Management Aspects of Groundwater Resources: Community Participation, Augmentation and Restoration

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Abstract: Ground water is the major source to meet the domestic, irrigation and industrial demands. Ground water occurs in a wide range of rock types and usually requires little or no treatment; therefore, it is often the cheapest and simplest water supply option. In India too, ground water is the main source both for irrigation and drinking purposes. In early days, abstraction from the shallow aquifer has been limited, mainly because water-lifting devices were animal-powered. However, since the 1950s groundwater abstraction has increased substantially, both as a consequence of the increase in the number of wells and of progressive replacement of the animal-powered lifting devices by energized pumps capable of much higher yields. This rapid development of groundwater resources in India and other developing countries had resulted in the declining of water table/levels rapidly in many parts of the country causing shallow wells to dry up with a particular impact on those rural poor farmers unable to deepen their wells to chase the declining water levels. In coastal areas, declining water levels are also associated with the ingress of saline water, leading to reduced crop yields, loss of drinking water supplies and ultimately loss of both fertile land and water supply wells.

Monitoring water level over three decades (from 1970), in many parts of the globe have provided clear evidence of a long-term water-level decline, as a result of increased groundwater abstraction. This has resulted in the deterioration of water quality and the widespread drying-up of wells following a 'failure' of the monsoon. Deepening of wells does not appear to be a viable option as most wells already fully penetrate the shallow weathered aquifer. This has resulted only in debt trap of farmers particularly from the monsoon climatic countries such as India and African continent. Therefore, a detailed discussion on the management of aspects have been given in this paper.

INTRODUCTION

Community Management of Groundwater Resources

The livelihood of rural population mainly depends on the sustainable development and management of groundwater resources as more than 70% of India's population live in rural areas. In India and elsewhere, groundwater is considered to be the personal property of the landholders and the abnormal growth of population and spurt in industrial activities for the last four decades and conversion of vast waste lands into cropping land forced more abstraction of ground water. This has resulted in socio-economic conflicts. The land has been divided into small land-holdings and each holder started developing new wells (shallow and deep bore wells) without any management approach. Today, in India millions of wells are not in operation as they are dried up. Competitive spirit in deepening wells is going on without understanding its consequences. During drought years entire rural folk suffers for their day-to-day food. Thus, ground water plays a major role in the livelihood of entire rural sector.

Addressing the problem of poverty and over-exploitation of ground water in India and other African countries is a complex phenomenon. If there is sustainable source of water available both for drinking and irrigation then, it may be possible to alleviate the rural poverty by 75% and this is possible only by effective groundwater management. If one answers the question to whom and how much the groundwater resources are to be distributed as depicted in Fig. 1, then one can resolve the management of groundwater resources.

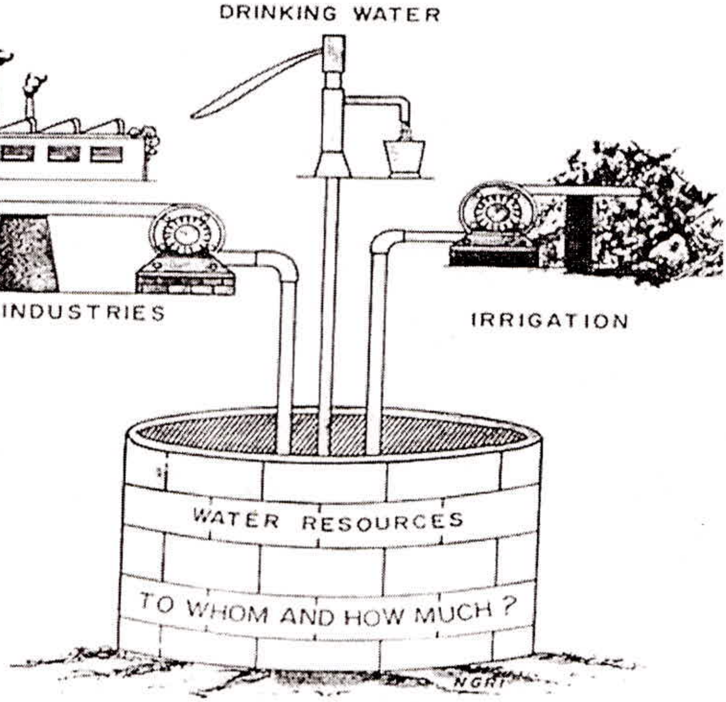

Fig. 1. Groundwater resources distribution.

