RURAL WATER SUPPLY SYSTEMS

M. Sundaravadivel
Graduate School of the Environment, Macquarie University, Sydney, Australia

S. Vigneswaran
Faculty of Engineering, University of Technology, Sydney, Australia

Keywords: Extraction devices, Rainwater harvesting, Rural water supply, Water intake structures, Water treatment, Water distribution system

Contents

Summary

Water supply for drinking and domestic uses is an essential basic requirement for households and communities. Unlike in large urban settlements, for small communities

in rural and outback areas conventional methods of water sourcing, extraction, and supply are not cost effective. Especially so in the rural areas of developing countries, which need simple, alternative methods to satisfy their domestic water needs. Water supply to such rural communities can be sourced from rainwater, groundwater or spring/surface water. Through simple rainwater harvesting techniques, household as well as community needs for water in arid and semi-arid regions, where no other water sources are available or feasible, can be met. Groundwater is, by far, the most practicable choice for safe water supply. There is a wide range of low-cost groundwater extraction techniques available. In areas where groundwater is not available in adequate quantities, the next best available option for water supply is from surface water sources. Often, surface water sources are more contaminated than groundwater, which necessitates treatment of water and hence increases the costs of water supply projects. There are simple treatment methods available to provide minimal levels of treatment to produce safe water free of microbial contamination. Depending on the quality of raw water, a treatment method can be selected from a limited choice of low-cost treatment methods to achieve better water quality. Distribution of water from a central source to the community is also an important aspect of water supply. For rural communities, distribution can be done through stand posts and yard tap connections via a branched network of pipes.

1. Introduction

Water is an indispensable natural resource for the survival and well being of human kind. It is also essential for production of food, energy that contributes to the economic and industrial development of a society. Safe and reliable supply of water is therefore essential for individual welfare and for community development. The first and foremost consequence of lack of safe water for community consumption is diseases. Infectious diseases, affected by the availability or the lack of protected water supply systems, may take the following forms:

- Infections spread through water supplies (water-borne diseases such as typhoid, cholera, gastroenteritis).
- Infections transmitted through living carriers found in water bodies (water-based diseases such as schistosomiasis, which is through an aquatic snail that burrows through skin).
- Infections spread by insects that depend on water (water-related diseases such as malaria, yellow fever spread through mosquitoes).
- Infections due to the lack of sufficient water for personal hygiene (water-washed diseases such as scabies, trachoma).

World Health Organization (WHO) estimates that as much as 80% of all diseases in the world is associated with water. Available evidences indicate that most of the health benefits from safe water are attainable at service levels of 30–40 liters per capita per day. Hence, the role of organized water supply in the prevention of water-borne diseases and in the promotion of public health can be well appreciated. It has been established that this role is best fulfilled when every house in a given community is connected to the public water supply system. But for most developing countries, this ideal is still unattainable due to financial and other constraints. According to the Human

Development Report of United Nations Development Programme (UNDP), as of 1996, more than 31% of the population in developing countries are yet to have access to safe water and more than three-fourths of this population lives in the rural areas.

2. Need for Alternative Water Supply Systems

Traditionally, the people in rural areas have obtained water from unprotected ponds or tanks, wells, cisterns and sometimes streams and rivers. These water sources are frequented daily for collecting drinking and cooking water, washing clothes, bathing, livestock washing, etc. Mostly, these waters are unsafe for consumption due to contamination by fecal matters as well as by their heavy use. Consequently, the populations suffer from frequent epidemics. To supply potable water to all such communities by an ideal comprehensive water supply system that supplies water with a quality matching international standards, is not feasible. Water quality standards which have less bearing on health (such as hardness of water, or the presence of iron and manganese or chlorides normally included in any drinking water of quality standards) can possibly be relaxed unless this causes technical problems, and so long as the rural population finds the water acceptable. This will help to minimize financial constraints in providing safe drinking water. Considering the present situation of rural communities, where water from polluted sources is carried over long distances and used directly, any simple improvement in service and water quality could be expected to have a large beneficial impact on health. That is to say that what is needed is an effective short-term alternative to the ideal situation. Such an alternative to achieve an overall low-cost water supply scheme consists of:

- an appropriate water source;
- an appropriate water extraction method from the source;
- low-cost water treatment systems, wherever required;
- an appropriate water distribution system.

