Natural Treatment Technique for Sustainable Drinking Water Supply in Jharkhand State

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Abstract: In this paper, an overview of Managed Aquifer Recharge (MAR) and Bank Filtration (BF) as methods of natural treatment technique for augmentation of groundwater resources and sustainable drinking water supply has been presented. The potential of employing bank filtration schemes in different alluvium stretches of rivers in Jharkhand have also been discussed. A detailed investigation of those potential sites would be necessary before implementation of BF schemes in those areas. The possible sites could be: Ranchi Lake, Bundu (Kanchi River), Lohardaga (South Koel); Daltonganj (Koel), Golmuri cum Jugsalai, Demkadih, Barabanki (Subernrekha); Baharagora (Subernrekha); Sahebganj (Ganga River); Udhowa Block (Ganga River).

Introduction

Deterioration of water quality, both surface and ground water, is almost a common evidence in every state in India mainly because of: (i) uncontrolled and unabated discharge of untreated sewage into rivers/streams; (ii) overexploitation of groundwater resources and depletion of groundwater level causing problems of groundwater quality originated from anthropogenic and geogenic sources; (iii) increasing demands in all sectoral uses coupled with population dynamics and insufficient sanitation services provision are other reasons, etc. On the other hand, water quality guidelines are getting more stringent due to the increasing number of emerging contaminants in water and consequently the cost of water treatment is increasing. In many developing countries, disinfection (very often by chlorination) is the only treatment applied to public water supply, where there is no planned treatment facility available. In this context, there is a need for a robust water treatment technology which is effective, low cost and could be operated and maintained relatively easily. Jharkhand State has varied hydrology, hydro-geological setups and water scarcity problem across the state is very common. The undulating topography and underlain crystalline hard rock in many parts of the state prevent rainfall water to recharge aquifers as it offer less permeability and porosity. There is paucity of surface water storage; water demand in many areas is met by groundwater. As reported by the state Groundwater Department, that water table in many parts of the state dropped by an average of three metres between 2009 and 2010, from 17 metres to 20 metres. Hence it is imperative to augment groundwater resources by taking necessary measures using advanced scientific techniques. Natural Treatment Techniques such as, Managed Aquifer Recharge (MAR) together with Aquifer Storage Treatment & Recovery (ASTR) by Bank Filtration(BF) can be entailed as a cost effective technology for conjunctive management of surface and ground water resources and thereby can resolve scarcity of drinking water supply.

Managed Aquifer Recharge (MAR) describes intentional storage and treatment of water in aquifers for subsequent recovery or environmental benefits (Dillion et al, 2009). The term “Artificial Recharge (AR)” commonly used in India also describes the similar activity as in MAR without consideration of quality of water resources. MAR allows storage of excess surface runoffs available seasonally that can be recovered for use during peak periods of demand. On other hand, BF is a low cost, effective natural multi-objective process of surface water treatment which removes particles, biodegradable organic compounds, trace organics, microorganisms as well as ammonia and nitrate to some extent to render it to a drinkable quality. Together these technologies can serve the objective of sustainable water supply and management.

River bank filtration (RBF) or simply, bank filtration (BF), which is a technique of MAR, is being used in Europe for more than 100 years for public and industrial water supply in cities and towns (Grischek et al., 2002) as a traditional, efficient and well accepted method. In India, BF technique is gaining popularity and its effectiveness has been studied under ‘Saph Pani’ project for sites located in Haridwar, Delhi, Srinagar and Nainital.

Jharkhand has good potential for both RBF and MAR in rural as well as urban pockets of the state. The objective of this paper is to highlight scope of natural treatment technique such as, MAR and RBF in management of surface and ground water resources and their potential of application in the state of Jharkhand.

Processes of Riverbank Filtration

Bank filtration (BF) is the abstraction of water from aquifers that are hydraulically connected to a surface water body which is in most cases a riverine system. By pumping from wells adjacent to a river or lake, the groundwater table is lowered and the surface water infiltrates into the aquifer. The infiltrated water moves towards the production wells where it mixes with the ambient groundwater originating from the land side. For drinking water production, BF is regarded as a pre-treatment step in the overall treatment chain, since not all undesired substances can be removed during aquifer passage.

