Improving the study of hydrogeological impact of mining in EIA studies- A focus on coal mining in India

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Abstract

Conducive policies have led to a vibrant industrial and mining sector in India, especially in the steel, power and coal sector with increased private sector involvement. However, a corresponding strengthening of the Ministry of Environment and Forests is underway to prevent degradation of the environment, with the release of the new EIA Notification of 14th September 2006. However, the new Notification does not give ample emphasis to the necessary hydrogeological detail of statutory environmental impact assessments (EIAs). This should be specified in order to furnish concise knowledge of the pre-mining groundwater conditions. Although such information can be obtained through pumping tests, it is avoided due to the costs involved. Yet hydrogeological data can be estimated from thin section and other studies on borehole cores obtained during routine mineral exploration as well as secondary data sources which are not so expensive. Combined with other "regional" methods of gathering groundwater information, these estimates provide a sound basis for baseline condition evaluation. Apart from improving mining EIA practices, the proposed approach aims at full coverage of the hydrogeological impacts which can also yield dividends for the mine operator, in terms of helping to find water for mine needs, and minimizing water ingress to workings and associated pollutant release. The present paper discusses all these aspects.

Keywords: Mining EIA; Hydrogeology, Groundwater, Impact assessment

1.0 INTRODUCTION

Mining changes the hydrodynamics of both surface and groundwater systems (Kuma, Younger and Bowell, 2002). It is extensively recorded in Indian literature that coal mining operations have adversely affected ground water table with the result that yield of water from the wells in adjoining villages has drastically reduced. There is also the danger of inundation of mine workings. (Tandon, 1990). Underground mining of coal and minerals, pumping of ground water and petroleum cause land subsidence which tend to damage surface, sub surface and underground properties and also physical and biological environment on the surface (Saxena, 1990). The hydrogeological impact of mining extends even after exhaustion of extractable minerals. This is substantiated by literature that once mining and dewatering have ceased, the mines flood and the groundwater attempts to attain a new chemical and dynamic equilibrium (Collon, 2006). Ground water contamination due to acid mine drainage (AMD), acid lakes, tailings, heavy metals and toxic catalysts for extraction have been investigated extensively. Pioneering work has been done in order to find some viable solution to minimize the problems arising due to these (Garcia 2001, Kalin 2004, Luptakova & Kusnierova 2005, Halberg & Johnson 2003, Santos et al 2004, Kuyucak 1998, Johnson & Hallberg 2005, Diels et al 2003, Erdem et al 2004, Brugen et al 2004, Ciccu et al 2003). The lowering of the ground water table and depletion of ground water storage due to underground mining operations may lead to the following problems (Sinha, 1990):

- Adverse effects on wells, tanks and even effluent reaches of streams/ rivers, enhancing draw downs in pump wells in alluvial/ sedimentary areas (coal/ sand mining operations)
- Changes in the hydrodynamic conditions of river/ underground recharge basins, and
- Reduction in volume of subsurface discharge to rivers, depending on the hydrogeological conditions

In many cases, where there are permeable strata near the surface, introduction of fines through leaching and percolation may reduce the effective transmissibility of the aquifers and their water yielding properties. Adverse hydrochemical alteration will be caused by chemical pollution from mining activities.

Our experience is that the impact of open cast mines working below the water table is similar to those of an underground mine.

In order to check the degradation of the environment the Ministry of Environment and Forests in India (MoEF) enforces laws regulating the activities of industries (mining included) with a view to minimizing their impact on the environment. Major changes in the Indian economy were initiated in 1993 through the Coal Mines (Nationalisation) Amendment Act 1993, including allotment of coal blocks for captive mining to non-government players. As per the approved Study Report in Integrated Energy Policy (IEP) by the Government of Indian (GOI), coal will remain as the main source of energy upto 2032, taking care of about 50% energy needs. From the present rate of coal production/ consumption of around 450 million tonnes per year (MTY), it is expected to go up to 2050 MTY by the year 2032. Coal sector will need further opening up and coal mining activities through opencast (O/C) and underground (UG) mining, which will increase several folds. Government of India needs to gear up at a faster pace to tackle the environmental problems resulting due to such rapid growth. The Indian Bureau of Mines and the Ministry of Coal are monitoring and regulating mining activities in the country for non-coal and coal mines, respectively. The domino effect can be felt with the initiation of ultra-mega power (>4000 MW) projects, integrated steel plants, cement plants, etc. in India by government and non government players, which in turn are highly polluting industries.

