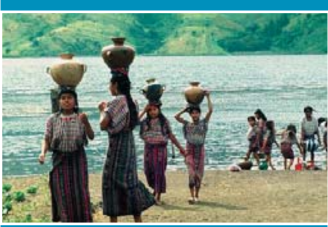
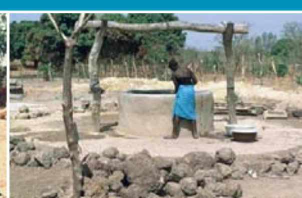
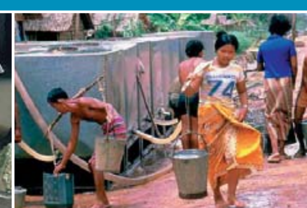
Report of the
Third World Academy of Sciences

Safe Drinking Water

The need, the problem, solutions and an action plan





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The **Third World Academy of Sciences** (TWAS) is an international autonomous scientific organization dedicated to promoting scientific capacity and excellence for sustainable development in the South.

TWAS was founded in Trieste, Italy, in 1983 by a group of distinguished scientists from the South under the leadership of Nobel laureate Abdus Salam of Pakistan, and officially launched by the then-secretary general of the United Nations, Javier Perez de Cuellar, in 1985. The Academy's operational expenses are largely covered by generous contributions from the Italian government.

Since 1986 TWAS has supported scientific research in 100 countries in the South through a variety of programmes. More than 2,000 eminent scientists world-wide, including TWAS members, peer review proposals free-of-charge for research grants, fellowships and awards that are submitted to the Academy by scientists and institutions from developing countries.

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Safe Drinking Water

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Foreword

The Third World Academy of Sciences (TWAS) has earned a reputation as one of the world's foremost organizations for the promotion of science in the developing world. This reputation is based largely on the worldclass research conducted by its more than 600 members. This reputation is also based on the Academy's annual awards, grants, and fellowships, given to young scientists from the developing world that have become among the most important sources of scientific capacity building in the South.

While TWAS continues to nurture and expand its roots in the basic sciences, it has increasingly examined how it might apply the scientific expertise of its members to the South's most pressing environmental, economic development and health problems.

Much of the Academy's work in this area has been conducted in close partnership with the Third World Network of Scientific Organizations (TWNSO) and is best represented by a series of monographs on best practices that has been published in cooperation with other international organizations, including the United Nations Development Programme's (UNDP) Special Unit for Technical Cooperation among Developing Countries (TCDC), the United Nations Environment Programme's (UNEP) Global Environment Facility (GEF) and the World Meteorological Organizations (WMO). The initiatives have focused on such issues as the conservation and wise use of medicinal and indigenous plants, the protection of biodiversity in arid and semi-arid regions, and the management of water resources in the developing world.

This report, "Safe drinking water: The need, the problem, solutions and an action plan," is both an expansion and narrowing of focus of the Academy's larger efforts to put science to work in meeting critical human needs in the developing world. It is an expansion because the Academy, for the first time on its own, is moving beyond its traditional focus on capacity building within the scientific community to applications of science in the larger society, especially applications to address pressing environmental and public health issues in the developing world. And it is a narrowing of focus, in the sense, that this volume, unlike our previous volumes produced in cooperation with TWNSO and its partners, largely avoids examining matters of policy and administration. Instead it concentrates on effective science-based strategies that have improved both water supplies and water quality in the communities, nations and regions that have adopted them.

Indeed there may be no more critical problem facing the South than securing adequate supplies of clean drinking water. As the following text makes clear, it is a problem that demands our immediate attention because, if neglected, it could have serious consequences for the health and well-being of billions of people. In fact, if today's clean drinking water problems are left unresolved, all other policy initiatives designed to promote sustainable development will likely fail because it is virtually impossible to envision future generations of adequately fed and reasonably healthy people in the South, particularly the arid South, unless we successfully attend to our current problems in ensuring adequate supplies of clean water.

As revealed in the report, the good news is that science-based strategies for attaining adequate supplies of clean drinking water have been put in place in many parts of the developing world. Such strategies could be readily adopted by others through concerted efforts designed to promote an exchange of information among experts and policy officials and sustained programmes to increase public awareness. This report is intended in large measure to facilitate such efforts.

Part of the wonder of science will always lie in laying the groundwork for what lies ahead. And part of the unmistakable value of science will always lie in showing the rest of the world what can be done to improve the conditions of all people, especially those who have been marginalized by circumstances beyond their control.

This volume speaks to the latter concern and does so in a language that we hope will achieve its ultimate goals: to increase public awareness about the nature of the problem and, equally important, to describe what can be done about it –now. This monograph, moreover, will form the basis of a more comprehensive study that TWAS plans to undertake with other academies and research organizations in the near future.

I would like to thank Dorairajan Balasubramanian, director of research, L.V. Prasad Eye Institute, Hyderabad Eye Research Foundation, Hyderabad, India, for his efforts in conducting the research and writing the draft manuscript. I would also like to thank Daniel Schaffer, public information officer for the Third World Academy of Sciences, Trieste, Italy, for his editorial help in preparing the final draft for publication. We welcome your comments and suggestions – both large and small – as the Academy moves ahead in addressing this and other critical economic, environmental and health issues.

