MILESTONE 1: REPORT C1

"DRWH WATER QUALITY: A LITERATURE REVIEW"

Prepared by

PROF. PADMA VASUDEVAN AND DR. NAMRATA PATHAK

Centre for Rural Development & Technology

Indian Institute of Technology, Delhi

India

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DRINKING WATER: THE INDIAN SCENARIO

The Global Dimension

Water is life. This colourless, odourless and tasteless liquid is essential for all forms of growth and development - human, animal and plant. Also, water is a fundamental basic need for sustaining human economic activities. Not only does water support a wide range of activities, it also plays a central symbolic role in rituals through out the world and is considered a divine gift by many religions. Availability of water in the desired quantity and quality, at the right time and place, has been the key to the survival of all civilizations. No other natural resource has had such an overwhelming influence on human history. As the human population increases, as people express their desire for a better standard of living, and as economic activities continue to expand in scale and diversity, the demands on fresh water resources continue to grow.

While water is a renewable resource, its availability in space (at a specific location) and time (at different periods of the year) is limited, by climate, geographical and physical conditions, by affordable technological solutions which permit its exploitation, and by the efficiency with which water is conserved and used. Much of the world's fresh water is consumed by the agricultural, industrial and domestic sectors. Increasing water demands and the inadequacy of these sectors to effectively manage this resource, has lead to crises situations in many parts of the world - crises over the availability of adequate and appropriate quality water. The limits of sustainable use in each climatic region are determined by local climate, hydrological and hydro-geological conditions. In many parts of the world, the amount of water being consumed has exceeded the annual level of renewal, creating a non-sustainable situation. The International Drinking Water Supply and Sanitation Decade and other international declarations have clearly recognized that access to water is a fundamental right of people.

Fresh water lakes and rivers, which are the main sources of water consumed by people, contain an average of 90,000 cu km of water, or just 0.26 percent of total global fresh water reserves. This tiny fraction is distributed in a very uneven manner on earth, creating wide range of environments, from arid regions and deserts to humid areas which experience regular flooding. In many parts of the world, the rainfall pattern is highly skewed and is characterized by small periods of intense precipitation followed by long, dry periods. Great disparities may even be seen on the same continent. About 20% of the total global run-off flows in the Amazon river in South America, while the Atacama Desert has consistently received non annual rainfall.

Such variations become very important as human activities diversify geographically and in scale. In many water scarce parts of the world, human engineering initiatives have been geared towards balancing this spatial inequity. In South-Western USA, e.g. engineering interventions in the form of extensive dams have already exhausted most possibilities for enhancing fresh water availability. In many other parts of the world, future options are becoming extremely complex and uncertain as the levels of total fresh water consumption approach the limits imposed by the annual renewal of fresh water resources.

Advances in climatology and hydrology have contributed to improved, quantitative estimations of the processes which make up the global hydrological cycle. Though this knowledge has resulted in increased availability of water in some situations, an almost exponential growth in the level of utilization of this resource has balanced off the advantages so created. In this way, in spite of advances made on the scientific front, human survival and well being today are probably no less dependent on fresh water availability than in the early years of human civilization. Not with standing some impressive records in activities related to the UN Drinking Water and Sanitation Decade (WHO 1990), the provision of water at affordable cost and of acceptable quality is emerging as a major environmental challenge. In particular the all dependence of future food security on the availability of irrigation water, as well as growing awareness of water resources for conservation purposes has created widespread concern.

There are distinctions between `water scarcity', `water shortage' and `water stress'. Water scarcity is a relative concept intended to convey the imbalance between supply and demand under the prevailing legal, institutional, regulatory and where applicable, price arrangements. Water shortage is an absolute concept indicating low levels of water supply relative to minimum levels necessary for basic needs. Water stress signifies acute water shortages for prolonged periods.

In this respect, it is important to examine whether the emerging water scarcity in various parts of the world is absolute, needing drastic reductions in demand, or can be adequately addressed through new and holistic management strategies and restrained consumption patters. The need for a totally new perspective and the manner in which people use fresh water has been felt and the existing perceptions of engineers regarding water supplies has been questioned.

The need to adopt a systems approach to water management has been stressed. Along with the various ecological linkages governing the flow of fresh water in the hydrological cycle, the need to understand the use of water in its many diverse roles and its economic implications is also being recognized. The Earth Summit Agenda 21, specifically calls for local and national level actions.

<u>Delhi and Dublin Principles</u>

Delhi "some for all rather than more for some". Guiding principles:

- protection of environment and safeguarding of health through integrated management of water resources and liquid and solid waste;
- institutional reforms, integrated approach and full participation of women at all levels;
- community management and strengthening of local institutions in implementation;
- sound financial practices.

Dublin: Emphasis on sustainability and the need to consider water as an economic good. Guiding principles:

- fresh water is a finite and vulnerable resource essential to sustain life, development and the environment;
- water development and management should be based on a participatory approach involving users, planners and policy makers at all levels;
- women play a central part in the provision, management and safeguarding of water;
- water has an economic value in all its competing uses and should be recognized as an economic good.

<u>Source</u>: Global Consultation on Safe Water and Sanitation for the 1990s, Delhi and International Conference on Water and the Environment, Dublin, 1992.

<u>Earth Summit, Agenda 21</u>

At the lowest appropriate level, delegation of water resources management, generally to that level in accordance with national legislation, including decentralization of government services to local authorities, private enterprises and communities.

At the national level, integrated water resources planning and management establishment of independent regulation and monitoring of fresh water, based on national legislation and economic measures.

Source: United Nations (1992)

Water: The Indian Scenario

In a country where the first measurement of rainfall was made by Kautilya as early as AD 1200, it is surprising that estimates of the total availability of water in India are only quite recent. The total average annual run-off of all river systems in India is estimated to be 1,674 billion cubic metres (BCM).

The National Water Policy estimates that total precipitation in India is around 400 million hectare metres. In addition, ground water potential is about 42 million hectare metres (GOI 1987). The first estimates of ground water resources on a scientific basis was made in 1979 by the Central

Ground Water Board. Recent estimates based on a state-wise assessment have put the annual replenishable ground water resources of the country at 453 BCM. With a provision of about 15% (69.8 BCM) for drinking, industrial and other uses, the utilizable ground water resources for irrigation is computed as 383 BCM (GOI/CGWB 1995).

The amount of available aggregate annual utilizable water in India, surface and ground is about 1,100 BCM. Population growth is expected to result in a decline in the per capita availability of fresh water. In 1947, this was measured at 5,150 m^3. By the year 2000, it is likely to be 2,200 m^3.

Such aggregate figures, however, are quite misleading, since there is considerable spatial and temporal variation in rainfall. Some areas receive slight rainfall, whereas others experience monsoon conditions which often result in flooding, loss of life and increased poverty. To better understand such variations and their consequences on people's lives, it is necessary to examine specific situations at the village or community levels under different ecological situations.

Attention must, however, also be given to fast growing urban centres, where water requirements are expected to double from 25 BCM in 1990 to 52 BCM in 2025. The situation concerning industrial supplies is even more difficult to analyse. It has been indicated that industrial water demand would increase from 34 BCM in 1990 to 191 BCM by the year 2025. Agriculture, the largest consumer of water resources in India, will probably require 770 BCM by the year 2025 to support food demand. The total estimated demand of 1013 BCM by the year 2025 would be close to the current available annual utilizable water resource of India.

With predicted demands such as these, the supply of rural drinking water and requirements for ecosystems conservation are sure to face an uncertain future unless anticipatory policy measures are taken. It is evident that the politically and economically powerful urban-industrial sectors would obtain the water resources they need by organising long distance transfers from surrounding rural areas or even by inter-basin transfers. In such a scenario, alternative solutions of conservation and sustainable management of fresh resources will find little support. In view of this, the focus has to be on the requirements of rural drinking water and ecosystem conservation, while at the same time suggesting alternative approaches for meeting urban demands.

The National Policy

The government's concern since independence, has been raising the quality of life and the health of the people. Several initiatives were taken at policy formulation level leading to various programmes in this direction. Supply of safe drinking water and provision of sanitation are the most important contributing factors for improving the health of the people in any country. As per a World Health Organization (WHO) report 80% of the diseases are due to unhygienic conditions and unsafe drinking water. It is estimated that every year about 1.5 million children under five years die in India of water related diseases. The country loses over 200 million man days each year due to water and sanitation diseases. Age old cultural practices coupled with illiteracy and lack of awareness further complicate and exacerbate the problem. Supply of safe drinking water has therefore, been given very high priority in Indian Planning.

Providing drinking water in rural areas is the responsibility of the state governments and the funds were provided for the purpose in their budgets from the first five year plan. During 1954 National Water Supply and Sanitation Programme was introduced in the social welfare sector. The states built up gradually the Public Health Engineering Departments (PHEDs) to attend to the problems of water supply and sanitation. Under the programme 100% grants-in-aid to implement the different water supply schemes for the `problem villages' were provided by the government of India. In the mid 1960s it was realised that these schemes were implemented only in the easily accessible villages and in the process the hard core `problem villages' remained unattended. The government of India during the fourth five year plan took steps to provide assistance to the states to establish special investigation divisions for the problem villages.

In order to accelerate the pace of coverage of problem villages, the Government of India introduced the Accelerated Rural Water Supply Programme (ARWSP) in 1972-73. During 1974-75 the Minimum Needs Programme (MNP) was introduced because of which the ARWSP was withdrawn but it (ARWSP) was reintroduced in 1977-78 when the progress of supply of safe drinking water to the identified problem villages was not found to be satisfactory.

In the year 1977 the United Nations Water Conference separated the issue of drinking water and sanitation from other water issues to stress the seriousness and magnitude of the problem of drinking water. The conference recommended that each country should develop national plans and programmes for water supply and sanitation giving priority to the schemes of the population which require greatest attention. India was a signatory to the resolution seeking to achieve the target by 1991. The water decade programme was launched in India on 1st April, 1981 to achieve definite targets of coverage of entire population by 31st March, 1991.

In August, 1985 the subject of rural water supply and sanitation was transferred from Ministry of Urban Development to Department of Rural Development with the objective of securing implementation of the programme and their integration with other rural development programmes.

The National Drinking Water Mission was launched as one of the five societal mission in the year 1986. The mission was since named as Rajiv Gandhi National Drinking Water Mission (RGNDWM) in 1991. Government of India continues to give highest priority to rural drinking water sector through the activities of the mission and ARWSP. It also forms the part of the state funded MNP and point No. 7 of the twenty point programme, 1986.

It is claimed that the RGNDWM over the last decade has successfully covered the majority of habitations with hand pumps/stand posts. However, it has now been realised that the objective of supplying safe water would not be achieved to the extent and satisfaction expected unless the pollution aspects of water supply, as well as the issue of sanitation were addressed simultaneously. The focus has now shifted from water to water and sanitation. The mobilisation of large funds and efforts through RGNDWM in this direction have not yielded the desired impact on the health of the general population. Many reasons could be advanced to explain the not so satisfactory results of the efforts under water and sanitation programmes over the years.

During the 1970s, there was a marked departure from sustainable utilization of water resources. Food scarcities of the 1960s encouraged government policies towards increased irrigation. In this way, the users of drinking water and irrigation, which had until then been a singular entity, started to be separated. This shift affected the management of common water resources in basic ways. One of the most visible changes was the manner in which upper catchments were managed, leading to a degradation of water resources in tanks, lakes and rivers. It also led to ground water being extracted from greater depths, making the shallow hand dug wells, which until then had provided drinking water, redundants. The situation has been described as human induced water scarcity, normally mistaken as being the result of natural drought. What made the situation even worse was increased pollution of both surface and ground water resources which are of both man made and natural origin. In this perspective, unless pre-sumptive measures in terms of new regulatory and policy instruments are adopted, the water situation in India is certain to become chaotic.

National Water Supply and Demand

The changing socio-economic situation in India is leading towards higher levels of ground water exploitation. With the increasing availability of more sophisticated drilling and pumping technology, the search for ground water is bound to increase. The results of excessive ground water use is already showing. Small streams, are drying up due to insufficient catchments even during the monsoon season, and in both rural and urban areas people are drilling deeper and deeper borewells. In other situations, a significant amount of rain might fall, but it is not possible to store it for domestic needs. In the hills, deforestation and reduced ground cover results in very little rainwater percolating into the soil to feed the springs. Soil erosion further reduces the capacity of the ground to retain water. Cheerapunji in eastern India, for example, may receive 10.5 m of rainfall in the short monsoon period, but it too suffers from water scarcity!

India is heavily dependent on ground water sources. It is estimated that this source provides about 80 to 90 percent of domestic water supply in rural areas, 50% of the urban and industrial demand, and 50% of the irrigated area through over 17 million energized wells. In drought years, ground water represents the primary reliable source for irrigation. (World Bank/ GOI 1997a &

1997b). However, domestic water needs account for only about 5% of the total water extracted from the ground.

A dramatic increase in ground water extraction took place in India from 1951 to 1990. The number of dug wells increased from 3.86 million to 9.49 million, shallow tubewells from 3,000 to 4.75 million and public tubewells from 2,400 to 63,600. The number of electric and diesel pumps also increased during this period, from 21,000 to 8.22 million and from 65,700 to 4.36 million, respectively, electric pumps becoming more common as a result of rural electrification. In gross terms, however, the current level of ground water use is 32%, suggesting that there is still vast potential for its further development, but there are significant variations with a number of blocks in the country classified as `dark areas' or `over exploited' with more than 85 and 100% of ground water development, respectively (GOI/Central Ground Water Board, 1995).

With the heavy dependence of the country on ground water, the government's strategy has been based on using the dynamic component of ground water (i.e. the amount available in the zone of water level fluctuation), and temporary use of the static component (i.e. the amount available in the permeable portion of the aquifer) to cope with drought situations. The National Water Policy (1987) sets out the framework for the implementation of this strategy. Current legislation (common law) assigns property rights of surface (natural) water resources to the state, while rights to the extraction of ground water, which is the major source of drinking water in India, rest with those individuals who own the land above the aquifer. There is no limit on the quantity of ground water that a landowner can extract.

National Water Policy (1987)

- Water is a prime natural resource, a basic human need and a precious national asset.
- Periodic scientific assessment of the ground water potential, taking into consideration the quality of water and economic viability.
- Exploitation of ground water resources should be regulated so as not to exceed recharging possibilities and to ensure social equity with ground water recharge projects formulated and implemented for augmenting the available supplies.
- Integrated and co-ordinated development of surface water and ground water and their conjunctive uses planned right from the start of a project.
- Avoidance of over exploitation of ground water near the coast to prevent ingress of sea water into sweet aquifers.
- Drinking water needs of human beings and animals should be the first charge of any available water.

The water supply and sanitation sector, particularly in rural areas, has been given priority from the inception of the five year planning process in India. In total, during the five year planning periods 1951-56 to 1992-97 Rs. 336 billion or 3.3% of the total government budget has been allocated to this sector of which 60% (Rs. 202 billion) was for rural areas. Government investment in rural water supplies and sanitation was Rs. 143 billion upto 1996. From 1991 to 1995 total external support to the water supply and sanitation sector amounted to US $ 330 million or US $ 56.5 million per year which represents 2 per of total external disbursements in India. But it is also noted that the utilization rate of both multilateral and bilateral assistance in India is low. For example in 1992-1993 it was only 10% of commitments (World Bank/GOI 1997b). Estimates of private investments are not available, but they are likely to far exceed that of the government if irrigation and domestic expenditures in water extractions are included.

According to the Rajiv Gandhi National Drinking Water Mission (RGNDWM) a total of 520 million people have been provided access to public water supply since the launch of the first national water supply programme in 1954. During the period 1954-55 to 1994-95 it is estimated that 478 million rural people were covered with water supply. By 1994, 95% of the rural population had access to a `safe` source of water, with 52% fully covered with 40 litres per capita per day (lpcd) or more, and 48% partially covered with 10-40 lpcd. Only about 5 percent of the rural population were without access to safe water.

In terms of physical infrastructure, more than two million handpumps have been installed on drilled tube and borewells, 1,16,000 mini and regional piped schemes have been constructed supplying 1.5 million standposts and 4.3 million house connections. Moreover, handpumps account for 95% of the total number of publicly funded rural water supply schemes, serving almost 395 million people, or 75% of the rural population.

A 1994 Government of India survey examined the status of handpumps. It found that many required repair (more than 33%), or rehabilitation (22%), or were completely defunct (12%). In the case of piped water supply the situation was less serious with about 26% requiring repair or rehabilitation. Eighteen percent of all standposts were found to be without taps (World Bank/GOI, 1997b).

The RGNDWM Validation Survey has also reported significant problems with water quality. Approximately 82,000 habitations or about 4 million people are suffering from water quality problems as a result of excessive quantities of fluoride, iron, nitrate and arsenic or excessive salinity. The Ground Water Sub-group of the Water Resource Management Sector Study by the World Bank and Government of India reports that arsenic is a recognized problem in West Bengal (1,000 habitations or an approximate population of 5,00,000), fluoride levels are considered high in Andhra Pradesh, Gujarat, Haryana, Karnataka, Punjab, Rajasthan, Tamil Nadu and Uttar Pradesh (28,000 habitations or an approximate population of 14 million), high iron levels have been found in the north-east and eastern parts of the country (58,000 habitations or an approximate population of 29 million), and high salinity is prevalent in Gujarat, Haryana, Karnataka, Punjab, Rajasthan and Tamil Nadu (World Bank/GOI, 1997b).

With an area of 3,268,100 km^2, India has 33 meteorological sub-divisions. Almost one-third of the country, 99 districts in 13 states, covering 108 million hectares have been classified as drought prone. As of March 1994, out of the 7024 blocks, Mandals, Talukas and watersheds in the country, 537 blocks and Mandals (102 Mandals in Andhra Pradesh, 32 in Haryana, 9 in Karnataka, 3 in Madhya Pradesh, 73 in Punjab, 68 in Rajasthan, 97 in Tamil Nadu, 65 in Uttar Pradesh, 2 in West Bengal), 45 Talukas in Gujarat and 35 watersheds in Maharashtra were classified as `dark` or critical where the projected net extraction in five years would be in excess of 85% of the ground water resources utilizable for irrigation. Another 600 blocks, Mandals, Talukas and watersheds are classified as `grey` or `semi-critical` with projected extractions in the 65-85% range.

