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INTERNATIONAL YEAR OF MILLETS 2023

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खण्ड 44, अंक 2
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Volume 44, No. 2
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नोटः पत्रिका में प्रकाशित रचनाओं की मौलिकता एवं उनमें व्यक्त विचारों के लिए रचनाकार स्वंय उत्तरदायी हैं। पत्रिका में व्यक्त विचारों के लिए संपादक मंडल तथा सीएमपीडीआई प्रबंधन किसी भी प्रकार से उत्तरदायी नहीं होगा।

The views expressed are of the authors
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TREATMENT OF ACID MINE DRAINAGE USING CALCIUM OXIDE IN AN INDIAN COAL MINE–A CASE STUDY

Neeraj Kumar Singh[1], Manish Yadav[2], Sukanta Mondal[3], Jitendra Kumar Dixit[4], R.C Sahoo[5], UK Mohanty[6]

ABSTRACT

Acid mine drainage is one of the most common problem observed in coal mines. Acid mine drainage problem usually occurs in open cast coal mines due to presence of pyrite band. These pyrites normally get suppressed in between coal seams, when the mining occurs these pyrite bands get exposed and reacts with water and air. This reaction results formation of acid mine drainage. CaO is one the most commonly used and economical neutralizing agent. In present study CaO dose and time has been optimized for neutralization of acidic mine water of a running coal mine of India.

Keywords: Acid Mine Drainage, Mine water, Coal mining

INTRODUCTION

Coal is the most important and abundant fossil fuel available in India. It accomplishes around 55% of the country's energy demand. Coal India Limited (CIL), a Government of India undertaking is the single largest coal producer in the world. Mahanadi Coalfields Limited is one of the subsidiaries of Coal India Limited and highest coal producing company among different subsidiaries of Coal India Limited in the year 2021-22. In coal mining acid mine drainage is a major problem due to presence of pyrite bands. Proper treatment of acid mine drainage is a key area of concern in coal mining to prevent environmental problems. Generally known as acid rock drainage (ARD) or acid mine drainage (AMD), occurs from mine waste rock, tailings, and mine structures such as from pits and underground workings which is mainly a function of the mineralogy of the rock material and the presence of water and oxygen. It highly varies from site to site as it depends on mineralogy and other geological conditions. Therefore, it is quite difficult to predict the exact potential for AMD (USEPA,1994). AMD can be categorized as high acidity, which possess sulphate and heavy metals like copper, iron, manganese, lead and can lead dangerous impact over terrestrial and aquatic life (Bai et al., 2012). AMD happens when sulphide minerals are come in contact with air and water under the presence of bacteria which can accelerate the cause of AMD (Akcil and Koldas, 2006). The major sources of AMD is given in Table 1.

Table1: Different sources of Acid Mine Drainage

Primary sources	Secondary sources
• Mine waste dumps • Tailings impoundment • Underground and open pit mine workings • Underground effluent discharged water • Seepage water from OB dumps • Construction materials used in roads, dams, etc.	• Treatment sludge ponds • Rock cuts • Concentrated load-out • Coal stocks • Concentrate spills along roads • Run off from coal stocks, OB dumps, haul roads etc.
Source: Akcil and Koldas, 2006	

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Generally acid mine drainage problem occurs when Sulphide minerals contained in the rocks gets exposed and reacts with water and oxygen. The reaction responsible for formation of acid mine drainage is as follows:

$$4\,FeS_2 + 15\,O_2 + 14\,H_2O \longrightarrow \underline{\mathbf{4\,Fe(OH)_3}}\downarrow + 8\,H_2SO_4$$

Reaction among mine water, pyrite and oxygen form sulfuric acid iron hydroxide precipitate. The step-wise chemical reaction involve is as follows:

Eq. 1: $FeS_2 + 7/2\,O_2 + H_2O \longrightarrow Fe^{+2} + 2\,SO_4^{-2} + 2\,H^+$

Eq. 2: $Fe^{+2} + ¼\,O_2 + H^+ \longrightarrow Fe^{+3} + 1/\,H_2O$

Eq. 3: $Fe^{+3} + 3H_2O \longrightarrow Fe(OH) + 3H^+$

Eq. 4: $FeS_2 + 14\,Fe^{+3} + 8\,H_2O \longrightarrow 15\,Fe^{+2} + 2\,SO_4^{-2} + 16\,H^+$

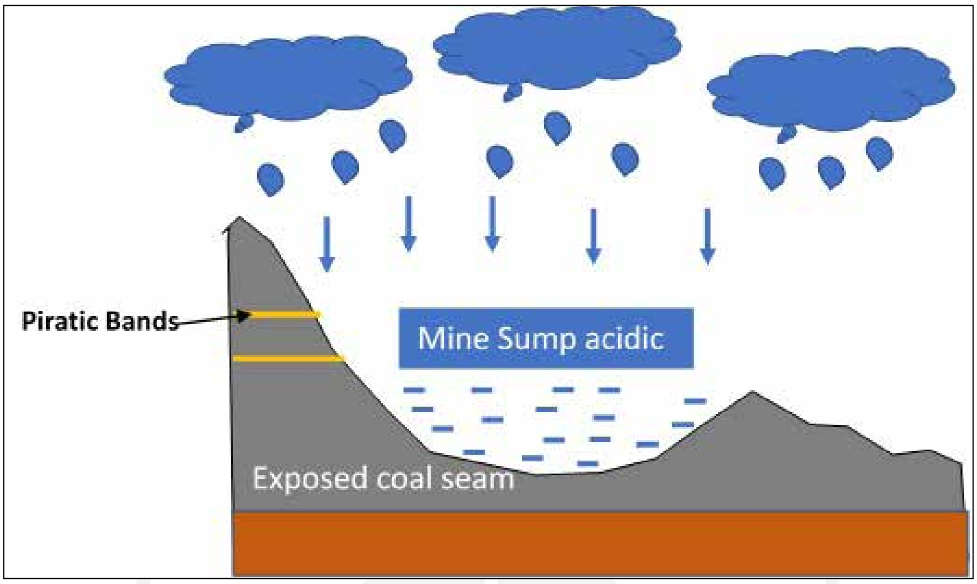

Fig 1: Acid Mine Drainage generation

AMD can pollute both surface and ground water due to its low pH and high concentrations of heavy metals and other toxic elements, AMD can also severely pollute the soil characteristics (Peppas et al., 2000).

Common sulphide minerals which are responsible for AMD are pyrite, chalcopyrite, chalcocite, and arsenopyrite. Common sulphide minerals which are responsible for AMD is given in Table 2.

Table 2: Common Sulphide minerals

Sl.No.	Sulphide	Formula
1	Pyrite	FeS_2
2	Pyrrhotite	Fe_xS_x
3	Chalcocite	Cu_2S
4	Covelite	CuS
5	Chalcopyrite	$CuFeS_2$
6	Arsenopyrite	$FeAsS_2$
7	Molibdenite	MoS_2
8	Galena	PbS
9	Millerite	NiS
10	Sphalerite	ZnS

There are several methods to treat AMD like chemical treatment, ion exchange and membrane (Madzivire et al., 2010). Instead of chemicals methodologies, organic matters such as goat manure fertiliser (Othman et al., 2015) and spent coffee grounds (SCG) (Lavecchia et al., 2016) can also be used to treat contaminated water such as AMD or industrial water.

Addition of quick lime or calcium oxide (CaO) is one of the best methodologies for treatment of acid mine drainage (AMD).

Due to Acid Mine drainage mine water needs to be treated before discharge to any natural water body. In this study due to accumulation of huge water in existing mine sumps, it has become difficult to excavate further coal. The working is already going on in the deep most point and de-coaled areas have yet not been developed for sumps. Therefore, to mine out the submerged coal seam it is required to pump out existing sumps and discharge it to nearby natural stream (Pandren Jhor). To assess the mine water quality the same has been analyzed and treated with quick lime.

MATERIAL AND METHODS

Mine Site

This is a running mine having two sumps namely main dip sump and north dip sump. The IB River flowing southerly which is at a distance of 700m from the mine lease boundary constitutes the main drainage of the area. The major part of the mine lease area falls in the Lilari nalla basin. Lilari, a 5th order stream, is one the main drainage tributary of Ib river. Pandren Nalla, which falls in the mine lease area is a 4th order stream, flowing southerly finally meeting with Lilari Nalla. Pandren nalla has been diverted as it falls within the mine lease area. The high flood level (HFL) in the area is reported to be 215.00 m above MSL, which limits the block on the south-eastern side. (Fig. 2)

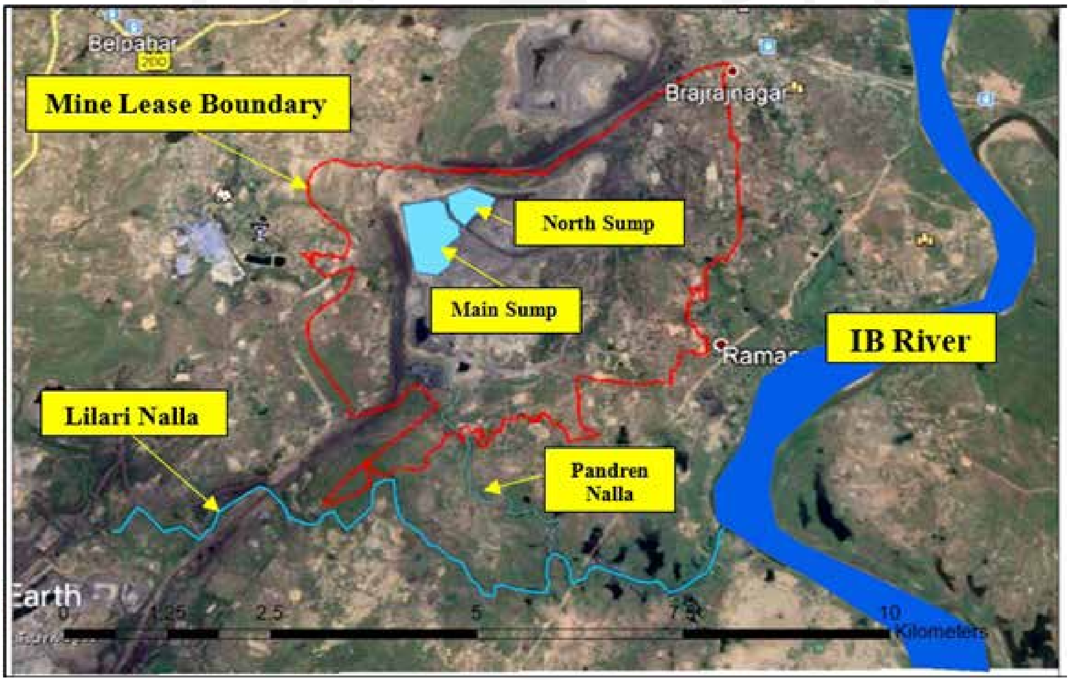

Fig 2: Map showing Mine Lease and nearby water bodies

Methodology

In present study CaO is used for neutralization. Lime dissolution is the first step of the neutralization process. CaO must first be hydrated (slaked) and is normally fed to the process as a slurry. The hydrated lime then dissolves to increase pH. The two following equations illustrate these reactions:

$$CaO + H_2O \longrightarrow Ca(OH)_2$$
$$Ca(OH)_2 \longrightarrow Ca_2^{+} + 2OH^{-}$$

In present study the following methodology has been adopted for obtaining the optimum dose and quantity of lime (CaO):

1. Qualitative analysis of mine water
2. Quantification of mine water
3. Calculation of optimum dose and time
4. Calculation of total quantity of lime required

RESULT & DISCUSSION

Qualitative analysis of mine water

To know the existing water quality of mine sump, water sample was collected from both the sumps on 8th July 2020. The same has been analysed as per the General Standards for discharge of effluent to Inland Surface water. (Table 3)

Table 3: Mine water analysis report

Name of the station	Unit	North Sump	Main Dip	MoEF-Sch-VI
Date of Samplings		08-July-20	08-Jul-20	Standards for
Colour	Hazen	7	6	-
pH		4.02	4.62	**5.5 to 9.0**
Total Suspended Solid	mg/L	30.0	40.0	**100.0**
BOD [3 days at 27°C]	mg/L	4	3.8	**30**
COD	mg/L	40.0	52.0	**250**
Oil & grease	mg/L	<4.0	<4.0	**10**
Nitrate Nitrogen (as N)	mg/L	<5.0	<5.0	**10**
Ammonical Nitrogen, (as N)	mg/L	<0.5	<0.5	**50**
Total Kjeldhal Nitrogen (as N)	mg/L	<1.0	<1.0	**100**
Arsenic	mg/L	<0.005	<0.005	**0.2**
Lead	mg/L	<0.005	<0.005	**0.1**
Hexavalent Chromium	mg/L	<0.05	<0.05	**0.1**
Total Chromium	mg/L	<0.02	<0.02	**2**
Copper	mg/L	<0.03	<0.03	**3**
Zinc	mg/L	<0.04	<0.04	**5**
Cadmium	mg/L	<0.001	<0.001	**2**
Nickel	mg/L	<0.1	<0.1	**3**
Fluoride	mg/L	<0.3	<0.3	**2**
Manganese	mg/L	<0.04	<0.04	**2**
Iron	mg/L	<0.1	<0.1	**3**
Dissolved Phosphate	mg/L	<0.1	<0.1	**5**

Quantification of mine water

There is major two sumps Main dip sump and North sump, the current water available in these sumps have been calculated considering present stored water and additional inflow of water during monsoon season.

Table 4: Present stored volume of water in mine sumps

Sl. No.	Name of the sump	Length (m)	Breadth (m)	Av Depth/ height ofwater column (m)	Volume of water(cum)	Volume of Water (gallon)	Say, approximately volume of water {Million Gallon (MG)}
1	Main dip sump	1235	220	4.40	1195480	263005600	260
2	North sump	700	350	3.00	735000	161700000	160
Total					1930480	424705600	420

1 cum m= 220 Gallons

Apart from above, there will be inflow of water during monsoon season, the calculation of the same is given in following table:

Table 5: Predicted inflow of water in mine sumps during monsoon season

Sl. No.	Name of the sump	Catchment area (m^2)	Total rainfall during monsoon period (m)	Total accumulated water (m^3)	Total accumulated water (gallons)	Total accumulated water (MG)	Total accumulated water due to strata seepage (MG	Total Inflow during monsoon period (MG)	Say (MG)
1	Main dip sump	3231000	1.5	2907900	639738000	639.74	74.87	714.61	715
2	North sump	595000	1.5	535500	117810000	117.81	74.87	192.68	193

Therefore, the total water available for dewatering is as follows:

Table 6: Total volume of water to be dewatered from the mine sumps

Sl.No	Name of the sump	Present Volume of water	Additional volume of water to be added due to monsoon and strata seepage	Total volume of water
1	Main dip sump	260 MG	715 MG	975 MG
2	North sump	160 MG	193 MG	353 MG

Calculation of optimum dose & time

From mine water analysis, it can be observed that the except pH mine water is good enough to directly discharge into a natural stream. But due to occurrence of AMD, neutralization of pH is required before discharging it to natural stream. The initial pH has been taken as 4.0 to calculate the optimum dose of quick lime. For calculation of the same, different dosage of CaO (100 g/l, 150g/l, 200g/l and 250g/l) has been added to mine water and corresponding pH values were noted at different time intervals of 15 mins, 30 mins, 45 mins and 60 mins.

Table 7: Optimum dose calculation of CaO

Lime dose in mg for per litre of mine water	**pH value at different time intervals**			
	15 min	**30 min**	**45 min**	**60 min**
100	6.12	6.34	6.40	6.42
150	8.20	8.15	8.18	8.14
200	8.63	8.67	8.64	8.60
250	8.84	8.85	8.87	8.81