Before a mining lease can be made operational by a mining company in India, the MoEF requires an EIA report that must be officially approved and environmental clearance obtained (MoEF 2006). While the MoEF has a well developed system in place for enforcing the environmental laws of the country, the hydrogeological reporting required by the guidelines is not sufficiently detailed to allow the intentions of mining lease owners/ operators to be properly scrutinized. As a result, some EIAs reveal little about the hydrodynamics of mining areas prior to the commencement of mining, which means that adequate safeguards cannot be put in place to prevent damage to water resources. There are even times when little or no hydrogeological information is presented or when present, important aspects are often neglected in the report.

This paper examines the coverage of hydrogeology in the guidelines for mining EIA reporting in India. It identifies inadequacies that seem to promote substandard groundwater sections in most mining EIA studies in the country. A format is suggested for additional coverage in an Environmental Impact Assessment Study, which prospective lease owners/ operators should be required to adopt. These guidelines are largely inspired by Kuma et al, 2002.

The objective of this paper is to create awareness amongst prospective mine owners and operators about the importance of a detailed hydrogeological study in pollution prevention and also safe operation of the mine.

2.0 CURRENT SCOPE FOR HYDROGEOLOGICAL STUDY IN INDIA'S MINING EIA

Kuma 2002 quoting Gray 1975 has exhaustively investigated the scope of hydrogeology in the literature and adopted the following definition. Hydrogeology is the study of 1. "The occurrence and movement of aqueous solutions through porous and permeable rock media, regardless of the phase or concentration of the solutions; 2. The modifications caused to the chemical composition of the solutions, of other subsurface fluids and of the rock media by their mutual interaction." Stone 1999, quoting from May 1976, defined hydrogeology more succinctly as ''the science that applies geologic methods to the understanding of hydrologic phenomena.'' These definitions indicate that geologic tools can be effectively employed to study the occurrence, movement, and chemical composition of aqueous solutions in rocks. All three aspects of the solutions (occurrence, movement, and chemistry) will be significantly affected by mining. Therefore, an assessment of the condition of the pre-mining groundwater system is necessary to enable the prediction of its likely level of distortion during and after mining. This in turn will suggest ways of formulating strategies to plan and manage the water regime in order to minimize any negative impacts that might be foreseen. In case of coal mines in India, the exploration is usually carried out in the past by agencies such as Mineral Exploration Corporation Ltd. (MECL) and the geological data processed by MECL or the Central Mine Planning and Design Institute Limited (CMPDIL). The geological report is prepared and available to the project proponents at some cost. Some blocks that are not well explored and detailed, exploration shall have to be commissioned by the project proponent on allotment of the block. After the allotment of the block, a mine lease is applied and the detailed mining plan prepared. A prior environmental clearance is obtained from the MoEF on the basis of a pre-feasibility report which outlines the terms of references for the preparation of the EIA. On the basis of the mining plan and the terms of references an EIA report is prepared for environmental clearance from MoEF. This EIA is appraised by the general public, State and then Central Authorities for granting an environmental clearance. The adequacy of the hydrogeological section shall therefore become a function of the expertise of the specific member of the expert committee at MoEF, whose presence or absence may completely affect the determination of the adequacy of the Hydrogeological Section of EIA report.

The groundwater studies required by this procedure address the hydrogeology at a point after the detailed exploration and mine planning has taken place. However, most of the data needed for groundwater studies are best gathered during the preceding exploration phase (Kuma et al., 2002). In addition, the consultants who prepare the feasibility report are not those who conduct the exploration. Although in principle a link between the two exists through the Exploration Manager, the foci of work of these two groups are different. The result is that some elements required in the water studies are overlooked in earlier exploration phases, or inadequately evaluated because of costs. This means that the ground water sections in EIA reports can be incomplete and of little value. Absence of clear cut guideline by MoEF with respect to the water section in EIA report leads to use of the discretion of the mining lease proponent. Consequently, there may be willful or genuine omission and incomplete reports. Of course the discretionary inclusion of further material by applicants is not to be discouraged but experience in India shows that inclusion of superfluous detail is far less common than the omission of crucial hydrogeological information as noted by Kuma 2002 for Ghana also.

