# MINE VOID AS FRESHWATER RESERVOIR – AN ECO-FRIENDLY CONCEPT OF COAL INDIA LIMITED

A.K. Debnath[1], D. Basu[1], V.K. Pandey[1] and Monika Agarwal[1]
[1]*Central Mine Planning and Design Institute Limited,*
*Gondwana Place, Kanke Road, Ranchi-834031, India*
*(Corresponding Author: vinodkpandey_in@yahoo.co.in)*

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### ABSTRACT

The water resource is key to survival of the mankind and this resource is now becoming critical in many parts of globe including India. As per an assessment of Central Ground Water Board (CGWB) of India, a huge shortfall of about 58 billion $m^3$ of water is anticipated by the year 2050. In order to counter this shortfall, there is thrust from Government of India to adopt water conservation measures. National Environment Policy, 2006 of Government of India also stresses upon the need to take up water conservation measures for water security of the country. The coal mines in India provide an excellent opportunity to take up water conservations measures therein. The mine water is not acidic unlike western countries and it conforms to the prescribed regulatory standards. This nature's gift is utilized in Coal India Limited by allowing mine voids to get filled with mine water. The net recharge potential of the opencast mining area is found to be about 5% in comparison to 2% in non-mining area offering good prospects for ground water recharge. The seasonal rainwater is also diverted into mine voids left at the end of mining operations which act as huge reservoirs/ pit lakes for storage of the water. They also serve as surface water bodies for recharging of water table in the surrounding areas. The area and space left from where coal has been extracted completely in underground mines and will not be entered by any man or machinery after the extraction, called goaf, are also potential source of water conservation. These additional water resources created are being utilized for meeting the industrial, domestic, irrigation and other requirements of the projects and local communities eliminating the need to tap other fresh water resources including ground water. Presently, 75% of the water demand of the coal mining project is being met from the water stored in the mine pits. In future, CIL is likely to create about 3.3 billion $m^3$ of water resource, on an average, in its opencast mines alone. In the mine closure plan of opencast mines, the last cut is proposed to be developed into water body for recharge of ground water and creating additional water resources. A clean potential source of potable water is thus developed after mine closure. This will ensure water security of the country.



### KEY WORDS

Mine void, Water reservoir, Coal mining, Ground water, Water conservation, CGWB, CIL


### PREAMBLE

The world is increasingly turning its attention to the issue of water scarcity. The availability of water on this planet is limited and growing industrial, irrigation and domestic requirement world over has driven this resource becoming scarce, putting a question mark on the future of society. Many countries face water shortage as a fundamental challenge to their economic and social development. By 2030, over a third of the world population will be living in river basins and have to cope with significant water stress. The global water requirements would grow from 4,500 billion $m^3$ today to 6,900 billion $m^3$ by 2030, necessitating efforts at all levels for effective planning and implementation of water conservation measures.

### INDIAN WATER SCENARIO

India is a nation with 16% of world's total population and only 4% of water resources. As per an assessment of Central Ground Water Board (CGWB) of India, present water availability is 1,122 billion $m^3$ and the projected water demand in the year 2050 is likely to be 1,180 billion $m^3$. Growing population will create further burden on the per capita water availability in the future. As depicted in Table 1, the per capita water availability in 1951 was 5177 $m^3$/y when the total population was 361 million and likely to reduce to 1341 $m^3$ and 1140 $m^3$by the year 2025 and 2050 respectively. Based on the average requirement of water for various purposes, the situation is considered as water stress condition when the per capita water availability ranges from 1000 to 1700 $m^3$/y and considered water scarce when the availability reduces below 1000 $m^3$/y. Most of the Indian States are likely to reach the water stress condition by 2020 and water scarce condition by 2025. Water pollution and inadequate water management strategies are the major factors for reduction in the water availability in India. Therefore, reduction of water pollution level and better water management strategies are required to sustain the growing domestic, irrigation and industrial water requirement of the country.

The freshwater resources comprise the river systems, groundwater, and wetlands. National Environment Policy, 2006 of Government of India stresses upon the need to support practices of rain water harvesting and artificial groundwater recharge to conserve this precious natural resource.