In response to the emerging problems of ground water, the RGNDWM has as far back as 1987 identified strategies for the short and long term for meeting drinking water needs and micro-watershed management such as the conservation of water and recharging of ground water aquifers and a model bill has been proposed by the Central Government.

Technology Mission: Some approaches for the conservation of water and recharging of ground water aquifers

- collection of hydro geological and related data in problem areas;
- reconnaissance to verify the available data and to update micro level data base;
- **chemical analysis of water for evaluating its suitability for drinking;**
- construction of suitable structures for ground water exploration and periodical monitoring of their performance;
- **designing and construction of suitable structures for rain water harvesting;**
- **artificial recharge of aquifers (wherever feasible);**
- development and adoption of measures for reduction of evaporation losses from surface water bodies;
- conservation of water through adoption of appropriate irrigation practices;
- identification of micro-watersheds in problem areas;
- assessment of hydro geological parameters of aquifers;
- estimation of recharge to ground water regime;
- assessment of total water potential in basins and micro-watersheds;
- scientific management of water resources using computerized mathematical modeling.

Key components of the Ground Water Model Bill

- Control and/or regulation of the extraction of ground water in any area deemed necessary and notified by a Ground Water Authority;
- Need to obtain a permit to extract and use ground water in the notified areas;
- Registration of existing and new users in the notified areas;
- Monitoring and enforcement of the controls and regulations by the Ground Water Authority.

In 1992, the constitution act (73rd amendment) gave responsibility for drinking water and sanitation to the Panchayati Raj Institutions. The underlying rationale is that the public health engineering departments and water boards are centralized, monopolistic, overstaffed, and lacked accountability to users. The Gram Panchayats as the local level tier are now expected to be responsible for choice of technology, recovering costs and operations, and maintenance of rural water supply and sanitation. The assets would be owned by the community. This process is, however in a very early stage in most states, but Gram Panchayats are now almost entirely implementing development programmes that are handed down to them by the state and central governments. However, because the governments continue to control the grants to the Panchayats, they continue to exercise control on the day-to-day functioning of the panchayats, and the state governments still continue to act as the providers of minimum coverage of free water supply in rural areas.

The broad picture of the demand and availability of fresh water has typically suggested certain generalized solutions such as the need for resource management rather than controlled resource extraction and improved environmental management in critical zones. Alternative mechanisms for water allocation in such a complex situation have been studied by Meinzen-Dick and Mendoze (1996). Specific solutions have pointed to the promotion of water markets, reforming the tariff structure of electricity, prohibiting certain crops in water scarcity areas, creating legal and institutional frameworks, and re-orienting investments in the sector.

The ability of some suggested changes has often not taken into account the regional and ecological differences that prevail in the nature and assessment of the fresh water situation, including social and cultural factors. Policies and plans developed at the national level, and calculations of per capita fresh water needs based on national data have little meaning in a country of this size. The water issues in India must be analysed in a dynamic context, both over time and for specific locations.

Drinking Water: Current Problem and Perspective

The lives of women and children as well as the environment have been seriously threatened by water shortages in the country.

- As a result of excessive extraction of ground water, drinking water is not available during the critical summer months.
- About 5 percent of the rural population does not have access to regular safe drinking water and many more are threatened by less and less access to safe drinking water in the not so distant future. Water shortages in cities and villages have led to large volumes of water being collected and transported over great distances by tankers and pipelines.
- High levels of fluoride, arsenic and iron, lead to major environmental health problems and in the case of iron, people simply do not like to drink the water because of its smell / taste.
- Ingress of sea water into coastal aquifers as a result of over extraction of ground water has made water supplies more saline, unsuitable for drinking and irrigation.
- Pollution of ground and surface waters from agro-chemicals (fertilizers and pesticides) and from industry poses a major environmental health hazard, with potentially significant costs to the country.
- The World Bank has estimated that the total cost of environmental damage in India amounts to US $ 9.7 billion annually, or 4.5 percent of the gross domestic product. Of this, 59 percent results from the health impacts of water pollution.

- It has been recently estimated that by 2017 India will be `water stressed' per capita availability will decline to 1600 cu m. Cities generate 2000 crore litres of sewage but treat only 10% of it. Poor drinking water and sanitation infrastructure will lead to high levels of water related diseases and death. It is estimated that 60% of irrigation water is wasted by seepage through unlined field channels and due to over application.

Evidence suggests that not only is there an emerging water crisis at the global scale, but that the crisis is already happening in many parts of India. Ground water is being over exploited, surface water is utilized inefficiently, as is water used for irrigation and urban water supply and water pollution is escalating at exponential rates, not least because of poor sanitation. The poor in rural and urban areas, particularly women and children, continue to be hard hit by these emerging problems. There is a fear that unless urgent measures are taken, present and future generations of children will have to bear immense health and economic costs. The government has recognized that there is a problem with availability of quality water.

India's National Water Policy recognizes the importance of providing safe drinking water to its people. It states "Drinking water needs of human beings and animals should be the first charge on available resources". For children, specifically, this right is also enshrined in article 24 of the convention on the rights of the child (CRD) ratified by the Government of India. It has been recommended that water be treated as not just as an `economic good' but as an `economic resource' which is essential for growth and development. But many aspects of the National Water Policy, legislation and regulations and the rights of children under the CRC have not been implementable in the Indian context for various reasons.

Water for irrigation is available as a `free' resource apart from its extraction costs, and while industry may be paying for water through a metering system, water is not treated as an `economic resource' whose price reflects its demand and supply in its competing uses. Ground water is considered a `free good', despite the fact that it comes from common pool aquifers. Subsidized water is often cornered by rich farmers who also cause long term aquifer damage due to excessive withdrawal by taking advantage of energy or water subsides intended for small farmers. The greatest pressure and the most serious impact is on availability of water for domestic uses which faces competition from irrigation and industry. The selling of water through water markets for irrigation has developed in parts of the country. There is, however, no effective regulatory mechanism to ensure ecological sustainability. Sustainable domestic water supply cannot be assured without at the same time addressing the inter-linked issues of water for irrigation, industry and ecosystem sustainability.

Market and state regulatory mechanisms which allocate water resources to competing uses agriculture, industry, domestic and ecosystem sustainability respond to different signals. The price of agricultural products, the major consumer of ground water, is a key determinant of the crops grown and the cropping pattern followed along with the soil, climate and water situation. However, partly because legal rights have been conferred to water which lies below an individual's land, and there has been no pricing of water, the cropping pattern does not take account of the cost of over-extraction. the issues in the case of industry are water tariffs based on usage, water pollution and recycling. Without an effective pricing and regulatory mechanism, the cost of water pollution may not be factored into the price of manufactured goods.

The fresh water problem in India, therefore, as suggested by existing analyses and policies, is that adequate quality fresh water is not available at an affordable cost in the right place at the right time for basic needs and ecosystem sustainability.

The problem is conceptualised further in terms of control and management issues. The fresh water resource from surface and ground water is physically available to each of the levels household/community, district, state, national and international. At the lowest level, a household, village or community has access to a well or surface water within its own boundaries, which is not shared with other levels. Water may also be obtained from an aquifer or surface source which is shared with other levels, from the household to the village/community, district, state, national and international levels. In these cases, if a household or community is using water from a shared aquifer, then the rate of extraction at each level will affect the level of availability at the other levels. Thus, concerns over water access may range from those of villagers in an isolated area, to people many kilometers .

The interlocking nature of concerns at different levels results in legal, institutional and economic issues which must be taken into account. While a household/community has control over a water resource wholly within its land, its ability to manage the resource varies as it is shared at successively higher levels. This has implications, for instance, for community management of water resources.

Conceptually, this also suggests that when designing actions, the shared nature of the resource must be taken into account. Although this would suggest that ground water should be regarded as a public good, the existing system of `water rights' and the grandfathering of the rights prevents the design of policies and programme along these lines alone. The fact that these rights has been conferred, and millions of ground water extraction structures created, that there is heavy reliance on ground water is a political look in India, all mean that the economics of water resource management in Indian will be quite complex. The conceptual framework itself suggests that actions will be required at different levels, household, village/community, district, state, national and international.

Thus the problem has to be addressed at all these levels. The integration of the issues of fresh water supply and demand and the water balance, technology, institutions, and the legal and socio-economic aspects at the local level have to be meshed into policies for water resource management.

Domestic Roof Water Harvesting (DRWH): How Relevant?

From the above discussions it is clear that all possible approaches must be tried to mitigate the immediate problem of drinking water, maximising the control of the households with regard to their own water security. Domestic roof water harvesting seems to be an appropriate option under these conditions provided it is cost effective. Infact traditionally this was the major option to the population in water scarce areas where the people had also learnt to control their demands, conserve water to the extent possible and manage to fulfil drinking and other domestic water needs, essentially by water harvesting. Given the ubiquitous contamination of not only surface but also ground water by pathogens and chemical contaminants induced by population growth, intensive agriculture and industrialization, DRWH has become more relevant than ever, even in areas which enjoy high rainfall. Infact these regions could be the best models for testing the feasibility of water security at affordable costs by DRWH. Fortunately the government is also supportive of propagation of DRWH. Water harvesting has been recognised as one of the appropriate technologies useful in different parts of the country (Ref. `Directory of Rural Technology', Volume 3, 1989. Drinking Water. Council for Advancement of People's Action and Rural Technology, New Delhi). A number of NGO's have shown interest in testing and propagating DRWH. In vies of this, the Indian partners of the current project on DRWH have taken up the study with special focus on Water Quality (WQ). In the subsequent chapters, the role of DRWH in international / national context is reviewed with focus on the WQ aspect.

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P.S.* Much of the above chapter has been adapted from reference number 1.

SECTION II
ROLE OF WATER HARVESTING IN INDIA

Introduction

Water harvesting is the deliberate collection and storage of rain water that runs off a natural or man made catchment surface. Catchments include roof tops, compounds rocky surfaces or hill slopes or artificially prepared impervious/semi-impervious land surfaces. Storage, on the other hand, may be done into tanks, lined pits, small dams or in the sandy beds of seasonal rivers. The `stores' are filled during rainfalls. Water users are thus left with a fixed volume of water until the next rain comes. The amount of water harvested (collected and stored) depends on the frequency and intensity of rainfall, the catchment characteristics and water demand and how quickly and how much runoff occurs (or conversely, how easy it is for the water to infiltrate through the surface to recharge the aquifer).

Water harvesting has been of particular importance in the arid and semi-arid regions and remote isolated habitations and in difficult terrains, where it may often provide the only feasible solution for an improved water supply. Hence in India, traditionally water harvesting technique had sustained in certain areas . For example, the type of water harvesting systems in different kinds of terrain's have been documented by Agarwal (Dying Wisdom, 1997).

Unfortunately traditional water harvesting techniques have been severely eroded. Modern attempts to restore them must reckon with the causes of their decline. Also since in the modern context, the problem of water scarcity (in terms of availability of uncontaminated water source) has become more wide spread and varied, the technology must be examined in the different eco-regions of India. The government of India has focussed on regions which suffer water scarcity, shortages or stress at some time during the year. The following have been identified as the main parameters which should be considered:

◊ Precipitation and topography
◊ Hydrological characteristics
◊ Geo-hydrological characteristics
◊ Level of industrialization
◊ Intensity of irrigation
◊ Level of urbanization

While combinations of these parameters can generate a wide range of situations, some broad generalization may be made. For example, India can be divided into several eco-regions which represent a broad range of situations where water resources are a major concern. These are:

- Arid and semi-arid regions in the west
- Rain shadow of the Western Ghats
- Drought prone regions
- Coastal regions
- Mountains and highlands
- Plains of the Ganges river
- Deserts
- Urban and metropolitan areas
- Other regions with severe chemical pollution

Realising importance of water related issues, various state governments as well as CAPART (Council for Advancement of People's Action and Rural Technology) and RGNDWM (Rajiv Gandhi National Drinking water Mission) have supported different projects on watershed management and RWH. Specifically DRWH has also been supported.S.E.R.C.(Structural Engneering Research Centre) has played a leading role in developing ferrocement technology and propagating this for building appropriate storage tanks. They have developed and commercialised a variety of techniques such as (I) Skeletal cage technique ,(II) SERC segmental casting technique and (III) Sac mould tecnique.

Dr.P. C. Sharma of SERC has also conducted several training programmes in South East Asia and India. However most of the Water Harvesting systems created by then are in the hilly areas of North and North eastern states.

However this technology has not been tested to a significant extent. A few leading NGO's and researchers have in the last 2-3 years, put up WH units on an experimental basis.(See Section iii). Keeping this in view in the current project, special attention has been paid to Kerala state which has good amount of biennial rain so that precipitation will not be a restricting factor. Rainfall pattern in Kerala is examined in the background of rainfall in India.

Rainfall Pattern in India

India (Fig. 2.1) has very good rainfall averaging around 1050 mm though it fluctuates widely over the country. Regions can be broadly classified according to rainfall figures: Desert (0-100 mm), Semi-desert (100-250), Arid (250-500 mm) and Semi-arid (500-750 mm) and medium-high rain fall areas (1000-3000 mm).

The coastal areas of the states receive high rainfall, decreasing over the interiors. The entire west coast covering the coastal areas of Maharashtra, Karnataka and Kerala receives annual rainfall of the order of 2500 mm. The rainfall increases all along the western ghats to 4000 mm. The rainfall decreases rapidly on the lee side of the western ghats over the plateau areas on the eastern side to about 500 mm. As we move further eastwards, the annual rainfall increases again to about 1000 mm along the eastern coast of Tamil Nadu and Andhra Pradesh. The states of Orissa, MP and coastal area of south Gujarat receive annual rainfall in the order of 1500 mm whereas the interior portion of Gujarat receives about 750 mm further decreasing to 400 mm over the extreme west. India's desert and arid regions are characterized by low and highly variable annual rainfall, strong variations in rainfall through space and time, high temperature and evaporation levels.

Under the current project, DRWH systems will be tried in state of Kerala (Fig. 2.1) as representative of humid tropics receiving a high annual rainfall.Therefore the variation in rainfall within the state of Kerala is discussed in detail. Representative sites will be selected based on both, rainfall and other considerations, for DRWH implementation in this state.

Rainfall over Kerala

Kerala which lies at the extreme southern parts of the peninsula is one of the smallest states in India. Through out the year Kerala receives rainfall, though the major rainy season is the South West monsoon period from June to September. The annual and seasonal distribution of rainfall is described briefly.

Climatology

Kerala occupies the portion of the subcontinent bounded by Lat. 8^o-13^oN and long. 75^o-77^oE. By physical features Kerala is divided into 3 natural divisions: (i) the low lands consisting of coastal areas, (ii) the middle land and (iii) the high land or the forest area of the Western Ghats on the eastern side. The extreme southern parts of the Ghats run along the eastern boarder of Kerala around 560 km in length.

The climate of the state is typical tropical monsoon with seasonally excessive rainfall and hot summer. There are basically 4 seasons (i) March to May the summer or pre-monsoon season, (ii) June to September the south west monsoon season (iii) October to December north east monsoon and (iv) January-February the winter season.

Rainfall

The annual rainfall in the state varies from 3800 mm in the north to 1800 mm in the extreme south. The annual average rainfall for Kerala is 3070 mm and the departure from this in different years is shown.(Table 2.1).

Seasonal Rainfall: South West Monsoon

The major rainfall season for Kerala is the south west monsoon period from June to September. The normal date of onset of south west monsoon is 1st June. During this period the average rainfall expected is 213o mm (Table 2.2) which constitutes 70% of the annual rainfall. This also varies from north to south, the variation being 85% in the north to 54% in south. The district wise normal rainfall during south west monsoon period is given in the tables (2.21-2.24). The captions in the tables are derived from the names of the district.

It can be seen that lowest rainfall during south west monsoon is being received in Thiruvananthapuram (TRV) district while the highest rainfall is in Wayanad (WYD) district. The annual highest average rainfall is in Kozhikode (KZK) district. The heavy falls during south west monsoon is due to the monsoon depressions which form over Bay of Bengal and Arabian Sea.

Next to the south west monsoon, the other principal rainy season is the northeast monsoon period which starts from October and ends with December. During this period Kerala receives 16% of its annual rainfall, i.e., 500 mm and there is a reversal in the order of rainfall activity from north to south. When the southern district receives around 600 mm of rain, only 350 mm of rain is received in the northern districts during this period.

During the summer period, i.e. March, April and May, Kerala receives 40 cm of rain which is 13% of the annual rainfall. This is mostly due to thuderstorm activity which is purely a local phenomenon.In winter season, i.e., January-February, only 1% of the annual rainfall is received. This amounts to only 3 cm of rain.

The state receives an annual rainfall of 307 cm which is much above the average rainfall (110 cm) for the entire country 86% of the total rain is being received during the two monsoon seasons, i.e., June to December. It may be noted that this rain water is the main source for the next 6 months, i.e., January-May for the different kinds of use in various activities. Any failure in the southwest monsoon or northeast monsoon will result in scarcity of water. This will also affect the availability of drinking water, electricity production and agriculture (see deviations in annual rainfall, Table 2.2). All efforts should therefore be made to plan and manage the use of water with utmost care so that even when the monsoon fails, water scarcity is not felt. Collection of rain water during the rainy season both for drinking and other purposes would hence be most useful.

In terms of water security, it may be that among the 35 Meteorological Sub-divisions in India, Kerala receives the maximum annual rainfall. Considering the area and population, around thirteen thousand liters of water is available per head per day out of which perhaps only one or two percent is sufficient for meeting the daily needs of a person. Thus water security in terms of quantity especially in the high rainfall areas of Kerala, is very good. This state is hence highly suitable for testing DRWH in terms of economic viability and water quality visa-vis other alternatives for at priding water.