3. Water Sources

Basically, all sources of freshwater originate from rainfall, which is slightly acidic due to dissolution of carbon dioxide in the atmosphere. In the form of surface run-off, it will gather considerable amounts of organic and mineral matters, soil particles, microorganisms, etc. When the surface run-off infiltrates into subsoil it forms groundwater. As the groundwater level increases and rises above surface level due to varying land formations, it oozes out as springs. Perennial springs are the fountainheads of surface water bodies such as streams, rivers and lakes. The source of water has a major effect on water system design and hence costs. Water from different sources varies in quality and hence requires varying degrees of treatment. The process of choosing the most suitable source for water supply largely depends on the local conditions. A source of water supply can be identified at any of the above stages of water cycle, provided it can supply in sufficient quantities for most periods of the time in a year. Thus, water supply for rural communities can be organized with use of rainwater, groundwater, and, spring and surface water.

4. Rainwater based Rural Water Supply Systems

Rainwater can be considered as a source of water supply in regions where the pattern of rainfall permits its harvesting. Rainwater harvesting is possible in countries where rainfall is heavy, with long intervals with no rainfall. It can be a suitable source in arid and semi-arid areas where people live in scattered settlements and no other sources are available. Rainwater harvesting may serve well for household as well as community level supplies. It can also be used in conjunction with supply from other sources when their supplies are unpredictable in nature. Rainwater harvesting at household level is done by storage of rainwater through roof catchments and at community level by storage through ground catchments.

4.3. Roof Catchment and Storage

Rainwater with reasonable qualities can be collected using rooftop areas that can be stored to provide individual households in rural areas with adequate water supplies. By directing the rainfall on the roof areas to flow through simple collection gutter arrangements, water that would otherwise join surface run-off can be gainfully utilized. Roofs made of tiles, slates, corrugated iron/tin or asbestos sheets are more suitable. Thatched and lead sheet roofs are not suitable because of health hazards. A typical roof catchment and storage arrangement is shown in Figure 1.