Table 1 – Per capita water availability

| Year | Population in millions | Per capita water availability ($m^3$/y) |
|---|---|---|
| 1951 | 361 | 5177 |
| 1955 | 395 | 4732 |
| 1991 | 846 | 2209 |
| 2001 | 1027 | 1820 |
| 2025 | 1394 | 1341 |
| 2050 | 1640 | 1140 |


## HYDROGEOLOGY OF INDIAN COALFIELDS

The ground water behaviour in the Indian sub-continent is highly complicated due to the occurrence of diversified geological formations with considerable lithological and chronological variations, complex tectonic framework, climatological dissimilarities and various hydro-chemical conditions. Indian Coalfields are normally bounded by crystalline rocks. The hydraulic conductivity of crystalline rocks varies from 0.1 to 1.5 m/d and yield ranges from 42 to 250 $m^3$/d. The aquifer in Indian coal bearing formation mostly constitutes Gondwana sandstone. The hydraulic conductivity ranges from 0.5 to 15 m/d and yield ranges from 84 to 1176 $m^3$/d. The Indian coal mostly acts as aquitard having hydraulic conductivity ranging from 0.005 to 0.03 m/d. The behaviour of aquifers in coal mines in case of both opencast and underground mines is as described below:

### Underground Mines

The zone along the perimeter of the mine that experiences hydrologic impacts is said to lie within the "angle of dewatering" or "angle of influence" of the mine. Angle of influence values of 27$^o$ to 42$^o$ were reported in many mines in western countries. Thus, a zone of presumptive liability for mining operations should be limited to the area of the mining operations including the area within 35$^o$ of angle of influence from the mine periphery. In undergroundmines in India, the impact zone has often been restricted within 100-300 m from the mine edge.

**Opencast (OC) Mines**

The unconfined aquifer that contributes the maximum inflow under gravity gets affected due to opencast mining operations. However, due to blasting, the porosity and storativity of aquifer units exposed gets enhanced. The ground water levels get lowered in areas close to the mine/ highwall face. The radius of influence is observed to be 150-500 m in general.

**UNDP Study on hydraulic characteristics of mining area**

In a study conducted by Central Mine Planning & Design Institute (CMPDI) Limited under a United Nations Development Programme (UNDP) project in mines of Western Coalfields Limited, various hydraulic parameters of mine site were determined. The findings of this study (Tables 2 to 4) indicate that at the mine site, there is improvement in hydraulic characteristics favourable for ground water recharge.

Table 2 – Average hydraulic gradient

| Area | Average Hydraulic Gradient |
|---|---|
| Non-mining | $3.60x10^{-3}$ |
| Underground mining | $3.00x10^{-2}$ |
| Opencast mining | $4.00x10^{-2}$ |

Table 3 – Average rise in water level

| Year | Rainfall (in cms) | Bhagirath (Non Mining Area) | Zatpat (underground mine area) | Motaghat (OC Mine Area) |
|---|---|---|---|---|
| 1989 | 104.5 | 203 | 437 | 611 |
| 1990 | 237.5 | 433 | 453 | 745 |
| 1991 | 123.5 | 226 | 348 | 643 |
| Average | 155 | 287 | 412 | 666 |

Table 4 – Normal water balance parameters in percentile

| Parameter | Non-mining area | Underground mine area | OC mine area |
|---|---|---|---|
| Actual evapo-transpiration | 69 | 69 | 69 |
| Surface run-off | 21 | 17 | 10 |
| Ground water run-off | 4 | 5 | 5 |
| Groundwater evapotranspiration | 4 | 3 | 3 |
| Discharge | 0 | 4 | 8 |
| Net Recharge | 2 | 2 | 5 |
| Normal precipitation | 100 | 100 | 100 |

## MINE PITS: HYDROGEOLOGY

Ground water inflow into mine workings is a natural phenomenon. Both underground and open cast mines behave as large sinks and create a hydraulic gradient towards the mine. Due to differential pressures, water flows toward the mine. The inflow is directly proportional to the mine depth, mine expansion rate, aquifer parameters and recharge potential. The residual pits developed due to large scale open cast mining may have large surface areas and great depths. The number of such voids is likely to grow providing an opportunity for water conservation. The void remaining at the last phase of an OC mine or the last cut at the end of mine life can also be developed as a water body. The water level gradually comes up to that of water table in the area over a period of time.