3.0 ISSUES

Though inclusion of hydrological regime study, both surface and groundwater system is mandatory for mining EIA according to the guidelines for preparation of EIA in India (MoEF 2001), but the scope of the study is not specifically defined. This section discusses the various components of hydrological studies required to be undertaken and the additional expenditure associated with the collection and processing date has also been estimated.

3.1 Physiography

The physiography has got great bearing on hydrological system. This includes land use, vegetation, relief and drainage of the area. The information on these issues is usually available on regional scale. The most obvious source of such information is the Toposheets available from Survey of India in scales of 1:250,000, 1:50,000 and 1:25,000 showing contour intervals upto 10m. These toposheets may or may not be recent (updated within 5 years); hence, supplementary information may be taken from interpreted satellite images. A satellite image, usually a false color composite (F.C.C.) of high resolution is available from Indian or foreign agencies which gives fairly good idea on smaller scale. The desk study is verified through field check during reconnaissance.

The analysis of the topography and drainage provides information for delineation of watersheds, and overland flow which in turn link with ground water profile, recharge and evapotranspiration. The watershed delineation can be also obtained from the All India Soil and Land use organization. The procurement of the toposheets or maps involves negligible costs to the tune of few 100 rupees while a satellite image involves slightly higher costs, not more than Rs. 30,000 for an area of approximately 25x35 km. Satellite images are acquired for land use analysis for EIA studies. Also local topographical information is generated during land survey of the mine lease. No additional field activity is necessary apart from that already carried out during the land survey. Therefore, there is no extra expenditure involved.

3.2 Pedology

The soil which host shallow aquifer is generally a neglected branch in India. The shallow aquifer is frequently exploited by local inhabitant to meet their drinking and irrigational requirement. It is highly vulnerable to pollution and over exploitation. If at all studied, the study is limited to top 2 to 3 meters depth. This shallow aquifer may be linked to deeper aquifer system.

The soil characteristic may be identified through exploratory trenching/pitting /drilling. The optimum sampling interval need to be determined based on various factors such as extent of variation. The recommended tests are (1) particle size analysis (2) density (3) moisture content (4) Infiltration tests. These tests give information on soil texture, sorting, lithology, porosity etc.

The study involves additional expenditure. The approximate expenditure per sample is about Rs. 1000/-.

3.3 Geology

The geology, an integral part of mineral prospecting, of the area controls the hydrological parameters such as hydraulic conductivity, specific yield and storativity. These information could be very well attained during exploratory drilling of mineral ore. The core obtained during drilling could be very well utilized to evaluate hydraulic properties in the laboratory using parameters and grain size analysis or using thin section under microscope (Younger, 1992). In addition the storativity may be assessed as a function of lithology and thickness (Younger 1993). The water rock intersection may be evaluated through thin section study. The magnitude of influence of ore mineral on groundwater chemistry specially in unsaturated zone helps in mining operation.

The activities involved are mapping, drilling, logging which are routine in mineral ore exploration. The important point to be stressed here is that the geological explorations are generally carried out by MECL or CMPDIL and they do not conduct the above tests for the purpose of preparing a geological report. Hence, additional tests need to be planned in advance in co-ordination with exploratory team at nominal cost of Rs. 2000/- per sample for permeability determination and thin section study.

3.4 Hydrology

The meteorological parameters specially rainfall and evaporation is required for hydrological evaluation which is available with Indian Meteorological Department (IMD). The regional information is available at nominal cost which forms a part of EIA study. Estimation of storm water flow and sediment load estimation is important for any mining industry for protection of environment likely to be affected. Invariably, precise information on overland flow is never available. The same may be evaluated based on studies made by various hydrologists/ engineers in India for different watersheds/ sub basins/ basins (redid 1992). The sediment load may very well be evaluated at no extra cost as the surface water monitoring is part of the EIA study. However, the silt load data is available for Indian rivers with their concerned administrative organizations. No extra cost towards field studies is needed.