C.N.R. Rao, President
Third World Academy of Sciences
July 2002

Safe Drinking Water

The need, the problem, solutions and an action plan

Summary

Safe drinking water is the birthright of all humankind – as much a birthright as clean air. The majority of the world's population, however, does not have access to safe drinking water. This is certainly true in most parts of Africa and Asia. Even in relatively advanced countries such as India, safe drinking water is not readily available, particularly in rural areas. One reason safe drinking water is of paramount concern is that 75 percent of all diseases in developing countries arise from polluted drinking water. Knowledge about how to make water safe for consumption is rare in most developing countries. We simply must do a better job of raising public awareness and understanding about the nature of the problem and the technologies and strategies that are available to address it.

The following document describes some of the best methods for purifying water inexpensively. The conclusion is encouraging: Appropriate, locally based, strategies can be devised to obtain safe drinking water in many different parts of the developing world. To this end, we hope the document proves useful.

We also plan to prepare a 'user friendly' version of this document in the form of a poster or a pamphlet. These publications will be publicized through our network of scientific academies and other organizations in developing countries. Each developing country could produce suitable material in local and national languages and develop other programmes to engage and educate the public. If we spark the interest of all concerned, we may indeed make progress in solving one of the most critical problems facing humankind.

Background

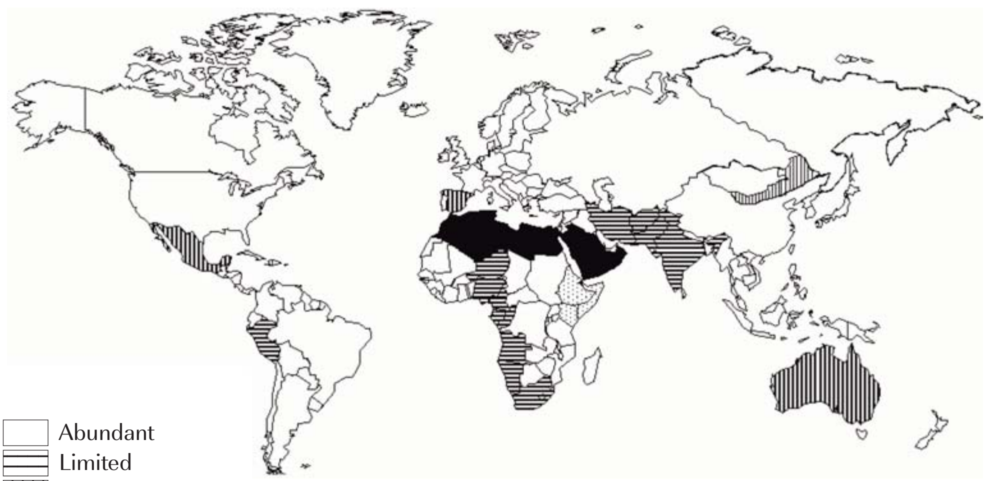
Safe drinking water is a human birthright – as much a birthright as clean air. However, much of the world's population does not have access to safe drinking water. Of the 6 billion people on earth, more than one billion (one in six) lack access to safe drinking water. Moreover, about 2.5 billion (more than one in three) do not have access to adequate sanitation services. Together, these shortcomings spawn waterborne diseases that kill on average more than 6 million children each year (about 20,000 children a day).

Water covers 70 percent of the globe's surface, but most is saltwater. Freshwater covers only 3 percent of the earth's surface and much of it lies frozen in the Antarctic and Greenland polar ice. Freshwater that is available for human consumption comes from rivers, lakes and underground sources and aquifers. Together these sources account for just 1 percent of all water on earth.

Six billion people depend on this supply and a significant portion of the world's population now face water shortages. Today 31 countries representing 2.8 billion people, including China, India, Kenya, Ethiopia, Nigeria and Peru, confront chronic water problems.

Within a generation, the world's population will climb to an estimated 8 billion people. Yet, the amount of water will remain the same. The challenge is as clear and compelling as pristine water cascading down a mountain stream: We must find new and equitable ways of saving, using and recycling the water that we have.

Fig. 1 Water availability



Abundant
Limited
Prone to severe shortage
Scarce
Stressed

The problem is not a lack of freshwater;[1] indeed plentiful freshwater resources are available in Latin America, the Caribbean, sub-Saharan Africa, Europe and Central Asia. Water resources, moreover, do not correlate with the level of economic activity within countries. The Congo has huge freshwater resources – 291,000 cubic metres per capita. Papua New Guinea has 170,000 cubic metres per capita. The United States, meanwhile, has just 9000 cubic metres per capita and Kuwait only 75 cubic metres per capita.

Unequal access. Access to safe water varies both among and within nations. For example, 77 percent of city and town dwellers in the Congo have access to safe drinking water but only 17 percent of rural inhabitants do. In the Lao Peoples' Democratic Republic, the situation is reversed: Virtually all rural Laotians have access to safe drinking water but only 60 percent of the residents in the capital city of Vientiane do.

Use of freshwater resources varies from one country to another. In low-income countries, almost 90 percent of freshwater is used for agriculture, 8 percent for industry and only 5 percent for households. In high-income countries, industry uses 59 percent, agriculture 30 percent and households just 11 percent.

