Editorial

M. Asoka T. De Silva

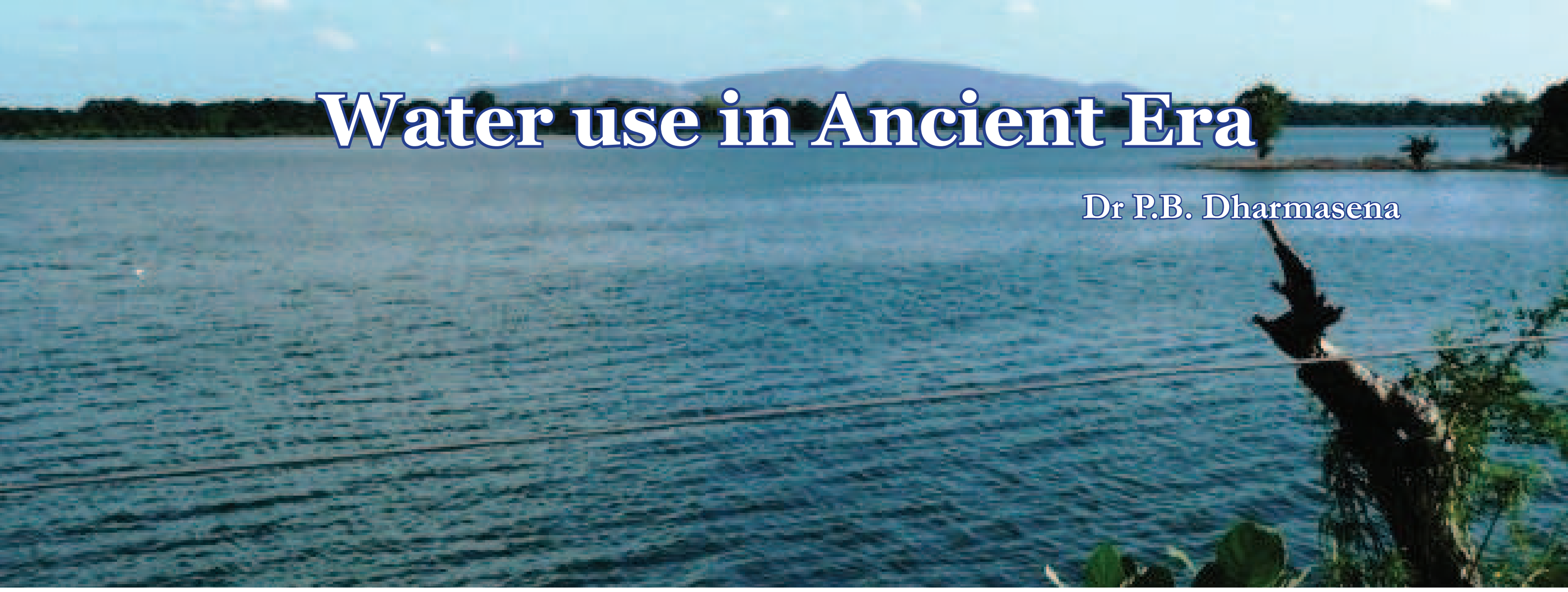
Water Security Now and Then

The articles presented in this edition cover the fields of water resources management, water-borne diseases, purification and bottling of water, and water resource management in ancient times.

Water no doubt has become a serious business of everyone with per capita availability of water decreasing over time. It has been said that *'Nations can be characterized by their water footprints and virtual water flows across their boundaries through the medium of international trade in commodities whose volumes change over times'*. All what this concept conveys is that a country can export food and other products with low water requirements for production, and in turn import food and other products that require more water for production, to ensure a balance in water security. With the expected shortfall of this resource due to population increase, the rising standards of living, and climate change consequences, water may not be an inalienable right of its consumers.

Let us look back at our systems of conservation and utilization of water in ancient times. It is well recognized that the prime policy of our ancient Monarchs was self-sufficiency and security of food, for which availability and security of water were prime considerations. The manner in which this great philosophy was put into action could be seen not only with the magnificent reservoirs, but also with the numerous small tank cascade systems, known locally even as late as the mid 20th Century, as ***Elangawa***. According to Dr M.U. A. Tennakoon, these were seen by villages as the stepwise suspended down-flow of water in a stream through canals from upper reaches, to a reservoir or river in lower reaches. According to Dr C.R. Panabokke, the District of Anuradhapura itself is said to have around 4000 small tanks of which about 3000 are still in working order. These fall into 280 cascade systems. But one of the most intriguing innovations of water management has been the "feed channel" known as the *Yoda-ela* that took off from a diversion anicut at Elahara on Amban Ganga (a tributary of the Mahaweli Ganga), to supplement the rain-fed Minneriya, Kaudulla and Kantale tanks 25 miles away. A topographical survey of 1898 of this channel which passed through a valley carved out between the Konduruwewa and Sudukanda mountain ranges had revealed many remarkable technological features that demonstrate the indomitable perseverance and intellectual capabilities of the ancient engineers in conserving water, while at the same time featuring structures which had resisted the impacts of flash floods from hill streams. Significantly in the 12th Century AD, King Parakramabahu I strengthened the headworks and the massive bund of this channel creating a sheet of water which was not only navigable, but also constituted the so-called "Second Sea of Parakrama", (referred to in *Chulawamsa* according to Mr D. L. O. Mendis), and now identified as the *Parakrama Sagara*. Incidentally, the so-called "Third Sea of Parakrama" (*Parakrama Samudraya*), was formed by the submergence of the Topawewa, Dumbutullawewa, Eramaduwewa and several other smaller tanks by another embankment 9 miles in length, that took water from a second diversion anicut of Amban Ganga at a village called Angamedilla.

Finally, we see how King Dhatusena in the 5th Century AD formed a huge lake by throwing back waters of Kala Oya with a massive embankment joining the Kalawewa and Balaluwewa, to take water to the "City Tanks" of Anuradhapura 54 miles away through the giant 40 foot wide canal the *Yoda Ela* or *Jaya-ganga*. These were the grandiose that guaranteed water security in a bygone era.



Water use in Ancient Era

Dr P.B. Dharmasena

We are proud of being Sri Lankans for many reasons, one of which that we had a glorious past of water resources management. Generally it is referred to as 'Hydraulic Civilization', said to be unique to Sri Lanka. The culture and lifestyle that evolved over the course of history during this era, were intricately tied to nature and the local landscapes. Interference of social, political and economic dimensions of neighbouring countries affected significantly the entire process of this evolution. The known history of Sri Lankan civilization records two main discontinuities due to external invasions that had taken place in 3,000 BC and 1,200 AD. This evolutionary process of the ancient hydraulic civilization of Sri Lanka, led to the formation of an administrative concept based on water movement, which is less known even to the Sri Lankans.

Evolution of a great civilization in the north central part of Sri Lanka was principally driven by the process of collecting water from rainfall for people and agriculture.It is somewhat a sacrifice made to form societies around small sources of water in a water scarce area and not moving to water rich areas found in the central highlands of the island. This is debatable and difficult to understand unless one deeply probes the interactive process of historic evolution. One might conclude that although the apparent problem in this area was water,the historic fate of the country nonetheless had enabled the development of a civilization through skillful management of the available water resource giving due regard to the national landscape features of the region.

Three main factors were responsible for the evolution of water resources management systems in the dry zone. They are the morphology of the landscape, the amount and distribution of the rainfall, and the nature of the substratum (in terms of pedology and geology).

This civilization evolved through millennia as a result of trying to find solutions to basic needs (food,water, and protection) and basic concerns of drought, floods, cyclones, epidemics, and invasions. It is difficult to trace especifically the timing of the special strategies adopted to mitigate such disasters or to what degree these approaches were indigenous or influenced by invading/ migrating foreigners.

Administrative Division	River Basin/s
1. Rakungiri (Ritigala)	Malwathu Oya
2. Upulwangiri (Dambulu)	Kala Oya
3. Kawasthalabha	Yan Oya
4. Neelagiri	Modaragan Aru
5. Kevesastha (Uththara)	20 river basins in the North
6. Chalaka (Thambapanni)	Mi Oya
7. Dhumakakaddeera	Deduru Oya
8. Mahagiri (Samanala)	Kelani, Kalu, Walawe, Mahaweli
9. Agni (South Eastern region)	Kumbukkan Oya, Menik Ganga, Kirindi Oya
10. Indra (Western region)	Maduru Oya, Mundeni Aru, Gal oya

Three main factors were responsible for the evolution of water resources management systems in the dry zone. They are the morphology of the landscape, the amount and distribution of the rainfall, and the nature of the substratum (in terms of pedology and geology).

The system of dry zone civilization might have first emerged around natural lakes (*vil*) and streams (*oya*) in varying sizes. Subsequently, human beings developed rainwater-harvesting methods to make living possible in other areas of the dry zone. Intrinsic networks of minor tanks and streams evolved with the formation of organized communities. More logical water-use systems evolved when farming societies developed. Culture, customs, agriculture, traditions, and all sorts of life styles evolved on this landscape through the influence of migration and invasion from the northern side of the island. These external factors might have accelerated or sometimes disrupted this evolutionary process of civilization. Two main types of supportive factors of the evolutionary process of this ancient civilization can be identified, namely, need based inventions and problem solving strategies. Basic needs were water, food, fibre, shelter, and protection. Problem-based driving forces of the evolutionary process of our human community include strategies to address natural disasters such as droughts, epidemics, floods, cyclones, and external invasions. Strategies adopted to face these challenges infiltrated to the social systems in the form of their lifestyle and as accepted facts in their traditions. The pre-historic evolution that took place in both Sri Lanka and India show great similarities due to continuous interaction between the two countries.

With the progressive acceleration of cognitive abilities and technology in the later pre-historic period (30,000–1,000 BC), the stage was set for a radical transformation in the interactive balance between man and environment. People steadily proceeded to dominate nature and transform it through collective effort. The advent of iron technology to Sri Lanka around 1,000 BC saw the ascendance of man. Excavations in the citadel of Anuradhapura have produced important evidence of iron technology, breeding of horses and cattle, and paddy cultivation, from cultural horizons nearly ten metres below the present ground surface. There is incidental evidence (faunal, sedimentological) for water management associated with paddy cultivation. Agriculture would undoubtedly have been dominated by paddy cultivation, which can only be intensified in the Sri Lanka dry zone, by the adoption of water management measures to control supplies from seasonal rainfall, streams, and perennial rivers.

The history and cultural heritage of Sri Lanka extends over a period of more than 5,000 years. The great King Ravana ruled the land of Lanka, which then covered also a part of India

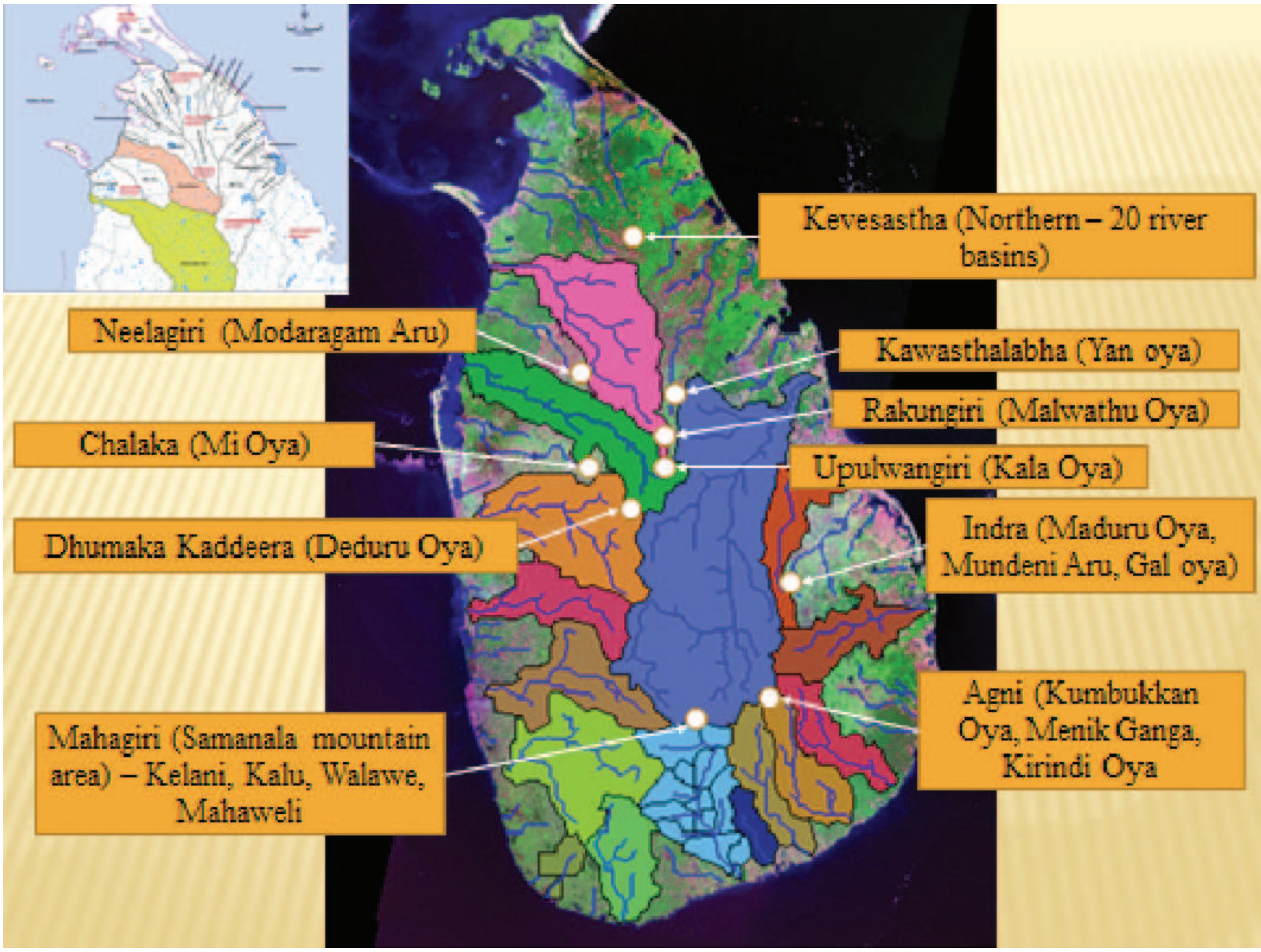


Figure 1 Ancient 10 administrative divisions based on water (3,000 BC)

around 3,000 BC, as mentioned in the popular Indian epic *'Ramayana'* (The Epic of Lord Rama) thought to have been written in 500 BC. The capital of the *Asura* King Ravana is said in the epic Ramayana to be situated in Anuradhapura. The invasion by Vijaya through the Princess Kuweni (Princess of land) occurred in 600 BC. The Princess Kuweni ruled the area 'Chalaka' (western region), which was one of the ten divisions at that time. Cities of these local kings were said to be on mountains and administrative zones had been based on river basins (Figure 1). These ten ancient administrative divisions and the pertinent river basins are given below.