3.5 Hydrochemistry

During the EIA study the water samples are usually collected to define the water quality prior to mining operations as per prevailing guidelines (MoEF 2003) adhering to BIS 10500. Therefore specific study may not add extra cost. For non-discharging mines at least four ground water samples are taken preferably from downstream direction of the mine in pre-monsoon and post-monsoon periods and analysed. For discharging mines six samples are to be analysed. A commonly observed omission is the analyses of minor and trace elements whose concentrations do get affected by mining operations. Furthermore, the coal mine specific contaminants such as sulphur, sulphates, sulphites, alkalinity pH, total dissolved solids, total suspended solids and trace heavy metals also need to be analysed. The overall expenditure in this section are expected as part of EIA anyway, hence, they shall not count as extra cost towards hydrogeological study. The total cost involved is around Rs. 8000/- per sample. The water sample should be prudently taken covering various structure / source such as tube wells, open wells, tanks and rivers. In order to ensure that ambiguity in results of analysis are eliminated, an NABL (National Accreditation Board for Testing and Calibration Laboratories) accredited lab can be chosen which covers sample collection and analysis in its scope of accreditation and follows the management and technical guidelines of ISO/IES 17025:2005.

3.6 Pumping Tests

To decipher the hydraulic parameters of the acquifer material which is the essential component to evaluate mine water seepage and impact of groundwater pumping for safe mine operation on ground water storage, pump test is the only accurate tool. To obtain precise value of hydraulic character of acquifer more than one test will be better. The pump test involves heavy expenditure towards construction of test wells and conducting tests. The entire operation requires an expenditure of Rs. 5,00,000 to Rs. 7,00,000. MoEF 2003 also recommends pumping tests for determining radius of influence of a mine.

3.7 Predictive Modelling for Impact Assesment

Various standardised models are followed all over the world for assessment of expansion of cone of depression on account of abstraction of water from ground water storage. These model studies help in calculation of ground water seepage into large mines. Simplified manual calculations may also lead to the desired result but the accuracy of such estimation is limited. The cost of the softwares for modelling is high, depending upon the features, but may not necessarily be purchased. Instead the services of an experienced and reputed firm specialised in hydrogeology can be availed. In the case of mines near the coastal areas, salinity ingress shall have to be not only practically estimated but also modelled, since it is one of the most serious issues with respect to ground water resources. The activity requires extra expenditure to a tune of Rs. 4,00,000 to Rs. 5,00,000.

4.0 DISCUSSION

Many adverse impacts of mining activity on hydrological regime could be avoided if a detailed hydrological study is taken before hand, perhaps prior to preparation of mining plan. Invariably EIA studies lack in hydrogeological detail, probably because of the high cost involved in conducting pump tests. The cost towards pump test to evaluate hydraulic character may be reduced by using the exploratory bore holes drilled at the time of prospecting / exploration through proper planning and coordination. These holes may be converted into observation wells to save the cost of hydraulic testing. Hydrological data is never recorded on boreholes at the time of mineral prospecting, which is a national loss. A guideline is required to document every possible information from such drill holes. The core obtained need to be examined through thin section and permeability test should be done invariably on these cores. The recommended phases of mineral exploration for hydrological data collection and additional cost of various stages is given in table 1.

For want of clear-cut and specific guideline for appropriate hydrological regime study, adverse environmental impacts has been noticed on groundwater storage on account of mining activity.

Few examples

1. The coal mining industry generally have shown remarkable impact on water quality of shallow aquifer system due to discharge of accumulated water in mine pit. The coal mines of Raigarh invariably show decrease of pH below 7. (Min Mec 2006, 2007)
2. Heavy withdrawal of groundwater in limestone in and around Raigarh and Bilaspur, Chhattisgarh have caused depletion of groundwater storage and lowering of water level. (CGWB 1999-2000)
3. Sand mining in Arawali belt along Delhi / Faridabad border has caused lowering of water table excessively (Bhatia 1998)
4. Migration of Hexavalent Chromium in Mahagiri Chromite mine area due to mining activity. (Min Mec 2003)
5. Enrichment of surface soil with iron content in iron ore belt of Orissa has been observed

