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Scientific Study on Assessment and Mitigation of Ground Vibration Induced by Heavy Earth Moving Machineries Used during Construction Works of Shree Mandir Parikrama Project, Puri, Orissa

Harsh Kr. Verma*

ABSTRACT

Shree Mandir Parikrama Project (SMPP), Puri is an ambitious project of Govt of Orissa under its Augmentation of Basic Amenities and Development of Heritage and Architecture (ABADHA) Scheme for developing Puri as "World Class Heritage City". The project is planned to provide essential amenities to the tourist, an opportunity to develop and give modern architectural design to the heritage structure and various Math around the temple and also protect the monument of vehicular pollution.

A study to evaluate the critical impact of ground vibration induced by Heavy Earth Moving Machineries (HEMM) operational during various construction activities of SMPP Project was carried out as by CSIR-CIMFR Regional Research Centre Bilaspur. Comprehensive investigation has been carried out in different phases to analyze attenuation characteristics of ground vibration induced by HEMM and its associated cumulative impact on the various structures of Shree Jagannath Temple. Various combinations of HEMM such as Rock Breaker (120 Ton), Rock ripper, and high capacity Hydraulic Excavator etc. were made operational individually and collectively to measure the induced vibration and frequency using advanced seismograms. Vibration monitoring was also carried out at various critical structures of temple to assess likely damage due to amplification in the induced vibration under different permutation and combination of HEMMs operations. The attenuation characteristics of observed vibration data in different experimental conditions have been analyzed and compared with the widely-accepted vibration standards.

The observed vibration data were analyzed and it was found that the vibration values induced by the construction equipment used in SMPP site, Puri were significantly less than the permissible safe limit of 2.0 mm/s. All the observed vibration values were lower than 1.0 mm/s barring few readings of cumulative operation observed at distance of approximately 3.0 m. Vibration reduces to less than 0.250 mm/s beyond a distance of 8.0 m. Faster decay of vibration may be attributed to the geological set-up of the site which is primarily sandy soil and gravel.

Keywords-: Construction induced vibrations, vibration impact assessment, ground vibration analysis.

INTRODUCTION

During construction, civil construction equipment's such as excavators, rollers, cranes etc are used. Construction activities using heavy earth moving machines can induce ground borne vibrations and thus pose an adverse effect on the surrounding environments. The impact of construction-related vibrations can be quantified by comparing the measured or predicted vibration intensities with the allowable vibration limits of the concerned objects. Various standards and specifications define allowable vibration limits that are typically expressed as peak particle velocity in the time domain and root mean square velocity in the frequency domain to assess the impact of vibration on nearby objects. A common way of assessing vibration impact is to conduct on-site ground vibration monitoring at several selected locations. A site-specific empirical formula was adopted to model the attenuation of measured vibration intensities with the increasing distance from the vibration source. As such, the combined utilization of the estimated vibration source location and the adopted empirical formula can achieve vibration intensity assessment in a broad surrounding area rather than being confined to a few monitored points.

Shree Mandir Parikrama Project (SMPP), Puri is an ambitious project of Govt of Orissa under its Augmentation of Basic Amenities and Development of Heritage and

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Architecture (ABADHA) Scheme for developing Puri as "World Class Heritage City". This project is being implemented by Works Department, Government of Odisha through its PSU, i.e., Odisha Bridge and Construction Corporation Ltd. (OBCC). The project is planned to provide essential amenities to the tourist, an opportunity to develop and give modern architectural design to the heritage structure and various Math around the temple and also protect the monument of vehicular pollution.

CIMFR team carried out comprehensive investigations and seismological monitoring during entire course of the construction of Shree Mandir Parikrama Project. Vibration induced by various construction equipment was measured with different experimental design to create severe condition and record maximum vibrations. This report is a record of the field investigations and observations of CIMFR team carried out at Puri as part of seismological monitoring during construction works of Shree Mandir Parikrama Project. A detailed review of various standards on vibration values based on their damage potential, attenuation characteristics of vibration obtained by analysis of the observed values are discussed in this paper.

PROJECT DETAILS

The project envisages construction of 75-meter-wide Heritage and Security Corridor around Meghanada Pacheri of Shree Jagannath Temple and broadly divided into nine zones on the northern, southern and western side. The first 7-meter is Green Buffer Zone which consists of a 2 m hardscape area abutting Meghanada Pacheri for access by staff and for maintenance purposes. The remaining 5 m is a 1-feet high terraced landscape green. For ceremonial procession of deities year-round and use by general public for parikrama of Shree Mandira complex a 10 m Antar (Inner) Pradakshina is proposed. The inner Pradikshina is followed by a 14 m Landscape Zone. There is 8 m wide Bahya (Outer) Pradakshina covered by trees on either side for providing a shaded pathway for visitors / pilgrims. A 10 m wide public convenience zone providing spaces for construction of facilities such as restrooms, drinking water fountains, information-cum-donation kiosks, and shelter pavilions for shade and rest is planned. A 4.5 m service lane is planned for access by service vehicles and maintenance of the corridor. Another 4.5 m wide dedicated shuttle cum emergency lane for any kind of emergency and disaster management is also provided. A pictorial view of various lanes of the corridor is presented in Fig. 1 and 2.

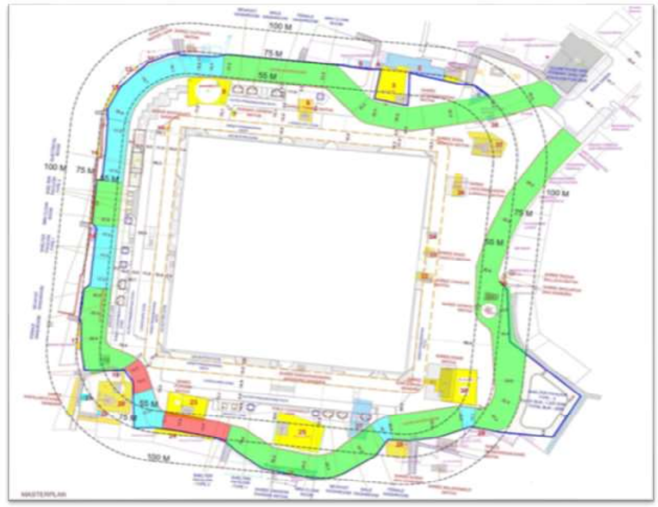


Fig. 1: Master plan of Shree Mandir Parikrama Project

A mixed traffic lane, 7.5 m wide to aid in movement of vehicles around the Heritage Corridor and to ensure access to properties abutting the outer access road is planned next to service lane. Towards the outer edge of the corridor, a 7.0 m wide shaded footpath with trees is designed adjacent to the mixed traffic lane for a smoother pedestrian flow around the corridor and neighbouring area for people to commute. This lane will also have a provision for waste bins, street furniture, drinking water fountain etc.

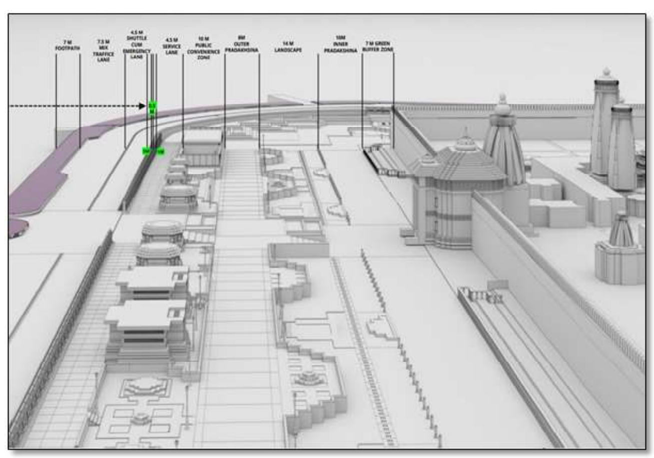


Fig. 2: Computer generated pictorial view of various proposed lanes of heritage corridor

FIELD INVESTIGATIONS

CSIR-CIMFR team visited the construction site initially for exploratory visit to undertake comprehensive investigation and measurement of the vibration induced by the heavy earth moving machineries in and around the site as part of Shree Mandir Parikrama Project, Puri. A detailed field investigations was made about the construction equipment and it may be observed that the major construction equipment of concern for generating ground vibration are backhoes excavator, Hydra crane and a double drum roller machine. These three machines are the major construction equipment which will be used during construction of Shree Mandir Parikrama Project. During field investigation, vibration from individual machines as well as cumulative operation of all the three machines have also been observed to create most severe condition and observe the maximum vibration level in severe condition of machines usage. It is important to note that the vibration observed is dependent upon the properties of the propagating medium. Therefore, vibration was measured with different combination of the machine's usage in different parts of the construction site.

During monitoring, observations of vibration at various locations both in day time as well as in night hours were taken. During day hour, temple premises were mostly crowded, therefore measurement during day hours were carried out at access road, outer Pradakshina path. In the night hours vibration measurement was carried out close to the temple premises in areas such as inner Pradakshina path, buffer zone, pathways along the temple wall. Depending upon the availability of site and HEMM, northwest direction of the SMPP construction site (Temple) was considered for vibration study during the second field investigations by CSIR-CIMFR Team. Vibration monitoring both in far field and near field was carried out simultaneously to record the maximum values taking into account the possibility of varying below surface geological conditions.

Vibration monitoring was carried out by team extensively in the temple. These sides were available for the site experiments. CIMFR team measured vibration of individual equipment as well as vibration induced by cumulative operations of the construction equipment. Various sensor locations are presented in Fig 3.

All the major construction equipment was available for field experiments in the west side like back hoe excavator, roller and hydra crane. Individual and cumulative operation of all the three machines were experimental conditions for measurement of vibrations induced during machines usage.

Another important noteworthy experimental condition in field experiment was measurement of vibration not only in the direction of temple but also in other direction in order to get vibration attenuation characteristics in all the direction. It may be noted that equipment's are fixed at same distance from the source but at the different locations along the temple boundary/wall. In another, seismographs may be seen fixed in parallel and perpendicular directions of temple wall. This enabled us to measure vibration in all directors and also to encompass the effect of heterogeneity of the propagating medium. It may be observed from some of the Figures of vibration monitoring locations showing multiple construction equipment simultaneously and vibration have been monitored as a cumulative effect of all the construction equipment. Such experimental conditions were designed to observed most severe condition and measure maximum value of vibrations in such practical conditions.

Fig.3: Photographs of vibration monitoring locations during cumulative operations of construction equipment

METHODOLOGY AND EQUIPMENT

Vibration monitoring at SMPP site, Puri was carried out using M/s Instantel, Canada make microcomputer-based seismographs namely Micromate (Two units) and MiniMate Plus (One unit). All these instruments are four-channel seismographs provided with one tri-axial transducer for monitoring of vibration (in mm/s or inch/s) and one-channel for monitoring of air overpressure/noise in dB (L) or Pa. They record vibrations in three orthogonal directions [i.e. Longitudinal (L), Vertical (V) and Transverse (T)] and peak frequency of vibration in individual directions as well as compute the peak vector sum of vibrations. Photographs of the vibration monitoring equipment are presented in Figure 4 and 5. These are all portable, high precision instruments which measure vibration intensity in terms of amplitude, particle velocity, frequency and air overpressure in British as well as Metric units. The instruments permit full wave recording at any instant of time for a present duration. Sensors are having an articulation of spikes for proper coupling with the ground for more precise reading of particle velocity.

Fig. 4: View of MinMate Plus and Micromate Equipment along with external geophone and microphone sensors

One of the most critical aspects of ground vibration monitoring is the placement of transducers in the field. Good coupling refers to the transducer that maintains proper contact with the ground. Poor coupling can cause slippage or toppling of the transducer resulting in distorted, often higher vibration levels. Most recommendations agree that the best coupling can be achieved by burying the transducer when the measurement surface consists of soil and by bolting or quick setting cement (plaster of paris) when the measurement surface consists of rock or concrete. Burial is desirable for particle acceleration exceeding 0.2 g but it is essential if it is greater than 1.0 g (Dowding, 1992; Stagg and Engler, 1980; ISEE, 2005, ISRM, 1991).In this study, coupling of the transducers were carried out using burial techniques in soil and plaster of paris (POP) in case of hard rock surface which can be seen in various monitoring photographs given in subsequent section.

VIBRATION CRITERIA FOR HISTORIC BUILDING

A review of existing criteria pertaining to historic and sensitive structures was undertaken, and the results are summarized in Table 1. Although there are differing opinions about maximum permissible levels, there is general agreement that peak particle velocity should less than 2.0 in./sec (50 mm/s). The criteria in Table 1 cover a variety of structural types and conditions, and some investigators have correlated allowable particle velocity with other dynamic variables and subsurface conditions.

Table 1. Existing Vibration Criteria for Historic and Sensitive Structures

Reference (1)	Maximum Peak Particle (in./sec) (2)	Velocity (mm/s) (3)	Vibration (4)	Type & conditions of structure (5)	Comments (6)
German Institute of Standards DIN 4150 [7]	0.12	3	Short term	Building particularly sensitive to vibration	Frequency <10HZ
	0.12-0.3	3-8	Short term		Frequency, 10-50 HZ
	0.3-0.4	8-10	Short term		Frequency 50-100 HZ
Rudder	0.10	2.5	Traffic	All	Threshold of structural damage
Esteves [6]	0.10	2.5	Blasting	Special care and historical monuments.	Loose and soft soils and rubble mixture.
	0.20	5			Medium to hard soils, uniform and well graded sand
	0.40	10			Hard soils and rock
Swiss Association (14)	0.12	3	Machines, traffic	Objects of historic interest and other sensitive construction	Frequency,10-30 Hz
	0.12-0.2	3-5			Frequency,30-60 Hz
	0.3	8	Blasting		Frequency,10-60 Hz
	0.3-0.5	8-12	Blasting		Frequency,60-90 Hz
Whiffin and Leonard (15)	0.20	5	Traffic	Houses of normal standard	Threshold of architectural damage
Ashley (1)	0.3	8	Blasting	Ancient and historic monuments	
	0.5	13	Blasting	Housing in poor repair	
Esrig and Ciancia (5)	0.5	13	Blasting and impact pile driving	Historic buildings in poor condition	Approximately 30 ft of soil cover over bedrock
Chae (3)	0.5	13	Blasting	Old residential structures in very poor condition	Scaled distance criterion: 50 (ft/
	1.0	25	Blasting	Relatively old residential structures in poor conditions	Scaled distance criterion: 30 (ft/
Siskind, et al. (13)	0.5	13	Blasting	Older residence, plaster on wood lath construction for interior walls	Frequency less than 40 Hz
	2.0	50	Blasting		Frequency greater than 40 Hz

REVIEW OF STANDARDS ON SAFE LIMIT OF VIBRATION

Over the years, numerous vibration criteria and standards have been suggested by researchers, organizations, and governmental agencies. Much of this work originated in the mining industry, where vibration from blasting is a critical issue. As per present Indian standards, as mentioned in DGMS (Tech) (S&T) Circular No. 7 dated 29th August, 1997 depending on the type of structures and dominant excitation, the peak particle velocity (PPV) on the ground adjacent to the structure shall not exceed the values given in the Table 2. While framing such standards the concept of resonant frequency was given due considerations. Objects of historical importance, heritage structure are given special status in Indian Standard as well as in standard of other countries. In lower frequency band, Indian standard allows only 2 mm/s of safe peak particle velocity where as in other standards such as DIN standard permissible PPV value is 3 mm/s for 0-10 Hz frequency range of vibration. In case of higher frequency band of greater than 25Hz, Indian standard allows 10 mm/s as safe peak particle velocity.

