INVESTIGATION OF THE HYDROGEOLOGICAL PROBLEMS IN SOME MINES IN INDIA

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ABSTRACT

An accurate knowledge of groundwater flow into the mine working is essential to plan for safe mining operations. The salient features and results of investigations on different groundwater problems in three selected collieries/mines in India have been presented in this paper.

The studies in the copper ore mine in Khetri Cooper Project, Jhunjhunu district, Rajasthan indicated that due to slow movement of groundwater in the mine area, conditions do not exist for sudden inundation of mines through the fracture systems but caving of water stored solution cavities in dolomites and old slopes may cause inundation depending upon the size and extent of caverns.

The problem of groundwater inrush in a few selected colliery areas from Chandrapur-Wardha coalfields have been investigated. Hydrogeological investigations in the Panandhro lignite field, Gujarat indicated that to control the artesian pressure of the confined aquifer in this lignite field effectively, for safe mining, it is necessary to construct a well field consisting of three wells, each with a discharge capacity of 10,000 m^3/day.

INTRODUCTION

Hazards of mine inundation due to heavy inrush of water from the saturated strata have posed serious mining problems in many mineral industries resulting often in fatal accidents and curtailment in mineral production. If an accurate knowledge of the anticipated groundwater flow into the mine workings is available, it greatly helps to plan for safe mining operations. The Central Ground Water Board, Ministry of Irrigation & Power, India has carried out investigations on different problems in several collieries/

mines in the country. The objectives of these investigations was to compute hydraulic parameters of the different aquifer systems and utilise these parameters for estimation of groundwater flow under natural and stressed conditions and to evolve plans for safer mining operations, avoiding sudden inrush of water, inundating the mines. The salient features and results of such investigations in three selected collieries/ mines are briefly presented.

PROBLEM OF MINE INUNDATION IN THE KHETRI COPPER MINES, RAJASTHAN

In the course of the development of the Cooper Ore mine in the Khetri Copper Project, Jhunjhunu district, Rajasthan; groundwater seepage was encountered during opening of the working level below the regional water level. The ground water seepage was observed to increase with the opening of another working level at a still lower level. In view of this, investigations were directed towards identifying the nature and extent of the problem and to evaluate the potential danger of inundation of the mines by groundwater during mining. Ground water Movement in Bed Rock Aquifers.

The groundwater movement in the study area is mainly controlled by the structural features like joints, shears and faults in the bed rock aquifer. The joints and shears bearing easterly and northerly dips act as the main conduits for the groundwater movement. Such joints and shears are innumerable and interconnected and they merge with the main Kudhan fault. The main kudhan fault dops northwards thereby controlling the groundwater movement mainly to the foot wall of the fault. The boreholes drilled in the south section of 300 m level which have crossed the kudhan fault zone and tapping ground water from the foot-wall side of the fault are giving the maximum yield. The boreholes located to the north of Kudhan fault have relatively insignificant discharge.

Some important observations were made while studying the hydraulic relationship between the aquifers. A continuous water level in the old working and the rate of discharge from the boreholes at 300 m level were recorded during the period of investigation. During the pre-monsoon period, the rate of decline of water level in the old workings was 7 cm per day and the rate of discharge from boreholes was also constant. The boreholes 445, 666, 687, 453 and 691 were plugged from 5th July to 16th July. During this period the water levels in the old working recorded a rise of 7 cm per day. When the boreholes were unplugged again there was decline in water levels at the rate of 7 cm per day. During and after the monsoon period, however, the rate of decline in water level in the old working has decreased to less than 3 cm per day and the water level maintained a nearly flat trend.

These observations indicate that the old workings are located in the bed rock aquifer, groundwater seeps through boreholes and shears are inter-connected and received replenishment from monsoon recharge also.

Movement of Ground Water in Bed Rock

Seepage was examined in all the levels, namely, 421 m level, 350 m level, 300 m level, 180 m level and zero m level. In 421 m level there was no seepage, obviously this level is much above the regional water table. In 350 m level some seepage was observed along a few sheared and joint planes and from old workings. In 180 m level seepage was found along easterly dipping shears and some prominent joints. In zero metre level heavy seepage occurs along the fault zone located to the north of service shaft and along steep, southward dipping shears. In 300 m level where the study was concentrated groundwater discharge is observed to be heavy through boreholes.

