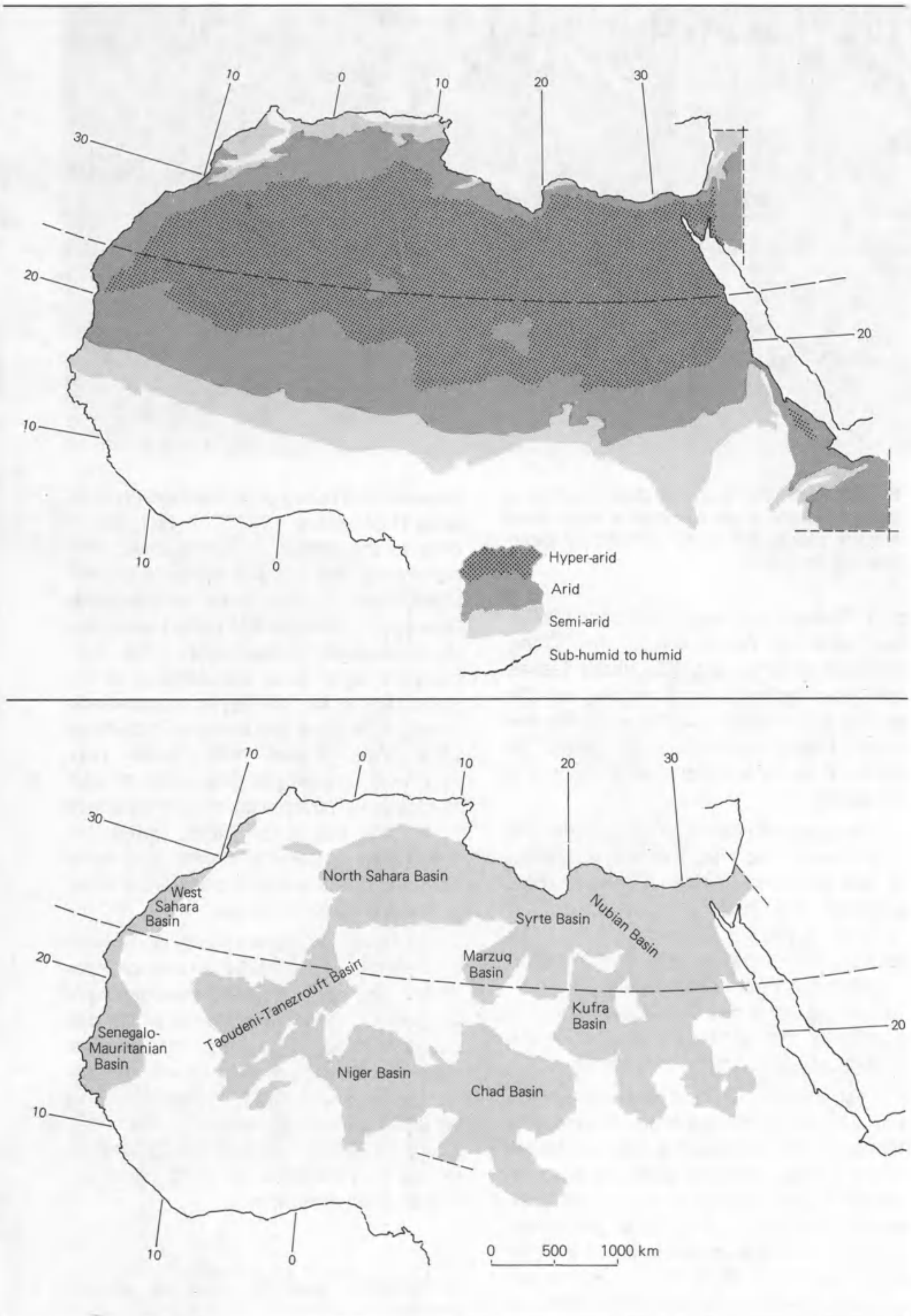
The study on Niger clearly underlines the fact that despite adverse climatic conditions, the natural plant formations have a good regenerative potential which can be enhanced if human and animal pressure is maintained at a level compatible with those formations' regenerative capacity. The area covered by the study, about 70,000 km², is sufficiently large to be quite representative of much of the Sahelian environment. ■

MOHAMED SKOURI *is a programme specialist in Unesco's Division of Ecological Sciences. An agronomist, he specializes in problems of arid zones.*

This article is based on a longer study published in Unesco's environmental magazine Nature and Resources, *Volume XX, No. 1, January-March 1984.*

Mining fossil water

by Jean Margat and Kamal Saad



Maps based on *Map of the World Distribution of Arid Regions*, Unesco, 1977.

Maps show, top, zones of aridity in north Africa and, lower map, the location of the main sedimentary basins containing deep aquifers.

FAR below the surface of the earth, vast quantities of life-giving water have lain concealed for thousands of years in huge aquifers (layers of water-bearing porous rock) formed in the extensive sedimentary basins that exist in every continent.

Most of these aquifers were first discovered and exploited during the nineteenth century, but, in some countries, it is only in the last few decades that intensive use has been made of them.

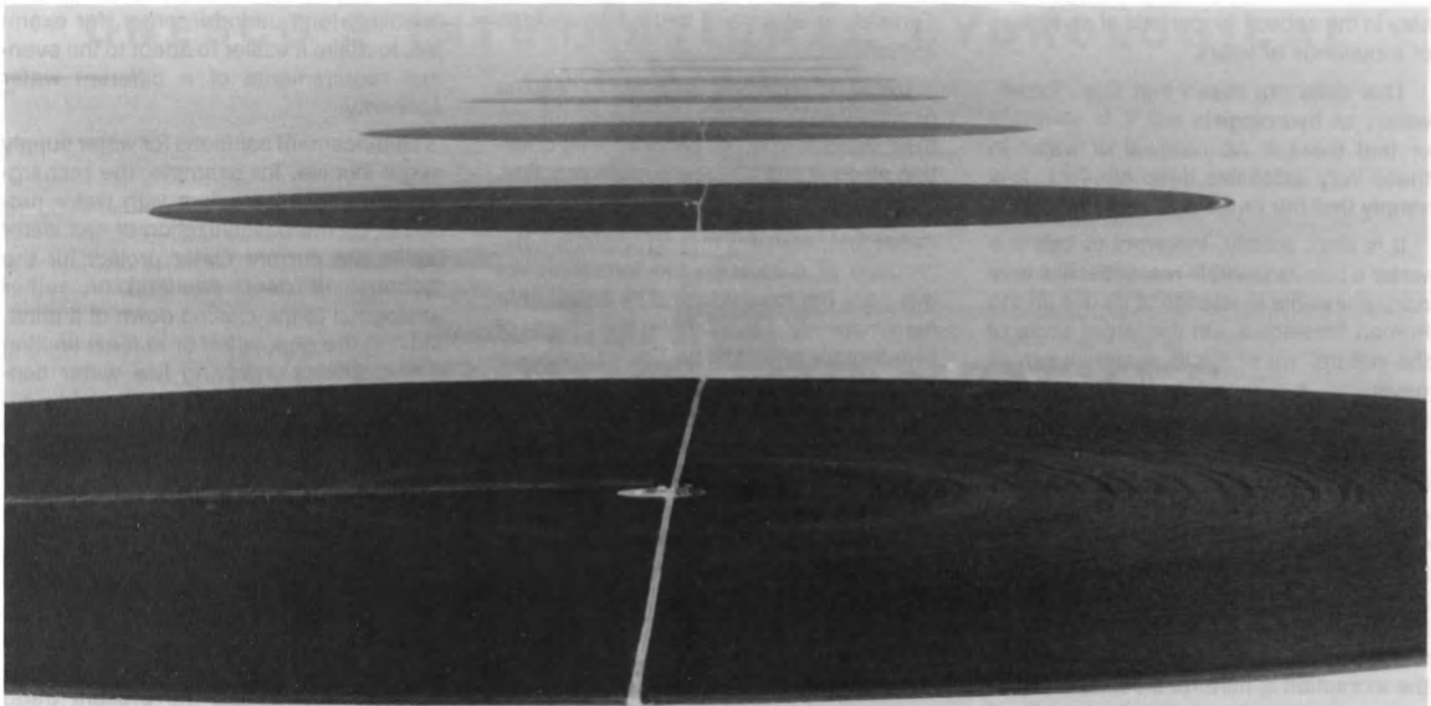
In arid areas such reservoirs have, of course, become of outstanding importance and often represent the sole permanent source of water. Fortunately reservoirs of this kind are to be found in the subsoil of several countries in arid areas, including, in particular, the huge desert area which stretches from the Atlantic Ocean to the Gulf, covering the north of the African continent (the Sahara) and the Arabian peninsula (see map).

Naturally enough, the primary concern in these countries was to improve prospection and exploitation techniques. More and more wells were drilled and water production was often substantially increased in each basin.

This increased exploitation had the predictable effect of reducing water levels and in some cases the quality of the water drawn deteriorated. It soon became evident that what was needed was to establish a strategy for the long-term exploitation of each basin as a whole.

Research carried out in a number of countries soon showed that the water confined in these deep aquifers represents a non-renewable resource. There was clearly a need for a special conception of water resources and special procedures for evaluating them. A model example of this type of approach is Unesco's *Study Project on Water Resources in the Northern Sahara*.

In absolute terms hardly any groundwater exists completely independently of the natural water cycle. However, water moves at very different speeds in different aquifer layers, and in addition the distances travelled may vary greatly. Where water has to cover hundreds or even thousands of kilometres at speeds of the order of several metres a year, it may ▶



Above, as this dramatic aerial view of a rotary irrigation system in northern Africa demonstrates, the mining of water from deep aquifers allows desert areas to be reclaimed for agriculture. In the Sarir region of the Libyan Arab Jamahiriya 500 productive wells have been drilled and 50,000 hectares of desert reclaimed for cultivation. Right, well and pivot mechanism round which the sprinkler rotates at the centre of an irrigated area. The huge sprinkler arm can be moved round as required and can irrigate an area of some 80 hectares.

▶ stay in the subsoil for periods of up to tens of thousands of years.

This does not mean that this "fossil" water, as hydrologists call it, is stagnant or that there is no renewal of water in these very extensive deep aquifers. It is simply that the renewal is very very slow.

It is also, strictly, incorrect to call this water a *non-renewable* resource; it is only non-renewable in relation to its use on the human time-scale. On the larger scale of the natural water cycle, water drawn is never lost, but is merely transferred and modified.

However, the local structure that provides the resource may, through intensive exploitation, undergo irreversible changes such as the compaction of the soil or an intrusion of salt water. Thus harnessing the water resources of one of these aquifers amounts to drawing on the water reserve capital and, by analogy with the extraction of mineral ores, it can rightly be described as the "mining" of groundwater.

"Water mines", productive drilling fields exploiting deep aquifers on the basis of withdrawal from storage, are in operation in various countries in the arid zone where they account for the bulk of water production.

In the developing countries in the arid zones of Africa and the Middle East such projects have been increasing rapidly and plans exist to intensify them, for example, in the northern Sahara (Algeria and Tunisia), in Egypt and in the Libyan Arab Jamahiriya.

Deciding whether or not to exploit groundwater reserves, whose use means their depletion, is not an academic question since this is already current practice.

The deliberate mining of groundwater raises first, as in any mining operation, the problem of evaluating the formation—in this case the reservoir and its exploitable resources—and forecasting the effects of withdrawals on usability. The exploitation of a dynamic reserve which reacts to exploitation is more complex than that of a passive ore deposit.

Furthermore, mining costs rise as water levels fall, with a marked increase when the change takes place from artesian exploitation to pumping or where the productivity of wells declines as a result of compaction of the aquifer.

Questions also arise in a wider perspective as to the long-term disadvantages of such exploitation. The gains for one or two generations are achieved to the detriment of future generations. The choice is between maximizing production for the benefit of the present generation in order to speed up socio-economic development or spreading production out over a relatively long period in order, for example, to make it easier to adapt to the eventual requirements of a different water economy.

Replacement solutions for water supply might involve, for example, the recharging of depleted aquifers with water produced by the desalinization of sea water (as in the current Qatar project for the recharge of deep aquifers) or, rather analogous to the closing down of a mine, moving the population or at least limiting it to activities involving low water consumption (as in the project to end irrigation in various counties in the State of Arizona, in the United States).

Should the mining of groundwater be encouraged or discouraged? In practice action has often preceded analysis and a commitment made to the mining option. Thus the question that now arises for those responsible for water resource management is primarily one of choosing between maintaining the present trend and even intensifying it, or modifying it with a view to prolonging production at a reduced level. ■

JEAN MARGAT *is a French hydrogeologist at the* Bureau de Recherches Géologiques et Minières, *Orleans.*

KAMAL F. SAAD *is a water specialist at Unesco's Regional Office for Science and Technology for the Arab States.*

This article is taken from a longer study published in Unesco's environmental magazine Nature and Resources, *Volume XX, No. 2, April-June 1984.*

Desert aquifers are to be found at depths ranging from 50 to 1,500 metres. Below, "fossil" water gushes forth after a successful drilling operation in Saudi Arabia.

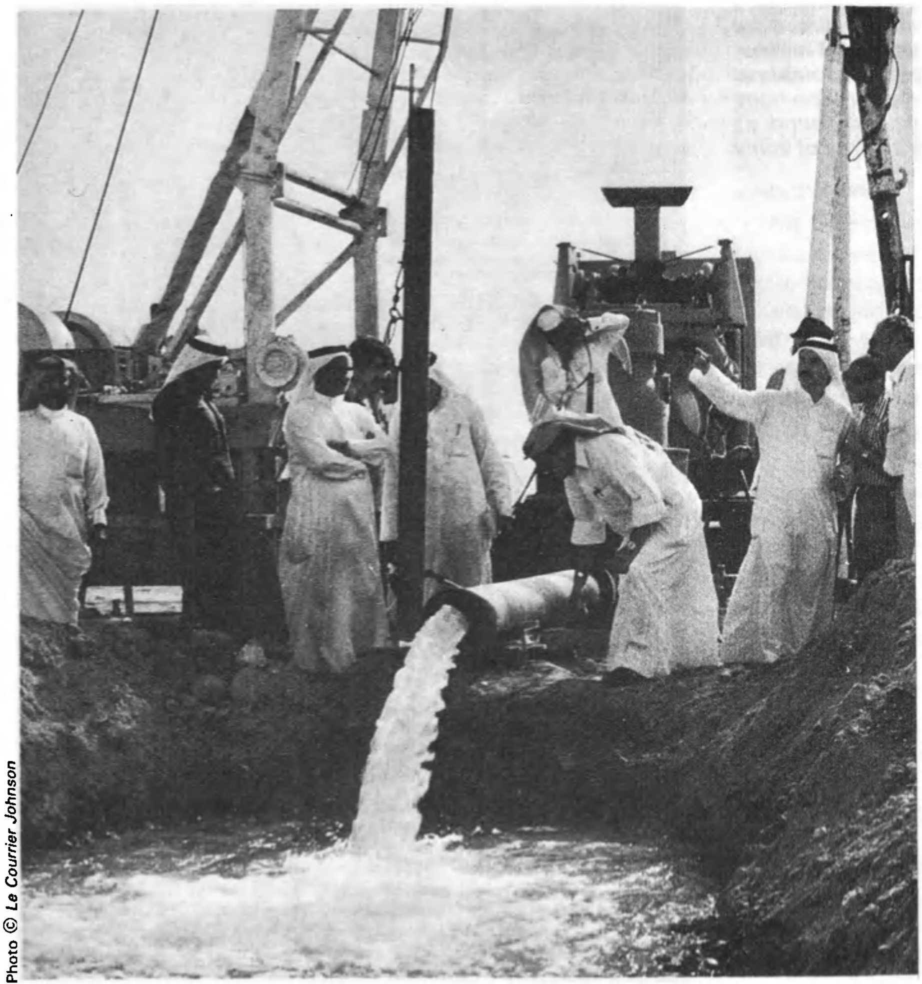


Photo © *Le Courrier Johnson*

Managing the world's most precious resource

HALF the population of the world, two billion men, women and children, lack easy access to an adequate supply of pure fresh water. In rural areas, where the situation is worst, only 29 per cent have access to safe water supplies and still fewer, 13 per cent, have sanitary facilities.