Table 2: Permissible Peak Particle Velocity (PPV) in mm/s at the Foundation Level of Structures as per DGMS (India) Criterion

Type of Structures	Dominant Excitation Frequency, Hz		
	< 8 Hz	8 - 25 Hz	> 25 Hz
(A) Buildings/structures not belong to the owner			
Domestic houses /structures (Kuchha brickand cement)	5	10	15
Industrial buildings (RCC and framed structures)	10	20	25
Objects of historical importance and sensitive Structures	***2***	***5***	***10***
(B) Building belonging to owner with limited span of life			
Domestic houses /structures (Kuchha brick and cement)	10	15	25
Industrial buildings (RCC and framed structures)	15	25	50

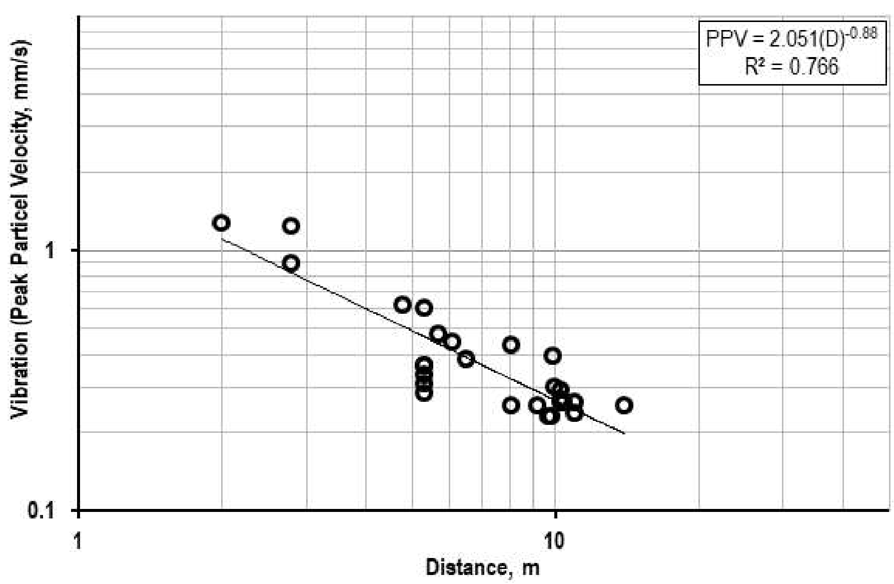


Figure 6: Plot of observed PPV values and distance in logarithmic scale

ANALYSIS OF DATA

The data of vibration observed during field experiments of CIMFR team and the permissible limit of vibration in terms of peak particle velocity, as given in Table 2, is 2.0 mm/s corresponding to frequency band of less than 8.0 Hz. Peak particle velocity of 2.0 mm/s is also the minimum value of permissible limit irrespective of frequency content of vibration as per DGMS (India) Standard as presented in table 2. A plot of observed peak particle velocity (PPV) and distance in logarithmic values are presented in Figure 6.

The observed vibration shows a good correlation with distance having coefficient value greater than 0.766 and same may be used for computation of vibration values for a given distance for this particular site. The correlation is presented in Equation 1.

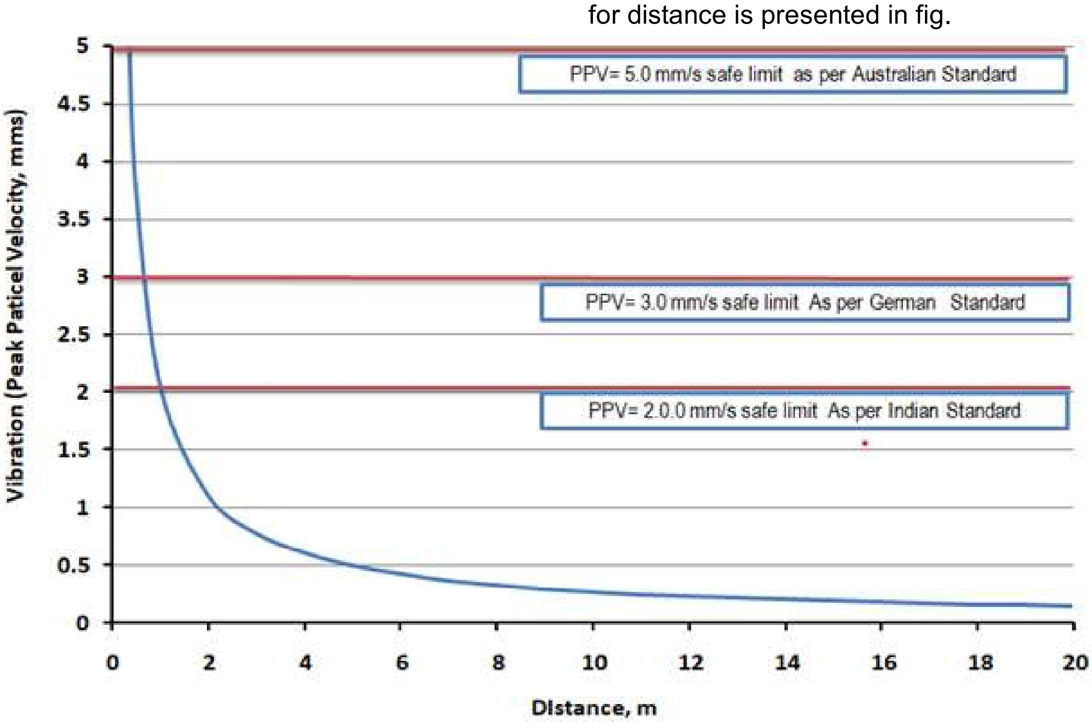
$$\vartheta = 2.05(D)^{-0.88} \qquad \text{Eq. 1}$$

Where,

$\vartheta = \text{Peak partilce velocity, mm/s}$

$D = \text{monitoring distance, m}$

Equation 1 shows relationship between distance and observed vibration in terms of peak particle velocity. Eq. 1 is further used to extrapolate vibration for a given distance which shows the decay pattern of the vibration at SMPP Project site. The plot of projected vibration values for distance is presented in fig.



It may be noted that the distance of monitoring varied from 1.5 m to 18.0 m. The closest distance of HEMM Analysis of the observed vibration data. Highest values of vibration (PPV) observed in the investigation is 2.336 mm/s at distance of 1.5 m induced by roller machine. The value decayed to less than 0.50 mm/s beyond a distance of 10 m distance in majority of the cases.

As per the project report of Shree Mandir Parikrama Project (SMPP), there is 7.0 m of buffer zone which will be a greenery and landscape. There will not be any usage of construction equipment within 7.0 m of the temple wall (Meghanad Pacheri).

Field experiments reveals that the majority of the vibration generated by construction equipment used in SMPP site are less than 0.250 mm/s and significantly lesser than the recommended safe permissible limit of vibration of 2.0 mms/ as per Indian standard. Decay of the vibration is very rapid and reduces to significantly lesser values than the recommended safe permissible values beyond a distance of 8.0 m.

CONCLUSIONS

CSIR-CIMFR Team has carried out extensive field investigations in two phases at SMPP, Puri Site. Vibration was monitored using three sets of tri-axial seismographs. During initial exploratory visit, it was found that the major construction equipment used at site are Hydra Crane, Double Drum Roller and Back-hoe excavator. Field experiments were conducted to monitor vibration of individual and cumulative operations of the construction equipment's. Efforts were made to create most severe condition and record maximum vibration values.

Review of various national and international standards was made and it was found that 2.0 mm/s of peak particle velocity (PPV) is minimum permissible safe limit of vibration as per Indian Standard. Other International Standards such as German and Australian Standards recommends 3.0 mm/s and 5.0 mm/s as safe permissible vibration limit.

The observed vibration data were analyzed and it was found that the vibration values induced by the construction equipment used in SMPP site, Puri were significantly less than the permissible safe limit of 2.0 mm/s. All the observed vibration values were lower than 1.0 mm/s barring few readings of cumulative operation observed at distance of approximately 3.0 m. Vibration reduces to less than 0.250 mm/s beyond a distance of 8.0 m. Faster decay of vibration may be attributed to the geological set-up of the site which is primarily sandy soil and gravel.

REFERENCES

1. Dowding, C. H., (1996). Construction vibrations, Prentice Hall, Englewood Cliffs, NJ, USA.
2. Dowding, C. H., (1985). Blast Vibration Monitoring and control, Prentice Hall, Englewood Cliffs, NJ, USA
3. DGMS (1973). Damage of structures due to blast induced ground vibrations in the mining areas, DGMS (Tech) (S&T) Circular No.7 of 1997 dated 29.08.1997.
4. DIN 4150-3 (1999-02). Structural vibration- Effects of vibration on structures.
5. Pal Roy, Pijush (2005) Rock blasting effects and operations, Oxford and IBH Publishing Company Pvt. Ltd., New Delhi (Also published by Taylor & Francis Group plc., U.K.), p. 345.
6. Stagg, M.S. and Engler, A.J. (1980) Measurement of Blast-induced Ground Vibrations andSeismograph Calibration, US Bureau of Mines RI 8506.
7. ISRM - Suggested Method for Blast Vibration Monitoring, 1991, in Int. J. Rock Mech. Min.Sci. &Geomechanics Abstracts, Vol. 29, No.2, pp143-156, 1992.
8. Federal Transit Administration (FTA), Transit Noise and Vibration Impact Assessment, U.S. Department of Transportation Report No. DOT-T-95-15, April 1995.
9. Hung, H. H. & Yang, Y. B., (2001). A Review of Researches on Ground-Borne Vibrations with Emphasis on Those Induced by Trains, Proceeding of National Science Council of the Republic of China, Vol. 25, No. 1, pp. 1-16
10. International Organisation For Standardization, 1989, ISO 2631-2: Evaluation of Human Exposure to Whole Body Vibration, Part 2: Continuous and Shock Induced Vibration in Buildings (1 to 80 Hz), Zurich.
11. J. T. Nelson, H. J. Saurenman (1983), "State-of-the-Art Review: Prediction and Control of Ground borne Noise and Vibration from Rail Transit Trains," U.S. Department of Transportation, Urban Mass Transportation Administration, Report Number UMTA-MA-06-0049-83-4, DOT-TSC-UMTA83-3, December 1983.

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Analysis of Stability of Slopes in Opencast Coal Mines Vis-a-Vis Development of TARP

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ABSTRACT

This paper presents the application of recent guidelines of Directorate general of Mine safety in January 2020 for a typical coal Opencast mine. TARP suggested for the opencast coal mine is demonstrated with reference to the typical geo-mining conditions from opencast coal mine on monitoring the movements and numerical model studies for design of stable dump slopes and high wall slopes along with sensitivity analysis on effect of ground water. Emphasis os made on development of TARP suitable for the geo-mining conditions of any opencast mine with observational approaches and meticulous monitoring and online interpretation and communication to the grass root level. Indian mining industry has recently witnessed the biggest slope disaster involving 23 persons under slope failure in the year 2017. Adopting a suitable TRAP will lead to self-reliant and sustainable practices with improved safety and stability of slopes.

INTRODUCTION

All geotechnical investigations aimed at collecting input design parameters, however complete, involve an inherent risk of inaccuracy. Hence, any attempt of slope stability analyses and evaluation need to be supported by a sound slope monitoring programme in order to ensure the safe and smooth mining operations.

The slope monitoring method allows failures to be predicted and safe working conditions. Slope monitoring can be used to confirm failure mechanisms. The review of monitoring results, visual inspection and regular briefing of field people help to detect the onset of failure. The slope monitoring is also advisable for three consecutive wet seasons to detect any failure well in advance for the dumps, which are more than 60 m high. Initially, the monitoring can be done twice (before and after the monsoon) in a year till any movement is detected. Then the frequency can be increased to monthly basis. The interval between the monitoring stations should be decreased (5m to 10 m) in the movement zone. The monitoring should be done weekly and then daily, in this situation, to predict the date of failure in advance for the safety of men and equipment.

The main objective of slope monitoring study is to detect any instability well in advance so that any damage to men and machineries can be avoided. If the failure is unavoidable then it can be brought down in a predictable manner. The early identification of movement zones allows steps to be taken to minimize the impact of mining on stability by the implementation of correct remedial measures and at the same time provides for optimum coal extraction. The system contrasts strongly with more common ‘passive’ systems that frequently only record the occurrence of an event for subsequent post-mortem examination. The active monitoring system permits early and confident decision making by management for safety purposes.

The first sign of instability is a tension crack. So, it is important to carry out regular inspection to detect the development of tension cracks on the crest of the slope as well as on benches and to carry out prompt remedial measure. They may develop as a function of high stresses in the slopes. The opening of cracks will tell whether any deep - seated failure can occur or not. Tension cracks should be filled with sandstone and sealed with clay to prevent the entry of water, which may cause failure.

The rate and scale of movement in the form of velocity or what can also be termed as average velocity is another key parameter for the identification of pit slope instability. The average velocity is a derivative of the accumulated displacement based on a reference time and an assigned time window.

Prior to failure of slopes progressive, regressive and steady movement are observed (Fig 1). Zavodni and Broadbent (1980) have studied these movement based on empirical formula with data obtained from multiple

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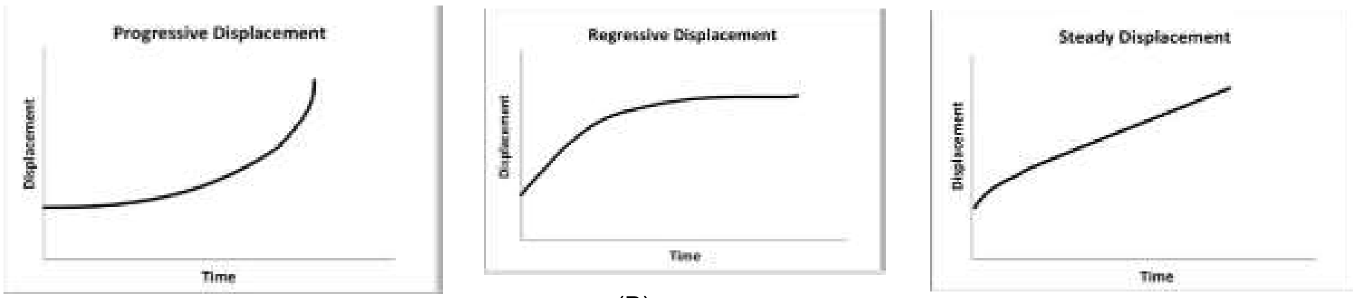
opencast mines. Progressive stage refers to the accelerated movement till failure whereas in regressive stage means decelerating movement towards stabilization. Displacement with no acceleration or deceleration is referred as Steady displacement. Recently DGMS vide its tech circular no 02 of Dt 09.01.2020 has laid down comprehensive guidelines towards slope monitoring methodology.



(A) (B) (C)

Fig 1: a.Progressive Displacement, b-Regressive Displacement, C- Steady Displacement (Zavodni, Z.M., and Broadbent, C.D. 1980)

GEOMINING CONDITIONS-CASE STUDY

The study site(Mine A) is an opencast coalmine project situated in IB valley coalfields in Odisha. The method of mining adopted is shovel dumper combination. Drilling and blasting is done to extract the overburden material. Surface miner is engaged for extraction of coal.

The top ten seams namely Parkhani, Lajkura Top III, Lajkura (I+II), Lajkura Middle, LajkuraBott II, LajkuraBott I, Rampur IIIB , Rampur IIIA, Rampur II & Rampur I seams are considered for quarrying considering Rampur I seam as base seam. The seams Rampur IAII &IAI are assessed separately without C: OB ratio lines. Locally these 2 seams are not developed, however in the area of their development they can be mined by deepening the quarry further and the parting between Rampur I and these 2 seams is around 5 to 10m only.

Opencast mining method has been adopted due to incropping of the coal seams at a shallow depth, OB: Coal ratio is favourable (2.59: 1) for opencast mining, and the mining by opencast method will be economical against underground method.

For the above geomining conditions, CSM was recommended due to its precision cuttings, thereby improving the quality of mined coal especially in seams having dirt bands. There will be more than 25 benches in the mine having 255 m depth (max) in which these machines cannot be deployed exclusively due to limitation of mobility /flexibility. Hence only two seams in Rampur horizons were chosen for deployment. These machines also require wider benches which will require comparatively higher volumes of OB to be removed in the initial stages leading to higher cost of production and imbalance in equipment utilisation due to subsequently decreasing OB: coal ratio. Therefore only top benches requiring lesser volume of OB handling was chosen as the place of deployment of CSM. In view of 15 seams and equal nos. of inter burden layers to be tackled, an equipment system which is capable of dealing many layers at a time (flexibility) of operations with the help of smaller units was also recommended as shovel dumper combination.

OB Dumps

The major constraint for this FY 2020-21 is OB dump as the temporary option of the internal dumping in the previous FY 2019-2020 shall remain the major dumping site. The actual OB dump is occupied by a nearby Village which was expected to shift. But as there is much delay in acquiring the land it shall majorly effect the mine scheduling.

Hence, the OB quantity which is around 84.6 Lakh cum is proposed to be dumped internally as well as in the external OB dump area. The Internally dumped quantity shall be re-handled to the de-coaled area later.

Upto 20 June 2020, the mine excavation has gone upto about 28 m depth with four OB benches including three benches of 6 m height, and about 2 m high Top soil bench. Coal bench of about 8 m thickness is being exploited by Surface miner while the OB is removed by Shovel dumper combination. The present status of OB dump is shown in figure 2.1, and 2.2.

Working Benches

Major coal production is done by surface miner or drilling blasting as per demand of situation. Shovel –Dumper combination is adopted for overburden removal. The prepared coal is loaded on to the trucks through front end loaders or with the help of excavators. As per the approved mining plan separate bench is suggested for coal and OB. For thicker coal seam of above 8 m it is feasible to employ surface miner. In case of thinner seams ,extraction of which is not economically viable are to be segregated with OB. Table no 1 and 2 shows the designed bench parametes of Mine A.