The questionnaire developed for appraisal of environment for mining projects as per EIA Notification of 1994 and subsequently revised in 2003 states "Provide a comprehensive hydro-geological assessment report if the average mine dewatering is more than 100 m^3/day and or going below water table in non-monsoon period. The report should be based on preferably latest one year pre-monsoon and post-monsoon baseline data covering information on ground water situation, aquifer characteristics, water level conditions (April – May and November), estimate of ground water resources, predicted impact of the project on ground water regime and detailed remedial / conservation measures such as artificial recharge of ground water etc. The report should be based on actual field inventory out of existing wells, at least 30 observation wells in the buffer zone with supplementary information from secondary sources (mention name). For estimation of ground water resource the designated study area of the buffer zone may be sub-divided into command and non-command areas, watershed-wise (in case of hard rock/ consolidated formations)/ block-wise/ mandal-wise in case of alluvial/ unconsolidated formations." For estimating ground water resources in the area follow the Ground Water Estimation Committee recommendations of 1997. With the release of the EIA

Notification of September 2006, the use of Questionnaire has been superceded by Form-1, which is a general form for all types of industries, mines, plants and construction project. As a result, such comprehensive and activity specific coverage is not done anymore.

Ideally, instead of restricting the preparation of a hydrogeological study to the intersection of mine workings and the water table, it should be conducted for mine workings going within a critical distance of the post monsoon water table. Mine workings shall effect the ground watertable without intersecting it in terms of hydrochemical properties through percolation of water collected in mine due to rains or other factors. What should be that critical distance between the post monsoon water table and the mine wokings, is a matter of further research. Furthermore, a concise hydrogeological report should cover location specific physiography, pedology, hydrology, hydrochemistry, acquifer parameters determined through pump tests and predictive modelling for radius of influence, salinity ingress (if applicable) and if relevant to the case, contaminant flow in to acquifer.

5.0 CONCLUSION

In view of indiscriminate ground water losses and considering safety problems in deep minining operations,specially open cast mines which is widely prevalent over the country, the hydrological regime need to be carefully examined to avoid the adverse impact of mining operation on over all environment specially the water resources. The associated problems with mining industry related to groundwater need to be carefully examined in order to plan the mitigation plan. The effort has been made to draw attention of planner and expert groups involved in according environmental clearance to mining sector projects towards the need for detailed and in depth study of hydrological regime to protect the environment by adopting suitable mitigation measures while operating the mining industry.

The various aspect of the study required to be performed have been spelt out and probable additional cost involved have been specified. The present scenario of prevailing hydrological conditions need to be precisely evaluated. The groundwater flow regime, resource utilisation, development level and quality need to be worked out. Probable impact of mining on groundwater storage need to be evaluated and the mitigation plan to minimise the adverse impact is required to be drawn. This could be acheived at nominal extra cost. The need in realisation of gravity of problem and inherent desire to protect the environment considering the over all cost of mining project the additional amount likely to be incurred to understand stand the hydrological senario, is peanut. A crude estimate for much study would be around 12 lakhs in addition.

It is only possible when stringent regulations are framed by the Government for strict compliance by the proponent. A detailed guideline need to be drawn which earlier was incorporated in questionnaire for appraisal but now has been dispersed with. The ambit of such questionnaire should have been expanded rather than shrinking or altogether removal.

References:

Bhatia A.K., Environmental Impact due to ground water abstraction on Badkal Lake, Central Ground Water Board, May, 1998; pp 10

Bruggen Bart Van der and Vandecasteele Carlo, Removal of pollutants from surface water and groundwater by nanofiltration: overview of possible applications in the drinking water industry, Chemical Geology, Vol. 204, Issues 3-4 , 15 April 2004, pp 303-323

Central Ground Water Board (CGWB-NCR), Ground Water Year Book, 1999-2000: Chattisgarh, pp 41-42

Collon P, Fabriol R, Bues M. Modelling the evolution of water quality in abandoned mines of the Lorraine Iron Basin. Journal of Hydrology 2006; 328: pp 620

Diels L., Spaans P. H., Roy S. Van, Hooyberghs L., Ryngaert A., Wouters H., Walter E., Winters J., Macaskie L., Finlay J., Pernfuss B., Woebking H., Pümpel T. and Tsezos M., Heavy metals removal by sand filters inoculated with metal sorbing and precipitating bacteria, Hydrometallurgy, Vol. 71, Issues 1-2 , October 2003, pp 235-241

Erdem M., Altundoan H. S. and Tümen F., Removal of hexavalent chromium by using heat-activated bauxite, Minerals Engineering, Vol. 17, Issues 9-10 , September-October 2004, pp 1045-1052