Two key factors lie at the centre of global concerns for the future availability of freshwater, particularly safe drinking water. First, total withdrawals of freshwater have increased dramatically in recent times. In fact, withdrawals have doubled over the past 40 years. As a result, groundwater aquifers are currently being depleted faster than they are being replenished in parts of India, China, and the United States. Inefficient irrigation practices that have played such a large role in groundwater depletion not only waste water but degrade soil quality and reduce farm productivity, placing the progress of the 'green revolution' at risk.

The second key factor of concern has been the relentless rise in population in various parts of the world, particularly in developing countries. Global population is expected to increase by 1.5 billion over the next 25 years (reaching some 8 billion people by 2025). If this population increase comes to pass, the amount of available freshwater per person per year will drop 40 percent – from more than 8000 cubic metres to about 5000 cubic metres.

Ways to save and replenish

We must meet the world's growing demand for freshwater. However, we must do so with limited financial resources and with practices that minimize

[1] Freshwater resources refer to total renewable resources such as rivers, groundwater and rainfall.

ecological disruption. Analyses of the situation suggests that our goals can be reached. Experts have proposed a four-fold path towards a viable solution for making water both potable and safe:

- Seek new sources.
- Save and redistribute supplies.
- Reduce demand.
- Recycle.

Some of these approaches are global in nature, while others are regional, national, local and even family-specific. These efforts will ultimately succeed only when we empower people with the knowledge and means to address the issue on their own.

Seek new sources. As we seek new sources, it is important to note that extracting freshwater from ocean saltwater is a time-honoured technique that can be further advanced through the development of new, energy-efficient methods of desalinization based on reverse osmosis. Earlier methods of heating, evaporating, condensing and then collecting the resulting freshwater proved too expensive for widespread use.

Reverse osmosis, however, represents a much cheaper, more energy-efficient, alternative. In reverse osmosis, a thin, semi-permeable membrane is placed between a container of saltwater and a container of freshwater. The saltwater is subject to high pressure, pushing the water molecules across the membrane into the freshwater container. The material comprising the membrane allows water to pass while leaving the salt and impurities behind. Development of sturdy, chemical-resistant membranes – made of thin, composite polyamide films that can last for 10 years – has made reverse osmosis an increasingly attractive and cost-effective technology for large-scale extraction of freshwater from the sea. Today less than 1 percent of the world's drinking water comes from the sea, but with advances in reverse osmosis, the percentage is likely to grow.

Redistribute. The second pathway for making water both potable and safe involves saving and redistributing water supplies in ways that enable supplies to reach those who need it in a waste-free and inexpensive manner. This strategy seeks to save existing sources, not to develop new ones. The simple act of plugging leaks from tanks, pipelines and taps can save large quantities of water. Peter Gleick, a water expert who is president of the Pacific Institute for Studies in Development, Environment, and Security, in the United States, estimates that water lost from Mexico City's leaky supply system, which serves 17 million people, would be enough to meet the needs of 3 million people. In many countries, more than 30 percent of the domestic water supply is lost to porous pipes, faulty equipment, and poorly maintained distribution systems. Periodic repair and upgrade of these systems, combined with modest modifications in domestic water facilities (for example, installing reduced-volume flush toilets), could make substantial amounts of water, which are currently wasted, available for consumption.

Many communities worldwide have harvested rainwater for centuries. However, this practice has waned in recent years for a variety of reasons, most notably the crowding of people into tenements, apartment blocks and group housing as part of the response to incessant population growth. Given current and looming shortages in water supplies, time-tested methods of water harvesting should be revived and encouraged. Many nations have pursued this path with great success. Several water harvesting case studies, detailed below, highlight one of the most eco-friendly and energy-efficient methods for meeting the water needs of large populations.