Table-1: Bench Parameters for OB Benches

Sl. No.	Particulars	Remarks
1.	Bench height OB Coal	Upto 10m or equal to parting thickness
2.	Bench width	2-=40m
3.	Slope of OB bench or coal bench	70°
4.	Slope of backfill or surface dump bench	37°
5.	Gradient of haul road	1 in 16
6.	Gradient of ramps	Usually 1:16, sometimes upto 1:10

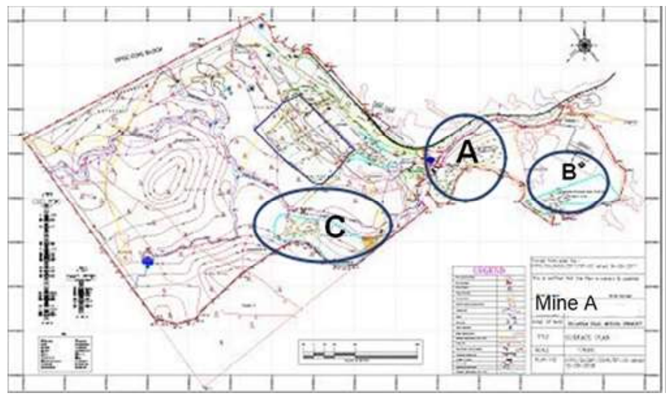


Fig 2.1.: Mine Plan showing three number of exisiting dump at mine A

(a) (b) (c)

Figure 2.2 a- Exisiting Dump A; b- Exisiting Dump B; c- Exisiting Dump C

Table-2: Bench Parameters for Coal Benches

Sl No	Particulars	Remarks
1	Bench height OB Coal	Up to 10m or equal to parting thickness. Up to 10m or equal to coal seam thickness.
2	Bench width	25 m
3	Slope of coal bench	70°
4	Gradient of haul road	1 in 16
5	Gradient of ramps	Usually 1:16, sometimes upto 1:10

NUMERICAL MODELLING

It is prudent to know the lithological units in which the slope is to be cut. Engineering properties of these litho units will influence the analysis for slope stability. The rock mass strength of lithology was appropriately reduced from laboratory test results of various samples and previous experiences of conducting simulation studies, along with data of geo-mechanical of Mine A. Properties of Overburden (OB) and rehandled Overburden (ROB) were also considered in the model. Cohesion, Friction angle, and density of OB material are 36 kPa, 310, and 1.80 gm/cc respectively. Cohesion, Friction angle, and density of coal are 300 kPa, 440, and 1.549 gm/cc, respectively. Cohesion, Friction angle, and density of sandstone are 350 kPa, 420, and 2.25 gm/cc, respectively. FLAC/SLOPE software is used for stability analysis for dump and quarry slopes. FLAC SLOPE determines the factor of safety of the slope by Shear Strength Reduction Technique. The "strength reduction technique" is typically applied in factor-of-safety calculations by progressively reducing the shear strength of the material to bring the slope to a state of limiting equilibrium. FIAC/SLOPE performs the bracketing function between the stable and unstable solutions for a given set of material properties. For a user defined strength properties FLAC/SLOPE determines the stable and unstable solutions. Then it sequentially decreases the limit between the two performing iterations till a certain level of tolerance.

DUMP SLOPES

The stability analysis was done considering typical vertical cross sections of the proposed pit and dump. The proposed external dump consists of two decks of 30 m each with total height of 60 m. The condition of two benches with bench angle of 37º and 30 m height of individual decks was simulated. The factor of safety estimated for the above sections is 1.67 indicating stability of dumps

Internal dump with total height of the internal dump as 290 m was simulated with 9 benches of 30 m height and one upper bench of 20 m height comprising of 50 m high crown dump. The factor of safety estimated for the above sections indicated stability of dumps. Resultant Factor of safety of 1.34 indicates stability of internal dump. FLAC/Slope models simulated for the external and internal dumps are illustrated in figure 3.1

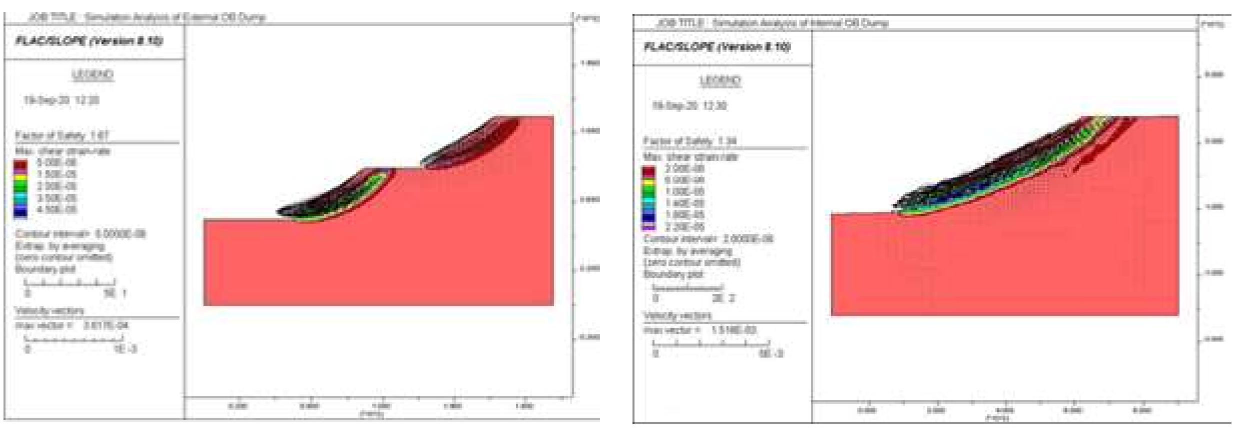


Figure 3.1: Left – Simulation of External Dump, Right- Simulation of Internal Dump

BENCH SLOPES

As per the approved mining plan Mine A project quarry cross sections in 5th year, 10th year, 20 th year and final stage were analysed in FLAC/SLOPE software. The Factor of safety output in drained and undrained conditions are tabulated in table 3. Figure 3.2 shows the two dimensional model of Quarry in 20th year with a depth of 160m. At this stage the working pit will be encountering fault plane. The effect of fault plane was also considered for deriving factor of safety

Table 3: Details of stability analysis through simulation of slopes at various stages of mining at Mine A as per approved Mining Plan

Stage/Year	Depth (m)	FOS with Dry condition of slope	FOS with Undrain condition of slop
5	50	2.4	
10	123	4.48	2.92
20	160	4.22	2.77
Final Stage	235	2.19	1.3

Sensitivity Analysis

The sensitivity analysis was done with an aim to know the influence of water on the factor of safety. This study is highly beneficial to choose the best method of remedial measure for any critical slope. The influence of groundwater on factor of safety is remarkable. The stability analyses of highwall slope have been conducted in undrained geo-mining condition also. It is evident that the highwall slopes which may stable in drained condition with cut-off safety factor of 1.3. The factor of safety is reduced to less than 1.3 when the slopes are subjected to undrained condition . As mentioned in table no.3.2.1 the varying factor of safety can be seen in drained and undrained condition. However, it may be recalled that the most likely condition of the slope was already adjudged to be drained condition. The slopes are likely to be stable with available shear strength of highwall slope material in this condition. In order to avoid undrained condition, attention must be paid to avoid entry of rain/ surface water in the slope by providing suitable drainage in and around the quarry, failing which the slope can become unstable. It should be taken up well before the onset of monsoon.

Numerical analysis was performed with varying water level of 20m, 15m, 10m and 5m for a 235 deep pit (Table 4). This analysis shows the effect of change in factor of safety due to change in ground water level. Evidently lowest factor of safety was obtained with 5m water level from original ground level. Hence care must be taken to arrest accumulation of water inside high wall. Depressurization and dewatering methods may be adopted to achieve the same.

Table 4 : Sensitivity Analysis for FoS of 235 m final stage pit with varying water level

Water Level(from OGL)	20m	15m	10m	5m
FoS	1.42	1.34	1.29	1.23

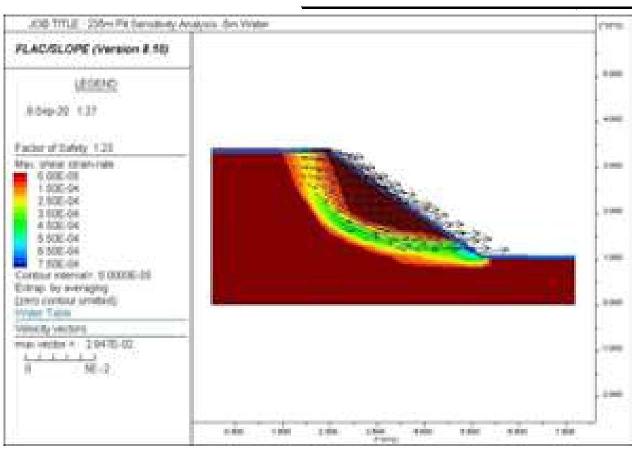


Fig 3.2.: Simulation of 235m deep Pit with 5m Water Level from OGL (Original ground level).

It is evident that with increase in water level there in decrease in factor of safety. Figure 3.2 shows a FLAC/ SLOPE model with highest water level (i.e 5m from OGL) displaying lowest FOS of 1.23. Even if the factor of safety of 1.23 considerably safe, with adoption of proper dewatering arrangement it will tend to increase.

FIELD MONIOTIRNG OF SLOPE MOVEMENTS

The main objective of slope monitoring study is to detect any instability well in advance so that any damage to men and machineries can be avoided. If the failure is unavoidable then it can be brought down in a predictable manner. The early identification of movement zones allows steps to be taken to minimize the impact of mining on stability by the implementation of correct remedial measures and at the same time provides for optimum coal extraction. The system contrasts strongly with more common ‘passive’ systems that frequently only record the occurrence of an event for subsequent post-mortem examination. The active monitoring system permits early and confident decision making by management for safety purposes.

The first sign of instability is a tension crack. So, it is important to carry out regular inspection to detect the development of tension cracks on the crest of the slope as well as on benches and to carry out prompt remedial measure. They may develop as a function of high stresses in the slopes. The opening of cracks will tell whether any deep - seated failure can occur or not. Tension cracks should be filled with sandstone and sealed with clay to prevent the entry of water, which may cause failure.The rate and scale of movement in the form of velocity or what can also be termed as average velocity is another key parameter for the identification of pit slope instability. The average velocity is a derivative of the accumulated displacement based on a reference time and an assigned time window. On filed the most common form of monitoring is by continuous measurement of Reduced Level by Total stations. The change in RL w.r.t to a time window provides a broader idea about the velocity of slopes if any.

Another common method of monitoring is monitoring widening of cracks by crack meter. It is a localized form of monitoring which provide micro level observations to estimate any impending failure. Figure 4 showcase a crack meter measuring crack movement.

Fig 4: Slope Movement Monitoring with crack meters -conventional and remote type

One recent development in countries such as Australia and USA is the development of Slope Stability Radar (SSR). Radar technology, used widely in a variety of fields for several. SSR is now being widely used in several countries to provide real time monitoring and advance warning signals before any slope or dump failure in opencast mines. SSR system can detect and alert movements of a wall with sub-millimetre precision, with continuity, and broad area coverage. This monitoring occurs without the need of mounted reflectors on benches or walls and the radar wave adequately penetrate through rain, dust, or smoke continuously. The SSR system produces data for interpretation quickly. The radar is moved around the mine in a repeatable manner to compare movements at each site and determine problematic areas. Several case studies of SSR providing improved operational risk management of slope have been reported from different places of world during last about 20 years, and in case of any necessity with trigger levels as in Table 5.1, this system may be adopted. The experiences of this mine regarding suitability of the system considering the technical and financial aspects is yet to be seen with reference to regular monitoring results of slope movements.

ANALYSIS AND TARP

Multi monitoring stations are installed on Dump A for recording the reduced level in continuous mode in a fixed interval. Observation of the monitoring stations was conducted with Total station on 16 March, 15 Apr, 4 May, 18 May, and 10 June 2020. Maximum variation observed in the vertical movement was not perceptible and hovering about 1 to 6 mm in majority of the stations indicating stability of the slope. Maximum vertical movement observed was about 12 mm at the station SM-3, which may be practically attributed to settlement of the ground in the initial stages of the monitoring. Vertical movement at various monitoring stations on the OB dump. From March2020 to First week of May 2020, accelerated movement was observed on almost all the stations; however the stability was indicated after May 2020 without any ostensible variation. Figure 5 shows the differential movement for various monitoring stations for the above mentioned period.

TARP (Trigger Action Response Plan)

Pit slope failures generally pass through several stages of movement, as shown in Figure 6. These stages are

(Sullivan, 2007): 1. Viscoelastic response 2. Primary Creep, which may eventually stabilise, or progress to 3. Secondary Creep 4. Tertiary Creep (cracking and dislocation) 5. Collapse 6. Post collapse deformation The first two stages or "initial response" include elastic rebound, relaxation and/or dilation of the rock mass (Zavodni, 2001). Secondary creep and pre-collapse deformation is associated with yielding, softening, strength loss, localised failure and slip on structures within the rock mass. The exact part of the curve in Figure.1 described by FOS = 1.0 is controversial, although generally accepted to be somewhere between Secondary Creep and Collapse.

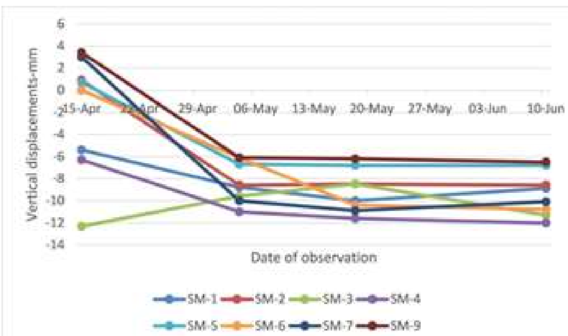


Fig 5: Differential movements at various monitoring stations on the OB dump

Work conducted by Sullivan (2007) summarizes the development of pit slope movement phases and provides a holistic view of the possible stages of pit slope movement from the perspective of velocity (Fig 6). Sullivan (2007) proposed the classification of pit slope velocities for planning as well as for the determination of critical velocities when imminent failure is expected, as shown in table 5

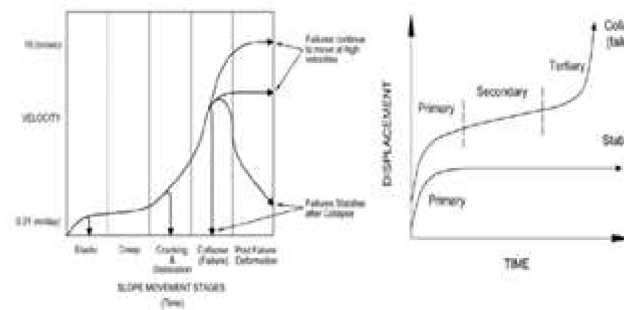


Fig 6: Stages of slope failure (after Sullivan 2007)

Table 5: Classification of pit slope velocities for the detection of critical velocities (Sullivan 2007)

Author	Velocity (mm/day)	Period over which velocity applies (days)
Ryan and Call (1992)	12	2
	50	2
Zavodni (2001)	17	2
Zavodni (2001)	15	
Martin (1993)	10-100	
Zavodni and Broadbent (1982)	50	2
Zavodni (2001) Borax Mine	150	
Call and Nicholas (from Zavodni 2001)	300	
Savely (1993)	30-10000	
Sullivan (1993)*	1000*	<hours

Note: * Minimum instantaneous velocity immediately prior to collapse.

The table above demonstrates a typical example of slope deformation measurement as an indicator of critical velocity. The author suggest adopting a monitoring protocol able to monitor the slope deformation in real time or near real time at mm level accuracy to better understand the slope behavior. Table 6 & 7 suggests the trigger level and monitoring plan to be adopted by mine management.

Table 6: Trigger level and monitoring plan for slopes

Average slope Movements (mm/day)	**Suggested method of monitoring**	**Suggested Monitoring period**	**Response and Control measure**
< 0.1	Conventional Total Station monitoring (CSTM)	Monthly	Normal condition of slope -No appreciable response required
> 0.1	Conventional Total Station monitoring	Monthly	Initial response should start
0.1 to 15	Conventional Total Station monitoring	Fortnightly	Indicates no failure expected within 48 hours
15-50	CTSM + Crack meters/Extensometers	Weekly	Indicates no failure expected within 24 hours
50-100	CTSM + Crack meters/Extensometers/Other instruments	Once in two days	Indicates progressive failure
>100	Slope Stability Radar or other systems of monitoring	Daily	Clear the vicinity
>150	Slope Stability Radar or other systems of monitoring	Hourly	Stop further working and Clear the Area

Table 7: Frequency of monitoring plan for dump movements

Average slope Movements (mm/day)	**Suggested method of monitoring**	**Suggested Monitoring period**	**Condition of slope - Response and Control measure**
< 2	Conventional Total Station monitoring	Monthly	Normal condition of slope - No appreciable response required
2-5	Conventional Total Station monitoring	Weekly	Initial response should start
5 to 10	Conventional Total Station monitoring (CTSM)	Once in two days	Indicates no failure expected within 48 hours
10-50	CTSM + Crack meters/Extensometers/Other instruments	Daily	Indicates no failure expected within 24 hours
>50 mm	Slope Stability Radar or other systems of monitoring	Continuous observation	Indicates progressive-failure Clear the vicinity

CONCLUSIONS

The analyses of factor of safety of slopes for existing slopes are found to be within prescribed safety limits. The monitoring results up to 20 June 2020, revealed the overall stability of dump slopes with practically considerable vertical displacement within 12 mm on the dump-A. However, these local movements observed from the Total Station reading is due to high moisture content of materials and deployment of HEMM near to the monitoring stations for the formation of benches in dump. The maximum horizontal movement at any station is within 14.5 mm across 19 days indicating a daily movement of 0.76 mm which is far below the critical limit proposed by various researchers, and hence the slope is considered stable. Further analysis may be carried out in future for the Mine A with a large scale monitoring data to obtain an insight of slope movements.