Yet drinkable water is necessary for life, for health, and for a productive existence. Without it, both men and animals sicken and die. Fresh water provides sustenance to plants, constitutes the habitat of fish and aquatic organisms, and makes agriculture possible. It is essential to some industries, and in rivers and lakes provides a medium of transportation and recreation. The United Nations has recognized the importance of fresh water and adequate sanitary facilities by naming the period 1981 to 1990 the *International Drinking Water Supply and Sanitation Decade.*

Water, or the lack of it, poses enormous problems for mankind. The World Health Organization estimates that 80 per cent of the illness affecting the population of the earth is directly associated with water: for example, 400 million people suffer from gastro-enteritis, 200 million from schistosomiasis, and 30 million from onchocercosis, and water is involved in the transmission of all of these. It has been estimated that if potable water were universally available, the world rate of infant mortality could be halved, primarily through eradication of diarrhoeal diseases.

Those who are ill cannot work productively. But even among those who are well, tremendous amounts of time and energy are wasted by the daily search for water. Women and children in developing countries often walk long distances each day in search of water. In one village in Burkina Faso, (formerly Upper Volta), ▶

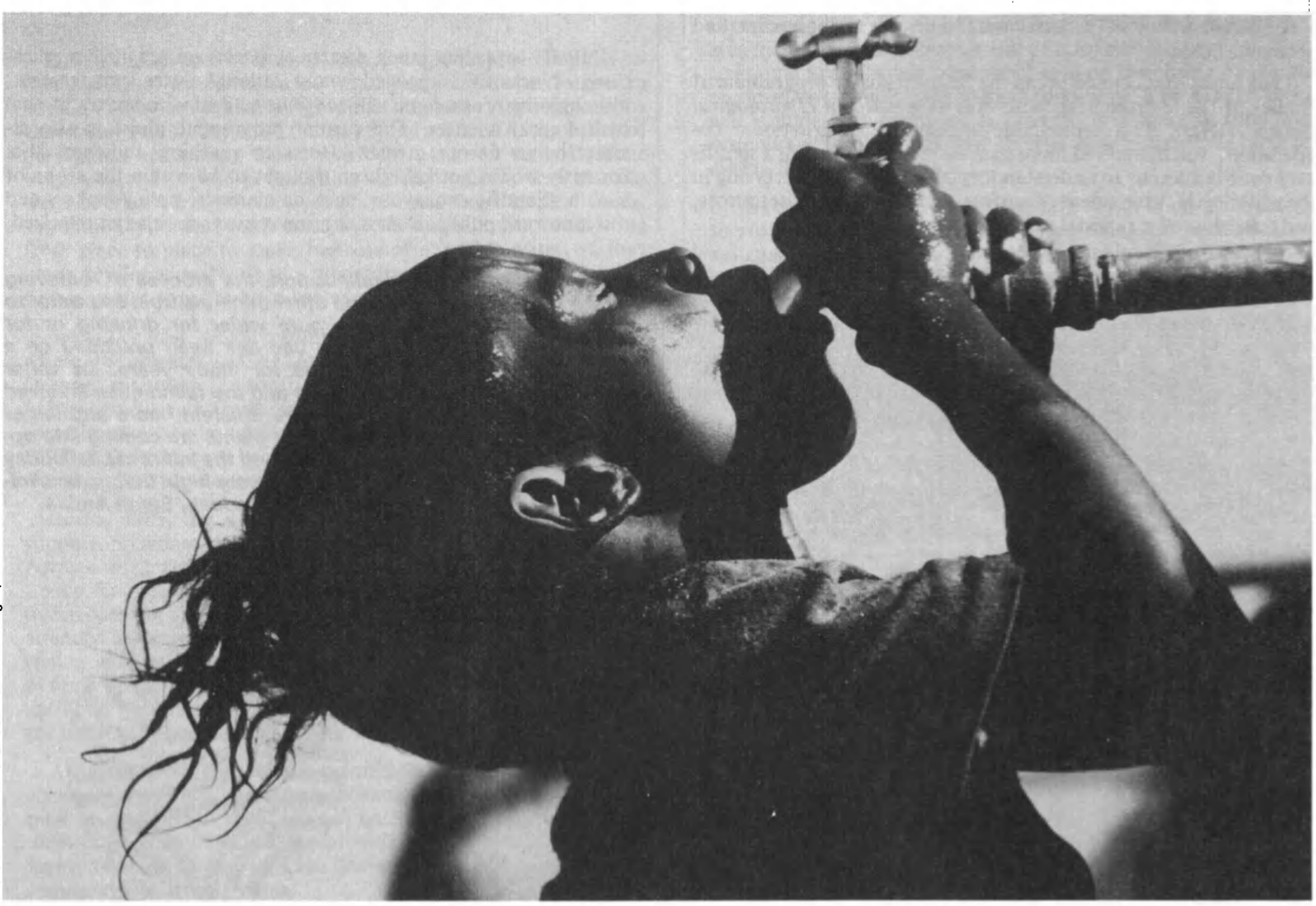


Photo David Burnett © Contact Press Images, Paris

▶for example, mothers walk for two to three hours a day to find a river or stagnant pond, and return to their homes carrying 25 kilograms of the precious stuff in earthenware jars on their heads. In some slums surrounding the cities of developing countries, families often have to spend 10 per cent of their income to buy water for household needs.

While water scarcity is the major problem for the majority of the world's people, a surplus is sometimes just as serious, as when floods occur, wiping out whole villages and sweeping food crops away. Tidal waves can be a deadly hazard for villagers living along coastlines.

Many such problems are the result of man's incomplete understanding of the ways in which water moves through and over the earth, is replenished by rainfall and disappears into the atmosphere through evaporation. Others are caused by man's mismanagement of the earth's waters, or by a lack of management. Pollution and over-enrichment (eutrophication) of inland water bodies are major problems worldwide, while coastal areas of the oceans, where two-thirds of the world's population live, have suffered extreme pressures as these people have advanced economically.

Man's fresh water problems are likely to increase in future unless steps are taken to improve the management of this valuable resource throughout the globe. Unesco's programmes are designed to contribute to this more rational management. The objectives are to improve scientific and technical knowledge, train the necessary personnel, build up research and training institutions and stimulate participation by the populations concerned in the conservation and development of water resources.

Unesco's programmes deal with both fresh water and the oceans, but in view of the immense scope of these subjects, this issue of the *Unesco Courier* focuses attention on some of the major problems involved in the rational development and management of fresh water resources.

Unesco's involvement in water problems goes back to 1950, when it launched a programme of research on the world's arid zones, in which hydrology played a major part. By 1965, despite Unesco's efforts, world water problems had increased. The rapid growth of population, together with the extension of irrigated agriculture and industrial development, had led to such environmental stress that nations realized they could no longer use the earth's water resources as carelessly and wastefully as they had in the past. The need for a consistent policy of rational water resource management had become evident.

Thus it was that Unesco began the first worldwide programme of studies of the hydrological cycle—the *International Hydrological Decade* (IHD). This remarkable example of international co-operation, which involved more than 100 countries, made a significant contribution to an understanding of the processes occurring in the water cycle, assessment of surface and groundwater resources, and adoption of a rational attitude towards water use.

The International Hydrological Programme

After reviewing these results and assessing the continuing need for co-operation in this field, Unesco's General Conference in 1974 decided to launch the long-term *International Hydrological Programme* (IHP). The IHP's purpose is to develop a scientific basis for the rational management of water resources, taking into account both quantity and quality. It is designed to help find solutions to specific water problems in countries with different geographical conditions and levels of technological and economic development, and constitutes the main components of Unesco's fresh water programme.

The IHP works through governmental representation on National Committees and National Focal Points (through which the work is carried out). By the end of 1983, 101 Member States of Unesco had established National Committees, and National Focal Points had been established in another 31. Thus a total of 132 Member States were involved in the programme. It is an open-ended programme: IHP's Intergovernmental Council, in Paris in March 1984, approved the third phase of its work, designated IHP-III.

IHP-III involves worldwide projects under 18 major themes. These range from assessment of the role of snow and ice on the water cycle to the compilation of information on the impact of climate change on droughts and catastrophic floods, to the application to water resources studies of new technologies like remote sensing from satellites.

Beginning with IHP-I, great emphasis has been placed on education and training activities. Nearly 1,500 specialists were trained in Unesco-sponsored or organized courses during the period (1975-1980). During 1981-1983, more than 600 specialists in the water sciences from developing countries obtained advanced training under Unesco sponsorship.

Because of a change in Unesco's budgetary period to coincide with other United Nations bodies, the second phase of the IHP (IHP-II) extended only over the period 1981-1983. The IHP has now returned to six-year phases, coinciding with Unesco's Medium-Term Plans, with IHP-III running from 1984-1989.

Practical Applications

IHP-III is placing much greater emphasis on practical applications of scientific knowledge and rational water management, although the programme will continue to deal with the traditional hydrological sciences. The current programme phase is also attempting to devote greater efforts to reaching audiences that formerly would not have been thought to be within the scope of such a scientific endeavour, such as planners, policy-makers and the concerned public. Demonstration projects are also emphasized,

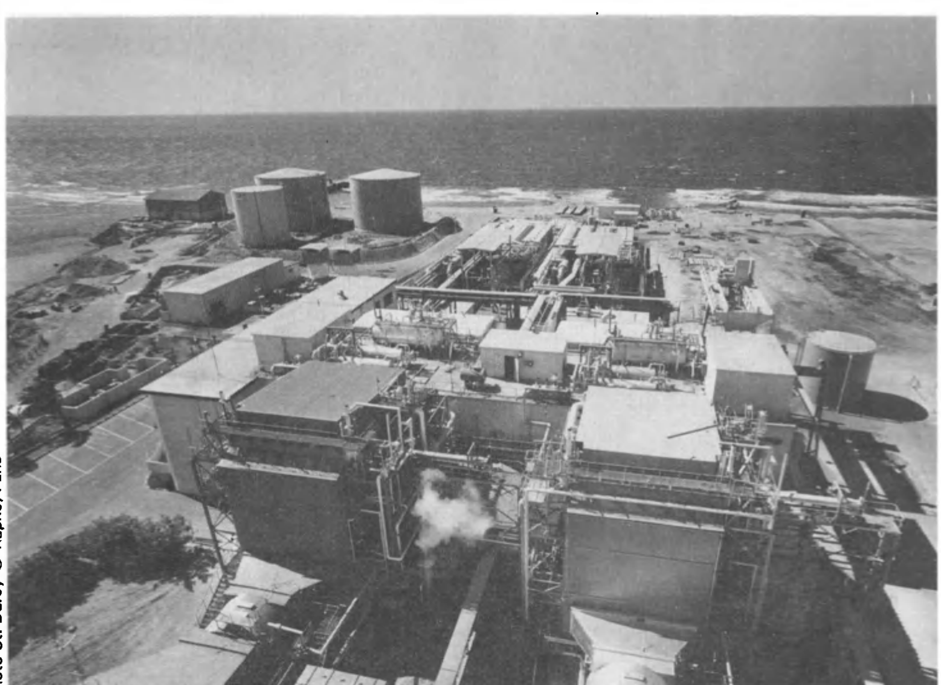


Photo St. Duroy © Rapho, Paris

Desalinization, the process of removing salt and other minerals from sea water to provide pure water for drinking or for industrial use has been practised on a small scale for many years. As water needs grow and the techniques involved become more efficient, more and larger desalinization plants are coming into operation, although the initial capital outlay required is still very high. Left, a desalinization plant at Jeddah, Saudi Arabia.

A typical family with five children needs about 40 litres of water a day just to survive and about 200 litres a day to keep clean and healthy. In many parts of rural Africa and Asia women and children spend up to eight hours a day on the soul-destroying task of fetching the water. Right, in Niger, a woman and her daughter at a water hole.

Photo © Claude Sauvageot, Paris

to reinforce learning. And the immediate practicality of results is being stressed. All these aspects are illustrated in the Major Regional Projects described below. Another characteristic of the programme is the attempt to use new techniques, such as remote sensing from satellites, for the study of water resources.

One notable aspect of the IHP as a whole is its participatory nature: the IHP works because a great number of experts and professional organizations around the world recognize the need for it and want to take part in it. Most of this participation is on a voluntary basis, through the IHP National Committees.

At the IHP Council meeting in Paris in March 1984, Unesco's Regional Hydrologist for Africa made an eloquent plea to the international community to assist in "making more heads free from carrying pots, pans and buckets in search of water several kilometres away".

Such is the purpose of Unesco's major regional project on the rational use and conservation of water resources in rural areas in Africa. (There are similar programmes for Latin America and the Caribbean and for the Arab States.) Some parts of Africa south of the Sahara are among those in which, as noted earlier, village women have to spend several hours a day walking to and from water sources during the dry season to meet their families' needs. Traditionally, such people have lived a nomadic life, wandering from place to place to make best use of available water, so they never developed methods of water storage. But as population has grown, water supplies have become exhausted.

In the Far East, where traditions are different, villagers in areas where groundwater is saline have taken easily to the idea of building ferrocement tanks for rooftop rainwater storage. The tanks are built inexpensively from concrete reinforced by metal mesh, or sometimes by bamboo poles. In north-east Thailand, for example, 1,500 such tanks have been built by villagers in a self-help project to store rainwater collected from rooftops.