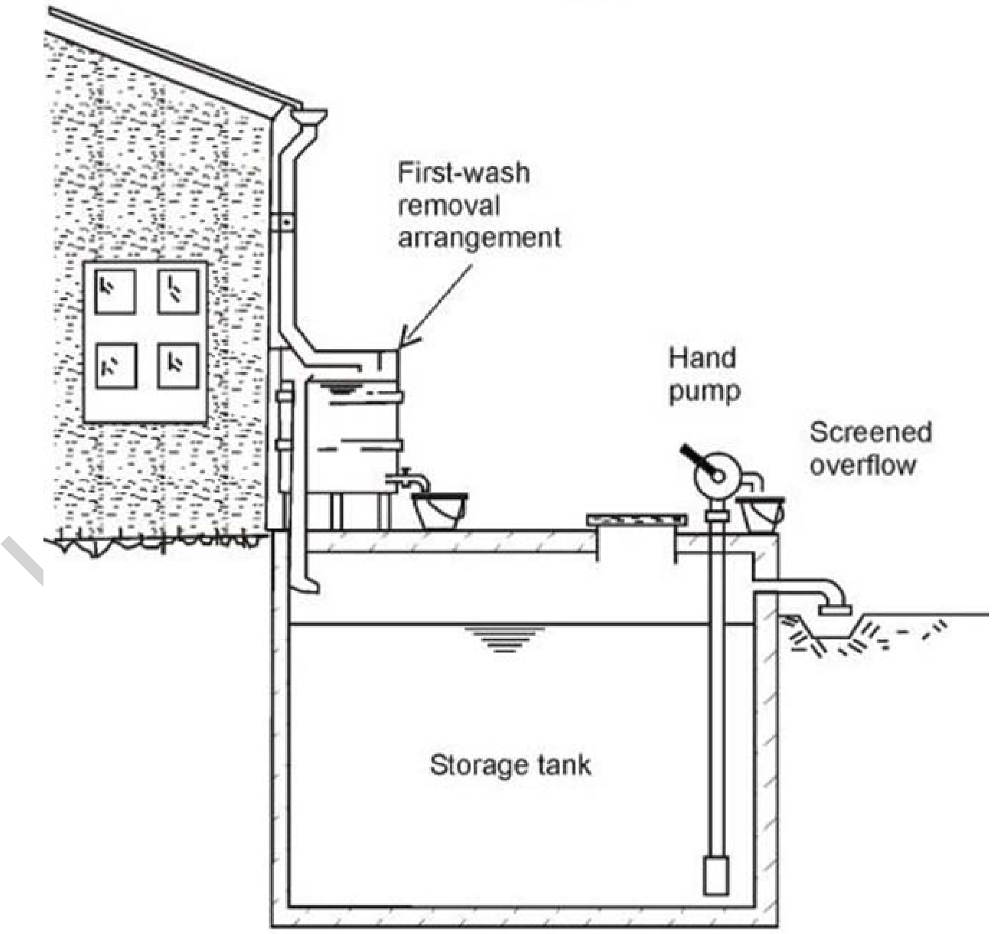

Figure 1. Roof catchment and storage

The roof guttering should slope evenly towards a downpipe to avoid sagging and hence pooling of water that may become a breeding place for mosquitoes. It may be helpful to arrange to divert the first flush of water from a roof collection, as it will wash with it the accumulated dust and impurities such as bird droppings, dead leaves, etc. The roof and guttering should be cleaned regularly. A wire mesh placed over the top of the downpipe would prevent it from becoming clogged with washed-off materials.

The amount of rainwater that can be harvested will depend on the area of the roof. The storage tank, however, has to be of sufficient capacity to take care of the longest dry season in a normal year. To take care of exceptionally dry years, another 50% surplus storage can be added. The minimum basic drinking and domestic water requirement of a family of six persons is 40 liters per day. Thus, for an average dry season of 3 months, the water storage required will be 3 × 30 × 40 × 1.5 = 5400 L.

4.4. Ground Catchment and Storage

By appropriately preparing a piece of surface on ground, it can be used as a catchment for harvesting rainwater for small communities. Part of the rainfall will serve to wet the ground or get lost due to evaporation or infiltration. A considerable reduction in such losses can be attained by making the catchment surface smooth and impervious using clay, tiles, asphalt or plastic sheets. Ground catchment involves land alterations for contouring, clearance of rocks and vegetation, simple soil compaction, preparation of surface (tiling, etc.) to reduce infiltration, construction of ditches along contours and construction of storage tanks. Arrangements in a ground catchment for rainwater harvesting are shown in Figure 2.