BIBLIOGRAPHY

1. Jayanthu Singam, 2018, and 2020, Interim reports on

Scientific Study On Design Of Pit And Dump Slope And Monitoring For Dulanga Coal Mining Project, Unpublished
2. Sullivan, TD 2007, 'Hydromechanical Coupling and Pit Slope Movements'
3. DGMS (Tech) Circular No 2 ,Dt 09.01.2020
4. DGMS (Tech) Circular No 3, Dt 16.01.2020
5. Approved Mining Plan, Dulang Coal Mine-NTPC
6. Adams, B.M. and T. Lucas (2011). Highwall design in intensely weathered basement rocks on the StocktonPlateau, New Zealand. Proceedings of the 2011 AusIMM NZ Branch Conference, Queenstown, NZ.AS/NZS (2004). HB 436: 2004. Risk Management Guidelines Companion to AS/NZS 4360: 2004 Standards NewZealand (note AS/NZS 4360: 2004 has now been superseded by AS/NZS ISO 31000: 2009).
7. Chiwaye, H.T. and T.R. Stacey (2010). A Comparison of limit equilibrium and numerical modelling approaches torisk analysis for open pit mining. J. Southern African Inst. of Mining and Metallurgy, Vol. 110, October 2010.
8. DME (1999). Guideline - Geotechnical Considerations in Open Pit Mines. Published by the Western AustraliaDepartment of Minerals and Energy (DME), Perth, August 1999.
9. Duncan, J. (2000). Factors of Safety and Reliability in Geotechnical Engineering. J. Geotech. Geoenviron. Eng.,Vol. 126, No. 4. pp. 307-316.
10. El-Ramly, H., Morgenstern, N.R., and Cruden, D.M. (2002). Probabilistic slope stability analysis for practice.Canadian Geotechnical Journal, Vol. 39, No. 3. pp. 665-683.
11. Gibson, W. (2011). Probabilistic Methods for Slope Analysis and Design. Australian Geomechanics. Vol. 46,No. 3, September 2011.
12. Hammah, R., Yacoub, T. and Curran, J. (2009). Probabilistic Slope Analysis with the Finite Element Method.Proc. 43rd US Symp. on Rock Mechanics & 4th US-Canada Rock Mechanics Symp., Asheville.
13. Hammah, R., Yacoub, T., Corkum, B. and Wibowo, F. (2007). Analysis of Blocky Rock Slopes with Finite ElementShear Strength Reduction Analysis. Proc. 1st Canada-US Rock Mechanics Symp., Vancouver.
14. Hoek, E. and Bray, J.W. (1981). Rock Slope Engineering. The Institute of Mining and Metallurgy, London, 1981.3rd ed.
15. Kirsten, H.A.D. (1983). Significance of the Probability of Failure in Slope Engineering, The Civil Engineer in SouthAfrica, Vol. 25, No. 1, 1983. pp. 17–27.
16. McMahon, B. K. (1985). Geotechnical Design in the Face of Uncertainty. E.H. Davis Memorial Lecture, Aust.Geomechanics Journal, November 1985.
17. Oka, Y. and Wu, T.H. (1990). System Reliability of Slope Stability. J. Geotechnical Eng. Vol. 116, No. 8, pp.1185-1189.
18. Pine. R.J. (1992). Risk analysis design applications in mining geomechanics. Trans. Inst. Min. Metall. (Sect. A)101: 149-158.
19. Priest, S.D. and E.T. Brown. (1983). Probabilistic stability analysis of variable rock slopes. Trans. Inst. Min. Metall.(Sect. A) 92: 1-12.
20. Safe Work Australia (2011). Draft Code of Practice: Ground Control in Open Pit Mines. Developed by Safe WorkAustralia, released July 2011. (www.safeworkaustralia.gov.au).
21. Sowers, G.F. (1979). Introductory Soil Mechanics and Foundations: Geotechnical Engineering, 4th Edition,Macmillan Publishing Co., Inc., New York, Collier Macmillan Publishers, London.
22. Sullivan, T.D. (2006) Pit slope design and risk – A view of the current state of the art. In: Proc. Symp. Series S44,Stability of rock slopes in open pit mining and civil engineering situations, 3–6 April 2006, Johannesburg,South Africa, Southern African Institute of Mining and Metallurgy, Cape Town.
23. Sullivan, T.D. (2007). Hydromechanical coupling and pit slope movements, Keynote Lecture. In: Proc.International Symposium on Rock Slope Stability in Open Pit Mining and Civil Engineering (Slope07), Y.Potvin (ed), 12–14 September 2007, Perth, Australia, Australian Centre for Geomechanics, Perth, pp. 3-43.
24. Terbrugge, P.J., Wesseloo, J., Venter, J. and O.K.H. Steffen (2006). A risk consequence approach to open pitslope design. J. Southern African Institute of Mining and Metallugy, Vol. 106, pp. 503-511.
25. U.S. Army Corps of Engineers (1995). Introduction to probability and reliability methods for use in geotechnicalengineering. Engineering Technical Letter 1110-2-547, U.S. Army Corps of Engineers, Washington, D.C.
26. Varnes, D.J., (1978). Slope movement types and processes. In: Landslides, Analysis and Control. Special Report176, Transportation Research Board, Washington, pp. 11-33.
27. Wesseloo, J. and Read, J. (2009). Chapter 9 - Acceptance Criteria. In: Guidelines for Open Pit Slope Design, J.Read and P. Stacey (eds), pp 221-236. CIRSO publishing. 496p.
28. Zavodni, Z.M. (2001). Time-Dependent Movements of Open-Pit Slopes. SME Proceedings, Denver, Colorado, pp.81-87.

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Hydrogeological Investigation in Kariari River Sub-Basin, Satna District, Madhya Pradesh, India

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ABSTRACT

A sustainable approach to managing water resources requires an understanding of the complex interactions between surface and subterranean water systems. The present work outlines hydrogeological investigation carried out in the Kariari River sub-basin, with the objective of elucidating the complex dynamics of groundwater systems for the purpose of sustainable resource management. Characterizing the hydrostratigraphy, evaluating the quality of the groundwater, and identifying the variables affecting the recharge and outflow patterns of groundwater in the river sub-basin are the main goals of this study. Using advanced geospatial tools and hydrogeological modeling software, we were able to accurately simulate the flow of groundwater. The result was the creation of a detailed conceptual model, revealing the exact spatial distribution of aquifer characteristics and their connection to the nearby river network. This study offers crucial insights to the sustainable management of water resources in the river sub-basin. By researching into the hydrogeological intricacies, policy makers and water resource managers can make conscientious choices regarding groundwater extraction, preventing contamination, and executing successful conservation strategies. Not only does this research provide a solid base for future investigations, but it also highlights the significance of comprehensive approaches to water resource management, taking into account the interplay between surface water and groundwater within the Kariari River sub-basin.

Keywords- Hydrogeology, Watershed Management, Kariari River

INTRODUCTION

Water is a valuable resource, supports life on earth and has a significant impact on the formation of landscapes and ecosystems. Groundwater plays a crucial role in sustaining human activities and maintaining environmental balance. Hydrogeological studies of rivers involve a variety of investigations that aim to understand the interactions between surface water and groundwater systems. These studies include analyzing the connection between rivers and nearby aquifers, measuring the rates of groundwater recharge and discharge, and assessing the effects of human activities on the water flow patterns. Moreover, the nature and amount of dissolved species in natural water is strongly influenced by mineralogy and solubility of rock forming minerals (Raymahasay, 1996). In earth science (structures, soil, lithology, lineament), hydrogeological researches are always crucial to hydrometeorology (climate, precipitation, evaporation, etc), geomorphology (drainage pattern, land use- land cover, groundwater prospects, slope etc). Morphometric analysis of various drainage parameters namely ordering of the various streams and measurement of area of basin, perimeter of basin, length of drainage channels, drainage density (Dd). drainage frequency, bifurcation ratio (Rb), texture ratio (T) and circulatory ratio (Rc) (Kumar et al., 2000). The quantitative analysis and water recharge structures have been carried out by Tiwari and Mishra, 2011. Drainage pattern provides information on the topography and underlying geological structures (Zaidi, 2011; Tiwari et. al, 2011). Tiwari (2014) undertook research in hydrogeology to evaluate the hydrogeochemical facies, quality, and contamination potential of Rewa City's groundwater. Mishra, et.al (2014) have done morphometric analysis of watershed using remote sensing and GIS techniques in Nagod area, Satna district. Mishra, (2017) studied the Impact of drinking water quality on the health of citizens of Rewa town of (M.P.). Chaurasia and Nigojhkar, (2017) evaluate Water Quality Assessment in Govindgarh Lake of district Rewa. Tiwari et.al. (2018) have discussed Morphometric analysis of Karihari Watershed Using RS and GIS Techniques Satna District, Madhya Pradesh India. Tiwari, R.N. (2018) detailed Physico-chemical characteristics of Silpari sub-watershed of Rewa district. Tiwari and Kushwaha, (2020) described

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Groundwater Potential Zones using Geospatial Approach of Sidhi Area, Madhya Pradesh. Tiwari and Kushwaha, (2021) investigated Watershed prioritization based on morphometric parameters and PCA technique: a case study of deonar river sub basin, Sidhi area, Madhya Pradesh, India. Tiwari et.al. (2023) have done Assessment of Groundwater Quality for Drinking Use in Bichiya River Sub Basin Area, Rewa Region, Madhya Pradesh, India. The assessment of groundwater quality for drinking use in the Deonar River Sub Basin Area, Sidhi District, Madhya Pradesh, India, was completed by Tiwari et al. in 2023. Using multicriteria decision analysis, Tiwari et al. (2022) evaluated the groundwater potential and recharge potentiality in Hanumana Block, Rewa District, Madhya Pradesh, India. We have chosen the hydrogeological investigation in kariari river sub-basin, satna district, madhya pradesh, india which was not discussed in detail by earlier workers.

Study Area (Fig. 1)

The Kariari River sub-basin is part of Tons River sub-basin which falls under larger Ganga River basin. It covers an area of about 592 sq. km. Major area of this sub-basin is situated in Satna district and some parts are also present in Rewa district of Madhya Pradesh. This area is located between 24º30' to 24 º46' N and longitude 81° to 81º16' E. Geologically, Ganurgarh Shale and Nagod limestone are two major formations and small part of this area also falls in Sirbu Shale. The summers in the basin are hot and mostly dry, with the exception of the south-west monsoon season. There are four distinct seasons in a year. The normal annual rainfall of Satna district is about 1050 mm. The district receives maximum rainfall during south-west monsoon period.

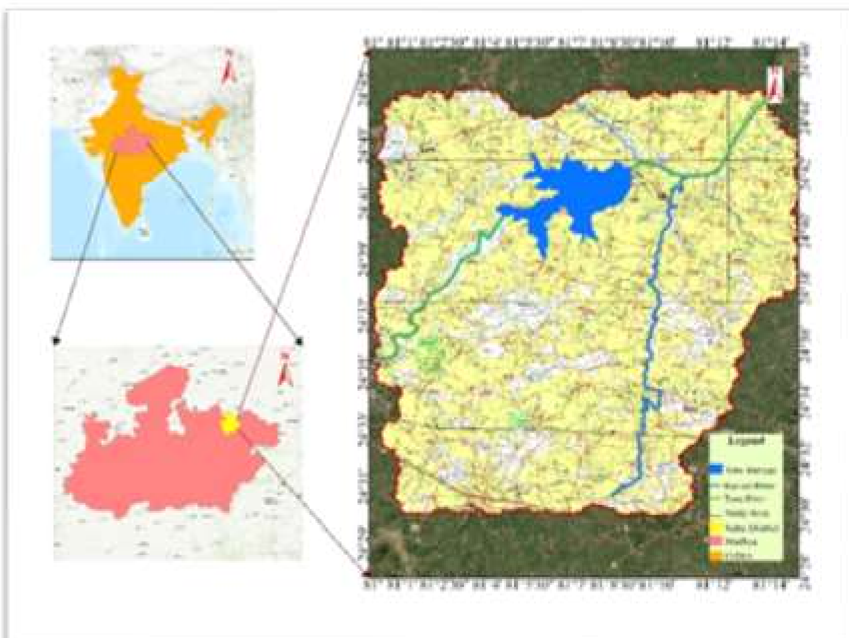

Fig. 1: Location map of the study area

OBJECTIVE AND METHODOLOGY

Landsat-8, Bhuavan (ISRO) data at scale of 1:50,000, and Survey of India toposheets at scale of 1:50,000 are used to study the land resources of the basin. A comprehensive analysis of the earth's surface has been conducted, showcasing a detailed mapping and interpretation of its geological units, landforms, and hydro geomorphic units. Through the use of tonal variations, texture, shape, shadow, and consideration of the various processes and agents involved, a thorough understanding of the formation of landforms is visually presented. The studies on land resources of area are carried out using toposheets, DEM data on Arc GIS software. The topographical map of the area has been digitised by the Arc GIS and attributes were assigned to create geological and geomorphological of the study area.

Geology (Fig. 2)

Geology of the basin is divided into two parts: Ganurgarh Shale and Nagod Limestone. Certain portion of study area also falls in third geological formation named Sirbu Shale. Ganurgarh Shale covers about 262 sq km of area. In general shales are not of permeable nature but due to soft nature of Ganurgarh shale, it has gone through deep weathering. Because of this development of dug wells have happened for limited groundwater exploitation. Presence of some joints and fissures have made it easier for groundwater to percolate deeper. Along with the contact of gypsum and limestone, the solution cavities have developed. Ganurgarh shale has bands of gypsum at lower depth. The presence of gypsum aids in the formation of artesian conditions, however, the ground water is deemed unsuitable due to its high levels of sulphates. The presence of alluvium in some parts of the area makes it good phreatic aquifer, particularly in places where its surface is overlaid by thick layers of alluvial sediment. This proves to be a reliable and productive supply for dug wells.

About 255 sq km of area is covered by the Nagod Limestone. Presence of joints and planes have made it easier the development of “Grikes” and “Solution Cavities” by the process of solution due to circulating water. This area holds a good quantity of groundwater but of harder quality.

Sirbu shale covers about 73 sq km of area. Since Sirbu shales has impermeable character so several small ponds have been developed in the area to retain water even in the heat.

Geomorphology (Fig. 3)

The sub-basin features moderately dissected hills and valleys, which are indicative of the erosional and depositional processes that have shaped the landscape over time. Major parts of this area about 570 sq km is covered by a pediment, pediplain complex. This suggests that combination of weathering, erosion, and tectonic process that have contributed to the development of this

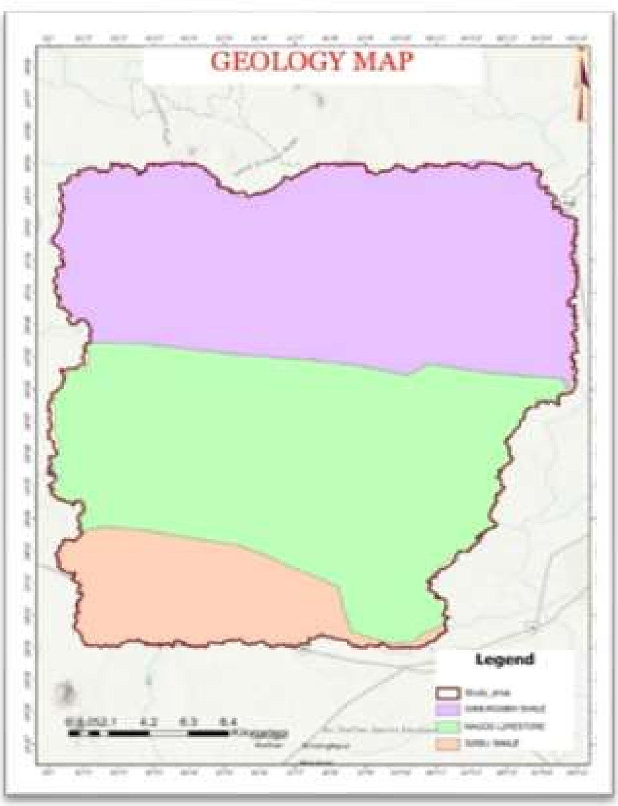

Fig. 2: Geology map of the study area

Fig. 3 Geomorphology map of the study area

geomorphic feature. There also some active quarries are present in the area. Due to this, the creation of dumps has happened which can disrupt the natural geomorphological processes and contribute to landscape changes in the study area. Various waterbodies, apart from rivers and reservoirs, exist in the area, influencing the local geomorphology and providing important habitats for diverse flora and fauna. This basin is mainly covered by the Kariari river and some of its parts also falls in Tons river area. The construction of Bakia Barrage in the study area has significantly altered the natural flow and sediment transport, impacting the geomorphology and ecology of the area.