Apart from the shears and joints the other main control of groundwater movement is the westerly dip of the formations. The ground water movement is mainly in vertical direction along the joints and shears in the hard rocks which is evidenced by the absence of seepage along the foot wall drive in all levels except in 180 and zero metres levels, where the seepage is relatively higher only along the fault zones. Also the absence of natural seepage and presence of heavy discharge through the boreholes in 300 m level where the boreholes are intersecting the joints and shears of the bed rock underlying the alluvium and weathered unit indicate that the movement is predominantly vertical.

Movement of groundwater in alluvial and weathered aquifers

Water table contour map indicates that the general groundwater flow direction is from south to north. The flow direction coincides with the surface drainage of Kharkhara rivulet. In the vicinity of old workings the general flow direction deviates towards the old working. The general hydraulic gradient of water table varies from 0.53/100 m to 1.3/100 m. But in the vicinity of old working the hydraulic gradient is 4.9/100 metres.

The analysis of the geological, hydrological and hydrochemical data has brought out that the Khetri Copper Mine area is underlain by an interconnected alluvium-weathered zone bed-rock aquifer system, and the ground water movement in the mine area takes place through the pore spaces in the granular formations and the structural planes in the bed rock aquifers. The alluvium-weathered zone aquifer system is contributing to the ground water flow through the structural planes in the bed rock aquifer through gravity drainage through the above aquifers. Additionally, underflow through the bed rock aquifer also occurs through the upper reaches. The highly permeable alluvium is separated from the fractured rocks by weathered rocks with comparatively low permeability. The ground water movement through the bed rock aquifer is slow under existing gradients. However, pressure differentials of the order of 50 psi exist at the 300 m.level, as observed in pressure gauges installed in underground boreholes. The seepage waters are mixture of ground waters from the alluvium-weathered aquifers system and bed rock aquifer with additional dissolved load through seepage through the mineralised zones. The seepage waters are acidic which is a characterstic feature of the mine water, the acidic character being due to the oxidation and leaching of sulphide ores. The long term dynamic reserve has been estimated at 0.95 MCM. The drainable static reserves has been estimated at 2 MCM. Significant reduction in the static reserve can occur only if the pumpage exceeds the long term dynamic reserve, i.e. over 0.95 MCM.

This will be achieved by extending the mine and increasing the pumpage of seepage water in course of time; and by encouaging irrigation through wells for which there is considerable scope. The flow through the bed rock aquifers due to under flow from the upper reaches of the rivulet could not be estimated in the absence of data on the hydraulic characteristics of the bed rock aquifer.

As indicated by the slow movement of ground water in the mine area it is apprehended that the conditions do not exist, for sudden inundation of mines through the fracture systems, but caving of water stored solution cavities in dolomites and old slopes may cause inundation depending upon the size and extent of caverns. Existence of these may be to a certain extent indicated during drilling. Any caving in of material from the surface during mine activity will result in the weathered mantle sealing the mine and cutting off direct connection with the permeable alluvium.

Supply of any water to Khetri mine for industrial utilisation from adjoining areas as is being done, should be discontinued at the earliest. Instead, the water pumped out from the mines should be suitably treated and put to use.

To evaluate the effect of adopting additional measure in the shape of interceptive pumping through a well field located in the upper reaches of the basin would require extensive testing of the precise hydraulic parameters of the alluvium-weathered zone-bedrock aquifer system. This will assist in studying the feasibility of such measures to reduce under flow and seepage into the mines.

Construction of any structure in the basin either for storage or diversion of the river would be dangerous as the stored water in these structures would aggravate the groundwater seepage into the mine workings.

To prevent rain water from reaching the slopes and thus inundating the mines during monsoons, gullies and nallahs should be diverted from such old workings. Also, the old workings should be kept dewatered.