The left out voids, with the natural inflow of groundwater or flooding with surface water/rain water can be converted into pit lakes. Partial diversion of stream flow into the final void wherever feasible would accelerate pit inundation and promote seasonal topping up of the lake. This option will also facilitate more rapid recharging of the depleted deeper aquifers. This option would ensure that the quality of the water in the mine void will be similar to that of the river.

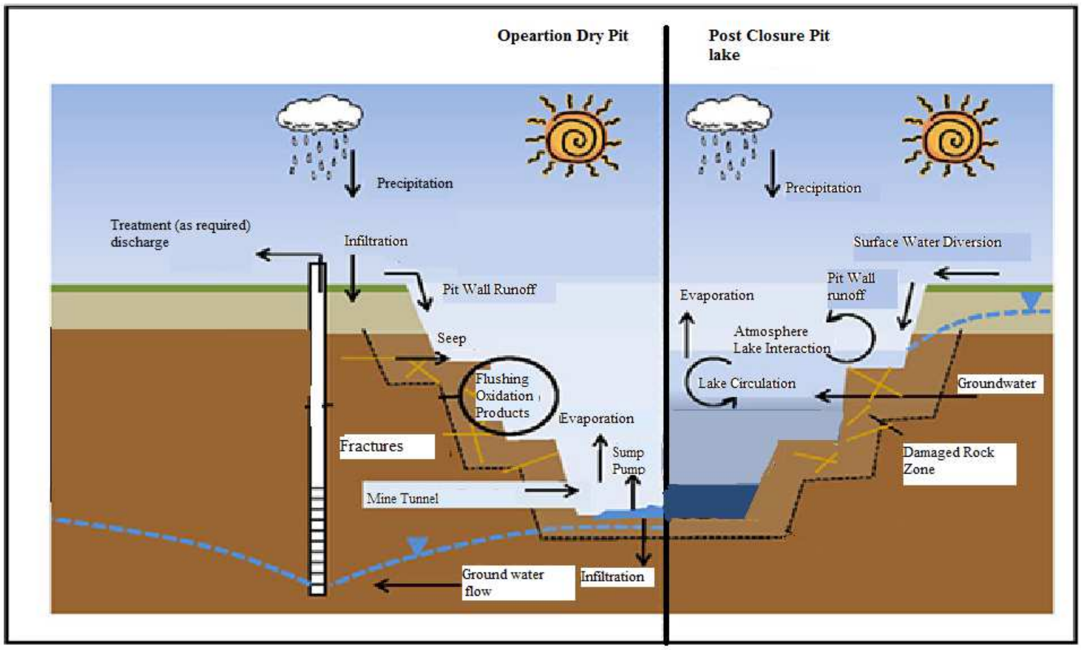


Figure 1 – Post closure pit lake

**Technical Parameters: Mine Pit**

Relative Depth ($D_R$)

Pit lakes are complex environments from a limnological and geochemical perspective. Limnologically, the key difference between pit lakes and natural lakes can be quantified by a parameter known as the relative depth ($D_R$) (Castro & Moore, 2000).

$$D_R = (z_m/d) \times 100\% \qquad (1)$$

Where, $z_m$ = the maximum depth of the lake,
And d = lake diameter.

The pit lakes commonly have relative depths (RD, expressed as percentage of maximum depth to the mean diameter of surface lake) between 10% and 40% compared to natural lakes which are between 0.4% and 7%. High RD causes the lake water to stratify in many cases, and the chemistry of the lake water can vary a lot with depth (Younger P.L., 2000). In a survey of mining pits around the world, it was concluded that most artificial lakes with RD> 25% are meromictic, although there were a few lakes with RD> 25% that were halomictic. Clearly there are other factors that dictate whether a given pit lake is permanently stratified (Doyle and Runnells, 1997). In India, the depth of pit lakes is generally kept at 50-60 m based on the regulatory prescriptions and therefore can be considered halomictic with an average relative depth of 5 to 15%. The water quality of the Indian mine pits monitored over a period of time reveals that there is no degradation of water quality and is fit for use by the local community.