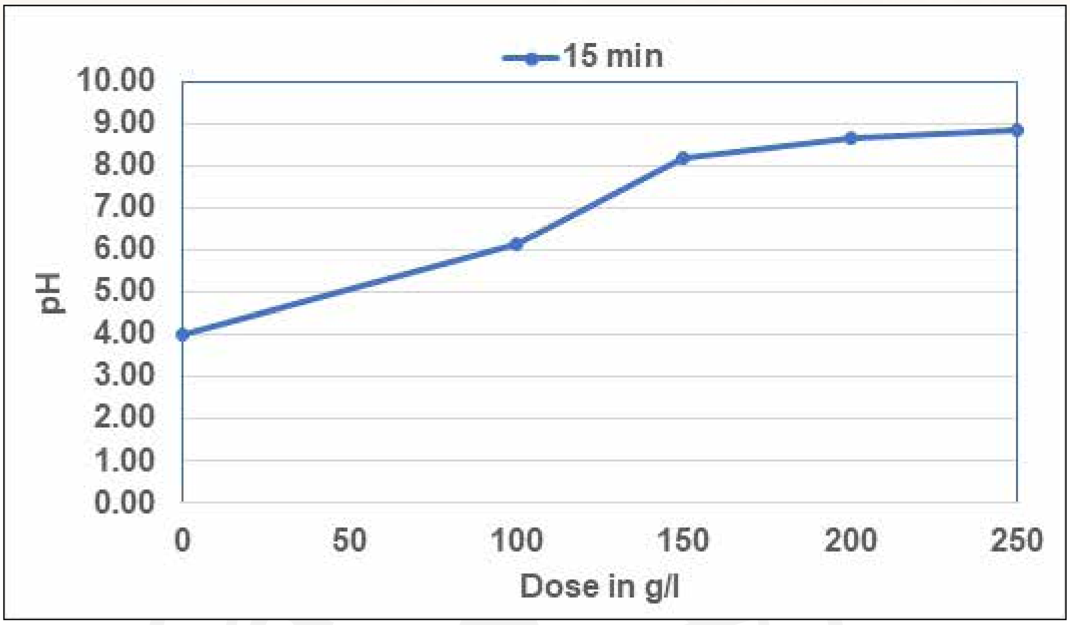

Fig 3: Results of laboratory tests for the operating time of 15 minutes

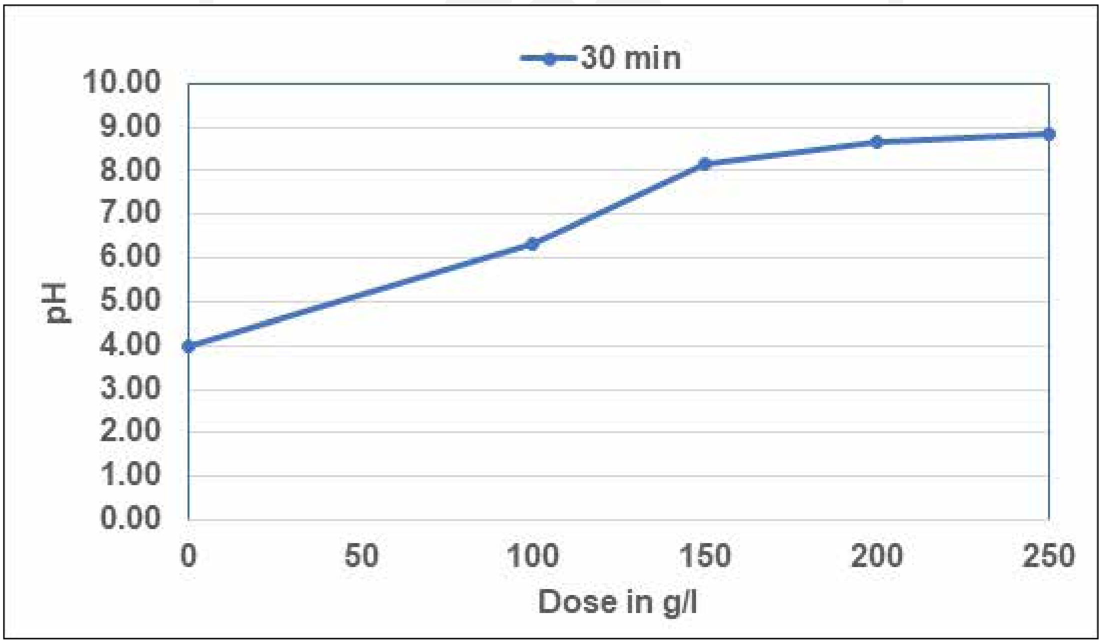

Fig 4: Results of laboratory tests for the operating time of 30 minutes

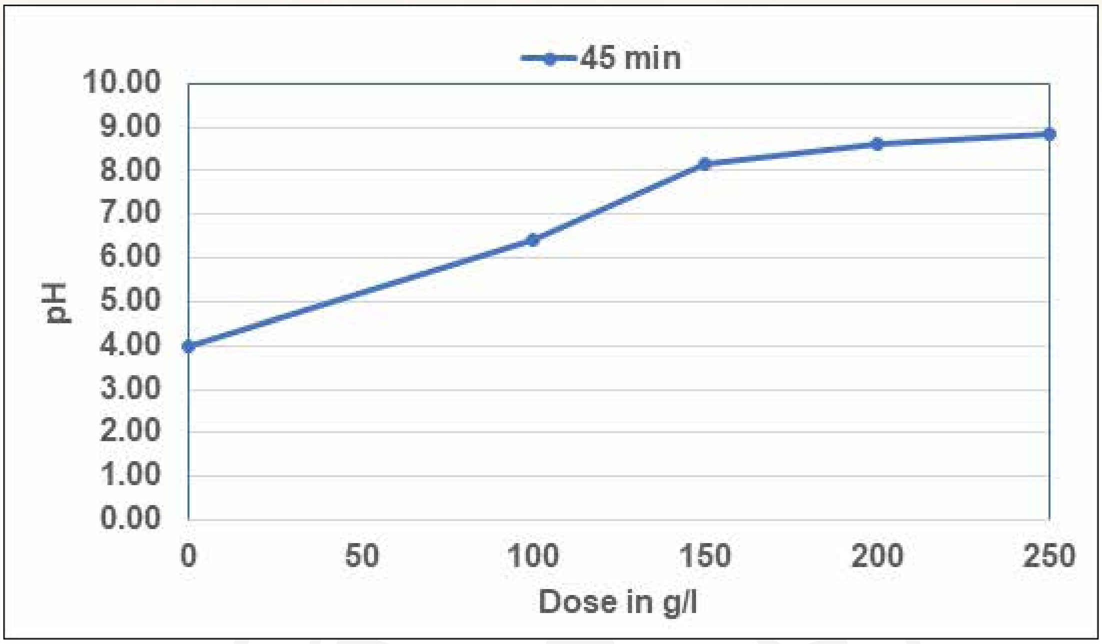

Fig 5: Results of laboratory tests for the operating time of 45 minutes

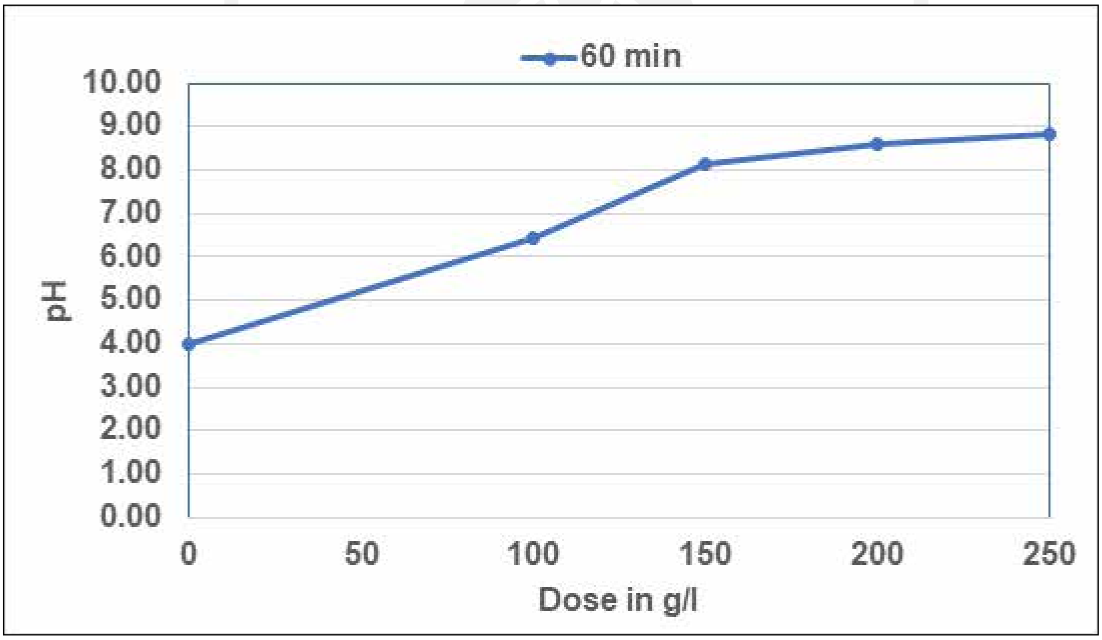

Fig 6: Results of laboratory tests for the operating time of 60 minutes

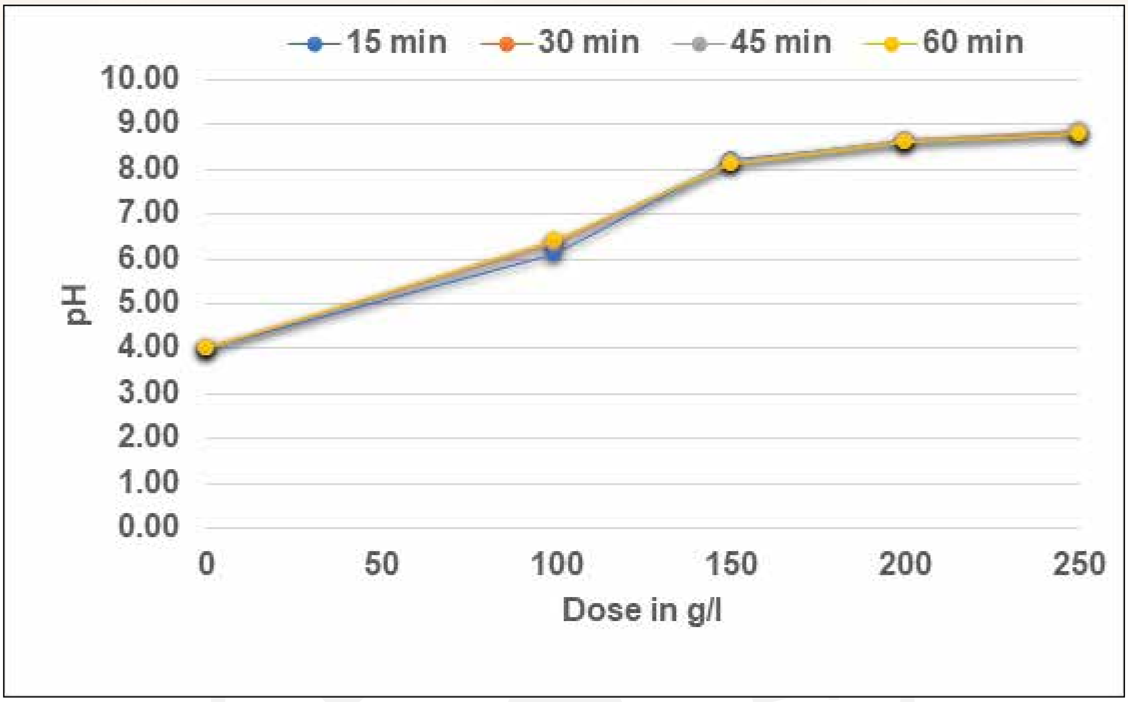

Fig 7: pH dose response curve

On the basis of above experimental setup, it has been observed that the optimal dosage of CaO can be taken as 150 mg for treatment of one litre of mine water to bring the pH in desirable range of 5.5 to 9.5 and a retention period of 45 min can be taken for sedimentation of flocculants. Similarly in other studies of acid mines drainage in coal mine 800mg/l was observed as optimum dose for 50 minutes (Rochyani et al., 2010).

Calculation of total quantity of lime required

Based on the availability of water pumps and their capacity a dewatering plan has been prepared and details of the same is given in following table:

Table 8: Dewatering Plan for Maindip Sump

Volume of water in the Maindip Sump (MG) (A)	Additional water potentially added to the sump due to additional rain and mine seepage water(MG) (B)	Total volume of water (MG) C= A+B	Minimum Capacity (in GPM) of Pump set to be used for dewatering (E)	Effective Capacity in GPM considering 70% efficiency of the pump	Pump Running Time for dewatering	Approximate Time Taken for dewatering Maindip Sump
260 MG	715	975	14400	10080	18	90 days

Table 9. Dewatering Plan for North Sump

Volume of water in the Maindip Sump (MG) (A)	Additional water potentially added to the sump due to additional rain and mine seepage water (MG) (B)	Total volume of water (MG) C= A+B	Minimum Capacity (in GPM) of Pump set to be used for dewatering (E)	Effective Capacity in GPM considering 70% efficiency of the pump	Pump Running Time for dewatering	Approximate Time Taken for dewatering Maindip Sump
160 MG	193 MG	353 MG	4800	3360	18	97 days

Note: It has been taken provision of stand by pump for each sump.

Considering the above it can be observed that total of 97 days will be required for dewatering the whole sump. The calculation for total lime required is given below:

Total lime required=Total water debit x Dose of lime
=(1328/220) x 10^6 x 0.150 kg
=9,05,454.54 Kg
=905.45 Tonne

Lime Treatment Process

For efficient treatment of acid mine drainage, proper mixing and retention period is required for which any of the following treatment methodology can be adopted as per requirement and availability of MCL:

- **Pond Treatment**

In this treatment mechanism lime gets added in a stream or mixing system and letting the precipitates to settle in a pond. The pond is usually divided in two parts a primary and secondary section. The function of primary pond is to accumulate the precipitated sludge and can quickly be filled. These generally require yearly dredging of sludge which then needs a storage area. The secondary pond is bigger and needs a stretched retention time with laminar conditions to allow for "polishing" of the effluent.

- **Conventional Treatment Plant**

In this conventional treatment mechanism AMD is neutralized in a mix tank with controlled

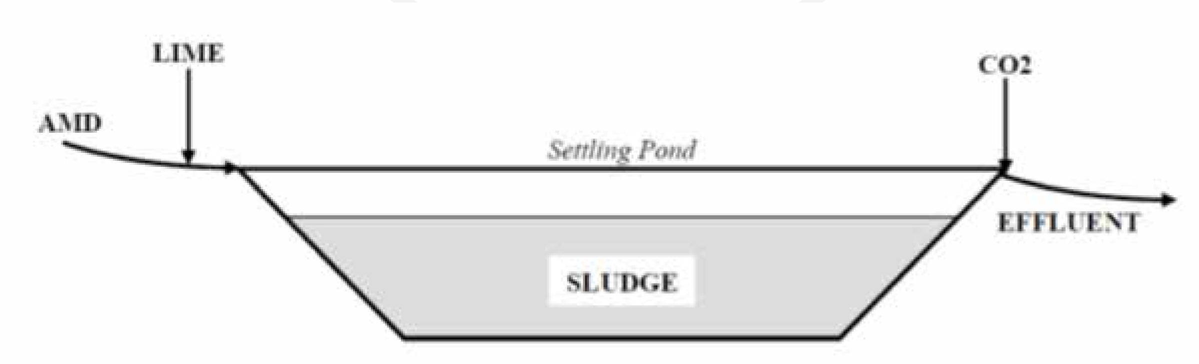

Fig 8: Pond Treatment (Source: Aube and Zinck, 2003)

addition of lime to attain a desired pH setpoint. The slurry is then contacted to a flocculant and fed to a clarifier for solid/liquid separation. The sludge is collected from the bottom of the clarifier and either pumped to a storage area or pressure-filtered to increase the density prior to transport.

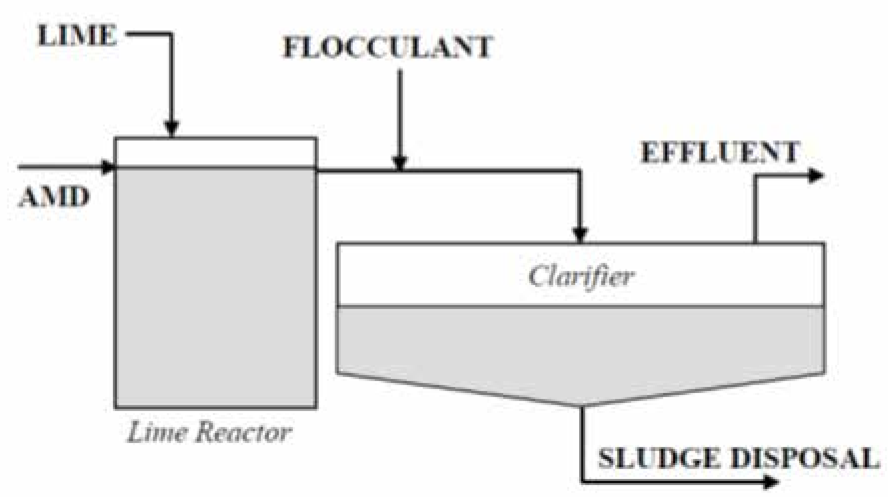

Fig 9: Conventional Treatment Plant

Source: Aube and Zinck, 2003

6.0 Conclusion

- From above study report it can be observed that to mine out the precious coal submerged in the sump, pumping of mine water for temporary basis is required.
- It has been further observed that there is occurrence of Acid Mine Drainage, for which proper quick lime treatment is essential before discharge to natural stream.
- The total mine water needs to be pumped out is 6.03 Mm3 for which 904.5 Tonne of CaO will be required to bring the desired pH level for discharge in inland surface water body.
- A continuous pH monitoring instrument can also be installed at outlet of treated mine water before discharge to natural water body.

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STUDY ON BASE FLOW OF THE AMB RIVER DUE TO MINING ACIVITY AT MKD-I OCP, UMRER AREA OF WCL

K A Pandian, GM(Civil) , CMPDI(HQ), Ranchi

ABSTRACT

Base flows or low flows form an important part of available waters, especially towards the lower reaches of watershed, as they are the flows sustaining over a prolonged period of time. Any water resources development of available surface water must consider the contribution of these low flows. As the low flows are the contributions from the discharges of the aquifers to the rivers, they depend on the drainage and the geotechnical properties of the formations of river basin. Low flows are important as the quality of the environment depends on the quantity of low flows occurring particularly in areas of urban living and having check on pollution.

Base flow studies can be undertaken by a number of techniques. The purpose for which the study is being undertaken mainly determines impact of base flow on the Amb River due to the mining activities adjoined to the river stream. In this study a procedure as suggested in the low flow studies report of by Gustard et.at, 1992 to estimate the Base flow Index using the mean daily discharge data is maintained by the mining authority as a statutory requirement at three locations of Amb river, only two stations have been considered i.e. one in U/S and D/S side mining areas and base flow indices are developed for two stations at U/S , D/S of the mining area using the daily flows over a period of last years i.e. 2017,2018 & 2019. The indices indicate the contribution of the base flow to the total available flows on these streams.

A visual basic microprogramme is written in Excel sheets for the procedure to estimate BFI's as recommended in the Low flows studies report of Institute of Hydrology, UK. The BFI's thus arrived at are varying from 0.249 to 0.332 at the U/S (Railway bridge site), 0.311 to 0.457 for the D/S (PWD bridge). It is observed that D/S of the mining Area has good base flow contribution. There is no impact on the base flow of the Amb river due to mining activity which may be a reason for very less area of mining activities involved in comparison to the total catchment area of the river, distance between the mining boundary & river edge including its sub-soil condition surrounded on this region of Amb river.

1.0 INTRODUCTION:

Rainfall runoff process is an important part of land phase of hydrological cycle. Runoff is defined as the portion of the precipitation flowing off from catchment through surface channels as surface or sub surface flow. Depending upon the catchment through surface channels as surface or sub surface flow.

A stream hydrograph is the time-series record of stream conditions (such as water level or flow) at a gauging site. The hydrograph represents the aggregate of the different water sources that contribute to stream flow. These components can be subdivided into:

(i.) Quick flow–the direct response to a rainfall event including overland flow (runoff), lateral movement in the soil profile (interflow) and direct rainfall onto the stream surface (direct precipitation), and;

(ii.) Base flow–the longer-term discharge derived from natural storages.

The relative contributions of quickflow and baseflow components changes through the stream hydrographic record. The flood or storm hydrograph is the classic response to a rainfall event and consists of three main stages (Figure 1):

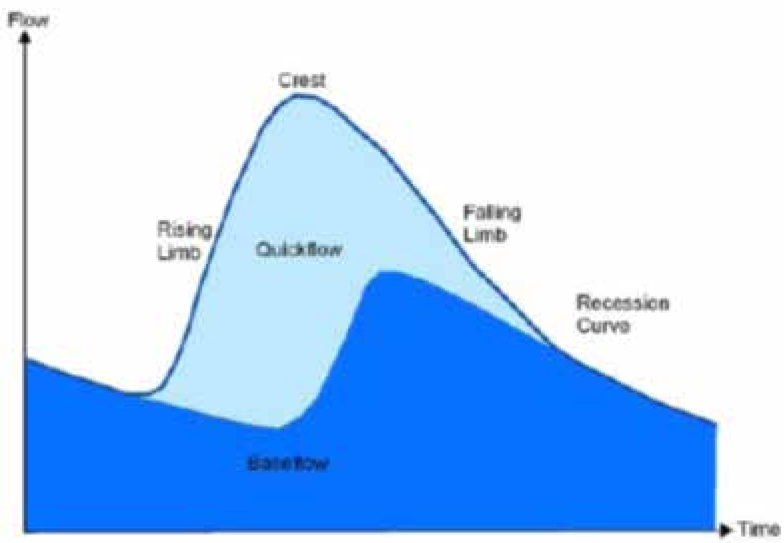


Figure 1 Flood or storm hydrograph

(i.) Prior low-flow conditions in the stream consisting entirely of base flow at the end of a dry period;

(ii.) With rainfall, an increase in stream flow with input of quick flow dominated by runoff and interflow. This initiates the rising limb towards the crest of the flood hydrograph. The rapid rise of the stream level relative to surrounding groundwater levels reduces or can even reverse the hydraulic gradient towards the stream. This is expressed as a reduction in the base flow component at this stage;

(iii.) The quick flow component passes, expressed by the falling limb of the flood hydrograph. With declining stream levels timed with the delayed response of a rising water table from infiltrating rainfall, the hydraulic gradient towards the stream increases. At this time, the base flow component starts to increase. At some point along the falling limb, quick flow ceases and stream flow is again entirely base flow. Over time, base flow declines as natural storages are gradually drained during the dry period up until the next significant rainfall event.

2.0 BACKGROUND:

In the meeting of the Expert Appraisal Committee held on 3rd& 4th October 2019 discussion on Makardhokra-1 Expansion OC mine (Phase-1) for expansion in capacity from 2 MTY to 3.50 MTY as per the special condition in TOR recommended by MoEF & CC New Delhi, it was asked to carry out an integrated hydrological study to study the impact of coal mining on the base flows in the downstream of the mine area.

The origin of the Amb River has been shown below.

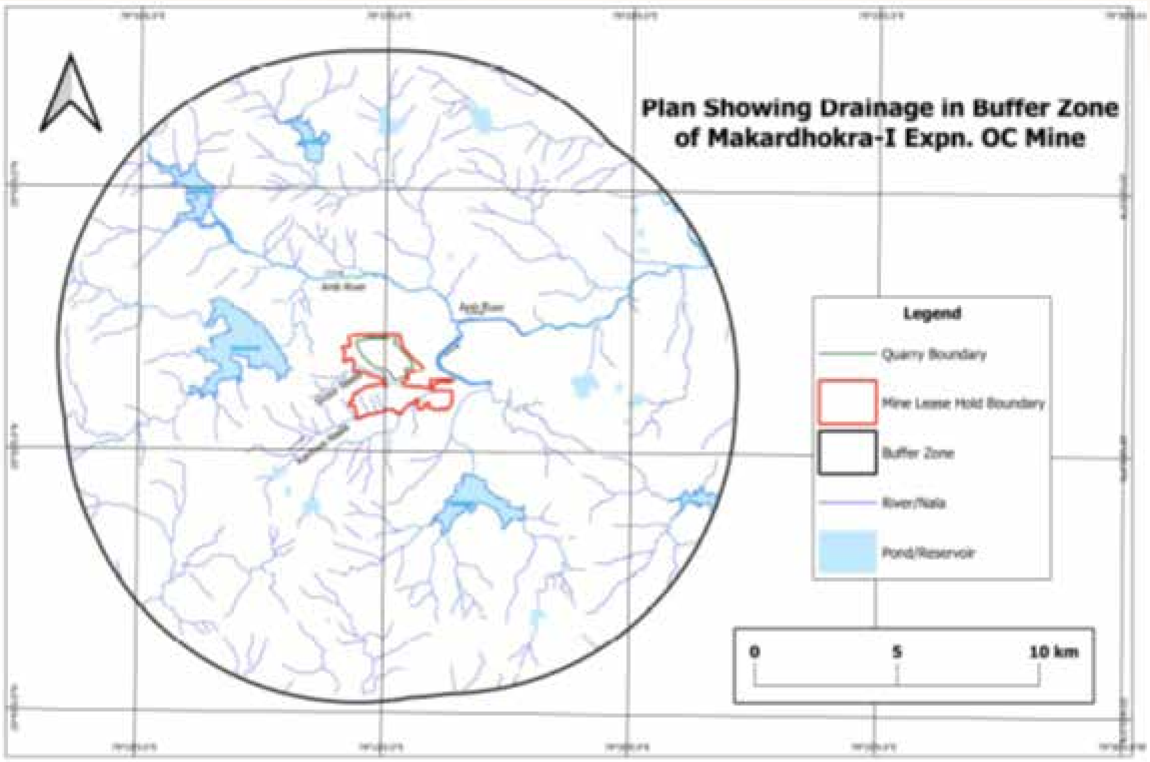


Fig. 2 Plan showing Drainage in buffer zone of Makardhokra

The geographical coordinates of the block are as follows:

Latitudes: N 20°51'06" and N 20°52'30"

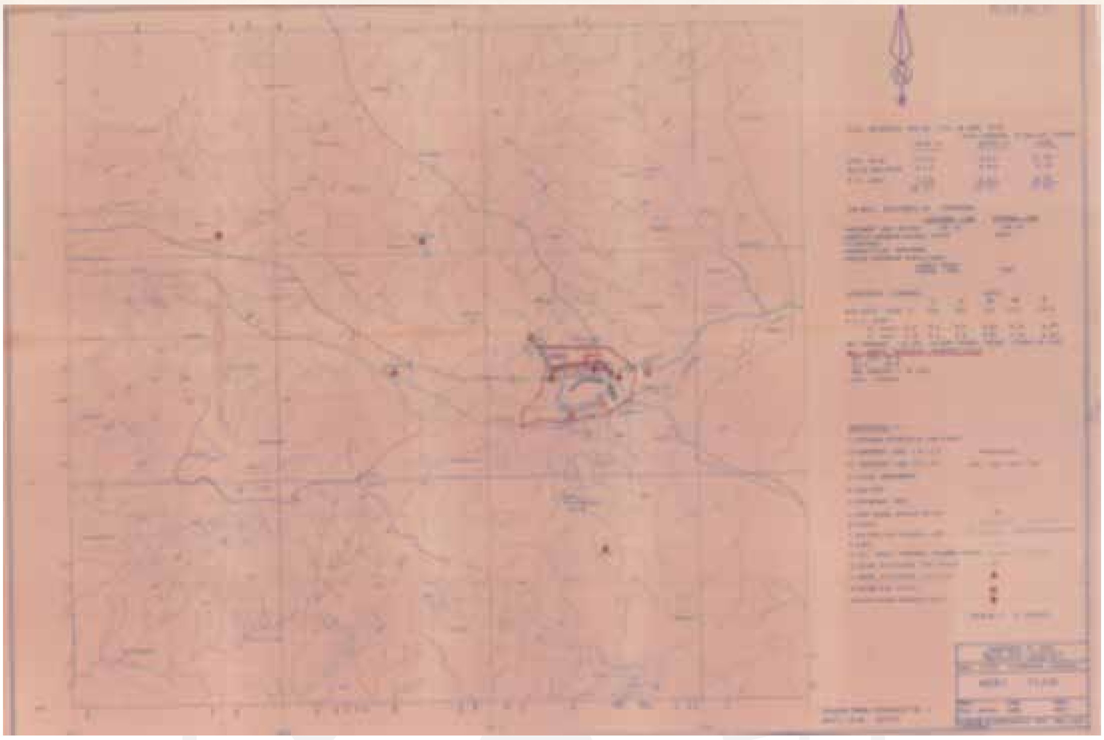
Longitudes : E 79°14'17" and E 79°15'52"

3.0 HYDROLOGY

Amb River is a tributary of Wainganga which further joins river Godavari. The total catchment area of Wainganga river is 61,093 sq.kms and it runs across the states of Chhattisgarh , Maharashtra and joins river Godavari at the border of Maharashtra & Telangana, The total catchment area of the Amb river upto proposed location of U/S of the proposed study is 191.40 sq.km and comprises of low lying plain land surrounded by scattered low hills. The total length of Amb river up to proposed location is 21.2 KMs. The average slope of river upto proposed point at u/s is about 1 in 300. The top layer of soil in Amb catchment is generally medium black cotton soil but red sandy soil and deep black soil are also found in the catchment of Wainganga.