MORPHOMETRIC ANALYSIS

For the study area, numerous morphometric parameters have been analysed and calculated. The area of the basin is about 592 sq km and perimeter about 141 km. The total number of first, second, third, fourth, fifth and sixth are presented in table 2. It is observed that 1st order stream has highest number 768 and sixth order has minimum 1. Various linear aspects are presented in table 2. The 1st order stream has maximum stream length about 412 km. Aerial aspects are presented in table 3. These are as follows: Mean Bifurcation Ratio 3.2, Drainage Density 0.88, Drainage Texture 5.08, Stream Frequency 1.93, Circularity Ratio 0.33, Constant of channel maintenance 1.14, Length of overland flow 0.57.

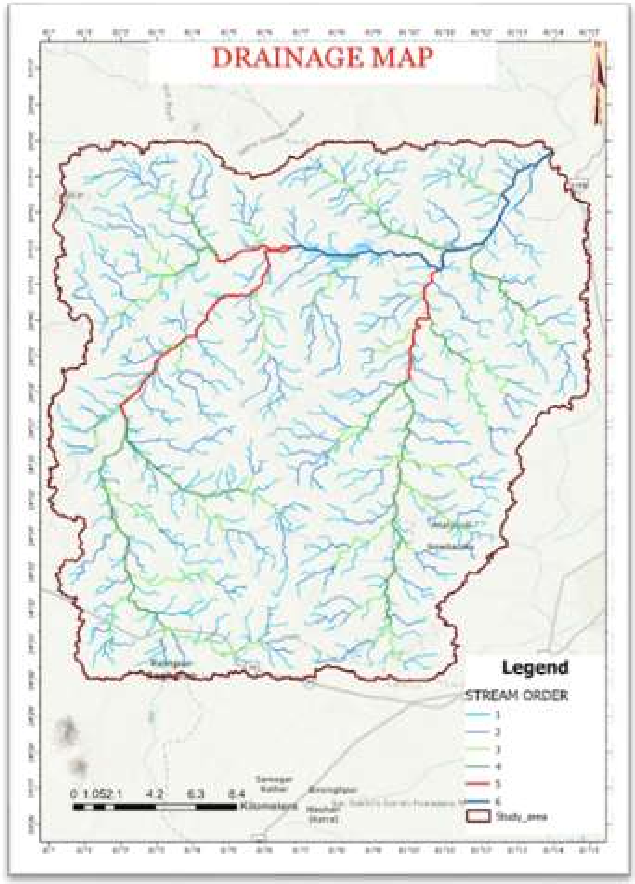

Fig. 4 Drainage map of the study area

Table:1: Basic Parameter of the Kariari River Sub-Basin

Basin Area (in km^2)	Basin Perimeter (in km)
591.91	141.22

Table:2: Linear Aspect of the Karihari Watershed

Stream Order (N)	Stream Number (Nu)	Stream length (Lu) (in km)	Mean Stream Length (Lsm)	Stream length ratio (RL)	Bifurcation Ratio (Rb)
1	768	411.68	0.54	-	-
2	178	89.06	0.50	0.22	4.31
3	42	15.95	0.38	0.18	4.24
4	9	1.50	0.17	0.09	4.67
5	3	0.48	0.16	0.32	3.00
6	1	0.37	0.37	0.78	3.00

Table:3: Aerial Aspect of the Karihari Watershed

Mean Bifurcation Ratio (Rbm)	3.2
Drainage Density (Dd)	0.88
Drainage Texture (Dt)	5.08
Stream Frequency (Fs)	1.93
Circularity Ratio (Rc)	0.33
Constant of channel maintenance (C)	1.14
Length of overland flow (Lg)	0.57

CONCLUSION

The hydrogeological investigation carried out for the Kariari river and it depicts important role of remote sensing and GIS. The study reveals valuable insights into the geological characteristics of the Kariari River sub-basin, consists of three formations: Ganurgarh Shale, Nagod Limestone and Sirbu Shale. Due to presence of fractures and joints, this area has high permeability which makes easier groundwater to percolate deeper. These insights are crucial for understanding the groundwater flow and storage potential of the area. Geomorphological and morphometric analysis provided a detailed understanding of landforms, drainage patterns and watershed characteristics within the sub-basin. This information is essential to assess the area's surface water-groundwater interactions, flow dynamics, and erosion susceptibility. The morphometric characteristics: Linear Aspects (La), Relief Aspects (Ra), and Aerial Aspects (Aa), were calculated and analysed. The Rb (bifurcation ratio) values in the study area indicate that the river sub-basin suffered minimum structural disturbances. Due to the presence of underlying shale and limestone, drainage density of the area is low that indicates a moderate level of runoff and moderate to high permeability of the terrain. The drainage pattern of basin is primarily of the dendritic type, indicating a homogeneous texture and a lack of structural control. Remote sensing and GIS provide important hydrological data and mapping capabilities. Creation of recharge structures contour bund, check dam, Nala bund and percolation pond etc. were suggested to enhance the groundwater resource of the area. The integrated understanding of the geology, geomorphology and parameters are fundamental for the sustainable management of water resources. The development of effective strategies for groundwater recharge will also provide a solid base for future investigations to address water scarcity and aware policy makers, local authorities and community stakeholders about sustainable water resources management in the region.

REFERENCE

- Shanmugamoorthy, Manoj, Subbaiyan, Anandakumar, Elango, Lakshman, Velusamy, Sampathkumar (2023). Groundwater susceptibility assessment using the GIS based DRASTIC-LU model in the Noyyal river area of South India, *Urban Climate, Volume 49, 101464, ISSN 2212-0955.* https://doi.org/10.1016/j.uclim.2023.101464
- Prayag, Ankita Girish, Zhou, Yangxiao, Srinivasan, Veena, Stigter, Tibor, Verzijl, Andres (2023). Assessing the impact of groundwater abstractions on aquifer depletion in the Cauvery Delta, India. *Agricultural Water Management, Volume 279, 108191, ISSN 0378-3774*. https://doi.org/10.1016/j.agwat.2023.108191
- Gautam, Vinay Kumar, Pande, Chaitanya B., Kothari, Mahesh, Kumar, Pradeep, Agrawal, Abhishek (2023). Exploration of groundwater potential zones mapping for hard rock region in the Jakham river basin using geospatial techniques and aquifer parameters. *Advances in Space Research, Volume 71, Issue 6, Pages 2892-2908, ISSN 0273-1177.* https://doi.org/10.1016/j.asr.2022.11.022
- Kadam, A.K., Patil, S.N., Gaikwad, S.K. et al. (2023). Demarcation of subsurface water storage potential zone and identification of artificial recharge site in Vel River watershed of western India: integrated geospatial and hydrogeological modeling approach. *Model. Earth Syst. Environ.* https://doi.org/10.1007/s40808-022-01656-4
- Lohani, T.K., Ayana, M.T., Mohammed, A.K., Shabaz, M., Dhiman, G. and Jagota, V. (2023). A comprehensive approach of hydrological issues related to ground water using GIS in the Hindu holy city of Gaya, India. *World Journal of Engineering, Vol. 20 No. 2, pp. 283-288.* https://doi.org/10.1108/WJE-04-2021-0223
- Sinduja, M., Sathya V., Maheswari, M., Dinesh, G.K., Prasad, Shiv, Kalpana, P. (2023). Groundwater quality assessment for agricultural purposes at Vellore District of Southern India: A geospatial based study. *Urban Climate. Volume 47, 101368. ISSN 2212-0955.* https://doi.org/10.1016/j.uclim.2022.101368
- Kumar, Abhishek, Maurya, Nityanand Singh (2023). Groundwater quality assessment using the WQI and GIS mapping: Suitability for drinking and irrigation

usage in the Sirdala block of Nawada district. *Water Supply vol. 23 (2): 506–525.* https://doi.org/10.2166/ws.2023.001

- Ribinu, S. K., Prakash, Pranav, Khan, A. Faizal, Bhaskar, Nikitha P., Arunkumar, K.S. (2023). Hydrogeochemical characteristics of groundwater in Thoothapuzha River Basin, Kerala, South India*. Total Environment Research Themes, Volume 5, 100021, ISSN 2772-8099.* https://doi.org/10.1016/j.totert.2022.100021
- Mahammad, Sadik, Hoque, Md. Mofizul, Islam, Aznarul, Majumder, Arijit (2023). Assessment of groundwater quality for irrigation purposes: A case study of Hooghly District, West Bengal, India. *Case Studies in Geospatial Applications to Groundwater Resources, Elsevier, Pages 289-314, ISBN 9780323999632.* https://doi.org/10.1016/B978-0-323-99963-2.00003-1
- Vahith, R.A., Mahadir, A.M., Sajitha, I., Sirajudeen, J., Ahamath, J.M. and Abuthahir, S.S. (2023). Evaluation of Groundwater Quality In And Around Ramanathapuram District, Tamil Nadu, India By Using Hydrogeochemical Facies Analysis And Wilcox Diagram*. European Journal of Molecular & Clinical Medicine, 10(01), p.*
- Bera, Amit, Chowdhury, Puja, Chakraborty, Ananya (2023). Integrated GIS-based MCDA approach for suitability zoning of irrigation water quality in semiarid Kansai River basin, Purulia district, West Bengal. *Case Studies in Geospatial Applications to Groundwater Resources, Elsevier, Pages 151-171, ISBN 9780323999632.* https://doi.org/10.1016/B978-0-323-99963-2.00010-9
- Panika, Tilak Prasad, Patgiri, Dilip Kumar, Bharteey, Prem Kumar, Salkia, Rituparna and Sonowall, Dipankar (2023). Morphometric Analysis of Ranganadi Watershed in Lakhimpur District of Assam, India, using Remote Sensing and GIS Techniques. *Biological Forum - An International Journal 15(1): 48-56. ISSN No. (Print): 0975-1130. ISSN No. (Online): 2249-3239.*
- Basavraj, Chikkansamshi, Swanand, A. Ajgaonkar, Devaraju J. and Manjunatha, S. (2023). Prioritization of Sub-watersheds through morphometric analysis in the Lower Hiranyakeshi Sub-basin, Karnataka. *Disaster Advances, Vol. 16 (4). E-ISSN No. 2278-4543.*
- Sonker, Irjesh, Tripathi, Jayant Nath, Swarnim, Singh, Anil Kumar (2023). Morphomertic and neotectonic study of Upper Teesta River basin, Sikkim Himalaya using geospatial techniques. *Journal of Applied Geophysics, Volume 212, 104978, ISSN 0926-9851.* https://doi.org/10.1016/j.jappgeo.2023.104978.
- Saravanan, S., Pitchaikani, S., Thambiraja, M. et al. (2023). Comparative assessment of groundwater vulnerability using GIS-based DRASTIC and DRASTIC-AHP for Thoothukudi District, Tamil Nadu India. *Environ Monit Assess 195, 57.* https://doi.org/10.1007/s10661-022-10601-y
- Tiwari Rabindra N. and Tiwari Pravin Kumar (2022), Surface Water Resources of Madhya Pradesh: An Overview. *Special Publication Of The Geological Society Of India No.12, 2022, pp. 114-120.*
- Tiwari Rabindra N. and Tiwari Pravin Kumar (2022), Surface Water Resources of Chhattisgarh: An Overview. *Special Publication Of The Geological Society Of India No.12, 2022, pp.138-144.*
- Arumugam, Thangavelu, Kinattinkara, Sapna, Kannithottathil, Socia, Velusamy, Sampathkumar, Krishna, Manoj, Shanmugamoorthy, Mano, Sivakumar, Vivek & Boobalakrishnan, K. V. (2022). Comparative assessment of groundwater quality indices of Kannur District, Kerala, India using multivariate statistical approaches and GIS. *Environment Monitoring Assessment 195, 29.* https://doi.org/10.1007/s10661-022-10538-2
- Sharma, Rajni Kant, Dewangan, Rakesh, Bind, Anita, Sharma, Ajay Kumar (2022). Ground Water Quality Assessment and Hydrogeological Scenario of Twin City Durg-Bhilai, Chhattisgarh State. *Journal of Indian Association for Environmental Management (JIAEM). Vol 42, No 4.* DOI: 10.56042/jiaem.v42i4.68906
- Kumari, S., Poddar, A., Kumar, N. and Shankar V. (2022). Delineation of groundwater recharge potential zones using the modeling based on remote sensing, GIS and MIF techniques: a study of Hamirpur District, Himachal Pradesh, India. *Model. Earth Syst. Environ. 8, 1759–1770.* https://doi.org/10.1007/s40808-021-01181-w
- Chakraborty, Baisakhi, Roy, Sambhunath, Bera, Amit, Adhikary, Partha Pratim, Bera, Biswajit, Sengupta, Debashish, Bhunia, Gouri Sankar & Shit, Pravat Kumar (2022). Groundwater vulnerability assessment using GIS-based DRASTIC model in the upper catchment of Dwarakeshwar river basin, West Bengal, India. *Environ Earth Sci 81, 2 (2022).* https://doi.org/10.1007/s12665-021-10002-3
- Bera, Amit, Mukhopadhyay, Bhabani Prasad, Chowdhury, Puja, Ghosh, Argha, Biswas, Swagata (2021). Groundwater vulnerability assessment using

GIS-based DRASTIC model in Nangasai River Basin, India with special emphasis on agricultural contamination. *Ecotoxicology and Environmental Safety, Volume 214, 112085, ISSN 0147-6513.* https://doi.org/10.1016/j.ecoenv.2021.112085

- Agrawal, P., Sinha, A., Kumar, S., Agarwal, A., Banerjee, A., Villuri, V. G. K., Pasupuleti, S. (2021). Exploring Artificial Intelligence Techniques for Groundwater Quality Assessment. *Water, 13(9), 1172.* https://doi.org/10.3390/W13091172
- Jayswal, P. S., Gontia, N. K., & Sondarva, K. N. (2021). Morphometric Study of Dhatarwadi River Basin Using RS and GIS Techniques. *Current Journal of Applied Science and Technology, 1–11.* https://doi.org/10.9734/CJAST/2021/V40I1031354
- Sutradhar, Subhasish, Mondal, Prolay, Das, Niladri (2021). Delineation of groundwater potential zones using MIF and AHP models: A micro-level study on Suri Sadar Sub-Division, Birbhum District, West Bengal, India. *Groundwater for Sustainable Development, Volume 12, 100547, ISSN 2352-801X.* https://doi.org/10.1016/j.gsd.2021.100547
- Tiwari, R.N., Kushwaha, V.K. (2021). Watershed Prioritization Based on Morphometric Parameters and PCA Technique: A Case Study of Deonar River Sub Basin, Sidhi Area, Madhya Pradesh, India. *Journal of the Geological Society of India 97, 396–404*. https://doi.org/10.1007/s12594-021-1697-z
- Saravanan, Subbarayan, Saranya, Thiyagarajan, Abijith, Devanantham, Jacinth, Jesudasan Jennifer, Singh, Leelambar (2021). Delineation of groundwater potential zones for Arkavathi sub-watershed, Karnataka, India using remote sensing and GIS. *Environmental Challenges, Volume 5, 100380, ISSN 2667-0100.* https://doi.org/10.1016/j.envc.2021.100380.
- Meshram, U. (2021). Morphometric analysis of a drainage basin A study of some part of Painganga river sub-basin, Maharashtra. *International Journal of Multidisciplinary Research and Development. Volume 8, Issue 9, Page No. 97-107 Online ISSN: 2349-4182, Print ISSN: 2349-5979*.
- Tiwari, R.N., Kushwaha, V.K. (2020). An Integrated Study to Delineate the Groundwater Potential Zones Using Geospatial Approach of Sidhi Area, Madhya Pradesh. *Journal of the Geological Society of India 95, 520–526.* https://doi.org/10.1007/s12594-020-1471-7
- Gaikwad, S. K., Pathan, N. D., Bansode, N. S., Gaikwad, S. P., Badhe, Y. P., Naik, T. S., & Sawant, S. V. (2020). Assessment of Groundwater Geochemistry of Vel River basin, Western Maharashtra, India. *Hydrospatial Analysis, 4(1), 14–28.* https://doi.org/10.21523/GCJ3.2020040102
- Pandey, H. K., Tiwari, V., Kumar, S., Yadav, A., & Srivastava, S. K. (2020). Groundwater quality assessment of Allahabad smart city using GIS and water quality index. *Sustainable Water Resources Management, 6(2).* https://doi.org/10.1007/S40899-020-00375-X
- Khurana, D., Rawat, S.S., Raina, G., Sharma, R., Jose, P.G. (2020). GIS-Based Morphometric Analysis and Prioritization of Upper Ravi Catchment, Himachal Pradesh, India. *Advances in Water Resources Engineering and Management. Lecture Notes in Civil Engineering, vol 39. Springer, Singapore.* https://doi.org/10.1007/978-981-13-8181-2_13
- Tiwari, R.N., Kushwaha, V.K. (2020). An Integrated Study to Delineate the Groundwater Potential Zones Using Geospatial Approach of Sidhi Area, Madhya Pradesh. *Journal of the Geological Society of India 95, 520–526.* https://doi.org/10.1007/s12594-020-1471-7
- Rane, Pratiksha Sanjay (2020), Morphometric Analysis of Kas River Basin in Ahmednagar using Remote Sensing and Geographical Information System (GIS) techniques. *International Research Journal of Engineering and Technology (IRJET) IRJE Vol: 07 Issue: 05, May 2020. e-ISSN: 2395-0056, p-ISSN: 2395-0072.* www.irjet.net
- C. Nair, Nithya, Y., Srinivas, N.S., Magesh, S., Kaliraj (2019). Assessment of groundwater potential zones in Chittar basin, Southern India using GIS based AHP technique. *Remote Sensing Applications: Society and Environment, Vol: 15, 100248, ISSN 2352-9385.* https://doi.org/10.1016/j.rsase.2019.100248.
- Arulbalaji, P., Sreelash, K., Maya, K. et al. Hydrological assessment of groundwater potential zones of Cauvery River Basin, India: a geospatial approach. *Environ Earth Sci 78, 667.* https://doi.org/10.1007/s12665-019-8673-6
- R. Siddi, Raju, G. Sudarsana, Raju, M., Rajasekhar (2019). Identification of groundwater potential zones in Mandavi River basin, Andhra Pradesh, India using remote sensing, GIS and MIF techniques. *Hydro Research, Vol: 2, Pages 1-11, ISSN 2589-7578*. https://doi.org/10.1016/j.hydres.2019.09.001.

