NARESH KR. KATARIYA
and
AMIT BISWAS

Sustainable development of groundwater in and around opencast limestone mine area by rainwater harvesting – a case study

Mining of minerals is essential part of life so is the groundwater. The present case study focuses on the sustainability of groundwater in and around the large opencast limestone mines area by rainwater harvesting in Satna region, Madhya Pradesh, India. It evaluates the quantity, quality, and management of groundwater encountered in mines and water positive for human consumption, irrigation and other plant uses. Field study and trials have been done with understanding of interrelationship between groundwater hydrology and mining, the basic objective of sustainability, that is, conserving for future generations with particular reference to the mines has been addressed. Such scientific approach makes the mine planning easier, ensures better water management and solves water scarcity as well as security problems in the vicinity of mining areas.

Keywords: *Sustainable development, water positive, impact of mining on groundwater, groundwater in hard rocks*

1.0 Introduction

Groundwater is of paramount importance for an agriculture-based country like India. Being a leading asset, the use of groundwater, primarily for irrigation and for various development activities over the years has adversely affected the groundwater regime in many parts of the country. With 2.4 per cent of the total land area and 4.0 per cent of the total available water India have to serve 17.5 per cent of world population and 30 per cent livestock. In the year 2010, annual water demand was 813 BCM and it is likely to be 1093 BCM by the year 2025 and 1447 BCM by the year 2050 [1]. Thus available utilizable water resource of the country is considered insufficient to meet all future needs.

The mining sector is gradually growing in the quality of human life. But, while permitting mining, the disturbance to the hydrological regime should be minimum or as less as possible. This study determines the interrelation of mining process with water in general and groundwater in particular.

Naresh Kr. Katariya, Research Scholar and Amit Biswas, Mine Geologist, Department of Mining Engineering, Indian Institute of Technology (ISM), Dhanbad, India. E-mail: naresh84kataria@gmail.com

To understand groundwater-related problems of mine, hydrological and geological set up of the area is first studied. With reference to any mine or the mining area, hydro-geological set up encompasses aquifer characteristics, that is, nature, type, parameters, etc.; all local and regional geological details; and plans for mining and total picture of hydrology, drainage, discharge, etc. The approach for scientific investigation, to search solution, usually includes field monitoring (pre-monsoon and post-monsoon monitoring), instrumental survey, groundwater modelling, and mine planning, that is, drainage, dewatering, etc.

The surface mining and underground mining are two major methods of mining for exploitation of mineral from the earth. Role of groundwater is very important in both methods because mining has influence on hydrology.

2.0 Study area

Satna district is one of the representative districts of Vindhya region of Madhya Pradesh. In turn the town derives its name from the Satna river, which flows through the vicinity and joins the Tamasa river. The study and field trials have been done in and around opencast limestone mines, with a wide range of products from cement, ready-mixed concrete, tiles, bath products. Opencast limestone mines are situated in Satna district, MP. The actions have been taken towards creating, maintaining and ensuring a safe and clean environment for sustainable development. However, a special emphasis is given on the groundwater resource management and development.

3.0 Scope of sustainable development of groundwater

The Rampur Baghelan Tehsil of district Satna was declared as over exploited zone by the Central Ground Water Board. According to Dynamic Groundwater Resources (2013) the stage of groundwater development was 102%. Therefore, there exists a huge scope of sustainable development in the groundwater resource management and groundwater recharge in and around the vicinity of the mines and plan. The location map is shown in Fig.1.

The mines and plant fall in the area that averages 1100 mm of annual rainfall and exists in watershed no.6 of 28 watersheds of the Tons river sub basin (Watershed Atlas-