The catchment Area has been calculated based on the topo sheet 55P/1 and 55P/5

The above has been divided into two limbs i.e. Northern Limbs and southern Limbs. The Catchment Area Northern Limb, southern limb is 191.40 sq.kms, 98.33 Sq.kms. The Sirpur nallah, Kanhwa nallah are under southern lims which covers 98.33 sq.kms only. This Amb river is non-notified river and it is considered as Nallah. The maximum Flood discharge at downstream side(D/S) has been assessed approx. 1660 cumecs.



<u>**Fig. 3 Topo sheet 55P/1 and 55P/5**</u>

4.0 SCOPE OF STUDY

The scope of the study covers the followings:

- Integrated Hydrological study of Amb River within territory of Coal Mines of MKD-I and Umrer Open cast Mines in terms of Base flow study of Upstream side (U/S) & downstream side(D/S) of the Amb River on the Open cast mines located on these regions.
- Daily Discharge at the U/s and D/S of the river for last three years is to be generated to assess the base flow Index(BFI)
- To carry out impact of mining activity on the base flow.

5.0 REVIEW OF LITERATURE

5.1 BASE FLOW ANALYSIS AND TECHNIQUES

Analysing the base flow component of the stream hydrograph has had a long history of development since the early theoretical and empirical work of Boussinesq (1904), Maillet (1905) and Horton (1933). Several useful reviews have been written including Hall (1968), Nathan and McMahon (1990), Tallaksen (1995) and Smakhtin (2001) to map this development. The multitude of methods that have evolved can be conveniently categorised into three basic approaches of baseflow separation, frequency analysis and recession analysis.

5.2 BASE FLOW SEPARATION

Base flow separation techniques use the time-series record of stream flow to derive the base flow signature. The common separation methods are either graphical which tend to focus on defining the points where baseflow intersects the rising and falling limbs of the quickflow response, or involve filtering where data processing of the entire stream hydrograph derives a baseflow hydrograph.

5.3 GRAPHICAL SEPARATION METHODS

Graphical methods are commonly used to plot the baseflow component of a flood hydrograph event, including the point where the baseflow intersects the falling limb. Stream flow subsequent to this point is assumed to be entirely baseflow, until the start of the hydrographic response to the next significant rainfall event. These graphical approaches to partitioning baseflow vary in complexity and include:

(i.) An empirical relationship for estimating the point along the falling limb where quickflow has ceased and all of the stream flow is baseflow;

$D = 0.827A^{0.2}$ where D is the number of days between the storm crest and the end of quickflow, and A is the area of the catchment in square kilometres (Linsley et al. 1975). The value of the exponential constant (0.2) can vary depending on catchment characteristics such as slope, vegetation and geology.

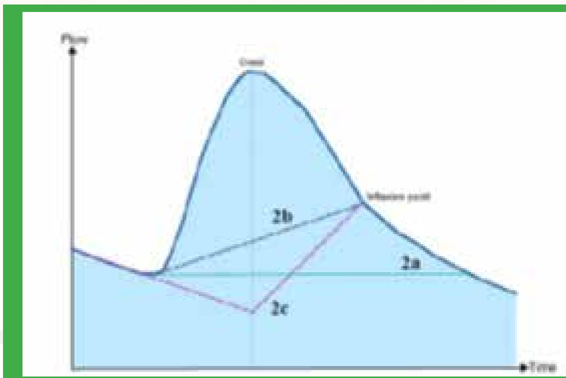
(ii.) The constant discharge method assumes that baseflow is constant during the storm hydrograph (Linsley et al. 1958). The minimum streamflow immediately prior to the rising limb is used as the constant value.

(iii.) The constant slope method connects the start of the rising limb with the inflection point on the receeding limb. This assumes an instant response in baseflow to the rainfall event.

(iv.) The concave method attempts to represent the assumed initial decrease in baseflow during the climbing limb by projecting the declining hydrographic trend evident prior to the rainfall event to directly under the crest of the flood hydrograph (Linsley et al. 1958). This minima is then connected to the inflection point on the receeding limb of storm hydrograph to model the delayed increase in baseflow.

(v.) Using the trends of the falling limbs before and after the storm hydrograph to set the bounding limits for the baseflow component (Frohlich et al. 1994).

(vi.) Use the Boussinesq equation as the basis for defining the point along the falling limb where all of the streamflow is baseflow (Szilagyi and Parlange 1998).



Graphical baseflow separation techniques including
(2a) constant discharge method
(2b) constant slope method and
(2c) concave method (Linsley et al. 1958)

5.4 FILTERING SEPARATION METHODS

The baseflow component of the streamflow time series can also be separated using data processing or filtering procedures. These methods tend not to have any hydrological basis but aim to generate an objective, repeatable and easily automated index that can be related to the baseflow response of a catchment. The baseflow index (BFI) or reliability index, which is the long-term ratio of baseflow to total streamflow, is commonly generated from this analysis. Other indices include the mean annual baseflow volume and the long-term average daily baseflow (Smakhtin 2001). Examples of continuous hydrographic separation techniques based on processing or filtering the data record include:

(i.) increasing the base flow at each time step, either at a constant rate or varied by a fraction of the runoff (Boughton 1988)

(ii.) The smoothed minima technique which uses the minima of 5-day nonoverlapping periods derived from the hydrograph. (Institute of Hydrology 1980; FREND 1989). The baseflow hydrograph is generated by connecting a subset of points selected from this minima series.

(iii.) The fixed interval method discretises the hydrographic record into increments of fixed time (Pettyjohn and Henning 1979). The magnitude of the time interval used is calculated by doubling (and rounding up) the duration of quickflow calculated empirically from Equation 1. The baseflow component of each time increment is assigned the minimum streamflow recorded within the increment.

(iv.) The sliding-interval method assigns a baseflow to each daily record in the hydrograph based on the lowest discharge found within a fixed time period before and after that particular day (Pettyjohn and Henning 1979).

(v.) Recursive digital filters, which are routine tools in signal analysis and processing, are used to remove the high-frequency quickflow signal to derive the low-frequency baseflow signal (Nathan and McMahon 1990). Table 1 outlines some of the digital filters that have been applied to smooth hydrographic data. Eckhardt (2005) has developed a general formulation that can devolve into several of the commonly used one-parameter filters;

$$q_{b(i)} = \frac{(1 - BFI_{\max})aq_{b(i-1)} + (1-a)BFI_{\max}q_i}{1 - aBFI_{\max}}$$

Where $q_{b(i)}$ is the baseflow at time step i, $q_{b(i-1)}$ is the baseflow at the previous time step i-1, qi is the stream flow at time step i, a is the recession constant and BFI_{max} is the maximum value of the baseflow index that can be measured.

(vi.) The streamflow partitioning method uses both the daily record of streamflow and rainfall (Shirmohammadi et al. 1984). Baseflow equates to streamflow on a given day, if rainfall on that day and a set number of days previous, is less than a defined rainfall threshold value. Linear interpolation is used to separate the quickflow component during high rainfall events.

(vii) Base flow studies can be undertaken by a number of techniques. The purpose for which the study is being undertaken mainly determines the particular procedure to be adopted. Raju ct.al., (1995) reviewed at length in their report on long term base flow studies on parameters affecting the base flow. They also presented some techniques of estimating base flow parameters undertaking while conducting base flow studies. In this study a procedure as suggested in the low flow studies report (Gustard ct. al., 1992) to estimate the Base Flow Index using the mean daily discharge data is employed. The procedure is discussed in detail here.

5.5 BASE FLOW LNDEX(BFI) :

A number of regional low flow studies (Wright, 1974, Klaassen and Pilgrim 1975, Institute of Hydrology 1980, Pirt and Douglas 1982) have highlighted the importance of indexing hydrogeology of catchment if flows are successfully to be predicted at the ungauged site. In order to avoid a profusion of relationship between low flow indices and catchment characteristics the low flow studies report (Institute of Hydrology, 1980) recommended using the proportion of base flow in a river defined by an index called Base Flow Index (BFI), for indexing the geology on the low flows. Values of BFI range from 0.1, for a very flashy river to nearly unity for a very stable river with high baseflow contribution.

Although BFI was originally related to geology and lake storages in the U.K., a wider use of the index by Pilon and Coridie (1986) in Canada; Green (1986) in Fijji, Meigh(1987) in Zimbabwe, NWSCA (1984) in New Zealand, Tallaksen (1986) in Norway; Nathan and McMohan(1990) in Australia have shown it to have been useful in regional flood and low flow studies.

BFI can be used as key variable in describing the hydrological response of catchments in order to develop the Hydrology of Soil Type (HOST) classification scheme (Bookman and Hollis, 1990 and Bookman et. Al 1991). BFI can also be used directly as a key variable linking low flow statistics (IH,l980). Accordingly BFI can be used for estimation of key low flow statistics where short period of low flow data are available

Also BFI may be used as a catchment characteristic and relationship between lowflow indices such as Q95 (10) i,e, 95 percentile ten day discharge. Raju et. Al (1995) describe about the following regression equation based on the lowflow studies, report (IH 1980) of Institute of Hydrology, Wallingford.

Q95 (10) 8.6 BFI 0.00377 Area*0.0414 SAAR-3.22------(1)
MAM (10)—9.39 BFI +0.00199 Area+0.0144 SAAR- 2.98 -----(2)

Where MAM (10)—Mean annual 10 day minimum flow SAAR = Average annual rainfall in a standard period Area = Catchment area in Sq.km.

The latest report on 'low flow studies (Custard ct.at; 1992) supplemented the earlier findings and procedures of low flow study of Institute of Hydrology. Relationships are developed between catchment characteristics and low flow statistics, specially the meanflow and two key low flow statistics, Q95 (1), the 95 percentile from the 1 day flow discharge and MAM (7), the mean annual 7 day minimum, representing the flow duration and low flow frequency respectively. The use of HOST (Hydrology of Soil Types) classifications was the principal development in their study. Their study conducted on 865 gauged catchments in the U K. has enabled parameter estimates for Q95 (1) and MAM (7) for 12 low flow HOST groups. They proposed regression equations using short period of continuous local flow data to find Q95 (1) and MAM (7), wherein BFI alongwith other catchment characteristic has been employed as below.

Q95 (1)= 44.BFI 1.43. SAAR -0.0330 .AREA 0.0342-----(3)
MAM (7)=190.99 BFI 1.52.SAAR -0.199 ----------------(4)

5.6 CLOSURE:

A wide variety of approaches have evolved to analyse the hydrographic record to derive the baseflow component and gain an understanding of underlying discharge processes. These approaches have been conveniently categorised into baseflow separation, frequency analysis and recession analysis. In baseflow separation, the early development of graphical methods has been largely replaced by data processing techniques. In particular, the application of recursive digital filters has played a significant role. Many of these filters have been adopted from signal processing and involve the separation of high frequency events. The major challenge is to develop algorithms that have a hydrological basis and can derive hydrogeological parameters. Such physically based filters are being developed, some based on mass balance equations for baseflow from hillsides (Furey and Gupta 2001 2003). In contrast, frequency analysis takes a statistical approach to describe the general low-flow regime. There has been a focus on the development of various low-flow indices but many of these are strongly intercorrelated (Smakhtin 2001). Also limited work has been done to link these indices directly to groundwater processes. To this end, some studies have combined low-flow frequency analysis with recession analysis (Loganathan et al 1986; Gottschalk et al 1997). As in baseflow separation, the traditional approach to recession analysis has been graphical. Early analytical solutions assumed exponential decay of baseflow recession, reflected in a linear relationship between storage and outflow. However, recession behaviour can be complex, variable and non-linear so more complex storage-outflow models have had to be developed. There is now the opportunity to tailor a storage-outflow model that better reflects the natural storages in a catchment. On this basis, it appears that recession analysis holds the most promise in deriving hydrogeological understanding from interpretation of the stream hydrograph.

6.0 DATA GENERATION

Stream Gauging Measurements: For statutory purposes, the Mine authority is maintaining rain gauge station, water level station at different position of the Amb River adjacent to the Mines.

These data is being recorded shift wise/daily especially during rainy season to keep watch the maximum flood Level (HFL) at every Mines.

One station has been strategically located at upstream side of mining activities i.e u/s side of Railway / Road bridge. Another location has been intentionally located near PWD bridge where all mining activities are ended. In this study, these two locations have been considered to assess the maximum River discharge at U/S and D/S based on the Mannings formula. The water level has been recorded at these location shiftwise/daily at monsoon and periodically measured the water level in the remaining seasons. Accordingly, the discharge of river have been calculated

Figure 4 Onsite measurement of depth of flow and flow velocity of river

To derive the maximum river discharge at the particular station, the water level at different section in the river has been assessed to convert into regular trapezoidal shape. Height of water level is being recorded periodically except rainy season. These data has been utilized to assess the daily discharge on U/S and D/S.

The rainfall data has been taken from the daily rainfall recorded in Rain gauge station by Indian Metrological department at Umrer Gauge station. These data has been downloaded from the Maharashtra state Official site.

Select Year : Select ▼ Selected Year : 2010
Select Month : Select ▼ Selected Month : July
Show Exit

Tehsilwise Daily Rainfall (in m.m.) of Maharashtra for the month of July-2010

Sr	District	Taluka	Taluka Normal RainFall	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
300	Nagpur	Nagpur city	393.5	29.7	0.0	4.2	18.3	2.3	3.4	7.7	53.0	40.0	2.0	0.0	21.5	37.4	0.0	7.0	0.0
301		Nagpur gramin	386.5	29.7	0.0	4.1	25.1	2.3	3.4	7.7	56.0	40.0	2.0	0.0	21.5	37.4	0.0	7.0	0.0
302		Kamthi	366.5	30.6	2.8	0.0	0.0	12.4	15.6	5.0	83.0	41.0	0.0	0.0	11.2	27.4	0.0	12.2	0.0
303		Hingna	366.5	29.4	0.0	0.0	0.4	18.0	0.0	3.0	40.4	20.2	4.1	0.0	18.2	11.8	0.0	8.2	0.0
304		Ramtek	361.0	0.0	1.6	36.0	0.0	10.6	0.4	1.0	33.0	28.2	0.0	3.4	3.4	0.0	1.0	8.4	0.0
305		Parshivani	317.3	15.2	0.0	23.6	45.2	18.0	2.2	19.2	50.2	15.2	0.0	10.3	5.6	5.5	0.0	0.0	0.0
306		Mauda	390.1	24.4	0.0	14.0	2.0	51.0	0.2	2.2	52.0	31.2	0.1	0.0	66.8	61.0	0.0	0.0	0.0
307		Katol	271.3	21.0	0.0	10.4	23.0	3.0	0.0	18.0	20.0	15.0	0.0	0.0	4.0	33.0	0.0	30.0	2.0
308		Narkhed	310.0	1.6	0.0	46.0	21.4	31.0	0.0	23.0	8.1	1.3	0.0	0.0	1.4	28.3	0.0	1.0	0.0
309		Savner	281.7	0.0	0.0	32.0	22.4	39.2	1.0	17.2	48.6	11.0	3.2	15.0	10.4	9.2	0.0	21.6	0.0
310		Kalmeshwar	230.3	0.0	0.0	6.4	7.6	18.6	0.0	29.2	70.2	21.0	0.0	0.0	7.6	33.6	0.0	18.6	0.0
311		Umrer	361.1	0.0	0.0	14.6	0.0	25.0	7.2	23.0	40.2	50.6	3.0	0.0	25.2	28.0	5.2	1.6	0.0
312		Bhiwapur	418.4	0.0	4.0	21.0	0.0	16.0	1.0	15.3	34.0	40.0	1.0	0.0	60.0	60.0	12.0	0.0	0.0
313		Kuhi	418.4	15.0	0.0	19.0	0.0	7.2	10.2	3.0	35.0	52.2	2.2	0.0	52.5	28.3	1.0	4.4	0.0

Taluka	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total RainFall	%RainFall	Rainy Days
Nagpur city	0.4	0.0	51.6	7.0	1.0	0.0	3.4	0.4	14.6	39.6	13.0	0.9	0.4	28.4	11.6	399	100.9	18
Nagpur gramin	0.4	0.0	56.1	7.0	1.0	7.6	3.4	0.4	14.6	39.6	13.0	0.9	0.4	28.4	11.6	421.6	111	18
Kamthi	0.0	0.0	0.0	0.0	3.0	0.0	0.0	0.0	20.0	40.7	3.0	0.0	5.0	20.0	40.8	402.3	109.8	18
Hingna	0.0	0.0	0.0	2.0	2.2	1.0	0.0	0.0	20.4	30.0	20.2	1.2	0.0	10.2	0.0	247.3	70.5	15
Ramtek	7.0	23.6	2.0	33.3	36.9	0.0	5.0	0.0	1.6	32.9	16.8	8.5	6.3	15.2	0.0	326.4	102.6	19
Parshivani	0.0	3.4	0.0	0.0	23.4	0.0	10.0	0.0	12.0	35.2	6.0	7.0	5.3	21.4	0.0	335.6	84.3	18
Mauda	0.0	19.4	0.0	9.2	4.4	0.0	28.6	0.0	16.6	32.0	3.4	8.2	10.0	8.2	7.0	512.9	109.1	19
Katol	10.0	0.0	0.0	0.0	5.0	40.0	0.0	0.0	13.6	36.2	8.2	0.0	0.0	8.2	0.0	305.6	98.3	18
Narkhed	3.2	0.0	0.0	30.1	6.3	3.0	0.0	0.0	13.7	33.6	11.9	0.7	0.0	6.2	21.2	294.4	104.6	16
Savner	0.0	4.6	5.2	18.2	1.2	0.0	40.6	0.0	17.2	44.6	9.0	5.2	7.0	52.6	5.4	444.8	103.1	22
Kalmeshwar	3.4	4.2	0.0	22.6	8.4	2.0	4.0	0.0	12.4	33.6	0.0	0.0	0.0	13.2	5.0	333.4	92.3	18
Umrer	50.2	3.2	16.0	0.0	3.2	1.2	49.6	1.2	33.2	55.4	8.2	1.0	3.2	16.0	43.0	512	122.4	21
Bhiwapur	39.0	0.0	0.0	0.0	4.2	0.0	20.0	1.0	40.3	35.0	2.3	2.0	2.2	17.0	29.0	470.3	112.4	18
Kuhi	0.0	4.1	0.0	0.0	5.2	0.0	1.0	0.0	12.1	33.7	8.3	1.0	3.2	42.0	19.0	348.6	84.1	18

The Rainfall data for three years have been shown graphically as below

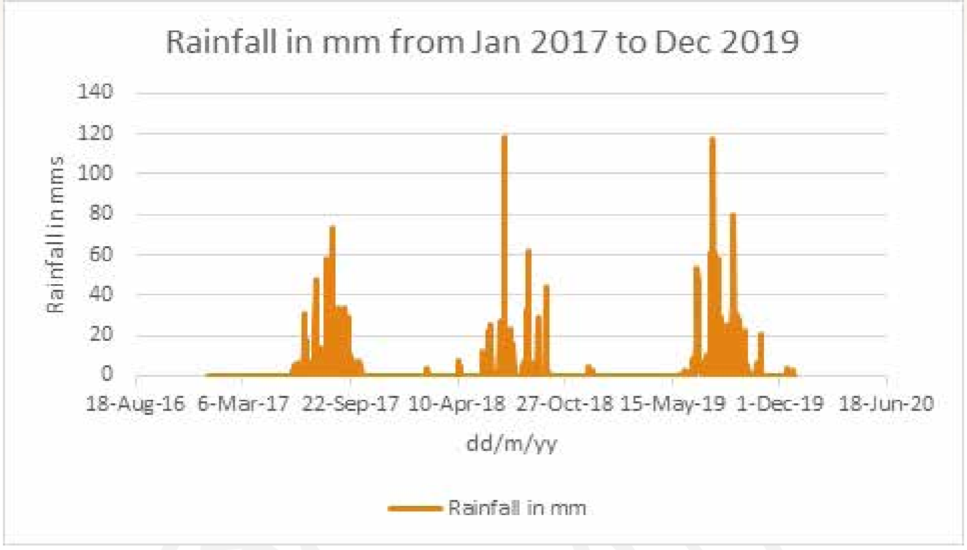


Figure 5 Rainfall in mm from Jan 2017 to Dec 2019

6.1 River Discharge Analysis

The Amb river is un notified and ungauged station as per CWC however the mine authority of Umrer Area is maintaining three gauge stations for their data collection and flood monitoring. The average water level at three gauged stations is being maintained and available for the last three years i.e. 2017, 2018, 2019.

The daily discharge of the river is being calculated using the water level at particular cross-section using Manning's formula for calculating the velocity and then multiplying by the cross section.