- Prakash, K., Rawat, D., Singh, S., Chaubey, K., Kanhaiya, S., & Mohanty, T. (2019). Morphometric analysis using SRTM and GIS in synergy with depiction: a case study of the Karmanasa River basin, North central India. *Applied Water Science, 9(1).* https://doi.org/10.1007/S13201-018-0887-3
- Patle, Deepak, Awasth,i M.K. (2019). Groundwater Potential Zoning in Tikamgarh District of Bundelkhand Using Remote Sensing and GIS. *Intemational Joumal of Agriculture, Environment and Biotechnology, Vol: 12, Issue: 4. pp: 311-318. P ISSN: 0974-1712. Online ISSN: 2230-732X.* DOI: 10.30954/0974-1712.12.2019.3
- Panda, Balakrushna, Venkatesh, Madavi, Kumar, Bijendra & Anshumali (2019). A GIS-based Approach in Drainage and Morphometric Analysis of Ken River Basin and Sub-basins, Central India. *Journal of the Geological Society of India 93, 75–84.* https://doi.org/10.1007/s12594-019-1125-9
- Tiwari, R.N., Singh, Shrutika (2018). Hydrochmical Investigation for Irrigation Purpose in Around Mukundpur Area, Satna District, Central India. *Excellent Publishing House.*
- Nag, S.K., Kundu, A. (2018). Application of remote sensing, GIS and MCA techniques for delineating groundwater prospect zones in Kashipur block, Purulia district, West Bengal. *Appl Water Sci 8, 38.* https://doi.org/10.1007/s13201-018-0679-9
- Tiwari, Rabindra N. and Kushwaha, Vikash K. (2018). Groundwater Potential Zone Mapping in and Around Satna City M.P. India using an Integration of Geospatial Approach. *Natural Resources, Environment and Health. Excellent Publishers, New Delhi. ISBN: 978-93-86238-474. pp. 38-67.*
- Malik, Mohammad S. & Shukla, J.P. (2018), A GIS-based morphometric analysis of Kandaihimmat watershed, Hoshangabad district, M.P. India. *Indian Journal of Geo Marine Sciences Vol: 47 (10), pp. 1980-1985.* http://nopr.niscpr.res.in/handle/123456789/45165
- Tiwari, Rabindra Nath and Dwivedi, Rashmi (2018). Morphometric Analysis in Part of Son River of Rampur Naikin Block of Sidhi District, Madhya Pradesh, India. *Resources, Environment and Health. Excellent Publishers, New Delhi. ISBN: 978-93-86238-47-4. pp 105-115.*
- Khabat, Khosravi, Majid, Sartaj, Frank, T.C. Tsai, Vijay P. Singh, Nerantzis Kazakis, Assefa M. Melesse, Indra Prakash, Dieu Tien Bui, Binh Thai Pham (2018), A comparison study of DRASTIC methods with various objective methods for groundwater vulnerability assessmen. *Science of The Total Environment, Volume 642, Pages 1032-1049, ISSN 0048-9697.* https://doi.org/10.1016/j.scitotenv.2018.06.130.
- Tiwari, Rabindra Nath (2018). Hydrochemical Facies and Groundwater Quality Assessment for Drinking Purpose: A Case Study from Silpari Subwatershed, Rewa District, Central India. *Natural Resources, Environment and Health. Excellent Publishers, New Delhi. ISBN: 978-93-86238-47-4. pp. 12-19.*
- Kumar, B., Venkatesh, M., Triphati, A. Anshumali (2017). A GIS-based approach in drainage morphometric analysis of Rihand River Basin, Central India. *Sustain. Water Resour. Manag. 4, 45–54.* https://doi.org/10.1007/s40899-017-0118-3
- Tiwari, R.N., Singh, Shrutika (2017). Hydrochemical Facies & Drinking Water Quality of Mukundpur Area, Satna District, Central India. *Excellent Publishing House.*
- Pandi, P. D., Thena, T., Nirmal, B., Aswathy, M. R., Saravanan, K., & Mohan, K. (2017). Morphometric analyses of Neyyar River Basin, southern Kerala, India. *Geology, Ecology, and Landscapes, 1(4), 249–256.* https://doi.org/10.1080/24749508.2017.1389494
- Pande, C.B., Moharir, K. (2017). GIS based quantitative morphometric analysis and its consequences: a case study from Shanur River Basin, Maharashtra India. Applied Water Science 7, 861–871 (2017). https://doi.org/10.1007/s13201-015-0298-7
- Rai, Praveen Kumar, Mohan, Kshitij, Mishra, Sameer, Ahmad Aariz & Mishra, Varun Narayan (2017). A GIS-based approach in drainage morphometric analysis of Kanhar River Basin, India. *Applied Water Science 7, 217–232.* https://doi.org/10.1007/s13201-014-0238-y
- Tripathi, A.K., Mishra, U.K., Mishra, A., Tiwari, S. and Dubey, P. (2012). Studies of hydrogeochemical in groundwater quality around Chakghat area, Rewa District, Madhya Pradesh, *India. Int J Mod Eng Res Technol, 2(6), pp.4051-4059.*
- Singh, V. and Dubey, A., (2012). Linear aspects of Naina-Gorma river basin Morphometry, Rewa district, Madhya Pradesh, India. *International Journal of Geomatics and Geosciences, 3(2), pp.364-372.*

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Hydrogeological Study of Simrawal River Sub Basin in Jaitwar Area, Satna District, Madhya Pradesh, India

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ABSTRACT

This hydrogeological study focuses on the Simrawal River Sub Basin, located in the Jaitwar area of Satna District, Madhya Pradesh, India. The research aims to provide a comprehensive understanding of the groundwater dynamics, aquifer characteristics, and overall hydrogeological framework of the region. The findings of this study contribute valuable insights for sustainable water resource management and informed decision-making in the context of increasing water demand and potential environmental challenges. The study employs a combination of field investigations and laboratory analyses to assess the geological formations, lithological characteristics, and aquifer properties within the Simrawal River Sub Basin. Groundwater level monitoring and hydro-chemical analysis are conducted to evaluate the quality and quantity of groundwater resources. Additionally, geospatial tools and Geographic Information System (GIS) techniques are utilized to create hydrogeological maps and delineate the spatial distribution of aquifers. The hydrogeological research seeks to identify critical elements impacting groundwater recharge, flow patterns, and possible aquifer vulnerability, comprehending the interplay of surface water and groundwater, particularly along the Simrawal River, is critical for comprehending the river's function in refilling the aquifers. Anthropogenic impacts on hydrogeological conditions in the Jaitwar region are also taken into account in the study. The study's findings are used to give recommendations for sustainable groundwater management methods, such as aquifer recharge schemes and groundwater conservation measures. The outcomes of this hydrogeological study are essential for regional water resource planning and management.

Keywords: Hydrogeological study, Simrawal River, Groundwater, Aquifer.

INTRODUCTION

Water shortage in general, and groundwater scarcity in particular, is a widespread issue in most sections of our country. Our country is experiencing a water crisis as a result of insufficient rainfall over the previous five years and an increased demand for groundwater in various industries. The systemic study of stream characteristics and its application in groundwater recharge may be extremely useful (Tiwari: 2016). The Simrawal river sub-basin, located in the Jaitwar area of Satna district of Madhya Pradesh, holds significant importance in the hydrological landscape of the region. The basin is an important component of the local ecosystem, supporting various human activities such as agriculture, industry and domestic needs. Understanding the hydrogeological characteristics of this sub-basin is important for effective water resources management and sustainable development in the region. Hydrogeological studies involve a multidisciplinary approach, integrating various aspects such as morphometric analysis, geology and water quality assessment. Morphometric analysis provides insight into the geometric characteristics and spatial distribution of landforms within the basin, helping to understand its hydrological processes and drainage patterns. Geology plays an important role in determining the lithological composition, structural characteristics and groundwater potential of the area, influencing the hydrological behaviour of the basin. Additionally, water quality assessment evaluates the chemical, physical and biological parameters of water bodies within the sub-basin, identifies potential sources of pollution and assesses the suitability of the water for various purposes. The assessment of streams by the measurement of different stream parameters is known as morphometric research. The creation of quantitative physiographic techniques to explain the formation and behaviour of surface drainage networks has received a lot of attention in geomorphology throughout the last several decades (Horton, 1945). In

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morphometry, the area, height, volume, slope, land profile, and drainage basin features (linear, aerial, and relief) of the region are all qualitatively studied. Morphometric analysis is a valuable technique for identifying the subsurface geological features and geological structures that regulate groundwater movement. As such, it can be applied to the delineation of recharge potential areas as well as the search for sites that could be used for artificial recharge (Biswas, 1991).

STUDY AREA (Fig. 1)

The study area encompasses the Simrawal River Sub-Basin situated within the Jaitwar area of Satna District, Madhya Pradesh, India. Geographically, the region lies between latitude 24°42' to 24°45'30" N and longitude 80°50' to 80°55' E. Its area is about 38 square km. The Ganurgarh Shale and Nagod Limestone are two of the area's most significant geological formations. Summers in the basin are hot and the climate is characterized as subtropical with distinct wet and dry seasons. A year consists of four different seasons. The Satna area typically receives about 1050 mm of rain a year. The south-west monsoon season brings the most rainfall to the area. The topography consists of undulating plains with occasional small hills. The Simrawal River, a tributary of the Tons River, is the primary surface water facility in the area.

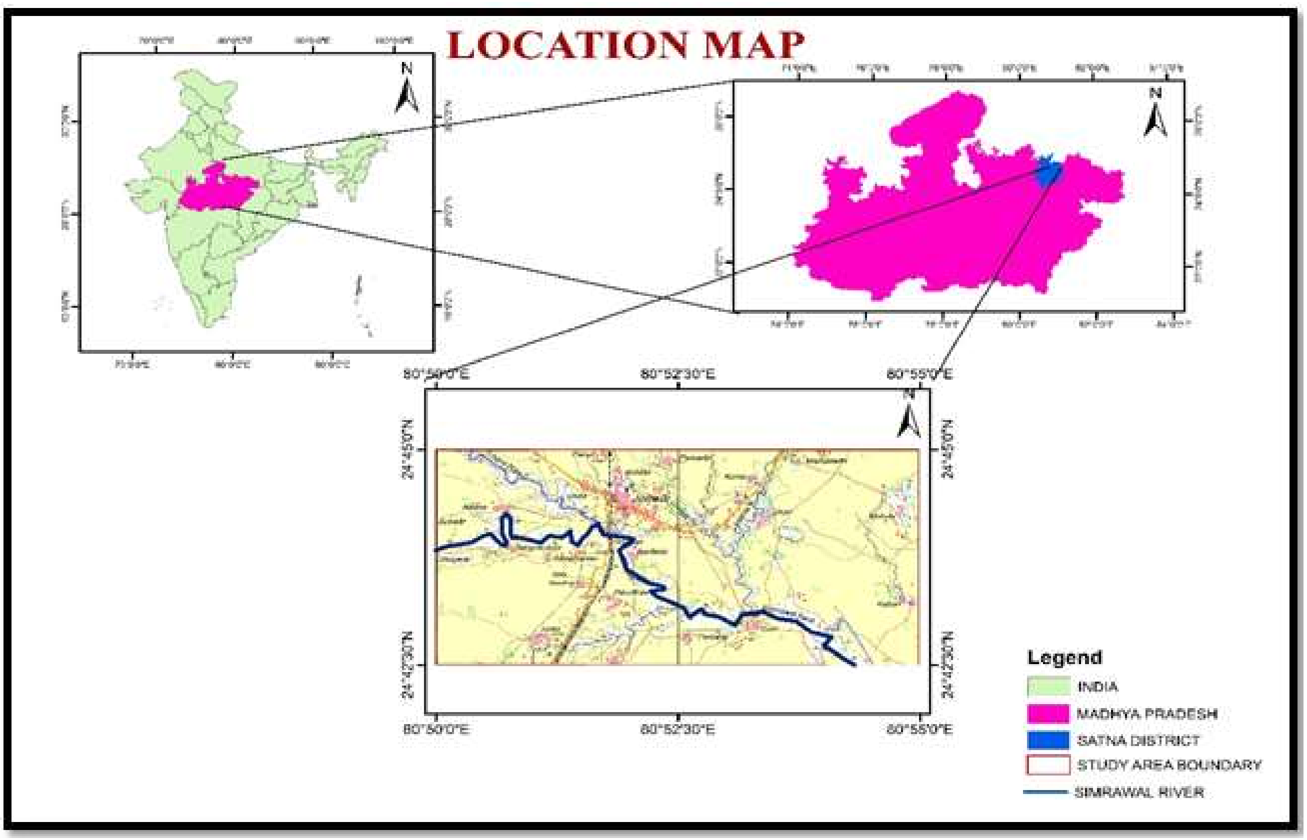


Fig. 1: Location map of the study area

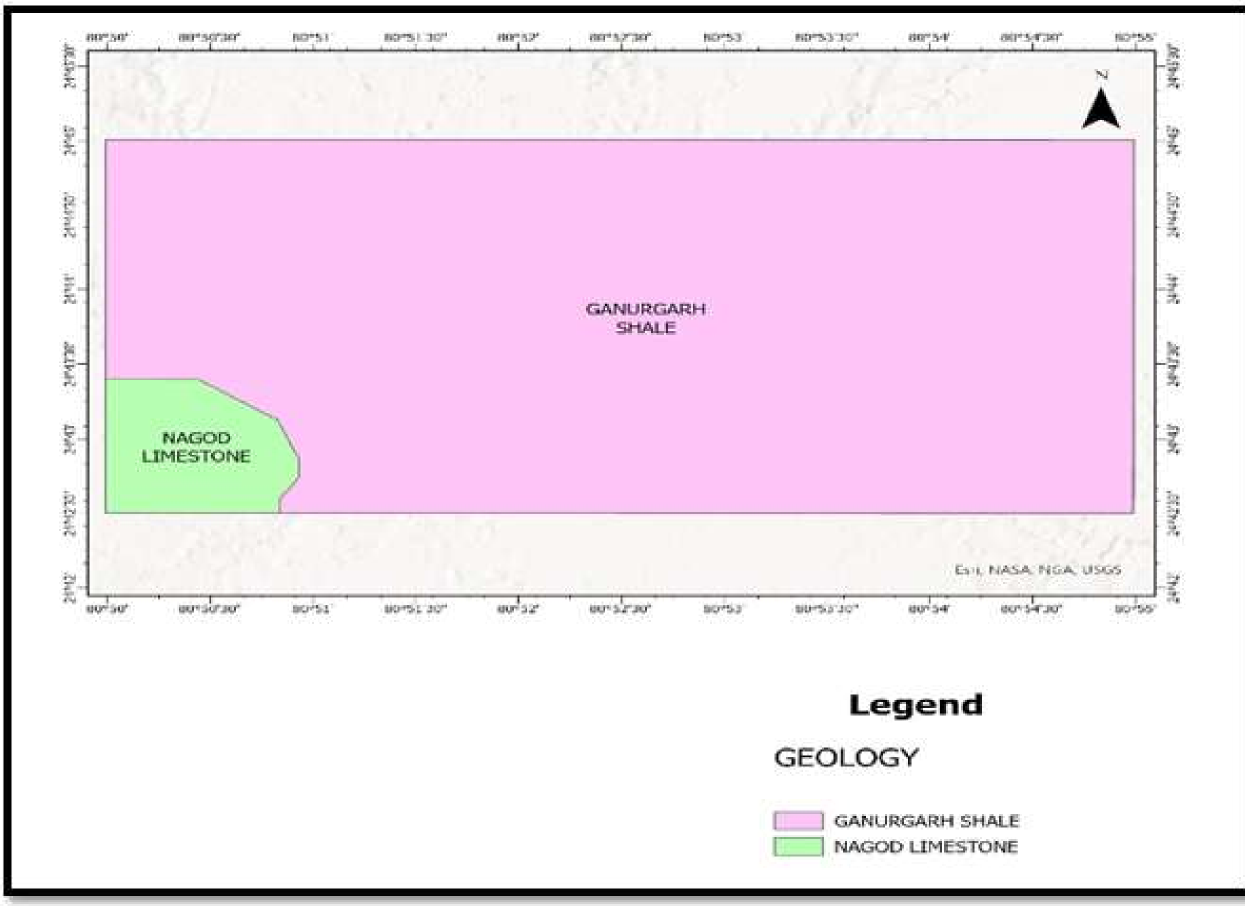
OBJECTIVE AND METHODOLOGY

The data sources required for morphometric analysis are Survey of India toposheets and digital elevation models (DEMs) that have been used to obtain various morphometric parameters: linear aspect, aerial aspect and relief aspect. This study has been done using Arc GIS software. Geological, Geomorphological, and drainage map has been created using ArcGIS.