During 1983, the *Asian Institute of Technology,* with Unesco support, organized a seminar and study tour of the Thai villages for African officials from Benin, Ghana, Liberia, Senegal, Sierra Leone, Zambia and Burkina Faso, to familiarize them with the use of ferrocement for rainwater harvesting from rooftops. The group attended lectures at the A.I.T. laboratory and visited the material-testing laboratory. They also travelled to Java, Indonesia, to observe the use there of tanks for rainwater storage as an alternative to water from heavily polluted irrigation canals, which are the traditional source of drinking water.

After the tour, participants recommended introduction of ferrocement to Africa, and the establishment of training centres and pilot projects. Since then, Unesco has proposed that the Government of the Republic of Congo provide funds for some 20 ferrocement rainwater storage tanks to demonstrate the suitability of this technology for rural Africa.

Subsurface dams are another possible way of providing water to drought-prone areas. These dams are simply sheets of metal or other impervious material placed perpendicular to the direction of water flow and introduced into dry sandy river beds. The dams force a build-up of water under ground which can then be tapped by bore-holes, and sometimes create sand reservoirs by retaining the bed load that moves in the stream during floods. In a Botswana project, two concrete weirs raised the level of the sand bed by about one metre. Other similar projects are going on in Kenya and Burkina Faso.

Major Regional Projects

The Major Regional Projects, begun in 1981, are intended to contribute to the growth of scientific and technical potential in the area involved, to the development of information networks, and to a rational use of water resources based on the choice of the most appropriate technologies for local conditions. The African project will include publication of an inventory of existing rural water systems and technologies, with the idea of identifying the most promising low-cost examples.

The purpose of the Major Regional Project in the Arab States is to promote the conservation and improvement of traditional water systems for use in rural areas. Here, too, an inventory of traditional methods is being compiled, this time in co-operation with the Arab Centre for Arid and Dry Lands. For each type of traditional system, the project determines the conditions under which it will best function. Studies are being undertaken to determine the applicability of the systems under present circumstances and the way in which they complement modern water management systems. Guidance material is prepared for teaching engineers and technicians; other material is designed for decision-makers and some for the general public. Local traditional skills are being revived to assure the survival of the traditional systems.

The Latin American and Caribbean Major Regional Project has similar aims: bringing back life to rural areas by combining principles of both traditional and modern technologies in low-cost, appropriate systems. National education and training programmes will be promoted through mass media informational campaigns, using radio, video, films, posters and training manuals.

Among the projects in this area are those that attempt to obtain water in arid areas from non-conventional sources such as fog and dew. Other projects will be aimed at obtaining energy for transporting, desalinating and pumping water from sources such as extreme daily temperature fluctuations, water currents and solar radiation. Attention is being given also to water resource management and erosion control through such techniques as terracing, construction of farm ponds, and water-saving practices such as irrigation through porous pots. ▶

The Secretariat for the International Hydrological Programme (IHP) is provided at Unesco headquarters in Paris by the Division of Water Sciences under its Director Sorin Dumitrescu. Under the supervision of the Intergovernmental Council of the IHP, the Secretariat co-operates closely with the IHP National Committees and Focal Points for the IHP established in over 130 Member States. An expert in water resources is stationed at each of Unesco's five Regional Offices for Science and Technology to provide on-the-spot advice and assistance.
Close contacts are maintained with other United Nations organizations with an interest in water resource problems such as the United Nations Environment Programme (UNEP), the World Meteorological Organization (WMO), the Food and Agriculture Organization (FAO), the World Health Organization (WHO) and the International Atomic Energy Agency (IAEA).

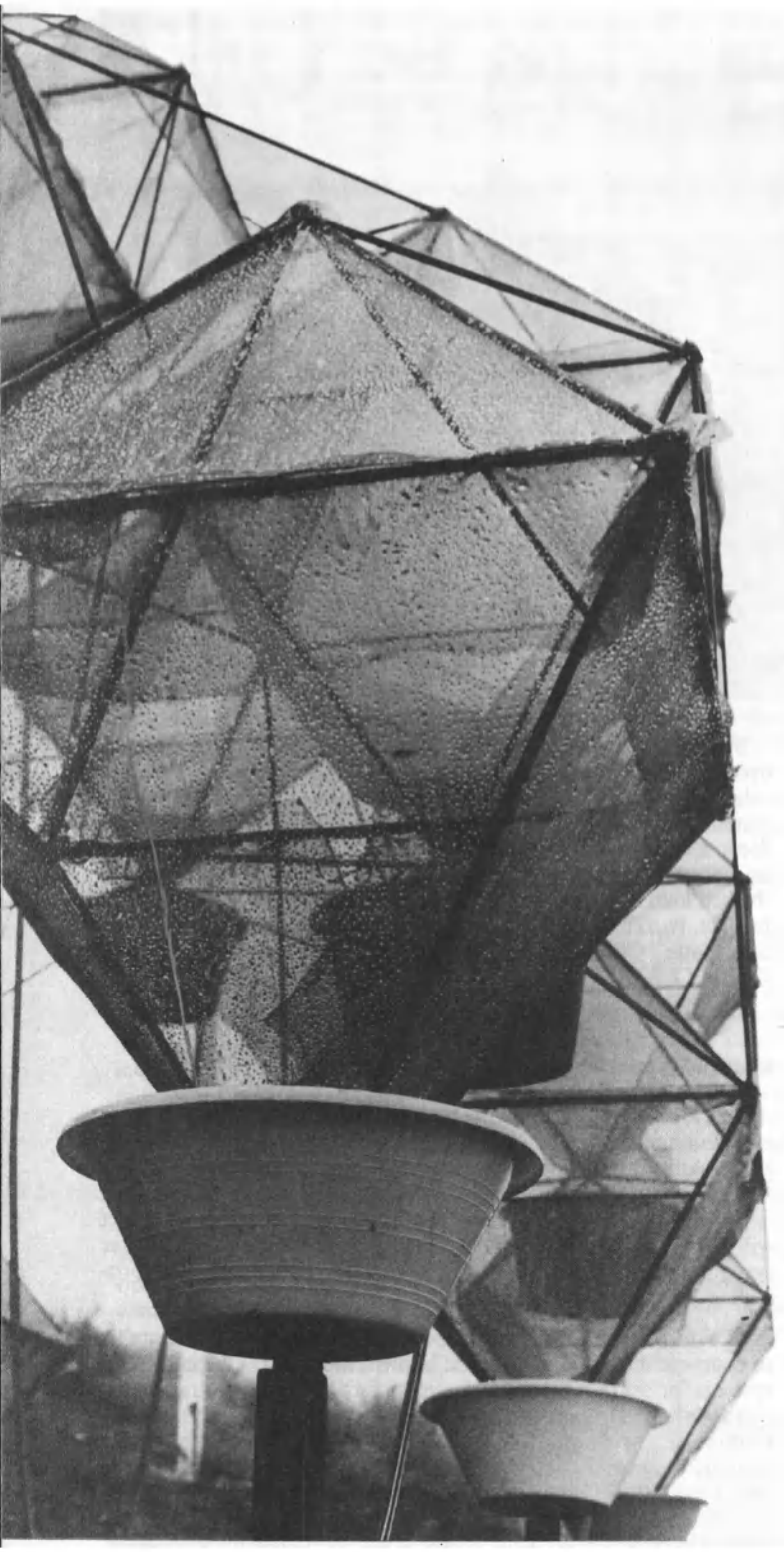


Photo Christian Gischler, Unesco

Rising from the skyline in the Pacific coastal regions of Latin America, in areas where there is very little rainfall, these curious, diamond-shaped structures are helping to solve the problem of a chronic lack of water. They are fog traps which have been installed at experimental sites in Chile, Ecuador and Peru as part of Unesco's Major Regional Project on the Use and Conservation of Water Resources in the Rural Areas of Latin America and the Caribbean. *Fog, which is frequent in these coastal areas due to an effect known as "thermal inversion", is often the only local source of fresh water. The octahedral structures, which are made of ordinary mosquito netting, intercept the moisture which condenses into water. Each octahedron can produce up to 200 litres of water a day.*

▸Other Field Projects

In addition to those included in its own annual budget, Unesco also administers a number of field projects financed by funds from outside the Organization. These deal with applied research, education and training, assessment of water resources and institution building. For example: In Algeria and Tunisia, a study of groundwater resources in the northern Sahara, completed in 1972, established the limits of exploitation of both shallow and deep aquifers underlying the area. The results were presented in a form useful for planning ministries. The International Atomic Energy Agency and the Food and Agriculture Organization of the United Nations co-operated in this project.

In Portugal, an environmental study of the Tejo estuary (1977-1982), dealing with quality aspects of water management, is to form the scientific basis on which the government will base its pollution and environmental regulations and its decisions for investment in waste water purification works. Other water resource assessment projects have been carried out in the Canary Islands, Spain, Brazil, Zambia and Mozambique.

In the Sudan, Unesco, with funds from the United Nations Development Programme (UNDP), has assisted the Ministry of Irrigation since 1974 in establishing a hydraulic research station in Wad Medani. This station is gradually becoming the water resources engineering study branch of the Ministry. It will be capable of carrying out hydrological surveys, hydraulic model studies and hydraulic computations. Similar projects have been carried out in Brazil, India, and Argentina.

In Nigeria, another Unesco/UNDP project has since 1978 assisted the Federal Ministry of Water Resources in establishing a *Federal Institute of Water Resources,* which gives top priority to training middle-level water resource technicians. Similar projects have been carried out in Brazil, Tanzania and India, some with financial support from Unesco's Funds-in-Trust projects.

In Sweden and Sicily (1977), India (1979) and Tanzania (1981), Unesco has organized short-duration training courses on groundwater development from hard rock with the support of the Swedish aid agency SIDA. With the assistance of the Norwegian Government, two to three-month courses for hydrology technicians were organized in Kenya (1977) and Zambia (1982 and 1984).

The unique characteristic of all Unesco's activities in science and technology is their international nature: no other organization is able to call on the entire scientific resources of the world. Furthermore, Unesco has in large part been responsible for creating some of the most important international scientific bodies and networks, such as those mentioned above, and for supporting them and encouraging their activities. Because the world's waters are in large part transnational resources, only an organization that works through governments, as Unesco does, can fulfill this role. ■

This text is taken from a booklet now being prepared by Unesco science writer David Spurgeon and which is to be published shortly by Unesco's Science Sector under the title Managing the World's Waters. *The booklet will also cover problems connected with the world's oceans.*

Acid rain

1. An unwelcome export

MANKIND has always reverenced what Tennyson called "the useful trouble of the rain". Without the 120,000 cubic kilometres of it that fall each year the continents would be barren.

Yet now the rain in parts of the earth has taken on a new and threatening complexity. It mixes in the air with pollution from burning fossil fuels—particularly in power stations, factories and motor vehicles—and brings down dilute sulphuric and nitric acid. This is killing fish and other water life, and corroding buildings, including some of the world's most important ancient monuments. It may also damage forests and croplands, and possibly pose a substantial threat to health.

Acid rain is not a new phenomenon—the term was first coined by a chemist, Robert Angus Smith, who described pollution in Manchester, England, over a century ago. What is new is the realization that it is an international problem. The air of towns like Manchester has been largely cleaned, partly by building tall chimneys at power stations and factories, which push pollution high into the air. These chimneys have made things better locally, by dispersing the pollutants, but have aggravated the international difficulties. For the sulphur and nitrogen compounds emitted by burning fossil fuels can be blown thousands of kilometres by the winds, to cause acid rain in countries far from their points of origin.

Acid rain was first raised as an international issue by Sweden at the United Nations Conference on the Human Environment in Stockholm in 1972, and it has now developed into a major international environmental issue. At first the Swedish views were treated with some disbelief, particularly by some of the emitting countries. Over the last decade, however, there has been a great deal of international research into the issue. Ample information was available by the end of 1982 through the activities of the Co-operative Programme for Monitoring and Evaluation of Long-range Transmission of Air Pollutants in Europe (EMEP), under the Convention on Long-range Transboundary Air Pollution 1979, and activities conducted in accordance with the Memorandum of Intent Between the Government of Canada and the Government of the United States of America concerning Transboundary Air Pollution. Furthermore, there was a special conference in Stockholm in 1982 on acidification of the environment, and this reviewed and assessed a large amount of scientific information not previously available.

So far, acid rain has been seen as an essentially regional problem, confined to the industrial areas of the northern hemisphere. But, though the problem was first perceived there, it may become much more widespread—for acid rain is likely to occur wherever fossil fuels are intensively used.

Acidification is an environmental problem, or becoming one, in parts of Europe and North America. Around five to ten million square kilometres of these continents are affected. Similarly polluted areas are likely to exist elsewhere in the world, especially around large urban and industrial conglomerations. We do not yet know where they are, because so far no evidence on them is available.

Industrial regions of the world suffer much more acidic fall-out than they did before the industrial revolution. This is because power plants, some industrial processes, vehicles and homes emit sulphur and nitrogen compounds, mainly from the burning of fossil fuels, and have greatly increased the amount of them in the environment.

Natural processes also put sulphur and nitrogen compounds into the air, besides man-made sources. Nobody knows precisely how much they contribute around the globe. Estimates vary between 78 and 284 million tons of sulphur a year in the form of sulphur oxides, and between 20 and 90 million tons of nitrogen a year in nitrogen oxides.

In comparison, man emits between 75 and 100 million tonnes of sulphur a year. So, despite the differences in estimates of natural sources, it can be concluded that man-made and natural emissions of sulphur are, globally, of the same order of magnitude.

Burning coal provides about 60 per cent of the man-made emissions, burning petroleum products gives rise to another 30 per cent, and various industrial processes account for the remaining 10 per cent. Approximate estimates indicate that burning fuel in electric power stations and industry provides almost three quarters of sulphur emissions in the European Economic Commission countries.

There are indications that sulphur dioxide emissions (the main pollutant in Europe and North America) have not increased during recent years, as they were predicted to do, and are not likely to rise over the coming decades either. This is the result of two factors: better pollution control, and less burning of fossil fuel as a result of energy conservation and, possibly, slower economic growth in the west than had been expected.

Like sulphur oxide pollution, pollution from nitrogen oxides is also of the same order compared to natural sources. Fossil fuel combustion yields about 20 million tons of nitrogen a year, which have already caused environmental problems on a regional and local basis in industrialized countries.