Inadequacy of rainfall especially the poor distribution, higher evaporation, and transpiration rates with respect to precipitation, occurrence of droughts, and resulting agricultural failures led the ancient rulers to construct reservoirs of varying sizes to create a favourable environment for human life. The legendary story of civilization in Sri Lanka begins when the island was inhabited by people of the original tribes *Yakka, Raksa,* and *Naga*. These early people gradually developed systems of sedentary agriculture based on irrigation, and folklore maintains that the *Yakka* built some ancient irrigation tanks. By the time of the arrival of Vijaya around 500 BC, small scale irrigation systems were already operational.

The first extensive Sinhalese settlements were along rivers in the dry northern zone of the island. Because of early agricultural activity, primarily the cultivation of wet rice which was dependent on unreliable monsoon rains, the Sinhalese constructed canals, channels, water-storage tanks, and reservoirs to provide an elaborate irrigation system to counter the risks posed by periodic droughts. Such early engineering attempts reveal the brilliant understanding these ancient people had of hydraulic principles and trigonometry. The discovery of the principle of the valve tower, or valve pit (*bisokotuwa*), for regulating the escape of water is credited to Sinhalese ingenuity more than 2,000 years ago. By the first century AD, several large-scale irrigation works had been completed.

Water was managed by sharing between river basins through diversion or feeder canals to avoid excess or shortage. Some examples are the Dambulu Oya–Malwathu Oya diversion canal (860 AD), the Malwathu Oya–Kanadara Oya diversion canal (860 AD), and the Yoda Ela–Nachchduwa feeder canal (540 AD). Within some river basins, water flow had been also regulated through link canals to avoid imbalance of water. Examples are the feeder canals of Kalawewa–Thisawewa, YodhaEla (470 AD), Nachchaduwa–Nuwarawewa (290 AD), Balaluwewa–Siyambalangamuwa feeder canal (290 AD), and Basawakkulama–MahaVilachchiya (470 AD).

The western invasion of the country began with the Portuguese in 1505 followed by the Dutch in 1656 and subsequently by the British in 1798. The hydraulic civilization evolved as a network of streams and tanks in varying sizes spread

Chena (Shifting cultivation) evolved through interaction of man with the environment over the dry zone of Sri Lanka forming tank clusters referred to as tank cascade systems. Prof. Madduma Bandara defined it as ‘a connected series of tanks organized within micro-catchments of the dry zone landscape, storing, conveying and utilizing water from ephemeral rivulets’.

Medieval villages developed in association with small tank cascade systems in the dry zone of Sri Lanka. The centre of the village is the tank, and houses are grouped on one or both sides of the tank on the relatively higher elevation around the tank bund (embankment). The wells for domestic water tap the shallow phreatic groundwater table. The irrigable area below the tank bund is located along the main axis of the inland valley. Rain-fed upland crops are grown on the unirrigable slopes of the upland under a system of shifting or chena cultivation. Tank water is conserved with tree belts (*gas gommana* and *kattakaduwa*) around the tank, upstream bunds (*iswetiya*) and water holes (*godawala*) above the tank bed. This is known as the traditional tank-village system typical to Sri Lanka (Fig. 2).

After King Pandukabhaya (437–367 BC) founder of the Anuradhapura city, 122 kings reigned for 1477 years up to 1040 AD, until the kingdom was moved to Polonnnaruwa (80 km to the west). The establishment of forests and construction of ponds, reservoirs and irrigation systems were considered great meritorious acts in accordance with Buddhism, the faith of the leaders and of the large majority of the people.Sri Lanka history is full of achievements of kings who contributed to the development of water resources. Since the first century AD, kings such as Vasabha (67–111 AD), Mahasena (276–303 AD), Dhatusena (455–473 AD), Agbo II (575–608 AD), and Parakrambahu (1153–1186 AD) built numerous reservoirs and irrigation systems that fed vast expanses of paddy field in the dry zone. Construction and upkeep of these irrigation systems became massive undertakings. An indigenous expertise developed over the centuries, which appears to have been utilized by other countries of South Asia.

Indigenous agriculture is mostly based on in-born principles. People observed natural phenomena operating around them and studied how they could be manipulated for their needs. This included management of the forest by observing its anatomy, association of coexistent species, regeneration after fire, spatial variations and so on. The farming system, which includes chena (shifting cultivation), paddy and home garden cultivation, evolved through interaction of man with the environment

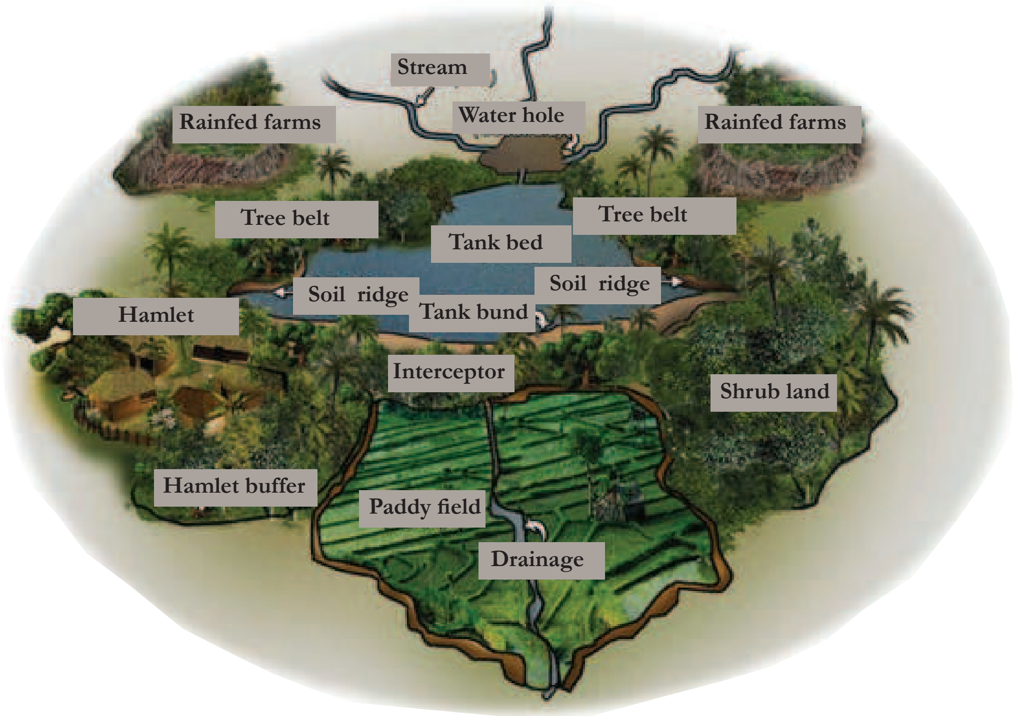


Figure 2 Features of an ancient village

and emerged in harmony with the natural landscape. Their experience and observations of rainfall pattern, wind, temperature, humidity, and landscape have been used to adjust their cultivation activities.

To reduce the risks of natural disasters they developed the tank-village community system that spread all over the dry zone. When they found that some of the disasters they faced in farming were beyond their control, they appealed to the support of religious, spiritual and cosmic influences. The most important fact they realized was that sustainability of their food sources was not possible without giving due respect to the resources used in farming. Paddy cultivation under rain-fed conditions or with supplementary irrigation water from reservoirs of varying sizes evolved to become a sustainable farming practice in the dry and intermediate zones of Sri Lanka. Basic problems faced by farmers were shortage of water in less rainy seasons, development of salinity in certain parts of the field, and damage from wild animals, pest, and diseases. The strategies that emerged to address these problems are not specific to a certain problem, but collective. The following strategies can be traced:

a. '*Bethma*' practice—It is a practice that temporarily redistributes plots of land among shareholders (paddy land owners) in part of the command area (territory) of a tank (reservoir) during drought periods.
b. '*Pangu*' method—The tank had to be maintained properly to avoid breaches, leaks, and excess seepage. Repair and desiltation of tanks and cleaning of canals during dry periods are shared tasks assigned to each farmer in proportion to land ownership.
c. '*Kekulama*'—Farmers advance the cultivation time using early seasonal rains whenever they feel that tanks would not get enough water to cultivate the command area. They have the experience that if September (2nd inter-monsoonal) rains are high, the total seasonal rainfall is not adequate to fill the tank.
d. '*Karahana*'—This is a water distribution device fixed across the canal made up of log with two weir-shape cuts. The size and bottom level of these cuts are made according to flow requirements of the two canals below, and the

Ancient communities were able to mitigate effects of floods, cyclones etc. by managing properly their landscape *karahana* is fixed by the village head ('*Gamarala*').

e. Village commons—micro-landscapes are utilized to reduce tank water losses, mitigate salinity effects, prevent tank sedimentation and so on.

The traditional communities addressed and continue to address all issues as a systematic and holistic concern rather than as an individual event. In addition to rain-fed farming (chena) area, the hamlet and paddy fields, they take care of the commons (their territory) surrounding them. It is vital to understand why these commons have been maintained purposefully. These communities had the wisdom to mitigate the effects of droughts, floods, cyclones, and epidemics by managing properly their natural landscape and conserving natural resources. Descriptions and importance of the commons are discussed below (Fig. 2).

Upstream tree belt ('*Gasgommana*') – This is the naturally grown vegetation in the upstream land strip above the tank bed, flooded only when spilling occurs from the reservoir. Large trees and climbers are found in this area. The *gasgommana* acts as a wind barrier reducing adverse effects of strong winds, minimizing evaporation from the tank, and lowering water temperature. It extends up to the bund (embankments) where roots of large trees create watery conditions suitable for breeding and living places for some fish species. This strip of trees demarcates the territory separating somewhat the human and wild animal domains.

Upstream meadow ('*Perahana*') - This meadow developed below the *gasgommana* filters out the sediment flowing from upstream chena lands. This helps in maintaining the tank capacity, reducing the threats of floods and droughts.

Upstream soil ridge ('*Iswetiya*' or '*potawetiya*') – This is an upstream bund constructed to prevent entering of eroded soil from upper land slopes.

Upstream water hole ('*Godawala*') – A man made water hole to trap sediment. It also provides water to wild animals.

Hamlet buffer ('*Tis-bambe*') – A fertile land strip found around the settlement area (*gangoda*) that is not privately owned. Tree species such as Madukalongifolia, mango, coconut are grown in a scattered manner. This area was mostly used for sanitary purposes and as the resting place of buffaloes. Buffaloes were used as a protection mechanism from wild animals and malaria.

Downstream drainage ('*Kiul-ela*') – This is the old natural stream utilized as the common drainage. Tree species, which could absorb salts, and a few rare species of small fish are also found in water holes along the *kiul-ela*. Most importantly it filters salts and iron polluted water, and improves the drainage condition of the paddy tract.

Interceptor ('*Kattakaduwa*') – This is a reserved area of land below the tank bund. Its micro-landscape consists of three micro-climatic environments: waterhole, wetland, and dry upland, which facilitate development of diverse vegetation. This land prevents soluble salt sand ferrous iron entering the paddy field. The waterhole referred to as '*yathuruwala*' minimizes bund seepage by raising the groundwater table. Villagers plant *Vetakeya* (Pandanuskaida) along the toe of the bund to strengthen the bund stability. It appears to be a village garden, where people utilize various parts of the vegetation for purposes such as fuel wood, medicine, timber, fencing materials, household and farm implements, food, fruits, and vegetables. Specifically they harvest raw materials from this vegetation for cottage industries.

Dr P.B. Dharmasena
Freelance Consultant (Agriculture, Hygrology, and Soil Science)
0777 613234

Water Resources of Sri Lanka:

Sources, Uses and Related Issues

Dr Sarath Abayawardana

Water Vision 2025

A society that values the sustainable use of its water to achieve the goal of an environment conducive to balanced social and economic development

(Lanka Jalani: Sri Lanka Water Partnership)

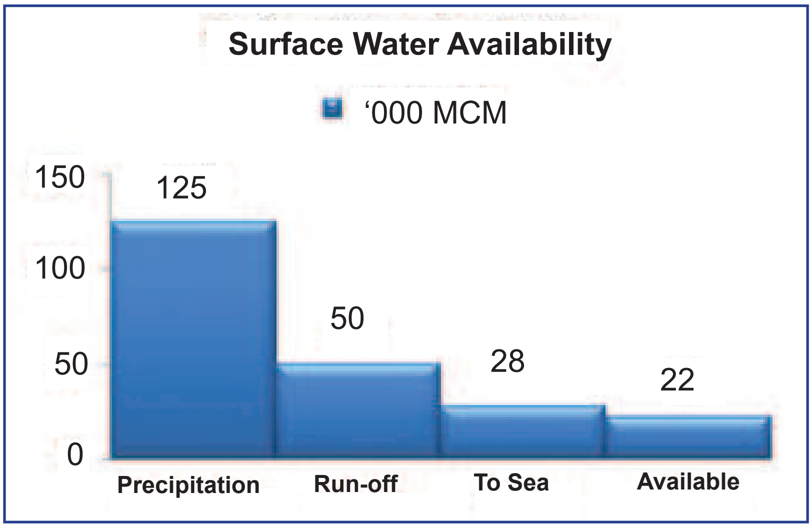
Sources of Water

Ours is an island relatively rich in water resources compared to most countries. We have an average rainfall of around 2000 mm a year. Our drier regions have 900. In contrast, India has 1100 mm, and Australia a mere 455 mm. With a population of 21 million and a land area of only 65,610 sq.km., at first glance Sri Lanka does not appear to be a country where water will be a critical resource in the development process in the coming decades. In reality, the spatial and seasonal variations, caused largely by the monsoon climate and the national geography, are very high and quality issues are significant, and if not addressed and properly managed will clearly result in major issues of scarcity. Added to physical scarcity, the concept of economic scarcity where water withdrawals are not possible due to economic or technological reasons aggravate the issue.

Surface Water Resources

Sri Lanka has 103 river basins radiating from the central mountains to the sea, with Mahaweli basin dominating in size (16% of island's total area or 10,327 sq.km.). Eighteen of the river basins have catchments of over 1,000 sq. km. Around 14 basins are of sizes ranging from 400-950 sq.km. while 45 basins are of size less than 100 sq.km. About 20 are classified as wet-zone rivers which carry about half the surface run-off. These river basins constitute about 90% of the land mass, and it is therefore clear that how we manage the land and water will have a very significant effect on our water resources.

The rainfall amounts to 125,000 MCM (Million Cubic Meters) of precipitation for a year, generating a run-off of 50,000 MCM. Roughly about 57% goes to the sea leaving an available surface water quantity of 22,000 MCM, quite in contrast to what King Maha Parakramabahu said – "not a drop of water should go to the sea, without being made use of". Some recharged ground water is also available estimated to be approximately 7800 MCM per annum.



Groundwater Resources

The available groundwater resources are in quantity much less than the surface water resources and are estimated to have a potential of 7,800 MCM. Based on geological formation characteristics the country can be divided into three hydro-geological formations, namely:

- The North Western and Northern Coastal belt comprising about 10% of the island and consisting of Miocene and quaternary sedimentary formations
- The Eastern, South Western and Western Coastal belts consisting of aquifers in inter granular rocks made up of dune sand, lagoon deposits and alluvial formations. These regions also cover about 10% of the land area.
- Crystalline basement complex, which consists of hard rocks fractured and weathered in some regions. These constitute the remaining 80% of the land area.

