STATE OF ART REPORT

Scientific Contribution
No.: INCOH/SAR-8/95

WATER SUPPLY FOR INDUSTRIAL AND DOMESTIC USE

Paritosh C. Tyagi

INDIAN NATIONAL COMMITTEE ON HYDROLOGY
(Committee Constituted by Minsitrry of Water Resources, Govt. of India)

INCOH SECRETARIAT
NATIONAL INSTITUTE OF HYDROLOGY
ROORKEE - 247 667, INDIA
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PREAMBLE

It has been estimated that the total world population will increase from 4.5 billion in 1980 to about 6.5 billion by the year 2000, with the most rapid growth in the developing countries. By that time, the countries within the humid tropics and the other warm humid regions will represent almost one-third of the total world population. This proportion will continue to rise in the twenty-first century. The developing and under-developed countries thus quite clearly are the regions facing potentially serious water problems. Hence, it is urgent to question as to whether the fields of hydrology and water resources management have the appropriate methods in place to meet the rising demands that will be made on the water resources. Hence it becomes very important and expeditious to review and update the state-of-art in different facets of hydrology and component processes. This calls for compiling and reporting present day technology in assessment of water resources and determining the quality of these water resources.

This state-of-art report brings out that the water resources are finite and are already becoming inadequate for meeting the growing requirements for drinking and industrial use. It describes that, at a number of places, the water quality of streams and wells is degraded due to pollution caused by untreated or partially treated wastes (domestic and industrial) and excessive abstraction for irrigation. The present and anticipated requirements of water for domestic and industrial use have been stated. The current practices for water supply in rural and urban areas and for industrial use have been reviewed to state the critical areas that need attention. The inter-relationship between water supply and water pollution control has been pointed out and new concepts in water management have been outlined emphasizing conservation and recycling of water resources. The report mainly focusses on India.

The Indian National Committee on Hydrology is the apex body on hydrology constituted by the Government of India with the responsibility of coordinating the various activities concerning hydrology in the country. The committee is also effectively participating in the activities of Unesco and is the National Committee for International Hydrological Programme (IHP) of Unesco. In pursuance of its objective of preparing and periodically updating the state-of-art in hydrology in the world in general and India in particular, the committee invites experts in the country to prepare these reports on important areas of hydrology.

The Indian National Committee on Hydrology with the assistance of its Panel on Water Quality, erosion and Sedimentation has identified this important topic for preparation of this state-of-art report and the report has been prepared by Mr. Paritosh, C. Tyagi, Former Chairman, Central Pollution Control Board, Govt. of India. The guidance, assistance and review etc. provided by the Panel are worth mentioning. The report has been compiled and finalised by Dr. K.K.S. Bhatia, Member Secretary of the Indian National Committee on Hydrology.

It is hoped that this state-of-art report would serve as a useful reference material to practicing engineers, researchers, field engineers, planners and implementation authorities, who are involved in correct estimation and optimal utilization of the water resources of the country.

(S.M. Seth)
Executive Member, INCOH
& Director, NIH

Roorkee

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INTRODUCTION

The prime needs in life are said to be food, clothing and dwelling. None of them is possible to be met without water. Water is needed for irrigation to grow food crops and for drinking; for growing or manufacturing textile fibres and cloth; and for producing many of the items used for construction of buildings.

Evidence of specific efforts for providing water can be traced to very old times. Inadequacies of the water supply systems have resulted in abandoning settlements (for example, Fatehpur Sikri during the reign of Akbar the Great). However, the first organised system for water supply were installed in India in the 1970s in the cities of Calcutta, Bombay and Madras. Later, such systems were introduced in most of the important cities, even if partially. At the time of independence, the small towns and all villages were without any system for providing safe drinking water.

The demand of water in urban areas is two to five times that in the rural areas. The percentage of population residing in urban areas has increased from 20 at the time of independence to 25 in 1991. Two-third of the urban population is concentrated in the larger cities having a population of more than 100,000 which numbered barely 300 out of 4689 in 1991. The demand is larger in larger settlements. The demand for water has been increasing not only due to increase in population. in particular the urban population, but also due to the changes in life styles and standards of living. The availability of water, on the other hand, has been declining due to abstraction by up-stream users, reduction in natural storage, and degradation of water quality caused by pollution of water resources. The result is water crisis which is already felt acutely at many places.