Not all the pollution is acid rain, i.e., sulphuric and nitric acid dissolved in precipitation. Some of it happens when the sulphur and nitrogen oxides themselves fall out on the land, in what is known as "dry deposition". In general this tends to be the main form of the pollution near its source, and the longer the gases stay in the air, the more likely they are to go through the complex changes that will turn them into acid rain (or wet deposition), to fall perhaps thousands of kilometres from where they began their journey. Wet deposition rates are fairly well known, but dry deposition is harder to calculate and rates remain more uncertain. Both types of deposition can be intercepted by vegetation canopies. The canopies of evergreen forests, in particular, can be subjected to high deposition rates.

Lakes and rivers were the first victims of acid rain to become evident. Hundreds of lakes in parts of Scandinavia, the north-east United States, south-east Canada and south-west Scotland have turned acid. Parts of these areas are particularly vulnerable because their soil and bedrock offer little protection against acidic rain. They are made up of minerals like granite, gneiss and quartz-rich rocks which contain little lime and do not weather easily, and therefore can do little to neutralize the acid when it falls.

As the water becomes more acid, the amount of aluminium in it starts to increase rapidly. Concentrations as low as 0.2 milligrams per litre of the metal in acid water kill fish. Large scale fish kills have been recorded in some Swedish lakes, and these have been attributed to aluminium poisoning rather than to high acidity alone. ▶

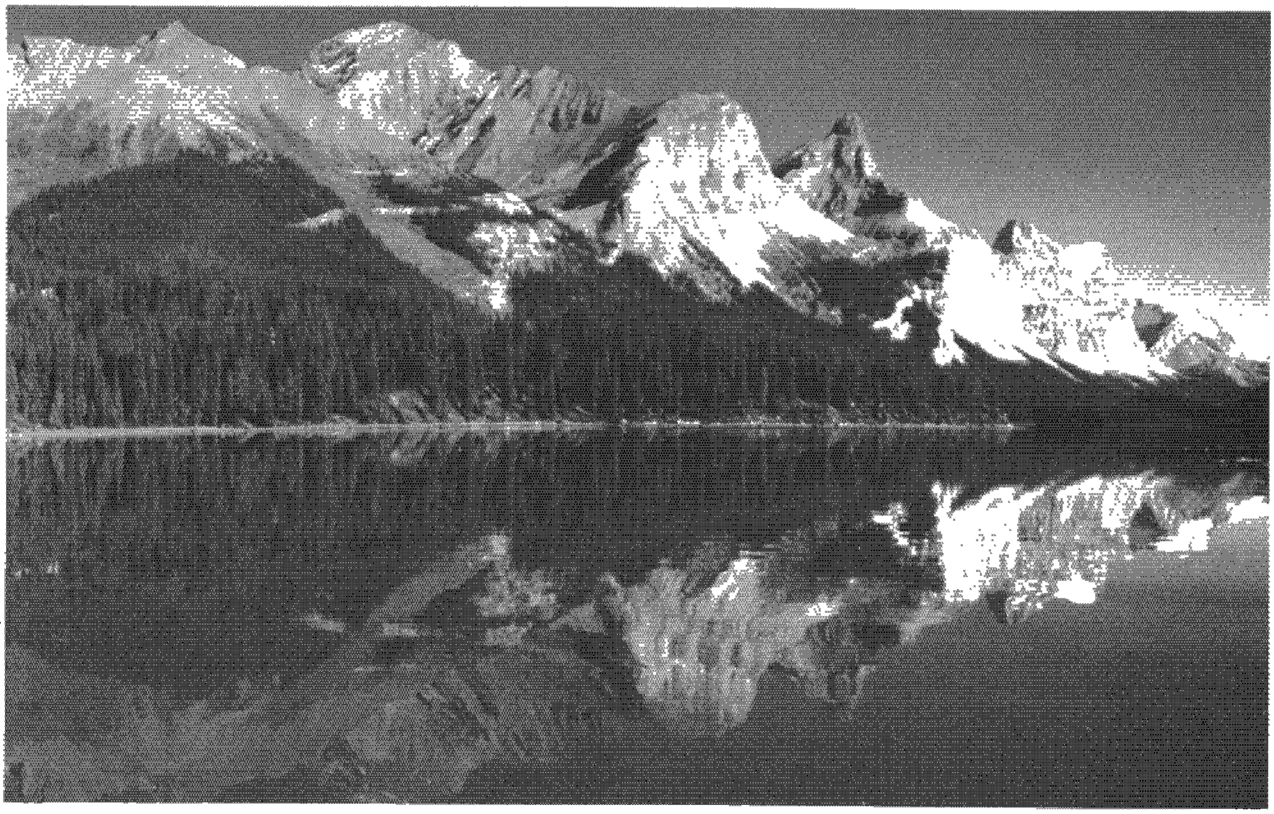


Photo Paolo Koch © Rapho, Paris

▶ At the same time, phosphates, which nourish phytoplankton and other aquatic plants, attach themselves to the aluminium and become less available as a nutrient. So increasing aluminium levels may reduce primary production on which all other water life depends. As the water gets more acid still, other metals, like cadmium, zinc, lead and mercury also become increasingly soluble. Several of them are highly toxic, and some may be taken up by water life through food chains, though little evidence of this is available so far.

Soils are normally much better able to resist acidification than lakes, rivers and streams, and so can take much more acid without noticeable ecological drawbacks. Their vulnerability differs depending on their type, the kind of bedrock they cover, and the use to which man puts them. The most vulnerable lands are those that have bedrocks poor in lime, covered with shallow layers of soil containing low concentrations of protective substances. Large parts of Scandinavia are like this.

Intensive experimental research into the effects of acidification on forest, land and wood production was carried out in the 1970s. It is still going on, but so far the results are inconclusive. Acid fall-out does seem to have a distinct effect on soil microbiology, chemistry and fauna—but the effects on the growth of plants, including trees, are far less clear. Indeed, depositions of nitrogen may even have a fertilizing effect and increase productivity significantly, at least in the short term. Studies on the trends of tree growth in southern Sweden between 1950 and 1974, for example, failed to reveal any statistically significant pattern.

In the Federal Republic of Germany, on the other hand, 7.7 per cent of the forest area was reported in 1982 to be damaged by wasting disease due to the consequences of deposition and accumulation of air pollutants. In addition, trees have suffered more storm damage and experienced regeneration difficulties. These forests receive much more fall-out than Scandinavian ones because they are close to cities and big industrial areas, such as the Ruhr, with many polluting sources.

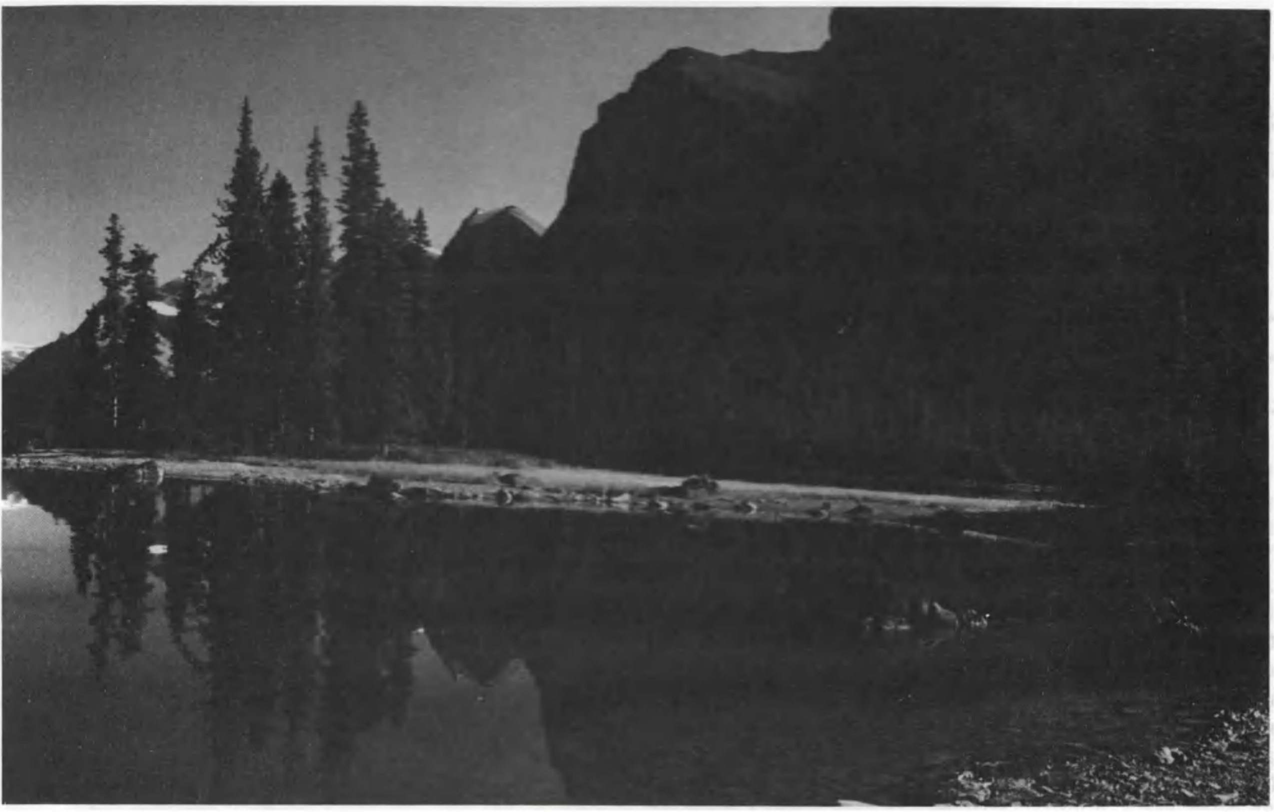
One reason postulated to explain this damage is the combined effects of surges of naturally produced acid, extreme climatic situations (very high or low rainfall, temperature extremes) and atmospheric acidic deposition. These release aluminium into the soil and make it easier for bacteria to damage the fine roots of the trees. This reduces their vitality, leads eventually to a rotting disease, and may make them more vulnerable to storms. High concentrations of sulphur dioxide in the air may damage leaves, and so cut the trees' productivity. Acid fogs, persisting for several days, may also damage trees in mountain areas.

As well as the health of important ecosystems, human health may also be put at risk by pollution. High concentrations of sulphur dioxide, nitrogen, oxides and dust have long been known to be harmful. This issue is only marginally related to the problem of acid rain, since such concentrations are usually only found close to the sources of pollution, and sulphur oxide levels in many European and North American cities have been decreasing recently. The minimum concentrations of sulphur dioxide and nitrogen dioxide considered to cause health damage are: sulphur dioxide, 250 micrograms per cubic metre as a 24-hour average or 100 micrograms per cubic metre as a long-term average; nitrogen dioxide, 190-320 micrograms per cubic metre, as a maximum one hour exposure not to be exceeded more than once a month.

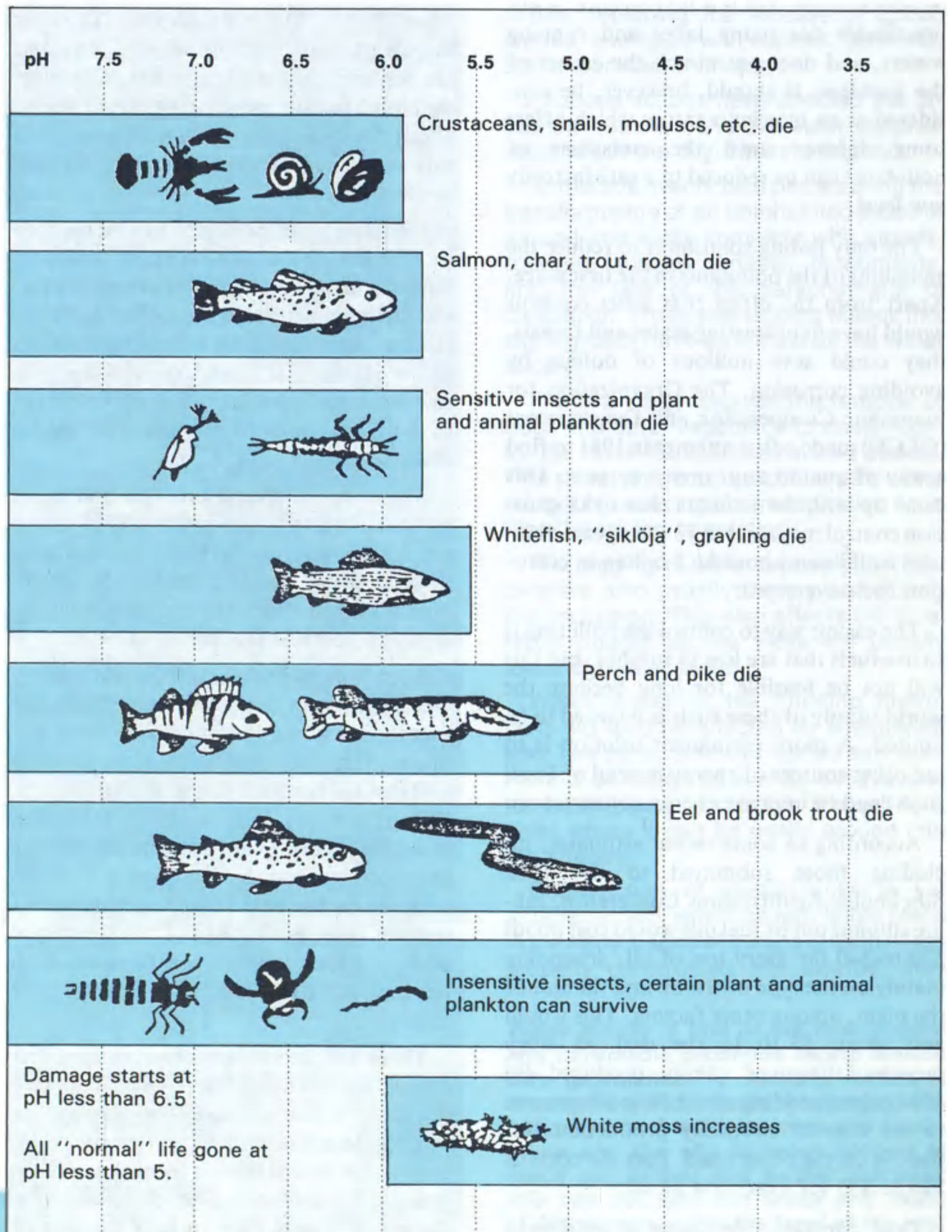
Other, indirect, health hazards are suspected. These would be caused by the metals like lead, copper, zinc, cadmium and mercury released from soils and sediments by increased acidification. They can get into groundwater, rivers, lakes and streams used for drinking water, and be taken up in food chains leading ultimately to man. The releases of cadmium in particular may give rise to a growing problem as acidity increases, as normal levels in human food are already close to the acceptable daily intake. Acid water may also cause galvanized steel and copper water pipes to release metals, and it seems that the risk arises as soon as the acidity of the water rises above normal. Most drinking water in industrialized countries, however, is supplied by public water works which eliminate this problem with proper treatment techniques; but much remains to be done in developing countries.