GROUNDWATER PROBLEMS IN COAL FIELDS OF MAHARASHTRA

i) Mahakali Coal Field Area, Maharashtra

The Mahakali Colliery is situated at about 3 km. east of the Chandrapur town in Chandrapur district of Maharashtra. Hydrogeological studies reveal that the area is occupied by the rocks of the Kamthi Series followed in depth by those of the Barakar Series of the Lower Gondwana System. The Kamthi formation which is about 34 m thick at well K_1 increases upto 99 m at well K_2 which is 300 m from the former in the easterly dip direction. Similarly the thickness of the saturated granular zones forming the aquifers also records an increase from 16 to 59 m. The aquifers of the Kamthis and the Barakars are all interconnected both laterally and vertically due to pinching nature of the shales and clays in the updip direction. The aquifer performance tests conducted on the wells tapping the Kamthi formation have recorded their influence on the wells tapping Barakar formations. Based on the analysis of pump test data, the average transmissivity of the Kamthi aquifers is estimated as 465 m^2/day and that of Barakars as 215 m^2/day. The coefficient of permeability of the Kamthi aquifers ranged from 7.0 to 31.3 m/day with an average of 19.3 m/day. The coefficient of permeability of the

Barakar aquifers is relatively low compared to Kamthi aquifers and varies from 4.0m/day in the middle parts to 0.7m/day in the bottom part of the granular zones above the coalseam. The magnitude of groundwater flow through the cross section of the aquifers in a radial distance of 300 m in Kamthi aquifers (867 m^3/day) is found to be nearly five times that in the Barakar aquifers (175 m^3/day). The leakage from Kamthis to the Barakars is estimated as 8.7 lps when the well piercing the Barakars was pumped at the rate of 10.7 lps.

Precipitation is the main source of recharge to all the water table and confined aquifers of the Kamthi and Barakar Series in the area. The Barakar aquifers (confined) and no where exposed in the vicinity of the Mahakali well field area and hence the direct recharge to these aquifers must be taking place in areas of their updip direction. The general ground water movement is from north-east to South-west towards the Wardha and the Erai rivers, which are both effluent. Considering the westerly steep slope of the terrain towards the Erai river and an easterly dipping nature of the beds of the well field area, it may possibly pose sudden and severe problem of flooding during the heavy rainy days due to sudden build up of peak flood storage and the influence of interconnected network of faults prevailing in the adjoining area of the Mahakali coal field. It is therefore, essential to study the surface flow characteristics of the Wardha and Erai rivers, the status of the interconnected faults traversing the adjoining areas and the daily rate of net groundwater withdrawal over all the coal mines located in the study area and its vicinity.

ii) Problem of groundwater in-rush in Durgapur Coal Field Area, Maharashtra :

During the mining of coal by open cast method, the inrushing groundwater is the main problem. If an accurate knowledge of the anticipated groundwater flow into the coal working is available, it greatly helps the mining engineers to properly plan for all future eventualities and extract optimum quantity of coal at minimum risk. A few select colliery areas from Chandrapur-Wardha Coal fields were chosen for such studies by the Central Ground Water Board (CGWB) jointly with the Central Mine Planning and Design Institute(CMPDI).

The sub-surface geology of the Durgapur coal field has been studied down to a depth of 275 m, based on the data collected during the drilling and geophysical logging of the boreholes.

The Talchir formation, which forms the base for groundwater investigations in the area, consists of greenish shales and pebby sandstones and limestone, the permeabilities of which are low.

The overlying Barakar formation is 150 to 200 metres thick and consists of greyish white sandstones, carbonaceous shales and a coal seam of about 15 m thickness. The sandstones are greyish white and coarse grained with a siliceous matric, while the shales are soft and fissile. The permeabilities of the aquifers in the formation are medium.

The Kamthi formation is 15 to 90m thick and consists of brown, medium to coarse grained, ferruginous, friable sandstones intercalated with thin bands of shales and argillaceous material. The permeabilities of the aquifers in the formations are high.

On the basis of the information available, a rather simple model of the hydrogeological environment can be considered. It consists of a hydraulically continuous medium with the lower boundary being an extended horizontal impermeable seam, while the upper boundary is a close somewhat subdued replica of the surface topography. Groundwater flow in such an environment is generated by the differences in fluid potential at the upper boundary and its distribution modified by the permeability distribution in the lithological horizons.