As in the case of any crisis, the solution to the problem is sought through (a) technological developments, (b) funding including the tariff, (c) management including the regulation of water resources and (d) public participation and cooperation.

WATER RESOURCES

The river basins of the world receive about 40,000 km^3 of fresh water annually of which Indian river basins receive about 1850 km^3 of which nearly 400 km^3 forms utilisable ground water. For nearly 16 per cent of world's population, the Indian share of fresh water is thus less than 5 per cent. With constraints of technical and financial nature for development of storage sites, India is able to make use of only about 36 per cent of its annual fresh water supply. The annual rainfall varies from nearly 100 mm in Rajasthan to 11,000 mm in Meghalaya in the Indian territory and most of it (about 80% in the Indo-Gangetic basin and about 90% in the peninsular region) occurs during four months in a year. The result is that availability and demand of water mismatch.

Scarcity of water becomes acute if the rainfall is less than normal. Continued withdrawal of ground water for irrigation in the rural areas and for domestic and industrial purposes in the urban areas has resulted in many cases in undue lowering of the water table. Surface wells dry up and proneness to drought increases. By now, nearly one-third of the country's area is drought-prone. For most of the metropolitan cities, additional sources of water are hard to find. Madras has to depend on R. Krishna in Karnataka State; Delhi seeks additional quantities of water from the Ganga Canal in Uttar Pradesh and by way of exchange of its waste water with the water from the Western Yamuna Canal system in Haryana State; Bangalore and Indore have to obtain water from long distance and have to lift it to considerable height; Agra and Ahmedabad have to contend with excessively polluted stretches of the Yamuna and the Sabarmati, respectively, and many others have similar tales of sorrow.

The quality of water in rivers, lakes and wells is degraded by various sources of pollution. The main source which contributes pathogens and toxic matter is the municipal sewage, containing domestic and industrial effluents, which is discharged untreated or only partially treated. The run off and overflow from the fields contain chemicals and toxic matter contributed by the fertilisers and pesticides. The practice of treating ponds and storm water drains as dumping areas for solid wastes has degraded water sources and has also created a danger that leachate from such areas can continue to degrade especially the ground water.

Ganga Action Plan is a path-setter for a concerted effort to protect a river. The emphasis has been on water quality, mainly by interception of sewage and industrial effluent, and their treatment and utilisation for generating bio-gas and irrigating the fields. To the extent waste water is utilised for irrigation, fresh water can become available by diversion from the intended use for irrigation to the domestic and industrial use involving a lower cost to treat water for domestic and industrial purposes.

Protection alone will not be adequate to augment water resources. Renovation and recharge will also be needed. Rain harvesting, tertiary treatment of effluent, desalination, and injection wells are among the technologies suiting local conditions for improving availability and quality of water.

WATER QUALITY

Water quality criteria have been laid by the World Health Organisation (WHO). The Indian Council of Medical Research, the Bureau of Indian Standards (formerly, the Indian Standards Institute) and the Central Public Health & Environmental Engineering Organisation of the Ministry of Urban Development have set standards for drinking water. The Bureau of Indian Standards and the Central Pollution Control Board have notified standards for ambient quality of water for various uses. The State Pollution Control Boards and the Ministry of Environment and Forests have notified standards for the quality of various industrial effluent. Despite the large number of sources for setting of standards, there is remarkable harmony in the various standards as each agency has tried to build on the work done previously by others.

Industrial water quality is industry-specific. In a given industry, the requirements for water quality is use-based. Water of relatively poor bacterial quality is acceptable for cooling, but not as process water in food industry. Softening and even deionization may be needed in certain operations in the textile, metal finishing and chemical industries. Removal of colour is important, for example, in the pulp and paper industry.

Abstraction of water can affect water quality in many ways. Intrusion of saline water near sea coast is a well-known phenomenon. Building up of brackishness, hardness and sand and fluoride contents is sometimes experienced. Depletion in the capacity of a receiving water body to assimilate pollutants may be a direct consequence of abstraction of water from that body.