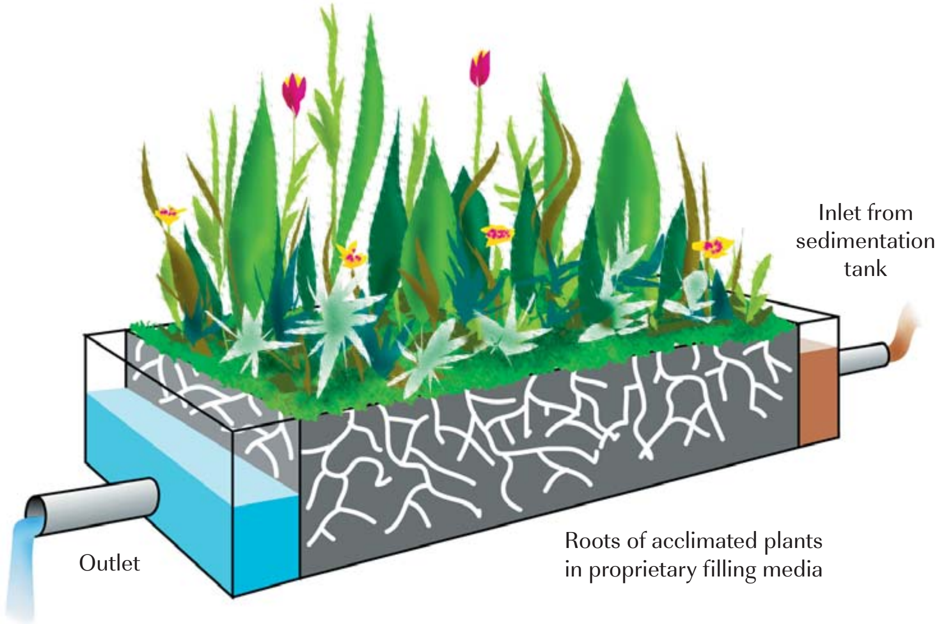
Reduce demand. The third path for ensuring adequate supplies of safe drinking water focuses on reducing demand. In developing countries, agricultural practices place the highest demand on water, accounting for nearly 90 percent of all water consumption. In developed countries, industry, which accounts for about 60 percent of all consumption, is the largest user. In both the North and South, domestic needs represent less than 15 percent of total water withdrawals. As these percentages show, reductions in demand for water must come from the agricultural and industrial sectors. The good news is that newer and more water-efficient processes for both of these sectors have been developed over the past 50 years. For example, the amount of water used in the production of one ton of steel has declined sharply from 80 tons in the 1950s to six tons today. Replacing steel with aluminium, other alloys and plastics (for instance, in the automobile industry) has reduced industry's need for water even more.

Traditional agriculture worldwide, particularly for the cultivation of rice and wheat, has been characterized by water-guzzling practices. For many farm commodities, minor improvements in agricultural efficiency could substantially reduce the demand for water without compromising the quality or size of the yield. Innovative water-saving methods (discussed below), which have been adopted in many countries, could serve as models for others to follow.

Recycle. The fourth path to a more secure water future lies in recycling. The dictum here is 'waste not, want not.' Terrace farming, practiced in many hillside communities throughout the world, may be the simplest example of effective water recycling and multiple use. In terraced farming, water flowing from the higher terrain is not drained but is used to irrigate plants in the lower terrain. Even wastewater or sewerage can be – and has been – processed and recycled for use.

The reed-bed system (fig. 2), used in many countries, represents an eco-friendly way of treating polluted wastewater for reuse. Such diverse countries as Israel, Namibia, India, and Singapore practice recycling. Even when circumstances make it difficult to recycle wastewater, 'grey' water can be used to recharge groundwater. Such practices help curb salinity levels, raise the water table in aquifers, and improve the ecological health of wetlands or sanctuaries.

Fig. 2 Reed-bed recycling system



Making water safe and potable

How should we apply the technologies and strategies described above to make drinking *safer* and *more potable* around the world?

Safe drinking water must be among the highest priorities for every nation on earth. Today contaminated water kills more people than cancer, AIDS, wars or accidents. It is vitally important that the water which humans drink be free of disease-causing germs and toxic chemicals that pose a threat to public health.

Moreover, given that more than 80 percent of the world's population lives in developing countries, technologies for making drinking water safe must be accessible, affordable, environmentally sound, and tailored to a nation's cultural norms.

Technological options fall into two broad categories – those used by municipal authorities at centralized points from where water is then distributed, and those that can be practiced in individual homes.

Chlorination is the most common and effective method for purifying water. Even under poor sanitary and hygienic conditions, in which people collect whatever water that is available from community tanks, wells, pumps and taps for use in their homes, if water is chlorinated, a dramatic decline in the incidence of water-borne diseases follows.

The island-cluster nation of Maldives, in the Arabian Sea/Indian Ocean, has developed an effective and inexpensive method for producing safe drinking water that can be done at home. Called the solar water disinfection technique (or SODIS), sunlight and plastic containers are used to kill pathogens contaminating domestic water. More than a dozen solar water disinfection techniques have been perfected and put into practice. A family, village or community may choose the technique it finds most suitable to its circumstances.

Simple ways to succeed: Some national examples

Seeking new sources of water often requires a great deal of effort and large sums of money. As a result, such efforts must take place at the national or transnational level. However, effective methods at the family and community level can bring a rich supply of substantially clean water with little effort and at a reasonable cost. Many countries have devised successful practices based on this strategy. The most common method is water-harvesting, which involves capturing rainwater and then using it to recharge groundwater sources and refill collection ponds.

Nepal: This small Himalayan nation has always had a water problem. Its population lives in far-flung isolated communities often on hillsides of varying altitudes where rainfall occurs only 3 months a year. Pipeline water supplies are neither easy to construct nor maintain. The Nepalese have developed innovative microlevel methods to capture and harvest rainwater on rooftops, soak pits and village ponds. Called *Baresiko Pani Thapne*, this community-based rainwater harvesting scheme has eased water-shortage problems in several districts in an economically efficient manner that also empowers people by encouraging them to participate in the process.

Sri Lanka: This pearl on the Indian ocean has a long-standing tradition of harvesting rainwater using palm leaves, trees trunks and rocks. Gutters, made of tin sheets, split bamboo, banana stems or arecanut sheaths, channel water onto rooftops where it is captured and stored. Studies suggest that households in the Anuradhapura District collect rainwater on rooftops not only because it is economical but because of the rainwater's incomparable quality.