Requirements for Effective Groundwater Management

The following are some of the requirements for effective groundwater management in rural area:

- good understanding of the aquifer system,
- practical measures to control abstraction can be identified including education to rural people about the aquifer and its behaviour, and

- augmentation of groundwater resource through artificial recharge.

Water resources management means intervention in matters concerning water, which may be planning, design and operation. Water resources management needs a number of steps carried out in sequence as given below:

- assessment of water demands/requirements,
- assessment of water resources through geophysical and other methods,
- evaluation of biochemical processes in the soil environment with special reference to the stability of soil organic matter and the carbon/nitrogen balance,
- selection of suitable plants and determination of the rotation system,
- determination of irrigation schemes and design of drainage pattern, if necessary,
- monitoring of water quality and pollution sources, vertical profiling of the unsaturated zone and aquifer,
- study of wash-out and leaching of salts from the soil into the unsaturated zone,
- study of solute transport and transformation processes in the unsaturated zone,
- modeling of groundwater flow and mass transport in the unsaturated and saturated aquifer system,
- evaluation of economic and social consequences of recommended changes in the agro-eco system, and
- identification of problems and constraints in decision-making.

Controlling abstraction is the most sensitive one and *could not be achieved by mere legislation* and it needs to educate the rural folk to share the available ground water by themselves. This again needs some sort of technical approach, which can induce them to understand the problem. Implementing such reforms is problematic as monitoring (controlling) the activities of individual owners and stopping subsidies, is very difficult. Against this background, the application of *simple groundwater models* and the development of *user group based institutions (community participation)* for groundwater management, could be a viable and an innovative idea and it has to be tested (BGS, 2000).

Augmentation of Groundwater Resources through Artificial Recharge

Augmentation of groundwater resources through artificial recharge is becoming popular slogan among the developing countries. Even in early days, the spreading (ponding) of surface water in minor and medium irrigation tanks had helped to infiltrate water into shallow and unconfined aquifers. The rapid decline of water levels in semi-arid and arid regions due to over-exploitation had forced to augment the ground water either through surface spreading (ponding) or direct injection into the deeper aquifer through boreholes. The artificial augmentation of ground water otherwise called derived recharge is defined as a process by which excess surface water is directed in to the ground, either by spreading on the surface, using recharge wells or by altering natural conditions to increase infiltration to replenish an aquifer. Pyne (1995), Pavelic & Dillon (1997) and Barber (2002) had reviewed the various techniques used to augment the groundwater resources. Aquifer storage and recovery (ASR) method is becoming more common nowadays wherein a single bore well is used both for injection and recovery. By using this method, the injection wells can be developed regularly during recovery phases and it helps for self-cleaning the clogging of bore wells. Surface spreading infiltration can augment only the shallow aquifer system whereas the ASR and recharge wells can be used to augment the deeper aquifer. The problem of clogging with solids and bio-films in the injection well is still a major bottleneck in ASR and recharge wells, which has to be rectified. Reducing the level of suspended solids to the level of 10 mg/l by pre-treatment can reduce this problem to some extent.

Surface spreading on the other hand attenuates the suspended solids in vadose zone while the water infiltrates vertically downward before reaching the water table. Here, the vadose (unsaturated) zone acts as a natural filter for suspended solids and other bacteria etc. This process is otherwise called soil-aquifer treatment (SAT) or geo-purification. Check dams and percolation dams constructed across the rivulets and small streams in hard rock region has proved to be a viable technique to improve the derived recharge close to the vicinity of the rivulet/stream and it is also proved that it will transmit the water very fast to a far place if it encounters a fracture of good length say a few kilometres.

REGIONAL GROUNDWATER QUALITY MANAGEMENT

It is suggested here to take up regional groundwater quality management approach to ensure sustainable and hazard-free water resources for drinking, agriculture and industries. The following can be considered for any regional groundwater basin:

- Remediation
- Planning to stop it happening again or getting worse (prevention is better than cure)

Possible Remedial Measures of Industrial Effluents

The following are some of the remedial measures to be considered for treating the contaminated groundwater system:

- Treatment of effluents and cautious disposal of residues
- Improving lining of flow channels and discharge of effluents in low permeability zones
- Pumping of polluted groundwater, treating and recharging into the system
- Use of treated or partially treated ground water in industry/agriculture

Treatment of effluents through common effluent treatment plants (CETP) is found to be economically and technologically viable one (Rajamani, 2002). Central Leather Research Institute (CLRI), Chennai, India, has designed a model plant to treat the tannery effluents and is shown in Figs 2 and 3. The collection of effluent from group of industries is done to treat them in a single plant and dispose the sludge in a low permeable zone.