GEOLOGY (Fig. 2)

Geologically the study of the Simrawal river basin is comprised of two major geological formations, the

Ganurgarh shale and Nagod Limestone. Still, in the Simrawal river basin, Ganurgarh shale covers a significant portion of the region. Which covers an area of 36.62 square km of the study area. The study area is an inter-stream region of the Tons River and Satna River a major part of the study area. The research area's geological structure is not uniform. The main rock type in the river basin is shale with a fine-grained texture. Nagged Limestone is present in the south-west region of the study area which covers an area of 2.27 square km. The permeability of shale is low whereas in limestone the permeability is high due to the presence of faults and joints (secondary structure). As a result, limestone can recharge more ground water than rock.



GEOMORPHOLOGY (Fig. 3)

Geomorphology is the systematic examination of landforms and the study of the mechanisms governing their evolution. Geomorphology, according to Bloom (2012), is the scientific study of landscapes and the processes that give rise to them. Geomorphology is described as "a discourse on earth shapes" by Thornbury (2004). He describes geomorphology as the study of landforms in other terms. The geomorphological and geological landscapes of the current research area are displayed in a panoramic mosaic. These upland highlands are the source of Sarawak tributaries that deposit alluvium, especially older alluvium, in the region's core area. Alone hills, buttes, and mesas are located in the pediment region of the plateau, as are frequent geological features like cuesta and hogbacks, along the escarpment. On the Rewa plateau, in the northeastern part of the research area, are the same hilly formations. The tributaries such as the Saathiya Nala, Chokar Nala and the Lagana Nala of the Simrawal river come from uplands and form sub dendritic to dendritic drainage patterns. The existence of these springs in both highlands is further confirmed by the area's topographical maps. Most tributaries also create asymmetrical, elongated sub-watersheds since the Simrawal basin is asymmetrical and has an elongated shape.

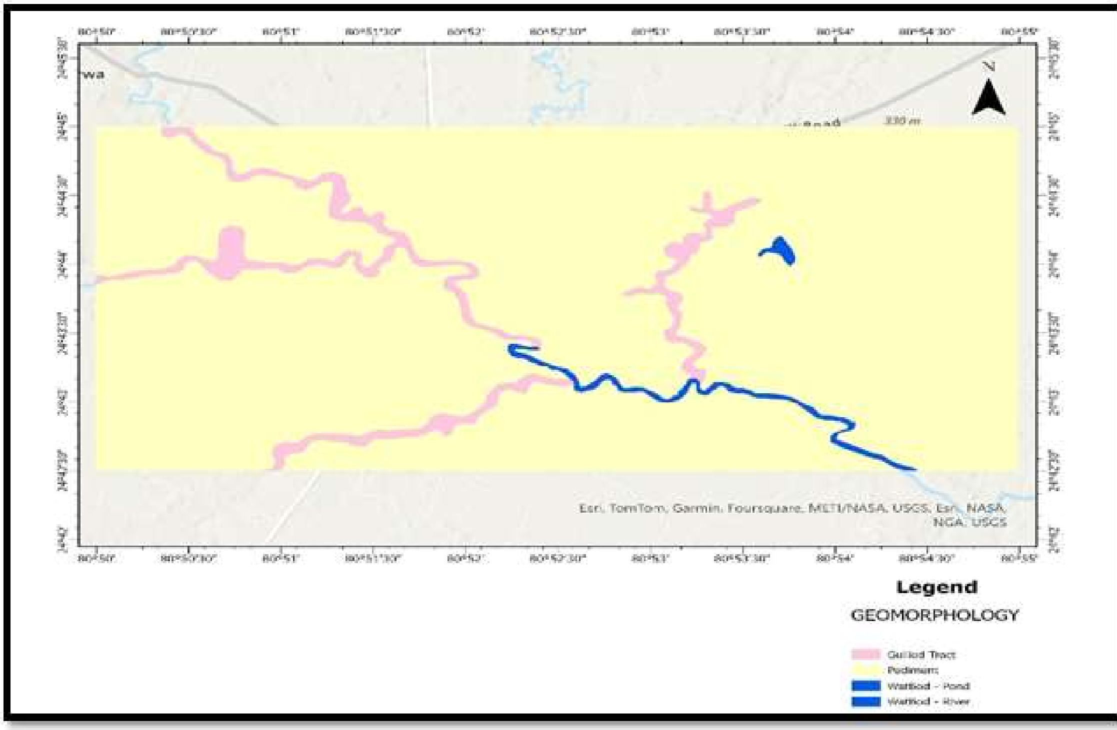


Fig. 3: Geomorphology map of the study area

MORPHOMETRIC ANALYSIS

Many morphometric parameters have been computed and analysed for the research region. The basin has a perimeter of around 26.08 km and an area of roughly 38.88 sq km. Table 1 displays the total number of first, second, third, fourth, fifth, and sixth. First order streams have the maximum number, while sixth order streams have the lowest number. Table 2 presents linear characteristics: mean stream length, bifurcation ratio, and the stream length. The longest length of the first order stream is approximately 6.54 km. The Table 3 displays Drainage Density about 0.42, Drainage Texture about 2.68, and Mean Bifurcation Ratio about 2.92.

Stream order	Sum of Stream order	Count of Stream order
1st order	6.54	51
2nd order	6.43	10
3rd order	0.31	2
4th order	2.71	4
5th order	0.26	2
6th order	0.17	1
Grand Total	**16.41**	**70**

Stream order	Mean Stream Length (Lsm)	Stream Length Ratio (RL)	Bifurcation Ratio
1st order	0.13	-	-
2nd order	0.64	0.98	5.10
3rd order	0.16	0.05	5.00
4th order	0.68	8.68	0.50
5th order	0.13	0.09	2.00
6th order	0.17	0.65	2.00

Mean Bifurcation Ratio (Rbm)	-	2.92
Drainage Density (Dd)	-	0.42
Drainage Texture (Dt)	-	2.68
Stream Frequency (Fs)	-	4.27
Circularity Ratio (Rc)	-	0.33
Constant of channel maintenance (C)	-	2.37
Length of overland flow (Lg)	-	1.18

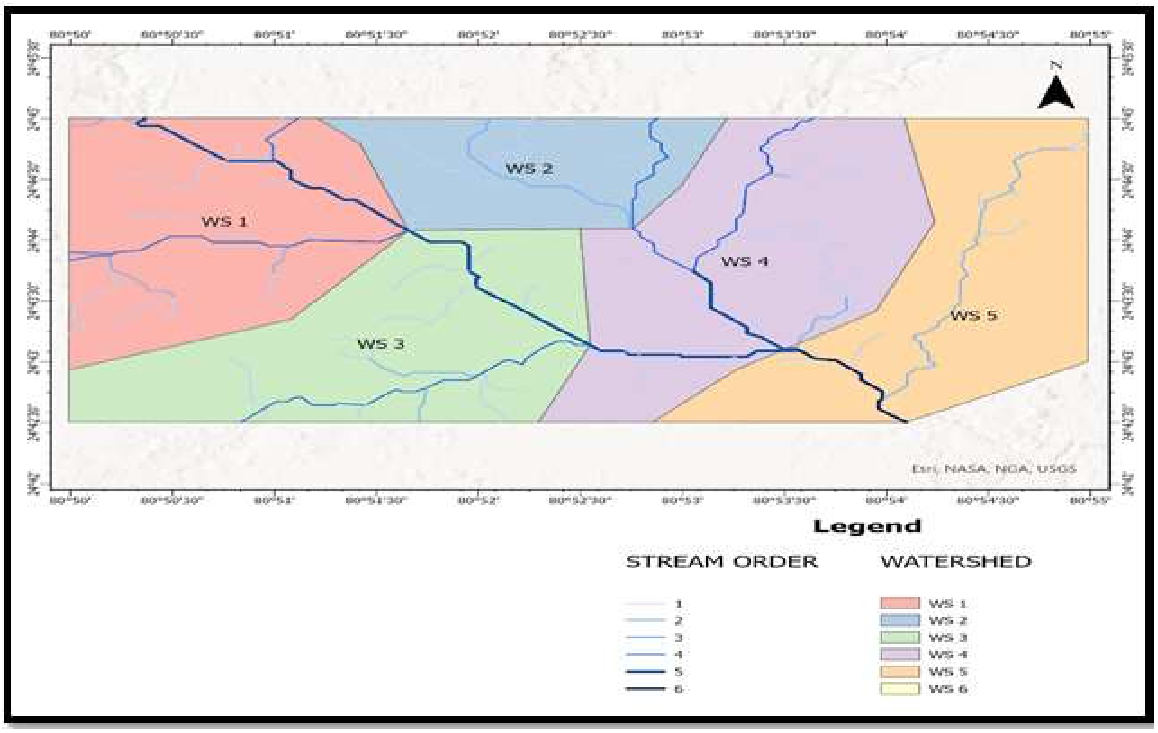


Fig. 4 : Drainage map of the study area

CONCLUSION

The hydrogeological study of the Simrawal River Sub-Basin in the Jaitwar area, Satna District, Madhya Pradesh, India, provides valuable insights into the groundwater dynamics, aquifer characteristics, and water quality in the region. The geological map of the area has been created. It has been found that the area has two geological formations: Ganurgarh shale and Nagod limestone. Geomorphologically area has gullied thrusts, pediment, river and ponds. Various maorphometric parameters has been determined by using DEM data in Arc GIS software. The findings contribute to a better understanding of groundwater resources and are essential for formulating sustainable water resource management strategies to address the challenges of groundwater depletion and contamination. The morphometric parameters helps in better understanding the nature of landforms and their processes, drainage pattern demarcations for basin area planning and management. So it is concluded that there is sufficient scope to save the rain water by constricting recharge structures. The recharge structures such as Contour bund, Check dam, Nala bund, Percolation pond have been suggested to enhance the ground water resource of the area.

REFERENCES

- Agarwal, S., Patil, J.P., Goyal, V.C. and Singh, A., (2019). Assessment of water supply–demand using water evaluation and planning (WEAP) model for Ur River watershed, Madhya Pradesh, India. *Journal of The Institution of Engineers (India): Series A*, *100*, pp. 21-32.

- Anand, Beena, Sharma, S.N., and Ratan, Murari (2015). Long term studies on the Impact of Sediments and Effluents of A Chemical factory on The health and Water Quality of Rihand Dam Project, UP. *Water and Environment, Excellent Publishers New Delhi, pp 10-16.*
- Nikita Shivhare, Prabhat Kumar Singh Dikshit, Shyam Bihari Dwivedi, (2018). A Comparison of SWAT Model Calibration Techniques for Hydrological Modeling in the Ganga River Watershed, Engineering, Volume 4, Issue 5, 2018, Pages 643-652, ISSN 2095-8099.
- Palma, Adriana, Alfonso Rivera, and Rafael Carmona. (2022). "A Unified Hydrogeological Conceptual Model of the Mexico Basin Aquifer after a Century of Groundwater Exploitation" *Water* 14, no. 10: 1584. https://doi.org/10.3390/w14101584.
- Pande, C., Moharir, K. and Pande, R., (2021). Assessment of morphometric and hypsometric study for watershed development using spatial technology–a case study of Wardha river basin in Maharashtra, India. *International Journal of River Basin Management*, *19*(1), pp. 43-53.
- Pandey, V.V., Singh, K.M., Ahmad, N. and Srivastava, S.K., (2022). Challenges and issues of groundwater management in India. *CURRENT SCIENCE*, *123*(7), p. 856.
- Patel, Sarvesh Kumar et. al. (2020). Assessment of Irrigation Water Quality Around Majhagawan Area, Satna District Madhya Pradesh; Shodh Chetana, G.H. Publication Prayagrai, Vol. 4, PP 95-99.
- Rajasekhar, M., Raju, G.S. and Raju, R.S., (2020). Morphometric analysis of the Jilledubanderu river basin, Anantapur District, Andhra Pradesh, India, using geospatial technologies. *Groundwater for Sustainable Development*, *11*, p. 100434.
- Rajaveni, S.P., Brindha, K. and Elango, L., (2017). Geological and geomorphological controls on groundwater occurrence in a hard rock region. *Applied water science*, *7*, pp. 1377-1389.
- Saha, A. and Singh, P., (2017). Drainage morphometric analysis and water resource management of Hindon river basin, using earth observation data sets. *International Journal of Interdisciplinary Research (IJIR)*, *3*(4), pp. 2051-2057.
- Saranya, T., Saravanan, S. (2023). Assessment of groundwater vulnerability using analytical hierarchy process and evidential belief function with DRASTIC parameters, Cuddalore, India. *Int. J. Environ. Sci. Technol.* **20**, 1837–1856 https://doi.org/10.1007/s13762-022-03944-z
- Sharma, Brahmanand and Tiwari, Rabindra Nath (2020). Sedimentological Characters and Economic Significance of Bhander Limestone of Amanganj area, Panna District Madhya Pradesh, India; Shodh Chetana, G.H. Publication Prayagraj, Vol.4, PP 100-107.
- Sharma, S.K., Gajbhiye, S. and Tignath, S., (2015). Application of principal component analysis in grouping geomorphic parameters of a watershed for hydrological modeling. *Applied Water Science*, *5*, pp. 89-96.
- Shrivastava, Prashant (2015). Water Pollution Study of Somni Stream Watershed Patan Block, Durg District, Chhattisgarh, India. *Water and Environment, Excellent Publishers New Delhi, pp 86-93.*
- Shukla, S., Gedam, S. (2019). Evaluating Hydrological Responses to Urbanization in a Tropical River Basin: A Water Resources Management Perspective. *Nat Resour Res* **28**, 327–347 https://doi.org/10.1007/s11053-018-9390-7
- Shukla, Sandeep, Dubey D.P. and Pandey, G.P. et. al (2014). Nitrate and Fluoride in Groundwater Sample for Rampur Baghelan area of Satna District, Madhya Pradesh. *Watershed Management for sustainable Development, Excellent Publishers New Delhi, pp 167-169.*
- Singh, A.N., Singhal, Anupam, Devi, Anuradha (2016). Assessment of Groundwater Salinity Using GIS and Vulnerability of Population; A Study of Shekhawati Region of Rajasthan, India. *Recent Advancements in Mineral and Water Resources, Excellent Publishers New Delhi, pp 147-152.*
- Singh, P., Gupta, A. and Singh, M., (2014). Hydrological inferences from watershed analysis for water resource management using remote sensing and GIS techniques. *The Egyptian Journal of Remote Sensing and Space Science*, *17*(2), pp. 111-121.
- Singh, Priyamvada and Singh, Sudhir Kumar (2016). Identification of Groundwater Conditions Using Geoelectrical Resistivity Technique. *Recent Advancements in Mineral and Water Resources, Excellent Publishers New Delhi, pp 118-125.*