Kenya: This lush equatorial country of great geographical contrasts has a national rainwater association. In Laikipia, the association first harvested rain in 200-litre drums but eventually turned to megalitre drums with capacities ranging from 50 to 100 cubic metres. Such large storage capacities proved sufficient for meeting human and livestock needs as well as the needs of small-scale vegetable farms. Coupled with the runoff created by terraced agriculture, the effort has helped to increase the efficiency of water harvesting. These advances, which have taken place within the past 10 years, have significantly raised agricultural productivity and living standards.

Ghana: The Ghana Water and Sewerage Corporation (GWSC), established in 1965, works with nongovernmental organizations, individuals and communities to provide safe, potable water by effectively tapping groundwater and surface water sources. Methods are similar to those used in Kenya. The GWSC-sponsored National Water Supply Programme provides water to about 60 percent of the 56,000 rural communities under its jurisdiction.

Indonesia: *Dean Desa*, a nongovernmental organization in this archipelago nation, encourages public participation in the development and wise utilization of water. Under a unique system of finance, affordable rainwater storage cisterns can be built even in the poorest communities. The system works like this: A family is given two female goats. When these goats bear four young goats (which is often the case), two of the goats are returned to the owner and two are given to the borrower. The borrower then rears the goats and uses them as payment for water tanks. The Philippines have adopted the same financial practice using hogs instead of goats as their medium of exchange.

Singapore: This tiny nation pursues the world's most comprehensive and multi-faceted strategy for capturing rainwater for human use. The effort, which is well-planned, easy-to-execute and cost-effective, could help solve water-shortage problems faced by many other cities. Each high-rise building is required to have a rooftop collection system. Water that is collected is sent to two tanks, one of which is used solely for toilet flushing. Mosquito infestation is controlled by fine mesh screens covering the tanks and dousing the stored water with a paraffin oil layer. In addition to apartment houses and high-rises, all educational institutions are required to collect, filter and chlorinate roof top rainwater. The airport has been turned into another huge catchments area. Runoff from rooftops, runways and hangars at Changi Airport provides 80,000 cubic metres of water. Computer analyses indicate resource savings of more than 14 percent. Rainwater, moreover, costs nearly 25 percent less than potable water to collect and distribute.

India: The sprawling desert province of India Rajasthan offers one of the most successful efforts in harvesting and using water to meet community farming and family needs. We highlight it for two reasons. First, many areas in Central and West Asia have remarkably similar geo-climatic conditions to those in Saharan Africa, which makes the experience in Rajasthan both relevant and replicable. Second, the experience showcases an example in which the 'technical solution of an urban engineer' – characterized by digging deeper borewells and using hand pumps – has been replaced by the 'commonsense' and 'rural wisdom' of local participants. Nongovernmental agencies recruited people from some 150 remote rural schools and 50 community centres located in dry or brackish water areas. After considerable interaction with and input from the villagers, more than 200 underground tanks were constructed during the ensuing decade using local labourers and materials. The initiative, which employed 6,000 people, provided an additional 12 million litres of collected rainwater upon its completion. Maintenance problems, which plagued the piped-water and hand-pump system, are now few in number. These communal tanks and wells, moreover, serve as a meeting place for rural women who come there not only for water but for news, gossip and a guilt-free respite from their men and families. In eastern Rajasthan, a rain-fed land, a nongovernmental organization, Tarun Bharat Sangh, has helped local people build 4,500 check-dams and water-harvest facilities in 850 villages using local money and expertise. This effort has raised well levels 2 to 3 metres and turned seasonal rivulets and tributaries into perennial sources of water for some 100,000 people. In 2000, project leader Rajendra Singh, won the Ramon Magsaysay Award for his efforts.

Making wastewater fit for use again

The examples cited above describe effective methods for harvesting water and improving aquifer levels. Such efforts, in turn, make it possible to recharge groundwater aquifers. Another source of water that has the potential to be recycled and made fit for consumption is wastewater. If left unrecycled, wastewater returns to earth either directly or as a result of evaporation. Under such circumstances, pollutants – if not recovered, controlled or treated – remain a source of contamination, usually near the location where the water is discharged. Consequently, recycling wastewater involves the removal and, if necessary, recovery of pollutants. Two pilot projects in Sri Lanka and Chile are worthy of discussion.

Sri Lanka: Sri Lanka extracts raw rubber from its rubber plantations and then processes it for use in a variety of value-added products. The nation also has vibrant coconut and textile processing sectors. These economic endeavours generate considerable wastewater effluents that can be treated and used again. To this end, the Rubber Research Institute built a pilot plant capable of treating 30 cubic metres (30 million litres) of effluent water each day. The system consists of (1) a 'matter trap' with five compartments that lengthens the pathway through which the water must pass; (2) an anaerobic digestion chamber with five compartments that holds and handles two days' worth of effluent in a vented rectangular tank. There, colonized anaerobic bacteria, which are found in the rubberized coconut fibres that fill the tank, convert dissolved organic pollutants into gas (methane, hydrogen sulfide and carbon-dioxide) – some 40 cubic metres of gas per 2 tons of rubber per day; (3) the outflow then returns to the aerobic tank where the biodegradable pollutants are digested in the presence of bubbled air; (4) the aerobically treated effluent is fed into a circular conical floored clarifier enabling the solids to settle into a sludge at the bottom. The effluent, meanwhile, flows from the clarifier's water surface into (5) a sand-bed filter consisting of sand at the top and 'metal' gravel and stones of increasing size below. The filtered liquid is subsequently discharged for reuse. Three such plants have been in operation since 1995 and the process has now been licensed to a commercial firm that plans to market it.