**Pit Lake Water Quality**

The final water quality in the pit lake is dependent on a host of factors including the oxygen status of the lake, pH, and hydrogeological flow system, composition of wall rock, concentration through evaporation (evapo-concentration), biological activity and hydrothermal inputs. The pit lake conceptual model is shown in Figure-2. The mine water quality data of coal mines of Coal India Limited (CIL) is monitored on routine basis and found to be quite good and therefore can be utilized (Table-5).

Table 5 – General Water Quality of Mines of CIL

| Sl. No. | Parameters | Value range | Prescribed Regulatory Standards |
|---|---|---|---|
| 1 | pH | 5.6-7.1 | 5.5-9.0 |
| 2 | Total Suspended Solids (TSS) | 60-140 mg/L | 100 mg/L<br>200 mg/L (land for irrigation) |
| 3 | Oil & Grease | 2-3 mg/L | 10 mg/L |
| 4 | Nitrate Nitrogen | < 3.0 mg/L | 10 mg/L |

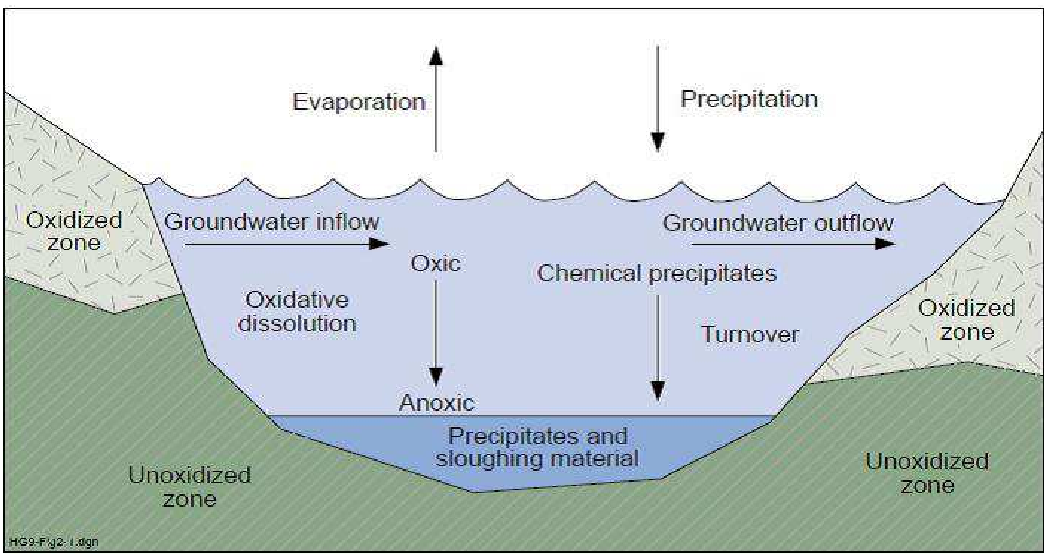


Figure 2– Pit lake conceptual model

Sometimes, the water quality and final pit lake level may take quite some time to reach equilibrium. By diversion of surface water flow into mine voids, the pit water quality would be similar to that of natural water resource. Rapid filling of the void with surface water and subsequent submergence of back filled over burden will inhibit release of pollutants if any (Johnson and Wright, 2003). Therefore, the option of the stream flow diversion has dramatic effect on the lake quality and makes it a resource. This option can be implemented wherever feasible.