Both the quantity and quality issues limit the use of ground water. It is widely used for domestic, small scale irrigation, industrial and other uses. In most rural areas, domestic water supplies are obtained from small diameter shallow wells sitting in the overburden. Groundwater recharge is estimated to be between 7% and 30% of the precipitation. Large diameter shallow wells are being opened up extensively in the dry zone to irrigate upland crops. At present over 12,000 such wells have been constructed and are operational. There is a demand for around 8,000 more wells of this category mainly in the dry zone, although the long-term sustainability of such large numbers of wells has not been confirmed by scientific study.

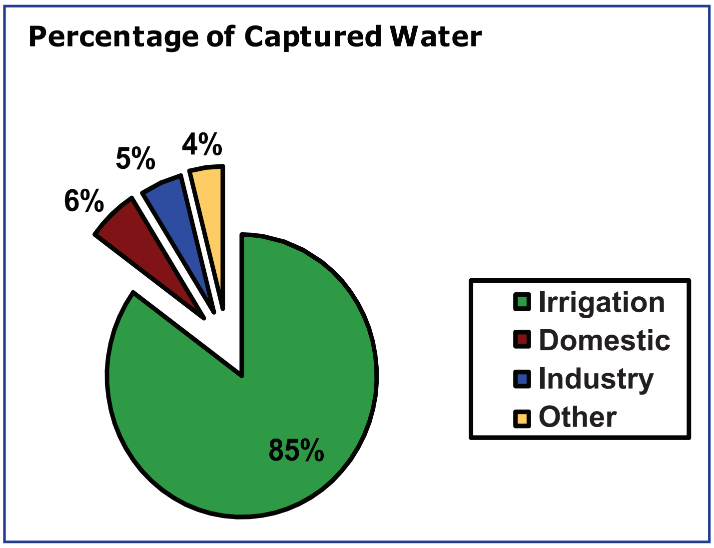
Deep bore holes are used at some locations to provide water for drinking purposes and for industries including the hotel industry. There is a concern of over-exploitation of the resource in certain parts of the country while cases of pollution of groundwater resources have been reported from certain main urban centres. Further studies have to be carried out to assess the safe groundwater abstraction rates in different areas.

Uses of Water

The main sector-wise users of water can be classified as Irrigation, Domestic and Industrial. A fourth classification as 'other' is frequently used which implies uses such as general services, other urban needs, tourism, aesthetic needs etc. Predominant user is

Some Sri Lankan water facts

Annual average rainfall:	1,900 mm
Wet zone	2,424 mm
Dry zone	1,450 mm
Annual rainfall	125,000 MCM
Annual replenishable water	45,000 MCM
Wet zone	22,000 MCM
Mahaweli basin	11,000 MCM
Dry zone – main rivers	5,500 MCM
Dry zone – other rivers	6,500 MCM
Annual GW recharge	7,800 MCM
Discharge to sea	28,000 MCM
Annual Water use	11,000 MCM
Irrigation – 85%	
Domestic - 6%	
Industry - 5%	
Other - 4%	
Land Area Total	65,600 sq.km.
Wet Zone	16,400 sq.km.
Dry zone	49,200 sq.km.



irrigation at around 85%, although estimates vary from 85 to 90%. This is also relative to a world average of 70%. Domestic and industrial users consume relatively low quantities at around 5% each. Use of water for generation of Energy is non-consumptive. However there is another big user, which we tend to ignore frequently – the Environment. The environment needs water to sustain itself which is an essential part of human settlements and their existence.

Water for Food

There are more than 260 major and medium irrigation schemes (serving over 80 hectares each) and nearly 18,000 minor irrigation schemes based on anicut systems and small tanks, of which around 12,000 are presently operational.

The area under irrigation facilities exceeds 560,000 ha which is approximately 27% of the total land area available for agriculture (~2 million ha). The plantation crops of Tea, Rubber and Coconut cover 40% while temporary and permanent crops other than Paddy account for more than 11%. Of Sri Lanka's rice production 80% comes from irrigated land, 21% from minor and 59% from major irrigation schemes.

Studies carried out at the International Water Management Institute (IWMI) show that if the current rate of irrigation efficiency continues in the future, several districts with major rice irrigated areas will have severe water scarcities by 2025. These districts will have to either reduce water demand by increasing irrigation efficiency or by importing food, or transport water from regions in the wet zone where water is abundant..

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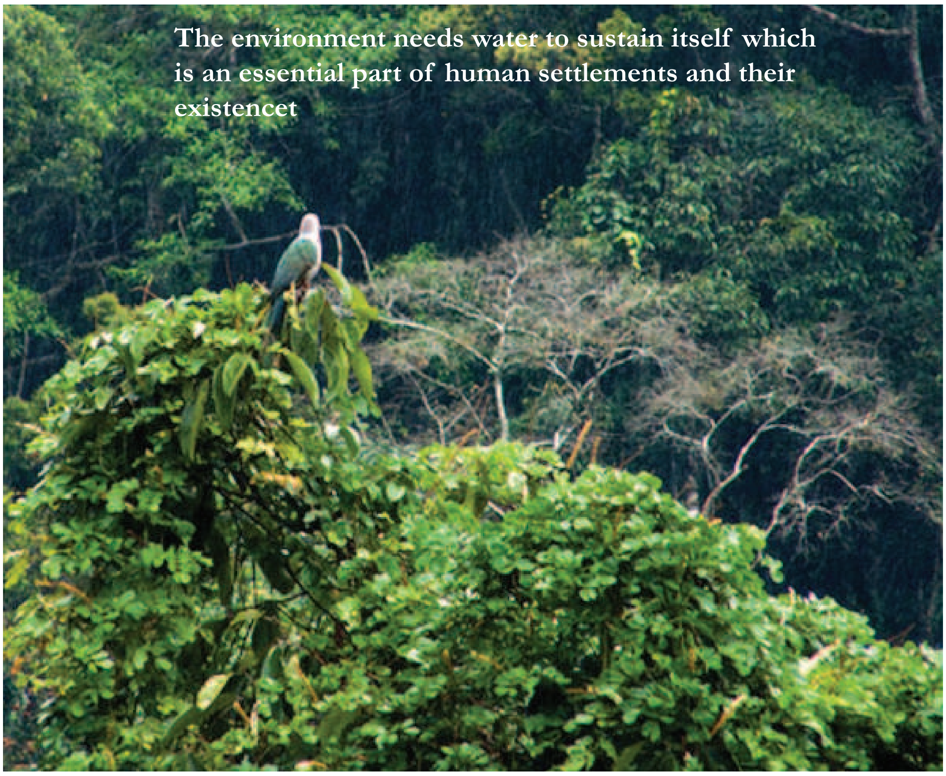

The environment needs water to sustain itself which is an essential part of human settlements and their existencet

A scenario with doubled irrigation efficiency however show that the total demand of most water-scarce districts can be reduced by 50 percent and these savings are adequate to meet future demands in the other two sectors. Whether the country has the financial and institutional capability to attain these high irrigation efficiencies is not clear. More importantly another issue to address is the cost/benefit factors of this approach versus importation of food in the long term.

In addition to what the large scale system managers apply, adoption of low-cost water technologies by smallholders also provide an opportunity for significant productivity improvements. Some examples of such technologies are: low-cost small electric and diesel pumps, manual devices such as treadle pumps, low-cost bucket and drip lines, sustainable land management practices such as low or zero-till agriculture, supplemental irrigation, groundwater recharge and water harvesting systems. Analyses suggest that access to water for agriculture through these technologies has a major potential to improve the livelihoods of the poorest farmers. IWMI's evaluation of the impacts of these technologies discovered enormous variety in type, scale, costs, benefits, adoption rates and management approaches, based on each socio-ecological context, making it difficult to work out economics that represent all of them. However, there are studies available of some of these technologies such as low cost drip irrigation and treadle pumps which demonstrate the general cost-benefits involved.

Water and Human Settlements

Sri Lanka has around 500 water supply schemes; of which 330 are urban, serving a population of 5.6M. 75% of the urban population is served with pipe borne water at a service level of 14hrs+, while around 20% has a 24h service level. Only about 15% of rural population is served with pipe borne water, ground water is used by about half of the rest. The rate of usage ranges from 20 l/day to 400 l/day at an average of 180-200 (effective use 100-115). In addition, over 4,000 very small rural piped water supply schemes and around 50 small town water supply schemes are managed

75% of the urban population is served with pipe borne water at a service level of 14hrs+, while around 20% has a 24h service level. Only about 15% of rural population is served with pipe borne water, ground water is used by about half of the rest.

Deep bore holes are used at some locations to provide water for drinking


Mini Hydro is a good solution for increasing energy demand

by Community Based Organizations (CBOs). Water needs of around 4 million people are met by these water supply schemes which use Village tanks, protected / unprotected shallow wells, Deep wells with hand pumps or motorized pumps, and rainwater as water sources.

It is estimated that the water demand will increase from about 3 MCM to about 4.6MCM in 2025. Capital cost of water supply is subsidized with the National Water Supply and Drainage Board charging less than the cost for the first 20 to 25 units, but overall there is better cost recovery now compared to the subsidies given a decade ago. There is scope for looking at more sustainable alternative scenarios with private sector/beneficiary participation.

The table below gives a summary of the water supply situation in 1999; unfortunately holistic current figures are not easily available.

Table 2: Water Supply Situation (1999) in Sri Lanka

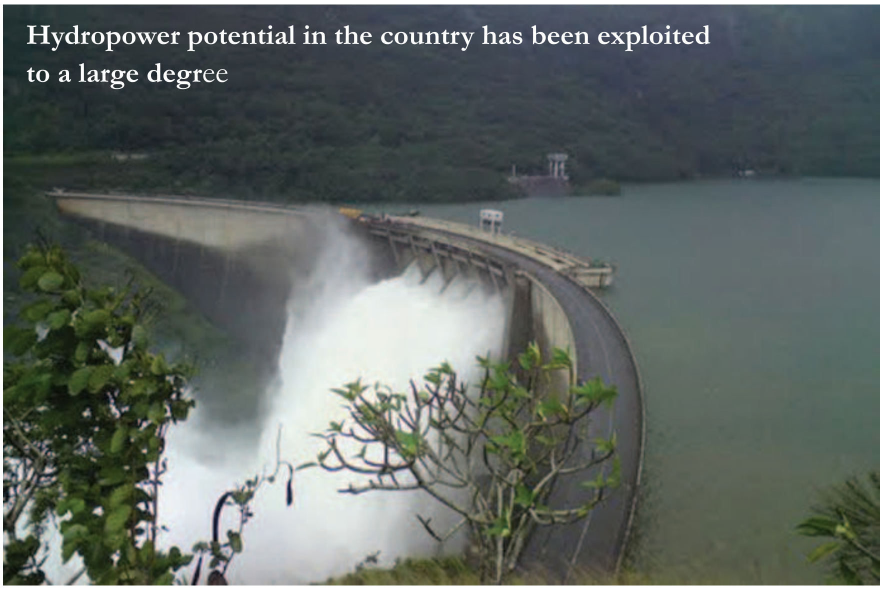
Description	Urban	Rural	Total
Population (1999) million	6.0	13.0	19.0
Piped water supply %	75	14	32
Tube wells %	10	11	11
Protected dug wells %	10	40	24
Other means %	5	35	33
Access to safe water	**90%**	**57%**	**67%**

Source: C.H. de Tissera 1999 Urbanisation and Water

The present level of sanitation in the country is low with at least 25% of the households lacking sanitary toilet facilities. Solid and liquid waste disposal too has become a serious problem in many towns.

Water and Energy

Water for hydropower is non-consumptive, but there are trade-offs arising from storage and timing issues impacting on downstream irrigation and drinking water needs. It is however significant to note here that the Mahaweli authority has an institutional mechanism for the allocation of its water optimally between these competing demands. Hydro power potential in the country has been exploited to a large degree and save for one or two schemes no major potential exists. Mini-hydro however is an aspect that is being looked into and is promoted for private sector participation. The generation capacity in the country has not kept pace with the rising demand, and the country has resorted to heavy fossil fuel based generation in the recent past reducing dependency on hydro power.



Hydropower potential in the country has been exploited to a large degree

While hydropower was almost 100% two decades back, it is currently in the region of 40% of the total requirement.

Water and Industry

Although the industrial sector does not consume a large quantity of water, its effluents have a significant effect on the quality of water bodies, negatively impacting on the quantum of available water resources. Regulations and incentives are available to control the discharge standards of industrial effluents, but implementation is ineffective. Industries even if willing, face serious resource issues in improving the situation.

Given that the urban sector is expected to rise from 23% to 60% by 2025, with parallel growth also in industrial activity, it is imperative that the government and the private sector address this issue with innovative approaches. Financing its own water supply and wastewater treatment facilities, or making capital contributions to installations that meet the needs of municipalities and large industry, is an investment close to home for the private sector. Such voluntary action by large corporations in its own interest and very much in the spirit of social responsibility, is frequently much better than waiting for external regulation to impose solutions. This also provides the additional social benefit of freeing public regulatory funds for dealing with other social issues.

Water for Nature

There are extensive marshes connected to rivers or seasonally flooded unconnected areas which serve to store large volumes of water helping to reduce flooding occurrences. They also provide the habitat for a variety of fauna and flora. There is a recent trend of filling up marshy areas for building purposes and this poses a threat as regards flooding in urban areas. Minor flooding has been an annual occurrence in certain parts of the western region while major floods have been experienced at periodic cycles.

Wetlands: There are around 41 wetland sites located in Sri Lanka, selected on the basis of uniqueness in the type of

Sri Lanka has greater bio-diversity per unit area thand any other country in Asia wetlands, occurrence of rare vulnerable or endangered plant or animal species, and whether the site regularly supported large number of water birds. Most of the important sites are coastal lagoons and mangrove swamps, many of which are threatened by conversion into housing sites, agricultural fields, and salt pans or are affected by drainage, siltation and pollution. The issues associated with management of wetlands include inadequacy of institutional mechanisms, legislative framework and a policy for conservation aspects.

Floodplains associated with rivers: Floodplains associated with rivers are best represented along the Mahaweli Ganga, Kala Oya and Modaragama Aru. The most extensive, the Mahaweli Ganga floodplain, occupies around 50,000 hectares of the eastern lowlands. Much of this floodplain has a natural or semi-natural vegetation cover consisting of a complex array of diverse habitats. These habitat types have intricate inter-relationships between biological and hydrological characteristics. Riverine marshes and adjacent floodplains form natural waterways that convey floodwaters from upstream to downstream locations.

Floodplains and wetlands, as well as deepwater habitats, store floodwater and release it slowly, thereby lowering flood peaks and protecting downstream areas. In urban areas subject to rapid storm water runoff and flooding, wetlands, particularly in the South Western coastal zone, provide especially valuable service as "sponges" able to absorb floodwaters for later slow release. As such they serve as highly effective buffers against property damage.