Table 2.1: All India - Annual rainfall (cm) departure

1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
0	1	+10	-10	-3	+4	-25	-9	-14	-16
1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
-26	-24	-13	-13	-14	+1	+9	-8	+11	-7

Table 2.2: India State by State rainfall data

2.21: Southwest monsoon district wise rainfall (cm)

TRV	KLM	PTA	ALP	KTM	IDK	EKM	TSR	PLK	MLP	KZK	WYD	KNR	KSG
96	140	178	179	202	232	222	223	162	209	276	292	279	296

2.22: Northeast monsoon district wise rainfall (cm)

TRV	KLM	PTA	ALP	KTM	IDK	EKM	TSR	PLK	MLP	KZK	WYD	KNR	KSG
53	62	68	62	57	59	53	47	41	48	48	35	35	32

2.23: Summer (Pre-monsoon) district wise rainfall (cm)

TRV	KLM	PTA	ALP	KTM	IDK	EKM	TSR	PLK	MLP	KZK	WYD	KNR	KSG
39	48	61	50	49	45	49	41	27	33	41	31	32	29

2.24: Normal annual rainfall district wise (cm)

TRV	KLM	PTA	ALP	KTM	IDK	EKM	TSR	PLK	MLP	KZK	WYD	KNR	KSG
192	256	313	296	313	338	327	313	233	291	367	360	347	358

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SECTION III

`DRWH' AND WATER QUALITY: A DESK REVIEW

Background

Effectively a modern DRWH system has to take into consideration 4 aspects:

i. Technology – Maximising efficiency of collection and storage at minimal cost.
ii. Water quantity/water security.
iii. Water quality to meet the current standards for drinking water.
iv. Attitude of people, policy makers, planners/administrators.

Under the EC project, all the above are being studied each aspect being led by one of the partners. A study on WQM is lead by I.I.T., Delhi, with support from the University of Warwick.

Water quality is a very important issue. According to WHO, 80% of diseases are caused due to contaminated water. The major contaminants may be classified into biological and non-biological. The diseases related to some of these are listed in the table 3.1 and 3.2

The water quality standards recommended for drinking water by WHO and other similar bodies are stringent. The maximum permissible limits of various physico-chemical parameters defining water quality (WQ) are given in table 3.3-3.6 as prescribed by the Indian RGNDWM and WHO. Each country while generally following international standards may provide for slight deviations depending upon the agro-climate, availability of water resources, socio-cultural practices, water conservation rates etc.

In the developing countries biological contaminants arising from water pollution by faecal waste and excreta of various animals are prevalent and is a major cause for concern. On the other hand a variety of metal ions which are highly toxic originate from improper handling and discharging of industrial effluents. Contamination by salts, fluoride and arsenic of geo-chemical origin also occur due to changing pattern of water use, resulting from over exploitation of water resources. Pesticides and other agro-chemicals originate from adoption of intensive agriculture practices for high yielding varieties of crops. Fortunately in `RWH', by the very nature of water collection process, many of the contaminants are not expected to be present in the water. For example ,if water is collected directly from roof and stored above ground, bacterial contamination should be minimal or absent unless the roof is accessible to human and animals. Bird droppings can be an issue and have to be guarded against by not having perches such as trees, in the vicinity. Also storage under anaerobic condition is expected to check the proliferation of bacteria due to lack of air and nutrients, even if it has been introduced from the roof. Problems of bacterial contamination may arise in ground water storage if there are cracks in the lining and contaminated water leaks into it.

As for chemical contaminants, these may arise from a variety of materials with which the rain water comes into contact starting from the atmosphere. Rain water could dissolve gases and wash off chemicals from contacting dust particles and roof materials. It could dissolve the metals or derived chemicals. Elution of chemicals from the walls is also possible from the storage tank.

The Global Scenario

A review of DRWH literature reveals that out of the large number of papers published, only a few have reported on `WQ'. In the traditional system, generally WQM is not done systematically WQ seems to be accepted as long as the water doesn't cause any diseases and the looks and taste are satisfactory. In the modern context however, the physical parameters are measured in terms of pH, turbidity, colour, odour and TDS. In addition tests are made to quantify various biological and chemical contaminants. The available literature related to WQM from different continents and sub-continents is summarised below.

Africa

- J.E. Gould[3.1] has discussed bacteriological analysis (total coliform, faecal coliform and faecal streptococci) from roof tank water. Accepted water qualtiy standards of Botswana is also tabulated. Generally high quality of properly stored rainwater is seen.

  Periodic chlorination is the most economic solution as suggested by the author. However the factors which will determine whether a water source is used or not are more likely to be related to taste, colour and odour, rather than necessarily directly to quality as stated in the paper.
- Gould and McPherson[3.2] have described bacteriological analysis of water samples from 13 roof tanks and 8 ground catchment tanks in Botswana. The results show that rainwater collected from corrugated iron roofs and stored in covered tanks is of high quality compared with traditional water sources. Water from roof catchment systems in Botswana presents a serious health hazard.
- Mayo and Mashauri[3.3] have given the bacteriological (total and faecal coliform and faecal streptococci), chemical (pH and total hardness) and physical (turbidity & colour) analyses of water samples from rainwater cistern system at the University of Dar es Salaam in Tanzania between October, 1988 and December, 1989. The results showed that 86% of samples were free from faecal coliform. However, faecal streptococci were obtained in 53% of the samples and 45% of the samples tested for total coliforms were positive. About 54% of the consumers raised objections over the taste of water. The pH range was found out to be 9.3-11.7 which is above standard limits.
- Otieno[3.4], Kenya has established from a study that except for the initial rainfall, the quality of rainwater is quite high, comparing favourably with river waters. (He has tabulated comparison of rainwater from roof catchment with river water and WHO standards). Guidelines for prevention of cisterns have been described and the need for maintaining quality of the stored water is emphasized.
- Bambrah and Haq[3.5] have discussed the suitability of using untreated rainwater for human comsumption in Kenya. They have reviewed existing literature on rainwater quality in their country. Guidelines for drinking water quality and various physical and chemical treatments have been described for disinfecting the stored water.

Australia

- Ghafouri and Phillips[3.6] have tabulated water quality guidelines by NSW recycling coordination committee. WQ of stormwater from urban catchments has been given. They have mentioned that roof water is seen as one of the possible sources of collecting rain water.
- Most extensive study on quality aspects of water stored in domestic rainwater tanks has been given by Fuller et al[3.7]. For South Australia. Water samples from three different areas (Vineyard and Orchard areas: 7 cities), industrial areas: 4 cities, and residential areas: 2 cities) were collected which reflected conditions in water stored in domestic rain

water tanks through South Australia. Galvanised iron tanks within the range of 10,000 to 25,000 liter with closed tops were selected. Tanks which had catchments of unpainted galvanised iron were chosen. Also householders were aksed to answer a series of question regarding use and maintenance of their tanks. Microbiogiological parameters, heavy metals (Pb, Zinc, Cd), pesticides and other physico-chemical tests (temperature, pH, suspended solids, total dissolved solids and salinity). Results of the study are summarised:

i) Coliform bacteria: coliform bacteria were present in 12 of 41 tanks, up to 500 coliforms/100 ml were recorded.

ii) E. coli: E. coli was detected in 6 tanks 15% of 41 tanks levels up to 220 E. coli/100 ml were recorded.

iii) Plate counts gave an indication of the general level of microbiological contamination of water. Plate counts in most rainwater tanks were in excess of 1000/ml.

iv) Heavy metals:
   - Cadmium: One of the tanks reported relatively high cadmium concentration (0.018 mg/l). This could be a sampling error or contamination caused by an isolated event.
   - Lead: Concentrations of lead in rainwater from tanks in Port Pirie were significantly higher (0.061 & 0.072 mg/l) than other sites. This could be a result of dust from surroundings country sides washed from roof tops with each rainfall.
   - Zinc: Zinc concentrations were found to be excess of 15 mg/l

v) Pesticides were not detected in the majority of samples.

vi) Suspended solids: Concentrations were negligible in all samples.

vii) pH: range of pH values was 6.1 to 9.2 low. pH values can accelerate corrosion problems in domestic appliances while high pH is an indication of undesirable biological activity in the tank.

viii) T.D.S.: Only samples taken from 2 rainwater tanks had T.D.S. concentrations in excess of 100 mg/ml (caused by sea spray).

Europe

- Per Jacobsen[3.8] has tabulated concentrations of lead (0.1 mg/l) and Zinc (0.1-1.00 mg/l) exceeding the standards for drinking water in Denmark. Lead, Zinc, Cadmium and copper were estimated.
- Wilhelm Meemken[3.9] has tabulated quality of rain water collected from roofs in Germany. Chemical parameters included (Fe, Mn, Cu, Pb, Zn, pH, Ca, Mg, Na, K, NH_4^+, SO_4^{2-}, Cl^-, NO_3^-, NO_2^- and electrical conductivity. The table showed the rainwater collected from roofs could be used for flushing toilets, washing cloths and watering plants without special treatment.

Asia

- Appan[3.10] has described roof water collection systems in some southeast Asian countries (Thailand, Indonesia, The Philippines, Malaysia and Singapore).

  Thailand: Physico-chemical parameters (pH, colour, turbidity, iron, manganese, lead and cadmium) and bacteriological analysis (T. coli, F. coli) has been tabulated. In terms of physico-chemical parameters, more than 83% of the samples were satisfactory except for about 40% of the samples exceeding the allowable limits of lead. In terms of E. coli, more than about 76% of the samples had values exceeding the WHO guideline standards.

In another series of bacteriological tests conducted in three locations in Khon Kaen, 709 water samples were collected from tiled roofs and gutters, containers located in homes, jars and the point of consumption. In terms of the three coli groups, only 10% to 67% of the samples were within the WHO guideline values. Samples other than those collected from the container showed that, due to an FC/FS ratio of less than one, 79% to 82% of the contamination could have emanated from animal droppings. In the same study, only manganese (in 2-20% of the samples) and zinc (in 4-26% of samples) did not meet the guideline levels.

Indonesia: Although RWCS seem to have been practiced with extensive experimentation using different types of materials, there is practically no available information on the quality of collected water. It has been observed that some measures such as fish rearing within the tanks have been practised so as to keep the water clean.

The Philippines: In a study spread over a period of one year in three villages in the Province of Capiz involving 25 ferrocement tanks, it was shown that not less than 24% of the samples had T. coli exceedings the WHO guidelines values.

Malaysia: The quality of rainwater and roof runoff has been monitored and 72 samples were collected from two types of roofs in West Malaysia. The range of turbidity, lead and F. coli values far exceeded the WHO guidelines values. The pH value of rainwater also has a tendency to lie towards the lower range of the guideline values.

Singapore: Roof water was monitored from a high rise building in the Nanyang Technological University for six years from May 1989. The values appear to be acceptable in all the physico-chemical parameters except pH which is quite low. T. coli and F. coli values also exceed the guideline values. Earlier field investigations have also shown that, during January 1974 to July 1983, the range of pH in 11 monitoring stations distributed throughout Singapore was 4.8 to 5.5.

- Appan[3.11], in a case study on rainwater catchment systems has summarised data on quantity and quality of water for non-potable uses. Physico-chemical parameters (pH, colour, turbidity, salinity, TSS, TCC, TDS, oil and grease) of raw rainwater and treated water are tabulated. Rain water is effective for non-potable uses like flushing, cleaning, gardening etc.
- Xijing et al[3.12]. from China have analysed and assessed WQ of the catchment and storage rainwater physico-chemical testing result have been discussed. pH, Cu, Pb, Se, Zn, K, nitrites, total alkalinity have higher values in the rainwater contained in concrete water cellars with cement or grey tile catchment surfaces. The indices of As, Fe, Ca^{2+}, Mg^{2+}, total hardness have higher values in the rainwater contained in soil water cellars. Total coliform become fewer in rainwater contained in concrete cellars with tile surfaces. The author emphasized that the problem could be solved through changing the building materials of catchment surfaces and water cellars, improving hygienic conditions and taking some effective disinfectant measures.
- Kita and Kitamura[3.13] from Japan have described fluctuation in the quality of rainwater stored in container during storage. The results are:
  - pH & COD remains constant
  - NH_4 first increases then decreases and finally remains O mg/l
  - Color and turbidity remain constant
  - Results of coliform group of bacteria were positive throughout the periods.

- Feasibility of using roof rainwater catchment systems in West Bank (Palestine) as supplementary water source have been investigated by Sharekh[3.14] water quality issues and discussed. Physico-chemical and bacteriological test results tabulated have been (pH, Ec, TDH, Ca, Mg, Na, K, Cl, CO_3^-, HCO_3^-). It was found, rainwater stored in cisterns was used for drinking and domestic purposes. Level of total coliform contamination were found 27%>0 coliform. Concentration of major constituents well within the prescribed limits.
- Metals (Fe, Zn, Pb) concentration greatly exceeded the standards in a study of rainwater collected from roof tops in Japan (Tachi-kawa).

  In Chiyuda city (Japan), quality of 1^{st} flash of rainwater after a 11 day dry spell have been investigated physico-chemical (Fe, Cd, Cr, Cu, Mn, Ni, Pb, Zn) parameters tabulated initial rainfall upto 1.5 mm shows that the voluem of pollutants had accumulated on the roof for a 11 day dry spell.

  Nariyuki Fukano[3.15] (Japan) has discussed, prevention of mosquito breeding in rainwater storage tanks. As for rainwater storage tanks installed in large structures, mosquito breeding can be prevented by installing insect proof nets or other insect proof devices in vent routes. In home use tanks, water is always consumed and replenished, so rainwater does not stay in storage tanks for a long time. Therefore, even if insect eggs are mixed into tank water or a misquito enters into the tank and spawn eggs, there is virtually no likelihood of mosquito proliferation. Mosquitoes seem to breed easily in rainwater drainage pits that drain rainwater from roofs and the ground surface into sewers because many leaves tend to accumulate producing a condition conducive to mosquito breeding. To change conventional rainwater drainage pits to ones made to permeable material is a good solution to avoid mosquito problems, even if some cost is involved because the rainwater in permeable rainwater drainage pits infiltrates into the grouns so mosquito larvae cannot breed there.
- Water shortage in various regions in Japan is taken care by utilizing rainwater as an alternative as reported by Kitamura et al[3.16]. Although rainwater quality is acceptable, variations take place during storage.
  - Physico-chemical parameters studied for rainwater and ground water
  - No bacteriological studies were reported.
  - Stored rainwater pH were almost constant except for the last 3 weeks duration.
  - Turbidity varied during first two weeks
  - Ammonia nitrogen varied decreasing storage, which was probably caused by the bacterial activities. Bird droppings and insect carcasses were stored together with collected rainwater. It was a sanitary problem.
- When the alternative water source which had normal fluoride levels such as rainwater is adopted, the water borne disease/fluoride endemics can be controlled or possibly eradicated as reported by Bo-ling[3.17] in China. Investigation demonstrated the highest fluoride contents were in the well water. 24-40 mg/l while the lowest was in the rainwater: 0.78 mg/l.
- Physico-chemical quality along with bacteriological quality has been tanlated for 3 selected sites in Sri Lanka by Heijen and Mansur[3.18]. Color/turbidity are a bit higher than expected. Dirt on the roof and the non-application of a first flush device or a simple filter were the likely causes. E. coli count was consistant low, though 21% of samples shown 100 colonies/100 ml of total coliform.
- Hussain et al[3.19]. in the paper described RWCS, storage and purification practices in 3 locations. Also it described materials used in gutters, rainfall, method of collection,

maintenance and water use. Periodic cleaning of tanks and proper closure of the month of the storage container was desired. Water quality control was not often practiced. Few villagers tried to maintain quality of water due to fear of water borne disease. Biological, chemical, filtration and sedimentation were some of the methods for water quality control.

- National Water Supply and Drainage Board, Sri Lanka[3.20] has tabulated all chemical and bacteriological analysis (total coliform, E. coli and faecal striptococci) report. No chemical pollution has been found, bacterial contamination was there and the board recommended boiling of stored rainwater before consumption.

India

- Sh. P.K. Sivanandan[3.21] has reported chemical analysis of water sample from open wells in Adimalathura area, Kerala (Jan.-Feb., 99). 11 samples from all around villages were collected and chemical testing was done. Parameters studied were pH, EC, D.O., chloride, total hardness, Ca hardness, Mg, total alkalinity, bicarbonates and carbonates). Results indicated that chemical quality of water had potable status.
- Mitraniketan[3.22] (Kerala) in a project report tabulated rainwater analysis. Chemical parameters included pH, alklanity, chloride, iron, nitrate, nitrates, sulphate, total solids and hardness. Bacterial examination was also done. In a span from 10.6.98 to 26.7.98, the results revealed that the stored water had potable status.
- Ruchi[3.23] (Solan, Himachal Pradesh) stated that water quality was tested. Initially and was suitable for drinking purpose.

Conclusions

The literature on WQ generally has reported on pH , EC, turbidity, total hardness etc. However correlation of these with details on technology of water (type of roofing/guttering) and storage are missing. The methodology for valuation of WQ is also missing. Besides quality of water one of the other concern is insect breeding in DRWH. Mosquito breeding would be a health hazard. Hardly any data related to this is available. To collect more authentic details of WQ, a survey format has been designed by IIT Delhi and will be administered in different parts of the country. Based on limited data is seen that generally metal ions and other chemical contaminants are reported. The survey is designed to get data for correlating WQ with DRWH design parameters based on which optional designs could emerge.

In Indian context, list of key organiszations/institutions who are working in DRWH area have been collected (Appendix 3). Only a few of these however have done WQM. In the next phase of the work, it is proposed to cover WQ of all organisations who are working in Kerala and a few from other states for comparison.