Meanwhile, acid accelerates corrosion in most materials used in the construction of buildings, bridges, dams, industrial equipment, water supply networks, underground storage tanks, hydroelectric turbines, and power and telecommunications cables. It can also severely damage ancient monuments, historic buildings, sculptures, ornaments and other important cultural objects. Some of the world's greatest cultural treasures, including the Parthenon in Athens and Trajan's column in Rome, are being eaten away by acid fall-out.

Tests have shown that materials corrode between twice and 10 times as fast in polluted urban and industrial atmospheres as they do in the countryside. Carbon steel (both coated and uncoated), zinc and galvanized steel, copper, nickel and nickel-plated steel, sandstone and limestone all corroded faster as the amount of sulphur dioxide in the air increased. On the other hand, materials such as aluminium and stainless steel were only negligibly affected. ▶



The damaging effects of acid rain first became apparent in lakes and rivers. In Sweden, damage to fisheries attributed to acidification has been observed in 2,500 lakes and evidence of acidification has been found in another 6,500. Of the 5,000 lakes in southern Norway, 1,750 have lost all their fish and another 900 are seriously affected. In Canada, nearly 20 per cent of all the lakes so far examined in Ontario have become acidified or are extremely sensitive to acidification. Between 30 and 60 per cent of the lakes of southwest Quebec are sensitive or highly sensitive to acidification. In Canada's Atlantic provinces many lakes have become 10 to 30 times more acid during the past two decades. Above, Lake Maligne, Alberta Province, Canada, is seen against the backdrop of the Henry MacLeod Mountains.



Source : Acidification Today and Tomorrow, Report by the Swedish Ministry of Agriculture to the 1982 Stockholm Conference on Acidification of the Environment.

The sensitivity of aquatic organisms to a lowered pH in fresh water

Chart © OECD Observer, Paris

Acid rain

2. Can we save our lakes and forests?

THE damage caused by acid rain can be alleviated by adding lime to lakes, rivers and streams and/or their catchment areas. Many chemicals such as caustic soda, sodium carbonate, slaked lime, limestone, or dolomite can be used to counteract the acidity. Slaked lime and limestone are the most popular. Sweden began a liming programme in the autumn of 1976, and by the summer of 1982 about 1,500 Swedish lakes had been limed at a total cost of about $15 million.

Liming alleviates some of the symptoms of acidification, but it is no real cure, is not practicable for many lakes and running waters, and does not attack the causes of the problem. It should, however, be considered as an interim measure which offers some defence until the emissions of pollutants can be reduced to a satisfactorily low level.

The only lasting solution is to reduce the emissions of the pollutants in the first place. Apart from the effect that strict controls would have in protecting water and forests, they could save millions of dollars by avoiding corrosion. The Organization for Economic Co-operation and Development (OECD) made a first attempt in 1981 to find a way of quantifying corrosion costs. This came up with the estimate that strict emission control measures in 13 European countries could save about $1.2 billion in corrosion costs every year.

The easiest way to control the pollution is to use fuels that are low in sulphur; but this will not be feasible for long because the world supply of these fuels is believed to be limited. A more permanent solution is to use other sources of energy instead of fossil fuels, and to improve energy conservation.

According to some recent estimates, including those submitted to the 1982 Stockholm Acidification Conference, taking sulphur out of fuel oils would cost about $20 to $40 for every ton of oil, depending mainly on the type of the oil and the size of the plant, among other factors. This would add about $5-10 to the cost of every megawatt/hour of energy produced (in 1980 prices), adding about 10 to 20 per cent to the cost of electricity production. Industry, on the other hand, puts the costs at $40 to $85 for every ton of oil.

Coal contains two kinds of sulphur—pyrite (iron sulphide) and organic sulphur. Washing coal, after first crushing and grinding it, will remove pyrite sulphur. The cost of this mechanical process is estimated to be $1 to $6 per ton of coal. On average it will remove about half of the pyrite, though at best the process can be made to remove up to 90 per cent of it from some coals. The chemical methods are more effective, but also more expensive and have not yet been fully developed. They can remove organic sulphur as well as pyrite. The cost of getting rid of 90 to 95 per cent of the pyrite and half the organic sulphur would be around $20 to $30 per ton of coal. The extra costs for coal washing range from less than $1 to about $3 per megawatt/hour, adding between one and six per cent to electricity costs. Chemical desulphurization would cost much more, about $8 to $12 per megawatt/hour, and this would add between 15 and 25 per cent to electricity costs.

Nitrogen oxide emissions can be reduced by changing the ways of burning fuel, particularly in heat and power stations. One of the methods proposed for doing this is to reduce the combustion temperature to below about 1500°C and/or to allow only low intakes of air. Such changes could cut in half the amount of nitrogen oxides emitted.

Removing sulphur from fuel and gases creates waste products—solids and slurries—which have to be disposed of properly to avoid water, groundwater, or soil pollution. Naturally, this problem grows as emission controls are increased.

According to preliminary calculations by OECD, it costs a total of some $800, on average, to stop a ton of sulphur from getting into the air. More recent estimates suggest that the costs may be somewhat higher. If northwestern and southern European countries were to cut their annual sulphur emissions by about half (around 5.9 million tons) within the next 10 to 25 years by controlling the emissions of conventional power stations, it would cost them about 10 per cent of the total cost of producing their electricity.

There are, moreover, other factors that complicate such analyses. One—common to many other instances of damage to shared natural resources—is that the countries which would benefit from the reduced pollution would often be different from those that would have to bear the cost of cutting it back. Another is that all the estimates of benefits assume that the damage caused by acid rain can readily be reversed if enough pollution control is implemented—and in reality this may not be so. It might be a long time before the ecological damage, in particular, began to be reversed. Unfortunately, scientific information on the recovery process is extremely scanty.

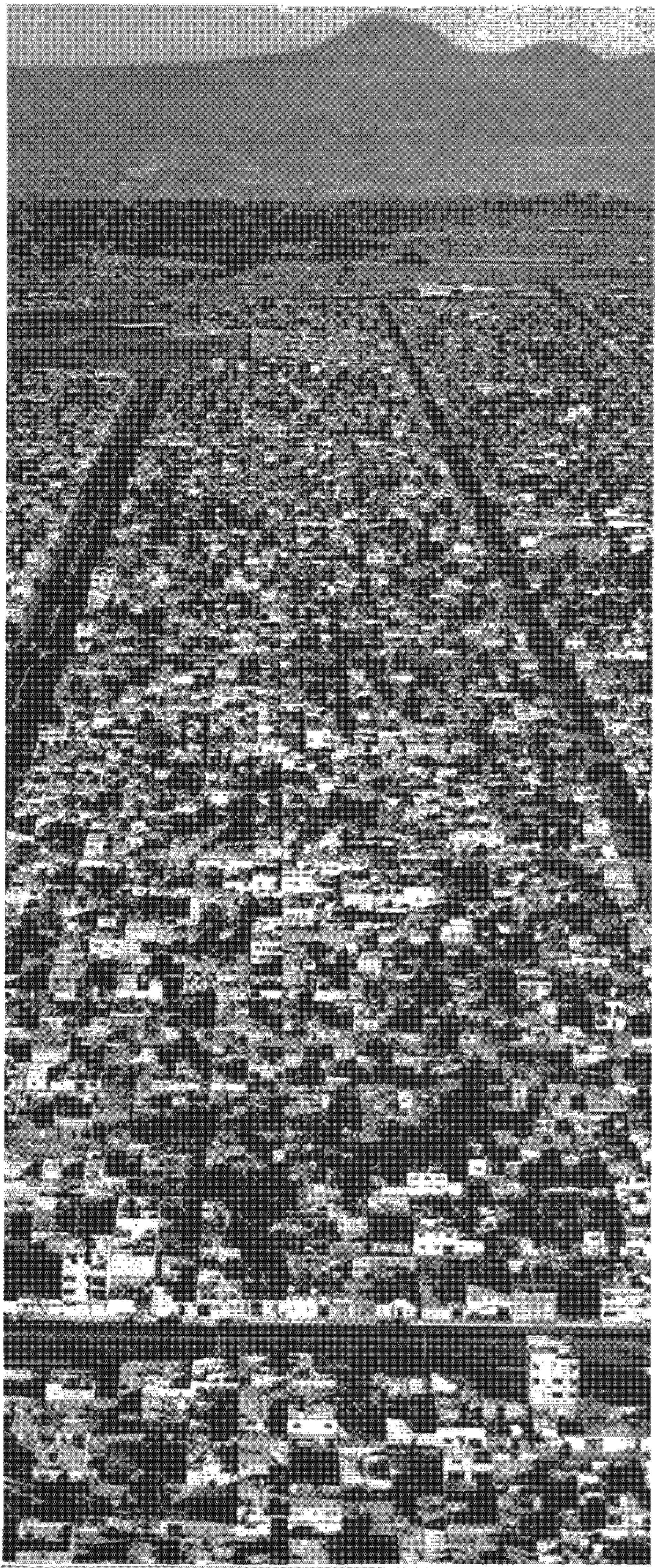
This is only one of the problem areas in the whole field which, despite considerable progress in research on the subject, still remain unknown or only superficially understood. Research is needed on dry deposition of polluting gases and particles, and their effects on water, soil, young and old foliage, and other recipients of their pollution; on how the pollutants undergo changes in the atmosphere, and how they are transported and deposited; on how bedrocks weather under different acid inputs and release nutrients; on how acid affects the soil, particularly in the long term; and on the possible adverse effects of acid fall-out on forest growth.

In addition to these meteorologically and ecologically orientated research topics, information is needed on the effects on health of the increasing spread of cadmium and other toxic metals as a result of acidification. Among other things, the levels of the metals in food, human tissues and body fluids must continue to be monitored.

Some areas in the tropics may be highly or moderately susceptible to acidification, and this could cause special problems. We need to work out the nature of these problems. In dry tropical areas, acid rain itself cannot play a major role owing to scarce precipitation, but the role of dry deposition is unknown. In humid areas the ecosystems, temperature and moisture levels are different from those in the temperate areas where acidification has been studied so far, and quite different problems may arise.

Besides, some soils have too little sulphur in them or are highly alkaline. These could benefit, to a certain extent, from extra sulphur and nitrogen fall-out—or merely from more acidic rain. This could add a significant new factor to calculations of costs and benefits from the pollution, but the issue has not yet been explored. ■

This article is based on a longer study published in the UN CHRONICLE, *Volume XX, No. 5, and entitled* State of the World Environment 1983, A Report from UNEP.



Cities athirst

TODAY'S metropolitan giants sprawl across wide areas and have an impact on the environment far from their city cores. London, Paris, Mexico City, Amsterdam, Los Angeles, and many others have pushed out into fertile farmland and, in so doing, have transformed it into endless blocks of masonry. They have stretched their tentacles of iron and concrete pipe many kilometres out into the countryside to capture the contents of remote streams and lakes. They have denuded much of the vegetation within their own city boundaries, replacing the verdure of grass, shrubs, and trees with asphalt, concrete, and impervious rooftops.

All these actions have affected the urban environment and the water supplies upon which the city dwellers depend.

Numerous events take place during the transformation of an uninhabited piece of ground into a city complete with streets, squares, subway tunnels, monuments, and the rest of the paraphernalia of civilization. Three overlapping stages in a city's growth have an impact on the water supply.

The first stage involves the removal of trees and other vegetation to make room for the initial homes, stores, and streets. This removal affects the local area's water budget by reducing the transpiration once "lost" from the vegetation.

The digging of wells to supply the city-dwellers also usually takes place during the first stage. This also affects the local water budget as the wells will usually lower the water table.

Watercourses in the budding metropolis will also be affected by sedimentation. The construction of homes and commercial buildings as well as excavations for water pipes can loosen the soil to a point where it can be easily eroded into the streams.

Construction of septic tanks is yet another activity which usually takes place in the early stages of a city's growth. If not properly constructed and located, they ►

Water supply is one of the most urgent and intractable problems facing Mexico City (population 17 million), which is among the world's fastest growing conurbations. Local water sources are inadequate and the city is being obliged to reach out further and further (between 150 and 200 km) and lower and lower (1,000 metres below the level of the city) for its water. Left, aerial view of Netzahualcoyotl, a district of Mexico City.

▶may pollute areas of the aquifer. Without a sewage collection system, cesspools and other effluent sources generally drain into groundwater horizons, and this has caused outbreaks of cholera and typhoid.

During the next stage of urbanization, excavations are made for bigger houses and buildings, more topsoil is removed, and small pools of water are filled up. Accelerated soil erosion and sedimentation in the watercourses result.

As the city expands there will be an increase in impermeable surfaces. Reduced infiltration into the groundwater will be a consequence. Because of the increased impermeability, peak flows will be increased in the remaining watercourses. Some flooding may occur.

The most dangerous situation for human health—which usually occurs during this second stage—is the discharge of chemicals or insufficiently treated waste water into the area's streams. This pollutes the receiving streams and often also leads to the killing of aquatic life. Waterbased recreation will be affected. The degradation of the streams' quality will also affect those human communities located downstream.

The final stage of urbanization is marked by nearly all of the original open soil being covered with buildings, streets and other near-impermeable surfaces. Infiltration to the groundwater is markedly reduced, and storm runoff is increased and accelerated.

With less water reaching the aquifer, wells may have to be deepened to meet the needs of a larger population. Or the municipality may have to reach beyond its own area to tap regional water sources. It has been observed that certain basic elements of water-supply technology—capture in distant catchment areas, conduction along aqueducts and distribution within cities—are as characteristic of recent works as they are of late nineteenth-century projects and indeed of Roman systems. In this respect modern engineering seems to have changed no basic principle, although it has come to have a better grasp of the problems involved.