Biological diversity: Sri Lanka has greater bio-diversity per unit area than any other country in Asia. It is one of eleven areas in the tropics identified by the Committee on Research Priorities in Tropical Biology (NAS, 1980) as demanding special attention because of its high levels of biological diversity, endemism and its vulnerability to habitat destruction. Most of this unique diversity concentrates to an extraordinary degree in the humid South-Western lowlands and central mountains.

Sri Lanka, like other countries around the globe, is depleting many of these resources at rates that have made many of them essentially non-renewable. Among the most significant causes of this growing problem are: forest clearing and burning, shifting cultivation, wetland damming and filling, timber logging, coral reef destruction, cultivation of mono-cultures in crops, over harvesting of plants and animals, careless introduction of exotic species, indiscriminate use of pesticides, and pollution of our aquatic ecosystems.

Water Quality

Major areas to be addressed in relation to water pollution are:

- Water pollution from industrial facilities (Industrial emissions, leakage and atmospheric deposition)
- Sewage and urban runoff pollution
- Water pollution by agricultural activities
- Human settlements/ Domestic waste water

Problems arising from point sources are relatively easy to manage although high in cost, but problems caused by non point sources such as: soil erosion and sediment transport, eutrophication due to presence of high level of nutrients, heavy metal contamination, and toxic and hazardous chemicals contamination etc. are more difficult to manage. Frequently solution entails careful management at the causative level in the first instance.

Discharge of untreated urban waste water to surface water bodies can be a significant issue in the future as these surpass regenerative capacities of the natural water bodies in time to come with the expected increase of urbanisation. The costs of treating these are high, but of the approaches of managing these discharges and directing for specific purposes such as agriculture may prevent wholesale negative impacts on the water bodies.

The reinforced effluent regulations for industrial discharges have been in effect since 1990, but problems with domestic waste water and urban run-off remain to be resolved and efforts to improve this situation have lagged because of insufficient sewerage treatment systems and related infrastructure in urban areas.

Issues and Challenges

The equation of water related issues is common right across the globe. We have a finite resource on the one hand and an increasing demand on the other, with the populations and the economies growing all the while. A growing population not only means an increased demand for water but also has negative impacts on its availability (resulting from denudation of forests, salinisation etc.) coupled with detrimental effects on quality. Thus depleting the resource. It is not only populations and related economic activity; there is also another user - the environment. The theory that residual water is sufficient for the environment is not acceptable anymore; it must be treated as a user with a rightful demand if our activities are to be made sustainable. In addition, extreme events like floods and droughts appear to be increasing in intensity and the regional and seasonal variations are quite high too.

In short a number of factors impact our use pattern of water and its availability:

- Population Growth
- Economic Growth and Social Development
- Regional and Seasonal Variations
- Climate Change, Extreme Conditions and Disasters
- Increased Pollution / Degradation of Water Quality
- Governance and Institutional Complexity

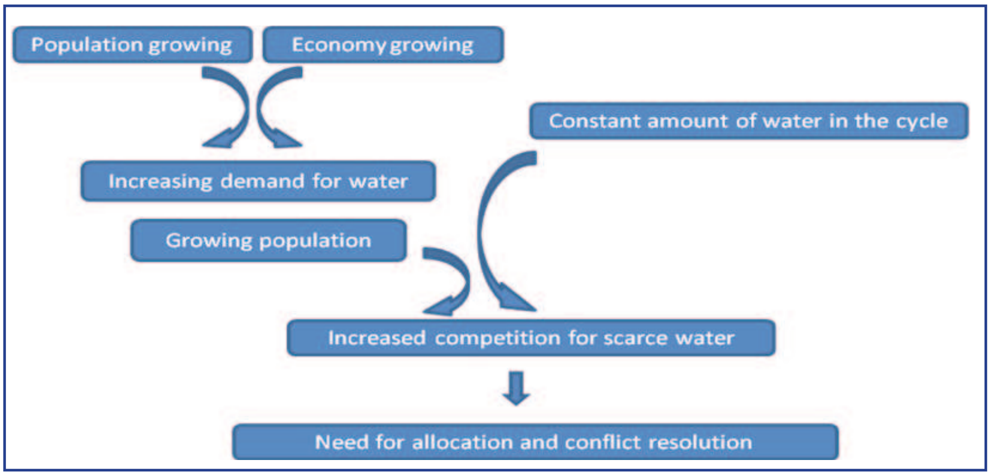
These represent the parameters of a very complex problem needing conscientious and sustained application of our energy if the issue is to be managed well in a sustainable manner.

The challenge, at least in the short to medium term, is not a lack of water in absolute terms, but how to utilize it more efficiently and equitably. In other words, it is a) how water can be made safe and accessible to the unserved for domestic use and sanitation; and b) how it can be used more productively to free the poor from poverty and food insecurity, whilst accommodating the rapidly increasing needs for urban and industrial sectors and without further penalizing the environment.

The Response Needed

With the all pervasive nature of the impacts of water in all aspects of our lives, planning or laying out specifics as a response to the big issues is not quite possible. As highlighted earlier it is a complex problem and a large number of stakeholders in different sectors have to play their role. However, as a stimulant for our thinking process, the key broad areas of action that we need to actively address are summarized below.

- Need for an overarching policy: Our principles, the framework within which



Source: Global Water Partnership

we need to operate and the guidelines need to be embodied in a policy document
- Building a recognition and awareness that water is a scarce resource, amongst the policy makers, professionals, students and the general public.
- Controlling the factors that affect availability and supply
    - Denudation of forests
    - Controlling the degradation and depletion of the resource (farming, industry, overexploitation, urbanization, waste water etc.)
- Improving water productivity in all spheres: agricultural, industrial and domestic
- Sustainable exploitation of GW resources - quantity and quality, avoiding over exploitation and pollution
- Management:
    - Take note of competing demands: people, food, industry, nature
    - Minimise fragmentation of responsibility, and unclear lines of demarcation of responsibility
    - Integrate: sectors, investments, supply, allocation, waste control, pollution and overexploitation
    - Include environmental water requirements in all water management strategies to avoid further degradation of ecosystem services
    - Create effective mitigation strategies to adapt to the impacts of climate change
- Governance
    - Participation of private sector and civil society
    - Policy development taking into account interdependencies between sub sectors: irrigation, hydro power, industry and domestic needs, and environmental consequences and eco-system conservation
    - Enact water resource legislation
    - Establish appropriate institutional structures
- Investment
    - Establish means for private sector investment, as it is unlikely that the full requirements in the coming years can be met with Government funding
    - Address principles of cost recovery - taking into account social equitability, particularly vulnerable groups
- Capacity Building
    - Development of a new generation of water professionals, who do not view water along short-term and narrow sectoral lines, but recognize its inter-sectoral complementarity
    - Investment in institutional strengthening at all levels and in R & D
    - Access to wider sources of knowledge
    - Develop a centralised knowledge base

In short, water scarcity is a real issue in Sri Lanka's case as well, and we need to carefully develop coping strategies. Strategies built around the hard elements of availability and quality alone are not enough. In fact more importantly, it is necessary to build strategies around the softer element of governance - our institutions, how we would manage inter-sectoral power plays, how we would manage scarcities arising from inequities and poverty etc. It is evident that we need to study and analyze these complex set of issues if we are to begin to understand the situation and take appropriate action, rather than just going on with the 'as we are' scenario? A large dose of political will coupled with professional capacity is what we require if we are to map out the right strategy before issues get out of hand compelling us to take 'damage control' measures. And who should do all this, whose business is water. Water is "Everybody's Business", and hence it the responsibility of all of us to act to ensure the wise use of water.

Dr Sarath Abayawardana
former Head,
Sri Lanka Program,
International Water Management Institute,
former Director, National Science Foundation
0773 165900

Waterborne Diseases

Dr Manjula Rathnabharathie

With its many uses water is the most precious global resource. Water is essential for life, but it can also spread illnesses when it is contaminated by disease causing organisms. Clean and safe water is a critical challenge which needs to be available sustainably to human health and life.

The term water born disease implies the direct spread of diseases caused by microbial pathogens or chemical contamination of water. Waterborne diseases are numerous which results from consuming water contaminated with microbial pathogens or chemical compounds.

Global Prevalence of Waterborne Diseases

Water-borne disease outbreaks have the potential to be rather large and of mixed etiology, but the actual disease burden is difficult to approximate, and most likely underestimated due to the diversity of occurrence and lack of proper surveillance systems. Current extreme weather conditions associated with global climate change events affects water availability, quality, access as well as contamination, posing a threat to human populations.

There are various forms and manifestations of waterborne diseases, but the universal form of disease occurrence is diarrheoa. WHO had estimated in their disease burden studies that there are about 2.2 million people inclusive of 1.9 million children dying of diarrhoeal diseases each year. This is almost equivalent to 20 jumbo jets crashing every day. According to WHO World Health Report 2001, it was estimated that in addition to this 2 million deaths, waterborne diseases had accounted for 59.7 million DALLYs lost due to diarrheoa. Out of this SEARO [South East Asia Region] accounted for the highest lost.

Types of water borne diseases

Water borne diseases can be categorized as infectious and non-infectious diseases. Infectious diseases are mainly due to the contamination of water sources by the microbial pathogens, and noninfectious type includes diseases occurring due to water contamination by chemicals, radioactive substance etc. Usually the waterborne diseases resultant from infectious origin are short term, and consequences are easily visible. The hardest part is that when water is contaminated with noninfectious substances, the resultant effects are long term and difficult to trace as well as to control.

Where are we?

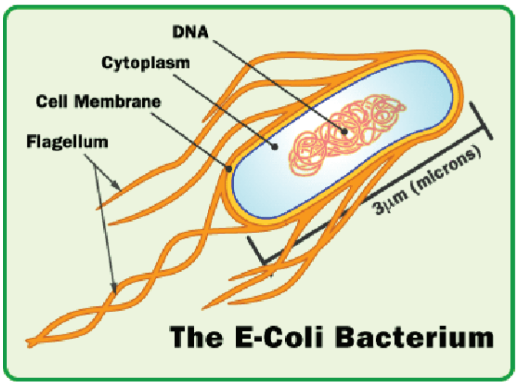
In comparison to other countries in the region, Sri Lanka reports

Table 1 Major pathogens causing waterborne diseases

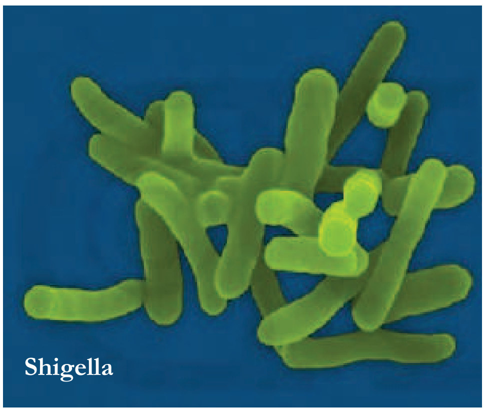
Pathogenic organism		Major Targeted organs	Major symptoms
Bacteria	E.coli	Intestines	Diarrhoea
	Shigella	Intestines	Diarrhoea/dysentery
	V.cholera*	Intestines	Diarrhoea
	Salmonella typhi Salmonella paratyphi	Intestines	Fever , abdominal pain, constipation, sometimes diarrhoea
Virus	Hepatitis A	Liver	Jaundice
	Hepatitis E	Liver	Jaundice
	Rota virus	Intestines	Diarrhoea
	Polio virus**	Nervous system	Paralysis of limbs
Parasites	E. histolytica	Intestines	Diarrhoea
	Giardia	Intestines	Diarrhoea
	Hook worm	Intestines	Weakness/anaemia
	Other intestinal worms	Intestines	Weakness/anaemia , sometimes diarrhoea

*not reported since 2003 from Sri Lanka

** not reported since 1993 from Sri Lanka



The E-Coli Bacterium

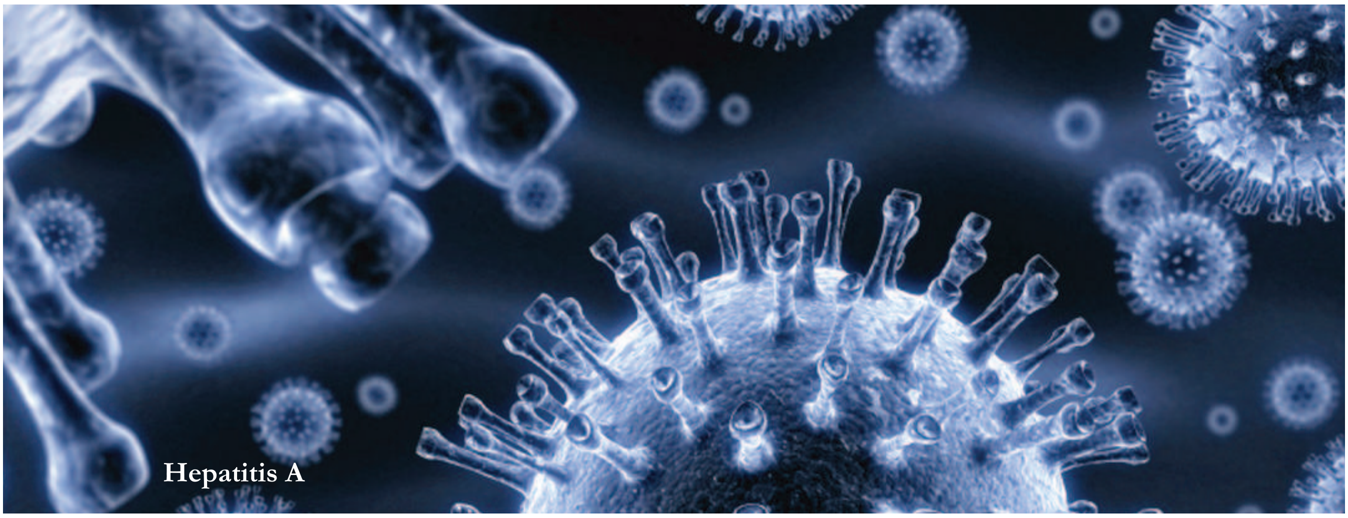

Shigella

lower rates of waterborne diseases, even though it is the commonest contributory factor for under five year malnutrition. Waterborne diseases occur mostly as either acute watery diarrhoea or dysentery. During the last 20 years, admission to government hospitals due to diarrhoeal [waterborne] diseases has been fluctuating between 676.1 and 961.3 cases per 100,000 populations.

During 2001, the cases treated in government hospitals for diarrhoeal diseases per 100,000 populations increased to 857.3 from 742.8 in 2000, and these have been ranked as the sixth leading cause of hospitalization. The last Demographic and Health Survey [2007] findings have shown that under five year old diarrhoeal incidences was 3.5% in Sri Lanka. Apart from acute watery diarrhea, dysentery, hepatitis and typhoid are the commonest waterborne diseases seen in Sri Lanka.