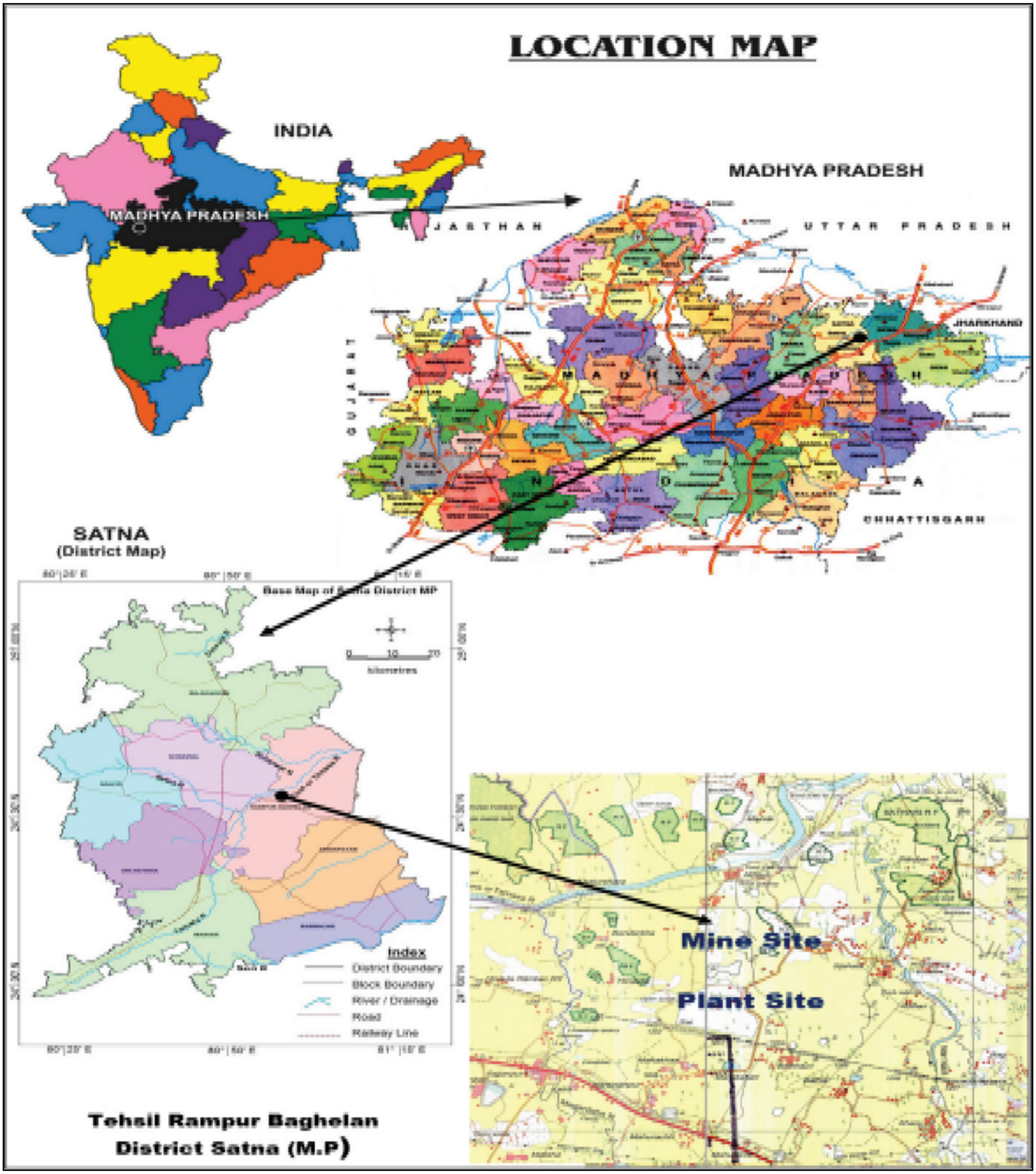


Fig.1: Location map where study was conducted

Central Ground Water Board). Despite having not any effective catchment programme in place, pro-activeness has been shown and took it as an opportunity to enhance the groundwater table with the help of rainwater harvesting, as the rainfall being the only source of water for groundwater recharge. The surface runoff available in the plant, colony and mining is used for this purpose.

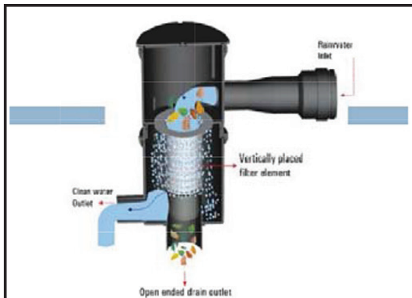
The area of plant and colony is around 987500 m^2 whereas the mine area being roughly 12778000 m^2 having annual rainfall of 1100 mm. The coefficient of runoff which depends on the type of land under use, is in the range of 0.1 to 0.85. The available quantity of rainwater is 4500000 m^3.