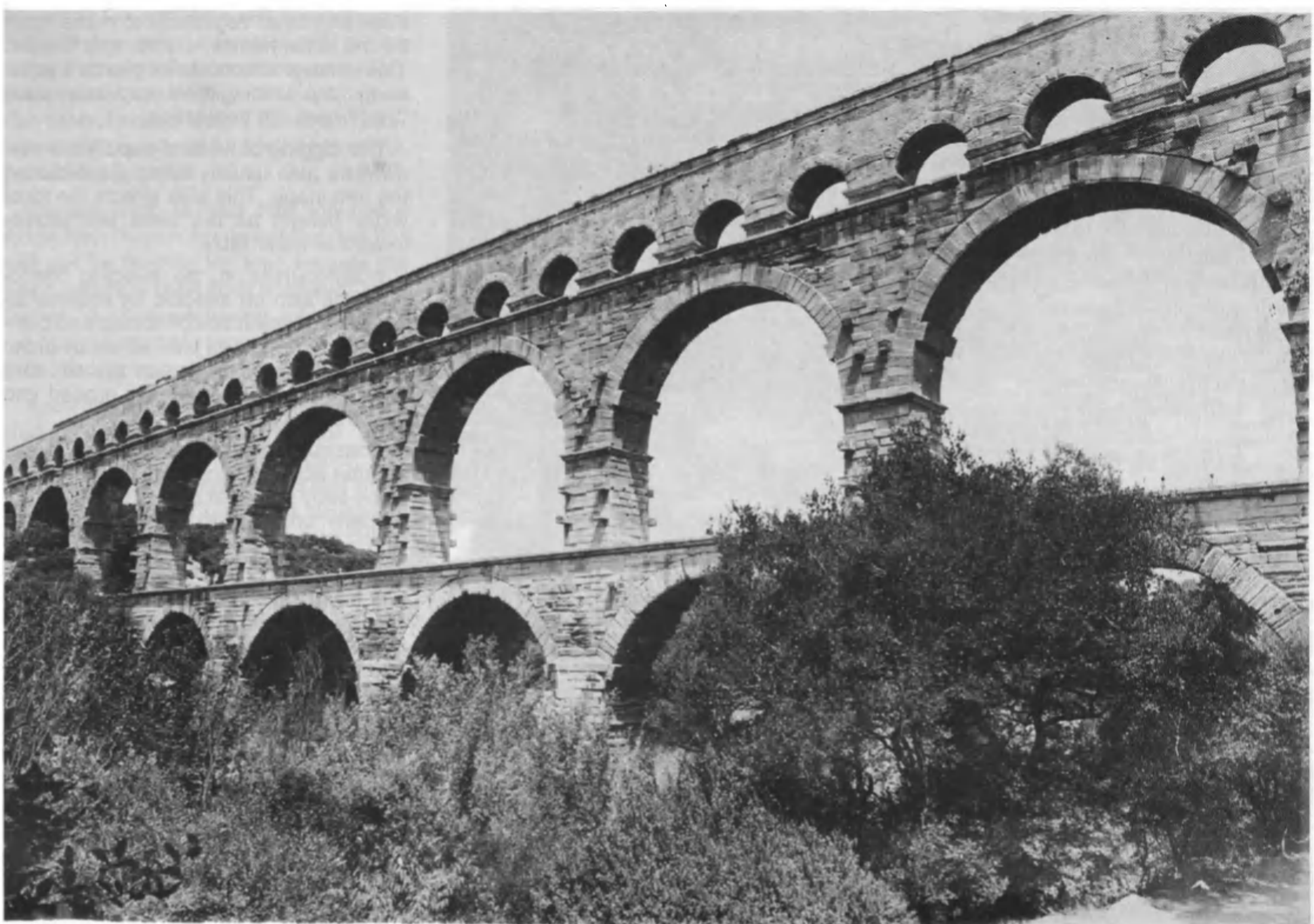
And yet the U.S. Environmental Protection Agency has identified a number of major sources of pollution to the groundwater in the United States. Most are related to urbanization. They include underground injection wells used to "dispose" of hazardous wastes; accidental spills of these materials on city streets, industrial sites, railroad rights-of-way, and airports; leaks from pipelines and storage tanks; abandoned domestic water wells; overuse of agricultural chemicals; unlined slurry ponds, and salt water encroachment into aquifers.

Pumping deeper and deeper for more and more water can also lead to land subsidence. In the United States, the boom metropolis of Houston, on the Texas coast, has an acute subsidence problem. So much water has been withdrawn that the land within a 64-kilometre radius of the city centre has dropped almost three metres below its original elevation. It has been pointed out, somewhat tongue-in-cheek, that should this subsidence continue at the existing rate, the top of a downtown landmark, a 45-storey building, will be below sea level by the year 2180!

Mexico City, situated at more than 2,134 metres above the sea, is obviously not going to suffer a similar fate. But this major metropolis has sunk some 10.7 metres during the past 70 years into the filled-in lake bed on which it has been built. The cause? Withdrawal of water from the aquifer below.

Mexican authorities have been attempting to meet the ballooning demand for water by planning to tap rivers more than 160 kilometres away from the capital. It has been suggested that by the year 2000, Mexico City's population may surpass 30 million, and therefore have the world's greatest urban concentration. It is interesting to note in that respect that from 1960 to 1976, the water supply to the city was more than doubled, but the amount available per person declined. In 1982, only 15 per cent of the residents in urban areas around Mexico City had piped water for their homes. ■

Roman engineers of Antiquity built highly developed water supply systems. The Pont du Gard (c. 19 BC) in southern France, below, is only a small section of a 40-kilometre-long conduit, mostly underground, which carried water to the city of Nimes. Its 3 tiers of arches rise to over 47 metres. The highest tier, carrying the conduit, consists of 35 4.6-metre arches.



Washing our dirty water

TODAY there is world-wide agreement, at least in principle, about the need to reduce pollution so that mankind can survive. It is now considered necessary to treat all effluents before they are discharged into water bodies.

The following are the principal substances and types of pollution which the treatment processes are designed to remove:
• Suspended solids, such as silt (which produce turbidity and form sludge deposits).
• Material that consumes oxygen.
• Nutrients necessary for the creation of new organisms.

Extremely important nutrients are the phosphates and nitrates. In waste water, phosphorus and nitrogen are mainly the result of the domestic use of water. They are also becoming a major problem as a result of the excessive fertilization of farmlands.

The role of phosphorus in waste water pollution has been debated since it was first recognized that synthetic washing detergents (when first introduced) contained large amounts of this substance which soon found its way into nearby surface waters.

Manufacturers have drastically reduced the phosphorus content. But treatment plants are still faced with large amounts of phosphorus and nitrogen contained in the waste water arriving at the plants.

• The waste water from municipalities also contains pathogenic bacteria, viruses, and chemicals. Mercury, lead, copper, zinc, and chromium (the so-called "heavy metals") are waste products of some industries.

Such substances can dramatically affect the health of many organisms which inhabit streams and lakes. Certain effluents also can change the pH (acidity) of the water. The pH is an indication of the acidic/basic nature of the liquid, running from 0 to 14. Seven is neutral; the lower the value the more acidic the liquid. Fish regarded as desirable game species (such as trout) need a pH of more than five in order to survive. Too high a pH on the other hand may be dangerous for fish. The paper and pulp industry is mainly responsible for effluents that cause low pH values. Tanneries and textile mills discharge waste water with high pH values.

• Two other groups of pollutants which can have major biological impacts are the pesticides and the hydrocarbons which escape from refineries, automobile service stations, garages, and streets.

The following four steps are used in waste water treatment processes:
• sludge separation
• biological treatment
• chemical treatment
• complementary treatment, such as filtering.

The handling of waste water at a sewage plant always begins with a pretreatment process that removes those materials that float, are large in size, or heavy. Sand and gravel also are removed during this initial stage.

Following this initial screening process the remaining materials move to a basin where the velocity of the waste water flow ▶

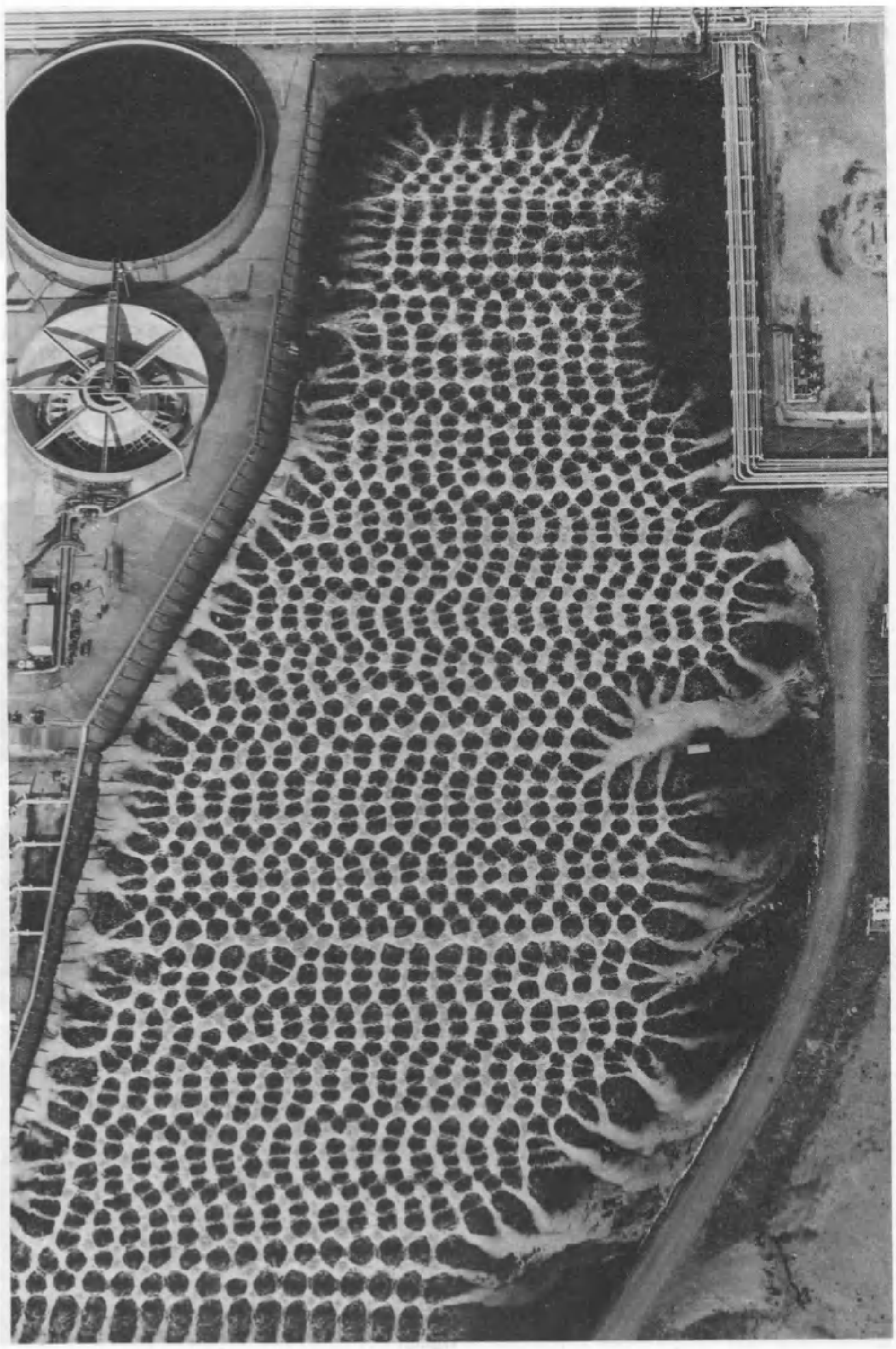


Photo Georg Gerster © Rapho, Paris

At this purification plant in Louisiana, USA, industrial waste water is literally being "washed". Highly oxygenated water is pumped into the waste water through hundreds of jets. The oxygen in this water (it shows up white in the photo) breaks down the organic matter in the waste water which is then returned to the Mississippi River.

▶ is purposely kept low. As a result, solid material will then sink to the bottom where it is removed by scrapers. This stage of the process may take up to three hours.

This phase of the process can be performed in two ways. In the first method, the aerated sludge process, the water enters a basin where it is aerated, together with a biological floc. The bacteria in the floc metabolize the waste solids. The air is introduced by air diffusion or a turbine aeration system, causing the water to be set in motion. Flocs of sludge are formed and grow in size. After one to three hours in the aeration basin the suspension moves on to a sedimentation basin where the sludge is allowed to settle, and is recycled or removed.

The second method uses a biologically active bed made up of layers of material, often of coarse stones. Microorganisms in a gel adhering to the stones remove and decompose the organic material and periodically slough off. As with the previous process, the partially treated sewage is then passed on to a sedimentation basin where settling of the sludge occurs.

The next step, when used, is chemical in nature. Aluminium sulphate and iron compounds are added to facilitate the creation of floc. The phosphorus in the sewage water is removed at this stage. As a final step, filtering may be carried out to remove the flocs still present.

A troublesome by-product from waste water treatment is the sludge. In earlier days, the sludge would be dumped into the sea in those countries located along an ocean coast. That option now is not acceptable because of the known harmful effects on marine life.

Sludge can be treated in digestion chambers where an oxygen-free condition transforms the organic material to more stable non-organic compounds. This procedure takes about three weeks. However, the digested sludge still must be processed, because it contains considerable water, which may be removed by the use of drying beds or by heating. The latter method requires considerable energy.

After the sludge has been dewatered. There are several options for the final disposal of the material:

- It can be removed to a sanitary landfill. There a new problem can be encountered—leakage from the landfill. If not properly constructed, precipitation may percolate through the sludge to the groundwater.
- The sludge can be composted with domestic solid waste products.
- The sludge can be incinerated. Unfortunately, this process may transform water pollution into air pollution. The ash, which remains after the incineration, also may contain hazardous heavy metals which could be taken up by living organisms.
- The sludge can be used as a soil improvement substance similar to cattle manure. Still remaining, however, is the problem of the heavy metals. In many countries rotted sludge cannot legally be used in vegetable gardens for fear that the heavy metals will find their way into food products.

It should be apparent that there are serious difficulties in getting rid of the harmful substances that man introduces into the hydrological cycle. We are often left with—if not exactly those pollutants which we originally added to the system—some degenerated pollutants which can still be biologically hazardous. The crucial point is that man continuously adds pollutants to the hydrological cycle. In the treatment plants these pollutants are mostly transformed into solid wastes. Something must then be done with the solids. If contaminants in these materials are allowed to reach the surface or groundwater the pollution cycle is closed.

What happens then? Do we have any alternatives? Unfortunately, not many. We need new industrial processes that do not cause water pollution, and we also need improved recycling processes to prevent polluted water from being discharged into streams and lakes. It needs stressing that all components of an urban area's water environment must be satisfactorily handled as a total system. An adequate and potable supply must be secured, the waste water must be effectively treated, and the leftover products such as sludge must be safely disposed of. A breakdown in any of these components of the system will place the entire process and the city in a hazardous position. ■

This sewage treatment plant at Lubbock, Texas, uses a 1,200-hectare-farm as its tertiary disposal facility. The nutrients that are normally absorbed during this stage of the treatment process are applied to the land as fertilizer.