Chile: The operational scales and methodologies used in Chile differ from those in Sri Lanka. The two-step Chilean technique, based on an aerobic process, is more suitable for the treatment of sewerage generated at domestic rather than industrial sites. The first step relies on a biofilter through which the wastewater is drained. This filter consists of several layers with large stones on the bottom, smaller stones and gravel above, followed by a layer of sawdust – all of which is topped by 20 to 30 centimetres of humus containing a large number of microorganisms and 5,000-10,000 earthworms per square metre. The wastewater passing through the biofilter becomes clear as its original organic content is drastically reduced. Because the process is aerobic, the larger the area and greater the aeration, the more effective it is. In the second stage, water is processed through a shallow chamber where it is irradiated with ultraviolet (UV) radiation from a UV-lamp delivering 30 watts per square meter per second. Such UV intensity kills all the bacteria in the water within one minute. Water exiting the UV chamber is not only sterile but of excellent quality. The bio-reactor can handle up to 1,000 litres a day per square metre. The system, moreover, is easy to maintain and does not consume a great deal of electricity. Because residues do not accumulate, the only regular maintenance consists of adding sawdust to the biofilter every few months. Some humus should also be removed periodically to maintain an active and growing biosystem. The system has been patented and commercially installed in several different sites in Chile – for example, in schools with several hundred students, settlements with 500 to 1,000 peoples, and even in a region with 12,000 people.

Private industry initiatives: In addition to national initiatives, private industry has financed and implemented several comprehensive programmes to improve the water quality of lakes, recycle water, and make potable water available to villages (for example, Unilever's PAGER programme Morocco). The 'Plebys' initiative in the United States has developed a simple two-stage filter (similar to the Chilean type) for use at home. Such programmes have encouraged community participation, sometimes with small financial incentives (for example, a few cents a day to pay for the materials and water supply). Nongovernmental organizations have turned to local talent, resources and institutional know-how to make safe drinking water available on consistent basis.

Technologies to make safe drinking water

Unless water is made safe for drinking, the war against water-borne diseases will be lost. Several convenient and easy-to-use methods have been devised. Some, which rely on high-technology, are more suitable for use at city/central point treatment facilities. Others, based on more modest technologies, can be used at the settlement cluster level – in schools, community centres, apartment buildings and villages. Then there are 'traditional' and/or 'appropriate' technological options that can be used in individual homes or during emergencies. The quality of water obtained by each of these techniques (high-, medium- or traditional- and appropriate-technology) should be excellent – free from pathogens and toxins and as fit for drinking as water sold commercially.

High-technology/high volume methods: Time-honoured methods of treating high volumes of water to meet the demand of urban populations involve sedimentation and filtration followed by the killing of pathogens through chlorination or sometimes ozone bubbling. While such processes remain logistically feasible and even acceptable for relatively low-volume demand (for example, in schools, hospitals and villages), these methods contend with 'flow through' or 'steady-state' volumes of water and not static captive pools of water collected in siphoned tanks. To addresses these challenges, several methods have been successfully devised and developed. A few are highlighted below.

- *UV-protected granulated activated charcoal bed:* This innovative method has been developed at the U.S. National Aeronautics and Space Administration (NASA) Johnson Space Center. Charcoal is an effective water-purification material that can adhere (adsorb on its surface) diverse classes of inorganic, organic or biological contaminants. The larger the surface area of the charcoal, the more effective it is. As a result, experts have opted to use powdered or granulated charcoal instead of charcoal lumps. The process extends the active life of the charcoal through the use of ultraviolet light that inhibits the growth of microbes on the carbon surface while disinfecting and purifying the water passing through the tubing. Unlike chlorinated disinfectants, UV light does not leave residual matter, which helps to prolong the life of the active charcoal bed.[2]
- *Titanium dioxide and UV light as the purifier:* More than 20 years ago, Japanese scientists illustrated that anatase, a naturally occurring mineral that is a form of titanium dioxide or $TiO_{2,}$ is an efficient disinfectant when subject to ultraviolet radiation. Under such conditions, TiO_2 produces reactive oxygen and free radicals that kill bacteria, fungi and viruses in a brief time. $TiO_{2,}$ a mineral found in abundance in nature in its purest raw form (in Africa, Australia, Sweden and Canada), has been used as a whitener in paints, toothpaste, cosmetics and paper. The addition of TiO_2 and the shining ultraviolet rays (similar to the Chilean experience cited above) purifies the water though 'photocatalysis' (*photo* refers to the UV light; *catalysis* refers to the fact that TiO_2 aids the purification process without being used up). A decade ago, the first International Conference on TiO_2 Photocatalytic Purification and Treatment of Water and Air, highlighting the advantages of using TiO_2 and UV-light to purify, took place in Canada. Since that conference, several improvements have made the TiO_2 photocatalysis method even simpler and more effective.