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Table 3.1: Water based disease transmission and preventive strategies

Classification	Transmission	Examples	Preventive strategies
Water-borne (water-borne diseases can also be water-washed	Disease is transmitted by ingestion	• Diarrhoeas (e.g. cholera) • Enteric fevers (e.g. typhoid) • Hepatitis A	• Improve quality of drinking water • Prevent casual use of other unimproved sources • Improve sanitation
Water-washed (water scarce)	Transmission is reduced with an increase in water quantity: • Infections of the intestinal tract • Skin or eye infections • Infections caused by lice or mites	• Diarrhoeas (e.g. amoebic dysentery) • Trachoma • Scabies	• Increase water quantity • Improve accessibility and reliability of domestic water supply • Improve hygiene • Improve sanitation
Water-based	The pathogen spends part of its life cycle in an animal which is water-based. The pathogen is transmitted by ingestion or by penetration of the skin.	• Guinea worm • Schistosomiasis	• Decrease need for contact with infected water • Control vector host populations • Improve quality of the water (for some types) • Improve sanitation (for some types)
Insect-vector	Spread by insects that breed or bite near water	• Malaria • River blindness	• Improve surface-water management • Destroy insects' breeding sites • Decrease need to visit breeding sites of insects • Use mosquito netting • Use insecticides

Ref.: Waterlines. "Technical Brief No. 52: Water: Quality or quantity", Vol. 15, No. 4, April 1997

Table 3.2: Pathogenic micro-organisms in water

Bacteria	Disease
Salmonella typhi	Typhoid fever
Salmonella enteritidis	Gastroenteritis
Shigella dysenteriae	Dysentery
Vibrio cholerae	Cholera
Escherichia coli	Gastroenteritis
Leptospira icterohaemorrhzgicae	Leptospirosis (Weil's disease)
Mycobacterium tuberculosis	Tuberculosis
Legionella pneumophila	Legionellosis (Legionnaives disease)
Viruses	
Hepatitis A virus	Infectious hepatitis
Polio virus	Infantile paralysis, poliomyelitis
Enteroviruses	Gastroenteritis
Protozoa	
Giarodia lamblia	Giardiosis
Entamoeba histolytica	Amoebioses

Reference: Otto F. Joklik, Potabilization of Rainwater (Austria). 7th International Rainwater Catchment System Conference, June 21-25, 1995, China, page 33-47.

Table 3.3 : WHO Guidelines for Drinking Water (1984)

Parameter	Guideline value*
Colour (TCU)	15
Turbidity (NTU)	5
PH	6.5-8.5
Hardness (as $CaCO_3$)	500
Iron	0.3
Manganese	0.3
Sulphate	400
Chloride	250
Total Dissolved Solids	1000
Nitrate	10
Arsenic	0.05
Cadmium	0.005
Chromium	0.05
Cyanide	0.1
Fluoride	1.5
Lead	0.05
Mercury	0.001
Selenium	0.01
Zinc	5
F. coli/100 ml	0
T. coli/100 ml	0

* Note: All units, except pH, in mg/l unless stated otherwise

Table 3.4: WHO Guidelines for Drinking Water Constituents
Microbiological and Biological Quality

Organism	**Unit**	**Guideline value**	**Remarks**
I. MICROBIOLOGICAL QUALITY A. Piped water supplies A1 Treated water entering the distribution system			
Faecal coliforms	Number/100 ml	0	Turbidity 1 NTU: for disinfection with chlorine pH preferably 8.0: free chlorine residual 0.2-0.5 mg/litre following 30 minutes contact
A2 Untreated water entering the distribution system			
Faecal coliforms Coliform organisms	Number/100 ml Number/100 ml	0 0	 In 98% of samples examined throughout the year in the case of large supplies when sufficient samples are examined
Coliform organisms	Number/100 ml	3	In an occasional sample, but not in consecutive samples
A3 Water in the distribution system			
Faecal coliforms Coliform organisms	Number/100 ml Number/100 ml	0 0	 In 95% samples examined throughout the year in the case of large supplies when sufficient samples are examined.
Coliform organisms	Number/100 ml	3	In an occasional sample, but not in consecutive samples
B. Unpiped water supplies			
Faecal coliforms Coliform organisms	Number/100 ml Number/100 ml	0 0	 Should not occur repeatedly if occurrence is frequent and if sanitary protection cannot be improved an alternative source must be found if possible.
C. Bottled drinking water			
Faecal coliforms Coliform organisms	Number/100 ml Number/100 ml	0 0	Source should be free from faecal contamination
D. Emergency water supplies			
Faecal coliforms failure Coliform organisms Enteric viruses	Number/100 ml Number/100 ml	0 0	Advise public to boil water in case of to meet guideline values
II. BIOLOGICAL QUALITY			
Protozoa (pathogenic) Helminths (pathogenic) Free living organisms (algae others)		Do Do	 Do

Table 3.5: Tentative Limits for Toxic Substances in Drinking Water

Substance	Upper limit of concentration (Mg/l)	Methods of estimation
Arsenic (as As)	0.05	• Polarographic estimation • Atomic absorption spectrophotometric method • Use of Gutzeit generator
Cadmium (as Cd)	0.01	Dithizone method
Cyanide (as CN)	0.05	Can be estimated by means of a number of methods of which the following are generally in use and are equally satisfactory. • Titration with silver nitrate in dilute ammoniacal solution using diphenyl carbazide as an absorption indicator • Colorimetric method: Conversion of cyanide to either cyanogen chloride or cyanogen bromide & coupling with a suitable aromatic amino compound, such as dimodone, pyrozikine or sulfanilie acid • Colorimetric method: Yellow ammonium sulfide converts cyanide to thiocyanate in slightly alkaline solution: the thiocyanate reacts quantitatively with ferrie iron to form coloured ferric thiocyanate
Lead (as Pb)	0.1	• Polarographic estimation • Atomic absorption spectrophotometric method • Calorimetric methods
Mercury (as Hg)	0.001	• Neutron activation analysis • Atomic absorption
Selenium (as Se)	0.01	Colorimetric method using gum arabic solution, hydroxylamine hydrochloride sulphur dioxide and concentrated hydrobromic acid

Table 3.6: Specifications for Drinking Water (RGNDWM)

S.No.	Characteristics	Maximum permissible limits	Adverse effects beyond permissible limits	Alternative extended limits if no toxicity confirmed
1.	Colour (Hazen units)	10	Consumer acceptance decreases	50
2.	Odor	Unobjectionable	-	-
3.	Taste	Agreeable	-	-
4.	Turbidity (NTU)	10	Consumer acceptance decreases	25
5.	T.D.S. (mg/1)	500	• Palatability decreases • May cause g-i irritations	3000 (WHO limits: 4500)
6.	PH value	6.5 to 8.5	Mucous membrane affect	9.2
7.	Total hardness as $CaCO_3$ (mg/1)	300	Encrustation and adverse effect on domestic use	600
8.	Calcium as Ca (mg/1)	75	Do	200
9.	Magnesium as Mg (mg/1)	30	Do	100
10.	Copper as Cu (mg/1)	0.05	• Astrigent taste • Discoloration & corrosion of metalc parts	1.5
11.	Iron as Fe (mg/1)	0.3	• Taste/appearamce affect • Promotes iron bacteria	1.0
12.	Manganese as Mn (mg/1)	0.1	Taste/appearance affected	0.5
13.	Chlorides as Cl (mg/1)	250	• Taste/palatability reduces • Corrosion increases	1000
14.	Sulphates as SO (mg/1)	150	Gastro-intestinal irritations when Mg or Na present	400 (provided Mg does not exceed 30)
15.	Nitrate as NO (mg/1)	45	Methnaemoglobinemia takes place	No relaxation
16.	Fluoride as F (mg/1)	0.6-1.2	• Low fluoride are linked with dental care • Above 1.5 fluorosis	1.5
17.	Phenolic compounds as C H OH (mg/1)	0.001	Objectionable taste and odour	0.002
18.	Mercury as Hg (mg/1)	0.001	Toxicity increases	No relaxation
19.	Cadmium as Cd (mg/1)	0.01	Do	Do
20.	Selenium as Se (mg/1)	0.01	Do	Do
21.	Arsenic as As (mg/1)	0.05	Do	Do
22.	Cyanide as CN (mg/1)	0.05	Water becomes toxic	Do
23.	Lead as Pb (mg/1)	0.1	Do	Do
24.	Zinc as Zn (mg/1)	5	• Astrigent taste • Opalescence	15
25.	Anionic detergents as MBAS (mg/1)	0.2	Frothing in water	1
26.	Chromium as Cr^{6+} (mg/1)	0.05	Carcinogenic	No relexation
27.	Polynuclear aromatic hydro-carbons as PAH (µ g/l)	-	Do	-
28.	Mineral oil (mg/1)	0.01	Undesirable taste and odour	0.03
29.	Residual free chlorine (mg/1)	0.2 (minimum)	-	0.5 For protection against viral infectn

Source: Indian Standard Specifications for Drinking Water, IS: 10500, 1983

Appendix - 3

Key Institutions/Organisations Working on `DRWH' in India

1) Uttarakhand Jan Jagriti Sansthan
Khadi, P.O. Jajal, Distt. Tehri Garhwal, U.P.-249175, India

2) Dr. SunderLal, Director
Social Centre for Rural Initiative & Advancement
Khori-123101, Distt. Rewari, Haryana, India
Ph: 01274-86625, 86652

3) Rural Centre for Human Interests (RUCHI)
Technology Complex, Bandh, P.O. Bhaguri Via Patla
Distt. Solan, Himachal Pradesh-173233, India
Ph: 91-1792-82454, 83732; Telefax: 91-1792-72649, 82516

4) Society for Integral Development Action
Koovally, Distt. Kottayam, Kerala-686518, India

5) Comprehensive Area Development Service
5/2, R.B.C. Road, P.O. Naihati, Distt. 24 Parganas-North, West Bengal-743165, India
Ph: 581-3073, 3341

6) Sh. Ramani, Dy. Manager (MM)
ONGC
Southern Regional Business Centre, CMDA Building, 9th Floor (E)
8, Gandhi Irwin Road, Egmore, Chennai-600008, India

7) Dr. Y.M. Kool/B.R. Singh/S.K. Pande
Studies on some effective rainwater harvesting systems
Plateu, Madhya Pradesh, India

8) Water & Land Management Institute
P.B.-538, Ravishankar Nagar, Bhopal-462016, M.P., India

9) Sh. R.N. Saran, Dean
College of Agriculture
Indore-452001, M.P., India

10) Mr. Rakesh Agarwal
`SAHAYOG' (Sahayog Society for Participatory Rural Development)
Prem Kuti, Pokharkhali, Almora, U.P., India Ph: 91-5962-22389

11) Sh. N. Kamalamurra
Gandhi Gram Rural Institute (Deemed University)
Gandhi Gram-624302, Tamil Nadu, India (1992)
(Technology for Rural Development, Series-4, Rain Water Harvesting)

12) Elements of Rainwater Harvesting
Centre of Science for Villages
Magan Sangrahalaya, Wardha-442002, India (1992)

13) Chennai Metropolitan Water Supply & Sewerage Board
No. 1, Pumping Station Road
Chintradripet, Chennai-600002, India

14) Sh. Shiv Kumar, Agriculture Engineer
JRD Tata Institute
M.S. Swaminathan Research Foundation
III Cross, Taramani, Chennai-600113, India

15) Dr.(Mrs.) Nirmala Raghunath
Scientist `C'
Environment Studies Division
CWRDM, Kunnamangalam
Calicut-673571, Kerala

16) Mrs. Jesintha Prosper, Manager
Centre for Appropriate Technology
5, Chidambaranathan Colony
Ramavarmapuram, Nagar Coil-629001, Tamil Nadu, India

17) Mrs. Sarawam, Field Coordinator
Women Empowerment Programme (WEP)
KSSS Community Health Development Programme
Thirumalai Ashram Social Centre
Chunkankadai-629807, Tamil Nadu, India

18) Sh. Vinay Mahajan/Sh. Charul Bharwada
Garage, 65, Brahman Mitra Mandal Society
Ellisbridge, Ahmedabad-380006, India

Sandarbh Studies & Interventions, Ahmedabad
Drying Water Traditions: Traditional Water Systems- Their use, status and decline in Kutch, Gujarat

19) MITRANIKETAN
Velland, Thiruvananthapuram-695543, Kerala, India
Ph: 0472-882045, 882680, Fax: 0472-882015

20) Dr. P.C. Sharma, Head
Material Science Division, Structural Engineering Research Centre (SERC)
(A constituent unit of CSIR)
Sector-19, Central Govt., Enclave, Kamla Nehru Nagar, P.O. No. 10,
Ghaziabad-201001 (U.P.), India
Ph: 0575-721884 (O) 0575-793082, 793102 ®

21) Centre for Science and Environment (CSE)
41, Tughlakabad Institutional Area, New Delhi-110062
Ph: 6983394, 6986399; Fax: 91-11-6985879, 6980870

22) Mr. Mihir Bhatt, Director,
Disaster Mitigation Institute
411, Sakar Five, Near Natraj Cinema, Ashram Road, Ahmedabad-388009, India
Tel: 79-6586234/6583607; Fax: 79-6582962

SECTION – IV

WATER QUALITY MONITORING TECHNIQUES

Introduction

In the earlier chapter, parameters to be tested for WQM in DRWH were listed. Elaborate testing requires appropriate instrumentation and availability of a variety of chemicals. Further requisite skills may be called for. All this contributes to high cost of water testing. It may not be feasible to conduct such elaborate tests especially at the field levels, which may be located in remote locations. In view of this, a number of rapid testing methods have been evolved and standardized against the more elaborate testing procedures. Also in many countries, a set of tests are made available as a package in a compact field kit along with manual of instructions which can be followed easily by field level personnel. While less accurate than elaborate laboratory tests, these rapid tests are adequate to monitor whether the value of a given parameter exceeds acceptable limits. If rapid tests indicate unacceptable values for WQ, further tests and in depth studies can be recommended for immediate corrective action.

It may however be noted that basic principles involved in the rapid and elaborate tests may be the same. Hence the general principles and procedures for each of the WQ parameters are discussed below to help the user conduct the tests with an understanding of the processes involved. This will also help the user in taking proper precautions while conducting the tests.

A. TESTING OF CHEMICAL CONTAMINANTS

4.1) **Turbidity (Suspended solids)**

As the rain water falls on the roof, it may pick up fine dust particles. These will get washed down into the storage tank in the first flush. With suitable filters and appropriate mechanisms for rejecting the first flush, the water should be without suspensions. However in case the fine particles are of colloidal dimensions they will still persist and the water could thus appear turbid.

Turbidity can be measured by a Nepherometer.

Principle: This method is based on a comparison of the intensity of light scattered under the defined conditions with the intensity of light scattered by a standard reference suspension under the same conditions.

4.2) **Total Dissolved Solids (TDS)**

Water, a polar solvent has the capacity to dissolve ionic components from materials it contacts. In DRWH, as water contacts the roofs, gutters and inner walls of the storage structure, it may dissolve metallic salts and polar organic compounds if present in the environment.

Total dissolved solids can be measured by evaporating the water from an aliquot of water sample and weighing the residue.

Procedure: Measured volume of well mixed sample is filtered through glass fiber filter. It is washed with three successive 10 ml volumes of distilled water, complete drainage between washing is allowed and suction is continued for about 3 min after filtration is complete. Filtrate is then transferred to a weighed evaporating dish and is evaporated to dryness on a steam bath (if filtrate volume exceeds dish capacity successive portions are added to the same dish after evaporation). It is dried for at least 1 hour in an over at 180 ± 2^oC and cooled in a desiccator and weighed until a constant weight is obtained.

$$\text{Total dissolved solids in mg/1} = \frac{(A - B) \times 1000}{\text{Sample volume (ml)}}$$

Where,

A = weight of dried residue + dish (mg)

B = weight of dish (mg)

Ref. Richards (1954)

4.3) **Electrical Conductivity (EC)Measurements**

Electrical conductivity is commonly used for indicating the total concentration of ionic (salt) soluble constituents. It is closely related to the sum of the cations or anions as determined chemically and usually correlates closely with the total dissolved solids. It is a rapid and reasonably precise determination that does not alter or consume any of the sample. The apparatus for measuring electrical conductivity consists of an electrical resistance bridge and conductivity cell having electrodes coated with platinum black.

Reagents

Standard potassium chloride solutions: 0.7456 gm of dry reagent grade potassium chloride is dissolved in freshly prepared double distilled water and made to one liter. At 25^oC it gives an electrical conductivity (EC) of 1411.8×10^{-6} mhos/cm. The conductivity bridge is calibrated and cell constant is determined with the help of this solution.

Procedure: The measurement of EC (expressed in mmhos/cm) is adjusted for a known temperature (usually 25^oC) of the solution by setting up the knob provided for this purpose. The higher the salt concentration, the higher is the EC

Currently digital conductivity metres are also available. Just by dipping this in the water sample EC can be measured. The cost of an Indian meter of this kind is ~ Rs. 4,000. Many of the rapid testing kits have an EC meter incorporated which is calibrated to directly give the TDS.

4.4) **pH**

pH (the negative log 10 of hydrogen ion concentration in a solution) is a solution) is a useful parameter to indicate the presence of acidic or alkaline substances in water. The pH of water without contaminants is around 7 (neutral). If acids are present pH goes below 7 and with alkali it rises above 7. pH can be measured by colorimetric methods using various indicators. The indicators are chemical compounds which undergo change in color rapidly at a certain pH due to changes in their chemical structure. The indicators may be used in a solution and the colour change is seen using a colorimeter. For rapid tests the indicator may be mounted on paper strips.

For accurate measurement of pH, use of electrometric method employing hydrogen ion sensitive electrodes, in a pH meter is preferred.

Apparatus: There are number of makes and models of pH meters. Portable pH meters operated by battery are also available. The accuracy of pH measurement can vary from 0.01 to 0.1 depending on the make. Some pH meters employ two electrodes, an indicator glass electrode, and a calomel reference electrode, while other may have a combined glass and reference electrodes. Most pH meters also have a temperature compensation systems to avoid the differences arising due to the different temperatures.

Procedure: The pH meter is calibrated using suitable buffers whose pH is known. The water sample is taken in a beaker and the glass electrode is dipped into it. Equilibrium between electrode and sample is established by stirring the sample to ensure, homogeneity and pH meter reading is read after dipping the electrode into sample for one minute.

4.5) **Estimation of Calcium and Magnesium Ions (Total Hardness)**

Hard water contains calcium and magnesium ions and estimation of these are important for determining the hardness of water. In the context of DRWH, water samples may contain these ions eluted from walls of storage tank if made of cement or lined with compounds containing calcium like lime or mortar.

Titration with EDTA (Ethylenediamine Tetra Acetate) is a common method for estimation of these ions.