Only a small portion (20 to 25 per cent in domestic use and 2 to 30 percent in industrial use) of the water used may be consumed. The remaining quantity of water used flows out as effluent. Back again in nature, the pathogens are likely to die first, next the organic matter gets decomposed and stabilised by the action of bacteria, and the heavy metals and less soluble compounds get precipitated out. Over a distance of about 100 km, the stream may appear clean again. Self purification is thus a natural phenomenon aided by dilution, temperature and certain other factors such as oxygenation caused by turbulence or by oxygen generated by algae. Contamination of ground water may take place slowly and insidiously over several years and its effect may persist for much longer over several decades.

DOMESTIC DEMAND

Domestic demand has been assessed to be within a wide range of 15 to 265 litres per capita per day (lpcd). The factors affecting per capita demand are mainly the life style and mode of supply. The climate and cultural practices influence the demand. In the urban areas, demand tends to increase with the size of the population as public facilities, including sanitation, require more water for larger settlements. Water-borne sanitation, i.e. sewerage, increases the demand for water quite significantly. In the rural areas, demand is reduced by the distance and height to which water is to be carried by the consumer and it is increased by the ease with which water can be drawn. Much more water is drawn from standposts than from handpumps. Watering the cattle and individual house connections cause significant increase in the water demand. Flushed toilets, even if they are pour-flush type, also increase the demand. Substantial part of demand consists of avoidable waste. One may consume 45 litres by keeping the tap running while brushing teeth or 20 litres while shaving, whereas half a litre may suffice for brushing teeth and less than 2 litres for shaving and washing the face.

The water supply systems are usually designed to provide for 150 to 200 lpcd in cities, 100 to 135 lpcd in town, 50 to 75 lpcd in villages in which house connections and cattle watering are included and 20 to 40 lpcd in villages where water is possible to be supplied only for drinking and culinary purposes. It is estimated that the present domestic demand of water is 23 km^3 which is likely to increase to 46 km^3 by the year 2025.

Intermittent water supply, i.e. supply of water during a set number of hours, is resorted to in the belief that the demand will thereby be reduced. Whereas the intermittent system prevents drawl and wastage of water during the non-supply hours, it fosters neglect towards overflow and wastage of water during the supply hours, and often the water stored during the previous hours of supply is thrown away to store fresh water. It is, therefore, doubtful whether water is saved by the intermittent water supply system. On the other hand, the intermittent system greatly increases the possibilities of the entry of contaminated water into the water distribution pipes, which is reason enough not to adopt this system. However, there seems no escape from intermittent water supply when the supply is far too short of demand. In Madras, Hyderabad and Ajmer, for instance, water is supplied on alternate days to be able to ration it during periods of extreme scarcity.

A major cause for shortfall in the availability of adequate quantity of water to meet the demand, especially in the cities, is that fully treated water is used for every use. The need for flushing the water closets, watering the lawns and kitchen gardens, and washing cars etc. can be met by water which is not filtered and disinfected. Water closets can be designed to require smaller quantity of water for flushing. Hand-flushed laterines consumes much less water than those using flushing cisterns. The suggestion for recycling bathroom and kitchen effluent after minimum necessary treatment deserves to be looked into. There will, of course, be extra expenses involved in plumbing for separate supplies for drinking, kitchen and bathroom, and for the toilet and garden. There will also be an additional risk of cross-connection. But in view of the constraint on available water resources, the costs of transmission of water and waste water, and the environmental degradation caused by large quantities of untreated waste water, the recycling and reuse of water is inescapable.

INDUSTRIAL REQUIREMENTS

To be precise, the demand of water for meeting industrial requirements has to be assessed industry-wise according to the nature, process and size of the industrial units. Rough assessments are also made in relation to the domestic demand (about 10 to 15 per cent of the domestic demand) and on the basis of area of the industrial sector (about 10 to 70 cubic meters per hectare depending upon the nature of the industry). It is estimated that the industrial demand is at present about 17 km^3 which is likely to increase to about 120 km^3 by the year 2025. In view of these estimates, it is evident that the usual per capita and per hectare provisions are substantially on the low side.

Certain industries, such as pulp and paper, textiles, fertilisers, chemicals, petro-chemicals, and mining have large requirement of water. Thermal power plants need water mainly for cooling. There are immense possibilities of reducing the quantity of water required for such industries. Water used for cooling can be mostly recycled. In thermal power plants upto 98 per cent of the requirement of water for cooling can be met by recycling. In the manufacture of pulp, counter-current washing can reduce water consumption to about half. For producing coke from coal, dry quenching by air can eliminate the use of water. Examples are galore.