Manning formula v = (kn/n) Rh2/3 S1/2

kn = 1.0 for SI units

n = Manning coefficient of roughness

Rh = hydraulic radius

S = slope - or gradient

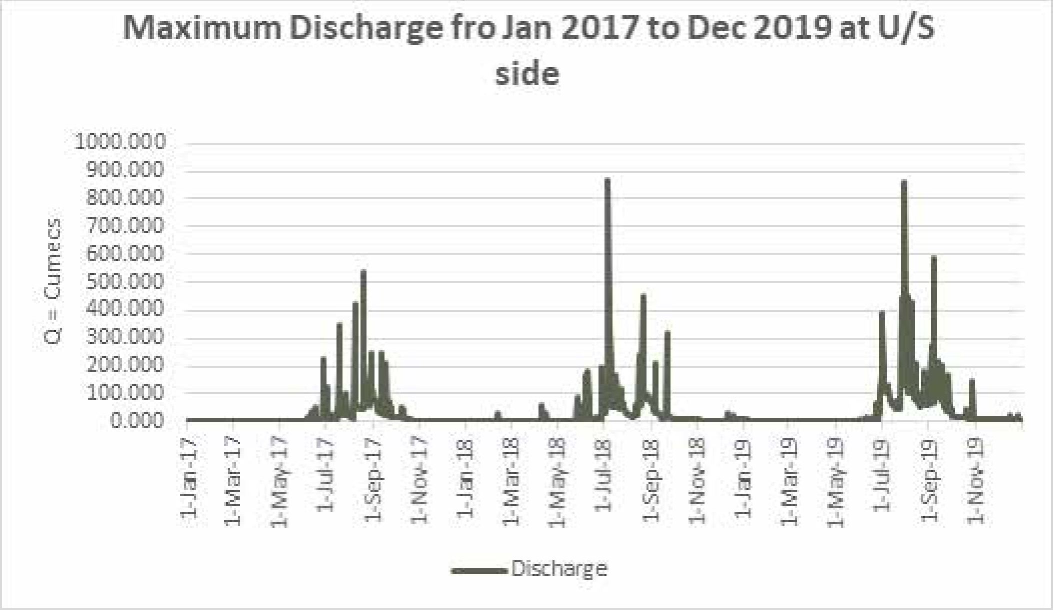
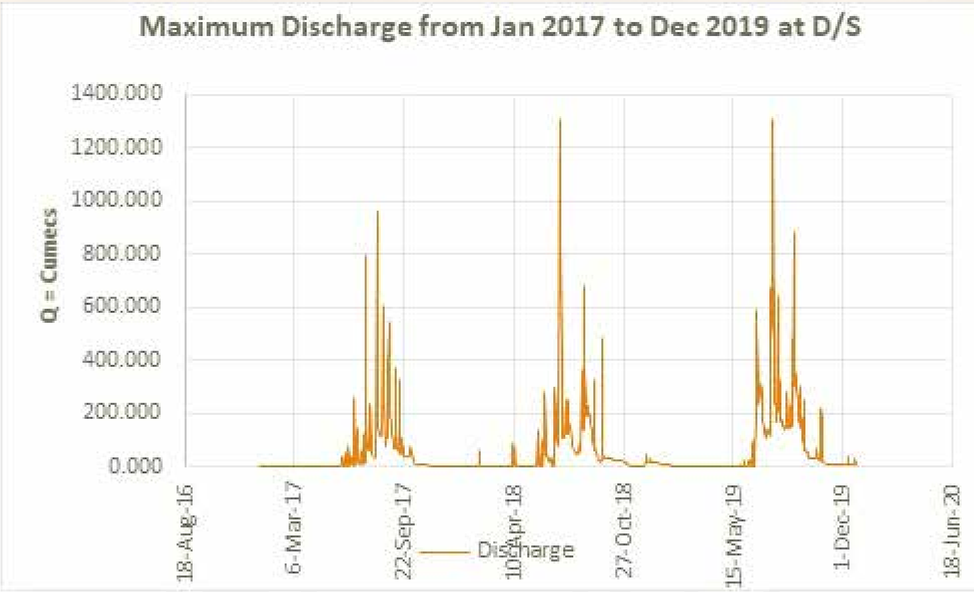


Figure 6 Maximum discharge from Jan 2017 to Dec 2019 at U/S side



Source: Water level monitoring by WCL,Umrer Area

Figure 7 Maximum discharge from Jan 2017 to Dec 2019 at D/S side

Hydraulic radius can be expressed as

$$Rh = A/Pw$$

where

A = cross sectional area of flow

Pw = wetted perimeter

The cross-section at the point is obtained by doing detailed survey and plotted on a paper and for calculation purposes smoothed to assume a shape in our case it takes the shape of Trapezoid. The daily discharge have been calculated for the U/S & D/S for last three years i.e 2017, 2018 & 2019 which has been graphically plotted in Fig.6

7.0 HYDROGEOLOGICAL STUDY OF THE AMB RIVER REGION

7.01 AQUIFERS:

The aquifers of the study area can be broadly classified as Shallow and Deeper aquifers, detail of the same are mentioned below:

7.01.01 SHALLOW AQUIFER:

The shallow aquifer is composed of black cotton soil/detrital mantle, weathered basalt of Deccan traps and Lameta formation. The entire study area is capped by black cotton soil. At places soil/detrital mantle is underlain by Deccan Traps or Lameta.

At places, Deccan Traps lies below the soil cover and is represented by hard Weathered/Massive Basalt. Weathered/fractured Basalt are known to be moderately potential aquifer. However, where hard cherty and calcareous sandstones of Lameta formation is present, it reduces the potentiality of the shallow aquifer. Moreover, the presence of Lameta formation also reduces the recharge of underlying Kamthi aquifer.

7.01.02 DEEPER AQUIFER:

The deeper aquifer is represented mainly by the Kamthi and Barakar Formation. The contact between Kamthi and Barakar Formation is unconformable in nature. The Kamthi formation consists of medium to coarse grained sandstone. The Barakar Formation is composed of fine to medium grained relatively compact sandstones, clay and shale with coal seams. The vertical permeability of Barakar Formation is less due to occurrence of impermeable coal seams/shale repeatedly.

The types of aquifers encountered in the study area are given below in the following table:
Type of aquifers in the study area

Type Aquifer		Formation	Thickness Range (m)
Shallow Aquifer	Unconfined	Soil / Detrital Mantle	0.15 to 9.15
	Unconfined	Weathered/fractured Basalt of Deccan Traps	4.55 to 53.70
	Semi Confined	Lametas	3.00 to 41.00
Deeper Aquifer	Semi Confined	Kamthi	0.55 to 50.35
	Semi Confined Aquifer	Upper Barakar	32.95 to 76.75
	Aquiclude	Coal Seam VI	1.40 to 2.73
	Confined Aquifer	Parting	40.85 to 42.19
	Aquiclude	Coal Seam V	2.65 to 6.27
	Confined Aquifer	Parting	17.40 to 26.16
	Aquiclude	Coal Seam IV	2.52 to 8.85
	Confined Aquifer	Parting	14.45 to 23.50
	Aquiclude	Coal Seam III	1.19 to 4.37
		Parting	2.25 to 7.25
		Coal Seam IIT	1.21 to 4.97
		Parting	0.25 to 9.30
		Coal Seam IIB	0.10 to 1.86
		Parting	1.10 to 10.92
		Coal Seam I	1.23 to 4.60

7.2 Groundwater Levels:

To collect the representative groundwater levels in the study area, CMPDI, RI-IV had established a monitoring network with 33 hydrograph stations spread over the buffer zone (10 km radius mine boundary). Ground water monitoring data for Pre-monsoon and Post-monsoon periods for last 4 years is given below in the following table

Groundwater level monitoring data of dug wells in the buffer zone of Makardhokra-I Expn. OC Mine

Well No. U	Name of village	Well location	Lat			Long			R.L.	Well dia (m)	Well depth (m bgl)	MP height (m agl)	Formation	Depth to water level (m bgl)							
			Deg	Min	Sec	Deg	Min	Sec						May'15	Nov'15	May'16	Nov'16	May'17	Nov'17	May'18	Nov'18
U1	Paradgaon	Adjacent to Nagpur-MKD road (W), about 1 km S of village, near nalla	20	55	9.18	79	13	35.28	291	7.20	11.05	0.50	B	9.35	9.35 (PO)	10.15	8.25 (PO)	10.00 (PO)	9.00 (PO)	9.35	Gate locked
U2	Sayaki	Adjacent to Champa Road Near upper L.P school	20	54	49.31	79	11	45.31	297	3.15	6.75	0.50	B	4.80	1.85	4.90	2.80	5.80	2.85	5.20	NA
U4	Sukri Mauza Field	About 1 km from X-roads, 30 m E of MKD road in the field, 600 m N of irrigation canal	20	54	2.54	79	13	12.10	298	4.80	8.70	0.50	B	6.40	4.10	8.55	4.80	8.50	4.90	7.35	3.75
U5	Hasti	S edge of village, adjacent to water supply borewell & road, in low lying area	20	53	26.83	79	14	51.58	280	3.80	11.56	0.80	B	6.20	1.98	8.00	2.35	7.95	2.65	5.85	2.00
U5A	Hasti	20 away from U5 in NE	...	...	...	...	...	...	...	0.20	~ 70	0.45	...	5.90	1.55	9.00	2.15	8.55	2.95	locked	Blocked with stones
U6	Makardhokra Paradgaon Road	About 2 km N of village, 150 m E of MKD-Nagpur road in the field of Eknath	20	53	13.34	79	13	6.29	285	6.05	8.70	0.50	B	7.50	4.95	6.70	3.80	8.80	4.65	5.80	2.1 (PO)
U7	Dahegaon	E of village, near Hanuman Mandir	20	53	30.32	79	11	6.73	308	3.35	7.28	0.80	B	4.90	4.75	Dry	4.50	6.90	5.10	7.00	4.35
U8	Dahegaon Road	About 1 km from village road junction, about 70 m S of Umrer-Butibori road in the field	20	52	53.78	79	11	4.88	310	5.80	8.23	0.85	B	6.25	7 (PO)	6.50	7.05	6.85	7.75	7.15	4.25 (PO)
U9	Tambekhani Road	Midway between two villages, about 50 m west of the road in the field, near to Farm house of Vakil	20	52	20.87	79	10	42.70	309	5.30	9.50	0.50	B	6.40	7(Water fed)	5.50	6.80	7.50	6.50	5.10	3.10
U9a	Tambekhani Road	gangadhar rambed meshram about 15 m west of road in the field								5.40	9.00	GL	..	7.05	7.30	7.25	7.85	8.90	7.15	....	5.10
U10	Makardhokra Bazar	C of village, adjacent to village road	20	52	22.79	79	13	9.27	288	2.00	9.85	0.90	B	3.95	3.80	5.17	3.05	4.85	3.25	3.55	2.92
U11	Makardhokra Bus stand	Adjacent (S) of Umrer-Butibori road, near to village road junction	20	51	52.42	79	13	32.86	298	4.05	10.60	0.60	B	4.85	2.70	6.20	3.20	6.70	4.15	5.05	3.35
U12	Sirpur Road	About 1 km W of village, about 15 m N of Umrer-Butibori road in the field	20	51	39.08	79	14	48.28	288	9.10	7.50	0.30	B	3.65	2.70	4.70	3.11	7.20	3.80	....	2.10
U13	Sirpur	E of village, about 50 m N of Umrer road, (Water injection well)	20	51	24.55	79	15	28.08	285	3.80	12.45	0.50	B	6.15	5.82	6.88	4.50	6.80	3.80	5.85	5.08

U14	Khursapar	E of village, in Bhim pat (Budh Vihar)	20	50	38.17	79	14	55.49	285	2.30	8.10	0.55	B	7.15	4.95	7.45	4.68	7.55	4.20	6.75	4.50
U16	Pipardol	Outside the village (East), E of Deoli road, Twin wells (first)	20	50	14.73	79	12	13.80	317	3.90	10.65	0.80	B	5.30	2.30	5.85	3.00	5.95	1.00	4.50	1.55
U17	Tumbkhani	Near Ambedkar statue, near blue flag	20	51	8.98	79	9	43.10	324	2.55	10.60	0.80	...	....	....	....	....	....	....	8.40	4.98
U18	Amgaon	Near mandir	20	50	30.04	79	9	46.80	312	3.00	9.80	0.80	...	6.80	2.62	5.10	3.20	6.90	2.30	5.20	3.38
U22	Whiri	C of village, in front of school/GP office	20	53	42.31	79	19	25.54	275	2.85	12.40	1.00	B	9.95	6.70	Dry	6.50	10.40	6.40		6.30
U23	Wabaskhra	SE corner of village, adjacent to village road in field	20	54	31.40	79	15	12.01	288	2.90	12.30	0.75	B	3.25	2.80	6.65	(PO) 6.5	3.45	3.55	3.85	3.55 (PO)
U24	Udasa	About 600 m NE of village (outside) about 50 m S of Themra road in field Back	20	54	6.73	79	16	53.98	287	3.00	11.70	0.45	B	7.85	1.80	9.35	1.48	9.61	1.85	7.25	1.95
U25	Themra	SW of village, near Hanuman Mandir	20	53	49.08	79	16	50.08	275	2.25	9.45	0.80	M	4.45	3.30	7.25	(PO) 4.1	5.65	3.65	4.90	3.65
U27	Piraya	SW of village, in school compound	20	52	10.14	79	20	35.44	278	3.05	8.85	0.80	T	7.20	6.17	Dry	DRY	dry	DRY	dry	dry
U28	Umrer (New Budhwari Peth) Mandir (shahid chowk)	NE corner of the town, near Hanuman temple	20	51	32.75	79	19	34.87	282	2.50	12.48	0.65	T	5.80	4.75	6.49	3.57	7.52	4.00	7.15	4.80
U30	Kanhwa	Adjacent (N) to Umrer road, E edge of village Dr. Ambedkar Statue	20	51	14.07	79	16	42.47	275	2.80	8.95	0.95	B	4.95	3.75	4.65	2.95	5.35	3.35	4.50	2.85
U32	Between Kumbhari and Umrer	Adjacent (W) to Umrer-Mohpa road in the field, About 1 km NE of Kumbhari village	20	49	29.28	79	18	51.90	304	7.00	6.40	0.95	B	4.00	1.90	3.05	2.23	5.69	2.25	6.70	5.00
U33	Kalamna	N side of village, adjacent to village road, near to primary school	20	50	19.14	79	16	40.30	280	4.20	11.20	0.85	B	4.50	Dry	Dry	DRY	dry	DRY	5.15	2.35
U34	Lohara	C of village, Forest office compound	20	49	22.73	79	15	15.78	293	2.40	14.80	0.80	B	11.70	3.93	11.45	3.68	8.70	4.30	3.10	3.18
U35	Kumbhari	About 300 m S of village (outside) near nala P.W.S well	20	48	54.24	79	18	5.06	290	2.85	9.85	0.75	B	6.35	3.00	....	3.40	6.15 (PO)	3.35	8.45	2.95
U37	Mohpa	NE edge of village, adjacent to village road	20	48	12.63	79	17	48.31	291	2.55	10.65	0.80	B	4.50	3.50	....	3.60	4.82	4.45	7.40	4.00
U38	Godhani	About 300 m N of village (out side), adjacent to nala	20	48	13.63	79	16	53.27	300	4.60	15.26	0.75	B		3.85	....	3.90	6.50	4.25	6.45	6.90
U39	Lohara Dongargaon Road	Right side of road near nala and Mandir	20	49	13.43	79	13	35.41	302	2.80	6.00	0.80	B	2.50	2.12	3.35	2.60	3.85	2.35	2.40	1.88
U40	Dongargaon	About 300 m E of village	20	47	58.73	79	11	55.44	287	3.20	6.40	0.50	...	1.80	0.95	2.60	1.59	3.10	3.90	6.00	2.72
m.bmp - Metre below measuring point, m. agl - Metre above ground level, m.bgl - Metre below ground level, MP - Measuring point, NA - Not Accessible, PO - Pump ON, GL - Ground level, B - Basalt, T - Takhir																					

The range of water levels (2018), measured from the core and buffer zone of Makardhkora-I Expn. OC Mine are given below:

Range of water level (2018) in core and buffer zone of study area

Pre monsoon period May-June (2018)	Core Zone (within 3 km)	3.55 to 6.75
	Buffer zone (within 10 km)	1.80 to 12.15
Post monsoon period Oct-Nov (2018)	Core Zone	2.00 to 5.06
	Buffer zone	1.20 to 7.50
Note-water level is in meter below ground level		

Water Level Fluctuation in Core and Buffer Zone of Makardhokra-I Expn. OC Mine Area

Core zone				Buffer Zone			
Period	Min	Max	Average	Period	Min	Max	Average
2011	1.05	4.85	2.88	2011	0.05	6.80	2.55
2012	2.15	5.50	3.38	2012	0.90	7.75	4.17
2013	1.84	4.80	3.09	2013	1.13	9.12	4.24
2014	0.80	3.95	2.31	2014	0.45	4.80	2.42
2015	0.33	4.35	2.35	2015	0.15	7.77	2.43
2016	1.59	6.85	3.21	2016	0.75	7.87	3.20
2017	1.40	5.60	3.42	2017	0.37	7.76	3.17
2018	0.63	3.65	1.81	2018	0.52	5.50	2.74
Note-water level is in meter below ground level							

7.03 Water Level Trend:

Hydrographs of two permanent observation wells fixed by CMPDI, RI-IV has been prepared based on pre-monsoon (May) and post-monsoon (Nov) water level data from 2011 to 2018 and presented in fig.8 & fig.9 to assess the water level trend.

The hydrograph of well U-10 at Makardhokra Bazar shows increasing water level trends for both pre-monsoon and post-monsoon periods and the hydrograph of well U-30 situated at Kanhwa village shows more or less constant water level trend during pre-monsoon period and increasing water level trend during post-monsoon period as shown below:-

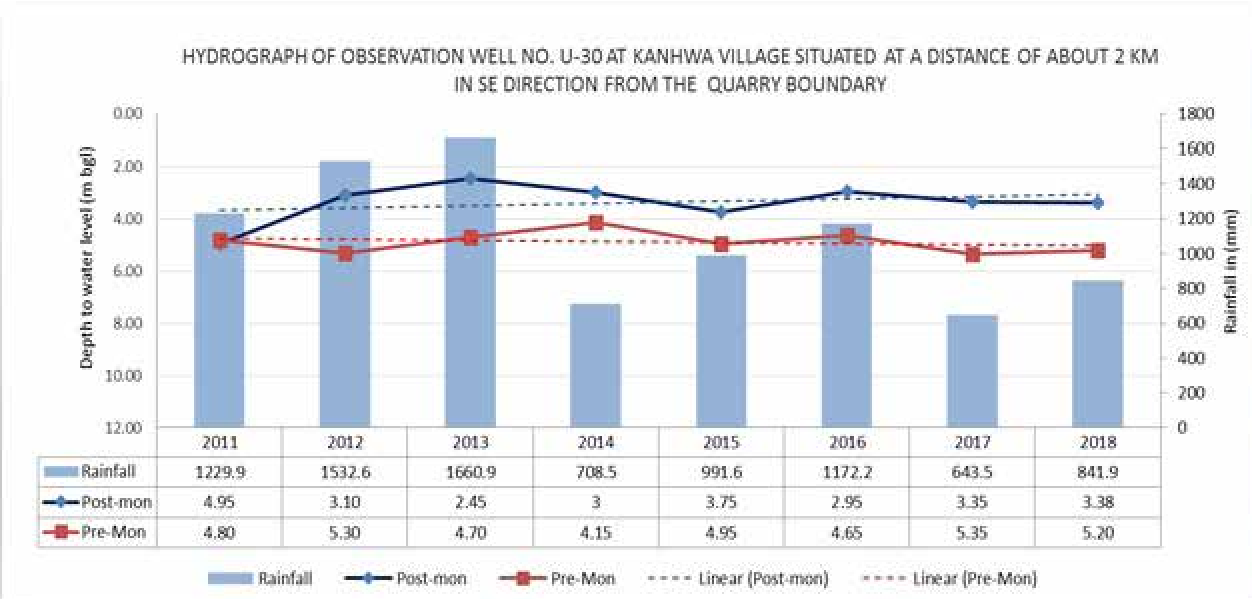


Figure 8 Hydrograph of observation well U-10

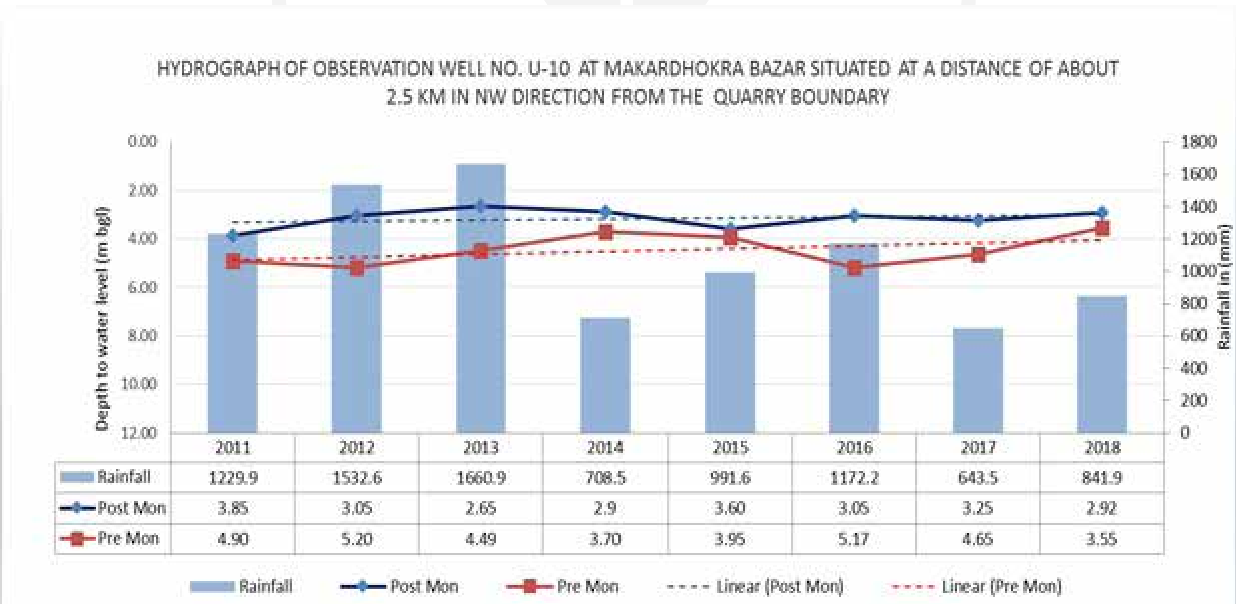
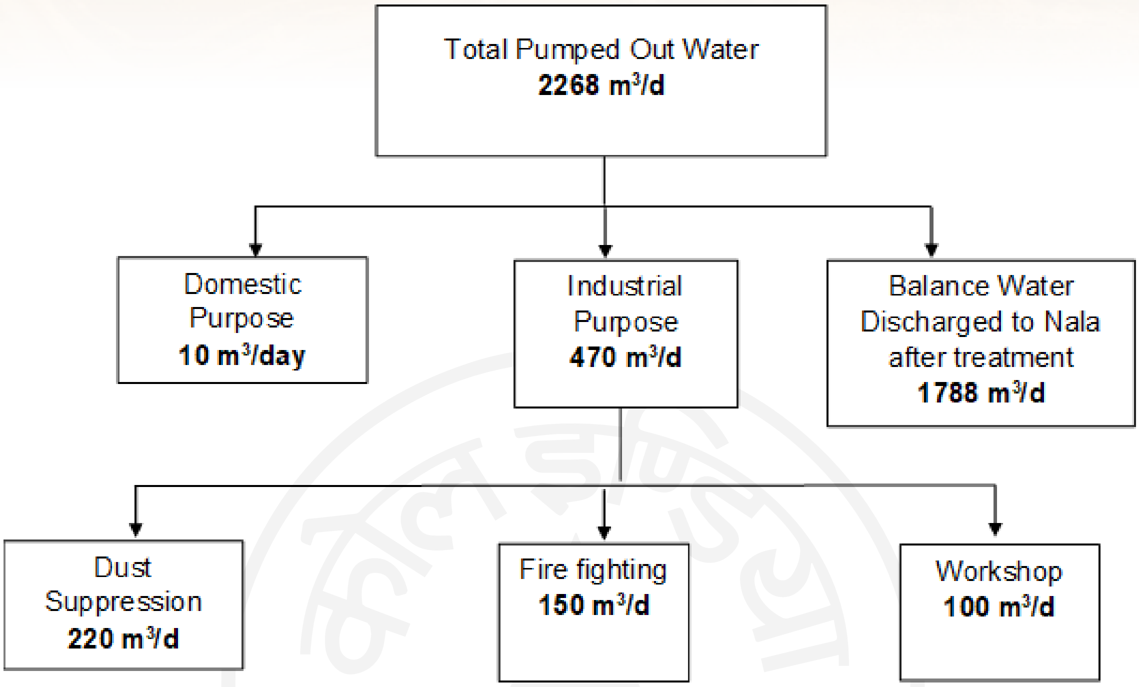