Total available runoff for rainwater harvesting by different measures adopted is around 2575000 KL which includes 6636 sq meter roof area (rooftop rainwater harvesting), catchment area for recharge pits constructed in plant and colony for harvesting ground runoff rainwater is around 150000 sq meter with varying coefficient of runoff as per the surface condition. The void available at 8 numbers of abandoned mine pits is 3107230 m^3 with a surface area of 476549 m^2 by which the net available water for recharge is around 2495020m^3, after deducting the loss of water due to evaporation. De-siltation done at nearby village pond has also enhanced its water accumulation capacity by around 3600 m^3.

4.0 Mechanism adopted for the rainwater harvesting and groundwater recharge

4.1 Groundwater recharge with rooftop rainwater harvesting

This is an efficient method of injecting fresh rainwater into groundwater, provisions to harvest the rainwater of around 6636 m^2 rooftop, including project office (386 sq meter), school (1150 sq meter), MRSS building (1900 sq meter) and cement mill load centre (1100 sq meter), cooler load centre unit 1 (1100 sq meter) and cooler load centre unit 2 (1000 sq meter) for which bore-wells have been made beside these buildings. All the drain pipes of roof are connected altogether and the common discharge is diverted to the respective tube well, passing through a specially designed rainy filter which is a registered product of "Rainy". Rainy filters are designed with self-cleaning mechanism and fixed to the wall by connecting rooftop rainwater drain pipes. The rainwater along with dirt particles enters into the inlet of filter through the hollow pipe tangentially to the filter housing and rotating slowly along the periphery of upper housing so as to flow into the filter element placed in lower housing of the filter unit in angular motion at specific velocity, which creates cohesive force and segregates dirt particles and clean water individually. However, when the intensity of rainfall increases the high volume of water moves in circular motion with high velocity in the upper housing and creates a centrifugal force. In both situations, involving low and high intensity of rainfall, the working principle of the filter based on cohesive and centrifugal force respectively, aids the filter element to divert clean water into the recharging well and simultaneously flushes out automatically sand, debris, and dirt particles through the drain outlet. These all will inject around 6400 KL clean water groundwater recharge.



Inner view and working of rainy filter

Rooftop drain diverted to bore-well through series of drain pipes

Installation of rainy filter

Filtered rainwater injected in bore-well

Pit receiving runoff water from outside plant boundary into groundwater.

Fig.2 Arrangements for water harvesting with rooftop

4.2 Rainwater harvesting by utilising abandoned bore-wells

There were three tubewells inside plant premises, which were declared, abandoned as they had dried. The company converted them to a groundwater recharge structure, for which a pit of 3×3×3 meter was made and filled with conventional filter media. Casing of tube-wells are made perforated and wrapped with fine PVC net. A conventional filter has been made with filling different layers of varying size stones and concrete to avoid entry of silt and other particles into aquifer. Total rainwater harvesting potential of these recharge structures is around 8938 m^3.

4.3 Groundwater recharge by diverting storm drain to recharge pit

Two numbers of recharge pits have been constructed which are connected with storm drains of colony area. Pit one receives entire rainwater of B&C type colony of PCL. The catchment area of this pit is around 70000 sq. meter which includes 22800 sq meter of roof/road area and 47700 sq meter earthen area. This pit feeds around 37000 m^3 of rainwater. Pit 2 receives entire rainwater of "A" type colony. The catchment area of this pit is 27000 sq. meter which includes 9700 sq meter roof/road and 17300 sq meter of earthen area, which may inject around 14800 m^3 of rainwater to groundwater.

Dimension of pit 1 is 6×3×3 meters with two numbers of bore-wells. Pit is filled with boulders of 60-90 mm size up to height of 800 mm above which, river bed stones of size 30-50 mm size up to height of 500 mm and fine concrete of 6 mm size at upper 200 mm. Remaining 1.5 meter void is filled with 60-90 mm size boulders with making a gentle slope towards pit opening. Service drain, which is connected to the storm drain, is made 500 mm deep from the opening of recharge pit which makes a sump for de-siltation of storm water before entering into recharge pit.