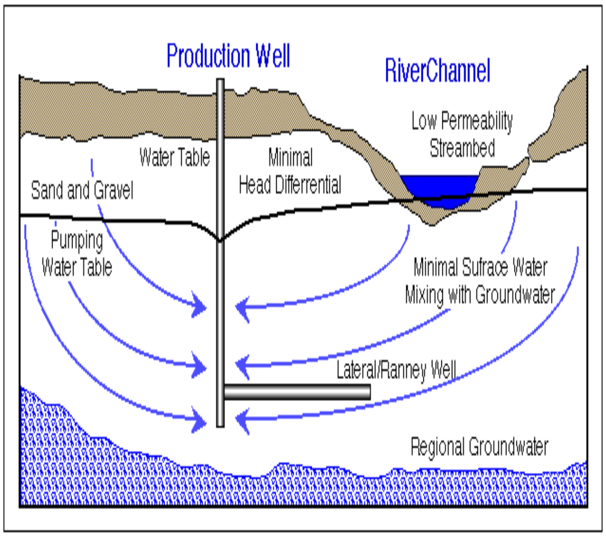

Figure 1: Schematic diagram of a bank filtration well

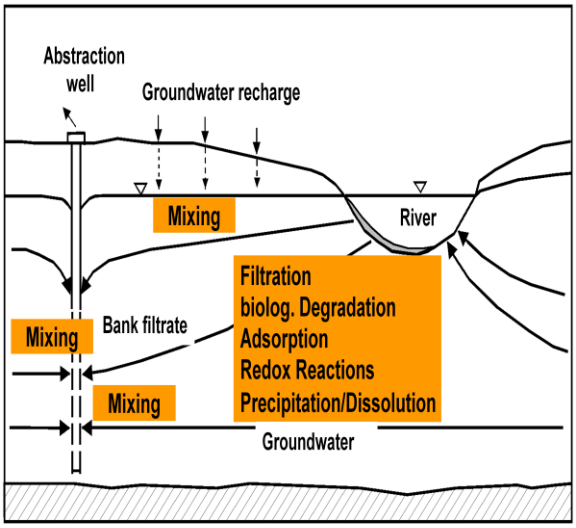

Figure 2: Schematic diagram of processes affecting water quality during bank filtration. Source: Hiscock and Grischek (2002).

Depending on the quality of the extracted raw water, treatment techniques that follow BF may include oxidation/ozonation, sand filtration, activated carbon filtration and safety disinfection (Schmidt *et al.*, 2003). BF as a pre-treatment for nanofiltration has been reported to be even more effective for reduction of membrane fouling than microfiltration (Speth *et al.*, 2002). Relevant parameters such as hydraulic conductivity, aquifer thickness, the flow velocity, gradient and discharge of rivers, and clogging of the riverbed are important characteristics to delineate feasible Bank filtration sites (Grischek et al. *2002*; Ray et al. *2002*; Schubert *2002*). Riverbank filtration is typically conducted in alluvial valley aquifers, which are complex hydrologic systems that exhibit both physical and geochemical heterogeneity. During RBF, which is similar to slow-sand filtration, the impurities of river water are attenuated through combination treatment processes. The performance of RBF systems depends upon well type and pumping rate, travel time of surface water to wells, site hydrogeologic conditions, source water quality, biogeochemical reactions in sediments and aquifer, and quality of background groundwater (Schijvenet al. 2002; Ray 2001).

In Europe, many cities have implemented BF as one of the main steps for drinking water treatment (Eckert and Irmscher, 2006). RBF technique is in use in Europe along the Rhine, Danube, Elbe, and Seine rivers (Kuehn and Mueller 2000; Doussan et al. 1997). Along the Rhine, the first RBF plants in Du¨sseldorf, Germany was implemented to supply drinking water to a population of about 600,000 (Schubert 2002). In India, RBF technique has been implemented in many places viz., at Haridwar (Ganga River), Satpuli, Agastmuni, Srinagar (Alaknanda River), and Karanprayag all in Uttarakhand, on the bank of river Yamuna in Delhi, and in Ahmedabad (Sabarmati River) and their performances have been found promising (Ghosh et al, 2015) Table 1 presents some compiled data of potential RBF sites of Indian cities.