Figure 9 Hydrograph of observation well U-30

Flowchart for present mine water utilization as per requirement of the project



8.0 BASE FLOW SEPARATION:

The methods to separate base flow from the flow have been investigated by many researchers, such as Arnold et al. (1995), Aksoy et al. (2009), Wang and Cai (2010), and others. Arnold et al. (1995) developed an automated base flow separation method using a digital filter and tested it against three other automated techniques and manual separation methods. Since then the automated base flow separation method has been widely used to separate base flow from the stream flow. Aksoy et al. (2009) coupled the smoothed minima base flow separation method of the United Kingdom Institute of Hydrology (UKIH) with the recursive digital filter (RDF) to develop the filtered smoothed minima base flow separation (FUKIH) method, in which a smooth hydrograph representing the base flow generating mechanisms is obtained. Wang and Cai (2010) provided an analytical base flow recession equation to discuss the impact of human interferences, which include groundwater pumping, water diversion and return flow, on the determination of the recession slope curve. In the study, the automatic base flow separation method proposed by Arnold et al. (1995) (hereafter noted as Arnold separation method) is used to separate the base flow of the daily stream flow at Beidao hydrological station in Upper Wei River basin from 2001 to 2004. The base flow index is defined as the ratio of the baseflow to the total runoff. With the daily base flow from the Arnold separation method, the average intra-annual monthly base flow index and annual base flow index are calculated.

This program performs a separation of the base flow from the total stream flow and calculates the Base Flow Index (BFI). It is written as a Visual Basic Application within Excel and contains the sample data used. The algorithm is based on the calculation procedures introduced by the Institute of Hydrology (1980) .

8.1 METHODOLOGY USED FOR BASE FLOW CALCULATIONS

In this study a procedure as suggested in the low flow studies report (Custard ct. Al, 1992) to estimate the Base Flow Index using the mean daily discharge data is employed. The procedure is discussed in detail here.

The BFI can be thought of as measuring the proportion of the rivers runoff that derives from stored sources. A excel program is applied to smooth and to separate the recorded or observed flow hydrograph from which the index is calculated as the ratio of the flow under the separated hydrograph to the flow under the total hydrograph.

The program written in visual basic in excel sheet calculates the minimum of seven-day non-overlapping consecutive periods and subsequently searches for turning points in this sequence of minima. The turning points are then connected to obtain the base flows hydrographs, which is constrained to equal the observed hydrograph ordinate on any day when separated hydrograph exceeds the observed. The procedure for calculating the BFI is as follows:

1. Divide the mean daily flow data into non-overlapping blocks of five days and calculate the minimum for each of the blocks and they may be called as Ql,Q2,Q3,.   , Qn.
2. Consider in turn (Ql, Q2, Q3), (Q2, Q3, Q4), (Qi-1. Qi, Qi+ I) etc., In each case if 0.9 times central value is less than other values, then the central value is an ordinate for the base flow line. This procedure is continued till all the data are analyzed to provide a derived set of base flow ordinates QB1, QB2,QB3,....QBn which will have different time periods between them.
3. By linear interpolation between each Qbi value as found above, daily value of QB1 to QBn are estimated.
4. If Qbi is greater than Qi then Qbi is made equal to Qi.
5. The volume beneath the base flow line thus separated VB is calculated between the first and last points QBt to QBn.
6. The volume beneath the recorded mean daily flow Qi and Qn is calculated as VA for the period QB1 to QBn.
7. The base flow index is derived as the ratio of VB and VA.

Base flow separation can not start on the first day of the data record and similarly will not finish on the last day of the record. It is important to recognize that when the dates of the beginning and end of base flow line have been established, then these same dates must be used in calculating the total volume of flow beneath the hydrograph as well as in calculating the volume of flow beneath the baseflow line.

8.1.1 Calculation of annual BFI

There are two alternative methods for calculating the annual BFI's. The first is to compute the separation for the entire record and the estimation of BFI for each year. The second is to run the separation program yearwise and finding lhe BFI's for each year of analysis, The two approaches differ slightly and for calculating the annual BFI, the first procedure is recommended.

8.1.2 Calculation of BFI for full period:

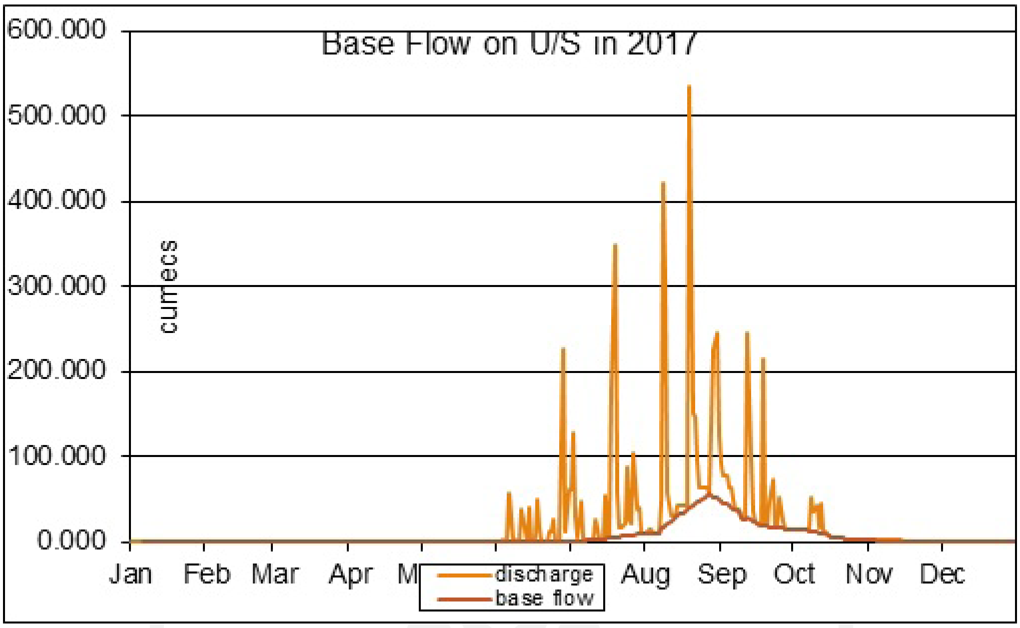
A mean value ot BFI can be calculated from a series annual BFI's as mentioned above. But the average BFI obtained thus, will be different from a single value obtained for the whole period. The recommended procedure is to calculate one value of BFI based on separation of the entire record.

Studies have shown that annual value of BFI were more stable than other low flow variables. The BFI value are sensitive to the missing data because several days of data are omitted from the base flow separation as a result of only I missing day of gauged data. Interpolation of missing data may be done only upto 5 days.

BFI values are to be used with caution if the recorded contains several gaps. Coming to sensitivity of BFl to hydrometric errors, it was stated that the percentage error in BFI was less than a given percentage of error in flow data. The error was largest for catchments with low BFI values. Gustard ct Al. (1992) mentioned that a l0% error in high mows (QS) or low flows(Q95) resulted in a 7% error in BFI for low BFI catchments(0.2) and less than 1% error in BFI for high BFI (0.9) catchments.

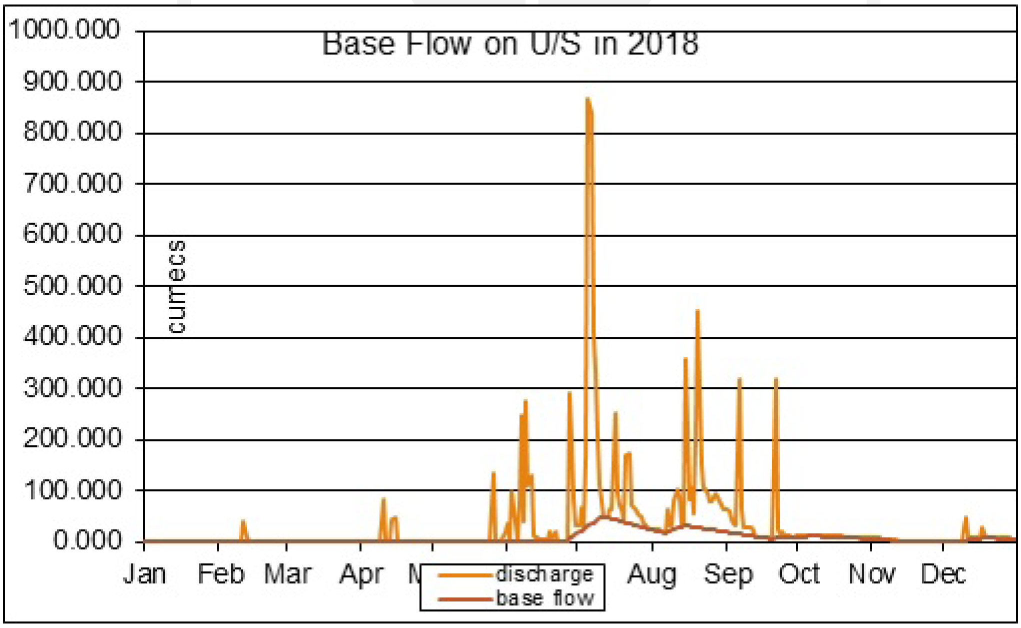
8.2 BASE FLOW ANALYSIS ON U/S:

Using the excel program, the base flow has been generated for the upstream Side (U/S) Amb river with Daily Discharge on the measuring station point for three years 2017, 2018 and 2019 . This has been shown in Fig.10, Fig.11 & Fig.12



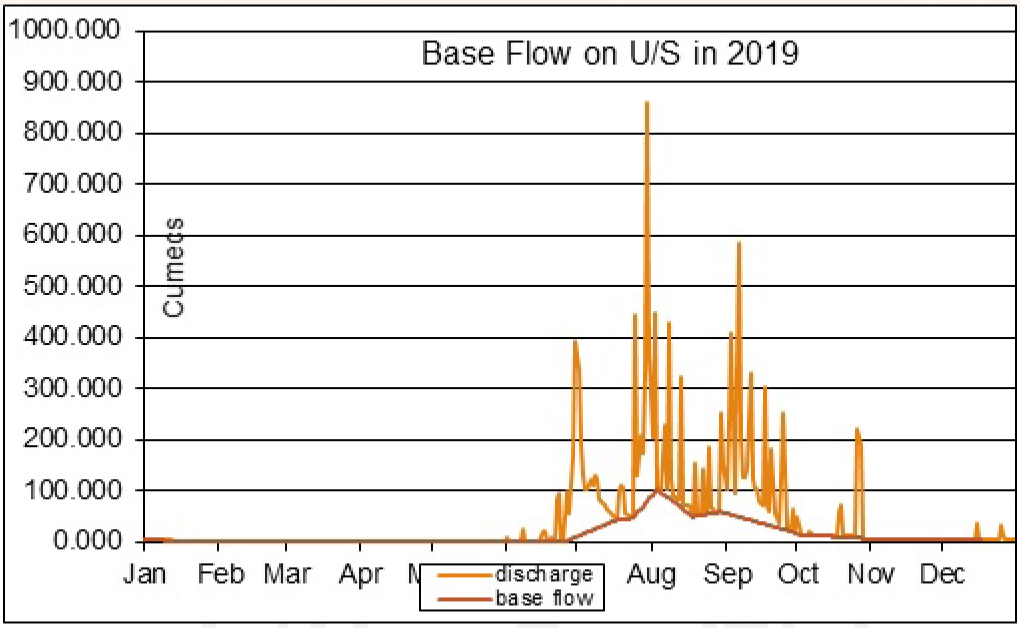
Source: water level monitoring by WCL,Umrer Area

Figure 10 Base flow on u/s of Amb river in 2017



Source: water level monitoring by WCL,Umrer Area

Figure 11 Base flow on u/s of Amb river in 2018



Source: water level monitoring by WCL,Umrer Area

Figure 12 Base flow on U/s of Amb river in 2019

Results: Whole series	
BFI	0.302
Mean of annual BFIs	0.301
Season Information	
Season start day	1
Season start month	1
Season end day	31
Season end month	12
Year shift during season	No
Series information	
Start of entire series	01-01-2017
Start of base flow line	06-01-2017
End of base flow line	17-12-2019
End of entire series	01-01-2020

The month wise discharge of U/S of the mining area located at railway bridge have been estimated and its bas flow of every month have been generated using micro programme of Excel sheets. This has been tabulated as below:-

Month wise Base Flow & Discharge at Up stream side (U/S)

Month	Base flow in cumecs	Discharge - cumecs	BF in %	Q in %
Jan-17	18.196	21.695	0.76%	0.29%
Feb-17	13.123	15.280	0.55%	0.21%
Mar-17	2.645	3.747	0.11%	0.05%
Apr-17	0.000	0.000	0.00%	0.00%
May-17	0.000	0.000	0.00%	0.00%
Jun-17	10.725	704.120	0.45%	9.49%
Jul-17	156.049	1392.203	6.56%	18.75%
Aug-17	994.833	3076.393	41.81%	41.44%
Sep-17	845.230	1708.903	35.52%	23.02%
Oct-17	253.254	406.688	10.64%	5.48%
Nov-17	48.045	53.125	2.02%	0.72%
Dec-17	37.240	41.296	1.57%	0.56%
Jan-18	21.695	21.695	0.75%	0.18%
Feb-18	19.334	67.636	0.66%	0.57%
Mar-18	8.053	10.189	0.27%	0.09%
Apr-18	3.745	187.155	0.13%	1.58%
May-18	0.000	164.790	0.00%	1.39%
Jun18	67.766	1817.674	2.30%	15.37%
Jul-18	1157.827	4674.949	39.34%	39.54%
Aug-18	781.445	2880.610	26.55%	24.36%
Sep-18	354.228	1285.917	12.04%	10.88%
Oct-18	295.844	331.272	10.05%	2.80%
Nov-18	75.402	95.327	2.56%	0.81%
Dec-18	157.756	287.022	5.36%	2.43%
Jan-19	85.908	105.419	1.61%	0.66%
Feb-19	24.184	28.048	0.45%	0.17%
Mar-19	15.462	18.339	0.29%	0.11%
Apr-19	1.212	2.204	0.02%	0.01%
may-19	0.0000	0.000	0.00%	0.00%
Jun-19	32.140	1114.580	0.60%	6.95%
Jul-19	1291.137	4909.850	24.23%	30.63%
Aug-19	2146.864	4124.298	40.30%	25.73%
Sep-19	1118.072	4394.175	20.99%	27.41%
Oct-19	346.367	920.718	6.50%	5.74%
Nov-19	170.456	172.325	3.20%	1.07%
Dec-19	96.053	241.643	1.80%	1.51%

The Annual Base flow Index have been calculated in terms of total discharge and the base flow on the U/S of the Mining area for the year 2017, 2018 & 2019, which have been tabulated as below:-

Year	Base Flow in cumecs	Discharge in cumecs	BFI
2017	2379.339	7423.449	0.321
2018	2943.097	11824.234	0.249
2019	5327.856	16031.599	0.332

To make pictorial representation for the three years 2017,2018 & 2019, the following chart has been provided in Fig.13.

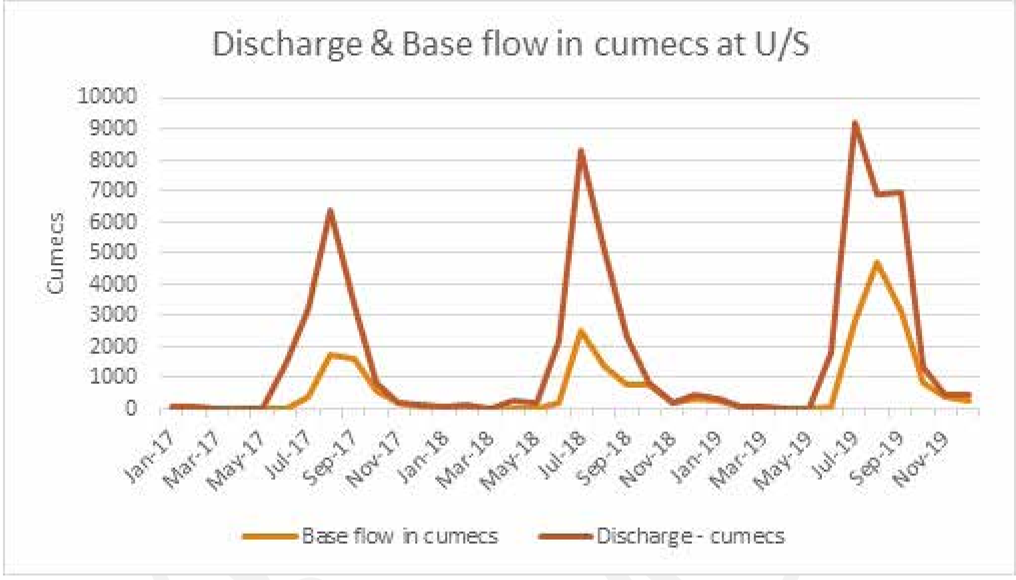


Figure 13 Discharge & Base flow in cumecs at U/S

It has been observed that the maximum discharge on the u/s of the river is between June to November of last three years. The Mean Annual Base flow Index (BFI) is 0.301. Further, It has been revealed that when over maximum rainfall occurs in these regions, the discharge and base flow is considerably increased. The maximum rainfall occurred in 2019.