In a typical large industrial unit, there are usually several streams of effluent. Their quality and characteristics vary. By carefully segregating the streams, it is often possible to tap a stream from one section as source of water for another section. Besides saving water, this can possibly save some cost of effluent treatment. Water from floor washing can usually be easily treated for meeting some of the requirements, especially if good house-keeping is ensured to prevent (a) leakage from joints in pipelines and glands of valves, (b) overflow from storage tanks and process units, and (c) spillage of the unavoidable leakage from any source. Industrial units such as sugar factories, dairies and distilleries provide excellent opportunities to practise this suggestion.

Equalisation is the opposite of segregation. In specific circumstances, such as to neutralise acidic and alkaline effluent and to facilitate coagulation and precipitation, equalisation is helpful in treating the effluent more easily than by segregating the streams. Equalisation may also help in diluting the effluent and making it amenable to be used for agricultural purposes thereby meeting a requirement of water otherwise met by a source of fresh water.

WATER POLLUTION CONTROL

Many enactments contain provisions for water pollution control. Perhaps the oldest among them is the Shore Nuisance (Bombay and Colaba) Act of 1853. There are others, such as the Indian Penal Code of 1860, the Factories Act of 1948, the Orissa River Pollution Act of 1953 and the Maharashtra Prevention of Water Pollution Act of 1969. The last named was the fore-runner of the first comprehensive legislation dealing with water pollution control, namely the Water (Prevention and Control of Pollution) Act, 1974 under which the Central and State Pollution Control Boards have been established. The Central Board sets standards for ambient water quality and suggests minimal national standards (MINAS) for the State Boards to set the standards for tolerance limits of specific pollutants in the effluent.

The Central Board has set standards for river and coastal waters for their various uses. For the river, such uses include drinking, bathing, irrigation, navigation and controlled disposal of wastes. For the coastal waters, such uses include shell fishing, salt manufacture, bathing, water sports, navigation and controlled disposal of wastes.

Water pollution is controlled by monitoring the quality of the water body which receives pollution load and the quality of effluent that bring such load. The status and trend of the former observations helps in identifying the critically polluted stretches of the rivers and other water bodies. It also helps in reviewing the effluent standards so that the water quality of the water bodies is maintained commensurate with their use. The observations of effluent quality are related to enforcement of the standards prescribed under the law. The law provides adequate powers to the concerned State Board to inspect, obtain information and samples, order stoppage of water and power supply to a polluting unit or to prosecute the defaulter for violation of law.

Water supply is axiomatically taken as a means for environmental improvement. No doubt, it is. But it is also the cause for generation of large quantities of sewage and industrial effluent. By the end of 1991, about 85 per cent of the urban population was served with organised systems of water supply, but only about 46 per cent of the urban population was served with sewerage systems only a few of which had sewage treatment facilities. If the waste water is not treated, as is the position in most of the cities and towns and practically all the over half a million villages in India, then the rivers, streams, lakes, tanks, wells -- all the sources of water -- become polluted.

Air pollution, likewise, is subject of another myth that it is unrelated to water pollution. The sordid experience of acid rain destroying fish in the lakes besides forests and property in certain European countries has shown how the products of combustion of coal and certain industrial emissions build up oxides of sulphur and nitrogen in atmosphere and lead to disaster on the ground during rains.

Disposal of solid wastes presents complex problems with regard to water pollution. First, the solid wastes are being dumped at various sites without any preparation at the sites to receive them. Secondly, the solid wastes are not covered. Thirdly, there is no protection against the leaching of wastes into ground and thus polluting ground water, nor against their being carried with storm water run-off to surface water bodies. The existing standards do not contain any tolerance limits for controlling or preventing soil pollution.

Water pollution is only a part of environmental pollution. The environmental components are interconnected. Therefore, only a hological approach befits projects and programames which can have any effect on environment.