[2] For additional information, see www.usrttc.org/PDF/TBQ298.pdf

• *TiO_2 and sunlight to purify water:* While TiO_2 is an inexpensive and non-toxic substance used to purify water, it does have some disadvantages. First, because it is suspended as a powder in water, it must subsequently be filtered. Second, TiO_2 uses ultraviolet light and most of the sun's light that falls on earth is above this range. To solve these drawbacks, a research team in Germany sought to immobilize the catalyst as coatings on glass using a process (sol-gel transformation) that produces solids from liquid solutions. Such coatings could be used as effectively and for longer periods without filtering. The researchers improved the light absorption character of TiO_2 by adding small quantities of iron oxide (Fe_2O_3) into the TiO_2 grid. This allowed the use of direct sunlight instead of UV-light. In experimental tests, the composite TiO_2 (Fe_2O_3 catalyst coated on glass), together with the use of sunlight, proved successful, opening the possibility of much broader use.[3]

• *Electrochemical activation (ECA):* In this method, electrical energy instead of light is used for purification. The catalyst is not TiO_2 alone, but a mixture of oxides of various metals (such as Ru, Ir, Pt and Ti) that are coated on the surface of electrodes. The electrodes are placed on either side of a vessel that is divided into two sections by a vertical diaphragm (ceramic, coated with other oxides) which separates the water contained in the two chambers. Rain water passes through one of these anode chambers to a second vertical chamber that contains replacement-free and regeneration-free catalyst granules. The latter oxidizes all organic and biological substances and decontaminates the water. The outflow is then fed into the other chamber of the electrolytic column, while a direct current electrical energy, generated by car battery, passes through. The electrochemical activation (double layer intensification) is intense enough to purify even the most obdurate pollutant. A business group from Estonia has commercialized the purifier as a low cost, easy-to-maintain purification device that provides drinking water which meets World Health Organization (WHO). The system yields 120 litres per hour, consumes small amounts of energy and the cartridge does not have to be replaced for years.[4]

• *Portable reverse osmosis water purifiers:* Commercial companies now make small reverse osmosis devices for home use that can regularly produce 7 litres per hour of pure water from any type of water. The devices, which can be mounted on a wall, consume little electricity, use membranes that do not need replacement for 2 to 3 years, and rely on filters that must be replaced just once a year. Home units currently cost US$200. Larger units, designed to serve an apartment building with throughput rates of 100 litres per hour, cost US$4000. These devices may prove attractive for middle- and upper-income homes or communities where water is hard or brackish.

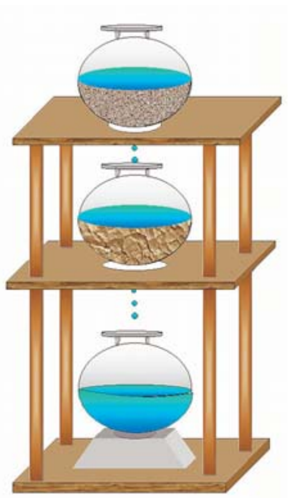
[3] For additional information, contact hopp@isc.fgh.de

[4] For additional information, see www.aquastel.com/summary.html

• *Efficient adsorbent filters:* Filtering water removes suspended particulate matter. The finer the filter, the more it can decontaminate and purify. Use of a membrane allows selective passage of water while preventing unwanted dissolved material from passing through. Water purification requires a quick-flow, corrosion-resistant, high-stability (in terms of pressure, temperature and contaminants) bactericidal and economical membrane filters. Recent research in Russia on such filters has been promising. Laboratory materials not have only met technical requirements but have been inexpensive to produce, suggesting that it could suitable for domestic community and industrial uses.[5]

Appropriate technologies for home use: In isolated rural communities in developing countries and during emergencies, there should be access to rapid but reliable methods of purification that supply small volumes of water (10 to 1,000 litres). The systems should rely as much as possible on local labour and material. Use of alum, permanganate and chlorine tablets for quick purification is easy and practicable at the domestic level.

Fig. 3 Mud-pot filtering system



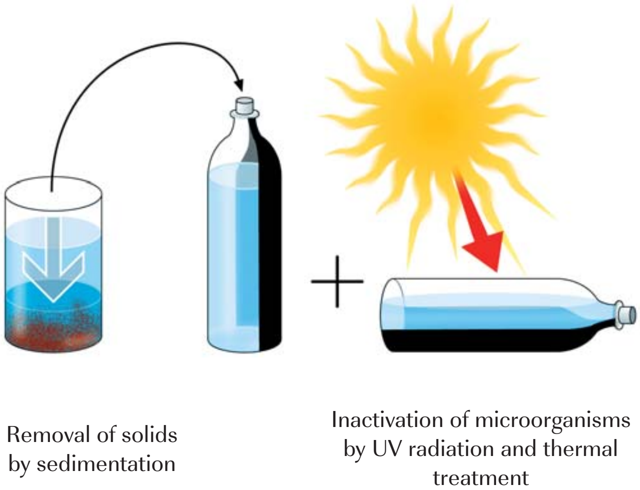
A well-known and safe method practised at homes in South Asia involves a *mud-pot filtering system* (fig. 3). The top pot contains pre-washed gravel and sand through which raw water passes. The water exits through a hole in the bottom of the pot into a second pot kept below. The mouth of the second pot is covered with a cloth filter while a crushed coal bed lies on a pad below, removing many toxins and germs from the water. Clean water exits through a hole in the bottom of the second pot and then is collected below in a third earthenware pot. The collection rate is slow, but it can be done overnight at home so that clean, cool drinking water is available throughout the day. This method needs no electric power, filters or chemicals. As a result, maintenance costs are minimal, requiring only funds for the charcoal, gravel and sand that must be replaced every few days.