The technological options recommended by CLRI are as follows:

- Segregation of certain sectional waste streams like soak liquor, chrome liquor etc. or mixing of suitable sectional wastewater from different process and cleaner technologies like recovery and reuse in tanning industries;
- Primary treatment in individual unit or in a CETP;
- Secondary biological anaerobic/aerobic treatment; and
- Disposal of sludge from the treatment sites to a far away low permeable zone.

Management Plan to Protect Aquifers and Well Fields

Scientific Approach

(i) Occurrence and distribution of pollutant sources,

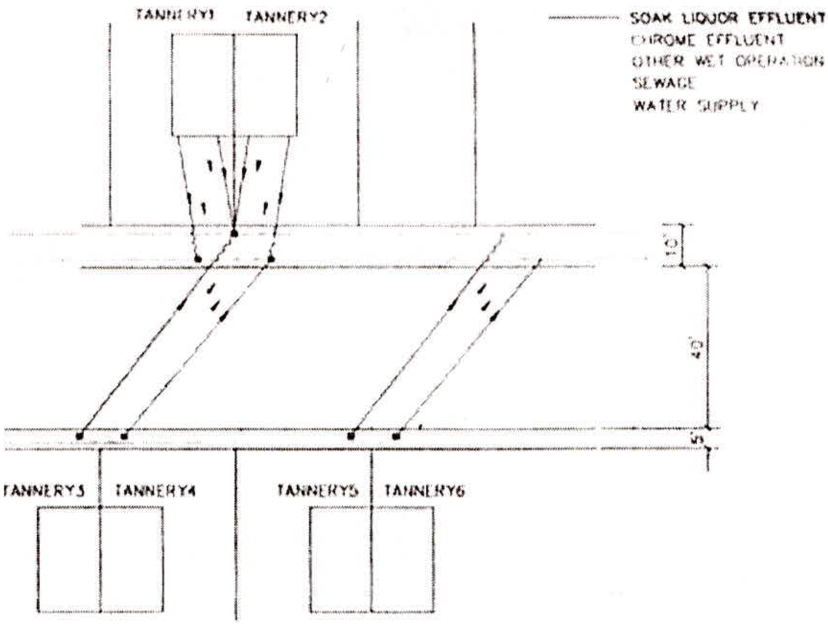

Fig. 2. Proposed effluent collection systems by CLRI (Chennai).

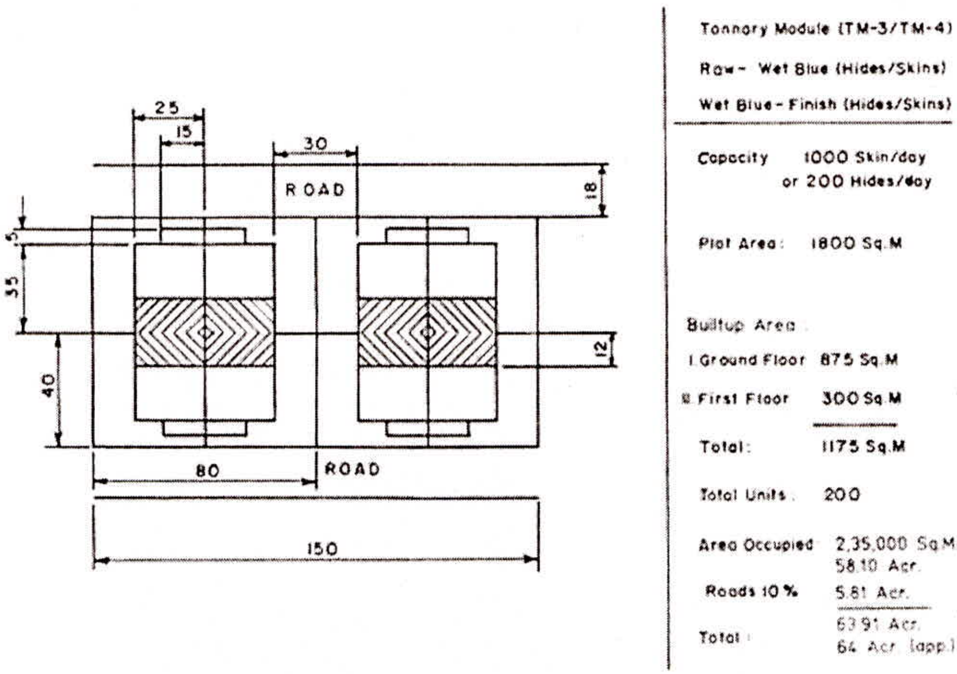

Fig. 3. Proposed tannery treatments module (TM-3/TM-4) by CLRI (Chennai).