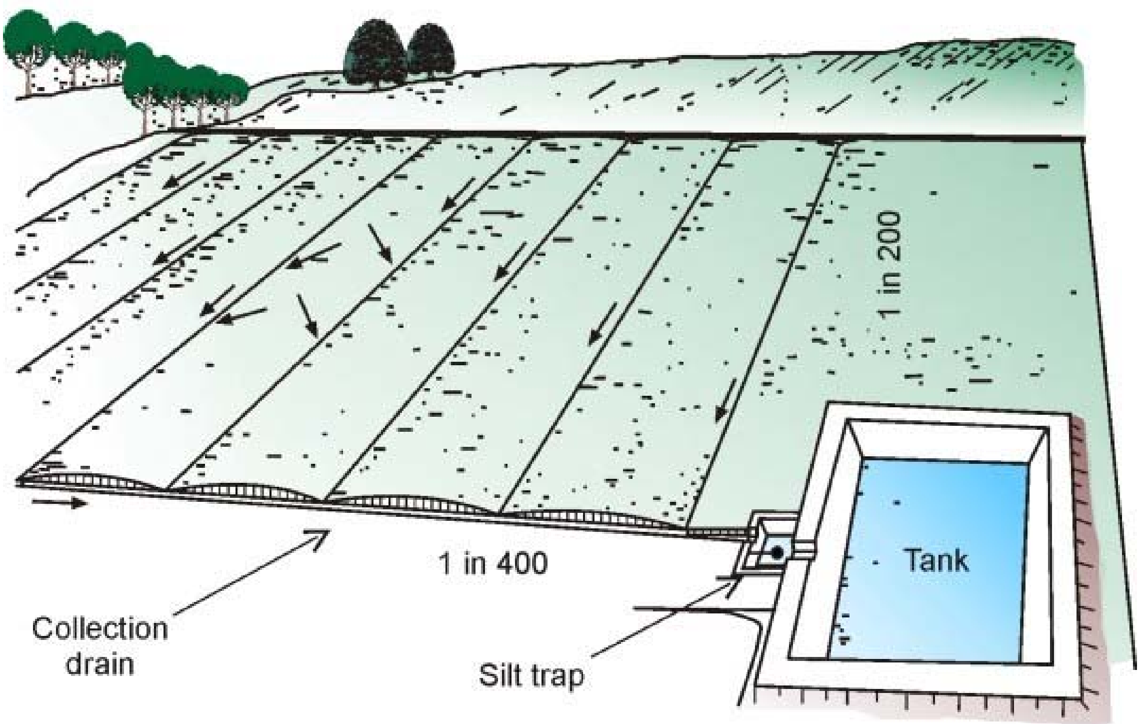

Figure 2. Ground catchment and storage

Storage facilities for ground catchment rainwater harvesting system can be either above-ground or below-ground. Whichever the type of storage, it should be protected from contamination by providing an adequate enclosure that prevents entry of pollutants. Dark storage conditions using a tight cover is required to prevent algal growth and mosquito breeding. There is a wide choice of materials of construction of storage tanks. Small storage containers can be built up of clay, wood or water-proofed bamboo frameworks. While large storage tanks can be constructed using stone or brick masonry works, ferro-cement or reinforced cement concrete works better.

Ground catchments for community water supply need proper management and maintenance. It may be necessary to provide fencing or hedging to protect against damage and contamination. Trees and shrubs can be planted around catchment to limit the entry of wind blown materials and dust into the catchment area.

5. Groundwater-based Water Supply Systems

Among the various sources of supply, groundwater is by far the most practicable choice. Groundwater can be extracted either from perennial springs or from open wells/tube wells, as they normally yield safe drinking water in rural areas. Exceptions are areas of fissured limestone where groundwater may be contaminated by intrusion of surface run-off. In areas where groundwater is available at moderate depths, constructing a number of wells fitted with hand operated pumps is by far the cheapest means of providing a good water supply.

5.2. Extraction Devices

Extraction of water from wells can be done with use of simple technologies that can be manually operated. Traditionally, there were number of water lifting devices that were being used in various parts of the world. These include, rope and bucket devices, counterpoise lifts and the Archimedes screws. With simple modifications, these traditional methods can be made more efficient in operation and at the same time protecting the source from contamination. Some of the modified versions of these simple water-lifting technologies are:

- sanitary rope and bucket system;
- bucket pumps;
- chain pumps;
- hand pumps.

5.2.1. Sanitary Rope and Bucket System

The sanitary rope and bucket systems are designed for open dug wells and are simple to maintain. The design was developed by WHO and is shown in Figure 3.

This simple arrangement apart from providing good service also protects the well from pollution. It contains a wooden roller fixed to the side walls of the well around which the rope winds.

One end of the rope is permanently fixed with the roller and the bucket tied to the other end. The top end of the bucket is attached with a weight to enable it to tilt when it touches the water surface in the well. As the roller is rotated, the bucket with water raises up to the stop hook level where it is tilted due to the hook and water is emptied on to a trough and flows out through a small pipe fitted to the trough to aid collection (Figure 3).