8.3 BASE FLOW ANALYSIS ON D/S:

The similar pattern base flow on down stream side have been calculated using the visual basic base flow program in the excel sheets for last three years in 2017, 2018 & 2019. This has been shown in Fig.14, Fig.15 & Fig.16

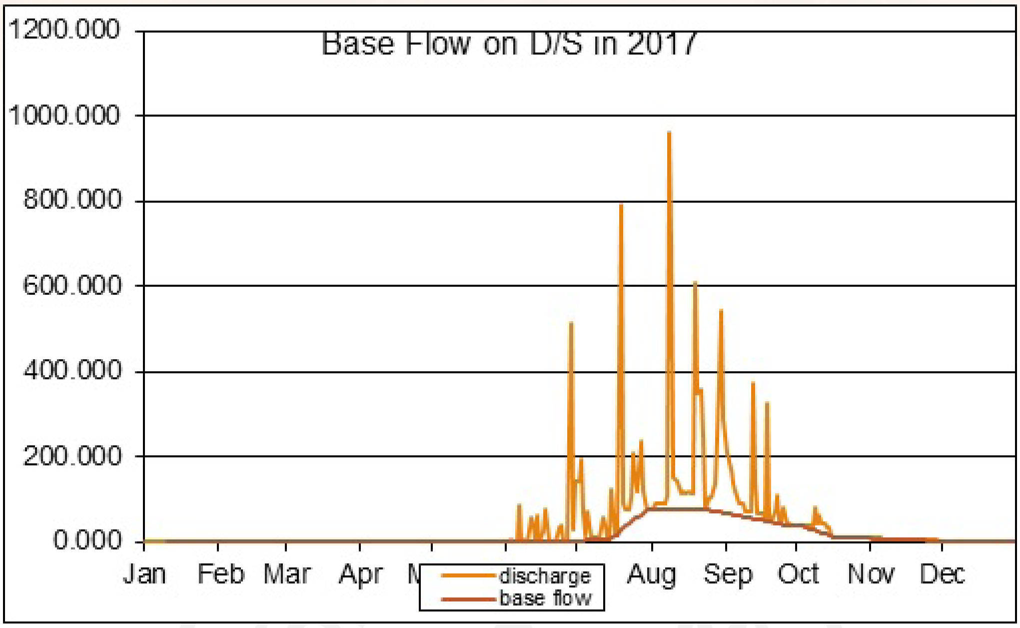


Figure 14 Base flow on d/s of Amb river in 2017

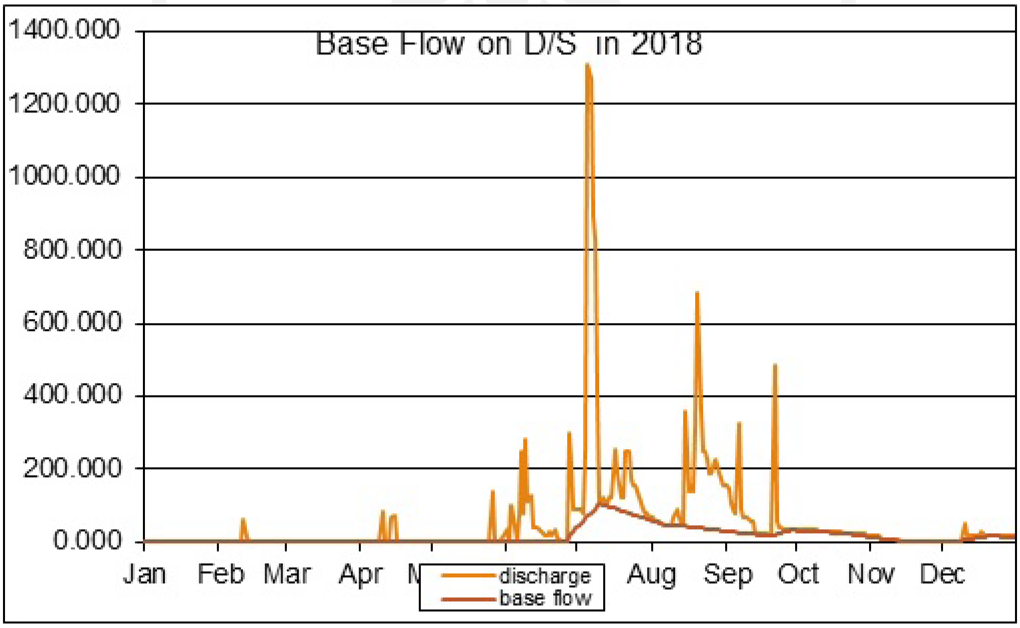


Figure 15 Base flow on d/s of Amb river in 2018

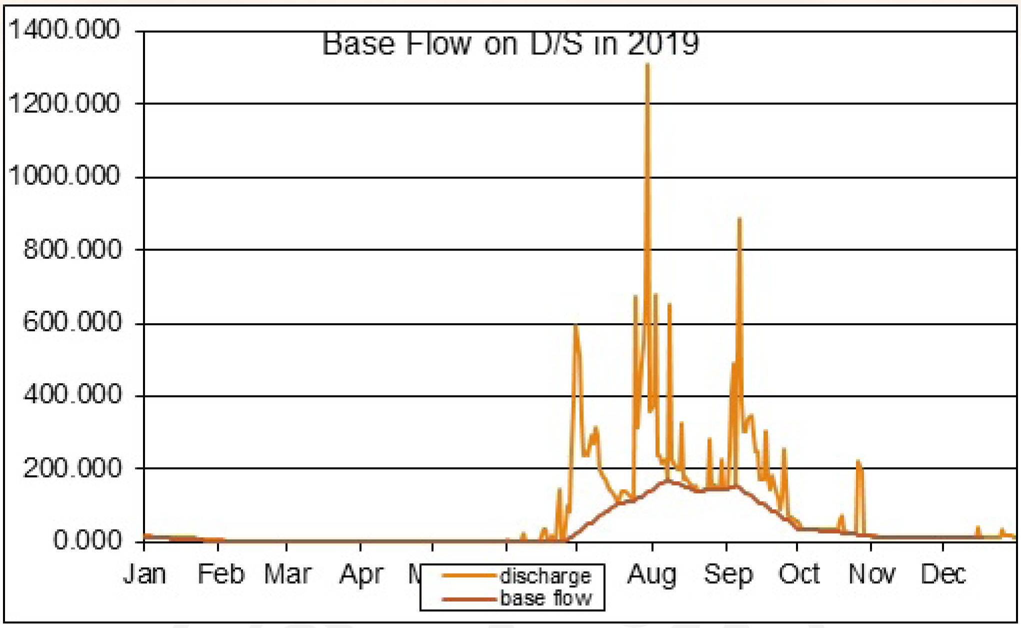


Figure 16 Base flow on d/s of Amb river in 2019

Results: Whole series

BFI	0.387
Mean of annual BFIs	0.376

Season Information

Season start day	1
Season start month	1
Season end day	31
Season end month	12
Year shift during season	No

Series information

Start of entire series	01-01-2017
Start of base flow line	10-01-2017
End of base flow line	17-12-2019
End of entire series	01-01-2020

The month wise discharge of D/S of the mining area located at railway bridge have been estimated and its bas flow of every month have been generated using micro programme of Excel sheets. This has been tabulated as below:-

The month wise Base flow has been calculated by the Visual program in Excel Sheets

Month	Base flow in cumecs	Discharge cumecs	BF in %	Q in %	% of BF of Q
Jan-17	36.946	66.656	0.64%	0.41%	55.43%
Feb-17	38.394	44.721	0.66%	0.28%	85.85%
Mar-17	11.372	13.753	0.20%	0.08%	82.69%
Apr-17	0.000	0.000	0.00%	0.00%	0.00%
May-17	0.000	0.000	0.00%	0.00%	0.00%
Jun-17	26.263	1455.185	0.45%	8.97%	1.80%
Jul-17	874.575	3484.553	15.10%	21.47%	25.10%
Aug-17	2309.732	6683.232	39,89%	41.17%	34.56%
Sep-17	1630.232	3355.997	28.15%	20.68%	48.58%
Oct-17	609.363	833.108	10.52%	5.13%	73.14%
Nov-17	163.571	193.663	2.82%	1.19%	84.46%
Dec-17	90.170	100.711	1.56%	0.62%	89.53%
Jan-18	52.060	52.060	0.84%	0.26%	100.00%
Feb-18	46.395	118.504	0.75%	0.59%	39.15%
Mar-18	19.326	24.450	0.31%	0.12%	79.04%
Apr-18	6.373	250.608	0.10%	1.25%	2.54%
May-18	0.000	166.300	0.00%	0.83%	0.00%
June-18	179.810	2168.808	2.89%	10.86%	8.29%
Jul-18	2543.294	8328.943	40.92%	41.69%	30.54%
Aug-18	1335.486	5018.822	21.49%	25.12%	26.61%
Sep-18	752.128	2323.037	12.10%	11.63%	32.38%
Oct-18	781.166	866.197	12.57%	4.34%	90.19%
Nov-18	162.202	181.817	2.61%	0.91%	89.21%
Dec-18	337.244	478.483	5.43%	2.40%	70.48%
Jan-19	256.518	313.295	2.03%	1.14%	81.88%
Feb-19	58.117	67.301	0.46%	0.24%	86.35%
Mar-19	46.884	52.060	0.37%	0.19%	90.06%
Apr-19	2.909	5.289	0.02%	0.02%	55.00%
May-19	0.000	0.000	0.00%	0.00%	0.00%
June-19	88.457	1793.235	0.70%	6.50%	4.93%
Jul-19	2832.643	9195.849	22.45%	33.34%	30.80%
Aug-19	4697.004	6886.498	37.23%	24.97%	68.21%
Sept-19	3141.867	6995.137	24.91%	25.36%	44.92%
Oct-19	851.125	1378.081	6.75%	5.00%	61.76%
Nov-19	409.340	420.693	3.24%	1.53%	97.30%
Dec-19	230.400	472.469	1.83%	1.71%	48.77%

The Annual Base flow Index have been calculated in terms of total discharge and the base flow on the D/S of the Mining area for the year 2017, 2018 & 2019, which have been tabulated as below:-

Months	Base Flow in cumecs	Discharge in cumecs	BFI
2017	5790.618	16231.578	0.357
2018	6215.484	19978.030	0.311
2019	12615.264	27579.907	0.457

To make pictorial representation for the three years 2017,2018 & 2019, the following chart has been provided in Fig.17.

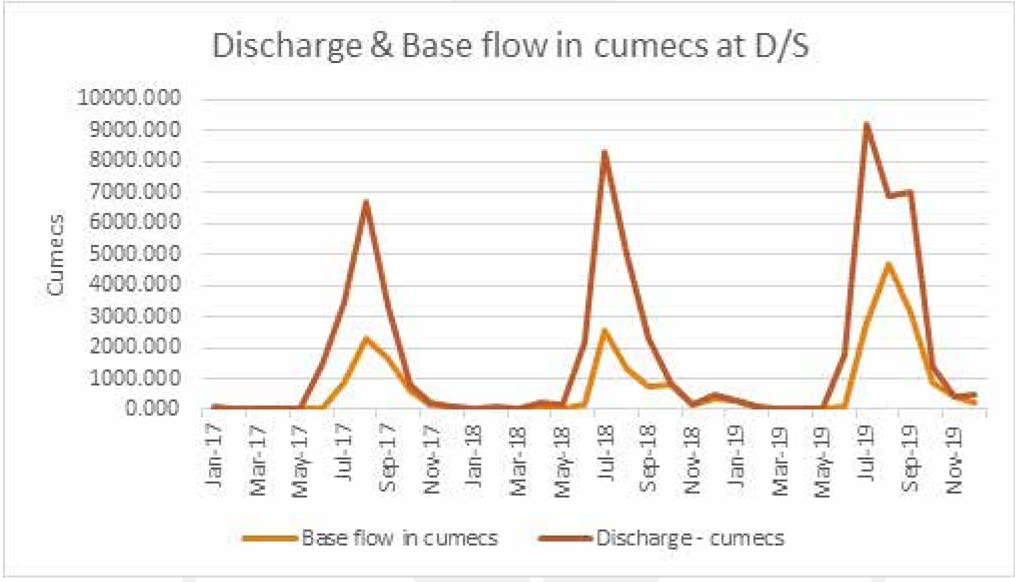


Figure 17 Discharge & Base flow in cumecs at D/S

It has been observed that the maximum discharge on the d/s of the river is between June to November of last three years i.e. 2017, 2018 & 2019. The Mean Annual Base flow Index (BFI) is 0.376. This indicates that the discharge and Base flow have been increased due to four nallahs joined to the Amb river which has substantial catchment area. In addition to that pumped out water from the three working mines adjacent to this portion of the River.

9.0 DISCUSSION & INTERPRETATION

The aim of the study is to find out the base flow of the River, for which two stations have been considered, one station has been strategically located on the upstream side (U/S) of the mining activities initiated and another one has been intentionally located in downstream side (D/S) after all working open cast mines ends so as to analyze the impact of mining activities on the base flow of River. It is pertinent to state that the main Amb river is tributary of Wainganga which is having catchment area 191.40 sq.KM comprises of low lying plain land surrounded by scattered low hills. The total length of Amb river up to proposed location is 21.2 KMs. The average slope of river upto proposed point at u/s is about 1 in 300. The top layer of soil in Amb catchment is generally medium black cotton soil but red sandy soil. Hence the U/S of Amb river is not disturbed with any mining activities. These base flow is considered as a reference base flow to find out the impact of the mining activities.

The base flow at D/S has been calculated which is strategically identified in such a location that all mining activities should be ended, subsequently the impact of base flow can be assessed. For this purpose, a comparison of discharge as well as base flow &BFI of U/s vs D/s river has been made. It has been has been revealed that in 2017, the annual Discharge at U/S is 7423.449 cumecs where as at D/S is 16231.578 cumecs, which is 119% more than U/S. The increase of discharge at D/S is due to additional four Nallah is joined in that region which has additional catchment area of 98.33 sq.km More over, there three working mines are continuously pumping out mine water and ultimately it has been put into river through sedimentation tank, which is 787.589 cumecs annually. The other details of calculation has been tabulated below:-

Year	Discharge in Cumecs		Increase in %age	Base Flow in cumecs		Increase in % age
	U/S	D/S		U/S	D/S	
2017	7423.449	16231.578	119%	2379.339	5790.618	143%
2018	11824.234	19978.030	69%	2943.097	6215.484	111%
2019	16031.599	27579.907	72%	5327.856	12615.264	137%

The month wise comparison has been shown below to analyze the base flow as well as discharge in terms of increase of %age on D/S with respect to U/S for the last three years in 2017,2018 & 2019

COMPARISION OF DISCHARGE &BASE FLOW BETWEEN U/S VS D/S						
Months	Discharge in cumecs		Increase in %age	Baseflow in cumecs		Increase in %age
	U/S	D/S		U/S	D/S	
Jan-17	21.695	66.656	207%	18.196	36.946	103%
Feb-17	15.280	44.721	193%	13.123	38.394	193%
Mar-17	3.74	13.753	267%	2.645	11.372	330%
Apr-17	0.000	0.000	0%	0.000	0.000	0%
May-17	0.000	0.000	0%	0.000	0.000	0%
Jun-17	704.120	1455.185	107%	10.725	26.263	145%
Jul-17	1392.203	3484.553	150%	156.049	874.575	460%
Aug-17	3076.393	6683.232	117%	994.833	2309.732	132%
Sept-17	1708.903	3355.997	96%	845.230	1630.232	93%
Oct-17	406.688	833.108	105%	253.254	609.363	141%
Nov-17	53.125	193.663	265%	48.045	163.571	240%
Dec-17	41.296	100.711	144%	37.240	90.170	142%
Jan-18	21.695	52.060	140%	21.695	52.060	140%
Feb-18	67.636	118.504	75%	19.334	46.395	140%
Mar-18	10.189	24.450	140%	8.053	19.326	140%
Apr-18	187.155	250.608	34%	3.747	6.373	70%
May-18	164.790	166.300	1%	0.000	0.000	0%

Months	Discharge in cumecs		Increase in %age	Baseflow in cumecs		Increase in %age
	U/S	D/S		U/S	D/S	
Jun-18	1817.674	2168.808	19%	67.766	179.810	165%
Jul-18	4674.949	8328.943	78%	1157.827	2543.294	120%
Aug-18	2880.610	5018.822	74%	781.445	1335.486	71%
Sept-18	1285.917	2323.037	81%	354.228	752.128	112%
Oct-18	331.272	866.197	161%	295.844	781.166	164%
Nov-18	95.327	181.817	91%	75.402	162.202	115%
Dec-18	287.022	478.483	67%	157.756	337.244	114%
Jan-19	105.419	313.295	197%	85.908	256.518	199%
Feb-19	28.048	67.301	140%	24.184	58.117	140%
Mar-19	18.339	52.060	184%	15.462	46.884	203%
Apr-19	2.204	5.289	140%	1.212	2.909	140%
May-19	0.000	0.000	0%	0.000	0.000	0%
Jun-19	1114.580	1793.235	61%	32.140	88.457	175%
Jul-19	4909.850	9195.849	97%	1291.137	2832.643	119%
Aug-19	4124.298	6886.498	67%	2146.864	4697.004	119%
Sept-19	4394.175	6995.137	59%	1118.072	3141.867	181%
Oct-19	920.718	1378.081	50%	346.367	851.125	146%
Nov-19	172.325	420.693	144%	170.456	409.340	140%
Dec-19	241.643	472.469	96%	96.053	230.400	140%

The base flow index(BFI) has been arrived for last three years namely 2017, 2018 and 2019. BFI of U/S & D/S is 0.321 to 0.357, 0.249 to 0.311, 0.332 to 0.457 for the year 2017, 2018 & 2019 respectively. It has been tabulated below:

Year	BFI	
	U/S	D/S
2017	0.321	0.357
2018	0.249	0.311
2019	0.332	0.457

The Comparison has been made to show Discharge of Amb River on the U/S & D/S for the last three years i.e. 2017,2018 & 2019 which has been shown in Fig 18:

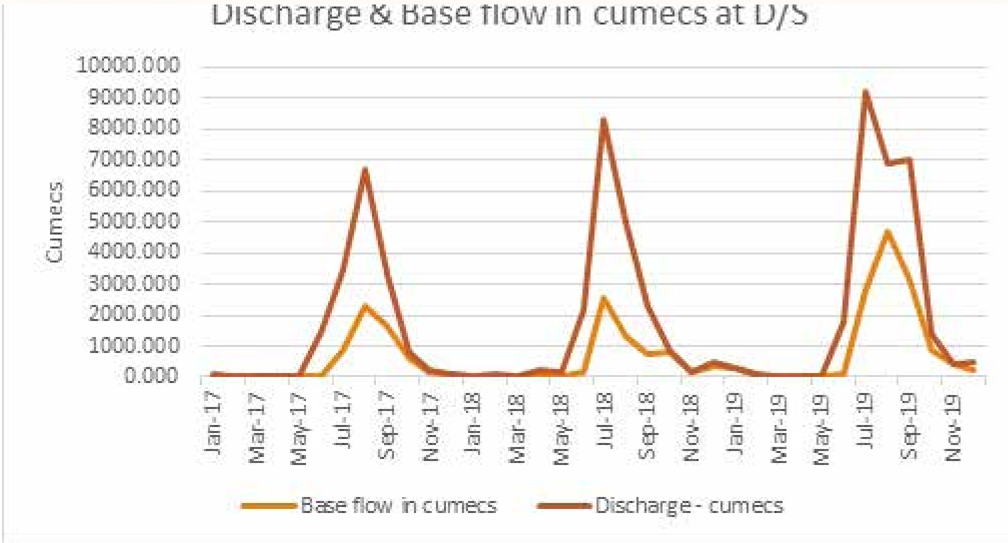


Figure 18 Comparison between discharge of Amb river on the U/S and D/S

The Comparison has been made to show Base flow of Amb River on the U/S & D/S for the last three years i.e. 2017,2018 & 2019 which has been shown in Fig.19:

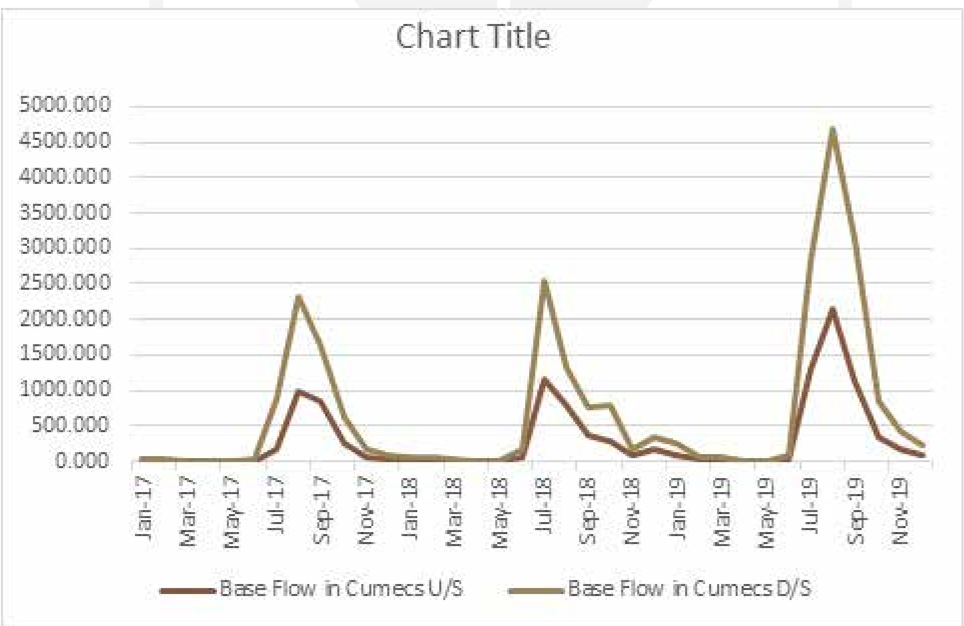


Figure 19 Comparison between Base flow of Amb River on the U/S & D/S

The graphs clearly indicates that substantial amount of discharge has been increased annually for the year 2017, 2018 & 2019. This has been shown in Fig. 20

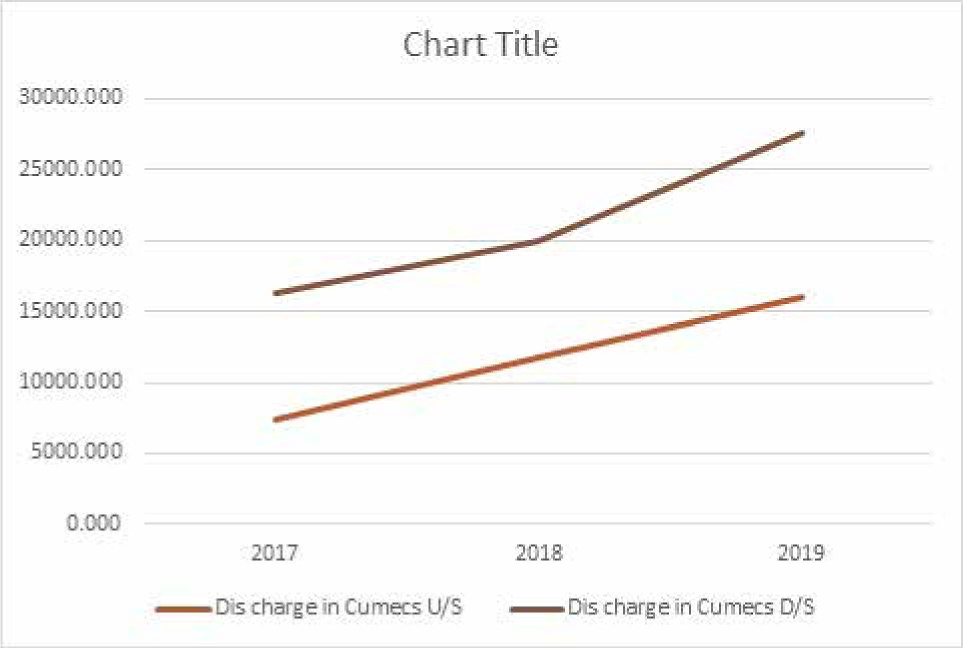


Figure 20 Annual discharge comparison on U/S and D/S of Amb river

The graphs clearly indicates that substantial amount of discharge has been increased annually for the year 2017, 2018 & 2019. This has been shown in Fig. 21

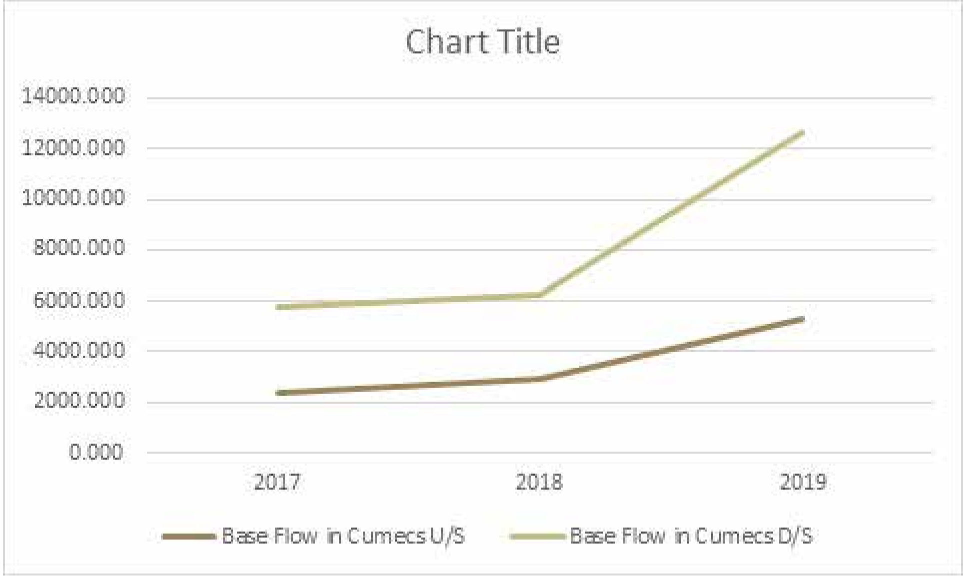


Figure 21 Annual base flow comparison on U/S and D/S of Amb river

At present, the following three working mines are discharging mine water to the Amb river which is given below:-

Mines	Cumecs/Year
MKD-1	229.95
Umrer OC	268.681
MKD-III	288.958
Total	787.589

Even the Mine water is excluded, the base flow on the D/S is not affected as tabulated below:-

Year	Base Flow in		Increase in %age
	U/S	D/S	
2017	2379.339	5003.029	110%
2018	2943.097	5427.895	84%
2019	5327.856	11827.676	122%

From the above Figures & tables shown different months of last three years 2017,2018 & 2019 on the U/S and D/S in terms of Base Flow, the Base flow has been increased substantially even after excluding pumping quantity of Mine water. Amb River on the D/S has been increased due to additional mine water added on the river. Therefore, it has been proved that there will be no impact on the base flow of river due to mining activities.