Table 1. Summary of sitting and design parameters of some existing operational small- and large-scale bank filtration systems in India. (Source: Sandhu, et al.2011)

Location	Source water body	Well-type	Production capacity in m^3/day	Depth in m	Distance from source water in m	Travel time of bank filtrate
Haridwar	Ganga	CW	33,000	7–10	15–110	2–>100 days
Patna	Ganga	VFW	>3500	150–300	9–236	–
Dehradun	Bandal	RCW(s)	140–430	1.5–2	Beneath riverbed	2–4 min
Muzaffar Nagar	Kali	VFW	29–300	8–15	68	–

CW large-diameter (10 m) caisson well; *VFW* vertical filter well (tube well); *RCW* radial collector well; *RCW(s)* small-scale radial collector well

Water Use in Jharkhand

Jharkhand population as per the census of India 2011 is 3,29,88,134 with rural population of 2,50,55,073 and urban population of 79,33,061 and projected to increase by the year 2031 to 4,44,51,000 and 5,44,47,000 by 2051 (Source: Population Foundation of India, August

2007). Total water availability in the state is 32.779 BCM (billion cubic meters) (Water Resources Department, Government of Jharkhand 2011), in which surface water and groundwater constitute 27.528 BCM and 5.251 BCM, respectively. As per the calculation of dynamic resources, the present scenario of groundwater and surface water in Jharkhand is as follows: (i) groundwater - 4292 MCM (ii) surface Water - 25876.98 MCM (iii) allocation for irrigation requirements - 3813.17 MCM (iv) industry requirement - 4338 MCM (v) urban requirement – 734.8 MCM (vi) availability in urban area – 333.8 MCM. The trend of population increase shows that the drinking water requirement in the urban area will face short by 401 MCM. Percent of households with access of safe water supply within 15 minutes is 34% compared to 62% for India, which is just half and it magnifies the poor status of drinking water facility in Jharkhand state. (Source: NSS 55th round, NFHS-II, NFHS-III, and Population census 2001). Hence there is a need for exploring alternative source and technique of water supply to meet the water demand sustainably. MAR and RBF can provide a potential solution to resolve water quantity and quality problems in Jharkhand.

Factors affecting Water Supply in Jharkhand

Five major factors affect drinking water supply in Jharkhand: (i) hydrological and hydrogeological setup of the water sources; (ii) lack of proper water supply infrastructures; (iii) drying up of water sources; (iv) river water pollutions as a result of agriculture runoff, industrial wastes disposal, lack of treatment of domestic sewerage; and (v) poor maintenance

About 30% of habitations across Jharkhand have access to safe drinking water, about 12% of sown area is irrigated, and the sanitation coverage stands at a paltry 7% and 44% of the water supply breaks down frequently. Reliability of public water supply sources come across as a major issue. Dry up of sources (34 percent) and poor maintenance (27 percent) has been reported as the major reasons for the sources being not reliable; a relatively higher proportion (40 percent) quoted poor maintenance as a reason for high levels of unreliability (PAF 2004). Beneficiary satisfaction with water supply and sanitation adequacy is about 24.9% and quality 24% (Source: Estimated from the 2005 Rural Jharkhand User Satisfaction Survey (RJUSS). Groundwater extraction to meet domestic water requirement is becoming unsustainable because of the lowering of the groundwater table.

There are numerous rivers in Jharkhand from which water is abstracted for treatment prior to supply for drinking and domestic purposes. Among such rivers are Subarnarekha, with its many tributaries on the bank of which major steel city Jamshedpur is situated. Daltongunj is situated on the bank of river Koel and Sahebgunj is on the bank of river Ganga. Ranchi city gets its water supply from Kanke reservoir, Rukka dam and Gaitalsud reservoirs. Hence there are possibilities to explore the potential for Riverbank Filtration a natural treatment system, as a supplement to conventional treatment technique for supply of domestic demand.

Few Potential Bank Filtration sites in Jharkhand

The selection of suitable sites for BF depends on: (i) hydrogeologic conditions including characteristics and composition of aquifer materials, (ii) river/lake water quality, (iii) ambient groundwater quality, (iv) distance of the well(s) from the river/lake, (v) pumping rate, (vi) soil/sediment characteristics at the river/lake-aquifer interface; (vii) hydraulic connection between river and aquifer; (viii) aquifer thickness and hydraulic conductivity, etc.

Based on the preliminary analysis of hydrogeological formation, hydrological features and water quality parameters relevant to the bank filtration, the potential bank filtration sites found feasible in Jharkhand are as follows: the stretch of the river Ganga in Sahebganj district, Rajmahal and Udhawa block, Koel River in Daltonganj district, South Koel in Lohardaga district, Ranchi Lake in Ranchi district, along Kanchi river in Bundu block, Subernrekha in Jamshedpur district. Figure 3 shows the river networks superimposed on the hydrogeological map of the Jharkhand state.