Dimension of pit 2 is 3×3×3 meters with two numbers of bore-wells. Pit is filled with boulders of 60-90 mm size up to height of 1400 mm above which, river bed stones of size 30-50 mm size up to height of 1000 mm and fine concrete of 6 mm size at upper 200 mm. Service drain, which is connected to the storm drain is made deep from the opening of recharge pit which works as sump for de-siltation of storm water and only the supernatant clear water enters into recharge pit. Boulder of 60-90 mm size has been spread on the top which adds another level of filtration which hinders the flow of water and prevents the entry of silt into underneath layers of filters.

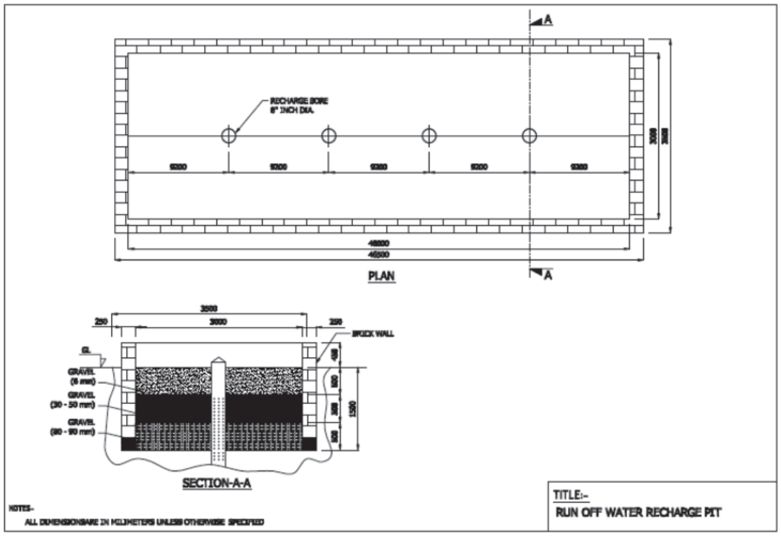


Fig.3 Drawing of recharge pit

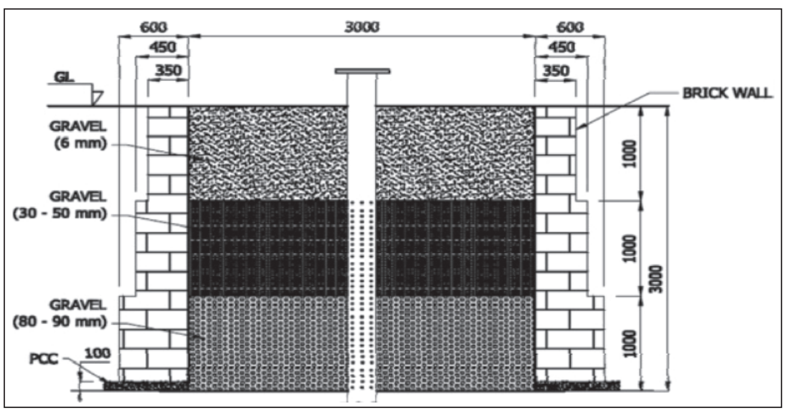


Fig.4 Drawing of recharge pit constructed with abandoned bore-wells

5.0 Summary and conclusion

Serious efforts have been made towards the groundwater recharge in and around the cement plant. The various initiatives like the construction of check dams, deepening of ponds, construction of artificial recharge structures, adoption of several rain water harvesting measures like roof top rain water harvesting structures started to pay the results. Using scientific approach to rain water harvesting, total 122061 m^3/year quantity of water by plant by structures and total 281241 m^3/year quantity of water in mines water reservoir and mined out pit has been channelized to recharge the groundwater and to use the rainwater for water positive. Recently, the Rampur-Baghelan block has been declared as semi critical zone by the CGWA, i.e. this block has been promoted two steps from over exploited zone to semi critical with the stage of groundwater development decreased from 102% to 81%. Continue efforts towards the sustainable development of groundwater in and around opencast limestone mine area by rainwater harvesting improved groundwater conditions. Further, studies and field trials are being done for "zero" wastage of water with latest technology for water management and to recharge the groundwater to make this region to be declared as safe zone.