10. CONCLUSION:-

From the analysis and interpretation, it has been observed that the base flow on the upstream side (U/S) of the MKD-I mines is not having any impact of mining activities. More over, all working mines i.e Umrer Open cast Mine, Makherdhokara –I Open cast Mines & Makherdhokara–III Open cast Mines are under regime of D/S of the Amb River. From the Base flow analysis, it has been clearly revealed that Base flow from U/s to D/S is 2379.339 cumecs to 5003.029 cumecs, 2943.097 cumecs to 5427.895 cumecs, 5327.856 cumecs to 11827.676 cumecs in the year 2017,2018 & 2019 respectively after excluding the mine water discharge in that river stream. The average % of increase in Base flow from U/S to D/S is 105.33%. The Base flow Index (BFI) at D/S of the Amb river for the year 2017, 2018 & 2019 is 0.357,0.311 & 0.457 respectively.

It has been concluded that D/S of the mining Area has good base flow contribution. There is no impact on the base flow of the Amb river due to mining activity which may be a reason for very less area of mining activities involved in comparison to the total catchment area of the river, distance between the mining boundary & river edge including its sub-soil condition surrounded on this region of Amb river. However, the study may be revalidated at every five years as the mining activity expanded in larger area.

11. Limitations:-

The study has been carried on available data for only three years however for more accurate study 7 to 10 years data is required for the impact on baseflow of Amb river due to mining activities. A permanent gauge station needs to be established to daily/periodical recording of flow of Amb river.

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1. Area General Manager, WCL, Umrer Area, Umrer
2. Sub-Area Manager, WCL, MKD-I, Umrer Area

3. Sub-Area Manager, WCL, MKD-III, Umrer Area
4. Sub-Area Manager, WCL, Umrer opencast Mines
5. Civil Department, WCL, Umrer Area , Umrer.

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Use of Metallophytes for remediation of metal-enriched soils

Prof. Dinesh Mani[1]

Abstract

Metallophyte have potential for use for phytoremediation for contaminated soils. Metallophytes commonly exist as specialized flora around on spoil heaps of mines. A metallophyte is a plant that can tolerate high levels of heavy metals such as Cadmium, chromium and lead. Such plants range between "obligate metallophytes" (which can only survive in the presence of these metals), and "facultative metallophytes" (which can tolerate such conditions but are not confined to them). Metal-tolerant plants avoid intoxication by an excess of heavy metal levels do not exceed the levels of metal tolerance. They can thus thrive on soils that are too toxic for non-adapted species and ecotypes. These unique plants with an ability to tolerate metal toxicities and survive and reproduce on metalliferous soils are called metallophytes.

Plants have two main strategies for growing metalliferous soil: (i)prevent metal from aerial part but contain high amount of metals in their root, or (ii)accumulate metals in their aboveground parts. Effective phytoaccumulation is dependent on two essential factors (1) having the capabilityof taking up and accumulating high levels of metals and (2) having the ability of producing as much biomass as possible. For adequate phytoextraction, the essential need is a phytoaccumulators that is fast growing and produces a large amount of biomass.

Metallophyte have potential for use for phytoremediation for contaminated soils. Metallophytes commonly exist as specialized flora around on spoil heaps of mines. A metallophyte is a plant that can tolerate high levels of heavy metals such as Cadmium, chromium and lead. Such plants range between "obligate metallophytes" (which can only survive in the presence of these metals), and "facultative metallophytes"(which can tolerate such conditions but are not confined to them.

Metal-tolerant plants avoid intoxication by an excess of heavy metal levels do not exceed the levels of metal tolerance. They can thus thrive on soils that are too toxic for non-adapted species and ecotypes. These unique plants with an ability to tolerate metal toxicities and survive and reproduce on metalliferous soils are called metallophytes.

Mining and milling of metal ores coupled with industries have bequeathed many countries the legacy of wide distribution of metal contaminants in soil. During mining tailings (heavier and larger particles settled at the bottom of the flotation cell during mining) are directly discharged into natural depressions including onsite wetlands resulting in elevated concentrations (P. S. DeVolder, S. L. Brown, D. Hesterberg, and K. Pandya, et al. 2003).Extensive Pb and zinc Zn ore mining and smelting have resulted in contamination of soil that poses risk to human and ecological health. Many reclamation methods used for these sites are lengthy and expensive and may not restore soil productivity. Soil heavy metal environmental risk to humans is related to bioavailability. Assimilation pathways include the ingestion of plant material grown in (food chain), or the direct ingestion (oral bioavailability) of contaminated soil. (Basta,N. T. and Gradwohl, R., 1998).

While several previous studies have documented variations in mineral ores and solid mine waste types as well as their composition over space (Manu

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et al., 2013; Tetteh and Effisah-Otoo, 2017) only few studies have focused on the characterization of wastes in order to give a generalized idea on the geochemical composition of mine wastes, their potential to enrich the environment with toxic elements and their potential ecological risks. Such information will help inform managers on their choice of waste dump location and other waste management measures (Aznar sanchez et al. 2018). In this study heavy metal enrichment and the potential ecological risks of different solid mine wastes (sulphide rich waste oxiderich waste and tailings) were determined to aid in chemical characterization of these mine wastes.

Mine wastes are multi-elemental in nature, containing elements such as sulphides, Fe, Mn oxides carbonates, silicates and heavy metals (Blight, 2011), with different chemical, biological and ecotoxicological characteristics (Santos et al., 2017).

The treatment and disposal of metal-accumulating plants is one of the most important concerns of phytoremediation. To avoid any dangers, metal-accumulating plants must be properly managed and disposed of. Because metal-accumulating plants are considered hazardous waste, they must be harvested and disposed of or recycled in accordance with applicable rules. The metal concentrations in the plants will indicate whether they should be landfilled or subjected to metal reclamation via biomass pyrolysis, smelting, or extraction. The expense of remediation may be mitigated by the value of reclaimed metals from plant biomass. The burned plant's ash must be disposed of in hazardous waste landfills, while radioactively polluted facilities must be treated as radioactive waste.

The idea of using metal accumulating plants to remove heavy metals and other compounds was first introduced in 1983 but the concept has actually been implemented for the past 300 years on wastewater discharges(R. J. Henry, 2000). Plants may break down or degrade organic pollutants or remove and stabilize metal contaminants. The methods used to phytore mediate metal contaminants are slightly different from those used to remediate sites polluted with organic contaminants. As it is a relatively new technology, phytoremediation is still mostly in its testing stages and as such has not been used in many places as a full scale application. However it has been tested successfully in many places around the world for many different contaminants. Phytoremediation is energy efficient aesthetically pleasing method of remediating sites with low to moderate levels of contamination, and it can be used in conjunction with other more traditional remedial methods as a finishing step to the remedial process.

In the last years, one of the major areas of research in phytoremediation is improvement of pollutant uptake by plants, in the case of heavy metals limited by their bioavailability. Synthetic chelators such as EDTA (ehthylene-diamine-tetraacetic acid) or NTA (nitriloacetate) are questionable and never used on large scale. They are expensive; moreover, some environmentalists treat them as additional man-made pollutants which create risk of leaching heavy metals to the groundwater during heavy rain just after application. The process of heavy metals chelation intensifies metal uptake in nature. Hence, plants use low molecular weight organic acids such as citric, ferulic, maleic, oxalic and tartaric acids; utilization of this phenomenon is always attractive for implementation. This can be recommended as a simple tool available in our hands. Lowering the pH of soil, which would increase metal solubility, can be obtained by application of strong acid fertilizers such as sulphuric salts or even elemental sulphur. Elemental sulphur, being slowly oxidized by bacteria, increases acidity as well.

The availability and uptake of heavy metals into the plant depends not only on direct uptake but also on rhizosphere. Plants' life is tightly associated with microorganisms surrounding the plants' roots. In this respect mycorrhizal fungi appear to play a central modulating role. Among them arbuscular mycorrhizal (AM) fungi intensify few crucial processes such as water and nutrients uptake in the plants but simultaneously heavy metals are taken up more efficiently as well, mycorrhizal fungi alleviate heavy metal stress on plants by detoxification via greater metallothioneins synthesis and consequently hold HMs in their tissue thus performing the role of a buffer between soil environment and plants. Mycorrhizal fungi express metallothioneins genes, but further steps, i.e., heavy metal transport to and accumulation in roots and upper parts of the plants are controversial. This is because both lowering and increasing of the level of metal pollutants in the plant tissue were recorded. Nevertheless, plants inoculation with mycorrhiza, even if it does not support phytoextraction, would allow plants to grow on polluted sites at concentration(s) that otherwise would be eliminated (of not mycorrhized). Moreover, it can be considered as an example of phytostimulation. The above shows that the ability of plants to heavy metal uptake, translocation and accumulation in particular organs depends on environmental factors. However, some of the species, families or even orders have capability higher than others for heavy metal tolerance and uptake.

As early as the 19th century, Baumann, identified plants capable of accumulating uncommonly high Zn levels. In 1935, Byers documented the accumulation of selenium in Astragalus spp. One decade later, Minguzzi and Vergnano identified plants capable of hyperaccumulating up to 1% Ni in shoots. Following the identification of these and other hyper-accumulators species, a great deal of research has been conducted to elucidate the physiology and biochemistry of metal hyper-accumulation in plants. Significant results have been obtained, and the understanding of metal accumulating mechanisms substantially advanced. However, a better understanding of the biological processes is needed if phytoextraction is to become a reliable, commercially available technology.

Plants have two main strategies for growing metalliferous soil: (i) prevent metal from aerial part but contain high amount of metals in their root, or (ii) accumulate metals in their aboveground parts. Effective phytoaccumulation is dependent on two essential factors (1) having the capability of taking up and accumulating high levels of metals and (2) having the ability of producing as much biomass as possible. For adequate phytoextraction, the essential need is a phytoaccumulators that is fast growing and produces a large amount of biomass

For most metals, uptake into roots takes place from aqueous phase. Strong binding to soil particles and/or precipitation renders a significant soil metal fraction insoluble, and largely unavailable for plant uptake. Low soil bioavailability is a major factor limiting the potential for phytoextraction of significant metal contaminants such as lead. A major objective of current phytoremediation research is to induce lead desorption from soil matrix into solution, and increase propensity for uptake into roots.

Phytostabilization, phytoextraction, and phytovolatilization are the three primary methods of phytoremediation for heavy metal removal. Phytostabilization prevents heavy metals from entering the food chain; phytoextraction adsorbs heavy metals from the soil and stores them in plant tissues; and phytovolatilization volatilizes heavy metals from the soil and releases them in a less toxic or non-hazardous form into the atmosphere. Several factors, including plant species, medium qualities, metal bioavailability, and the inclusion of a chelating agent, can influence these pathways. (Desai et al. 2019).

A plant used for phytoremediation needs to be heavy-metal tolerant, grow rapidly with a high biomass yield per hectare, have high metal accumulating ability in the foliar parts have a profuse root system and a high bioaccumulation factor. Phytoextraction is no doubt a publicly appealing (green) remediation technology. Two approaches have been proposed for phytoextraction of heavy metals namely continuous or natural phytoextraction and chemically enhanced phytoextraction. Continuous or Natural Phytoextraction. Continuous phytoextraction is based on the use of natural hyperaccumulator plants with exceptional metal accumulating capacity. Hyperaccumulators are species capable of accumulating metals at levels 100-fold greater than those typically measured in shoots of the common nonaccumulator plants. Thus a hyperaccumulator plant will concentrate more than 10 mg kg-1 Hg, 100 mg kg-1 Cd, 1000 mg kg-1 Co, Cr, Cu and Pb. 10000 mg kg-1 Zn and Ni. Hyperaccumulator plant species are used on metalliferous sites due to their tolerance of relatively high levels of pollution. Approximately 400 plant species from at least 45 plant families have been so far, reported to hyperaccumulate metal. Some of the families are Brassicaceae, Fabaceae, Euphorbiaceae Asterraceae, Lamiaceae, and Scrophulariaceae. Crops like Willow (Salix viminalis L.), Indian mustard (Brassica juncea L.) corn (Zea mays L.), and sunflower (Helianthus annuus L.) have reportedly shown high uptake and tolerance to heavy metals. A number of processes are involved during phytoextraction of metals from soil: (i) a metal fraction issorbed at root surface, (ii) bioavailable metal moves across cellular membrane into root cells, (iii) a fraction of the metal absorbed into roots is immobilized in the vacuole, (iv) intracellular mobile metal crosses cellular membranes into root vascular tissue (xylem), and (v) metal is translocated from the root to aerial tissues (stems and leaves). Once inside the plant, most metals are too insoluble to move freely in the vascular system so they usually form carbonate sulphate or phosphate precipitate immobilizing them in apoplastic (extracellular) and symplastic (intracellular) compartments. Hyperaccumulators have several beneficial characteristics but may tend to be slow growing and produce low biomass, and years or decades are needed to clean up contaminated sites. To overcome these shortfalls, chemically enhanced phytoextraction has been developed. The approach makes use of high biomass crops that are induced to take up large amounts of metals when their mobility in soil is enhanced by chemical treatment with chelating organic acids

Certain species of higher plants can accumulate very high concentration of metals in their tissues without showing toxicity. Such plants can be used successfully to clean up heavy metal polluted soils.

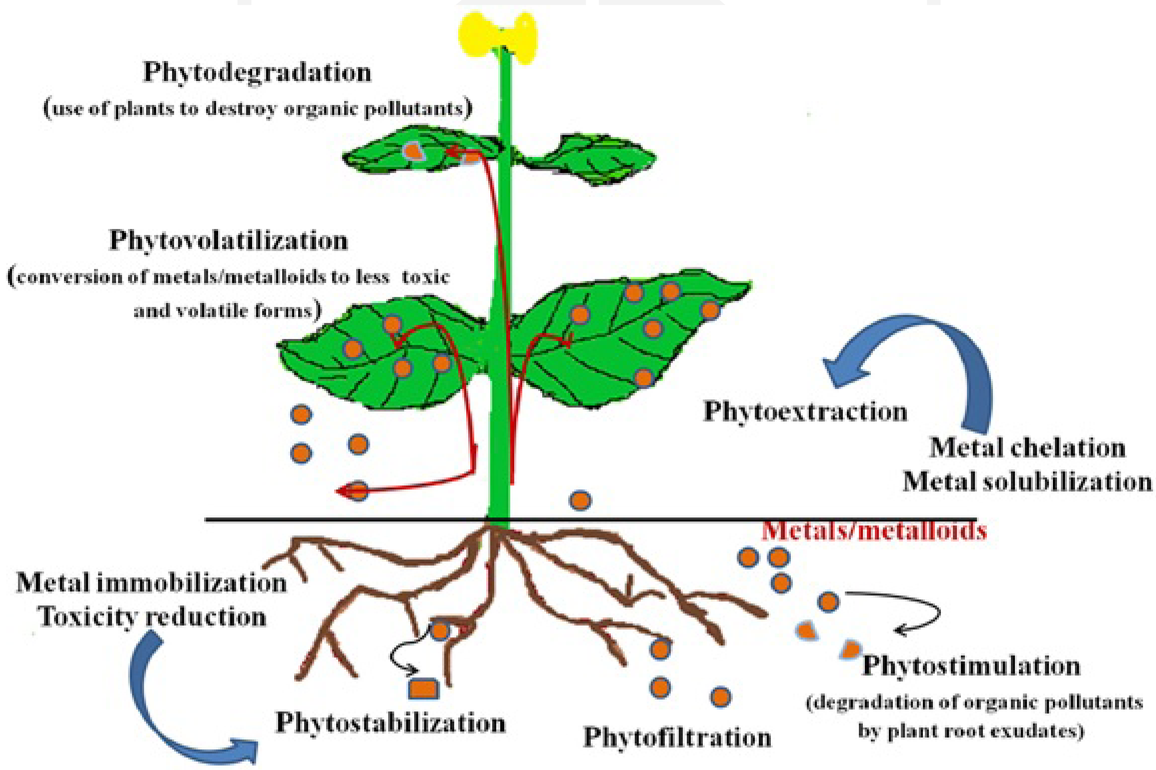

Figure : Representation illustration of phytotechnology mechanisms

Table : Phytotechnology mechanisms

Mechanisms	Discription; Ability of plants	Clean-up goals; Contaminants treated
Phytodegration	to take up and break down contaminants within plant tissues via internal enzymatic activity	Remediation by destruction; Organic compounds
Phytovolatilization	to take up, translocate, and then volatilize contaminants in the transpiration stream	Remediation by removal through plants; Organic molecules, Hg, Se, and As
Phytoextraction or Phytosequestration	to take up contaminants into the plant and sequester contaminant within the plant tissue	Remediation by removal of plants containing the metals; Heavy metals (e.g., Pb, Cd, Ni, Co, Cr, Zn) and radionuclides
Phytostimulation and/or Rhizodegradation	to release phytochemicals to enhance microbial biodegradation of contaminants in rhizosphere	Remediation by destruction; Organic compounds, Chlorinated solvents, Herbicides, Phenols
Phytostabilization	to immobilize contaminants in soil through absorption and accumulation by roots, adsorption onto roots or precipitation within root-zone	Containment. Remediation by reducing bioavailability of contaminants; Heavy metals and radionuclides

For having a feasible cleanup method, the plants must (1) extract large concentrations of heavy metals into their roots, (2) translocate the heavy metal into the surface biomass, and (3) produce a large quantity of plant biomass. In addition, remediative plants must have mechanism(s) to detoxify and/or tolerate high metal concentrations accumulated in their shoots. In the natural setting, certain plants that have the potential of uptaking heavy metal have been identified. Indian mustard is a high biomass, rapidly growing plant that has an ability to accumulate Ni and Cd in its shoots. It is a promising plant for phytoremediation.

Plants that can tolerate and accumulate excessive levels of metals are defined as hyperaccumulators. It has been identified that approximately 400 terrestrial species are hyperaccumulators. The Brassiceceae family is the most common known heavy metal accumulator. Indian mustard has an ability to grow in heavily contaminated soil and accumulate metals in its aboveground parts.

The identification of metal hyperaccumulator species demonstrates that plants possess the genetic potential to remove toxic metal for contaminated soil. Understanding the plant-based remedial mechanisms is important for several reasons. For example, the elucidation of these mechanisms may provide clues for optimizing the effectiveness of phytoremediation with appropriate agronomic practices. In addition, the identification and biochemical characterization of the remedial mechanisms are necessary preliminary steps to isolating plant genes responsible for the expression of the remediating phenotype. The identification and isolation of these genes many open the opportunity to use biotechnology to ameliorate plants for environmental cleanup.

In general, plants express an incomplete set of remediating features. For example, most of the metal hyperaccumulators are small and slow growing. Conventional breeding and biotechnology have been used to correct these shortcomings by transferring desired traits from metal hyperaccumulators plants to several high-biomass-producing nonaccumulator species.

The use of plants in remediation, which is usually named Phytoremediation is a cost-effective means to reduce the risk from exposure to hazardous constituents at waste and spill sites. The use of metal-accumulating plants to clean up soil and water contaminated with toxic metals is expanding rapidly in several countries. Certain chelating agents facilitate metal uptake by soil grown plants. The techniques of phytoremediation is being developed as a potential remediation in many of the contaminated sites in the US and other countries. This method, though not widely utilized, may be effectively used in industry to treat contaminants at a substantially lower operating cost than more traditional remediation techniques. However, operators must have good knowledge to apply phytoremediation successfully.

The success of phytoextraction, as an environmental clean-up technology, depends on several factors including the extent of soil contamination, metal availability for uptake into roots(bioavailability), and plant ability to intercept, absorb, and accumulate metals in shoot. Ultimately, the potential for phytoextraction depends on the interaction between soil, metal and plants. The complexity of this interaction, controlled by climatic conditions, argues about generic and in favor of a site specific phytoremediating approach. This underlines the importance of mechanisms and processes that govern metal uptake and accumulation in plants.