Noninfectious waterborne diseases

Contamination of water sources by chemical compounds is a growing threat worldwide. There are certain countries where naturally occurring chemicals such as arsenic and fluoride occurring in ground water, but in most circumstances this had become a manmade threat. Contamination of water bodies by agricultural runoffs and industrial waste water is a growing public health problem where no proper data source is available, as well as weak regulations which would need a broader consideration especially in developing countries.


Hepatitis A


Rota virus


Hook worms

Challenges ahead

Waterborne diseases are resultant from exposure to waterborne infectious pathogens, or from exposure to waterborne chemicals and radiological contaminants. Waterborne diseases are essentially environmental health related issues as these are related with polluted water, sanitation and hygiene and these three are intertwined determinants of waterborne disease occurrence. Unlimited human intervention in terms of rapid urbanization and industrialization invariably cause population growth, poor sanitary facilities, poverty, and poor planning, in polluting water sources by infectious microbial pathogens and toxic chemicals. In addition to the above mentioned scenario, political and economic instability in developing countries together with unawareness of the issues among general population and weak regulations, has aggravated the problem.

Increasing economic disparity among populations and making poorer segments more vulnerable for water related diseases, together with different socio cultural practices specific for different ethnic groups in relation to water consumption, are problems faced by different countries. Greater the poverty level, the lesser is the chance for better sanitation and safe water.

In majority of developing countries the real burden of waterborne associated diseases are grossly nderestimated due to poor surveillance facilities.

According to WHO and UNICEF figures, in 2000 nearly 2.5 billion people in the world lacked acceptable means of sanitation, while 1.2 billion people were estimated to lack safe drinking water. Hence these water deficient populations in the world are at risk of getting ill due to the unsafe water as well as public health issues of monitoring, surveillance and prevention.

Waterborne Diseases

Attributing water pollution to a disease is more often neglected, while evidence is collected of further cases to occur which can result in much higher level of disease due to persistence or recurrent contamination. Mercury poisoning in Minimata is a classic example of delayed attribution of water related cause for a disease.

Ground water becoming gradually unfit for consumption due to seepage of microorganisms from polluted surface waters of rivers, is a future challenging issue that should be considered by all stake holders in the field.

Noninfectious waterborne diseases increasingly recognized as a public health problem, requires different type and complex surveillance methods from the traditional systems based on microbiological agents.

Accurate and timely diagnosis of waterborne disease by the medical community is critically important since the medical, public health, and economic consequences of a waterborne disease outbreak are high, particularly if public drinking water is contaminated. Water consumers are frequently unaware of the potential health risks associated with exposure to waterborne contaminants, and often consult medical practitioners who are unfamiliar with water contamination from biological, chemical or radiological hazards and their subsequent impact on human health.

Increased population, mobility and travel to different countries have globalized the risk of spreading waterborne disease outbreaks, and furthermore it is difficult to keep these illness confined to few geographical areas. Priority consideration should be given for waterborne diseases in the context of the impact of climate change including the effects of global warming on water habitats, and adverse weather events threatening the security of water supplies as well as the emergence and re-emergence of waterborne diseases, which are the invariable results of adverse climatic conditions.

Preservation of water quality and prevention of water-related disease is a complicated task requiring a

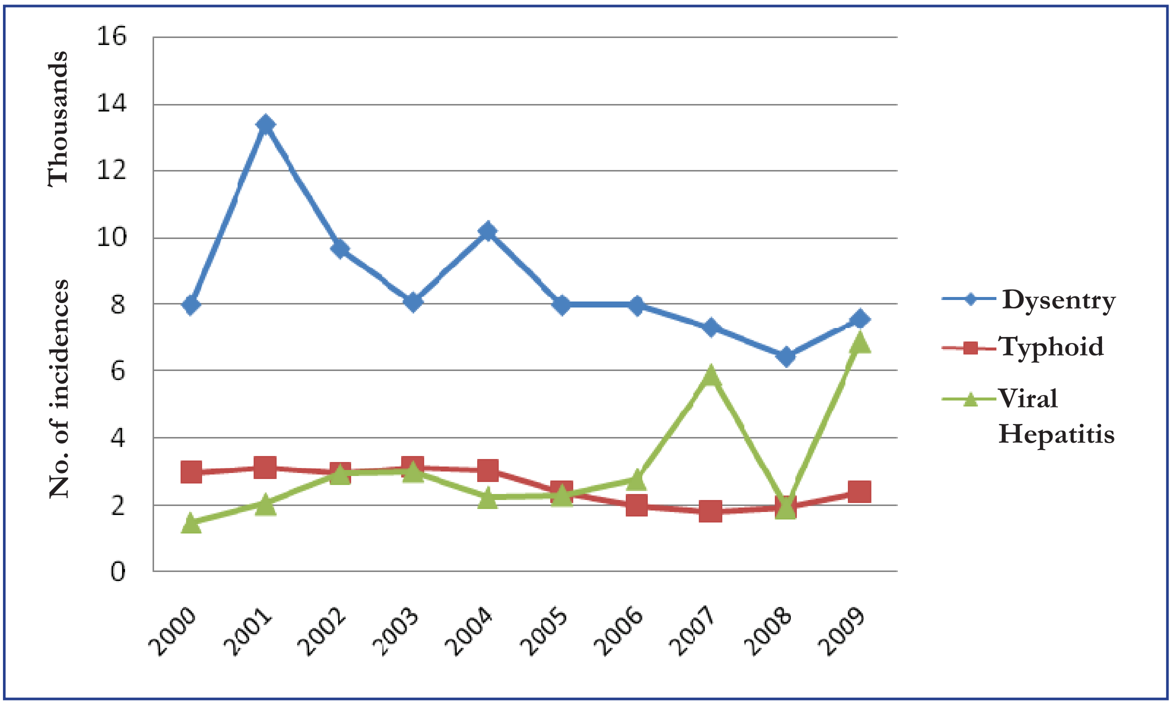


Figure 1 Incidence of dysentery, typhoid and vital hepatitis for the past 10 years in Sri Lanka - Data Source ; Epidemiology Unit

Table 2 Main chemicals causing noninfectious waterborne diseases

Chemical	Organ affected	Major health effect
Arsenic	Skin, lung	Hyperpigmentation, skin cancers, lung cancer, Acute toxicity causes gastrointestinal symptoms
Fluoride	Bones	Bone fractures, bone pain and tenderness,
Nitrates	Circulatory system	Methaemoglobinaemia [blue baby syndrome]
Cadmium	Lungs, Kidney	Acute inhalation may be life threatening Chronic exposure cause kidney damage[chronic renal failure]
Mercury	Lung, nervous system, kidney	Lung damage Chronic poisoning cause Personality disorders, restlessness, anxiety, sleep disturbances Kidney damage[chronic renal failure]
Lead	Nervous system Intestines	Headache, irritability, abdominal pain Chronic exposure may cause memory deterioration, prolong reaction time

coordinated effort from many diverse disciplines including physicians, healthcare providers, epidemiologists, microbiologists, academic scientists, local and national health authorities, public and environmental health specialists, water engineers and water purveyors. Since majority of waterborne disease-related issues occur in developing countries where the highest population burden persist, capability of the governments of these countries to bare the cost needed for future preventive strategies, and also the political backup needed to coordinate globally, are international issues that should be addressed.

Waterborne diseases are the major killers of under five year old children worldwide. It is also attributed to child morbidity in terms of malnutrition in alarming rates. Waterborne diseases as a result of water pollution, are a threat to the global environmental sustainability. Both of these are Millennium Development Goals, the achievements of which are still not within sight.

Prevention of waterborne diseases and health effects of water contamination are vital to global health due to the fact that safe drinking water is a required cornerstone for public health. As this article has highlighted there are numerous barriers and obstacles to be overcome to provide quality safe drinking water, as well as identifying water related diseases at early stages. Higher female literacy rate, free education and free health sciences with developed low cost transport systems are prime factors for the country to rise against waterborne diseases.

Dr Manjula Rathnabharathie
Registrar[Community Medicine]
Epidemiology Unit, Colombo
0718 111960

Geographic Information System

Dr H.K. Kadupitiya

Almost every phenomenon we come across varies with space where it belongs to. Often we need to evaluate geographically varied data as a single variable, or analysis integrating several variables, and extract information and visualize them in an illustrative form to make important decisions. Geographic Information System (GIS) which is capable of dealing with spatial information is one versatile tool specially designed for this purpose.

Geographic information system

Geographic information system (GIS) is a system designed to capture, store, manipulate, analyze, manage, and present all types of geographical data. The acronym GIS is sometimes used for Geographical Information Science or Geospatial Information Studies which refer to the academic discipline, or career of working with geographic information systems. In the simplest terms, GIS is the merging of cartography, statistical analysis and database technology. Remote sensing or satellite imagery which was derived from spectroscopy provides additional data into GIS. Other attribute data can also be incorporated into GIS with the help of a portable instrument called Global Positioning System (GPS) which can communicate with a specific satellite network and record geographic location of the data considered.

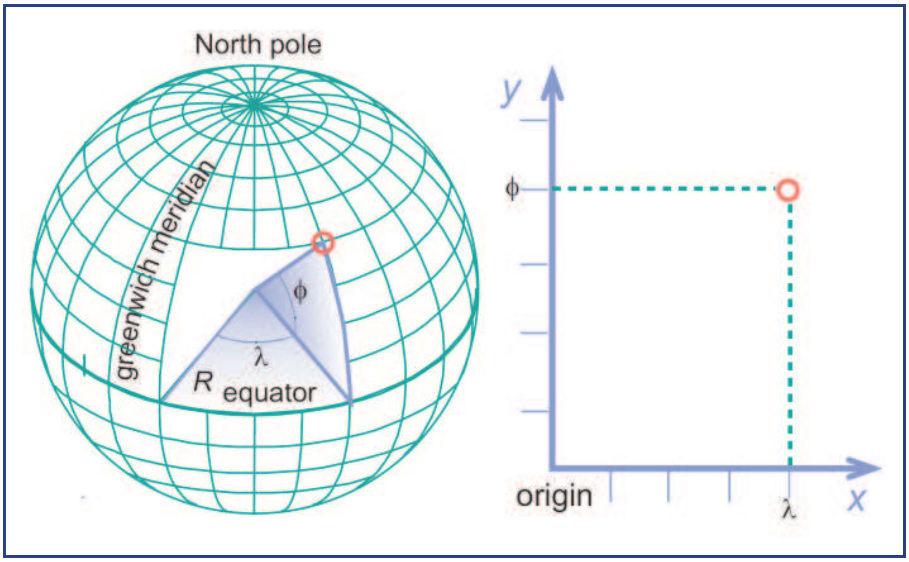


Figure 1 Two 2D spatial referencing approaches through geographic coordinates (x, y)

How GIS represent the real world

GIS allow mapping any location on the earth in a two dimension plain relative to the Greenwich line and the equator to represent parts of the surface of the Earth on a flat paper map or on a computer screen. The curved horizontal reference surface must be mapped onto the 2D mapping plane.

In GIS, homogenous collections of geographic objects such as roads, towns, buildings, districts and others are organized into data themes or layers. Many types of software exist offering a rich collection of tools for processing geographic data layers to derive many relations between the geographic elements they contain. In a Geographical Information System we can represent real world and objects in formats that can be stored, handled and displayed in a computer. The two most commonly used formats for representing the real world objects are vector and raster data models.
In a vector model the real world can be represented and modelled as homogeneous and discrete features. Features can be points, lines or polygons. For example a city or a well can be represented as a point, roads or rivers as a line and lakes a polygon. For all of these three types of features an attribute code is created in the database to identify the object. Points are stored as discrete coordinate's pair, lines as sets of coordinates and polygons in the same way as a line having the same beginning and ending coordinates. The Database can be furthermore filled with other characteristics and attributes concerning the objects.

In the raster model the real world is represented in continuity as a gridded matrix. Spatial and attribute data are stored together for each cell in the grid. Each cell in the raster model corresponds to a location. The location of each grid cell is defined by row and column coordinates with associated attribute value. Selection of either the vector or the raster format depends on the application and on the aim of the user. Vector format is used to represent entities with clear boundaries such as buildings, roads, districts etc. Raster format is used to represent occurrences which are continuous in nature such as temperature, altitude, pollution. A GIS can simultaneously manage both types of data formats. Furthermore, there are many tools available for conversion from the one format to the other, which have been improved in the last few years.

Advantages of GIS
Geographic Information Systems have a number of advantages compared to the traditional mapping systems. Traditional maps are static, with fixed projection, scale and coordinate systems; it is difficult to combine multiple map sheets, and overlays are restricted. They are difficult to copy and share between many users.

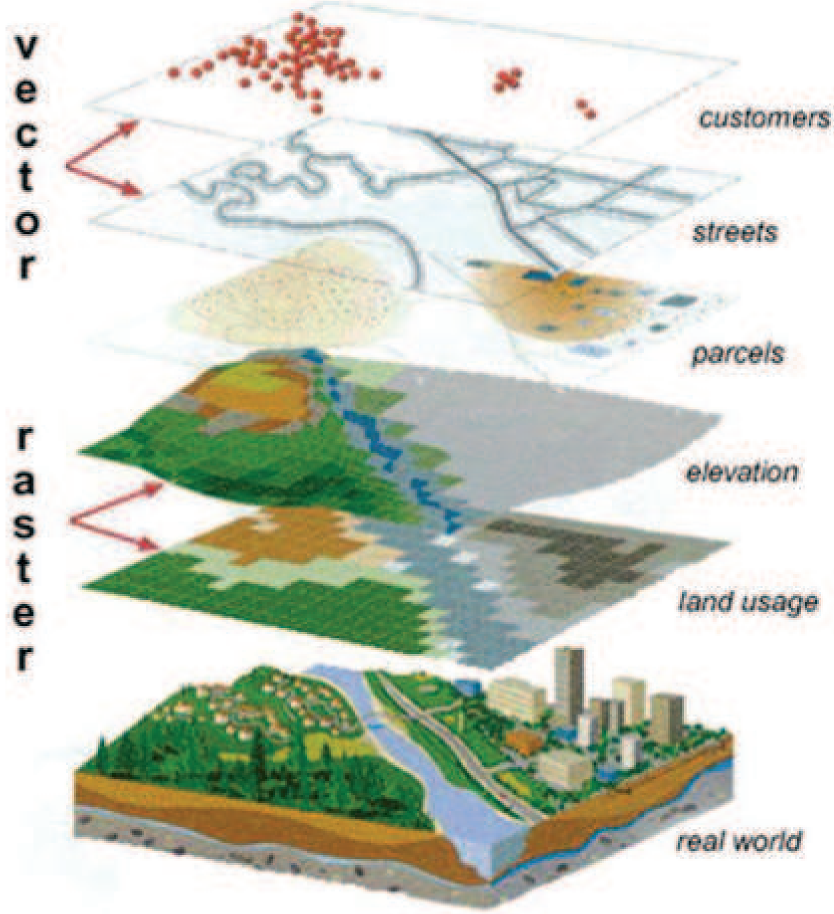


Figure 2 Layer representation model of real world in GIS

It is easy to update data in GIS, by analysing spatial data and converting to new scales or coordinate systems. Maps can be easily combined and overlaid, offering various types of information. Densities, quantities and patterns of a specific item in a specific area can be easily derived and terrain models can be generated to aid 3D visualization.
Data is digitally organized in a GIS, so the user has no need to store numerous maps, datasheets and charts. There is no need for manual checks, the search is done automatically by computers, making work easier, cost effective and less time consuming. Interactive maps provide information about how geographical features interact with each other. Users can point to a location and retrieve information, perform editing and analysis, discover new relationships between objects and phenomena. Access to geographic information is easy and there is a range of tools which give the capability to interact with the map contents.