The *solar disinfection method* (or SODIS) is an easy, small-scale and cost-effective technique for providing safe water at homes or in small communi-

[5] For additional information, contact head@ism.ac.ru

ties. Water is filtered to remove the solids and particulate matter. The water is then moved into a throw-away, colourless and transparent bottle where it is kept in the sun for irradiation. To maximize the effectiveness of the process, the bottle should lie on the ground and its surface should be blackened to better absorb the light and generate heat (fig. 4).

Fig. 4 Solar disinfection method



The combination of solar radiation and heat inactivates pathogens. The treated water can now be stored in a cool mud pot for drinking. This method has been successfully tested in Bolivia, Burkina Faso, China, Colombia, Indonesia, Thailand and Togo.[6] In places where electric supply is available, filter cartridges (with or without irradiation) can be used either on stored or flow-through water supplies.

Action plan

Prospects for providing adequate access to safe drinking water to homes and communities on a global scale may not be grim as we think. Ongoing efforts by communities, townships, state, provincial and national governments have made safe water a realizable goal. This is the theme of the Africa 2000 Initiative for Water Supply and Sanitation, launched by World Health Organization (WHO), in 1993. The effort led to the Brazzaville Declaration 1996, which established relevant principles and recommendations for enabling the people of Africa to have access to safe water supplies and sanitary waste disposal facilities.

Individuals and communities. Efforts need not be left solely to governmental and nongovernmental agencies. Individuals, families and communities also have a vital role to play. Such responsibilities include:

- Water harvesting at home, schools and community buildings.

[6] For further details, contact wegelin@eawag.ch

- Water recycling at the microlevel, including at homes, buildings and communities.
- Saving water by ensuring taps and pipes are not leaky and by using optimum amounts of water for washing and toilet flushing.
- Making sure that the water is purified by methods suited to family conditions and needs.
- Maintaining proper levels of sanitation at home.

Governments. Participants at the Second Regional Meeting on the Africa 2000 Initiative, held in Harare, Zimbabwe, agreed to a framework for action and series of recommendations. While the efforts focused on Africa, the recommendations and action plan could prove relevant for much of the world. Based on these and other deliberations, and on the material discussed above, we suggest the following action plan whose objectives are to (1) assist countries in the formulation, implementation and monitoring of policies and action plans designed to ensure safe water supply, and (2) to promote cooperation among governments, international agencies, nongovernmental organizations, and the private sector to advance the interrelated goals of safe water and adequate sanitation. Major areas of focus include community empowerment and management, private-sector involvement in water supply and sanitation, country-level collaboration and cooperation, and sanitation and hygiene education.

The action plan should include:

- Encouragement of political commitment through effective policy formulation, support for the implementation of plans, and improved budgetary allocations.
- Promotion of intersectoral coordination and cooperation to forge a policy consensus for the promotion of safe water drinking.
- Support of local efforts and community-based strategies for addressing the issue.
- Facilitation of access to appropriate technologies.
- Development of legal and regulatory frameworks for private industry and nongovernmental participation.
- Devising of mechanisms that enable governmental agencies to pursue sanitation as a national priority, including development of sanitation policies and guidelines, organization of advocacy campaigns focusing on policy makers, and the integration of hygiene education into all water supply and sanitation projects.
- Involvement of women in water-supply activities by identifying women's groups and movements at all levels and incorporating their

views into community-level water-harvesting, recycling, saving and purifying, and supply initiatives.

Private industry and nongovernmental organizations. Many countries – for example, India, Indonesia, Kenya, and Nepal – have active non-governmental organizations that involve communities in the funding and implementation of programmes designed to transform arid and semiarid terrains into productive agricultural regions receiving sufficient amounts of water. Such efforts should be expanded by:

- Exchanging information among and between industry and nongovernmental organizations on relevant and novel methods and strategies.
- Focusing on sociological factors that may have an impact on the most suitable technologies and programmes for a given region/community.
- Ensuring equity in both services and benefits.
- Involving communities in all aspects of water harvesting, recycling, storage, purification and supply.
- Coordinating efforts among governmental and intergovernmental sectors for the purposes of achieving harmonious processes and results.

The proverbs "waste not, want not," "little drops of water make the mighty ocean," and "what is saved is what is earned" represent simple truths. Water is plentiful. What is needed is to ensure that it is not wasted but treated, purified and made available in a fair and safe manner. The task is doable, thanks to the earth's hydrological cycle. The earth does not let a drop of water escape but wraps it tightly within and around itself. We who live on earth can – and should – do so too.