García C., Moreno D. A., Ballester A., Blázquez M. L. and González F., Bioremediation of an industrial acid mine water by metal-tolerant sulphate-reducing bacteria, Minerals Engineering, Vol 14, Issue 9 , September 2001, pp 997-1008

García C., Moreno D. A., Ballester A., Blázquez M. L. and González F., Hallberg Kevin B. and Johnson D. Barrie, Novel acidophiles isolated from moderately acidic mine drainage waters, Hydrometallurgy, Volume 71, Issues 1-2, October 2003, pp 139-148

Gray DA. The scope of hydrogeology. Q J Eng Geol 1975;8: pp 177 –91.

Johnson D. Barrie and Hallberg Kevin B., Acid mine drainage remediation options: a review, Science of The Total Environment, Vol. 338, Issues 1-2 , February 2005, pp 3-14

Kalin Margarete, Passive mine water treatment: the correct approach?, Ecological Engineering, Vol 22, Issues 4-5, 1 July 2004, pp 299-304

Kalin Margarete, Wheeler W. N. and Meinrath G., The removal of uranium from mining waste water using algal/microbial biomass, Journal of Environmental Radioactivity Vol. 78, Issue 2 , October 2004, pp 151-177

Kuma JS, Younger PL, Bowell RJ. Expanding the hydrogeological base in mining EIA studies: A focus on Ghana. Environmental Impact Assessment Review 2002; 20: pp 273-287

Kuyucak Nural, Mining, the Environment and the treatment of mine effluents, Int. J. of Environment and Pollution, Vol. 10, No. 2, 1998, pp. 315-325

Luptakova Alena and Kusnierova Maria, Bioremediation of acid mine drainage contaminated by SRB, Hydrometallurgy, Vol. 77, Issues 1-2 , April 2005, pp 97-102

May JP. Geohydrology/hydrogeology: letter to the editor, Geotimes, May 1976, pp 15

Min Mec Consultancy Pvt. Ltd. Environmental Impact Assessment and Environmental Management plan of Gare IV/6 opencast coal mine project at village Lamdarha, Saraitola, Gare, Khamharia and Karwahi in tehsil Gharghoda, district Raigarh of Chhattisgarh (extent: 381.42 ha) September, 2006; pp 3-14

Min Mec Consultancy Pvt. Ltd. Rapid Environmental Impact Assessment and Environmental Management Plan for 2 x 150 MW middling and coal fine based thermal power plant at Dongamahua village, Raigarh district, (c.g.) Chhattisgarh, February, 2007; pp 3-18

Min Mec Consultancy Pvt. Ltd. Environmental Management Plan for Mahagiri Mines (Chromite) at Village Kaliapani, District Jajpur, Orissa, May, 2003; pp-15

Ministry of Environment and Forest. Proforma for environmental appraisal of mining projects (mining sector projects). 2003

Ministry of Environment and Forests (MoEF). Environment Impact Assessment : A Manual. January 2001

Ministry of Environment and Forests (MoEF). Notification. Gazette of India, Extraordinary, Part-II, and Section 3, Sub-section (ii). 14 September 2006

R. Ciccu, M. Ghiani, A. Serci, S. Fadda, R. Peretti and A. Zucca, Heavy metal immobilization in the mining-contaminated soils using various industrial wastes, Minerals Engineering, Vol. 16, Issue 3 , March 2003, pp 187-192

Reddi PJ. A Text Book of Hydrology. Laxmi Publications, India. 2nd Ed. 1992; pp 336-338

Santos S., Machado R., Correia M. Joana Neiva and Carvalho Jorge R., Treatment of acid mining waters, Minerals Engineering, Volume 17, Issue 2 , February 2004, pp 225-232

Saxena NC. Environmental Impacts if Underground Mining. Environmental Management of Mining Operations. Ed. Dhar BB. Ashish Publishing House 1990; pp 208

Sinha Subrata. Impact of Mining on Water Regime. Environmental Management of Mining Operations. Ed. Dhar BB. Ashish Publishing House 1990; pp 361

Stone WJ. Hydrogeology in practice. A guide to characterising ground-water systems. Upper Saddle, (NJ): Prentice-Hall, 1999; pp 48

Tandon GL. Scenario of Environmental Status in Coal Mining in India. Environmental Management of Mining Operations. Ed. Dhar BB. Ashish Publishing House 1990; pp 30

Younger PL. The hydrogeological use of thin sections: inexpensive estimates of groundwater flow and transport parameters. Q J Eng Geol 1992; pp 159– 64.

