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EDITORIAL

# Providing safe drinking water: a challenge for humanity

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The importance of continuing the development of a safe water supply for humanity across the globe cannot be overstressed. Safe water is necessary for health and well being and is a basic human right. Historically, in industrialized countries, virtually all diseases, such as cholera, polio, and typhoid fever were eliminated in communities where safe and clean drinking water was made available. The same would be the case in developing countries if safe and clean water supplies were to become available. No amount of medical supplies or healthcare facilities can achieve such a goal at a reasonable cost.

Developing water systems that allow over six billion people to have access to safe and clean water is no small feat. The efforts of governments and international organizations such as UNICEF and the World Health Organization (WHO) have provided over one billion people access to clean water which they otherwise would not have had, however, there still remains over one billion people who do not have access to safe water supply. According to the 2008 UNICEF "Handbook on Water Quality," insufficient water supplies coupled with poor sanitation causes 3.4 million deaths per year, which translates into someone dying every 10 s. The majority of these deaths occur in children due to their higher susceptibility to catching diseases.

## Nature and extent of the problem

To further grasp the disparity and the magnitude of the water crisis it must first be understood how much water is used by major industrialized countries. For the sake of making a point, the United States will be used as an example. The consumption of the US economy equates to 1,400 gallons per person per day. This includes water used in agriculture, thermo-electric generation, industry, and household use. In 1990, the average US resident used between 185 and 200 gallons per day for household use.

Compare this information with the 1.1 billion people who do not have access to clean water: UNICEF estimates that they use 1.3 gallons per person per day (UNICEF Handbook on Water Quality 2008).

On a basis of volume comparison, multiplying the average daily use of 304 million Americans (July 2008) and the use of 1.1 billion water-stressed people, the result is as follows: The US uses 55.6 billion gallons per day when the world's water-stressed people use only 1.4 billion gallons per day. That means that 5% of the world's affluent populations use 39 times as much water as 16% of the world's population.

Provision of clean water at an affordable price is also inextricably tied to efforts to erase gender inequality, alleviate poverty, enhance productivity, and afford educational opportunities. Providing access to clean water at an affordable price requires that four major requirements be met: the existence of a source of sufficient quantity, adequate water quality for the intended purpose of use or the ability to increase water quality to meet requirements, a transmission network to a location proximal to usage clusters, and a pricing structure which reflects economic and social capacity.

It is a well-known fact that the majority of the Earth is made up of water, however, the freshwater required to sustain and enrich human life is barely 2.5% of the water available. Two thirds of this water is tied up in glaciers and permanent snow cover leaving a scant 1% to supply the

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growing needs around the globe. Demands of maturing economies, increasing population, industrialization, and increasing standards of living in many regions of the world are all contributing factors to the current environment of water stress and shortage. At the same time, global fluctuations in climate and a growing imbalance of population distribution between rural and urban centers are adding to the logistical complexity of providing access to water where needed most. Sustainable watershed development, rainwater harvesting, and responsible use of groundwater sources are needed to make access to clean, affordable water a reality.

The competing demands for water range from ecological services, food and feed production, power generation, shipping, as well as domestic and industrial needs. While the framework to satisfy each of these demands in a socially acceptable manner can be highly complex and location specific, water conservation as a basic tenet in any such framework is largely non-controversial and a keystone component. Examples of such conservation measures are a more sustainable life-cycle, less water intensive food and industrial production systems and processes, and a more efficient transmission network.

While all of the above-mentioned measures—watershed development, production, and protection; judicious water harvesting; and water conservation—will be the predominant tools to meeting the Millennium Development Goals, they need to be supplemented by additional measures to identify, develop, and upgrade alternative sources of water to meet the anticipated gaps in the demand–supply equation in the long run. This is important if water is not to become the critical bottleneck in the development of large parts of the world facing increasing population, dwindling supplies of fresh water, and increased pollution of existing water supplies.