Groundwater flows vertically downwards from the phreatic surface through highly permeable semi-consolidated materials constituting the Kamthi rocks into the deeper Barakar beds which comprise relatively less permeable sandstones and carbinaceous shales. Groundwater flows laterally from these aquifers into discharge areas elsewhere into the topographic lows.

The direction of groundwater flow in the semi-confining beds is towards south as established from the non-pumping piezometric elevation contours.

The rate of natural downward groundwater flow is increased under conditions of groundwater withdrawal in the well field areas and consequently, water table levels decline more rapidly than under natural conditions.

Groundwater occurs in the Durgapur well field area in the pore spaces of the semi-consolidated sediments under semi-confined conditions. The study area is originally one of recharge and consequently water moves vertically downward through semi-confining materials into the underlying rocks and laterally into the discharge areas elsewhere. The direction of natural groundwater flow is towards south with a hydraulic gradient of 2×10^{-3}.

The regional transmissivity of the aquifers constituting Kamthi and Barakar sediments is estimated and 700 m^2/day while the hydraulic conductivity is 9 m per day. The specific yield has been computed to be 0.08 m. Groundwater storage available within an area of 0.5 sq.km. (1000 m x 500 m) is estimated at 3.4 MCM. Groundwater flow estimates under natural conditions indicate the flow to be 2.08×10^{-4} lps/m^2 while under a stressed field it is estimated at 3.38×10^{-4} lps/m^2.

Hydraulic conductivity worked out for the aquifers around well M^3 indicate a higher value. If mining progresses to the area in its vicinity, it should be borne in mind that the flow expected would be around 3 times more than for an area in the undisturbed zone.

Since mining of coal involves human life, it is suggested that a 10% safety factor be considered to the results arrived. It is recommended that more piezometric elevations closely monitored over a sufficiently long period, while simultaneously maintaining data on daily pumpage. This would facilitate ground water discharge computations with greater accuracy. Data on daily pumpage in other mines under similar hydrogeologic conditions could perhaps be beneficial in varifying the findings. As the pumping tests for the present study were done during the summer months, it is recommended that recharge to the aquifer due to rainfall may also be considered when planning for pumpage is done.

CONTROL OF ARTESIAN PRESSURE IN PANANDHRO LIGNITE FIELD, GUJARAT

The Panandhri lignite field is located in the north western part of Kali Nadi basin in Kutch district, Gujarat covering an area of about 8.2 km^2. The reserves of lignite located near Panandhri have been comprehensively evaluated by the Gujarat Mineral Development Corporation Ltd.,(GMDC) and Directorate of Geology and Mining (DGM) through drilling. Reserve estimation survey revealed that the lignite deposits are underlain by saline groundwater under confined conditions. Some of the boreholes drilled into the underlying aquifer resulted in flow artesian wells yielding highly saline water. The piezometric surface of the confined aquifer being above the lignite base, lignite mining, it was realised, faced problem of bursting of the mine bottom due to artesian pressure of confined groundwater.

The sub-surface geology has been synthesised from the analysis of sub-surface data from the exploration programme conducted by the Central Ground Water Board. Additionally, date of DGM and GMDC boreholes duly keyed to CGWB exploration boreholes have also been used in studies.

The geological sections reveal that the lignite bearing Tertiary rock formations with basalt silts are underlain by a thick sequence of very friable white sandstones (in drill cuttings the samples were obtained as loose sand) ranging in thickness from 147 to 217 m. (The geological data analysis and geological sections shows that these belong to the Umia Series

The sandstone, medium to coarse grained, occurs associated with clay shale intercalation at various levels. Near the outer parts of the Lignite Field the intercalation are predominantly of white clays; in the Central part greyish shale occur. The thickness of individual shale intercalation do not exceed 1.5 m in the Central part; in the outer parts of the field the white clay thickness range upto 6 m or more above the sane horizon.

Groundwater occurs in the friable sandstone which underlies lignite. The average thickness of the aquifer is 182 m. The sand grains are well sorted and fine to coarse grained.