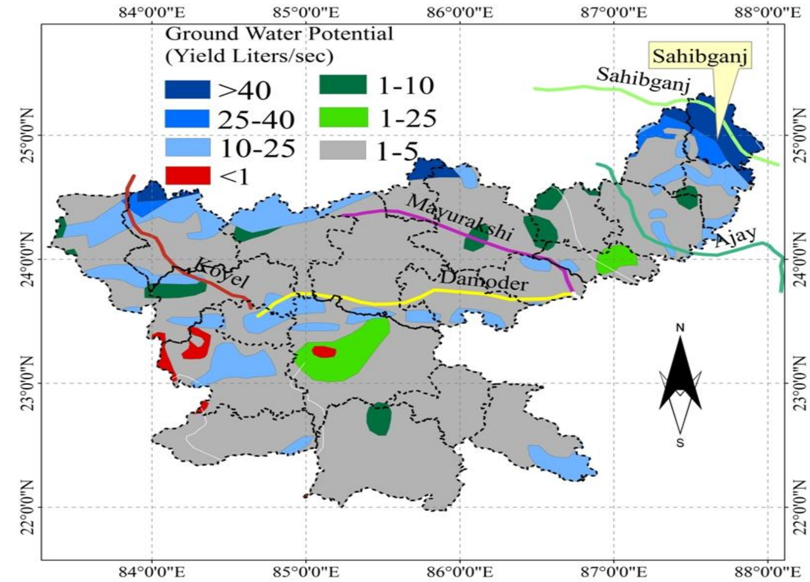

Figure 3. Hydrogeological map of Jharkhard showing Potential of Bank Filtration in Jharkhand-Sahebganj area, along Ajay River, along Koel River (Daltonganj), along Damoder River

The identified sites are along the major river having alluvium sandy and gravelly soils (Figs 3, and 4). The hydraulic connection between the aquifer and surface water body for those sites are quite possible, as many large diameter open wells of depth 7m- 12m with diameter 1.22 m -6.09m are located at a distance of 49 m-771m from the river. Groundwater potential for those sites mostly ranges from 10-25 litres/sec. These sites can have the potential to develop as the RBF schemes for supply of drinking water. However, there is a need of detailed investigations of those sites before considering implementation of RBF schemes.