Remote Sensing
Remote sensing is the acquisition of information about an object or phenomenon without making physical contact with the object. In modern usage, the term generally refers to the use of aerial sensor technologies from space (satellite or aircraft) to observe by means of propagated electromagnetic radiation reflected or emitted by the object or surface. Reflected sunlight (visible & infrared region) is the most common source of radiation measured by sensors mounted on satellite or aircraft.

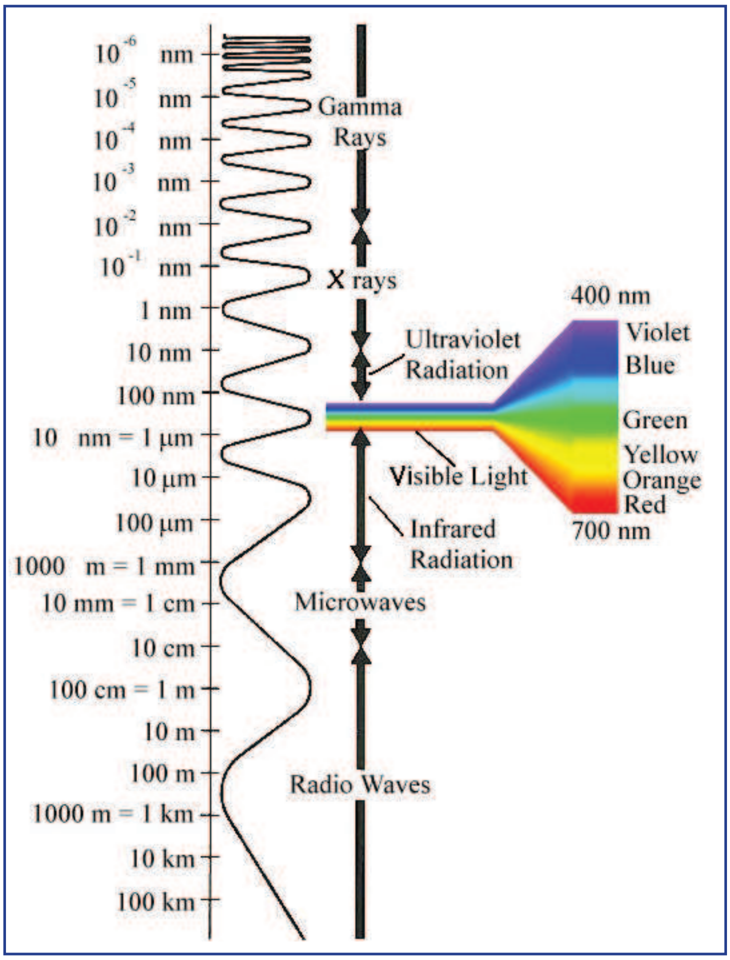


Figure 3 Electromagnetic Spectrum

Satellite images are the most widely used data that are compatible with raster GIS. Satellite image consistent with grid containing reflectance values belong to visible and infrared (IR) region, and contains bands that belong to Blue, Green, Red and IR bands for each grid cell recorded in a format that can be combined with GIS.

The quality of remote sensing data consists of its spatial, spectral, radiometric and temporal resolutions.

Spatial resolution
The size of a pixel that is recorded in a raster image – typically pixels may correspond to square areas ranging in side length from 1 to 1,000 metres.

Spectral resolution
The wavelength width of the different frequency bands recorded – usually, this is related to the number of frequency bands recorded by the platform. Current Landsat

Figure 4 Portable GPS receiver

collection is that of seven bands, including several in the infra-red spectrum, ranging from a spectral resolution of 0.07 to 2.1 µm. The Hyperion sensor on Earth Observing-1 resolves 220 bands from 0.4 to 2.5 µm, with a spectral resolution of 0.10 to 0.11 µm per band.

Radiometric resolution

This is the number of different intensities of radiation the sensor is able to distinguish. Typically, this ranges from 8 to 14 bits, corresponding to 256 levels of the gray scale and up to 16,384 intensities or "shades" of colour, in each band. It also depends on the instrument noise.

Temporal resolution

The frequency of flyovers by the satellite or plane, and is only relevant in time-series studies or those requiring an averaged or mosaic image as in deforest monitoring. This was first used by the intelligence community where repeated coverage revealed changes in infrastructure, the deployment of units or the modification/ introduction of equipment. Cloud cover over a given area or object makes it necessary to repeat the collection of said location.

Global Positioning system

Global Positioning System satellites transmit signals to equipment on the ground. GPS receivers passively receive satellite signals; they do not transmit. GPS receivers require an unobstructed view of the sky, so they are used only outdoors and they often do not perform well within forested areas or near tall buildings. GPS operations depend on a very accurate time reference, which is provided by atomic clocks. Each GPS satellite has atomic clocks on board.

Each GPS satellite transmits data that indicates location and the current time. All GPS satellites synchronize operations so that these repeating signals are transmitted at the same instant. The signals, moving at the speed of light, arrive at a GPS receiver at slightly different times because some satellites are farther away than others. The distance to the GPS satellites can be determined by estimating the amount of time it takes for their signals to reach the receiver. When the receiver estimates the distance

The signals, moving at the speed of light, arrive at a GPS receiver at slightly different times because some satellites are farther away than others.

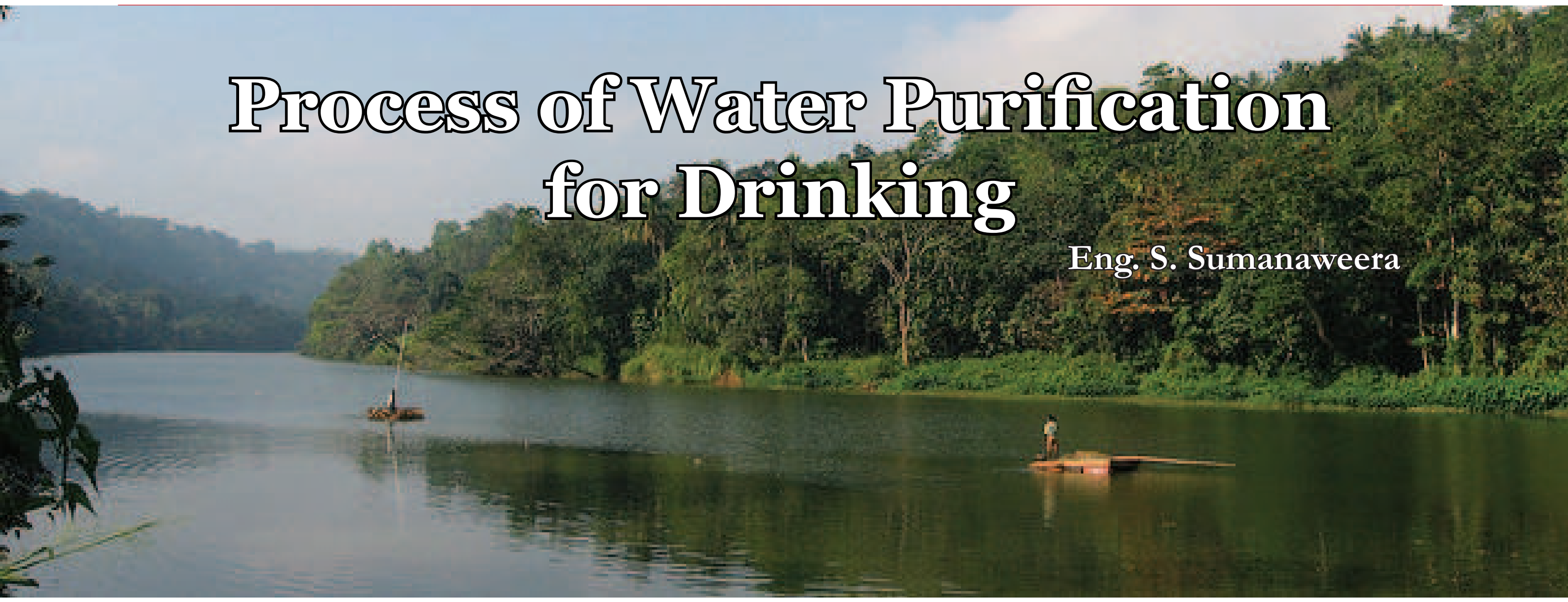
to at least four GPS satellites, it can calculate its position in three dimensions.

There are at least 24 operational GPS satellites at all times. The satellites, operated by the U.S. Air Force, orbit with a period of 12 hours. Ground stations are used to precisely track each satellite's orbit.

Determining Position

A GPS receiver "knows" the location of the satellites, because that information is included in satellite transmissions. By estimating how far away a satellite is, the receiver also "knows" it is located somewhere on the surface of an imaginary sphere centered at the satellite. It then determines the sizes of several spheres, one for each satellite. The receiver is located where these spheres intersect. The coordinates of required location can be incorporated in to GIS.

Dr H.K. Kadupitiya
Research Officer
Natural Resources Management Centre
Department of Agriculture
0718 619661



Process of Water Purification for Drinking

Eng. S. Sumanaweera

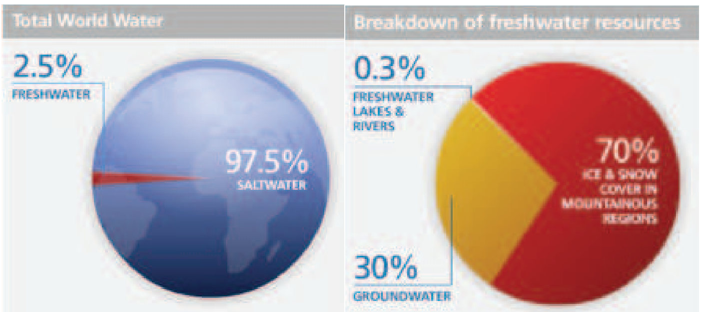


Figure 1 World's fresh water availability

Fresh Water availability for Drinking

Seven billion people of the world have only 2.5% of world's water for consumption as the balance 97.5% is salt water. This fresh water source will not grow against the expected population of 9.3 billion in 2050. World usable fresh water resources remain at 200,000 km^3.

Water cycle is a natural dynamic activity powered by solar energy. It creates rainfall by evaporation of water mainly from the sea. The rainfall feeds the rivers and the ground water flow, thus completing the water cycle back to the sea. Global warming accelerates the water cycle. The outcome will be more rains and stronger runoff. The world population is increasing at the rate of 2 persons per second. So can one imagine the impact of human activity on the "Water Cycle"? The main impact on "Water Cycle" by population growth will be the green house gas emissions and deforestation. Deforestation rate of Sri Lanka stands between 1 to 1.4% per year.

How safe is the water around us for drinking?

People drink water from rivers and wells. With the growing population and the depletion of the forest cover, the catchments allow the rain water to flow faster to the sea through the rivers. This makes the water muddy due to aggravated soil erosion and creates flash floods giving less time for absorption of water into the ground. Garbage dumping and sewage discharging into streams by the communities makes the water more polluted. Pollution discharges from industries make the situation worse.

Figure 2 Global warming makes glaciers melt

How can we make the water safe for drinking?

We can make water safer for drinking by managing the man made pollution. People need to be determined not to discharge waste matter into streams, and to grow more trees. Forests make the water to flow slower, and also help to reduce carbon dioxide in the air thus helping to mitigate global warming by acting as a carbon sink. Alternatively if we do not pollute water it will remain pure. Microbial pathogens present in drinking water are more hazardous than the chemical pollution effects with respect to consumer health.

How natural water can be unsafe for drinking?

Even natural water sources can contain dissolved ionic contents originating from underground soil and rocks. Although we claim that these are pollutants, some ionic contents in low concentrations are of nutritional value to the consumer. Considering all these aspects, health based quality standards have been developed for drinking water. We follow the Sri Lanka Standard 614 for drinking water quality. In case this standard is not detailed enough the drinking water quality guidelines published by the World Health Organization are followed.

The common parameters that are checked in drinking water are Electrical Conductivity, Turbidity, Color, pH (a measure of acid base condition), Iron, Manganese, Chloride, Sulphate, Nitrate, Nitrite, Fluoride, Hardness and Alkalinity. The first four parameters mentioned are physical parameters and the rest are chemical parameters. Additionally there are parameters termed bacteriological quality parameters. These parameters are indicators of the spread of water borne diseases. Water treatment processes are needed to treat water to bring the quality of water to acceptable levels meeting the quality standards mentioned above.

According to one definition, "Water Treatment" shall produce water that is palatable with no unpleasant taste, safe with no pathogens or harmful chemicals, clear with no suspended solids, aesthetic to drink being colourless and odourless, reasonably soft with easy to use soap, non corrosive to the pipes and fittings and low in organic content with no support to biological growth within pipes and fittings.