NEW CONCEPTS IN WATER MANAGEMENT

Over a very long period, the use of water progressively took the form of exploitation of water. The result was the depletion of water resources and their pollution. A new water policy became necessary. In the 1980s, the national government recognised this need and took several measures to modify the approach towards use of water. The name of the Union Ministry was changed from the Ministry of Irrigation to the Ministry of Water Resosurces signifying a change in the focus from use to resource. The National Water Resources Council was set up under the chairmanship of the Prime Minister. In 1987, the Council announced the National Water Policy which described water as a prime natural resource, a basic human need and a precious national asset. The policy states that water should be made available in water-short areas even by inter-basin transfer based on the national perspective. This elevation of the subject of water from state level (as it appears in the State List in the Constitution of Inia) to the national level is a significant conceptual change.

The National Water Policy also lays down water allocation priorities as follows:

a) Drinking water
b) Irrigation
c) Hydro-power
d) Navigation
e) Industrial & other uses

The National Water Policy further states that water resource should be planned, developed and conserved on an integrated and environmentally sound basis, available water resource should be put to optimum use and recycling and reuse of water should be an integral part of water resource development.

In all water supply systems, a portion is wasted. It is termed as "unaccounted-for water" and it includes leakage, wastage and all such use that does not yield income. In practice, such portion is about 10 per cent of the quantity of water supplied in well maintained systems. In India, estimates for unaccounted-for water lie in the range of 25 to 60 per cent and that for leakage alone about 17 to 44 per cent. Several studies have shown that over 80 per cent of the leakage of water is between the supply pipe and the consumer's facilities. This highlights the significance of implementing a programme for leakage detection and control, and for generating awareness for avoiding wastage, in cooperation by the water supply utility and the consumer. Besides conservation of the precious resource of water, prevention and abatement of leakage and wastage reduces the quantity of waste water, thus protecting the water resources from getting polluted and saving enormous costs in procuring and treating water for supply and collecting and treating waste water before disposal.

Methods of leakage detection have steadily improved in reliability and effectiveness. The methods broadly rely on observation and inference. Measurement of the minimum flow in a district during night provides a good clue for assessing leakage in residential areas. Large leaks may become visible on ground and they can be approximately located by measurement of pressure during reduced supply. Sounding by trained workers with acoustic rods (listening sticks) or stethoscope-like geophones helps in pinpointing the leaks but traffic and other activities can make the task difficult. Electro-acoustic geophones and probe microphones were developed to amplify feeble sounds. Where the pipelines are laid below the ground water table, attempts have been made to trace leaks with air under pressure. The latest technique for locating the leak quite precisely is to co-relate the sound from a leak by placing two microphones in contact with the pipe or valve stems at the same time, one on each side of the leak, and comparing the time taken by the sound of leakage to reach the microphones. Computer simulation of the distribution system and comparing line pressures as per design and as observed at selected spots is, in a way, an elaboration of the night flow measurement technique. It helps in identifying the suspected points of heavy leakage or waste.

Metering a connection has its own merits and demerits. It serves to equitably charge for the water supply service; it surely is a deterrent to wilful wastage by the consumer, and it is more easily possible to raise the tariff (thereby the revenue) for a metered system than for an unmetered system. Metering is criticised for the cost and logistics involved in installation and reading of meters, meter maintenance and repairs, and complicated and dispute-prone billing procedures. For regulating the supply, it is better to bear with the disadvantages of metering than to go in for intermittent water supply. Tight administration is most helpful in this matter.

Public hydrants too have points for and against them. They meet a social need; help in lowering initial costs and provide a balance between affordability and demand. On the other hand, public hydrants are a significant source of wastage, insanitation and loss of revenue. Pilferage of taps and other materials is common experience at these points. Good design coupled with good management can derive the best from public hydrants.

A water supply project is intended to improve environment. In specific cases, however, it may degrade environment such as by excessive drawl from a stream or from wells, induce salinization of ground water near sea coast and cause water pollution due to increased consumption of water and flow of untreated sewage to water bodies. It is, therefore, necessary that an environmental impact assessment of a water supply project is also made. During maintenance and operation, environmental audit of the water supply system should be periodically carried out to ensure that environmental benefits are not unduly offset by the wastage of resources and environmental degradation.