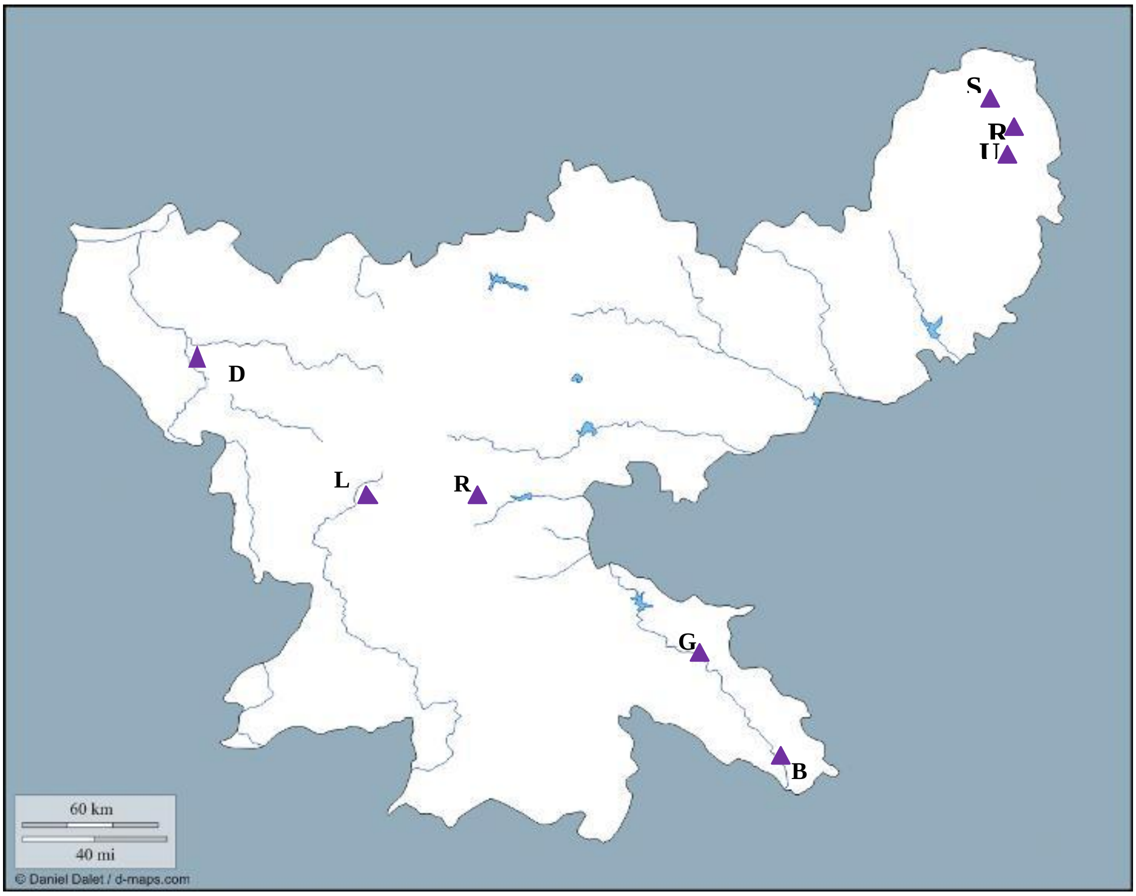

Figure 4: Location of Potential Riverbank Filtration Sites in Jharkhand **;** R- Ranchi (Ranchi Lake); L- Lohardaga(South Koel); D- Daltonganj (Koel); G-Golmuri cum Jugsalai[vil Demkadih, Barabanki](Subernrekha); B- Baharagora (Subernrekha); S-Sahebganj Block (Ganga); R-Rajmahal Block (Ganga); U-Udhowa Block (Ganga).

Among the identified Potential Riverbank Filtration sites Sahebgunj (Ganga) and Lohardaga (South Koel) as suitable RBF sites are illustrated below.

Bank Filtration sites in Sahebganj District (along River Ganga)

Sahebganj, Udohwa and Rajmahal blocks under Sahibganj district are located along the River Ganga mainly comprises of Alluvium, soil/boulder conglomerate, older Alluvium and Laterite (Figure3), which indicate potentiality for RBF site. Few pockets in the Sahebganj district have been reported exposed to groundwater Arsenic contamination. Arsenic contamination has been reported close to the Ganga River and in those areas from where the Ganga River shifted during recent past. Presently, the city has no organized water supply system and the populations are mostly dependent on spot sources like well and tube wells. Majority of the house owners have their own bore wells within their premises and the population who have no such systems are solely dependent on government hand tube well, people who are economically sound have their own tube wells fitted with electrically operated pumps. During summer season, the situation becomes worse and the piped water supply facility available in a limited area remained in operation till the end of the last decade but the system became defunct at the end of the last decade due to diminishing yield of the tube wells.

Sahebganj town occupies the inter-fluvial belt of Ganga River, which is a perennial river, carries huge volumes of water during the rainy season. The town is located adjoining the river Ganga. Sahebganj district is mainly characterized with Ganga, alluvial plain. The alluvium comprises mainly of sand and sub-ordinate clay. Groundwater and river water quality in the Sahebganj area as reported by many investigators didn't show any sign of major contaminations except Arsenic contaminated in groundwater in few pockets. Being an area exposed to groundwater Arsenic contamination, use of surface and ground water for drinking purpose without treatment is a big challenge. Therefore, feasibility of using riverbank filtrate water can be explored as an alternate technique.

Lohardaga (South Koel)

Lohardaga district is situated in the south western part of Jharkhand State. The district covers an area of 1491 km² in the tribal belt of Chotanagpur plateau and has a number of small hill blocks covered with forests. The general slope of the district is from west to east. The main rivers of the district are South Koel, Sankh, Nandni, Chaupat's and Fulijhar etc. These are mainly rain fed rivers and dried up in the summer months. Geologically the area in comprised with Archean Granites and Gneisses. In the uplands considerable thickness of late-rite of Pleistocene age is found in the Granite and Gneisses tracts. Alluvium of recent to sub-recent age is found in the river valleys. The major part of the district is covered with Golden Alluvium, Red and Sandy and Red and Gravelly soils. According to the 2011 census Lohardaga district has a population of 461,738 and 80% of the population depends upon agriculture. In the small irrigated area wheat is grown to meet the annual food sufficiency. The main source of water for irrigation is through wells located on fields. MAR through conservation of monsoon surface runoff can bring sustainability in use of groundwater based irrigation and RBF can serve as an alternative for sustainable water supply for drinking purposes in those areas.