Water Treatment processes

There are different types of water treatment processes to suit different raw water qualities. For example river water is often muddy while well water may be relatively clear but can be of hard taste ("Kivula") and may

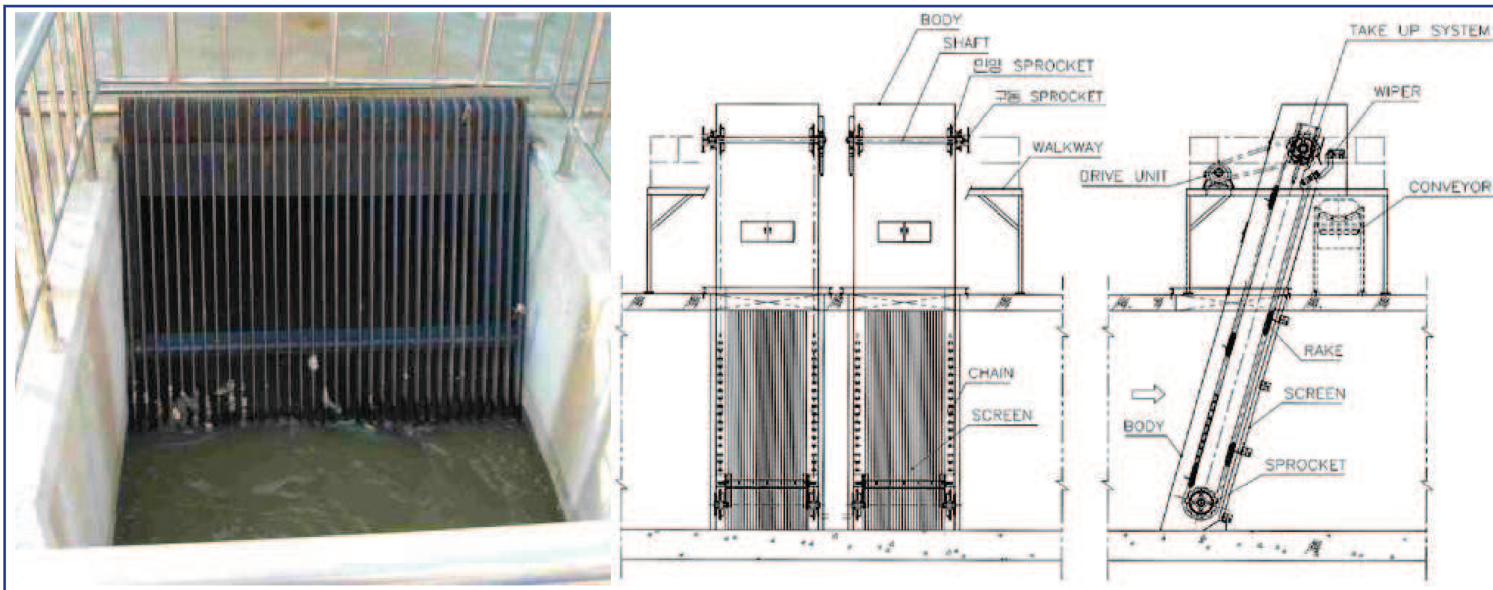


Figure 3 Intake screens

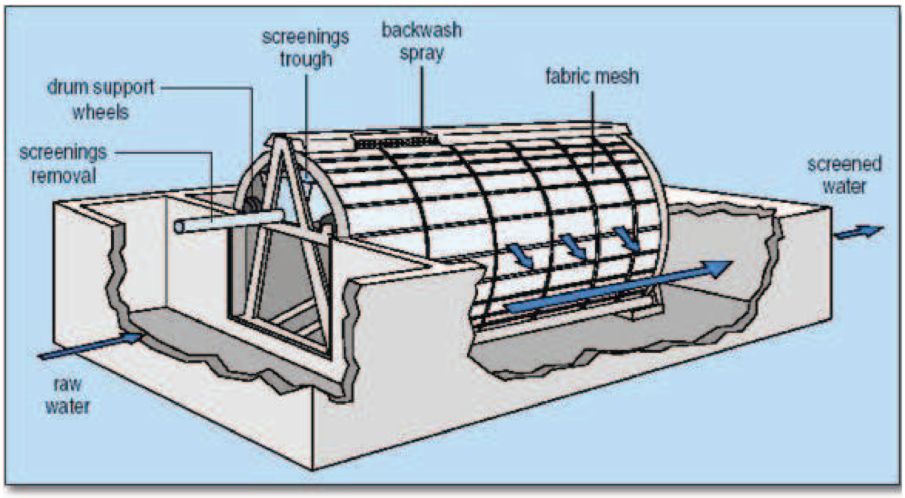


Figure 4 Microstrainer for algae removal

Figure 5 Cascade aerator made by NWSDB

contain ions such as Fluoride, iron and manganese in excess which may not be visible. Therefore complete laboratory testing is essential to select a process for treatment of a particular raw water.

Impurities in raw water can be in forms such as suspended matter, colloidal matter and dissolved matter. Suspended matter could be removed by settling. But removal of colloidal and dissolved matter is not so easy. Colloidal matter is in continuous movement within the water body which is referred to as "Brownian Movement".

The dissolved matter consists of salts and other ionic and organic compounds. The dissolved matter cannot be seen by the naked eye. They may be toxic for human beings if consumed beyond the recommended values. Further there are living organisms in natural water such as microbial pathogens and algae.

Water Treatment processes can vary from simple boiling or sand filtration to advanced treatment such as ozonation, membrane filtration or adsorption by activated carbon. The objective of water treatment is the removal of impurities from water, thus making it acceptable and safe for drinking.

Screening

Screening is the first step in water treatment process. Raw water is screened through a set of coarse screens of around 100 mm size to remove suspended solids such as litter, branches etc. Then a fine screen will be used to remove fine floating solids. Further there could be a micro strainer to remove any algae present is raw water.

Aeration

Ground water extracted through borehole wells could be lacking dissolved oxygen. Dissolved oxygen in water is very important to make the content oxidized, thus reducing the corrosiveness. Aeration helps to remove dissolved gases in water such as Carbon Dioxide, Hydrogen Sulphide and dissolved Volatile Organic Compounds (VOC). Aeration also helps to remove dissolved iron from water by an oxidation process. There are different types of aerators used in practice such as Spray aerator and Cascade aerator.

Coagulation

After the screening step many suspended particles could be removed by a sedimentation step. However colloidal matter is difficult to remove by sedimentation alone. Therefore a coagulation and flocculation step is necessary. Colloidal particles are very small, less than 10 micrometers in size with very low settling velocities. Most of these particles are negatively charged. So they never aggregate due to the repelling action caused by these negative charges. Coagulation is the removal of the electrical charge on these colloidal particles, thus destabilizing them and making them capable of aggregation or flocculation. Coagulation is done by using a coagulant aid such as Aluminium Sulphate which is generally termed “Alum”.

Coagulation facilitates flocculation of the particles. Destabilized or neutralized particles attach each other due to lack of an electrical charge forming micro flocs, and then such attached particles form more dense groups named flocs. These flocs are easy to settle. Coagulation takes place in a water treatment process within a unit termed flash mixer or rapid mixer. Flash mixers can be mechanical or hydraulic.

Flocculation

Flocculation is the process of neutralized particles getting together to form flocs. The first barrier to flocculation is the repulsion among particles, which is eliminated by the coagulation step. If coagulation is successful, flocculation can easily happen by Brownion motion of the particles. But the process can be accelerated by creating velocity gradients in water. This could be achieved by providing slow mixing. This happens usually in three compartments fitted with slow mixers as shown in Figure 6. The mixers operate at different speeds from high to low to minimize floc breakage. Flocculation could also be done in a hydraulic baffle flocculator.

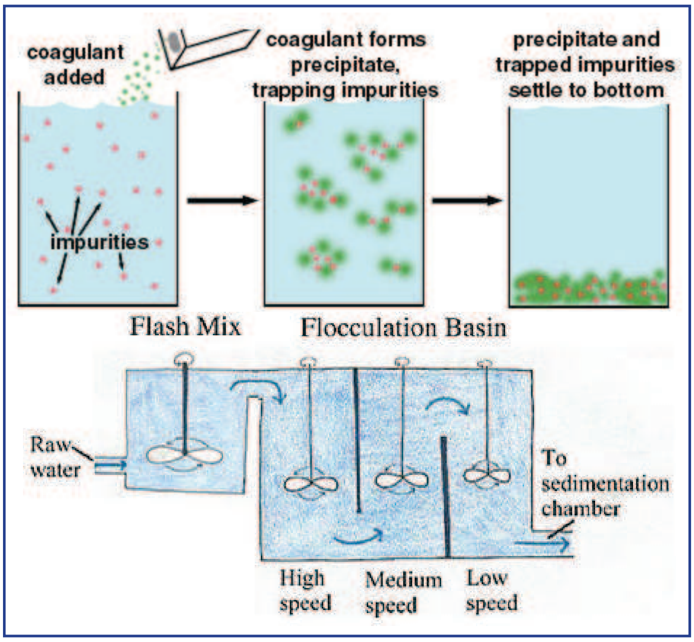


Figure 6 Coagulation & Flocculation

Sedimentation

Sedimentation or settling step is the unit process of water treatment where the flocculated particles are allowed to settle in a tank. Particle settling occurs vertically in the tank while the water slowly moves horizontally. The sediments are collected from the bottom of the tank as shown in Figure 7 below.

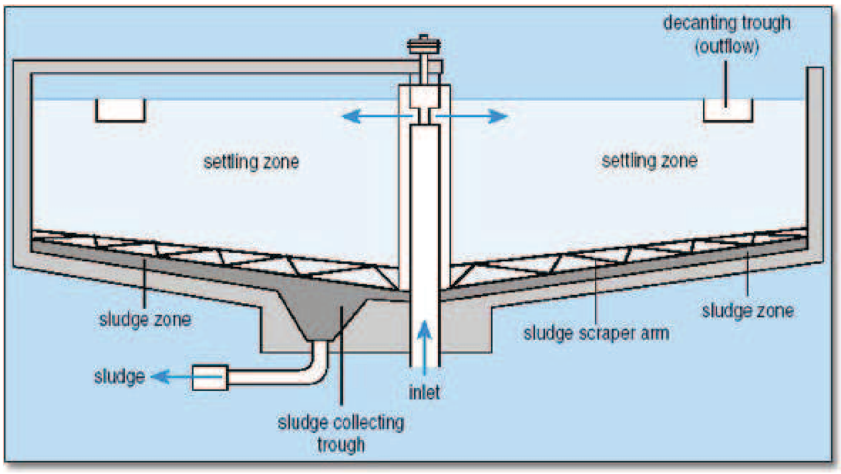


Figure 7 Sedimentation Tank

Tube settler is a much efficient particle settling device. It is about seven times efficient in time and space requirement compared to a plain sedimentation tank. Water is allowed to flow upwards in inclined tube modules. The settled particles fall down along the tube and drop down while clear water flows out from top as shown in the Figure 8.

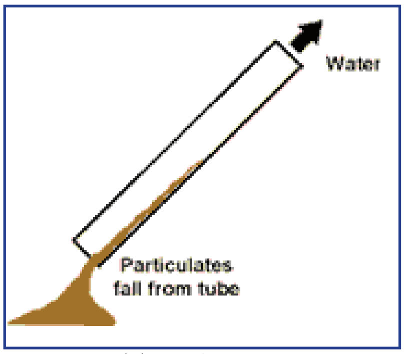


Figure 8 Tube Settler principle

Figure 9 Tube Settlers at Thanthirimaley & Oya Maduwa by NWSDB

Sand filtration

Filtration is a simple technique of water purification with a long history of application. In fact the earth acts as a kind of sand filter in cleaning the surface water stored as ground water, which is extracted by people through the wells. Sand filtration has two categories namely slow sand filtration and rapid sand filtration. Slow sand filter which consists of fine sand in the size range of 0.15 to 0.3 mm, can remove most of the microbial contaminants with about 98% removal efficiency. It suits to cleaning less muddy water. The main mechanism of a slow sand filter is through biological activity which happens in the top layer termed "Schmutzdecke". It traps bacteria, algae, protozoa and rotifers present in natural waters. A cross section of a slow sand filter is given in figure 10.

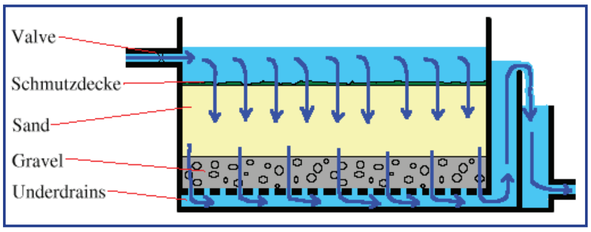


Figure 10- Slow Sand Filter

Rapid sand filter with sand particles of 0.5 -0.8 mm size is used to remove larger particles of impurities in water. However the rapid sand filters are less effective in removal of pathogens. A cross section of a rapid sand filter is shown in figure 11.

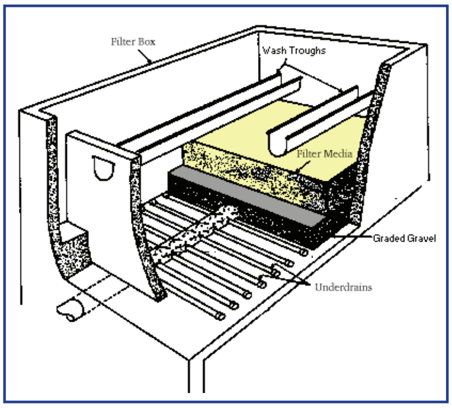


Figure 11 Rapid Sand Filter

Mechanism of a sand filter is not only straining. Settling and adsorption too as shown in Figure 12 take place within a sand filter.

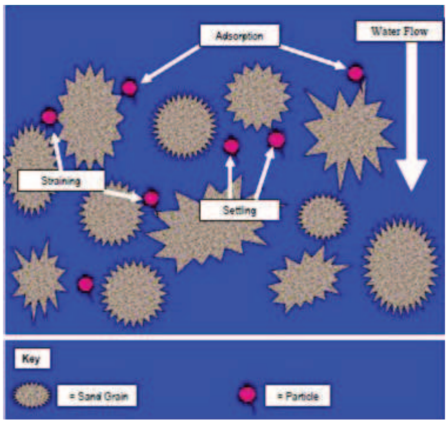


Figure 12-Filtration mechanisms

Disinfection

After all of the above water treatment steps disinfection has to be practiced at the point of consumption of water to be safe from the harmful effects of pathogens. Boiling and chlorination are common disinfection methods.

Boiling water can ensure the bacteriological safety of water as almost all the pathogens get killed. This is the most commonly practiced household water treatment technique.

Adding chlorine solution drops is another successful means of household disinfection. It makes water safe for drinking from any source although the taste will be a drawback.

How to make use of water treatment processes

The processes mentioned above could be utilized to treat water to make it safe for drinking. But the selection of unit operation modules explained above should be done based on the quality of raw water. For example the water in the well of your home may be very clean and no treatment is needed. To be safe from pathogens you may just boil and drink this water. If the well water looks clean but creates brownish color in the surrounds, presence of iron in water could be suspected and aeration and rapid sand filtration could be tried as the treatment.

Figure 13 Domestic Slow sand filter (Bio sand filter)

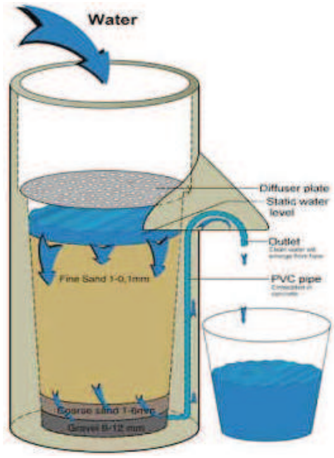


Figure 14 Domestic Slow sand filter (Bio sand filter)

Figure 15 Household water treatment, boiling and disinfection by Chlorine liquid

Figure 16 Conventional water treatment plant at Thanthirimaley (A joint effort by the Research & Development Unit, the central workshop and the Anuradhapura regional Office of the NWSDB)

So water treatment could vary from simple domestic to conventional treatment as described. However we should be careful to be aware of raw water quality variations annually. Long term water quality variations can occur due to climate change effects and human activity. Currently, pollution induced mainly by human activities at source is a major problem. Hence we should not pollute or disturb our catchments in order to protect our precious and limited fresh water sources.

Eng. S. Sumanaweera
Assistant General Manager
Research & Development
National Water Supply & Drainage Board
0773 580522

Natural Mineral Water and Bottled Drinking Water

P. Madarasinghe

Every cell in the body needs water, and that is why it is so important to drink a sufficient quantity of water daily. The brain consist 90% of water and when the body is under supplied the brain cannot function well and signs of dehydration manifest.