Photo Ted Spiegel © Rapho, Paris

The waterlords of ancient Sri Lanka

by Ananda Gurugé

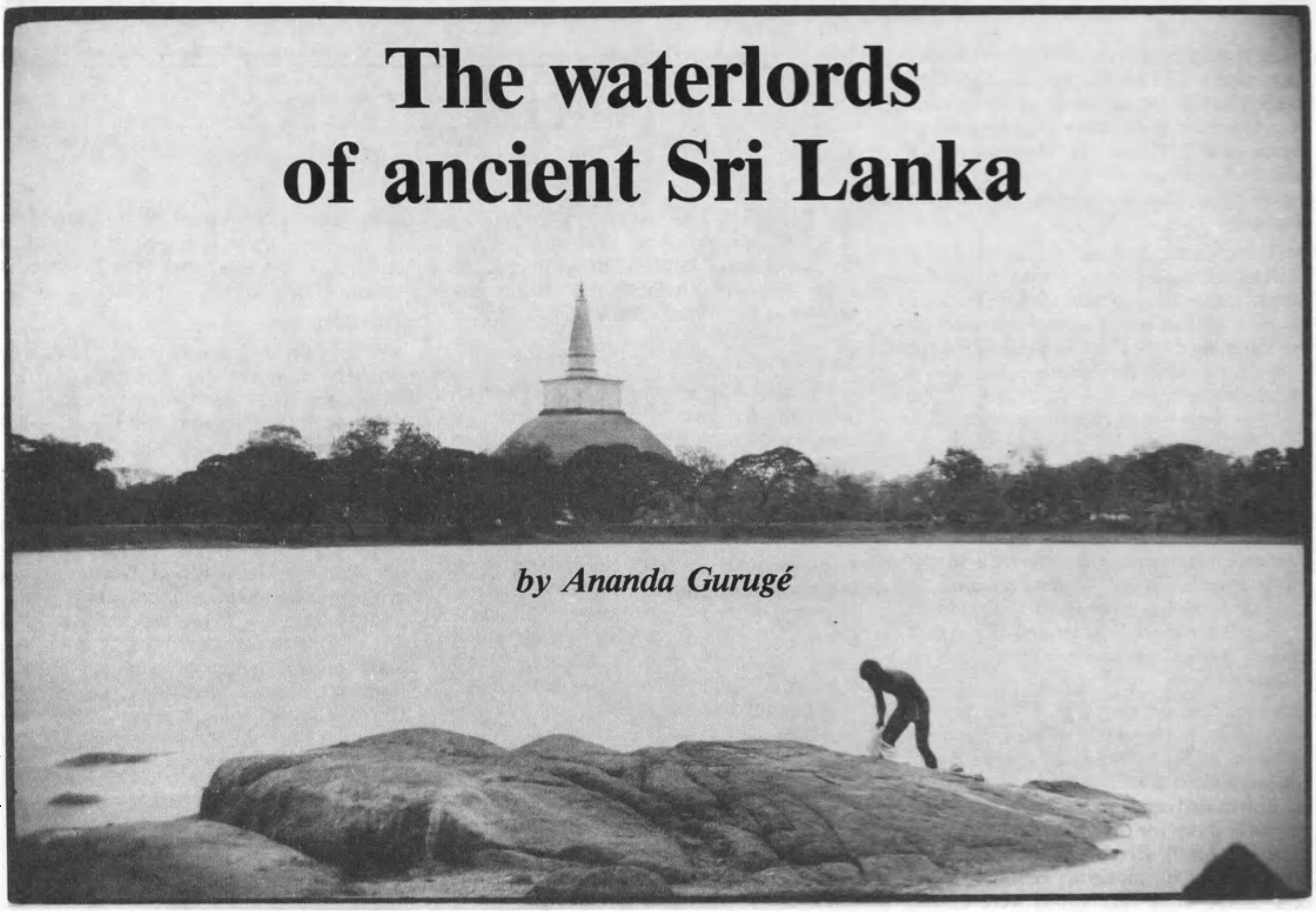


Photo © François Dupuy, Paris

The great artificial lake of Anuradhapura in the north of Sri Lanka, with a monumental stupa, Ruvanvalisaya, in the background. The kingdom of Anuradhapura (2nd century BC-10th century AD) created a remarkable irrigation system which was the basis of its prosperity.

"LET not a single drop of rain that falls on this island flow into the ocean without first serving humanity." This was the governing principle of a massive water resources development programme undertaken by one of the greatest kings of ancient Sri Lanka, Parakramabahu I (1153-1186). The king's record was impressive. The Sri Lankan Chronicle, the *Culavamsa* which was written in the Buddhist canonical language Pali, enumerates his works both as a provincial ruler in western Sri Lanka and later as the monarch of the whole country: he either built or restored 163 major reservoirs (called "tanks" in Sri Lankan usage), 2,617 minor tanks, 3,910 irrigation channels, 328 stone sluices and 168 sluice blocks, besides repairing 1,969 breaches in embankments. Among the reservoirs he built was the tank at Polonnaruwa, called on account of its size the Sea of Parakrama. With an area of 3,000 hectares and an enclosing embankment fourteen kilometres long, it irrigated nearly 10,000 hectares.

The resulting improvement in the conservation and distribution of water brought about an expansion of cultivated land. Consequently, during his reign the production of rice increased to the point that Sri Lanka exported so much of it to neighbouring countries that the country is said to have become known as the granary of the east.

In executing this vast programe, Parakramabahu I was fulfilling one of the most important royal duties laid down by tradition. The obligations of kings were conceived as serving the two-fold interests of the nation: the *material* and the *spiritual*, expressed in Pali as *loka-sasana-abhivuddhi*. Under the first category came the two fundamental duties of defending the nation against external and internal threats to its security, and the conservation and management of water resources to promote rice cultivation. Included in the second category of duties was the sustenance of Buddhism through the promotion of monastic institutions and the construction of impressive edifices. Every Sinhala monarch who is rated great in history has excelled in all or at least two of these three functions.

King Mahasena, who constructed the Minneriya tank in the fourth century, was actually deified by the people, and in a temple on the lake bund he still receives homage from local cultivators who seek his help in growing successful crops. When the fifth-century king Dhatusena was asked by his rebellious son Kahsyapa to reveal where the royal treasures were hidden, he led his captors to Kalaweva, a lake with a circumference of ninety kilometres which he had constructed. Taking a handful of water, he said, "This, my friends, is the whole of my wealth."

These constructions involved a very high level of technological knowledge and skill. Perennial rivers were dammed with stone barrages and diverted kilometres away from their courses. Seasonal streams were dammed in stages to form a series of reservoirs along the valleys. The earthen embankments of these reservoirs extended from a few hundred metres to fifteen kilometres and in some places were eighteen metres high. The *Jaya-Ganga*, an irrigation channel aptly called the Victory River, was a masterpiece of engineering ingenuity. Still functioning today, it is over eight kilometres long with a uniform width of twelve metres. To minimize silting and erosion of banks, its gradient for the first thirty kilometres is an imperceptible 1 in 10,000. It connects two river systems and maintains adequate water supplies in a series of interlinked tanks which irrigated over 46,000 hectares of rice-fields.

Though little is known of either their techniques or the tools they used, the skills of the ancient Sinhala engineers in hydrodynamics as well as surveying and levelling were of a very high order. The stone sluice gate with its control well, called in Sinhala the *Biso-kotuva,* was a remarkably effective apparatus which displays a full understanding of water under pressure. It regulated the speed and the quantity of water issued to the fields and thus protected both the channel and the fields from erosion and flooding. It also prevented a reservoir from being tapped to its last drop by eager cultivators in times of drought, to the detriment of the survival of man and beast. Similarly, a stone spill or flood escape was constructed to a required height, often some kilometres away from the sluice gate, to safeguard the embankments from the heavy pressure of sudden rain or flood water.

Many a modern engineer has been baffled by the sophisticated designs on which these reservoirs and channel systems were constructed. It is known that the Dutch engineers of the eighteenth century and their British counterparts in the nineteenth ▶

failed to understand the design of the giant tank near Mannar on the northwestern coast. Only in recent years, when the tank was restored in conformity with the original design, was it found that levelling by the unknown engineer of the past was vastly superior to that attempted by modern engineers.

The origin and early development of a Sri Lankan science of water resources are not easy to trace. The earliest recorded instance of the construction of a reservoir dates to the founding of the Sinhala kingdom in the sixth century BC. But whatever the source of their technological knowledge, the Sinhalas won wide recognition for their skills in irrigation. Pliny's account of the Sri Lankan embassy to Rome in 45 AD to the court of the Emperor Claudius refers to the artificial lake near the capital, Anuradhapura. Though couched in mythological terms, the reference in the Kashmirian history *Rajatarangani* to Lankan experts who helped Jayapida to drain a lake sometime around the eighth century records a possible case of technical assistance.

A complex system of rules and regulations on the management of water has been operating in Sri Lanka since ancient times. Not only did it prescribe how water was to be distributed and used, it also assigned responsibilities for the upkeep of tanks and channels. Until driven to obsolescence by the advent of the monetary economy in recent times, these regulations were upheld through a process of co-operative self-help, and the tradition persists in remote villages.

The royal duty to develop water resources and thus provide life blood to rural Sri Lanka and its multi-faceted culture has been carried on by the Government of the country ever since political power was vested in national leaders in the 1930s. In a massive effort to regenerate the rural settlements of the Dry Zone in the north central and southeastern regions of the island, over 3,000 reservoirs of varying sizes together with their channel systems have been commissioned into service and vast stretches of new rice-fields have been brought under cultivation.

The *Senanayaka-Samudraya* (the Sea of Senanayake, so named in commemoration of the first Prime Minister of independent Sri Lanka, who was an indomitable pioneer in restoring ancient water resources and establishing new villages) vies with the Sea of Parakramabahu of 800 years ago. The most impressive effort in this direction is the current programme to divert Mahaveliganga, the island's longest river. This multipurpose project which, besides producing electricity and controlling floods, will bring thousands of hectares under cultivation, symbolizes the persistent belief of Sri Lankans that the glory of their nation lies in the village with its lake, rice-fields and temple. ■

ANANDA GURUGE *is chief of Unesco's unit for co-operation with UNICEF and the World Food Programme. He is a specialist in Asian and Buddhist cultures on which he has written several books.*

Irrigation

NEARLY one eighth (230 million hectares) of all the world's agricultural land is under irrigation. An additional 50 million hectares are expected to be added to this total by 1990.

The Benefits

• *Increased food production.* Over the past twenty years the productivity of agricultural land has been increasing on average by two per cent a year. Some sixty per cent of this increased agricultural output has come from newly irrigated areas.

• *Increased income for the small farmer.* Irrigation can double or treble the number of crops that can be grown in a single year. This means that, with irrigation, a once inadequate plot of land can provide a reasonable living for a peasant farmer and his family.

• *More land can be brought under cultivation.* Thanks to irrigation, wheat and maize now grow in parts of northern Mexico and rice grows in the Kuban Valley in the USSR on land that was previously uncultivated.

The Dangers

• *Water-borne diseases.* Badly planned irrigation schemes can increase the incidence of water-borne diseases such as schistosomiasis, malaria and river blindness (see box page 32).

• *Salinization and waterlogging.* When poorly drained land is irrigated in hot climates, the sun evaporates the surface water leaving behind an accumulation of alkaline salts near the surface in which crops cannot grow. In addition, inadequate drainage eventually causes the water table to rise and the land becomes waterlogged. In the mid-1970s the Food and Agriculture Organization of the United Nations estimated that 952 million hectares of land were affected by salinization. ■

Photo D. Mason, FAO, Rome

Effects of salinization (salt build-up in the soil) due to poor drainage and waterlogging, in India (above) and the United States (below).

Photo Peter Menzell © Cosmos, Paris

Photo © *China Features*, Beijing

Villagers search for snails along a drainage ditch at Dongfeng, near Shanghai. Since the early 1970s, such ditches have been dug deeper to prevent the fields from becoming waterlogged, a situation in which the disease-bearing snails flourish.

The deadly snails of Dongfeng

How a Chinese community vanquished schistosomiasis

by Zhang Bihua

DURING the last decade living conditions have changed dramatically for the 400 families of Dongfeng, near Wuxi city in South China.

In Dongfeng (literally, East Wind), as in all the rural areas of Wuxi county, the village roads have been paved and the old, single-storey brick houses are being replaced by two and three-storey houses with tiled roofs. As family incomes rise, the villagers are acquiring a range of consumer goods: hi-fis, television, washing machines and cameras.

The other significant change is not so easily apparent to a visitor. There are no snails in Dongfeng now. And since 1972 there has not been a single new case of snail fever, a debilitating disease which has afflicted China since the time of the Hans, 2,000 years ago.

Medically called schistosomiasis (or bilharzia), its symptoms include fever, liver pains, blisters on the skin, and blood in the faeces and urine. It is caused by the schistosome, a parasitic worm, which spends part of its complex life cycle in fresh water, part inside a particular species of snail and part in the human body (see diagram). People pick up the disease by wading or bathing in an infected canal, lake or pond.

The Wuxi area is criss-crossed by rivers and canals, and it is bordered on the south by Lake Tai, one of China's biggest lakes. The city gets its water from the Grand Canal which carries water from the Yangtze River to Lake Tai, branching on its way into the villages built on its banks. The fertile soil, moderate climate, and the abundance of water has made this a very productive and prosperous area: a "Land of Fish and Rice".

However, the water is a mixed blessing, for it has also brought the schistosome, snails and disease. Early post-Liberation (1949) statistics show that snail fever affected 100 million people in 11 provinces (including Jiangsu where Dongfeng is) south of, and along, the Yangtze River.

The Dongfeng brigade is part of the Luyuan commune in the suburbs north of Wuxi city. Here the Grand Canal flows through five branches of the Liangqi River into a spider's web of waterways—the very best environment for the schistosome and its host, the snail.

Though Dongfeng was not as badly affected as many other areas, its people were exposed to the "swollen belly disease" every time they collected water from the Liangqi—the only source for drinking and all other domestic purposes. The brigade had two old community wells, but there were no household wells.

Children sometimes used to defecate in the fields, and the adults used bucket latrines which were also emptied out in the fields. The buckets were washed in the same river from which they got their water, and this helped spread the schistosome eggs. ▶

▶ But the peasants of Dongfeng had no idea why their stomachs swelled or how they caught "the disease of laziness", as they called it. They knew it made them feeble and unable to work. If the pain were too great they would pierce their abdomens to release the accumulated fluid.

It took Dongfeng more than 20 years to get the better of the scourge that its waters brought. How was it done? First came the national programme to eradicate snail fever, emphasizing preventive measures such as destroying the snails and their habitat, and strictly controlling water usage and nightsoil disposal. A special group was set up at every level, from the central Health Ministry at Beijing, down through county and province to the brigade.

The campaign to rid Dongfeng brigade of snails began, as part of this national programme, in the 1950s, but it took many years to get fully organized.