## CIL: AN OVERVIEW

CIL is the single largest coal producing company in the world. Spread over 14 coalfields, CIL is an apex body with 7 wholly owned coal producing subsidiaries and 1 mine planning and consultancy company spread over 8 provincial states of India and its current annual production stands at over 430 million tonne. CIL owns a mining company in Mozambique christened as 'Coal India Africana Limitada'. CIL produces around 81.1% of India's overall coal production, meets 40% of the primary commercial energy requirement of India, commands nearly 74% of the Indian coal market, feeds 82 out of 86 coal based thermal power plants in India, accounts for 76% of total thermal power generating capacity of the utility sector. It supplies coal at prices discounted to international prices and makes the end user industry globally competitive.

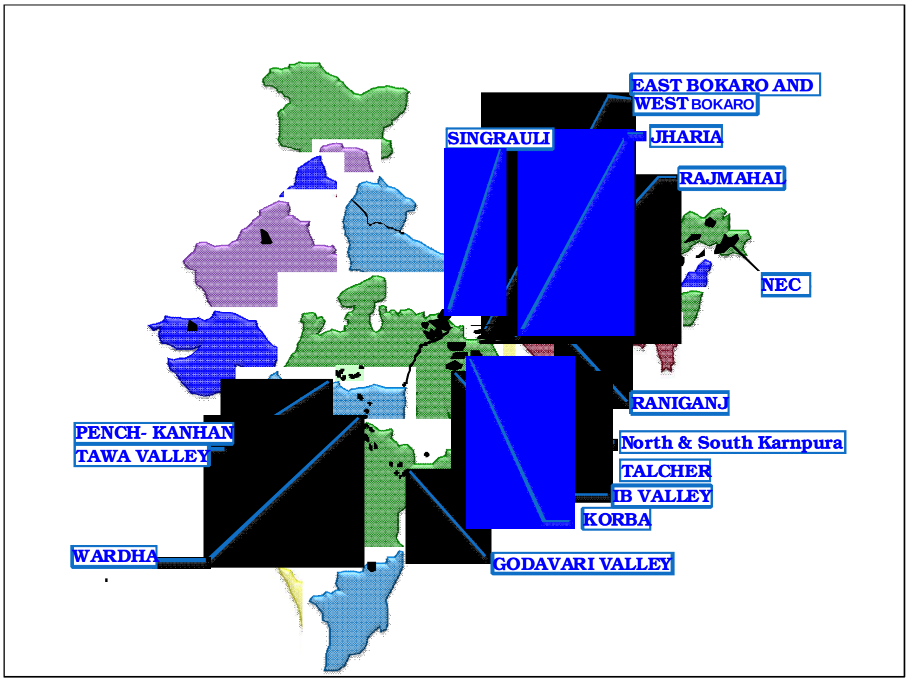


Figure 3– Location of coalfields in India

## EFFORTS MADE BY CIL FOR WATER CONSERVATION

CIL is presently operating more than 470 mines (both undergroundand OC) and has taken steps for conservation of mine water in OC and undergroundmines to address the water scarcity of the country.

### Water Conservation measures adopted by the subsidiaries of CIL

The effluent generated from various sources like mine, coal handling plant and workshops are treated through integrated effluent treatment plants. The treated water is being stored in reservoir and utilized for various industrial usages and the surplus treated water is discharged into natural water streams. This helps in conservation of fresh water resources in and around the coal mines. Similarly, the domestic effluent is being treated in sewage treatment plants and treated water is utilized for horticulture.

Figure 4 – Mine pit filled with water: Piparwar OC mine of CIL

In many parts of the country, small voids are being constructed through various Government schemes with the participation of local community. Such voids are being created with the objective to store water for use by the local village community and also to tackle water scarcity being faced by them. In the CIL mines, such voids are being created as a result of mining operations and they offer an opportunity for storage of mine water for the benefit of the local community. Since the mine water, in general, is not acidic unlike the western countries, this offers a good potential for storage in the mine void. With the ever increasing consumption of water and dwindling fresh water resources in India, CIL has started sustained effort for use of mine voids as water storage structures.