The piezometric surface varies from 26.345 to 27.955 m above mean sea level and is 12.80 to 2.14 mbgl. The piezometric surface slopes in northerly to northwesterly direction at average gradient of 1:1076 to 1:3500 respectively. The piezometric level fluctuation is insignificant but minor daily fluctuations are caused due to tidal loading effect.

Aquifer performance tests were carried out on two testwells for 7.4 and 8 days and hydrological boundaries were determined. The values of Transmissivity, Hydraulic conductivity and storativity range from 600 to 1500 m^2/day, 2.1 to 11.0 m/day and 4.5×10^{-5}, respectively.

The recharge discharge relationship shows that the Kali Nadi basin gets an annual recharge of 30 MCM & has a discharge of 20 MCM thereby has a surplus of 10 MCM.

In Panandhro Lignite Field the groundwater outflow is 1350 m^3/day and the inflow is 1800 m^3/day for a section length of 3.4 km. Additional 0.1 MCM of water will be available due to reduction of artesian pressure and consequent expansion of water from a cone of radius of 1.75 km. and drop of pressure head of 40 m during pumping.

The thickness of clay, shale bed separating lignite from the confined aquifer sranges upto 18 m. However, in the central part of the field, the lignite was found to be in direct contact with confined aquifer.

For calculating the safe depth of mining lignite without depressing the artesian pressure, the depth at which the effective pressure will be zero between the downward pressure of clay/shale/lignite and the upward pressure of piezometric head was calculated. Based on the computations, the safe depth of mining was worked out to be ranging from 18 to 40.5 m below ground level in the entire lignite field.

For safe mining lowering of piezometric head below the lignite base varies from 18 to 20 metres in the southern part and over 60 metres in the north and north eastern part.

With a well field in the Northern part of the lignite field, pumping at a rate of 30,000 m^3/day the piezometric head will be lowered effectively through-out the Lignite Field. Also this would meet the requirement of water for cooling purposes of the proposed Thermal Power Plant.

To control th e artesian pressure of the confined aquifer in the Panandhro Lignite Field effectively for safe mining it is recommended that the well field consisting of three wells, each with a discharge capacity of 10,000m^3/dayhas to be constructed. Each well will be located at the apex of an equilateral triangle with the distance between each well of 50 metres.

Other than these three wells, three more additional stand-by wells will have to be constructed by the side of each well at a distance not exceeding 5 metres. It should be ensured that the source of electricity for running the pump is continuous and in case of failure the alternate source should be commissioned automatically without any lapse of time. This is most important because at any time during continuous pumping, the drawdown will be at its maximum and stoppage of pumping even for a fraction of a minute would lead to dissastrous inundation of mines.

The p^H (field value) of groundwater is 6.8 to 7 and the total dissolved solids are very high. The dissolved salts are dominantly chlorides followed by sulphates. This suggests that well corrosion will certainly be a problem; incrustation should not pose a problem since the water is neutral. Iron bacteria is not expected in waters with high total dissolved solids, high chloride, high temperature (23.8^{o}C), in deep wells in arid zone and in high sulphate waters.

Although corrosion and incrustation cannot be eliminated it can be ameliorated by keeping (i) entrace velocity low, (ii) drawdown above top of screens and (iii) selecting casing material based on the groundwater quality.

References

1. Rai J.N. etal 1978-79 Hydrogeological Investigations in selected colleries of Chandrapur district, Maharashtra; unpublished Report of C.G.W.B., India.

2. Sinha, B.P.C. and Srinivasan N.S. 1983, Control of artesian pressure in Panandhro lignite field, Kutch district, Gujarat Proc. Seminar on Assessment Development & Management of Ground Water Resources Vol.1 pp 113-119,CGWB, New Delhi, India.

3. Srinivasan, N.S. 1978 Hydrogeological Investigations for control of Artesian pressure in Panandhro Lignite field, Kutch district, Gujarat, Unpublished Report of CGWB, India.

4. Srinivasan, N.S. 1979, Report on the Mine Inundation problem in th e Khetri Copper Mines, Jhunjhunu district, Rajasthan, Unpublished Report of CGWB, India.