The brigade collectively owns all the land and all the other resources, and also controls all the finances. A percentage of its total annual income is accumulated in a community welfare fund, which supports co-operative medical care. Money for the anti-snail campaign came from this fund.

It was only in 1972 that the Dongfeng campaign gathered momentum when a four-member anti-schistosome group was formed to lead the work. All four were recognized local leaders—the Communist Party secretary, two heads of the brigade production teams, and a "barefoot" doctor. (The barefoot doctor, crucial to China's rural medical system, is not a medical graduate but a middle school-educated peasant).

In 1972, 27-year-old Su Guiying was the brigade's barefoot doctor working on the campaign. As a child Su had seen people in her village suffer from schistosomiasis. "I vowed that one day I would become a doctor and relieve their pain", she says. In the 1960s she trained as a barefoot doctor and devoted herself completely to helping snail fever patients.

To qualify as a barefoot doctor Su had to take a four-month training course in Wuxi city, which included elementary pharmacology, the diagnosis and treatment of common illnesses such as influenza and diarrhoea, and midwifery. For the anti-snail campaign she had to take a brief additional course on the disease, learn about the ecology of the snail and the basics of testing stools.

The Party secretary and the two brigade heads in the anti-snail group were also trained on the non-medical aspects. The entire group watched films about the disease, examined the larvae and the eggs of the worm, and even dissected an infected rabbit to see how the victims suffered. All this knowledge had to be disseminated to the people of Dongfeng.

Lu Guomin, a doctor at the Wuxi city centre, says they soon found it was more efficient for peasants to spread the information among themselves than for professionals to carry the message from village to village.

But this required a tremendous publicity effort. Posters and slogans were hung on walls, blackboards were used to carry cartoons and short articles on snail fever. And during work breaks in the fields, loudspeakers constantly broadcast basic information about the disease. In the evenings, amateur actors performed skits and sang ballads to get the message home.

Mass participation was vital to the campaign. Su says propaganda is essential to pave the way for such mass participation, but believes that patience is the key.

All the hard work paid off. In the early 1970s at least one person in each of the brigade's then 300 households was affected. But in 1975, three years after the campaign got properly organized, there were only 18 remaining cases.

The improved health conditions were the result of three major activities of the campaign. These were:

- the elimination of snails;
- building new channels for irrigation, drainage and transport; ▶

Waterborne Diseases

THE World Health Organization has estimated that 80 per cent of all sickness and disease in the world is attributable to inadequate water or sanitation. This includes the effects of drinking contaminated water, water acting as a breeding ground for carriers of disease, and disease caused by lack of washing.

Five types of disease are related to water and sanitation:

- *Waterborne diseases* spread by drinking (or washing food, utensils, hands or face in) contaminated water. They include typhoid, cholera, dysentery, gastro-enteritis (diarrhoea) and, where pollution is exceptionally severe, infective hepatitis.
- *Water-washed infections* of the skin and eyes spread by inadequate water for personal washing. They include trachoma, scabies, yaws, leprosy, conjunctivitis, skin sepsis and ulcers.
- *Water-based diseases,* so called because the vector (carrier) is an invertebrate aquatic organism. The most important are schistosomiasis and the guinea worm.
- Diseases with *water-related insect vectors.* Mosquitoes (carriers of malaria, filariasis, yellow fever) and blackflies (carriers of river blindness) need water for breeding. Certain tse-tse fly vectors of sleeping sickness usually bite near water.
- *Infections primarily caused because of defective sanitation,* such as hookworm.

• DIARRHOEA directly kills 6 million children in developing countries each year, and contributes to the death of up to 18 million people. Victims often die of dehydration. Survivors are weakened and easy prey to other diseases. In unsanitary conditions the disease easily passes from child to child. The cure is rehydration, the replacement of lost fluid and salts by weak sugar and salt solution taken either orally or by intravenous drip.

TRACHOMA is a virus infection of the outer parts of the eye, eventually causing build-up of scar tissue over the eye and blindness if untreated. Spread by flies and touch. 500 million people infected world-wide.

SCHISTOSOMIASIS (bilharzia, or snail fever) is caused by a parasite spread by freshwater snails (see article). It is today a cause of misery and debility for 200 million people in Africa, the Middle East, parts of Latin America and southeast Asia. Infectious schistosome larvae penetrate the skin when a person swims or wades in water. The larvae migrate to the blood stream where they become adult worms. Eggs leave the body via faeces or urine. Symptoms include fever, painful liver, blisters on skin and blood in faeces and urine. Ironically schistosomiasis has spread dramatically because of the spread of irrigation canals and dams which provide a suitable habitat for the snails and their parasite.

RIVER BLINDNESS (onchocerciasis) is caused by minute worms carried from person to person when bitten by small black flies that breed in fast flowing water. Worms spread inside body often to eyes where damage and scarring eventually cause blindness. An estimated 30 million people are affected.

MALARIA, common in many of the hot, tropical parts of the world, is carried from person to person by carrier mosquitoes. Almost any amount of water is sufficient for the mosquitoes to lay their eggs. Each year it is estimated that 800 million people suffer from the fevers of malaria. ■

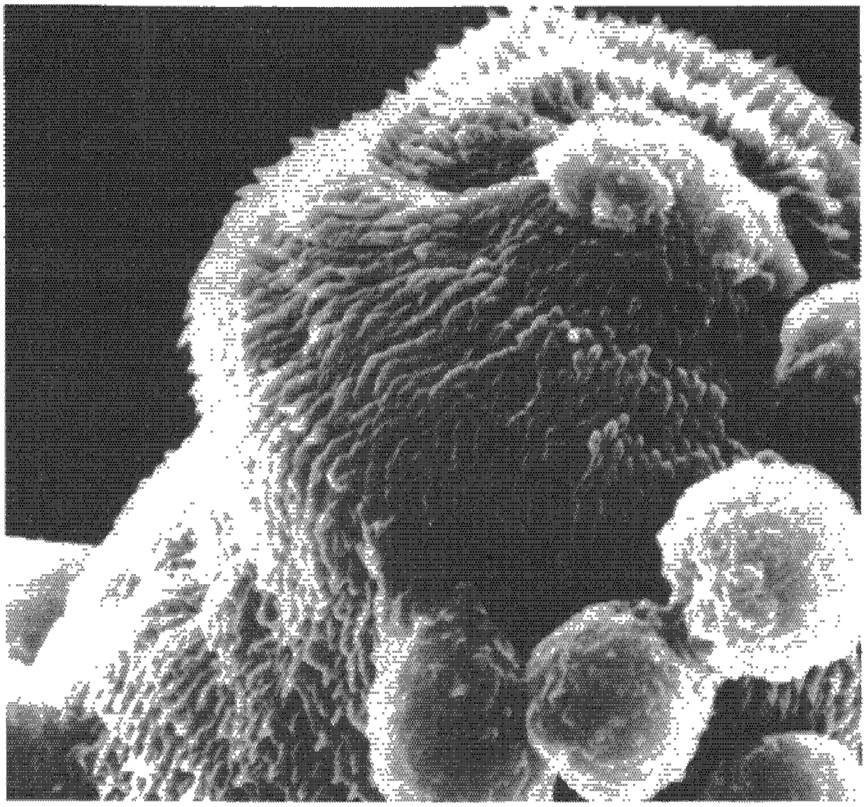
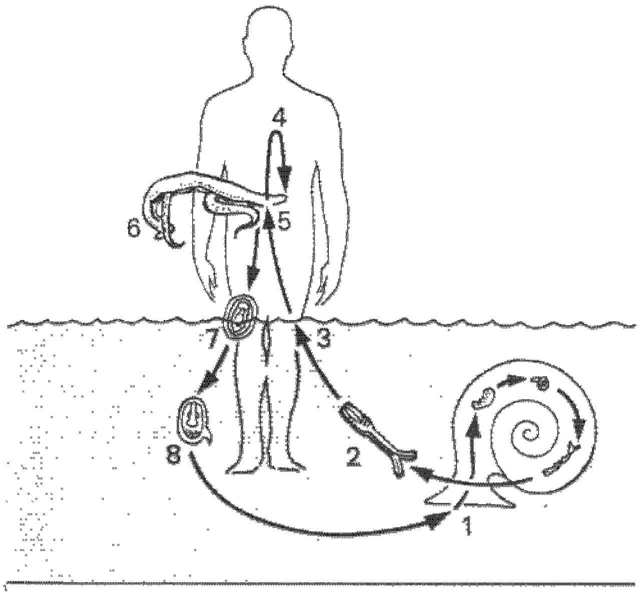


Photo G. Torpier and WHO, Geneva

Above, photo taken with an electron scanning microscope of the parasitic worm that causes schistosomiasis or bilharzia. Right, the anopheline mosquito which transmits malaria.



The life cycle of the schistosome, the parasitic worm which causes schistosomiasis, also known as "swollen belly disease" or snail fever.

1. Fluke escapes from snail
2. Enters water
3. Fluke penetrates human skin
4. Young flukes mature in blood vessels of lungs
5. Adults reach the small intestine
6. Eggs are laid and move through tissue to intestine—they are passed out with waste
7. Mature egg when passed reaches water and hatches almost immediately
8. Larva seeks out an appropriate snail

Drawing adapted by Earthscan from *Rockefeller Illustrated*, Vol. 5 no. 3

Photo © WHO, Geneva

• changing methods of water supply and nightsoil disposal.

In each of the three activities, there was a combination of government support, community action and motivation from local leaders.

Some work had been done to destroy snails in Dongfeng during the early years of China's anti-snail campaign during the 1950s and the 1960s. Like many other local leaders, Yang Zoji, an agricultural technician, had also suffered from snail fever. He says that in the early days of the campaign they used boats to search the river banks for snails. The snails were caught and killed by immersing them in boiling water on a stove on the boat. This was a slow and laborious process because of the number of small rivers.

The snails could have been poisoned with chemicals but these were too expensive. Yang calculates that a tonne of imported chemicals cost the equivalent of four tonnes of rice.

By the early 1970s, the methods changed. An "army" of sharp-eyed village children, armed only with a pamphlet picturing different kinds of snails, searched the irrigation channels and the drainage ditches for the particular snail species which causes schistosomiasis.

Within two months, the people of Dongfeng dug new ditches and used the fresh earth to fill the old ones (totalling 18 kilometres), effectively killing the snails by burying them. "No sophisticated technique was required and it didn't cost us anything except for our muscle-power, as we fought with our own spades and rakes", Yang remarks.

The new channels and ditches, which were straighter and deeper than the old ones, were necessary to prevent the fields from getting waterlogged (a favourable environment for the snail). But this involved changing the contours of the fields. Many in the brigade were initially opposed to this: they thought it would just be a waste of labour.

Yang recalls that an old man complained that a new ditch, which ran alongside the graves of his ancestors, affected the direction of the wind and altered the flow of the water. He believed this had brought bad luck to the family and made his grandson


Photo Nik Wheeler, UNICEF

Two Thai villagers slake their thirst with water from a tap installed by UNICEF (the United Nations Children's Fund).

ill. Su treated and cured the child and that helped people accept the changes.

Dongfeng also used the east-west branch of the river to transport goods to Wuxi city. Wang suggested constructing a new north-south channel which would halve the travel time of three and a half hours, and help clear the river of snails. The residents of Dongfeng contributed their labour, working often by gaslight at night.

The campaign's third area of activity, water supply and sanitation, was perhaps the most difficult. The peasants had always used the contaminated river water for drinking. A strict ban was imposed on washing the latrine buckets in the river and on collecting drinking water from it. The brigade dug several public wells, and each household was also asked to dig its own shallow well.

It took a couple two days to dig a well three metres deep and line it with bricks. They needed 300 bricks and 50 kilograms of cement and sand, and the brigade supplied half of this.

Lu Wenying, the health worker, distributes chemicals to each household to purify the water. A plastic tube with two holes is filled with solid bleach (sodium hypochlorite), and is lowered into the water. This lets in the water slowly and releases chlorine, a much safer method of purification than immersing the chemical powder directly in the water as used to be done.

A special three-chambered pit was introduced for disposing of nightsoil. The faeces are fermented in the first chamber for 15 days, during which time 90 per cent of the schistosome eggs settle at the bottom of the chamber. The fermented mixture then flows into the second chamber, and the process is repeated. When this chamber too is filled the mixture flows into the last chamber, from which it is removed. The final product is good quality fertilizer, high in nitrogen content and without any schistosome eggs.

Snail fever has now been eliminated in Dongfeng. But preventive measures continue. Snail searches are made in the spring and autumn, when snails are active. A reward of 20 yuan (US$40) has now been introduced for reporting a snail. (When the work was at its peak, however, no monetary incentives were given).

Better water supply and nightsoil disposal have also helped to improve the health of the people. Better irrigation has increased the production of vegetables and other crops. Individual incomes have risen.

Joint community effort and government support has helped Dongfeng eradicate the bloodsucking worm. Lu Wenying sums up the success of the Dongfeng campaign with an old Chinese saying: "Two chopsticks are easily broken but not a bundle". ■

ZHANG BIHUA, *of China, is a journalist working at* China Features, *Beijing.*

This article is based on a longer study first published in Who Puts the Water in the Taps, *a paperback book published by Earthscan, London.*

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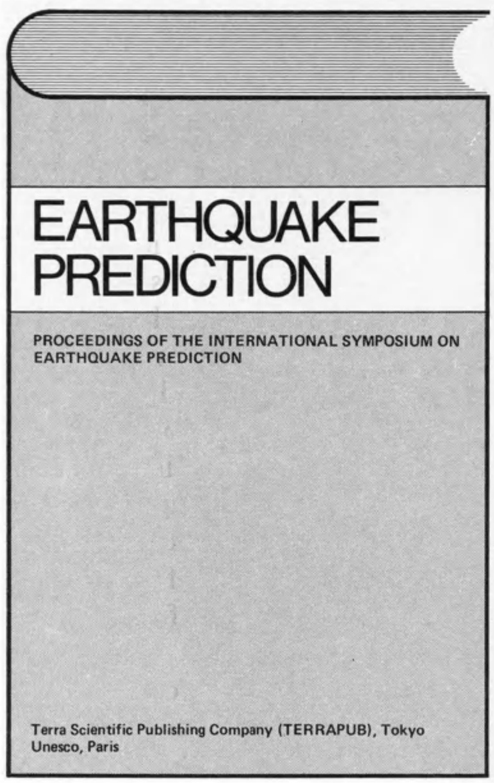

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Acid rain

The deposition of acid in rain and other forms of precipitation is today causing extensive environmental damage in parts of Europe and North America. These two photos of Hanskuhnenburg in Lower Saxony (Federal Republic of Germany) were taken eleven years apart, in 1972 (above) and 1983 (below). See article page 21.