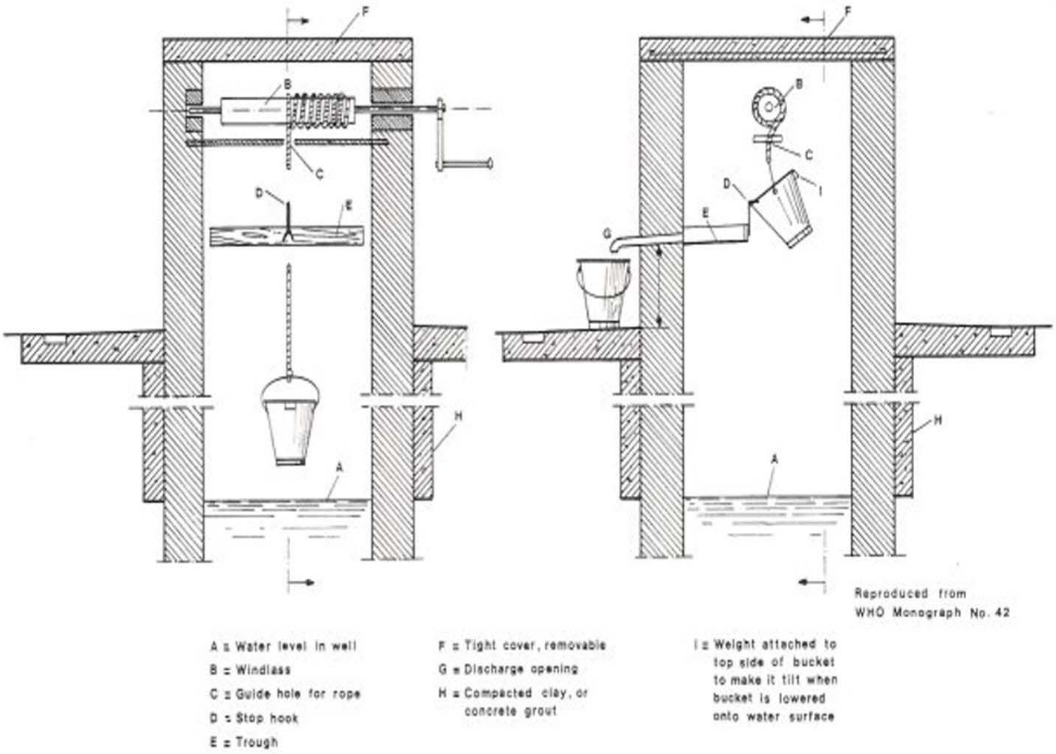

Figure 3. Sanitary rope and bucket system

The arrangements are simple and can be changed to fit the local conditions. The cover for the well should be removable to facilitate cleaning and maintenance of the well and the rope and bucket mechanism.

5.2.2. Bucket Pumps

The schematic arrangement of a bucket pump to extract water from open well is shown in Figure 4. In this arrangement, small buckets are attached to an endless chain. The chain is rotated on sprockets using a handle. As the buckets move down and dip into water, they get filled. Further rotation brings to the top and to run around the sprocket, as they empty into a collection trough attached with a pipe.

Depending on the local conditions and availability of materials, the buckets can be replaced with earthenware jars or wooden or metal boxes and the sprockets with bicycle wheels to run the endless chain.