## Water contaminants

According to the WHO and UNICEF "Progress on Sanitation and Drinking-Water 2010 Update", 2.6 billion people do not use improved sanitation facilities, with the largest population being in Southern Asia. Improved sanitation facilities are those that separate human excreta from human contact. The interplay between inadequate sanitation and insufficient water is both inextricable and complex, with each exacerbating the other. Water quality is really an issue of sanitation that arises from the widespread presence of contaminants in our waterways. There are many sources of water pollution and most are due to anthropological activities. Major sources of contamination include:

- Discharge of untreated sewage containing chemical wastes, nutrients, and suspended matter. Discharges include industrial waste, direct input from animals or open sewage sources, as well as leakage or poor management of sewage systems.
- Waste disposal sites including both solid and liquid waste disposal.
- Surface runoff from fields, roads, agricultural, construction sites, and other highly permeable zones with high human interference containing pesticides, herbicides, fertilizers, petroleum products, and other modified or fabricated additives.
- Climate or weather changes leading to increased rainfall events or flooding leading to heavy runoff.
- Discharge of heated and/or contaminated water used in various industrial processes.
- Atmospheric deposition of contaminants.

Generally speaking, water contaminants can be categorized into four groupings: Microbiological, Chemical, Radiological, and Physical. Microbiological contaminants can be broken down into four main classes: Bacteria, Viruses, Protozoa, and Helminths. Of all types of contaminants, microbiological contamination poses the greatest risk to public health due to their ability to cause diseases with small infectious doses and can become widespread rather quickly. Also, some microbiological contaminants are extremely persistent due to their ability to proliferate in aquatic environments. These contaminants are also difficult to monitor because they are discrete and are not evenly distributed throughout a water system. Often, the only indication that microbiological contamination is present is the occurrence of disease.

Microbiological-related diseases, for public health purposes, are distinguished using the Bradley classification system which categorizes as follows: waterborne, water-washed, water-based, and water-related (insect vector). Waterborne diseases are caused by ingesting water contaminated with industrial waste, human or animal feces, or urine containing pathogens which leads to gastrointestinal tract infections which cause diarrheal disease, typhoid fever, hepatitis, polio, legionellosis, and leptospirosis. Water-washed diseases are caused by inadequate use of water for domestic and personal hygiene which can cause diarrheal disease, soil-transmitted helminth infections, acute respiratory infections (e.g., pneumonia), skin and eye diseases (e.g., ringworm), and flea, lice, mite, and tick-borne diseases. Water-based diseases are caused by parasitic pathogens found in aquatic hosts and lead to diseases such as schistosomiasis and dracunculiasis. Water-related diseases are caused by insect vectors which bite near or breed in water such as the mosquito vector diseases malaria and yellow fever. Thus, it is important to note that not all water-related diseases are related to drinking water quality.

Chemical contaminants are both naturally occurring and the result of anthropogenic activities such as agriculture, water treatment, and industry. UNICEF lists arsenic, fluoride, and nitrate as priority chemical contaminants. Arsenic occurs naturally in soils and rocks while fluoride is found in the earth's crust. Nitrate is a common ingredient used in fertilizer which is applied to crops and can be washed into surface waters through runoff. A second priority is compounds that cause drinking water to be rejected due to esthetic purposes such as metals and salinity.

Chemical contamination of water systems causes diseases after prolonged, chronic exposure. These diseases caused are of particular concern because contamination is only evident once diagnosed and simply switching to a safe water source does not alleviate the problem. Health risks associated with acute exposure are also possible; however, excessive chemical contamination typically changes the taste, odor, and appearance of the drinking water.

The risk for radiological contamination is typically much lower than that for microbiological and chemical contamination. However, the introduction of radioactive materials into the drinking water system may lead to radiation exposure. Radionuclides can be naturally occurring or the result of human activities such as manufacturing and nuclear energy facilities. The public health risk associated with radiological contamination usually occurs after prolonged exposure, similar to chemical contamination.

Physical contamination occurs when the esthetic quality (e.g., taste, color, and odor) of drinking water is affected. The danger associated with this type of contamination is that it can lead to the ingestion of water that appears clean but is in fact contaminated with pathogens or chemicals. Physical contaminants affect the consumers' perception of drinking water quality and can be of biological or chemical origin. Some examples of biologically derived contaminants are fungi, algae, and small invertebrate animals such as snails. Some examples of chemically derived contaminants are aluminum, chlorine, and copper.