The mine water is being utilized for meeting the industrial and domestic requirement of the coal mines. The balance mine water is discharged into nearby natural streams, which helps in regeneration and recharge of natural water regime and augmentation of water resources, benefiting the local population. Hence, CIL does not tap fresh ground water resources for its industrial and in some cases for domestic use as well. The mine discharge, water demands and mine water utilization in the CIL at present is depicted in Table-6.

Table 6 – Mine Water Utilization in CILSubsidiary of CIL

| | Average Mine Discharge (cum/day) | Demand | | | Mine water supply | Balance Mine Discharge (cum/day) | Mine water Utilization on total demand |
|---|---|---|---|---|---|---|---|
| | | Domestic | Industrial | Total | | | |
| Eastern Coalfields Ltd. | 146045 | 71721 | 44180 | 115901 | 100458 | 45587 | 87.00% |
| Bharat Coking Coal Ltd | 106050 | 82552 | 18746 | 101298 | 78425 | 27625 | 77.00% |
| Central Coalfields Ltd. | 121140 | 41105 | 49371 | 90476 | 81511 | 39629 | 90.00% |
| Western Coalfields Ltd. | 292030 | 67200 | 30509 | 97709 | 69403 | 222627 | 71.03% |
| South Eastern Coalfields Ltd. | 411866 | 85226 | 54283 | 139549 | 97927 | 313939 | 70.17% |
| Northern Coalfields Ltd. | 64800 | 15956 | 35576 | 51532 | 26797 | 38003 | 52.00% |
| Mahanadi Coalfields Ltd. | 101185 | 16632 | 24641 | 41273 | 24721 | 76464 | 60.00% |
| Overall | 1243116 | 380392 | 257306 | 637738 | 479242 | 763874 | 75.14% |

**Post Mining Water Conservation Planning**

The primary concern at mine closure has always been to ensure that any mine void is geologically stable and safe. Although recently, both industry and regulators have started to focus on the environmental, visual and social impacts associated with abandoned mine voids. There are three mine void closure strategies that are commonly applied at mine closure. These are: (1) open void, (2) waste storage, and (3) water storage.

The open voids are avoided due to safety risks associated with them. However, the voids are being planned for waste storage primarily to achieve the objective of restoring the lands biologically for productive use as far as possible. The concurrent dumping of the waste material in the mine voids is planned including biological reclamation depending upon the end use of the land during post-mining period. However, water storage in the mines is considered best practice approach in Indian context in view of the water stress situation being faced by the local community, growing industrial and domestic requirement, shrinking fresh water resources and thrust given by regulatory agencies. The last cut at the end of mine life is developed into a water reservoir for storage of mine water. Thus, additional water resources get created and a clean potential source of potable water is developed after mine closure. Voids created on account of mining is being treated as infrastructure for storage and subsequent reuse by coal mines, industries and local community at large for irrigation and domestic water requirement. This is need of the present day situation due to substantial increase in domestic and industrial water requirement, deterioration of surface water quality and decreasing water resources.

Considering an average depth of about 50 min each of the 164 operating opencast mine pits of CIL, about 3.3 billion $m^3$ of additional new water resources on an average can be developed in future. The mega opencast projects offer greater potential for water storage. The regulatory authorities stress upon implementation of rain water harvesting in coal mines. The rain water harvesting measures will also supplement the water conservation measures undertaken by CIL to augment the water resources for benefit of the community. The mine closure plans are prepared keeping in view the objective of creating additional new water resources for the benefit of the society at large in and around the mining areas.

## POTENTIAL FOR WATER CONSERVATION IN SOME MEGA COAL PROJECTS IN KORBA COALFIELD

The Korba Coalfields in the State of Chhattisgarh comprise of some of the mega opencast coal projects in India, capacity of few of which has been planned to produce more than 40 million tonnes/year of coal. In this coalfield, by converting the terminal voids of largest opencast mines into pit lakes, a string of water reservoirs with a total holding capacity of around 2.118 billion $m^3$ can be developed which can meet the growing future water demand in the area. The details of major pit lakes that can be developed in Korba coalfield is as below:

Table7 – Water Conservation in Some Mega Project of CIL

| Sl. No. | Mine | Void area, Ha | Mine Void Depth, m | Relative Depth, % | Volume of water stored, million $m^3$ |
|---|---|---|---|---|---|
| 1 | Gevra OC | 659.25 | 290 | 10.01 | 1035 |
| 2 | Dipka OC | 570.00 | 128 | 4.75 | 425 |
| 3 | Kusmunda OC | 199.32 | 235 | 14.75 | 300 |
| 4 | Manikpur OC | 188.00 | 60 | 3.87 | 85 |
| 5 | Kartali OC | 233.61 | 242 | 14.03 | 273 |
| | | Total volume of water stored, (in million $m^3$) | | | 2118 |

In the above mines relative depth is between 4–15%, and therefore can be considered halomictic. These mine pits as a result offer good potential for water conservation. The water stored in the above pit lakes, would be about 35% of the total capacity of various water reservoirs developed in Chhattisgarh where these mines are located. Post mining, these pit lakes will be available with sweet and fresh water at no additional expenditure. These mine voids can also be filled by diverting the flood water from the adjacent rivers/nallas (i.e.Lilagarnadi and Hasdeo rivers).

In addition to meet the water requirement of local people, domestic and irrigation uses, these pit lakes can also be utilized for the huge water demand of the nearby industries (*i.e.* power plants, washeries and mine use), which are transporting water from long distances. These pit lakes once developed can provide irrigation to 1,238,600 ha command area or support 43,000 MW power generation. These can also be used to promote tourism, aquaculture, scientific study and socio-economic development of the area.

## CONCLUSIONS

There is an excellent opportunity in India to use the mine pits to store good quality mine water. Government of India has taken various steps to create small ponds for storage of rain water for water security of the country. The mine pits can supplement the efforts of Government of India in creating additional water resources for benefit of the society at large. CIL is taking steps for water conservation and about 75% of water demand for industrial and domestic use in the mining projects is being met from the mine water. This has resulted into less fresh water intake from the natural water resources.CIL is likely to create on an additional water resource to the tune of 3.3 billion $m^3$ from its opencast mines. The mine water is not acidic unlike western countries, conforms to the prescribed regulatory standards and provides us an opportunity for it's storage and use by various stakeholders. The mega coal mining projects offer a great potential for water conservation. In the mine closure plan, creation of water body is considered a priority for meeting the domestic and industrial requirement of the mine areas. Thus, additional water resources will get created and a clean potential source of potable water developed after mine closure. In Indian context, this could be the best practice for mine void management seeing the growing domestic and industrial requirement and diminishing water resources. This will, in long run, help in ensuring the water security of the country.

## REFERENCES

Hegde, N. G. (2012). Water scarcity and security in India", Indian Science Congress, Bhubaneshwar, Orissa.Retrieved from,"http://www.indiawaterportal.org/sites/indiawaterportal.org/files /WaterScarcityAndSecurityInIndia_NGHegde_BAIF_ISC_2012.pdf".

Johnson, S.L. & Wright, A. H. (2003). Mine void water resource issues in western Australia" Western Australia, Water and Rivers Commission, Hydrogeological Record Series, Report HG 9, 93 p.

SubbaRao, D. V. & Biswas, R.N. (2011). Conversion of mine voids into pit lakes-a beneficial use in coal mining environment".

McCullough, C. D., & Lund Mark A., (2010). Mine Voids Management Strategy (IV): Conceptual Models of Collie Basin Pit Lakes".

Bowell, R. J. (2002). The hydrogeochemical dynamics of mine pit lakes. *In* Younger, P.L., & Robins, N.S., (eds), *Mine Water Hydrogeology and Geochemistry*. Geological Society, London.

Mohan Anand. (2011). Hydrogeology of Indian Coalfields, CMPDI, Ranchi, India.Retrieved from http://www.fossil.energy.gov/international/Publications/ucg_1106_cmpdi.pdf"

2030 Water Resources Group, Executive Summary. Retrieved from," http://www.2030waterresourcesgroup.com/water_full/Charting_Our_Water_Future_Final.pdf"

Retrieved from," http://www.coalindia.in/"