Figure 5: South Koel River near village Kolsimri under Kuru Block, Lohardaga.

Figure 6: Dug well near the Kolsimri village being used for irrigation water supply.

How MAR can help Jharkhand?

Jharkhand due to its geographical setup and shortage of proper storage capacity, about 80% of surface water and 74% of groundwater go out of the state without much productive utilization. Consequently, the state faces drought in 38% of its area (Groundwater Division, Water Resource Department Govt of Jharkhand). To overcome such situation, MAR can be used as a potential strategy to conserve monsoon surface runoff for groundwater recharge in feasible areas. Jharkhand topography is undulating plateau, which has the characteristics of enhanced surface runoff, and the lithology comprises of hard crystalline rock in most part of the state which prevents rainfall water to recharge aquifers as it offer less permeability and porosity. For such condition, MAR at suitable surface storage sites to augment groundwater resources can be implemented for meeting irrigation and domestic water requirements. Presently, groundwater extraction to meet domestic water requirement is becoming unsustainable because of the lowering of groundwater table as indicated in the Annual water level fluctuation from January 2010 to January 2011(Source: Ground Water Year Book – India 2010-11 by CGWB). To avert the declining groundwater levels, MAR with detailed feasibility study can be used to stabilise and raise groundwater levels. Surface water availability in Jharkhand state is about 29200 MCM of which 75% is dependable flow and groundwater availability is 2000 MCM hence emphasis can be laid on more utilisation of surface water than groundwater level to reach critical stage. Figure 7 shows the water resources potential of Jharkhand state.

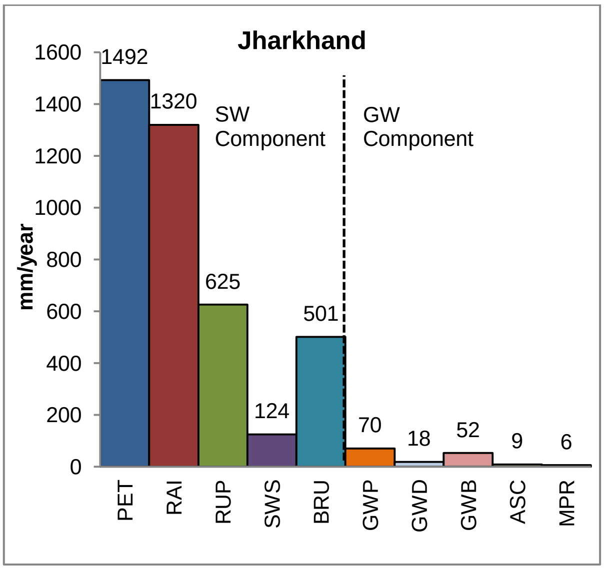

Figure 7 : Shows water resources scenarios of Jharkhand state: (PET : Potential evapotranspiration; RAI – Average annual rainfall; RUP- Surface runoff potential; SWS - Surface runoff committed for surface storage; BRU- Balance surface runoff; GWP-Groundwater resources potential; GWD- groundwater draft + natural discharge; GWB- Balance groundwater resources; ASC-Aquifer storage capacity; MPR-feasibility of utilizing surplus runoff for groundwater recharge).

From Figure 7, it is clearly evident that Jharkhand state has enormous surface runoff (501 mm/year) that flows out from the state without much productive utilization. The estimate given by the CGWB showed that the state has potential aquifer storage capacity to accommodate about 9 mm/year of surface runoff, out of which feasibility of utilizing surface runoff as MAR is about 6 mm/year. Hence, the state should think to adopt MAR at feasible sites based on condition of hydro geological setup. However, a detailed investigation and analysis would be necessary before a master plan is prepared for implementation of MAR.

Conclusions

The paper highlights an overview on Managed Aquifer Recharge (MAR) and Bank Filtration (BF) technique. The scope of adopting these techniques in Jharkhand state for attaining water security particularly in the irrigation and domestic sectors have been discussed. Few potential locations for employing BF have been suggested, however, the feasibility for implementing BF schemes in those sites would need detailed scientific investigation. The scope of employing MAR in the state has also been highlighted. It is recommended that the state should develop a master plan for integrated water resources development and management to address the emerging issues.

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