Reagents

A. Sodium hydroxide (0.1 N)

B. Standard calcium solution : Weighed 1.0 gm of anhydrous calcium carbonate into a 500 ml erlenmeyer flask. A funnel was placed in the flask neck and 1+1 HCl is added until all $CaCO_3$ gets dissolved. The volume is made upto 1 liter.

C. Erichrome black T indicator – 0.5 gm of Erichrome black T in 100 g triethanolamine.2 drops of indicator is added to per 50 ml solution to be titrated.

D. EDTA (Versenate) solution (0.01 M) – 3.723 gm of disodium dihydrogen ethylene-diamine-tetra-acetate is dissolved in water and diluted to 1 liter. The solution is standardized ($CaCl_2$), using titration procedure given below using indicator (Erichrome black).

E. Buffer solution : 16.9 g ammonium chloride (NH_4Cl) is added in 143 ml conc. ammonium hydroxide. 1.25 g of magnesium salt of EDTA is then added and the volume is made to 250 ml with distilled water.

Procedure:

Titration of sample:

25 ml sample is diluted to 50 ml with distilled water. 1-2 drops of buffer solution are added (to give a pH of 10.0). 1-2 drops of indicator solution are added and the solution is titrated with standard EDTA solution, with continuous stirring till the end point is reached. (blue color)

Calculation

$$\text{Hardness as mg } CaCO_3/l = \frac{A \times B \times 100}{\text{ml sample}}$$

Where,

A = ml titration for sample

B = mg $CaCO_3$ equivalent to 1.00 ml EDTA titrant

A x B x 400.8

Calcium as mg Ca/l = ----------------------
ml sample

A = ml titrant for sample
B = mg $CaCO_3$ equivalent to 1 ml EDTA titrant at the calcium indicator end point

Magnesium as mg/l
Total hardness (as mg $CaCO_3$) -Calcium hardness (as mg $CaCO_3$/l) x 0.244

4.6) **Chloride**

Determination of chloride is important where water is brackish. Normally in DRWH, the water is not expected to have chloride. However since chlorine is also used for water treatment, the method of estimation of chloride is included herein. One of the procedures involves titration of the chloride containing sample with silver nitrate using chromate as indicator. The method is discussed below.

Reagents

a) Potassium chromate indicator solution: 50 gm K_2CrO_4 is dissolved in little distilled water. $AgNO_3$ solution was added until a definite red precipitate is formed. It is allowed to stand for 12 hrs. Then it is filtered and diluted to 1 liter with distilled water.
b) Standard silver nitrate titrate (0.0141 N): 2.395 gm $AgNO_3$ in distilled water is diluted to 1000 ml. It is standardized against 0.0141 N NaCl (1.0 ml = 500 gm Cl). It is stored in a brown bottle.
c) Standard sodium chloride (0.0141 N): 824.0 mg NaCl (dried at 140^oC) is dissolved in distilled water and diluted to 1000 ml (1.00 ml = 500 μg Cl).
d) Special reagents for removal of interference:
   1. Aluminium hydroxide suspension – 125 gm aluminium potassium sulphate of aluminium ammonium sulphate, AIK $(SO_4)_2$. $12H_2O$ or $AlNH_4(SO_4)_2$. $12H_2O$ in 1 liter distilled water. It was warmed to 60^oC and 55 ml concentrated ammonium hydroxide (NH_4OH) are added slowly with stirring. It is allowed to stand for 1 hour and transferred to a large bottle. The precipitate is washed by successive additions, with thorough mixing and decanting with distilled water, until it is freed from chloride. When freshly prepared, the suspension occupies a volume of approximately 11.
   2. Phenolphthalein indicator solution
   3. Sodium hydroxide, NaOH, 1 N.
   4. Sulphuric acid, H_2SO_4, 1 N.
   5. Hydrogen peroxide, H_2O_2, 30%.

Procedure

a) Sample preparation: Suitable portion of the sample is diluted to 100 ml. [If found coloured, 3 ml $Al(OH)_3$ is added to the sample, and the suspension formed is allowed to settle and filtered. If sulphide, sulphite or thisulphate is present, 1 ml H_2O_2 is added and stirred for 1 min.

b) Titration: Samples are directly titrated in the pH range 7 to 10. The pH of sample is adjusted to 7 to 10 with H_2SO_4 or NaOH, if it was not in this range. 1.0 ml $K_2Cr_2O_4$ indicator solution was added and titrated with $AgNO_3$ titrant to a pinkish yellow end point.

$AgNO_3$ titrant is standardized and reagent blank value was obtained by titration. Calculation is outlined below.

Calculation

$$\text{mg } Cl^-/l = \frac{(A - B) \times N \times 35450}{\text{ml sample}}$$

where,

A = ml titration for a sample
B = ml titration for blank, and
N = normality of $AgNO_3$
mg NaCl/l = (mg Cl^-/ L)x 1.65

4.7) **Nitrate**

Nitrates from decomposition of organic residues may reach ground water. Rain may normally be free of nitrate unless there is a high level of oxides of nitrogen in the atmosphere and rainwater dissolves it. The spectrophotometric method for measurement of NO^-_3 is discussed below.

Principle: Measurement of UV absorption at 220 nm enables rapid determination of NO^-_3. The NO^-_3 calibration curve follows beers law up to 11 mg/ml.

Reagent

Nitrate free water
Stock nitrate solution of KNO_3 (100 ppm) standard nitrate solution is diluted (50 ml stock solution made to 500 ml with water (10 ppm).
HCl soln (IN)

Procedure: Prepare NO^-_3 calibration standards in the range of 6-7 ppm by diluting the standard solution. Add 1 ml of HCl solution and mix thoroughly. Read absorbance against distilled water set at zero absorbance at 220 nm.

4.8) **Fluoride**

Normally fluoride is not expected to be present in rain water. Occurrence of F^- however depending on the level of industrialization and contamination has been reported under certain conditions. The method of measurement is discussed below:

Flouride (F^-) SPADNS method (spectrophotometric)

The reaction rate between flouride and ions is influenced greatly by the acidity of the reaction by increasing the proportion of acid in the reagent the reaction can be made practically instantaneous.
Reagent – Standard flouride solution of NaF (1000 ppm)
SPADNS solution dissolved 958 mg SPADNS sodium 2- (parasulfolthenylzao)- 1,8 dehydromy 3, 6 naphthalene disulfonate, the distilled H_2O and dilute to 500 ml

Zirconyl acid reagent dissolve 133 mg zirconyl chloride octohadrate, zrocl in about 25 ml distilled water. Add 350 ml Conc. HCl and dilute to 500 ml with distilled water.

Phenanthroline Method

Principle: Iron is brought into solution, reduced to the ferrous state by boiling with acid and hydroxylamine, and treated with 1,10-phenanthroline at pH 3.2 to 3.3. Three molecules of phenanthroline chelate each atom of ferrous iron to form an orange red complex. The colored solution obeys beer's law; its intensity is independent of pH from 3 to 9. A pH between 2.9 and 3.5 insures rapid color development in the presence of an excess of phemanthroline. Color standards are stable for at least 6 months.

Reagents

a) Hydrochloric acid, HCl, conc, containing less than 0.00005% iron.
b) Hydroxylamine solution: Dissolve 10 g NH_2OH HCl in 100 ml distilled water
c) Ammonium acetate buffer solution: Dissolve 250 g $NH_4C_2H_3O_2$ in 150 ml distilled. Add 700 ml conc (glacial) acetic acid. Because even a good grade of $NH_4C_2H_3O_2$ contains a significant amount of iron, prepare new reference new reference standards with each buffer preparation.
d) Sodium acetate solution: Dissolve 200 g $NaC_2H_3O_2$ $3H_2O$ in 800 ml distilled water.
e) Phenanthroline solution: Dissolve 100 mg 1,10-phenanthroline monohydrate, $C_{12}H_8N_2H_2O$, in 100 ml distilled water by stirring and heating to 80 C. Do not boil. Discard the solution if it darkness. Heating is unnecessary if 2 drops conc HCl are added to the distilled water. (Note: one milliliter of this reagent is sufficient for no more than 100 μg Fe.

Procedure

Preparation of calibration curves for samples analyzed in accordance with is below:
Range 0 to 100 μg Fe/100 ml final solution pipette 2.0, 4.0, 6.0, 8.0 and 10.0 ml standard iron solution [3 gl] into 100 ml volumetric flasks. Add 1.0 ml NH_2OH HCl solution and 1 ml sodium acetate solution to each flask. Dilute each to about 75 ml with distilled water, add 10 ml phenanthroline solution, dilute to volume, mix thoroughly and let stand for 10 min. Measure absorbance in a 5 cm cell at 510 nm against a reference blank prepared by treating distilled water with the specified amounts of all reagents except the standard iron solution.

Acid zirconyl-SPADNS reagent: Mix equal volumes of SPADNS solution and zirconyl-acid reagent.
Reference solution: Add 10 ml SPADNS solution to 100 ml distilled water. Dilute 7 ml conc HCl to 10 ml and add to the diluted SPADNS solution. The resulting solution, used for setting the instrument reference point (zero).

Procedure

Preparation of standard curve: Prepare fluoride standards in the range of 0 to 1.40 mg/l by diluting appropriate quantities of standard fluoride solution to 50 ml with distilled water. Pipet 5.00 ml each of SPADNS solution and zirconyl-acid reagent, or 10.00 ml mixed acid-zirconyl-SPADNS reagent, to each standard and mix well. Set photometer to zero absorbance with the reference solution and obtain absorbance readings of standards immediately. Plot a curve of the fluoride absorbance relationship.

Stannous Chloride Method

Principal: Molybdophosphoric acid is formed and reduced by stannous chloride to intensely colored molybdenum blue.

Reagents

1. Ammonium molybdate reagent I: Dissolve 25 g $(NH_4)_6Mo_7O_{24}$ $4H_2O$ in 175 ml distilled water. Cautiously add 280 ml conc H_2SO_4 to 400 ml distilled water. Cool, add molybdate solution, and dilute to 1l.
2. Stannous chloride reagent I: Dissolve 2.5 g fresh $SnCk_2 2H_2O$ in 100 ml glycerol. Heat in a water bath and stir with a glass rod to hasten dissolution. This reagent is stable and requires neither preservatives nor special storage.
3. Standard phosphate solution

Add with thorough mixing after each addition, 4.0 ml molybdate reagent 1 and 0.5 ml (10 drops) stannous chloride reagent 1. After 10 min, but before 12 min, using the same specific interval for all determinations, measure color photometrically at 690 nm and compare with a calibration curve, using a distilled water blank.

4.9) Estimation of Metal Ions

Metal ions could be eluted from the roof material. Generally toxic metal ions are not expected. The estimation of these can be done by titrimetry, atomic absorption spectrophotmetry etc. The methods are available in standard reference books.

Reference

1. Standard Methods for the examination of water and waste water (1995). 16th Edn. APHA, AWWA/WPCF.

B. **TESTING FOR BACTERIAL CONTAMINANTS**

If rain water gets infected by bacteria and conditions are conducive to their growth it will become unpotable. To ensure that the drinking water satisfies public health requirements, it is necessary that samples should be examined at regular intervals for indicator micro-organisms. Pathogenic organisms are difficult to monitor as the methodology involved is time consuming and highly involved.

Any indicator bacteria selected should be closely associated with source of pathogen. It should be able to provide an accurate estimate of the number of pathogens present at the levels which pose a health risk. It should have same survival characteristics of the most resistant pathogen and be measurable by simple methods with accuracy. It should occur in greater numbers than the intestinal pathogens concerned and should be more resistant to disinfectants and natural processes than the pathogens.

The recommended bacterial indicator is coliform group of organisms. Coliform group of organisms are not pathogenic, they are aerobic, facultatively anaerobic, gram negative, non-sporulating, rod shaped bacteria, that ferment lactose with gas formation and aldehyde/acid with in 48 hours at 35^{o}C inculation. Coliform are capable of growth in presence of bile salts or other surface active agents which are cytochrome oxidase negative. Coliform belongs to family Enterbacteriaceae which includes genera *Escherichia, Klebsiella, Salmonella, Shigella, Aerobacter, Scrratia, Citrobacter* and *Proteus*.

Coliform group (total coliform) are almost always present in large number in faeces of man and other warm blooded animals. They can be detected even after dilution. Detection of thermotolerant faecal coliform particularly presence *Escherichia coli* one of the members of the coliform group is considered specific faecal pollution. However unlike many others which are not thermotolerant *E. coli* groups grow well at 44.5^{o}C, i.e. they can ferment lactose and also mannitol at elevated temperatures with the production of acid and gas and form tryptophan. Confirmed *E. coli* indicates positive reaction to methyl red test (undergoing change in colour due to pH change) failure to produce acetyl methyl carbinol (V.P. test) and failure to utilize citrate as sole source of carbon. The four biochemicals tests popularly known as IMViC test give confirmation of E. coli (Table 1).

Table 4.1: Characteristic based on IMViC pattern

Organism	**Indole**	**Methyl Red**	**Voges Proskauer**	**Citrate**
Escherichia coli	+	+	-	-
Shigella sp	+ or -	+	-	-
Citrobacter freundii	-	+	-	+
Citrobacter diversus	+	+	-	+
Klebsiella,Enterobacter & Aerobacter group	+ or -	-	+	+

The presence of faecal coliform cannot definitely identify human contamination of water systems and this has led to the introduction of supplementary indicator organisms. Another important component of human microflora is faecal streptococci. A group that includes all streptococci found in the intestine of warm blooded animals. The group `D' streptococci known as Enterococci includes *Streptococcus bovis*, Streptococcus equines and *Streptococcus* *fecalis*. Faecal Streptococcus and sulfile reducing *Clostridia* are useful in determining the origin of faecal pollution and also assessing the efficiency of water treatment process.

Ratio of faecal coliforms (FC) to faecal Streptococcus (FS) (FC-FS ratio).

Human population has a much higher ratio of FC-FS usually in excess of 4.0 whereas other warm blooded animals has FC-FS ratio less than 0.7. This kind of ratio can indicate as to whether contaminant in a water sample is of human origin or not.

Sample Collection, Storage and Transport

Samples should not be taken from leaking taps as there is possibility of external contamination. Water should run for 1 minute to ensure stagnant water is flushed from the pipes before sample is collected. It is desirable to flame the mouth of the tap before sampling.

Containers for sample should be clean, sterile, glass or autoclavable plastic bottles containing 0.1 ml of a 1.8% solution of sodium thiosulphate per 100 ml of sample bottle capacity to neutralize residual chlorine if chlorination has been done. Samples should be kept cool at 4-10^{o}C and transported to the laboratory within 6 hours of collection but never >24 hours.

Methodology for Coliform Detection

1) IMViC reaction
2) Multiple tube method or most probable number method (MPN)
3) Membrane filtration (MF) technique
4) Simple field test for detection of faecal pollution in drinking water (H_2S strip test).

1. **IMViC reaction**
1. Indole Test
    a. Reagents:
    1) Medium – Tryptophane broth
    2) Test reagent – Dissolves 5 g para-dimethyl-aminobenzaldehyde in 75 ml isoamyl (or normal amyl) alcohol. ACS grade and add 25 ml conc HCl. The reagent should be yellow. The amyl alcohol solution should have a pH value of less than 6.0.
    b. Procedure : Inoculate 5 ml portions of medium from a pure culture and incubate at 35$\pm$0.5 C for 24$\pm$2 hr. Add 0.2 to 0.3 ml test reagent and shake. Let stand for about 10 min and observe results.
    A dark red color in the amyl alcohol surface layer constitutes a positive indole test, the original color of the reagent, a negative test. An orange color probably indicates the presence of skatole.

2. Methyl Red Test
    a. Reagents:
    1) Medium: buffered glucose broth
    2) Indicator solution: Dissolve 0.1 g methyl red in 300 ml 95% ethyl alcohol and dilute to 500 ml with distilled water.
    b. Procedure: Inoculate 10 ml portions of medium from a pure culture. Incubate at 35^{o}C for 5 days. To 5 ml of the culture add 5 drops methyl red indicator solution.

Record a distinct red color as methyl red positive and a distinct yellow color as methyl red negative. Record a mixed shade as questionable and possibly indicative of incomplete culture purification.

3. Voges-Proskauer Test
   a. Reagents:
   1) Naphthol solution: Dissolve 5 g purified ∝-naphthol (melting point 92.5°C or higher) in 100 ml absolute ethyl alcohol. When stored at 5 to 10°C, this solution is stable for 2 week.
   3) Potassium hydroxide, 7N: Dissolve 40 kg KOH in 100 ml distilled water.
   b. Procedure: Separate 5 ml of the culture inoculated for methyl red test after 48 hr or inoculate 5 ml of salt peptone glucose medium from a pure culture and incubate for 48 hr at 35±0.5°C. To 5 ml of culture add 3 ml naphthol solution and 1 ml KOH solution, and shake vigorously. Development of a pink to crimson color within 15 min to 1 hr constitutes a positive test.
4. Sodium Citrate Test
   a. Alternate media: Use either Koser's citrate broth or Simmons' citrate agar.
   b. Procedure:
   1) Lightly inoculate liquid medium with a straight needle, never with a pipette. Incubate at 35±0.5°C for 72 to 96 hr. Record visible growth as positive, no growth as negative.
   2) Inoculate agar medium with straight needle, using both a stab and a streak. Incubate 48 hr at 35±0.5°C. Record growth on the medium with (usually) a blue color as a positive reaction, record absence of growth as negative.

2. Multiple tube method or Most Probable Number Method (MPN) for standard total coliform (Table 4.2)

(1) Measured volumes of the samples of one or more dilutions are inoculated into a series of bottles or tubes containing suitable differential medium containing lactose. The tube should have inverted Durham tubes. After incubation at 35 or 37°C for 48 hours tubes are examined for acid and gas production. Positive reaction is only presumptive as in addition to coliform other lactose fermenters also grow and produce acid and/or gas.

- This should be followed by confirmatory tests using selective differential media

- MPN method is a statistical estimate of most probable number of coliform in a given volume of sample.
- Sub-cultures made from positive tubes can be used for differentiation of coliforms.