Although 70% of the earth is covered with water, most of it is not available for human consumption without being processed first. Of the planet's water, the oceans make up for 97%, while glacial shields hold another 2%. Only about 1% is soft water from lakes, rivers, and underground sources, but even out of that tiny amount an increasingly large volume is unsafe for human consumption. Finding quality water for consumption has become a problem for humans.

Due to the vast expansion of industries, agriculture, population growth, and increasing use of harmful chemicals, as well as geographical factors, contamination of drinking water occurs through a range of chemical, microbial, and physical hazards which cause health risks when present at high levels. Examples of chemical hazards include lead, arsenic, and benzene. Microbial hazards include bacteria, viruses and parasites such as *Vibrio cholerae*, and hepatitis A virus, and due to these reasons providing safe and accessible drinking-water has become a major challenge world over.

This situation, linked with the prevalence of market trends, has caused the business of bottled water to flourish. Consumption of bottled water has been increasing consistently over the last decade, even in countries where pipe-borne water quality is considered good.

Bottled water industry has grown dramatically in the last few decades, and today millions of people around the world in developed and developing countries consume bottled water regularly. Most people believe that bottled water is safe, and hence it has become an increasingly popular beverage all over the world.

Food (Bottled or Packaged Water) Regulations

In Sri Lanka, bottled water is regulated by the Ministry of Health through the Food

Of the planet's water, the oceans make up for 97%, while glacial shields hold another 2%. Only about 1% is soft water from lakes, rivers, and underground sources, but even out of that tiny amount an increasingly large volume is unsafe for human consumption.

(Bottled or Packaged Water) Regulations 2005 framed under the Food Act No. 26 of 1980, which regulates bottled water as a 'food', and manufacturers are obliged for producing safe wholesome and honestly-presented products.

Regulations include a standard of identity that define two different types of bottled water, namely 'Natural Mineral Water' and 'Bottled Drinking Water'. The regulations mandate the obtaining of a certificate of registration from the Chief Food Authority (CFA) prior to bottling or packaging or importing Natural Mineral Water or Bottled Drinking Water.

Provision 4 specifies that;
No person shall sell, offer for sale, keep for sale, transport or advertise for sale any Bottled or Packaged Natural Mineral Water or Bottled or Packaged Drinking Water unless such product has been duly registered by the Chief Food Authority and a registration number in terms of the foregoing provisions of this regulation has been assigned thereto.

Applications received from prospective manufacturers for registration are processed by an institution that has the expertise in the required field, and presently the Sri Lanka Standards Institution functions as the recognized body under a Memorandum of Understanding with the Ministry of Health. At present there are about 130 brands of bottled drinking water, 9 brands of Natural Mineral Water, and 09 brands of imported products from countries such as France and Italy, registered by the Ministry.

The regulations define 'Natural Mineral Water' as "water that originates from an underground water bearing strata and is extracted for human consumption from natural or drilled sources such as springs, wells or boreholes" and 'Bottled or Packaged Drinking Water' as "water that is sealed in bottles (containers) ready for human consumption; but shall not include Natural Mineral Water".

Special provisions related to Natural Mineral Water to guarantee the original purity of the products, are also specified, and accordingly "Natural Mineral Water be collected under conditions, which guarantee the original purity, not be subjected to any treatment other than separation of unsuitable constituents by decantation or filtration, and if necessary, accelerated by pre-aeration, be bottled or packaged close to the point of emergence of the source under hygienic precautions, not be transported in bulk containers for packaging, pipeline transport is allowed if all precautions have been taken to maintain the purity of water".

The Food Act requires that bottled water should be safe and processed, bottled, stored, and transported under sanitary conditions. Processing practices addressed in the regulations include protection of the water source from contamination, sanitation at the bottling facility, quality control to ensure bacteriological and chemical safety of water.

Bottled water labels should meet the appropriate standard of identity, or it will be considered as violatory under the Act. For example, a bottle labelled as containing "mineral water" must meet the criteria set out for "Mineral Water" and it must come from a geologically and physically protected underground water source and it must contain no added minerals.

No person shall sell, offer for sale, keep for sale, transport or advertise for sale any Bottled or Packaged Natural Mineral Water or Bottled or Packaged Drinking Water unless such product has been duly registered by the Chief Food Authority and a registration number in terms of the foregoing provisions of this regulation has been assigned thereto.

Standard of Quality Regulations

There are microbiological standards that set

Table 1: Physical Chemical and Microbial requirements

Characteristic	Mineral Water Requirements	Drinking Water Requirements
Colour Hazen Units (Max)	5.0	15.0
Odour	Unobjectionable	Unobjectionable
Taste	Unobjectionable	Unobjectionable
Turbidity, NTU (max)	5.0	5.0
pH	--	6.5 to 8.5
Total dissolved solids, (values are presented hereunder as mg/l (max)	1500.0	1000.0
Arsenic as As	0.01	0.01
Aluminum as Al	0.2	0.2
Cadmium as Cd	0.003	0.003
Cyanide as CN	0.07	0.07
Chromium as Cr	0.05	0.05
Mercury as Hg	0.001	0.001
Nickel as Ni	0.02	0.02
Selenium as Se	0.01	0.01
Lead as Pb	0.01	0.01
Copper as Cu	1.0	1.0
Antimony as Sb	0.005	--
Barium as Ba	0.7	--
Manganese as Mn	0.5	0.5
Zinc as Zn	--	3.0
Total iron as Fe	--	0.3
Total hardness as CaCO3	--	250
Free residual Chlorine as Cl2	--	0.2
Alkalinity total as CaCO3	--	200
Free ammonia as NH3	--	0.06
Chloride as Cl	250.0	250.0
Fluoride as F	1.5	1.5
Nitrate as NO3	50.0	50.0
Nitrite as NO2	3.0	3.0
Sulphide as H2S	0.05	--
Sulphates as SO4	--	250.0
Chemical Oxygen Demand (COD)	--	10.0
Phenolic compounds and mineral oil	Absent	Absent
Grease and oil	Absent	Absent
E. coli and coliforms	Absent	Absent
Pathogenic organisms	Absent	Absent

Source: Food (Bottled or Packaged Water) Regulations 2005

permissible coliform levels, and physical standards specifying levels for turbidity, color, and odour as shown in the table.

Treatment during processing of bottled drinking water

The regulations provide for chemical and physical treatment methods during processing to reduce, remove or prevent growth of micro-organisms such as chlorination, ozonation, carbonation, high heat, ultraviolet radiation, and filtration. Treatment process includes the use of sand or compressed fiber filers, cartridge filters, pleated membrane filters, activated carbon filters, aeration, demineralization, de-ionization and/or water softening.

Inspection of Bottled Water Plants

The Authorized Officers appointed under the Food Act monitors and inspects bottled water products and processing plants. In addition, follows up on consumer and trade complaints and other leads, as appropriate, on use of potentially violative products, and also collect samples for analysis and submit these to Food Laboratories gazetted under the Food Act to test for microbiological or chemical contamination. It is the responsibility of all consumers to report observed faults such as presence of foreign particles, unusual or unpleasant odours, suspicious label information etc. to Health Authorities.

Shelf Life of Bottled Water

Bottled Water Regulations neither set nor suggest limitation to the shelf life of bottled water. Most bottled water containers retailed bear a two-year expiry period. General position of the International Bottled Water Association (IBWA) is that as long as bottled water is packaged in accordance with regulatory processing in compliance with Good Manufacturing Practices(GMP), and meeting the quality standards, the product's shelf life should remain intact for a considerable period of time provided that product storage and other post-packaging and handling practices do not adulterate or deleteriously affect the finished product.

Misleading Bottled Water Labelling and Marketing

The Labelling Regulations define essential labelling and advertising rules, specify mandatory information which should be on product labels, and impose restrictions in relation to the declaration of false claims, or misleading descriptions in such a manner as to mislead the purchaser or consumer, or presented in a manner that is likely to create an erroneous impression regarding its character in any respect. In addition to the above, special provisions have been introduced to control false or misleading descriptions under the Bottled or Packaged Water Regulations, such as:

Nothing shall be printed or published on the label or on the bottle in respect of medical or other benefits that can be gained by a consumer using Drinking Water ;

Shall not print or publish on the label or on the bottle any statement or any pictorial device, which may create confusion in the minds of the public, or in any way mislead the public about the nature, origin, composition and properties of Drinking Water.

Some labels may carry descriptions such as "Spring water" with graphics of mountains and a lake on the label, whereas the actual source is located in an entirely different locality, thereby misleading the public about the product’s origin.

Moreover the use of descriptive terminology suggesting bottled water is extraordinarily pure and uncontaminated are observed. For instance, descriptions such as ‘Pure’, ‘Naturally Purified’, ‘Premium’, ‘Mountain Water’, ‘For Health Conscious’ are being used to boost sales.

Enforcement officers should be vigilant to identify such exaggerated descriptions and take appropriate action, and consumers also should pay more attention to the labelling information and be sharp enough to make a correct choice without being misled by exaggerated claims.

Reported illnesses due to bottled water

As far as Sri Lankan experiences are concerned no water-borne illness have been traced to bottled water since the introduction of bottled drinking water. This is evident from the

Weekly Epidemiological Reports published by the Ministry of Health, and to date bottled water has not been responsible for an outbreak of any such diseases. Nevertheless there have been waterborne-disease outbreaks elsewhere traced to bottled water. For example, in 1996 a bottled water-related cholera outbreak was reported in the Morbidity and Mortality Weekly Report of the United States. In Portugal, during the cholera epidemic of 1974, bottled mineral water was identified as one of the vehicles of transmission of *Vibrio cholera*.

Imported bottled water:
Regulatory provisions make it mandatory to obtain a Certificate of Registration from the Chief Food Authority to import Bottled Water. For registration it is necessary to submit samples of the product along with a Certificate of Analysis from an accredited laboratory relating to the content of such sample. The Food Authority with the concurrence of the SLSI makes decisions regarding awarding the certifications based on the above reports. Evidently the Food Authority has no access for inspection of Good Manufacturing Practices, sources, and bottling facilities which are outside Sri Lanka to evaluate compliances.

Public concerns on bottled drinking water:
Major concern about the consumption of bottled water can be cited as the issues related the Bisphenol-A (BPA) in Bottled Water containers. Studies regarding BPA and how this chemical may adversely affect the health have been conducted and results released by independent researchers. BPA is used in the production of epoxy resins and polycarbonate plastics worldwide. It is used to make plastic bottles of all kinds. However, as these plastic bottles become aged, BPA has a tendency to leach into the contents. According to several studies, they adversely affect health in many different ways.

Results of studies conclude that BPA causes long-term effects on mammary tissue development, increasing risks to cancer in rats, chromosomal disorder in mice, and BPA alters development of the reproductive tract as well as increases prostate tumor proliferation.

Almost all the research papers highlight the formation of BPA and other toxic substances due to the aging of plastic bottles, and leaching of these compounds were found to depend on storage conditions, temperature, and exposure to direct sunlight.

Thus the consumers should be well aware in selecting bottled water which should be properly sealed with tamper-proof coverings, and appropriately stored in a cool and dry place, before causing an alarm when consuming bottled drinking water. In addition when considering the polluted water and the possible contaminants in water available in urban and rural food establishments, it can be argued that consumption of quality bottled drinking water is advantageous.

Other controversies on Bottled Water include concerns over the energy and material that are used for making bottles and transportation of water countrywide as well as the implications of climate change concerns regarding the bottles which are not recycled, the harmful toxins that are released to the environment during incineration, the accumulation in the decomposing process in landfills, and over-extraction of spring water resulting in harming natural water resources.

Food for thought:
Sri Lanka being a tropical country is fortunate to have a vast number of natural fruit drinks and especially several varieties of coconut such as “Thambily”, Kundhira” and “Kurumba”. All these products are totally free from chemical and bacteriological contamination and provide essential nutrients that the body requires.

It is worthwhile to know that 100g of coconut water provide

Potassium 250 mg, Calcium 24g, Copper 40 mcg, Magnesium 25 mg, and so forth, and coconut water can be marketed as a natural energy or sports drink due to its high potassium and mineral contents. Nutrition values obtained from the National Nutrition Data Base of the United States Department of Agriculture (USDA) is cited as reference in support.

Furthermore the following data published in the Journal of Physiological Anthropology and Applied Human Science provide nutritional composition of plain water, fresh young coconut and carbohydrate - electrolyte beverages.

Table 1 Nutrient composition and osmolality of plain water, fresh young coconut water and carbohydrate-electrolyte beverage. Data presented as Mean ± SEM

Variables	PW	CW	CEB
Glucose (mmol 1^{-1})	0	139.63 ± 4.95	179.40 ± 2.40^{++}
NA^{+} (mmol 1^{-1})	0	5.09 ± 0.40	19.01 ± 0.29^{++}
K^{+} (mmol 1^{-1})	0	52.66 ± 0.59	3.75 ± 0.14^{++}
C^{1-} (mmol 1^{-1})	0	1.11 ± 0.59	0
Osmolality (mOsm kg $^{-1}$)	0	405 ± 10.89	404 ± 10.73

PW = Plain water
CW = Fresh young coconut water
CEB = Carbohydrate-electrolyte beverage
$^{++}$ = significantly different from CW at $p<0.01$

SEM- standard error of mean ; mmol l- millimoles per litre ;
mOsm kg - milliOsmols per kilogram;
Osmolality is the measure of solute concentration, defined as the number of osmoles (Osm) of solute per litre (L)

Above factors should be borne in mind when selecting a beverage to quench the thirst. The law mandates traders to abide by all the rules and regulations. In addition all the manufacturers and traders are bound to comply with ethical aspects of marketing, all of which cannot be taken as granted for continuous supply of quality, wholesome, and safe bottled drinking water. It all depends on the honesty, dedication and commitment of all persons involved in the chain from the source to consumption.

Coconut water (*Cocus nucifera*)
Fresh, Nutrition Value per 100 g
Source: USDA National Nutrient database

Principal	Nutrient Value	Percentage of RDA
Energy	19 Kcal	1%
Cabohydrates	3.71 g	3%
Protein	0.72 g	1.5%
Total Fat	0.20 g	1%
Cholesterol	0 mg	0%
Diatary Fiber	1.1 g	3%
Vitamins		
Folates	3 µg	0.75%
Niacin	0.080 mg	0.5%
Pantothenic acid	0.043 mg	‹1%
Pyridoxine	0.032 mg	2.5%
Riboflavin	0.057 mg	4%
Thiamin	0.030 mg	2.5%
Vitamin C	2.4 mg	4%
Vitamin A	0 IU	0%
Vitamin B	0 mg	0%
Vitamin K	0 mcg	0%
Electrolytes		
Sodium	105 mg	7%
Potassium	250 mg	5%
Minerals		
Calcium	24 mg	2.4%
Copper	40 mcg	4.5%
Iron	0.29 mg	3.5%
Magnesium	25 mg	6%
Manganese	0.142 mg	%
Zinc	0.10 mg	1%

P. Madarasinghe
Rtd. Assistant Director
Food Control
Administration Unit
Ministry of Health
(Consultant, Food
Products Evaluation n&
Consultative Services)
0773 559758