(ii) Knowledge about pollutant sources,
(iii) Knowledge about hydrodynamics of the aquifer system,
(iv) Spatial and temporal distribution of characteristic parameters,
(v) Cause and effect, and
(vi) Impact on management action etc.

Data Network and Monitoring

Integrated geophysical, geohydrological and geo-chemical approach should be followed to assess the groundwater pollution. This needs a systematic data, which have to be monitored through a network of stations.

Regulations

Adequate legislation to prevent pollution and enforce clean up through pump and treat technology, dilution through artificial recharge, soil reclamation etc.

Changing Practices and Changing Technology

Industries with out-dated technology should be closed down and opt for modern eco-friendly technology. The industries also should be provided incentives.

Relocation of Industries

If it is found very difficult to remediate the contaminant aquifer, it is preferred to relocate the industries after studying the vulnerability of the area to the contaminants. One such attempt was made at Calcutta, where a number of tannery industries have been brought under one roof and all effluents are collected and treated. The site view of the Calcutta leather complex is shown in Fig. 4.

Fig. 4. Relocated leather industries in Calcutta (India).

Water Quality Management

A schematic block diagram on the concept of water quality management is shown in Fig. 5.

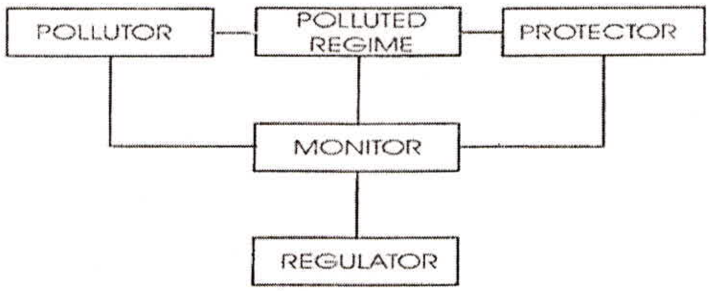

Fig. 5. Concept of water quality management.

RURAL DRINKING WATER MANAGEMENT

As we have discussed in this article, there is an urgent need to manage the water resources for its sustainability in coming years. Getting adequate both in quantity and quality should be the main concern. Groundwater pollution is one of the hindrance to have adequate freshwater. It is, therefore, suggested to evolve a comprehensive groundwater management plan so that an adequate supply of drinking water is assured to the rural poor. A schematic block diagram of rural water supply management scheme is illustrated in Fig. 6. The schematic is based on the idea of World Health Organization (WHO) and it is explanatory one. It is, hence, emphasized that those who are involved in water affairs to unite together and take the community at the center-stage and evolve a pragmatic management plan so that sustainable development and management will ensure an adequate and potable water supply to the rural folk who are really in need of it.

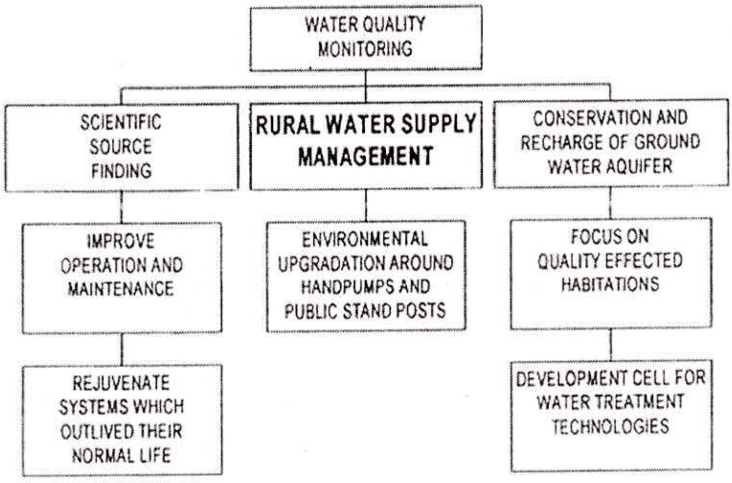

Fig. 6. Rural drinking water management schemes.

It is suggested that for sustainable development of groundwater resources, exploitation of deeper aquifers for irrigation should be avoided, except where it can be proved that recharge to these aquifers is considerable and does not occur as leakage from shallow aquifer. Here afterwards, deeper aquifers should be reserved for emergency drinking water supplies. Groundwater model can play a major role in the assessment and management of groundwater system in an area.

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