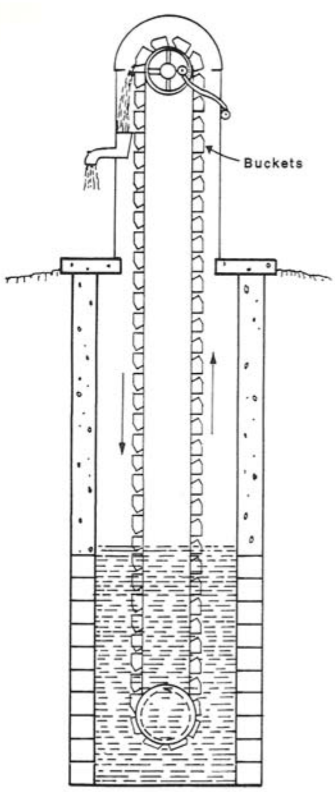

Figure 4. Bucket pump

-
-
-

Bibliography

IRC (1977). Hand pumps for use in drinking water supplies in developing countries. *Technical Paper Series #10*. WHO International Reference Center for Community Water Supply, The Hague, Netherlands. [Comprehensive information on description, operation and maintenance of various types of hand pumps.]

IRC (1978). Public stand posts for developing countries. *Bulletin Series #11.* WHO International Reference Center for Community Water Supply, The Hague, Netherlands. [Proceedings of an international expert meeting held in Accra, Ghana that describes technological, economic, socio-cultural and management aspects of public stand posts.]

IRC (1979). Public Stand Post Water Supplies—Design Manual. WHO International Reference Center for Community Water Supply, The Hague, Netherlands. [Details of planning and design aspects of water supplies using public stand posts.]

IRC (1981). Small community water supplies—echnology of small water supply systems in developing countries. International Reference Center for Community Water Supply and Sanitation, The Hague, Netherlands. [Comprehensive document detailing all technological aspects of small water supply systems for developing countries]

Letterman R. D. (1999). *Water Quality and Treatment: A Handbook of Community Water Supplies*, 5th edition, McGraw-Hill Inc., Washington DC. [Comprehensive overview of drinking water quality standards, public health issues and detailed information on different water treatment processes.

Schulz C. R., and Okun D. A. (1984) Surface water treatment for small communities in developing countries. Wiley Interscience, New York [An excellent overview on simple water treatment options in community water supplies. Also gives detailed design of water treatment plants suitable for Africa, Asia and South America, with a number of case studies.]

Thanh N. C., and Hettiaratchi J. P. A. (1982). *Surface Water Filtration for Rural Areas: Guidelines for Design, Construction, and Maintenance.* Environmental Sanitation Information Center, Bangkok, Thailand. [Provides design, construction and operation details of simple water filtration systems for rural areas of developing countries.]

Vigneswaran S., Tam D. M., and Visvanathan C. (1983). Water filtration technologies for developing countries. *Environmental Sanitation Review #12*. Environmental Sanitation Information Center, Bangkok, Thailand. [Comprehensive overview of history and development of water filtration technologies and details of appropriate low-cost filtration technologies for developing countries.]

Biographical Sketches

M. Sundaravadivel is an Environmental Engineer with the Central Pollution Control Board, Ministry of Environment and Forests, Government of India. He holds a Bachelors Degree in Civil Engineering and a Masters Degree in Environmental Engineering. He has been working in the field of environmental management and industrial pollution control since 1989, particularly in the area of environmental audit, waste minimization and cleaner production in agro-based industries. He has also been an engineering consultant for planning, design and development of wastewater collection and treatment systems for many large cities of India. Currently, he is engaged in research on 'environmental economic approaches for liquid and solid waste management in small and medium towns of developing countries' at the Graduate School of the Environment, Macquarie University, Sydney, Australia.

S. Vigneswaran is currently a Professor and Head of Environmental Engineering Group in Faculty of Engineering, University of Technology, Sydney, Australia. He has been working on water and wastewater research since 1976. He has published over 175 technical papers and authored two books (both through CRC press, USA). He has established research links with the leading laboratories in France, Korea, Thailand and the USA. Also, he has been involved in number of consulting activities in this field in Australia, Indonesia, France, Korea and Thailand through various national and international agencies. Presently, Dr. Vigneswaran is coordinating the university key research strengths on "water and waste management in small communities", one of the six key research centers funded by the university on competitive basis. His research in solid liquid separation processes in water and wastewater treatment namely filtration, adsorption is recognized internationally and widely referred.