Thus, metallophytes may offer a viable solution of the problem of contamination and has drawn great attractions of environmental scientists. It is based on the fact that a living plant can be considered as a solar- driven pump, which can extract and concentrate toxic elements from contaminated soil. For phytoremediation of metal-contaminated soils, it is essential to understand the interaction between metal-tolerant plant species and soil chemical properties controlling the bioavailability of metals.

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REFORM, PERFORM AND TRANSFORM

Tadimalla H Mohan Rao[1]

Abstract:

RPT-Reform, Perform & Transform-these super vibrant words often given to the nation by the Hon'ble Prime Minister to define good governance, provide the necessary dynamics wherein the government introduces reforms, the bureaucracy performs in line with the reforms, leading to realization of the desired transformation in the intended field. Whether it is policy implementation, realization of stability, attainment of coordination, accomplishment of ease of doing business, or development of the economy by meeting the rising energy needs of the nation, the RPT approach holds good for all sectors and at all times. In view of its inherent strength, the model has proved significantly effective in delivering the goods and perfectly scripted the nation's growth story on several parameters.

India, besides emerging as the fastest growing economy among the G20 nations, has attracted a record FDI inflow of USD 83.57 bn during 21-22 (Source: The Economic Times/Business news dt. 21.05.2022), and USD 81.72 bn during 20-21, a 10% jump over that of the previous fiscal figure of USD 74.39 bn (Source: Press Release dt. 24.05.2021 issued by the Ministry of Commerce & Industry). According to Kearney, the leading global management consulting firm operating in more than 40 countries, India holds the 2nd position in the Global Retail Index after China. Further, according to World Energy & Climate Statistics Year Book 2021, India has also emerged as the 3rd primary energy consumer after China and the USA. As is known, a direct relationship exists between economic development and the per capita energy consumption of a country.

The basis to propel the economy of any nation lies in the continuous augmentation of the existing level of performance of the nation's industries/organizations/establishments, etc., besides the cost-effective rejuvenation of its ailing industries wherever possible, and commencement of further new industries in key sectors. This approach holds an unparalleled relevance for the coal sector as well, which is the backbone of the nation's energy security.

The distinction of India being the 3rd primary energy consumer globally, though a great positive indicator of a fast-developing economy, has simultaneously placed a heavy responsibility on the country, particularly CIL, in meeting the ever-rising energy requirements of the country in a qualitative and cost-effective way. With 622.6 mt of coal production out of the all-India figure of 777.26 mt, CIL contributed more than 80% of the country's coal output during 21-22.

In order to meet the rising energy demand, the country is required to generate quality power, which is directly dependent on the consumption of quality coal by the power sector, which in turn is dependent on the supply of quality coal by the coal sector. Therefore, the purpose of meeting the rising power demand may not be really served by merely producing more and more quantity of coal, unless due attention is simultaneously not paid to sustain the natural quality of coal so produced.

As per NITI Aayog's 2017 study, the peak production of coal in India is likely to be reached in another one and half decades, ie., in 2037, beyond

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which India would become strongly dependent on coal imports to meet its requirements. Thus, strategic and efficient utilization of the remaining coal reserves is essential, if the country's future energy security is to be ensured. And this onerous task unequivocally calls for qualitative mining....

The prevailing general insensitivity to coal quality issues amongst the rank and file of CIL and its coal-producing subsidiaries in particular, is causing a hindrance to the sustainability of the natural quality of coal. Removal of this hindrance primarily requires an attitudinal change. Needless to say, CIL and its coal-producing subsidiaries are well equipped to enforce this change. However, what's sadly lacking is the willingness to unequivocally adopt and absorb the QUALITY CULTURE as the fundamental policy, and the willingness to put Quality before Quantity and produce Quantity WITH Quality.

A target of 700 Million Tons each against the production and offtake parameters for CIL for the current fiscal 22-23 in line with the nation's ambitious goal of achieving 1 Billion Tons of coal production by 23-24, has been firmed up by the Government. This huge demand for coal further enhances the Govt's expectations from CIL to rise above the ordinary and produce and deliver the required Quantity WITH Quality. As such when the Govt says more 'coal', it by default means 'quality coal', but IN NO WAY, 'just anything that is mined in the name of coal'! It must therefore be always kept in mind that the call for more Quantity is never a call for compromising on Quality. After all, coal without energy cannot produce energy!

Thus, the issue at hand is too big to be ignored as it involves not only the realization of the grand objective of Mission 0&0 (Zero Grade Slippage & Zero Consumer Complaints), but also the conservation of the nation's scarce natural resource, besides protecting the globe from the harmful emissions. And India is a signatory to the Paris Climate Treaty signed 6 years ago. Absorption of the Quality Culture with passion and the subsequent resolute demonstration of the same through the three-pronged RPT approach offers the right solution to deliver the goods.

The ensuing paper is an attempt to identify and put in place the much-needed Institutional Reforms in the Coal Quality segment. As a sequel to above, it's anticipated that the officials concerned of CIL and its coal-producing subsidiaries would study the reforms proposed, make necessary amendments wherever required, resolutely Perform on the amended reforms, and make all-out efforts to decisively Transform the current scenario for the better, from the perspective of meeting the rising energy demands of the nation in a qualitative and cost-effective way. As the slightly modified old adage goes, where there is a will there is a way forward, always.....

"Let's Put Quality Before Quantity And Produce Quantity WITH Quality"

Introduction:

International Energy Agency projections show that coal will provide more than half of the 'on-grid' electricity needed to deliver energy for all. High Efficiency Low Emission (HELE) technologies, such as advanced coal-fired power generation, and Carbon Capture and Sequestration, also called Carbon Capture and Storage (both abbreviated as CCS) or Carbon Capture, Use and Storage (CCUS), can enable the world's coal resources to be used in line with the global environmental and climate objectives (Source: World Coal Association). The IEA predicts that coal will generate more electricity in 2040 than all new renewable technologies (excluding hydro) combined. Besides providing gainful employment and economic sustenance to millions world-wide, coal provides electricity to billions of people across the globe. Its abundance, low price, and availability make it the preferred fuel. The IEA World Energy Outlook published in late 2016 forecasts that 730 gigawatts (GW) of new, HELE coal plants will be built by 2040, more of these in developing countries.

In recent years, efforts and budgets have focused on the advancement of Clean Coal Technologies (CCT). Such initiatives have managed to cut the harmful environmental and health impacts of the power industry in the country, to certain extent. Coal is traditionally the most important source of energy in India, and the country continues to significantly rely on coal for electricity generation in future as well. NITI Aayog predicts that India's coal reliance is likely to persist in the coming few decades but coal's share in India's energy mix is most likely to reduce to 42-48 % by 2047. The dismal consequences of coal usage on environmental degradation are prompting India and many other countries to further reduce their dependency on coal.

Current Scenario:

Presently, coal accounts for 50.89% (204079 MW out of the total installed capacity of 401010 MW) in the nation's power-mix as on 30.04.2022, against 53.25% (199864 MW out of the total installed capacity of 375322 MW) prevalent as on 31.12.2020 (Source: CEA). Despite 2.11% (4215 MW) rise in coal's share in absolute terms during the above 14-month period, however, coal's share in the total installed capacity has come down by 2.36% during the same period. Still, the dynamic nature of above figures over the years reveals the fact that the thermal installed capacity position in the country is poised for growth, which concomitantly emphasises on the need for production and delivery of coal in conformity with the grades notified.

It's a known and uncontested fact that generation of quality power is directly dependent on the production, delivery and consumption of quality coal. This indispensable link also specifies that in order to meet the rising demand for electricity, we need more and more higher quantities of coal. However, one significant fact to remember here is, increase in coal consumption is not only because of new capacity addition but also because of deterioration in coal quality in terms of its heating value (Siddhartha Bhatt M and Rajkumar N-The Journal of CPRI, Vol. 11, No. 4, December 2015 pp. 773-786), which clearly implies that the lower the quality of coal, the higher will be the quantity of coal required for generation of the same quantum of electricity and vice versa. The above quantity-quality paradox can be appreciated better by looking at the revised coal consumption norms fixed by the CEA during July 2021.

Coal Consumption Norms:

As per the revised norms circulated by CEA vide letter No. 219/GC/BO/ TPPD/CEA/2021/224, dt. 20th July 2021, coal consumption of a non-pithead thermal plant increases from 4.51% to 227.03% (which is more or less the same for any plant irrespective of its installed capacity) with progressive drop in quality from G2 to G17 grades with G1 taken as the reference grade, as tabulated in the next page.

As an illustration, let's take the coal consumption norms fixed for a subcritical unit with an installed capacity of 250 MW and above, PLF slated at 85%, and a Unit Heat Rate of 2375 Kcal/Kwh (Col 4 of above table). As per the new norms, while the said unit requires 2714 Tons of coal of G1 Grade per MW per annum, the quantity of coal required increases to 2837 Tons per MW per annum if quality slips to G2 grade, and so on progressively up to 8873 tons per MW per annum (which is more than a 3-fold increase) if the quality further slips to G17 grade. From a careful perusal of the above table, it can be inferred that the quantity of coal keeps on progressively increasing with drop in quality by each grade, which indicates that quantity would enormously increase for generation of the same quantum of electricity if quality is compromised.

Considering that the average grade of thermal

Revised Grade-wise Coal Consumption Norms For Non-Pithead Thermal Plants In The Country w.e.f. 14th July 2021

Grade of Coal	Annual Coal Consumption at 85% PLF (Tons Per MW Per Annum)			
	Subcritical Units			Supercritical Units (2250)*
	Less than 200 MW (2600)*	200 MW to less than 250 MW (2500)*	250 MW and above (2375)*	
(1)	(2)	(3)	(4)	(5)
G1	2971	2856	**2714**	2571
G2	3105	2986	**2837**	2687
G3	3253	3128	2971	2815
G4	3415	3284	3120	2955
G5	3594	3456	3283	3111
G6	3794	3648	3465	3283
G7	4061	3862	3669	3476
G8	4266	4102	3897	3692
G9	4550	4375	4156	3937
G10	4874	4686	4452	4218
G11	5247	5045	4793	4541
G12	5683	5464	5191	4918
G13	6197	5959	5661	5363
G14	6814	6552	6224	5896
G15	7567	7276	6912	6548
G16	8507	8180	7771	7362
G17	9714	9340	**8873**	8406

Note: 1). The above position more or less holds true in respect of pit-head plants also
2). *Unit Heat Rate in Kcal/Kwh

coal from CIL sources conforms to G10, the requirement of ACQ comes to 11.13 LT as per the above norms in respect of a non-pithead plant of 250 MW installed capacity. However, if the quality progressively slips through G11 to G17 grades, the ACQ increases considerably by 7.63% to almost 100%, from 12.47 LT to 22.18 LT for the same 250 MW plant, which otherwise would remain at 11.13 LT if supply of coal in G10 Gr is ensured throughout. The consequences arising out of the failure to supply coal in notified grades thus not only leave an immense burden on the nation from all angles, but also lead to faster depletion of the precious natural resource. The critical need therefore is for production of quantity with quality but not, quantity without quality!

Quality Must Precede Quantity:

Nevertheless, focus towards production of more and more quantity of coal in order to meet the nation's rising energy needs is a great welcome sign. However, the point to remember is, the demand in fact is for coal free from contaminants that is capable of producing energy, since coal without energy cannot produce energy! It's therefore essential that as in the dictionary, Quality must precede Quantity in the entire gamut of CIL's operations.

The Paris Treaty:

The globe is a sad witness to the damage being caused to the environment world-over due to release of numerous toxic pollutants by coal mining activities (ranging from mining, cleaning, transportation, electricity generation and finally to its disposal as end product). In order to check the said damage, the Paris Climate Treaty was signed at the global level in April 2016 by total 193 parties (192 countries including India plus EU). As required under the Treaty, India and several other countries have committed for a gradual switchover to the HELE technologies, like super critical and ultra-super critical methods, IGCC (Integrated Gasification Combined Cycle), etc., requiring coal of higher heat value, lower ash content and consistent size for thermal generation. Besides, India has further committed to have about 40% of its total installed generating capacity to be non-fossil fuel based (other than thermal), and the country is already very close to honour this commitment with the total 'other than thermal' installed capacity clocking at 41.12% as on 30.4.2022 as outlined in the following table (Source: CEA):

Position of Installed Capacity in the country as on 30.4.2022 (MW):

Thermal				Nuclear	Renewable		Overall Total
Coal	Lignite	Gas	Diesel		Hydro	RES (MNRE)*	
204079	6620	24900	510	6780	46722	111399	401010
50.89%	1.65%	6.21%	0.13%	1.69%	11.65%	27.78%	100%
Total Thermal: 236109 (58.88%)				Total other than Thermal: 164901 (41.12%)			

Break-up of RES:

SHP	Wind	Bio Power		Solar	Total RES
		BP/Cogen	Waste to Energy		
4851	40528	10205	477	55338	111399

*RES: Renewable Energy Sources; these include SHP [Small Hydro Power (≤ 25 MW)], BP (Bio Power), U&I (Urban & Industrial Waste Power), Solar, and Wind Power; MNRE=Ministry of New and Renewable Energy

Major Takeaways:

In this regard, it may be apt to cite here the following three major takeaways from the actionable points finalized in the Review Meeting taken by Secretary (Coal) way back in Jan 2017 on maintenance of coal quality:

i. Fixing of responsibilities in case grade slippage occurs at sidings

ii. Adopting systematic mining practices so as to avoid grade slippage

iii. Avoiding of mixing of stones/bands with coal during mining operations

The highest responsibility and national duty of the captains of the coal industry, who are the custodians of the nation's scarce coal resources, therefore, is to put in place cost effective coal mining from coal quality perspective so that grade slippage is totally overcome and quality of coal extracted conforms to the grades notified, as specified in the Jan 2017 Review Meeting taken by Secretary (Coal).

In order that the above efforts fructify, an attempt has been made to identify various Institutional Reforms aimed at sustenance of coal quality. The said Reforms framed under twelve categories for implementation at the ground level are outlined hereunder:

INSTITUTIONAL REFORMS FOR SUSTENANCE OF COAL QUALITY

I). Change of QC Policy:

1. Inculcation of Quality Culture amongst the rank and file of CIL right from the entry level in both executive and non-executive cadres.
2. Complete shift of focus from Quantity to Quality and making "quantity with quality" as CIL's fundamental QC policy.
3. Simultaneous shift in the working performance of CIL from the present quantity-centric model to the quality-centric model.
4. Integration of the QC Department with Production and Planning Departments (the Singareni-way).

II). Commencement Of Monthly Training Classes On Coal Quality At IICM/Ranchi:

5. Coal Quality being a very high priority area, the urgent need of the hour is to commence committed regular classes of minimum 3-day duration on coal quality & allied matters at IICM on a monthly basis for all MTs, Middle and Senior Level Executives irrespective of the discipline they belong to, instead of the sporadic classes being conducted at present as a mere formality. Being the future custodians of the coal industry, all the executives of CIL are required to critically understand the role quality plays in either making or breaking the present and future of CIL. Nevertheless, imparting the required training on all facets covering CIL's activities is an integral part of CIL's HR Policy.

III). Coal Quality Monitoring:

6. Early filling of the post of ED (QM) at CIL Hq (created vide OM No. CIL/C5A(PC) ED Posts/796, dt. 18.10.2021) with the right incumbent duly vested with well-defined authority as stated in the above OM.
7. Creation of an independent and separate QC cadre (by delinking its present strapping-in with the M&S discipline) in conformity with the global practices.
8. Creation of the posts of Staff Officers (QC) at Area level, with adequate authority to strictly enforce different QC measures at unit levels.
9. Posting of E7/E-8 level executives from Mining discipline as Staff Officers (QC).
10. Nomination of E-5 to E-7 level executives from Mining and/or QC disciplines as Nodal Officers (QC) at each Unit and each Siding with exclusive functions & adequate authority so as to enable them to function independently.
11. Posting of Nodal Officers (QC) and all QC technical staff on the rolls of Area Hqrs at all the operating Areas, and their placement under the administrative control of Staff Officers (QC).
12. Placement of Staff Officers (QC) under the administrative control of GM (QC).

13. Shift-wise deployment of NOs (QC) and QC staff at all Units, pit-head stocks, CHPs/FBs and railway sidings/dispatch points for round-the-clock monitoring of coal quality.
14. Empowerment of SOs (QC) and NOs (QC) with adequate authority for spot suspension of coal transportation from a particular mine if it is noticed that coal transported from the mine in question is either contaminated, on fire or over/undersized.
15. Initiation of action against the colliery authorities concerned for their attempts to tarnish the image of CIL due to their anti-quality moves.
16. Deployment of QC Staff exclusively for QC-related activities, viz., for activities connected with coal quality monitoring, coal grade-declaration & coal quality assessment and for no other activities.
17. Strict enforcement of stone/shale picking activities at all pit-head stocks, from slow moving belts before crushing, and at siding stocks before loading.
18. Proper disposal of the segregated stones/shale and other extraneous matter after proper accounting of the same.
19. Strict enforcement of fool-proof fire-fighting measures at all pit-head & siding stocks.
20. Shift-wise post-production coal quality assessment at mines after initial stone/shale removal, and before effecting transportation/dispatch. In the event grade of coal produced in a particular shift from a particular mine is found lower than the notified grade, separate stacking of the whole quantity and commencementof dispatch from above stock, only after its grade is improved by thorough removal of extraneous matter and/or sweetening with superior grade coal (the Singareni-way).
21. Award of incentives to colliery authorities concerned in the event of upward revision of coal grades of the Units under their jurisdiction and simultaneous maintenance of the higher grades.
22. Fixing of responsibilities on officials connected with coal production & dispatch in the event of grade slippage.

IV). Coal Analysis Facilities:

23. Strengthening of coal testing laboratories at Area level with state-of-the art equipment and posting of qualified and competent staff for regular and timely analysis of coal samples.
24. Establishment of coal testing labs and installation of instant ash monitors at each unit/mine.

V). Declaration of Coal Grades & Stacking:

25. Section-wise declaration of grades of coal seams in place of composite declaration for the entire seam, in the event severe variations in the quality of coal are noticed within the same coal seam.
26. Grade-wise and Size-wise stacking of coal in all mines.
27. Declaration of grades in respect of ROM fraction only, in OC Mines.
28. Initiation of action against Colliery Manager, Sub Area Manager, Dispatch I/c & Nodal Officer (QC) of the Unit in the event quality of coal stock falls below the quality of coal seams/section of the coal seams, as the case may be.
29. Half-yearly review of grades of coal seams and immediate revision of the same based on the said review.

VI). Stock Liquidation:

30. Adoption of FIFO (First In First Out) policy in handling coal stock liquidation, i.e., old stocks to be liquidated first and fresh stocks next (already an MoC-guideline) as weathering adversely affects the quality of coal in the stocks
31. Temporary suspension of coal production in a particular mine in the event the quantity of coal stocks at the mine in question exceeds say, one month's coal production level of the mine and resumption of coal production in that mine only after the coal stocks fall below one month's production level.

32. Simultaneous initiation of action against Colliery authorities concerned in the event of occurrence of point 31.

VII). Sizing of Coal:

33. Compulsory routing of ROM coal through CHPs/FBs for crushing to required size after complete segregation of the contaminants.
34. Non-transportation of uncrushed coal to sidings under any circumstances.

VIII). Sale of Coal:

35. Suspension of sale of coal in Mix Grades (the system is probably prevalent only in WCL).
36. Sale of coal from OC Mines only in Cr. ROM fraction after due crushing to the required size (this reform is also in line with the Ministry's directive to introduce surface miners at all OC Mines).
37. Sale of coal from UG mines in all the 3 size fractions, viz., Steam/Slack/Cr.ROM.

IX). Railway Sidings:

38. Withdrawal of the system of loading and dispatch of coal in multiple grades from a single siding.
39. Loading and dispatch of coal in a single grade or in a single composite grade from sidings.
40. Non-acceptance of coal contaminated with extraneous matter, on fire, uncrushed, or not crushed to required size, at sidings/dispatch points.
41. Temporary suspension of on-going loading from siding(s) in the event coal conforming to above requirements is not available in adequate quantity at the railway siding(s).
42. Resumption of loading only when the above requirement is fulfilled in totality and making the officials connected with coal production, sizing and dispatch activities responsible for all consequential losses, like demurrage, etc., if any.

X). Coal Billing:

43. Release of coal on receipt of advance payments for Monthly Scheduled Quantities as per declared grades.
44. Raising of coal bills on the basis of mutually accepted analyzed grades in respect of dispatches by rail.
45. In respect of rail quantity lying unbilled on account of disputed results, raising of coal bills at a later date on receipt of referee results. These reforms totally eliminate the need for issue of credit notes or raise debit notes.
46. Fixing of Penalties on TPA (Third Party Agency) for late submission of Analysis results.
47. Fixing of Penalties on Referee Laboratories for late submission of Referee Results.
48. Execution of necessary amendments in the Tri-partite Agreements (existing with Power Utilities and Third Party Agencies) revising the timelines for submission of analysis results and incorporating the necessary penalty clauses.

XI). Career Growth of QC Technical Staff:

49. Regular promotions of QC Technical Staff strictly in line with the timelines mentioned in the Cadre Scheme.
50. Holding of departmental examinations every year for promotions of technical staff from Non-Executive Cadre to Executive Cadre.

XII). Last but not the least: Change of QC Deptt's name:

51. Re-naming of Quality Control Department as "Quality Assurance" Department, or "Quality Monitoring" Department uniformly across CIL since the word "Control" is normally associated with something we want to eliminate or reduce as "Damage Control", "Cost Control", "Pollution Control" and "Accident Control," etc.

Conclusion:

By putting quality before quantity and producing quantity with quality only, the nation's rising energy requirements can be purposefully met with, simultaneously ensuring conservation of the precious and priceless national resource and the environment. It's time to Perform the Reforms identified and to Transform the current scenario for the better, with regard to sustenance of the natural quality of coal. It's time to realize the above objective without delay, taking cue from the RPT Mantra often given to the nation by the Hon'ble Prime Minister.

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