Table 1: Rain water harvesting by plant by structures

	Land use type	Area (M2)	Rainfall (M) 2018- 19	Runoff coefficient (as per CGWB guidelines)	Quantity of rainfall runoff generated (available for harvesting/ artificial recharge) (in m^3/year)
1	Roof - project office	386	1.174	0.85	385
2	Roof – school	1150	1.174	0.85	1148
3	Roof of MRSS	1900	1.174	0.85	1896
4	Roof of cement mill load center U2	1100	1.174	0.85	1098
5	Cooler load centre U1	1100	1.174	0.85	1098
6	Cooler load centre U2	1000	1.174	0.85	998
7	Runoff water harvesting structure near guest house	30000	1.174	0.3	10566
8	Groundwater recharge with abandoned bore well - 1	10000	1.174	0.3	3522
9	Groundwater recharge with abandoned Bore well - 2	10000	1.174	0.3	3522
10	Groundwater recharge with abandoned bore well - 3	2500	1.174	0.85	2495
11	Groundwater recharge pit connected with storm drain – A type colony	9746 17307	1.174 1.174	0.85 0.3	9725 6095
12	Groundwater recharge pit connected with storm drain – near nursery	22828 47748	1.174 1.174	0.85 0.3	22780 16817
13	Ground water recharge with abandoned bore well near steel yard	40000	1.174	0.85	39916
	Total				122061

Table 2: Rainwater harvesting in mines water reservoir and mined out pit

	Pit name	Bottom area (acres)	Bottom area (M²)	Rate of infiltration	No of days water available	Coefficient for water cover area	Depth of water (m)	Volume of water (M³)	Recharge R=(A×l×D×C) /1000
			A	I	D	C			R
			(M²)	(mm/d)	(days)	Coefficient	m	(M³)	(M³/y)
1	H9 & H16	6.32	25577	1.4	300	0.60	6	153462	6445
2	H12	6.67	26993	1.4	365	0.60	6	161961	8276
3	Old pit (A)	24	97128	1.4	365	0.60	10	971280	29779
4	New pit	58.76	237802	1.4	180	0.60	4	951207	35956
5	Old pit (B)	13.76	55687	1.4	365	0.60	10	556867	17074
6	H15	51.12	206883	1.4	300	0.60	6	1241296	52134
7	East pit	63.73	257915	1.4	300	0.60	4	1031661	64995
8	Plant reservoir	30.12	121896	1.4	365	0.60	10	1218956	37373
9	H18	5.5	22259	1.4	365	0.60	4	89034	6824
10	H21	6.41	25941	1.4	365	0.60	6	155648	7954
11	H24/25	5.5	22259	1.4	365	0.60	6	133551	6824
12	S/20	6.13	24808	1.4	365	0.60	6	148849	7606
	Total effective groundwater recharge								281241

6.0 References

1. Basin Planning Directorate, CWC, XI Plan Document. Report of the Standing Sub-Committee on "Assessment of Availability & requirement of Water for Diverse uses-2000"
2. Evaluation of Water Utilization Directorate – Ministry of Water Resources, River Development and Ganga rejuvenation – April 2017.
3. Sustainable Development framework (SDF) for Indian Mining Sector - Ministry of Mines, Final Report, 30 Nov. 2011.
4. Naik, Bibhuti, Kumsr, Nail, Papu Kumar and Pattanayak, Sanjaya Kumar (2017): Groundwater Quality Assessment Using Canadian Water Quality Index Around Jurudi Mining Area, Odisha, India, *International Journal of Current Research,* Vol. 9, Issue, 08, pp.55434-55442, August
5. Bell, Sarah J. Frameworks for urban water sustainability, Institute for Environmental Design and Engineering, UCL, London, UK

Printed by Pradip Kumar Chanda at The Indian Press Pvt. Ltd. 93A Lenin Sarani, Kolkata 700 013 and published by him for Books & Journals Pvt. Ltd. from 62 Lenin Sarani, Kolkata 700 013.