RESEARCH & DEVELOPMENT

New techniques in metallurgy and the advent of plastics have introduced many new materials in water supply practice. Mention may be made of ductile iron, new alloys, poly-vinyl-chloride and high density poly-ethylene. Anodization and plastic-coating of metallic items have improved their finish and durability. Use of metals, natural rubber and wood has been replaced in many cases by new synthetic materials and fibre glass.

Consumption of water in the flushing cisterns is possible to be reduced up to one-fifth through modifications in its design and the toilet pan. Faucets which permit a low or limited flow or are self-closing may reduce the consumption up to half of that through normal ones. New equipment and construction techniques have made it possible to draw ground water effectively through wells, tubewells, radial collector wells, syphon wells, infiltration galleries and filter basins. Prestressed concrete pipes have reduced the dependence on steel pipes of large sizes. Hand pump attachable fluoride removal units and compact plants for removal of iron and manganese have been developed for rural areas.

There is no major break-through in the treatment technologies. However, many improvements have been introduced to make the known technologies more effective. Slow sand filtration has been adapted for field conditions in small water supplies; simple devices like pot chlorinators have been developed for disinfecting wells and small sources of water supply; flocculation and coagulation have been improved with new materials and techniques; many innovations in the direction of flow and filter media in rapid sand filters have been tried; the formation of trihalomethanes in chlorinated waters have been extensively studied; use of ozone and ultra-violet rays is now better understood for disinfection of water; rehabilitation of sick tubewells has been investigated, and techniques have been developed for design and manufacture of membranes used in the reverse osmosis process for desalination of brackish water. Domestic water treatment units have lately become quite popular in the affluent section of the society as the quality of public water supplies is not perfectly reliable.

In the instruments used for water quality control, significant improvement has been achieved with the help of ion-selective electrodes and the use of electronic data logging. Computer applications have helped in regulating various treatment processes and pumping arrangements besides the computer-aided design of the treatment process and distribution system and the computer-based accounting, inventory control and management information systems. Water quality monitoring and modelling have entered a new phase of development with the help of bio-indicators, remote sensing, continuous recording instruments and computer applications which offer great prospects in water quality management. Nucleic acid probes are being developed for rapid detection of enteric viruses in water.

An important area of research is the village-level operation of water supply services. The notion that rural facilities are simplified or reduces urban facilities has rightly been dispensed with. The reliability and effectiveness of handpumps used in rural water supply systems has been a subject of detailed international study in the UNDP/World Bank assisted projects. The ruggedness of the components, ergonomic considerations in the design, capacity to endure normal use and abuse, efficient performance, the ease with which repairs can be made, and the possibility of training in maintenance and repair are some of the factors germane to satisfactory village-level operation of water supply facilities. In short, reliability is the key to success in rural water supply.

CONCLUSIONS

Water crisis is not a matter of conjecture, guess or anticipation: it is already being felt severely at almost all metropolitan cities and the scarcity hit areas in our country. The crisis is deepening day by day as the demand is increasing for domestic use and even more so for industrial purposes due to continuing urbanistion and industrialisation. There are many possibilities of reducing demand through modifications in fittings and plumbing practices, improvements in equipment, recycling and reuse of water and generating awareness for conservation. It is imperative that management of demand of water receives as much attention as management of its supply.

The supply of water without commensurate arrangement for drainage, treatment and disposal of waste water has resulted in insanitation. Recycling and reuse of waste water has the advantage of lowering the demand for water and also minimising the investments for dealing with waste water.

Water resources can be augmented by conservation and recharge. There is still much scope of increasing water storage through new river valley projects and by reducing losses due to evaporation. As for recharge, especially of the ground water resource, little has been done in our country to identify suitable recharge sites and to study the recharging techniques best suited for them.

While technical skills and materials for construction are by and large available in India, there is urgent need for stepping up efforts for research and development, especially by or on behalf of the field organisations engaged in providing water supply facilities. The other areas calling for urgent attention are the databases for water resources and water quality, the management information systems for water supply services, an effective system of inspection and evaluation of water works, and the promotion of public participation, especially women, in the management of water resources and water supply services.

The house connections are responsible for bulk of leakage and the behaviour of consumers plays a major role in the wastage of water. The profession of plumbers should, therefore, be improved and strengthened, and the campaign for generating awareness for water conservation and water quality should be further stepped up to be almost at par with that for family planning.

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