Younger PL. Simple generalized methods for estimating aquifer storage parameters. Q J Eng Geol 1993;26: pp127– 35.

TABLE 1

Hydrogeological data collection and the additional costs incurred at each stage for a lease upto 1 sq. km

S. No	Hydrogeological aspect	Source of Information	Hydrogeological outcomes	Extra expenditure
1	Phisography • Relief • Drainage • Land use • Vegetation	Toposheets of 1:2,50,000, 1:50,000 or 1:25,000 from Survey of India supplemented, if required, by satellite image interpretation.	Watershed is identified, relief, drainge and vegetaion maps at a suitable scale are produced. Recharge and discharge areas are determined.	The basic map and FCC form a partof the EIA study. The additional job is desk study which would require expertise to interpret FCC. Additional cost is Rs. 30,000.
2	Pedology • Soil logging and sampling • Particle Size Distribution • Moisture content, bulk, and particle densities • Infiltration tests	Pitting and trenching are useful if the weathering profile is thin. Test results.	Soil thickness map, soil texture, sorting, porosity, and changes in lithology. Results are also useful during assessment of groundwater recharge.	10 samples @ Rs. 1000/sample = Rs 10,000
3	Geology • Lithological • Structural • Stratigraphic • Thin Section and microscopy • Probe permeameter	From the desk study of geological reports, evaluation drilling, surface mapping, and core logging	Thin section study reflects mineralogical composition, grain size, sorting, and porosity. Use porosity to estimate specific yield and storativity. Permeability determined from probe permeameter. Prediction of rock – water interactions for assessment of possible discharges to streams. 3-D conceptual hydrogeological model from above information coupled with surface geological mapping and core logging.	<u>Option A:</u> No additional drilling required then 10 samples @ Rs.2,000 = Rs 20,000 may be done for thin section and permability study <u>Option B:</u> In case additional drilling is required because no testing relevent to hydrogeology was carried out, then drilling and piping @ Rs1000/m for alluvial strata upto depth of say, 100m = Rs1,00,000 per bore x 3 bores = Rs 3,00,000. On the higher side, the budget

S. No	Hydrogeological aspect	Source of Information	Hydrogeological outcomes	Extra expenditure
				may range betw een Rs. 5,00,000-7,00,000. This cost is in additional to cost incurred in Option A.
4	Hydrology 1. Rainfall and evapotranspiration 2. Infiltration capacity 3. Groundw ater storage 4. Generation of strom water 5. Ground w ater resource and utilisation 6. Suspended load 7. Ground w ater regime	Corresponding sources: 1. IMD 2. Field test 3. Field observation 4. In field or estimation 5. Desk study 6. Field observation 7. Desk job	Corresponding outcomes: 1. Water balancing 2. Recharge estimates 3. Quantification of dynamic ground w ater resource and identification of ground water scenario. 4. Mine planning and bank storage estimation 5. Impact on ground w ater storage 6. Impact on land and w ater environment 7. To ascertain make up w ater quantity and annual ground w ater loss	1. IMD data Rs 10,000 2. 4 sites @Rs. 5000 per site = Rs. 20,000 3. Pre and post monsoon season, rs. 50,000 4. Rs. 25,000 for one season 5. No estra cost, deskw ork 6. 3 samples @ Rs. 1000 = Rs. 3000 7. No estra cost, desk job
5	Hydrochemistry	Surface and ground water sampling and analysis.	Hydrochemistry of the area determined	No extra cost as it is pasrt of routine EIA study
6	Conducting pump tests	Field tests	Hydraulic parameters	In case bores are to be drilled, the cost is included in option B of S.No 3. In case exploration bores are used then cost would be for pump only, say, Rs 1,00,000.
7	Modelling for impact of mine pump out	Standard models for ground w ater flow	1. Impact on ground w ater storage in space and time 2. Saline w ater ingress in coastal belt	Total expenditure including software data and analysis w ould be around Rs. 3,00,000 to get desired result.