## Sustainable technologies for safe water

Reasons for the unavailability of safe water relate to enormous capital investment and operating expenses that must be incurred to be able to provide reliable and safe water; this is simply out of the reach of most developing countries. Preventing contamination and implementing sustainable treatment technologies are ways to increase access to safe drinking water.

In many regions of the world, including the United States, rivers carry significant amounts of pollutants derived from industrial and municipal discharges, nonpoint sources such as agricultural and urban runoff, and accidental spillage. Water utilities that use surface water for supply must remove these chemicals in the plant prior to distribution. This involves the use of significant amounts of chemicals and advanced treatment technologies such as activated carbon or membrane units if micropollutants (e.g., pesticides, gasoline, and solvent constituents) are present in the source waters. Not only these technologies are expensive, they also need highly skilled operators.

Many small communities, even in industrialized countries, do not have such resources to meet the challenges. For long-term sustainability, incorporation of the most advanced technologies may not be feasible for small communities in developed countries and for most communities in developing countries. Appropriate and sustainable technologies need to be developed to respond to this crucial need.

The first step to ensure a safe drinking water supply is to prevent contamination from occurring which involves decreasing the amount of contamination entering the water stream and creating barriers to keep contamination from entering the water supply. Decreasing the amount of contaminants entering the water stream can be achieved through improving sanitation practices and ensuring that the source water is of acceptable quality. In addition, drinking water should be properly stored and handled to ensure safety.

Water treatment methods such as solar distillation, membrane filtration utilizing techniques and materials that are affordable, and natural soil/aquifer filtration may be considered sustainable. These systems can function effectively at various scales and be able to provide potable water with very little need for additional treatment. Also, these technologies can be affordable in developing countries.

Solar distillation has been practiced in many arid and desert countries. In certain places, solar stills are coupled with membrane units for drinking water production. There are several variations of the stills used for drinking water production. One of the recent versions, patented by the US Department of Interior (inventor: J. Constantz), can be used for drip irrigating row crops and producing drinking water.

Currently, membrane filtration is an expensive treatment technology and it is used for desalination of sea or brackish waters or other process waters. Depending on the pore sizes of the membranes, they are classified as "microfiltration", "ultrafiltration", "nanofitration, and "reverse osmosis". Membrane cost and energy needed to pressurize the water chamber for filtration control the per unit production cost of water. It is still possible to produce membrane filtrate from low-cost materials using alternate energy sources so that the process can be "democratized".

Natural filtration is a process that utilizes the pollutant adsorption and degradation capability of soil and aquifer materials and it has been formally deployed for drinking water production in Europe for more than a century. Wells, either vertical or horizontal, are placed some distance away from the river and are pumped on a sustained basis. This induces the river water to flow to the pumping wells. During soil and aquifer passage most contaminants from surface water are removed via sorption or degraded through microbial processes.

In biblical stories, it is mentioned to drink water from a hole next to the Nile River rather than drinking the water from the river directly, thus using natural filtration process to provide safe drinking water. In most areas of the developing world, especially in rural communities, the spread of cholera diminished after the use of hand pumps compared to the situation when surface water was used for drinking. So, the soils and the underlying aquifer materials have tremendous capacity to remove surface water pollutants.

If properly designed and operated, most natural filtration systems (called bank filtration systems) do not need significant additional treatment with the exception of disinfection. However, excessive pumping using infiltration galleries or scouring of riverbeds may reduce the effectiveness of such systems. In all instances, the quality of filtrate from these systems is still superior to that of the river water.

Generally speaking, it is desirable to use less amounts of chemicals, energy, and manpower in drinking water production. Greater sustainability is achieved when comparable quality of water is produced without the need of excessive amounts of energy, labor, and expensive equipment/technology.

Some of the sustainability strategies that need to be examined in detail are: (a) reduction in chemical and energy use in water treatment, (b) production of water that contains less pathogens and disinfection byproducts compared to the use of surface water, (c) focus of water utilities and communities on improving source water quality if the water treatment plant wants to reduce further treatment of the filtrate, and (d) developing institutional framework and public policies that focus on giving safe drinking water availability, at an affordable cost, one of the highest priorities for reasons discussed earlier.

Providing access to safe drinking water, at an affordable cost, to over one billion people remains a challenge for humanity: development and implementation of appropriate and sustainability technologies and requisite institutional framework can make the crucial difference.