1. Presumptive test
   Use Mac Conkey Broth in the presumptive test
   a. Procedure: Take 10 ml of Mac Conkey broth in fermentation tubes, add inverted durham tubes, plug and autoclave.
   1) Inoculate a series of fermentation tubes ("primary" fermentation tubes) with appropriate graduated quantities (multiples and submultiples of 1 ml) of sample. If 100 ml sample portions are used prewarm bottles at 35°C. After adding sample mix thoroughly.
   2) Incubate inoculated fermentation tubes at 35±0.5°C. After 24±2 hr shake each tube gently and examine it and if no gas has formed or been trapped in the inverted

vial, re-incubate and reexamine at the end of 48 ± 3 hr. Record presence or absence of gas formation regardless of amount at each examination of the tubes.

b. Interpretation: Formation of gas in any amount in the inner fermentation tubes or vials within 48+3 hr constitutes a positive presumptive test.

2. <u>Confirmed Test</u>

Use brilliant green lactose bile broth fermentation tubes for the confirmed test.

a. Procedure: Submit all primary fermentation tubes showing any amount of gas within 24 hr of incubation to the confirmed test. If active fermentation appears in the primary fermentation tube earlier than 24 hr preferably transfer to the confirmatory medium. If additional primary fermentation tubes show gas production at the end of 48 hr incubation, submit these to the confirmed test.

b. Procedure with brilliant green lactose bile broth: Gently shake or rotate primary fermentation tube showing gas and with a sterile metal loop, transfer one loopful of culture to a fermentation tube containing brilliant green lactose bile broth.

Incubate the inoculated brilliant green lactose bile broth tube for 48 ± 3 hr at 35 ± 0.5^{o}C. Formation of gas in any amount in the inverted vial of the brilliant green lactose bile broth fermentation tube at any time within 48 ± 3 hr constitutes a positive confirmed test.

3. <u>Completed Test</u>

Use the completed test on positive confirmed tubes to establish definitively the presence of coliform bacteria and to provide quality control data. Double confirmation into brilliant green lactose bile broth for total coliforms and EC broth for fecal coliforms may be used. Consider positive EC broth results as a positive completed test response.

a. Procedure:

1) Streak one or more eosin methylene blue plates from each tube of brilliant green lactose bile broth showing gas, as soon as possible after the appearance of gas. Incubate plates (inverted) at 35 ± 0.5^{o}C for 24 ± 2 hr.

2) The colonies developing on eosin methylene blue agar are called typical (nucleated with or without metallic sheen); atypical (opaque, unnucleated, mucoid, pink after 24 hr incubation), or negative (all others). Pick two or more colonies considered most likely to consists of organisms of the coliform group and transfer growth from each isolate to a lauryl tryptose broth fermentation tube and to a nutrient agar slant.

Incubate secondary broth tubes at 35 ± 0.5^{o}C for 24 ± 2 hr, if gas is not produced within 24 ± 2 hr reincubate and examine again at 48 ± 3 hr. Microscopically examine gram-stained preparations from those 24 hr agar slant cultures corresponding to the secondary tubes that show gas.

b. Interpretation: Formation of gas in the secondary tube of lauryl tryptose broth within 48 ± 3 hr and demonstration of gram negative, nonspore-forming, rod-shaped bacteria in the agar culture constitute a satisfactory completed test, demonstrating the presence of a member of the coliform group.

The sequence of tests for coliform for deciding on bacterial contamination in water are summarised in the flow chart.

Detection of coliform in water

Presumptive test

Inoculation of Mac Conkey Broth

Gas produced = Presumptive evidence of Coliform present

No gas = Coliform not present
Examination stops here

Confirmed Test

Brilliant green lactose bile broth (BGLB) this medium inhibits the growth of Lactose fermenters other than coliform, thus gas formation in the BGLB medium constitutes a confirmed test, i.e. Coliforms present

or

Eosin-methylene blue agar (EMB) (coli-aerogenes organism produce characteristic colonies; Escherichia, small colonies, dark, almost black centres with green metallic sheen; Enterobacter; large pinkish mucoid colonies, dark centres, rarely show metallic sheen; presence of typical colonies constitutes a confirmed test, i.e., coliforms present)

Completed test

The most typical colonies are selected from EMB plate or BGLB and are inoculated into

Lactose broth (coliforms produce gas)

Agar slant (Gram stain prepared from growth, coliforms are Gram-ve, non sporulating bacilli)

Table 4.2: For most probable number (MPN) index and 95% confidence limits for various combinations of positive results when five tubes are used per dilution (10 ml, 1.0 ml, 0.1 ml)

Combination of Positives	MPN Index/100 ml	95% Confidence Limits	
		Lower	Upper

0-0-0	<0	-	-
0-0-1	2	<0.5	7
0-1-0	2	<0.5	7
0-2-0	4	<0.5	11
1-0-0	2	<0.5	7
1-0-1	4	<0.5	11
1-1-0	4	<0.5	11
1-1-1	6	<0.5	15
1-2-0	6	<0.5	15
2-0-0	5	1	13
2-0-1	7	2	17
2-1-0	7	2	17
2-1-1	9	3	21
2-2-0	9	1	21
2-3-0	12	2	28
3-0-0	8	2	19
3-0-1	11	4	25
3-1-0	11	4	25
3-1-1	14	5	34
3-2-0	14	3	34
3-2-1	17	5	46
4-0-0	13	5	31
4-0-1	17	7	46
4-1-0	17	9	46
4-1-1	21	7	63
4-1-2	26	9	78
4-2-0	22	9	67
4-2-1	26	11	78
4-3-0	27	12	80
4-3-1	33	7	93
4-4-0	34	11	93
5-0-0	23	15	70
5-0-1	31	11	89
5-0-2	43	16	110
5-1-0	33	21	93
5-1-1	46	17	120
5-1-2	63	23	150
5-2-0	49	28	130
4-2-1	70	25	170
5-2-2	94	31	220
5-3-0	79	37	190
5-3-1	110	44	250
5-3-2	140	35	340
5-3-3	180	43	500
5-4-0	130	57	300
5-4-1	170	90	490
5-4-2	220	120	700
5-4-3	280	68	850
5-4-4	350	120	1,000
5-5-0	240	68	750
5-5-1	350	120	1,000
5-5-2	540	180	1,400
5-5-3	920	300	3,200
5-5-4	1,600	640	5,800
5-5-5	≥2,400	-	-

2. **Membrane Filtration Techniques (MF)**
Coliform organisms in water is determined by filtering known volume of the sample or appropriate dilution of it through porous cellulose acetate membrane, which is then incubated face upwards on suitable selective media in the absorption pads in the petri-dishes at 35-37^{o}C for 24-48 hours. Colonies that develop can be counted with the help of magnifying lens. Counts are expressed per 100 ml basis. It is usual to use 2 membranes for each sample, in order to incubate at 35-37^{o}C for total coliform and the other at 44.5^{o}C for faecal coliform.

Laboratory apparatus

Sample bottles, dilution bottles, pipettes and cylinders, containers for the culture medium, culture dishes, filteration units, filter membrances, absorbent, incubator, microscope

Procedure

Selection of sample is governed by expected bacterial density which in finished water samples will be limited only by the degree of turbidity.

Filteration of sample

Using sterile forceps, place a sterile filter over porous plate of receptacle, grid side up. Place matched funnel unit over receptacle and lock it in place. Filter sample under partial vacuum. With filter still in place, rinse funnel by filtering three 20-30 ml portions of sterile dilution water. Unlock and remove funnel, immediately remove filter with sterile forceps and place it on sterile pad or agar with a rolling motion to avoid entrapment of air. Use sterile filtration units at the beginning of each filtration series as a minimum precaution to avoid accidental contamination. A filtration series is considered to be interrupted when an interval of 30 minutes or longer elapses between sample filtrations. After such interruption, treat any further sample filtration as a new filtration series and sterilize all membrane filter holders in use. Decontaminate the equipment between filtrations by sterilization.

Enrichment technique

Place a sterile absorbent pad in the upper half of a sterile culture dish and pipette enough enrichment medium (1.8 to 2.0 ml lauryl tryplase broth) to saturate pad. Carefully remove any surplus liquid. Aseptically place filter through which the sample has been passed on pad. Incubate filter without inverting dish for 1.5 to 2 hr. at 35 ± 0.5^{o} C in an atmosphere of at least 90% relative humidity. Remove enrichment culture from incubator, lift filter from enrichment pad and roll out the agar surface. If the liquid medium is used, prepare final culture by removing enrichment culture from incubator & dish halves. Place a fresh sterile pad in bottom half of dish and saturate it with 1.8 to 2.0 ml. of final M-Endo medium. Transfer filter to new pad. Discard used pad with either agar on the liquid medium invert dish and incubate for 20-22 hr at 35 ± 0.5^{o}C.

Counting

Typtical coliform colony has a pink to dark red colour with a metallic surface sheen. The sheen area may vary in size from a small pinhead to complete coverage of colony. Count the colonies with colony counter

Calculation of coliform density:

$$\text{Total coliform colonies/100 ml} = \frac{\text{Coliform colonies counted x 100}}{\text{ml sample filtered}}$$

3. Simple field test for detection of faecal pollution in drinking water (H_2S strips)

The test is based on detection of hydrogen sulfide producing organisms in samples in water. It has been observed that coliform in drinking water is consistently associated with organisms that produce H_2S (*Salmonella, Proteus, Citrobacter* and same strains of *Klebsiella*)

Methodology: The method uses concentrated medium containing:

i)	Bacto peptone	20 g
ii)	Dipotassium hydrogen phosphate	1.5 gm
iii)	Ferric ammonium citrate	0.75 gm
iv)	Sodium thiosulphate	1.0 gm
v)	Teepol	1.0 ml
vi)	H_2O	50 ml

One ml of concentrated medium were absorbed on to 80 cm^2 folded tissue paper, which was placed in McCartney bottles sterilized and dried at 50^oC. The water samples to be screened for faecal pollution were placed in bottles up to pre-calibrated mark (20 ml) and allowed to stand at ambient temperatures (30-37^oC). Faecal pollution is indicated if the contents of the bottle turned black due to formation of iron sulfide in 12-18 hours.

H_2S producing organisms	Release H_2S + Fe	FeS
Coliforms in H_2O sample	During growth in medium that contain Ferric ammonium citrate	Black colour in the medium

The new test medium has good correlation with MPN test. The method is reliable and simple to perform.

Note: Recently UNICEF held a workshop on the efficacy of H_2S strip test and modifited methods to make it more rapid and accurate.

Tests for the faecal streptococcus group

Multiple tube technique

1. Presumptive test procedure

a. Take a series of test tubes containing 10 ml. Azide dextrose broth. Use 10 ml single strength broth for inocula of 1 ml or less and 10 ml double strength broth for 10 ml inocula

b. Incubate inoculated tubes at 35$\pm$0.5^oC. Examine each tube for turbidity at the end of 24$\pm$2 hrs. If no turbidity is present, reincubate and read against at the end of 48$\pm$3 hrs.

Confirmed test

Subject all azide dextrose broth tubes showing turbidity streak a portion of growth from each positive azide dextrose broth on a petridish containing PSE agar. Incubate the inverted dish at $35\pm0.5^{o}C$ for 24 ± 2 hr. Brownish black colonies with brown holes confirms the presence of *Faecal stretococci*.

Computing & recording of MPN as given in table 2.

C. TEST KITS AVAILABILITY AND DETAILS IN INDIA

For rapid testing kits have been developed by a number of Indian institutions and are being marketed. Also other countries have developed kits. Recently the Central Pollution Control Board (CPCB), Delhi and the Sriram Institute for Industrial Research, Delhi have conducted a comparative evaluation of various water testing kit packages available in India. Some manufacturers names and address are listed below . References on major reports concerning WQ monitoring are also listed.

Details of selected Water Quality Kits: Availability in India

1.	Developed by	:	Defence Laboratory, Jodhpur
	Method of Analysis	:	Qualitative, visual colour comparison
	Parameters that can be analysed	:	Fluoride, nitrate, iron, nitrite, residual chlorine, chlorides, total dissolved solids, faecal coliform
	Power Supply	:	220V AC mains or 12 V/DC battery
	Weight	:	10 kg
	Size	:	42 cm x 28 cm x 25 cm
	Components	:	Single unit with built in incubator
2.	Developed by	:	Industrial Toxicology Research Centre, Lucknow
	Method of Analysis	:	Quantitative, colorimetric & titrimetric
	Parameters that can be analysed	:	pH, fluoride, nitrate, iron, nitrate residual chlorine, chlorides, alkalinity, hardness and faecal coliform
	Power supply	:	AC mains, 20/110 volts for 1 KVA generator
	Weight	:	16 kg
	Size	:	50 cm x 35 cm x 28 cm
	Components	:	Incubator and calorimetric unit with suitcase holding chemicals (2 units)
3.	Developed by	:	National Environmental Engineering Research Institute, Nagpur
a)	Name of the kit	:	Rapid Aqua Tester
	Method of analysis	:	Colour comparison
	Parameters that can be analysed	:	pH, fluoride, iron, residual chlorine
	Power supply	:	No power required
	Weight	:	300 g
	Size	:	9.7 cm x 9.7 cm x 3.1 cm
	Components	:	Single unit
b)	Name of the kit	:	Rapid Bacteriological Tester
	Method of analysis	:	Bacteriological
	Parameters that can be analysed	:	Faecal coliform (12 hours)
	Power supply	:	230 volts AC
	Weight	:	10 kg
	Size	:	39 cm x 34 cm x 30 cm
	Components	:	Single unit
c)	Name of the kit	:	Aquazer

	Method of analysis	:	Visual colour comparison, titrimetric tablet count method, bacteriological examination
	Parameters that can be analysed	:	pH, fluoride, iron, residual chlorine, chlorides, hardness, nitrite, nitrate and faecal coliform (12 hours)
	Power supply	:	230 volts AC
	Weight	:	10 kg
	Components	:	Single unit
d)	Name of the kit	:	Titrimetric Water Analyser
	Method of analysis	:	Titrimetric tablet count method
	Parameters that can be analysed	:	Acidity, alkalinity, hardness and chlorides
	Power supply	:	No power required
	Components	:	Single unit
e)	Name of the kit	:	Mini Digital Colorimeter
	Method of analysis	:	Quantitative
	Parameters that can be analysed	:	Fluoride, iron, residual chlorine, nitrate and chromate
	Power supply	:	Single 9 volt battery and 2 1.5 volt cells
	Weight	:	400 g
	Components	:	Single unit
4.	Developed by	:	Elico Water Quality Analyser
	Method of analysis	:	Through probes
	Parameters that can be analysed	:	pH, temperature, dissolved oxygen, conductivity
	Power supply	:	Two 9 volt battery
	Weight	:	6 kg
	Size	:	Medium size VIP suitcase
	Components	:	Single unit
5.	Developed by	:	CSIO, Chandigarh (Central Scientific Instruments Organisation)
	Parameters that can be analysed	:	Turbidity, conductivity, salinity and pH
	Operated by	:	Main supply and battery
6.	Developed by	:	AIIH & PH (Calcutta) All Indian Institute of Hygiene & Public Health
	Parameters that can be analysed	:	Turbidity, pH, hardness, chloride, iron, nitrate, fluoride, residual chlorine and arsenic Bacteriological test kit with incubator is provided

INTERNATIONAL AGENCIES

A) Millipore Kits
   - i) Faecal coliform field kit
   - ii) Portable water analysis kit

B) HACH kit (USA)
   - i) Colorimetric
   - ii) Titrimetric

iii) Acid mini drainage test kit

C) Acid mine drainage test kit

REFERENCES ON WQ-KITS/MONITORING

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5. `Prevention and Control of Fluorosis'. Water Quality and Defluoridation Techniques, Vol. II. Rajiv Gandhi National Drinking Water Mission, Ministry of Rural Development, 9^{th} Floor, B-1 Block, Paryavaran Bhawan, C.G.O. Complex, New Delhi-110003, (1993) (pp. 9-30) (Drinking water – physical & chemical standards p. 59).
6. Studies have been conducted by Central Pollution Control Board (CPCB), India.

SECTION – V

WATER TREATMENT IN DRWH

A Desk Review

In limited cases where water treatment has been reported for `DRWH', boiling, chlorination and use of traditional plants (e.g. *Morenga olifera* seeds, *Semacarnus anacardium* seeds, *Eletaria cardamum* seeds, *Vetiveria zizanoides* etc.) and alum are referred to for treatments of water.It is noted that often only the physical status (color, odour and tests) of water is considered before consuming it, and as long as there is no adverse effect effect, the water is taken to be acceptable.

The available data from different regions of the world are summarised below:

Africa

- In a report[5.1] by UNEP describing treatment of water using traditional methods of treatment of water using indigenous plants and natural products is described. Certain soils, such as the clay known as `clarifying earth' in the Gezira and Northern province in Sudan, produce floc in turbid water and induce sedimentation. A similar flocculation of suspended solids can be achieved by adding certain pounded or crushed plants to water. (Common practice in Sudan and the coastal region in East Africa.
- Bambrah and Haq[5.2] discussed the following physical and chemical methods used for treating stored rain water in Kenya.

  i) Physical Disinfection

  ii) Boiling

  iii) ii)UV irradiation: protects the water against new contamination and can serve as a control and monitoring mechanism. (UV light disinfection is rarely applied in developing countries)

  iv) Chemical Disinfection: Chemicals used include

  v) Chlorine and chlorine compounds

  vi) Iodine doses in suitable form

  vii) Ozone

viii) Potassium permanganate (oxidant)

ix) Hydrogen peroxide (oxidant)

- Gould[5.3] described chlorination as a suitable treatment for rain water in Botswana and observed that periodic chlorination (2 mg chlorine per litre water requires ½ hour contact to be effective and application approximately every 3 months) will be adequate to combat bacteriological contamination.
- Otieno[5.4] discussed quality issues in rain water in Kenya and recommended that rainwater to be used for drinking may be disinfected by chlorination. For example, household bleach containing the active ingredient sodium hypochlorite may be used, at the rate of 1 ml/25 litres of water. Where resources and technology permit, filters could be used along with ultravoilet (UV) light to disinfect drinking water.

U.S.A.

- Fujioka et al.[5.5] described a solar powered UV-system to disinfected cistern water at (Honolulu/Hawaii). Water in the cistern tanks contain high concentrations of total bacteria as well as faecal indicator bacteria well in excess of drinking water standards. The paper describes a system which is a small, solar powered UV unit which uses gravity flow to process 1.5 litres of water per minute. This unit was shown to be effective in inactivating up to 99.9% of faecal indicator bacteria (faecal coliform, E. coli, Enterococci) and upto 99.999% of total heterotrophic bacteria present in cistern water samples.
- Fujioka et al.[5.6] also recommends a simple to do home owners test for bacteria in cistern water to indicate level of contamination. The hydrogen sulfide (H_2S) test described is a simple, reliable test that home owners can use to analyse cistern water in their own homes without the use of special equipment. This is a semi-quantitative test. The home owners are provided with a 10 ml test container and 100 ml test container to analyse each water sample. The smaller (10 ml) container is filled upto the line indicating 10 ml volume and the larger (100 ml) container to a line indicating 100 ml volume. Both containers have the appropriate dried test paper which includes all the necessary reagents. After filling the two containers with water, containers are recapped and held at ambient temperatures (23-30^{o}C). If blackening of the test paper

is observed after 24-48 hours it is taken as a positive test result for H_2S and hence the bacteria. A cistern sample which is positive in 10 ml and 100 ml sample indicates that the water is heavily contaminated with bacteria and should be disinfected. On the other hand, if the test is negative for H_2S bacteria in the 10 ml sample but positive in the 100 ml sample, a lower level of contamination is indicated.

Europe

- Joklik[5.7] described potabilization of water using ultra violet plant in Austria. A rainwater potabilization plant with a design capacity of 2000 litres of safe potable water/hour is described. The plant uses uv short wave UV-C radiation of 253.7 nm for rainwater disinfection without the use of chemicals. The rainwater is collected from the roof into a rainwater cistern and then directed to a combined filtration unit consisting of a pre-filter, a coarse filter and a fine filter for the removal of mechanical impurities and then passed to an activated carbon filter for the removal of dangerous chemicals and for taste and smell improvement. The filtered and activated carbon treated water is then proceeded to a photo reactor with a coaxilally arranged UV-C sensor and all the process data are recorded on an UV-C data logger. The disinfected water is finally passed onto a hardness increase filter and a micro dosage unit for the addition of essential minerals, vitamins and trace elements to obtain a healthy drinking water of excellent quality. Also the author has tabulated pathogenic micro-organisms in water.

Asia

- Appan[5.8] described utilization of rainfall in airports in Singapore for non-potable uses. The raw water is treated before usage. Rain water from impounding reservoir is pre-chlorinated and then dosed with alum and lime. The coagulated water is then flocculated in an upward flow sedimentation tank and the settled water is filtered in rapid sand filters.
- Appan[5.9] also reported on the water quality control in some southeast Asian countries and has listed some treatment methodologies. In some cases quality control is arbitrary and limited to few cases to diverting of first flushes and rearing of fish

within the container. Boiling, despite its limitations, is the easiest and surest way to achieve disinfection. Alternatively, simple methods of adding any halogen compounds could be practiced. Chlorine in the form of household bleach has been successfully applied to collected roof water, retaining residual levels of 0.2 mg/l.

The cheapest UV system could still be prohibitive in many developing countries. It is also recommended that, as most of the countries in the region have abundant amount of sunlight, research should be undertaken to study the possibility of using solar radiations as T. coli, F. coli & F. steeptococci have effectively been removed when exposed to sunlight in Honolulu and Thailand.

- Bo Ling[5.10], (China) discussed a novel disinfection process, termed KDF-55.

  Water in cistern tanks , contains high concentrations of total bacteria as well as faecal indicator bacteria, well in excess of drinking water standards. One simple to operate reliable and low costs disinfectiong method which can be used in the cistern water without the need for electrical power source and without changing taste of water is a kind of processing medium which is made of a very purified alloy of Cu-Zn which is called as KDF-55.

- Different water treatment and water protection methodologies in Iran are reported by Hussain et al.[5.11], and are summarised below:

  i) Biological Control: A special kind of fish known locally as Loi, Sing or Magur (cat fish) was allowed to grow in the stored water. These species ate the larva of mosquitoes and other insects. On the other hand, the fishes discharged their own excreta into the water which caused deterioration in the quality of drinking water

  ii) Chemical Treatment: Lime or alum is used to purify water. A few households in the area developed a technique to maintain the quality of stored water by treating it with about 25 g/200 litre of burnt snail shell. Some households claimed that water treated with burnt ash of snail improved taste of drinking water.

  iii) Filteration: Several types of filter elements such as a piece of cloth or mosquito netting were used to filter water. In hilly and forest areas a sand filter unit was used to filter rainwater before it was consumed. Pond water was also filtered sometimes to remove suspended particles before drinking. Sedimentation or boiling were also practiced before river or canal water was consumed.

India

- Ramani[5.12] (Madras) described various treatments of stored rainwater as follows:
  - i) A piece of Alum is tied to a rope is swirled through the water for 5-7 minutes. In 2-3 hours the flocculated mass with a mild film formation on the top of the water level along with the other foreign materials is allowed to settle. (if ferric alum is used, the duration can be reduced and better results are obtained).
  - ii) To prevent bacterial growth ,a mild dozing of chlorine powder/liq. Chlorine is given as preservative agent and the storage tank is kept closed (anaerobic). For using residual chlorine 2-3 drops of Ortho-Tolidine is used in a small quantity of water. (if color of H_2O changes to yellow, presence of residual chlorine is indicated. The water sample is then taken to be bacteria free and safe for drinking).
  - iii) $KmnO_4$ may also be used for disinfection.
- In a report[5.13] From RGNDWM, Avinashilingam Institute (Coimbatore) described rain water purification methods/treatment at household level. These include;
  - i) <u>Physical Methods</u>: Filteration through cloth, Boiling and Boiling and filtering
  - ii) <u>Chemical Methods</u>: Chlorination, Alum and Lime treatment.
- In the rainwater harvesting system designed by P.C. Sharma at SERC, Ghaziabad designed a pre filter is inbuilt at the mouth of the storage tank. Water is chlorinated as needed.

A number of compilations are available on water treatment in general . These can also be applied to DRWH. In the Indian context Vasudevan and Saxena[5.14] have listed available technologies for water treatment in the directory on Drinking Water of Rural Technologies, Volume 3 on drinking water, 1989, compiled by the authors. They have described low cost methodologies appropriate for the rural areas where there are financial and infrastructural constraints. It includes domestic filter unit, charcol water filter, filter Aid FA-5 for mobile filtration, slow and filtration plant, water filter candles, package water treatment plant, traditional .water purifying seeds, chlorine tablets for distribution and pot chlorination respectively. and Rural Energy Journal has discussed `Solar water disinfection' as treatment procedure. The details are reproduced in appendix (5A-1 – 5A-10).

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India

5.12 R. Ramani, March, 99 (1050, 41st Street, T.N.H.B. Colony, Korattur, Chennai-600080), page 15, 17, 22-23.

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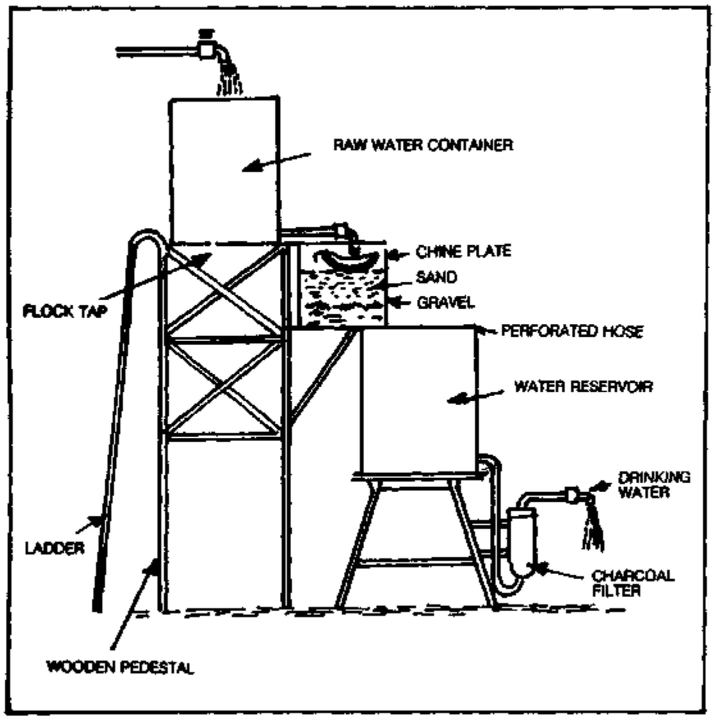
Appendix 5A-1

Drinking Water | **Water Purification, Storage and Supply** | DOMESTIC FILTER UNIT

Code PS 2001

CLASSIFICATION

Lab. stage	•
Prototype field tested	
Manufactured	



DOMESTIC FILTER UNIT

SCOPE

It is a simple device for purifying and disinfecting raw water for drinking purposes.

SALIENT FEATURES

The equipment provides a simple way of performing disinfection, sedimentation and filtration. It consists of three tanks namely a raw water tank, a filter and a clean water reservoir.

The unit is operated by adding half a teaspoonful of calcium hypochlorite to about 100 l of raw water in the tank, it is stirred gently for a few minutes (five minutes or so), then one spoonful of aluminium sulphate or two spoonfuls of potassium alum is added and stirred for five minutes until sediments start forming. At this point one spoonful of calcium carbonate is added and the water in the tank is stirred and the flow is drained through cock which is at the bottom.

Then the tap is opened and water flows on the swash plate in the second container until the tank is full, the outlet tap allows water to flow through a charcoal filter contained in a cylindrical vessel of about 75 cm length and 25 cm diameter (it is filled with charcoal between two layers of fibrous material such as palm fibre). Filtered water through this is collected in a clean water reservoir.

The unit can be easily fabricated in the village and would cost approximately Rs. 250/- only.

CONTACT AGENCY

Director
Appropriate Technology Development Association
Gandhi Bhawan
Lucknow-226 001

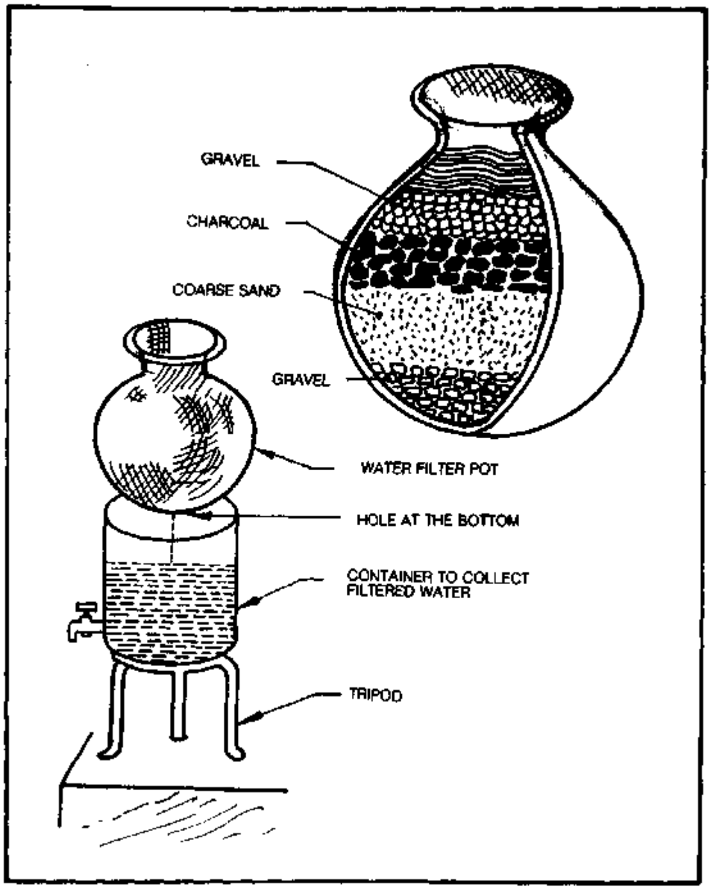
Appendix 5A-2

Drinking Water	**Water Purification, Storage and Supply**	CHARCOAL WATER FILTER

Code PS 2002

CLASSIFICATION

Lab. stage	
Prototype field tested	
Manufactured/In use	•



CHARCOAL WATER FILTER

SCOPE

It is an effective technique for the removal of solids, suspended materials and other harmful bacteria. Suitable for adoption at the family level.

SALIENT FEATURES

It consists of a clay pot fitted with a tap at the bottom. Layers of washed gravel, coarse sand, charcoal and another thin layer of gravel again are piled respectively upto 2/3rd of pot. Lowermost layer of gravel removes dust and dirt and the uppermost layer of gravel prevents the charcoal pieces from floating and keeps them stationary. It is advisable to add a few drops of chlorine solution (5-25 concentration) to a jug of filtered water as a disinfectant.

SPECIFICATIONS

Diametre of clay pot	42 cms
Height of clay pot	100 cm
Thickness of lowermost gravel layer	25 cm
Thickness of coarse sand layer	25 cm
Thickness of charcoal layer	15 cm
Thickness of uppermost layer	5 to 10 cm

PRECAUTIONS IN USE

The filter requires cleaning or renewal of the beds when these become clogged. To avoid frequent washing larger clay pots (200 l) can be used.

FIELD APPLICATION

It is being used in rural areas of Maharashtra.

CONTACT AGENCY

Director
National Environmental Engineering Research Institute,
Nehru Marg, Nagpur-400 020
Maharashtra.

Appendix 5A-3

Drinking Water

Water Purification, Storage and Supply

FILTER AID FA-5 FOR MOBILE FILTRATION

Code PS 2003

CLASSIFICATION

Lab. stage	
Prototype field tested	●
Manufactured	

SCOPE

Pressure filtration through precoat filters is very useful for water filtration on a small scale.

SALIENT FEATURES

The filter aid FA-5 is made from wood charcoal powder of very fine grit (50-100 μm). Raw water having turbidity upto 125 formazin units can be filtered through it without any chemical treatment. With a raw water turbidity of 20-40 FU, upto two cubic meter of filtered water can be obtained from 0.46 m^2 septum area while using 1075 ± 10 g of FA-5 per square meter septum area. The filter aid could be reused particularly at turbidity levels of less than 60 FU, 3-4 times.

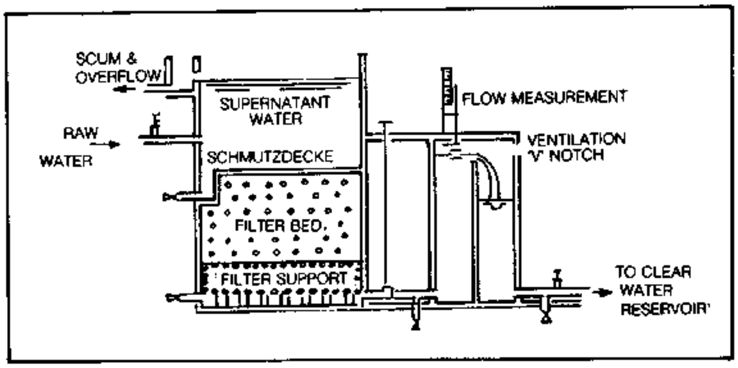
The estimated cost of FA-5 is about Rs. 5/- per kg. and cost of filtration is about 50 paise per cubic meter.

CONTACT AGENCY

Director
National Environmental Engineering Research Institute
Nehru Marg, Nagpur-440 020
Maharashtra

Appendix 5A-4

Drinking Water | **Water Purification, Storage and Supply** | **SLOW SAND FILTRATION PLANT**



SLOW SAND FILTRATION PLANT

Code PS 2004

CLASSIFICATION

Lab. stage	
Prototype field tested	
Manufactured/In use	•

SCOPE

It is a simple and economical treatment plant, which does not require any chemicals. It has an edge over rapid gravity and high rate type filters.

SALIENT FEATURES

Slow sand filtration is a simple method for purifying polluted surface waters, especially for rural and small community water supplies. It provides a single step treatment for surface waters of low turbidity (20 NTU). It also improves simultaneously the physical, chemical and bacteriological quality of raw water. For surface waters of high turbidity suitable pretreatment steps such as an infiltration system, sedimentation tanks or lagoons, horizontal flow roughing filtration etc. are required.

The filter unit consists of large size open watertight tanks 2.5–3 m deep (built in masonary/RCC) and filled with fine grade sand (0.25–0.30 mm E.S.) overlaying layers of gravel. Raw water is distributed gently over the top of the filter bed without addition of any chemical, and clean filtered water is collected by a system of under drains constructed at the bottom of the filter.

The process of purification of water by slow and filtration is as follows:

Water passes slowly through the filter bed at a rate of 0.1–0.2 m/hour. Its quality gets improved considerably during this passage due to removal of impurities and reduction in the number of micro-organisms (bacteria, viruses, cysts etc.) Soon after the start of the process a biological film or filter skin forms on the surface of the sandbed, which contains a wide variety of biologically active micro-organisms. These break down organic matter, including bacteria and viruses in water and convert it into water, carbon di-oxide and harmless inorganic salts. At the same time, a great deal of suspended inorganic matter is retained by straining. The continuous straining process gradually increase the resistances in the filter skin.

SPECIFICATIONS

Initial depth of filter bed	0.8–1.21m
Number of filter beds	minimum two
Minimum depth of sand before resanding	0.5 m
Depth of underdrains	0.2-0.4 m
Sepcification of filter	effective diameter 0.15–0.35 mm, uniformity coefficient 5
Specification for sand support Coarse sand gravel	1-1.4-100 mm deep 4-5.6–100 mm deep 16-23–100 mm deep
Rate of filtration	0.1–0.3 m/hour
Period of operation	24 hours capacity 8000 m^3/day

PRECAUTIONS IN USE

After about 1–3 months the resistance in the filter skin becomes high enough to decrease the capacity of the plant for filtration. Hence cleaning of the filterbed by scraping off the top 2 cm of sand including filter skin, must be taken up periodically.

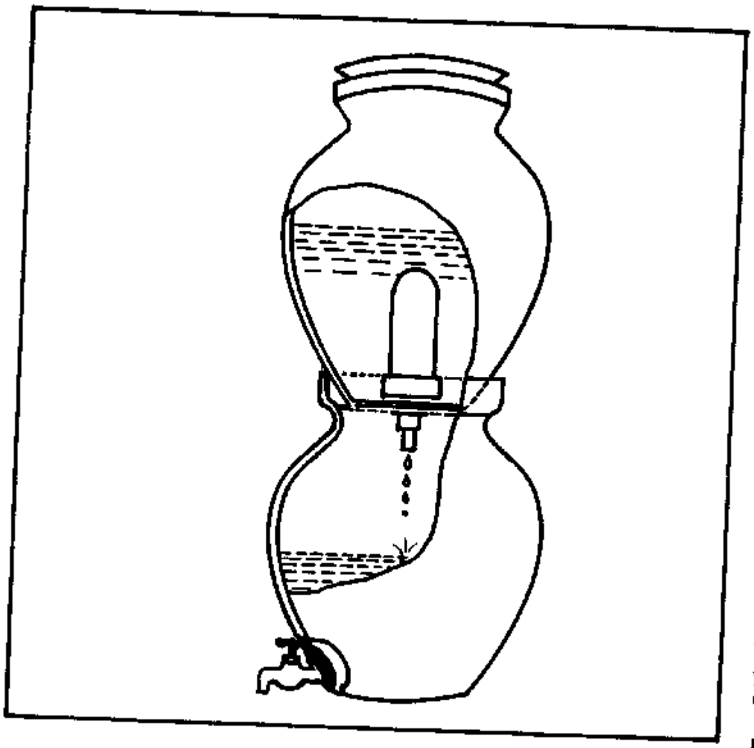
FIELD APPLICATION

These plants have been constructed in villages of Punjab, Haryana, Uttar Pradesh, Andhra Pradesh and Tamil Nadu. Demonstration is available at National Environmental Engineering Research Institute, Nagpur.

CONTACT AGENCY

Director,
National Environmental Engineering Research Institute,
Nehru Marg, Nagpur-440 020.

Appendix 5A-5



Code PS 2005

CLASSIFICATION

Lab. stage

Prototype field tested

Manufactured •

SCOPE

This is an inexpensive way of getting potable water in the house. The filter candle can be fitted in any type of container and can remove all suspended impurities including harmful bacteria.

SALIENT FEATURES

The water filter candles are manufactured from non plastic materials like quartz and felspar, which are ground to the required fineness in a ball mill and mixed with china clay, plastic clay and some organic combustible materials in required proportions. A casting slop is prepared by adding the required quantity of electrolytes. Candles are made by the usual casting process with plaster of paris moulds. These are finished and baked at a suitable temperature. Candles are then given a special chemical treatment so that they could give bacteria free water. The life of a candle is generally 2–3 years and can be installed in any domestic container.

PRECAUTIONS IN USE

The candle should be handled carefully as it is easily breakable. After long use the surface should be cleared off the mud coating, with the help of a knife or blade periodically.

CONTACT AGENCY

(i) Director
Regional Research Laboratory
Council of Scientific & Industrial Research
Jorhat-785 006.

(ii) Director
Central Glass and Ceramic Research Institute
Jadhavpur University
Calcutta-700 032.

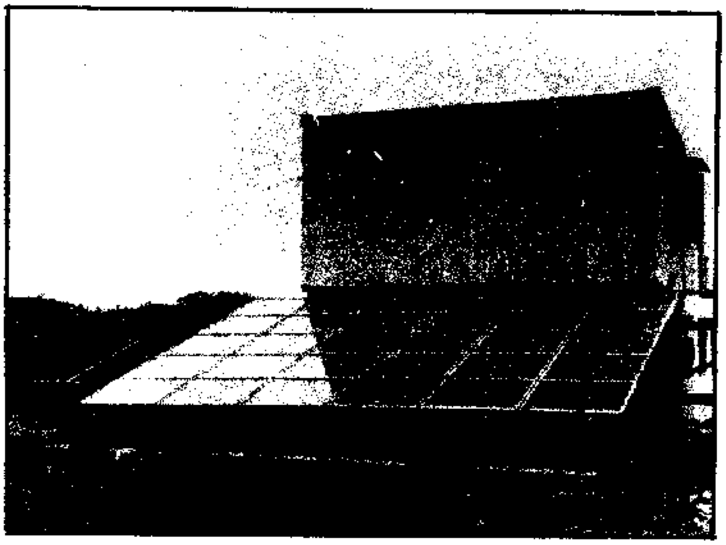
Appendix 5A-6

Drinking Water | **Water Purification, Storage and Supply** | **PACKAGE WATER TREATMENT PLANT**

Code PS 2006

CLASSIFICATION

Lab. stage	
Prototype field tested	●
Manufactured	



SCOPE

This is a compact plant for providing safe drinking water in rural areas.

SALIENT FEATURES

The package plant consists of units for chemical coagulation, sedimentation and filtration. There are three concentric cylindrical compartments, the inner most is the flocculator and central compartment is a hopper bottom sedimentation basin. The flocculator is equipped with paddles. The alum solution is fed by a constant head gravity device, the flocculated and settled water is filtered. A bleaching powder solution is added to the flocculated water before it flows into the sedimentation basin.

The plant produces clean water with less than 2 NTU turbidity from raw water having turbidity upto 400 NTU. The plant can supply safe drinking water to small communities. The alum required is about 7–20 mg/l.

The advantages of the system are that it is easy to operate, maintain and does not need sophisticated mechanical equipment. The units can be pre-fabricated and assembled in the villages.

PRE-REQUISITE FOR ADOPTION

A short training in maintenance and operation is required.

PRECAUTIONS IN USE

Periodic maintenance is required.

FIELD APPLICATION

Evaluation studies on the equipment are carried out in villages of Nagpur district.

CONTACT AGENCY

Director
National Environmental
Engineering Research Institute
Nehru Marg, Nagpur, 440 020

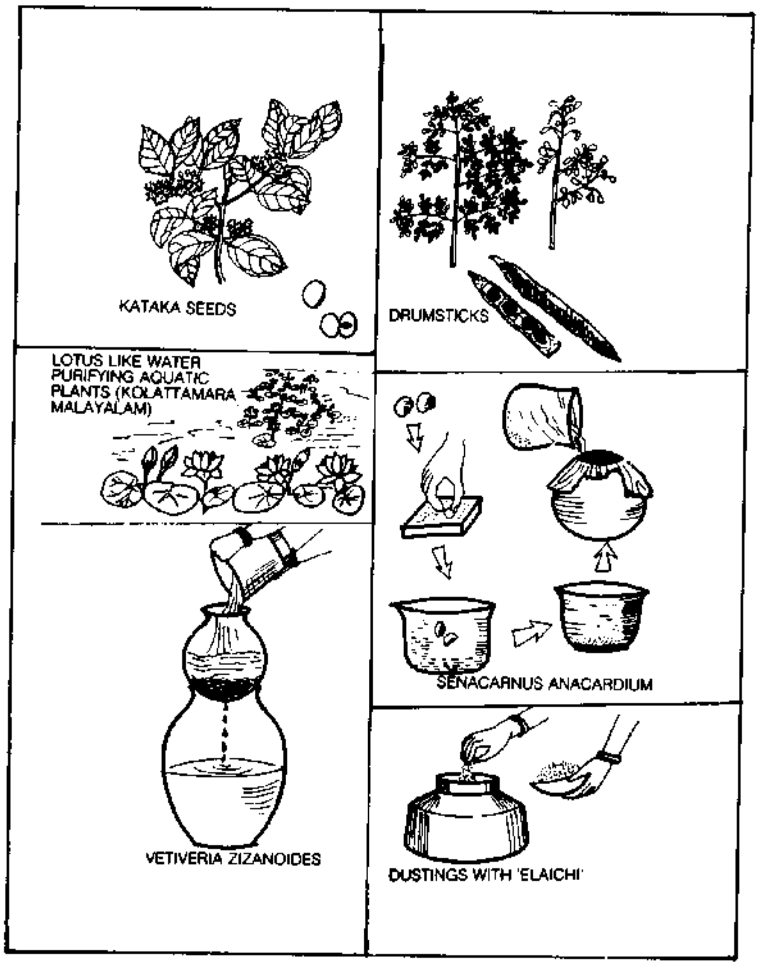
Appendix 5A-7

TRADITIONAL WATER PURIFYING SEEDS

Code PS 2007

CLASSIFICATION

Lab. stage	
Prototype field tested	•
Manufactured	



SCOPE

Good potable water can be had by using some purifying seeds.

SALIENT FEATURES

Many local seeds are used as natural coagulants for treating muddy water. Eg. Kataka Seeds (Strychanos potatorum). A dose of 1.5 mg of seed extract per litre of water is used (seed extract is prepared from a thick paste of crushed seeds with clean water). The water is stirred for 3–5 minutes after putting the seed extract, and it is then treated with 10–15 mg/l of alum. This treatment reduces the turbidity to safe limits.

Similarly, drumsticks (Morenga olifera) seeds are crushed and the powder is mixed with a small quantity of purified water in a glass and stirred vigorously for 5 minutes. The suspension is used for treating turbid water. Generally 30 seeds are required for treating 40 l of raw water.

Seeds of Bhela (Semacarnus anacardium) are rubbed on stone and made into a thick paste, this can be added to turbid water for treatment.

Sometimes coagulants like plant ashes, earth from termite hills, paddy husk or crushed seed of Elaichi (Eletaria cardamum) is dusted on water surface to treat turbidity.

Wiry roots of the rhizome from Ramaccham (Vetiveria Zizanoides) are laid in a pitcher with small holes in the bottom and the pitcher is used as a filter.

Some aquatic plants like Kolattamara may be introduced in the ponds or wells. These plants check the pollution created by animal wastes.

CONTACT AGENCY

Director
Appropriate Technology Development Association
Gandhi Bhawan
Lucknow-226 001

Appendix 5A-8

CHLORINE TABLETS FOR DISTRIBUTION

Code PS 2008

CHLORINE TABLETS

CLASSIFICATION

Lab. stage

Prototype field tested

Manufactured •

SCOPE

Water in rural areas can be made safe for drinking by addition of chlorine tablets.

SALIENT FEATURES

The chlorine tablets are compounded with normal harmless salts and chemicals. For quick dissipation, powdering of the tablets before addition to the water is recommended. For uniform distribution water, slowly stirred about 30 minutes are allowed after administrating the tablet, so that complete disinfection takes place. The shelf life of tablet, stored in a dark place is about two years.

SPECIFICATIONS

Chlorine tablets are available in different sizes and conform to IS: 9825–1981

Weight of a tablet (in gm)	Strength of chlorine (per tablet) (in mg)	Capacity to treat water (in litre)	Packing (Tablets)
5.0	600	550	500
2.5	300	300	1000
0.5	30	25	1000
0.25	5	5	1000

Note: A packet of 1000 tablets of 0.25 gm costs approx. Rs. 80/-

PRECAUTIONS IN USE

Water should be filtered or cleaned and should not have much suspended solids and turbidity.

FIELD APPLICATION

Widely used in villages in India.

CONTACT AGENCY

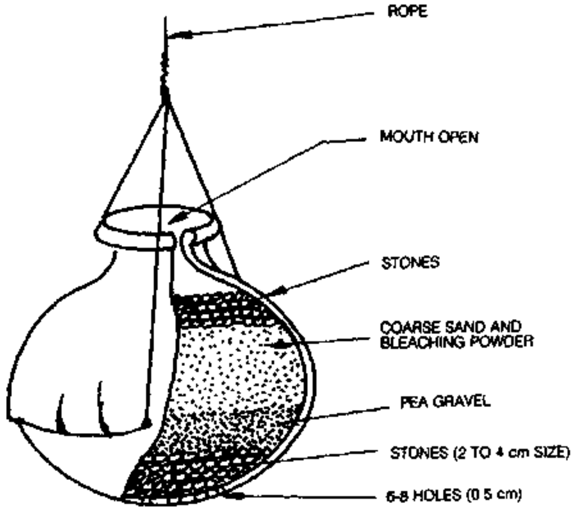
Director
National Environmental Engineering Research Institute
Nehru Marg
Nagpur-440 020

Appendix 5A-9

Code PS 2009

CLASSIFICATION

Lab. stage	
Prototype field tested	
Manufactured	•



SCOPE

It is an inexpensive technique for continuous disinfection of water in open wells.

SALIENT FEATURES

It consists of a plastic pot of 5 l capacity, filled with 2.0–2.5 cm size gravel to a height of 5 cm from bottom. A mixture of bleaching powder and coarse sand (1:4 by weight) is placed on top of the gravel to about an equal height. Again an equal layer of gravel is put and the pot is covered. Two half centimetre holes are made in the cover, and is put in a stout wire cage and is lowered in the centre of the well which is to be disinfected. The length of the rope is so adjusted that the pot is kept submerged in water to a depth of about 1 m. The chlorine from the bleaching power oozes out slowly maintaining a residual concentration of about 0.2–0.5 mg/l for a period of about a week (when the draw off rate of water from well is about 1200 l/day. The process is simple and can be operated by villagers themselves.

PRECAUTIONS IN USE

1 Care should be taken to keep the surroundings of the well to be clean, disinfected and avoid contamination of water through spillage or seepage of used water.

2 Repeat fillings of the pot are required periodically, generally when the residual chlorine is about 0.005–0.002 g/l (it can be estimated by a chloroscope). Otherwise pot may be recharged at intervals of 7–10 days.

FIELD APPLICATION

Being used in a number of villages in Maharashtra, Uttar Pradesh, Madhya Pradesh, Andhra Pradesh, Tamil Nadu etc.

CONTACT AGENCY

Director
National Environmental Engineering Research Institute
Nehru Marg
Nagpur-440 020

Appendix 5A-10

SOLAR WATER DISINFECTION

Putting solar energy to its simplest of uses, for water disinfection, has caught on in several countries. In fact, it is one technique that must score over the more costly ones as potable water in most developing countries need treatment before it is consumed. Interestingly, nature has bestowed such countries with adequate sunshine during most part of the year.

Solar Water Disinfection (SODIS) technique has been perfected. Dissemination of SODIS is not a technological problem, but rather a question of marketing and dissemination of information. Adequate information and controlled demonstration are necessary for large-scale SODIS use. It is the volume of water versus the exposure to solar radiation that needs to be conveyed to the masses.

Yayasan Dian Desa, an NGO in Indonesia, introduced SODIS in the initial phase to 29 families only. However, at the end of the two-year official project phase in 1998, this number increased tenfold to 330 participating households. But wherever government institutions were involved in SODIS dissemination, the impact was far from desirable.

The objective of the SODIS demonstration projects, conducted by local institutions in seven different countries, was to study the socio-cultural acceptance and affordability of this treatment option. The recently carried out survey in Colombia, Bolivia, Burkina Faso, Togo, Indonesia, Thailand and China revealed that an average of 84 per cent of the users will certainly continue to use SODIS after conclusion of the project, and about 13 per cent consider using it is in future. Only 3 per cent thought otherwise because they were presumably not affected by the present water quality.

The most interesting part of the project was the preference of local people for reusing plastic bottles for this purpose – a waste product of the soft drinks industry. An average of 66 per cent of users favour SODIS plastic bottles as these are easy to handle, sturdy and durable. With bottles being available in plenty, replacement of broken bottles is not a problem. The project, which was implemented by the Swiss Federal Institute for Environmental Science and Technology, is now negotiating with the local plastic bottle industry for a joint venture with the SODIS project.

Reference:Rural Energy Journal. `Solar Water Disinfection'. Volume 9 (2) 1999. AFPRO partners

SECTION VI

SCOPE OF FURTHER WORK

Based on the extensive literature review and survey data reported herein, the following work elements have been identified for further action:

1. A number of test kits are available in India and abroad for rapid testing of water samples. There have been modifications and improvements on bacteriological and other tests for water contaminants. In India some institutes/organizations like UNICEF, RGNDWM, CPCB, Sriram Institute for Industrial Research and CAPART have made comparative evaluation of water testing kits. Information from all these agencies will be pooled. The Indian partners will also buy some of these kits and test them. (Already some work has been initiated in this direction). Based on this, recommendations will be made on the choice of kits for rapid testing and most suitable methods for laboratory testing of water samples, specifically in context of DRWH.

2. A questionnaire for collecting field level data on WQM has already been sent to all partners. Each partner is requested to collect available data and also gets sample survey done with regard to WQM in their respective areas of work.

   The Indian partners have already compiled available WQM data based on literature survey and personal interaction and have shown that there is paucity of authentic and accurate information in this regard. They have collected names and addresses of institutes/organisations in India who have put up DRWH in different parts of the country. DRWH systems will be tested with the help of water form some of these institutions. Special attention will be paid to existing units in Kerala and nearby states. A thorough study will be made in these places in collaboration with Sh. P.K. Sivanandan and Mrs. V.K. Sulochana.

3. The Indian partners are to collaborate with Warwick University on storage structures. It has been noted that extensive work has been done by Dr. P.C. Sharma (SERC, Ghaziabad) in this regard. They have essentially used ferro-cement storage tanks of capacity from 600-25000 litre. The shape is cylindrical and the DRWH has inbuilt first flush rejection and filtration facility. To gain from their experience, a training programme is being organised on ferro-cement technology for building some model structures at I.I.T., Delhi. The Indian partners are also working on computer modelling of storage systems.

4. Various parameters contributing to deterioration of water quality have already been identified. WQM has to be related to different roofing materials. (Research has been initiated by consctucting small sheds with different roofing material. New DRWH designs suggested by University of Warwick will be field tested). By inoculation of E. coli and other bacterial strains in water samples and observing their shelf life in aerobic and anaerobic conditions, data will be generated for DRWH designs.

5. Water treatments by sunlight (UV), chlorination and slow sand filter will be studied further.

6. Studies on mosquito breeding will be initiated. To begin with a review will be made and will be submitted under the **Milestone 2: Report C2.**