- Singh, R.B., Rathore, N., Mishra, P., Singh, U., Pysai, S.K. and Dubey, A., (2019). Rainfall variability analysis of Rewa district in Madhya Pradesh. *Bull. Env. Pharmacol. Life Sci*, *8*, pp. 74-77.
- Singh, Smita, Singh, A.K., Chauhan, A.S., Tiwari, R.K. et al. (2015). Water quality: A need for Sustainable Agriculture Development. *Water and Environment, Excellent Publishers New Delhi, pp 58-65.*
- Singh, Yamuna and Dubey, D.P. (2014). Hydrogeology of the Rewa Region, Central India. *Watershed Management for sustainable Development, Excellent Publishers New Delhi, pp 122-134.*
- Sinha, L., Rathore, R. and Jain, U., (2015). Watershed delineation of narmada Basin-Indira sagar dam to maheshwar dam of Madhya Pradesh. *Int. J. Eme Tec. Adv. Eng*, *5*(8), pp. 307-312.
- Solodovnikov, D.A., Shinkarenko, S.S. (2020). Present-Day Hydrological and Hydrogeological Regularities in the Formation of River Floodplains in the Middle Don Basin. *Water Resour* **47**, 977–986 https://doi.org/10.1134/S0097807820060135.
- Surinaidu, L., Rao, V.G. and Ramesh, G., (2013). Assessment of groundwater inflows into Kuteshwar Limestone Mines through flow modeling study, Madhya Pradesh, India. *Arabian Journal of Geosciences*, *6*, pp. 1153-1161.
- Suryavanshi, S., Pandey, A. and Chaube, U.C., (2017). Hydrological simulation of the Betwa River basin (India) using the SWAT model. *Hydrological Sciences Journal*, *62*(6), pp. 960-978.
- Talati, J. and Kumar, M.D., (2019). From watershed to sub-basins: Analyzing the scale effects of watershed development in Narmada River basin, central India. In *Current Directions in Water Scarcity Research* (Vol. 1, pp. 87-101). Elsevier.
- Tiwari, P., Pandey, G.P., Shrivastava, R., Tiwari, V.K. and Mishra, U.K., (2014). Hydrogeochemical Studies of Groundwater around Churhat Area, Sidhi District, Madhya Pradesh, India. *Watershed Management for Sustainable Development*.
- Tiwari, Praveen, Pandey, G.P. and Shrivastava, Ramesh (2014). Hydrogeochemical Studies of Groundwater around Churhat Area, Sidhi District, Madhya Pradesh, India. *Watershed Management for sustainable Development, Excellent Publishers New Delhi, pp 36-43.*
- Tiwari, R.K., Tripathi, S.K. and Khan, I.M. et al. (2014). Management Techniques of Water and Nutrient for Rice Production. *Watershed Management for sustainable Development, Excellent Publishers New Delhi, pp 92-96.*
- Tiwari, R.N. (2014). Assessment of Groundwater Quality for Drinking use and Evolution of Hydrochemical Facies in the Upper Catchment of Beehar River Basin, Madhya Pradesh, India. *Watershed Management for sustainable Development, Excellent Publishers New Delhi, pp 164-166.*
- Tiwari, R.N. (2014). Hydrochemical Facies, Quality and Pollution Potential studies of Groundwater, Rewa City Central India. *Watershed Management for sustainable Development, Excellent Publishers New Delhi, pp 16-26.*
- Tiwari, R.N. and Dwivedi, R.,(2015). Assessment of Groundwater Quality of Tilkhan Area, Baikunthpur, Rewa District, MP. *Water and Environment*.
- Tiwari, R.N. and Kushwaha, Vikash k. (2018). Groundwater Potential Zone Mapping in and Around Satna City M.P. India using an Integration of Geospatial Approach. *Natural Resources, Environment and Health. Excellent Publishers, New Delhi. pp 58-67*
- Tiwari, R.N. and MISHRA, U., (2011). Morphometric Analysis of Sirmour Area, Rewa District, Madhya Pradesh using Remote Sensing and GIS. *Intnational Jour of eart Sciences and Engineering*, *4*(3), pp.512-521.
- Tiwari, R.N. and Mishra, U., (2012). Groundwater quality and pollution potential studies around Baikunthpur area, Rewa District, Madhya Pradesh, India. *International Journal of Water and Environmental Engineering*, *4*(12), pp.377-385.
- Tiwari, R.N. and Singh, Rakesh (2014). Innovative Hydogeological Approach in Eradicating High Fluoride Content in Groundwater - A Major Solution to Drinking Water Challenge of Fluoride Affected Granitic Region of M.P. *Watershed Management for sustainable Development, Excellent Publishers New Delhi, pp 44-51.*
- Tiwari, R.N., Dwivedi, R. and Shukla, S., (2014). Irrigation Water Quality Assessment in and Around Maihar Area Satna District (MP). *Watershed Management for Sustainable Development*.
- Tiwari, R.N., Kushwaha, V.K. (2020). An Integrated Study to Delineate the Groundwater Potential Zones Using Geospatial Approach of Sidhi Area, Madhya

Pradesh. *J Geol Soc India* **95**, 520–526 https://doi.org/10.1007/s12594-020-1471-7.

- Tiwari, R.N., Kushwaha, V.K. (2021). Watershed Prioritization Based on Morphometric Parameters and PCA Technique: A Case Study of Deonar River Sub Basin, Sidhi Area, Madhya Pradesh, India. *J Geol Soc India* **97**, 396–404 https://doi.org/10.1007/s12594-021-1697-z
- Tiwari, R.N., Mishra, U.K., Tiwari, R.K., Mishra, A., Mishra, A. and Sharma, B., (2015). Irrigation Water Quality of Groundwater around Jawa Area, Rewa District, Madhya Pradesh, India. *Water and Environment*.
- Tiwari, Rabindra N. (2015). Groundwater Quality Studies in Naraini Watershed, Rewa District, Madhya Pradesh, India. *Water and Environment, Excellent Publishers New Delhi, pp 131-137.*
- Tiwari, Rabindra N. and Singh, Shrutika (2016). Assessment and Management of Groundwater Resources around Govindgarh Area, Rewa District, Central India. *Recent Advancements in Mineral and Water Resources, Excellent Publishers New Delhi, pp 142-146.*
- Tiwari, Rabindra N., and Dwivedi, Rashmi (2015). Assessment of Groundwater Quality of Tilkhan Area, Baikunthpur, Rewa District, M.P. *Water and Environment, Excellent Publishers New Delhi, pp 112-117.*
- Tiwari, Rabindra N., Pandey, G.P. et al. (2016). Assessment of Groundwater Quality, Drinking and Irrigation Studies of Rampur Naikin Block, Sidhi District, Madhya Pradesh. *Recent Advancements in Mineral and Water Resources, Excellent Publishers New Delhi, pp 126-131.*
- Tiwari, Rabindra Nath (2018). Hadrochemical Facies and Groundwater Quality Assessment for Drinking Purpose: A Case Study from Silpari Subwatershed, Rewa District, Central India. *Natural Resources, Environment and Health, Excellent Publishers New Delhi, pp 12-19.*
- Tiwari, Rabindra.N., Mishra, R.P., Tiwari,R.k. et al. (2016). Water Level Fluctuations and Suitability of Groundwater for Drinking Purpose, Teonther Area, Rewa District Madhya Pradesh. *Recent Advancements in Mineral and Water Resources, Excellent Publishers New Delhi, pp 167-170.*
- Tiwari, Sars, Mishra, U.K., Tripathi, A.K. et al. (2016). Hydrogeological Study of Ken River Basin Central India. *Recent Advancements in Mineral and Water Resources, Excellent Publishers New Delhi, pp 162-166.*
- Tripathi, A.K. et.al. (2020). Assessment and Management of Groundwater Resources of Gohparu Area, Shahdol District Madhya Pradesh, India; Shodh Chetana, G.H. Publication Prayagraj, Vol.4, PP 132-136.
- Tripathi, A.K., Mishra, U.K., Mishra, A., Tiwari, S. and Dubey, P., (2012). Studies of hydrogeochemical in groundwater quality around Chakghat area, Rewa District, Madhya Pradesh, India. *Int J Mod Eng Res Technol*, 2(6), pp.4051-4059.
- Tripathi, Shashikant, Sengupta, H.P. and Tripathi, Shashank (2014). Village Level Watershed Based Water Security Plan Using Geopatial Technology; A Case Study of Gore Mau Kalamn of Naraini Block of Banda District, U.P. *Watershed Management for sustainable Development, Excellent Publishers New Delhi, pp 97-109.*
- Wang, Xiujie, Pengfei Zhang, Lüliu Liu, Dandan Li, and Yanpeng Wang. (2019). “Effects of Human Activities on Hydrological Components in the Yiluo River Basin in Middle Yellow River” *Water* 11, no. 4: 689. https://doi.org/10.3390/w11040689
- Yadav, S.K., Singh, A.K. et al. (2015). Strategies and Innovations for Improving the Water Quality. *Water and Environment, Excellent Publishers New Delhi, pp 118-126.*
- Zakwan,M., Ahmad, Z. (2021). Trend analysis of hydrological parameters of Ganga River. *Arab J Geosci* **14**, 163. https://doi.org/10.1007/s12517-021-06453-4.

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Physical and Chemical Characterization of Fly-Ash and Overburden Soil for Metal Recovery

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ABSTRACT

Large amount of overburden soil and fly-ash produced from mines, thermal power plants pose huge concern for country due to its detrimental environmental impact. Ash and overburden soil generated from different mines are frequently utilized as geo-material where its spontaneous behaviour and characteristics is necessary. Fly-ash is primarily a by-product of coal mines, thermal power plants which severely affects water, air and land. Overburden soil is the soil layer which are removed during ore mining. Overburden soil usually considered as waste leading to environmental pollution and soil degradation. In this study overburden soil and fly ash collected from various mines are analysed for physical and chemical characteristics. The physical properties like specific gravity, bulk density, grain size distribution, porosity has been determined. Specific gravity of overburden soil from several mine samples ranges around 1.9-2.7g/cm^3. Chemical characterization of both ash and overburden soil has also been assessed. The physical, chemical and mineralogical properties of fly ash and combined with its readily availability make this an appealing raw material for several applications. With an aim to explore the potential use of fly ash and overburden soil, it is necessary to observe its characteristic properties. This study also highlights the characterization of fly ash and overburden soil by various techniques, including fourier transform infrared spectroscopy (FTIR), X-ray fluorescence (XRF), X-ray diffractometer (XRD) and strive to correlate the same with its potential applications. XRF analysis indicate the presence of SiO_2, Al_2O_3, TiO_2 and Fe_2O_3 while FTIR analysis suggest the presence of functional groups like S=O, O-H, C=O, C-F and O=C=O. Water samples collected from various mines were also tested for different physical-chemico analysis such as pH, salinity, temperature, conductivity. pH of different mine samples lies between 6.2-6.9 while temperature varies from 27°C-31°C.

Keywords: Chemical characterization, Fly-Ash, Overburden soil, Physical properties, Specific gravity.

INTRODUCTION

Recovery of metals from various waste deposits is a promising alternative to minimise negative impact of waste content on humans and environment and to supply essential materials alleviating the dependence on primary ore mining and resource depletion (Kinnuen and Hedrich, 2023). Due to the rising metal demand, rapid release of metal raises concern for not only human health and environment but also accelerates the risk of depletion of metal resources. Metal recovery popularly carried out from primary minerals (Brar et al., 2022) but these primary mineral reservoirs are gradually exhausted due to long ore mining and sometimes cost and difficulty during mining are also rising (Rai et al., 2021). In the past when dumping waste is not well maintained and production was low during that time recovery of metals from mining waste and polluted soil is an excellent approach. Acid leaching and alkali leaching were generally utilized for recovering valuable elements from fly-ash (Xing et al., 2023). Suffia et al., (2023) reported recovery of metals from e-wastes in a sustainable way using eco-friendly and green solvent DES to reduce the depletion of metal reservoir and alleviate the harmful affect pose by e-waste. Chen et al., (2023) investigated metal recovery from industrial wastewater using combine deposition strategy for effectively minimising metal pollution and promoting resource utilisation. Metals such as chromium has been recovered utilising bacteria from fly-ash (Dokania et al., 2023). Fly-ash is primarily a by-product produced from coal mines, thermal power plants across the world. Around 300 million tonnes of fly-ash generated annually, of which only 10-20% is used (Dan et al., 2021). Highest production rate of fly-ash has been observed in countries such as China, Europe, India, USA, South Africa and Australia (Authority CE, 2018).

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Fly-ash generation is gradually rising each year occupying huge space for disposal and posing detrimental impact on environment. Overburden soil is the upper soil layer that are removed during coal mining. Significant amount of overburden soil is released due to surface mining. Owing to space constraints and accessibility, huge quantity of overburden soil dumped at great heights and in vast areas of usable land close to mining area adversely affecting mining operation. Overburden soil possess wide range of particles such as silt, clay, rocks making the open dumping area unsafe and harmful for environment. Proper disposal of fly-ash and overburden soil and efficient recovery of metals are two major challenges faced by mining industry. Several efforts have been done previously to address the issue of disposal and utilisation of fly-ash and overburden soil as construction material, building material, soil stabiliser, for concrete production, in agriculture and so on. But recovery of metals from fly-ash and overburden soil still not been explored properly.

Fly-ash and overburden soil known to serve as source of valuable elements and heavy metals which can be further recovered and recycled. Major metals such as aluminium (Al), iron (Fe), magnesium (Mg), calcium (Ca), lithium (Li), gallium (Ga), copper (Cu), cadmium (Cd), lead (Pb), zinc (Zn), arsenic (As), Tin (Sb), numerous inorganic compounds like SiO_2, TiO_2, Al_2O_3 and certain trace elements are found in fly-ash and overburden soil. Previous studies indicate presence of 17 rare earth elements like scandium (Sc), lanthanum (La), terbium (Tb), gadolinium (Gd), dysprosium (Dy) and europium (Eu) in fly-ash (Sahoo et al., 2016). Physical and chemical properties of coal fly-ash from nine thermal power plants were extensively studied for recovery of rare earth elements by Jeong et al. (2015). Recovering and recycling these metals will not only eradicate the shortage of metal resources but also convert harmful waste to solid waste (Min et al., 2018).

With depleting metal resources and increasing demand recovery of these metals from fly-ash and overburden soil will be a promising solution as well as challenging for the scientists. This study aims to explore the recovery of metals from overburden soil and fly-ash for which physical and chemical characterization of fly-ash and overburden soil is essential. The physical, chemical and mineralogical properties of fly ash and combined with its readily availability make this an appealing raw material for several applications. So, this study highlights the physical and chemical characterization of fly-ash and overburden soil. Further extensive studies can be carried out for eco-friendly and sustainable strategies to recover metals from fly-ash and overburden soil. In this way, fly-ash and overburden soil in future not only will utilize to recover metals, but also to preserve mineral resources paving way to mitigate environmental risk and sustainable utilisation of resources.

MATERIALS AND METHODOLOGY

Materials

Fly-ash and overburden soil samples were collected from gevara, chal, kushmunda, NTPC, CSEB mines and stored at room temperature for further analysis. Water samples were collected from the same and further tested for physico-chemical parameters.

Methodology

XRF analysis

First, three samples including flyash and overburden soil were dried in hot air oven then fine powdered using pestle and mortar and 10g of each sample were further processed for XRF analysis using model ZSF-Primus IV.

FTIR analysis

First, all the samples including flyash and overburden soil were dried in hot air oven then fine powered using pestle and mortar and very minute quantity of each sample were analysed for FT-IR analysis (Model-Alpha-II). The FT-IR analysis was performed in the range of 500–4000 cm^{-1}.

Physico-chemical analysis

All the water samples from different mines were analysed for pH, pH sensor (mVpH), dissolved oxygen concentration (% & ppm), oxidation-reduction potential (ORP), electrical conductivity (µS/cmA or µS/cm), resistivity (M&!.cm), pressure (psi), temperature (ºC), total dissolved solid (Tds) and salinity (PSU) using Hanna (HI98194) pH/EC/DO multiparameter.

Physical characterization

Specific gravity

First all samples were dried in hot air oven then fine powdered using pestle and mortar and 20g of each sample were further assessed for specific gravity. Specific gravity for each sample is determined by using below formula:

$$\text{Specific gravity} = \frac{\text{Weight of sample \& kerosene with bottle \& lid}}{\text{Weight of kerosene with bottle \& lid-weight of empty bottle \& lid}}$$

RESULT AND DISCUSSION

FTIR analysis

FTIR analysis has been done to predict the presence of functional groups. It works on the absorption phenomenon that occurs at certain wavenumber because of particular chemical bond, physico-chemical nature of molecules, presence of organic and crystalline material (Kumar et al., 2019). From figures, it was detected the occurrence of broad absorption peaks of OH stretching vibration between 3600-3000cm^{-1} in fly-ash manikdur, fly-ash NTPC and fly-ash Shiv samples. Certain medium and small sharp peaks seen in Gevara and Deepika OC mine sample are also OH vibrations. NH stretching occurs at 3450cm^{-1} in Deepika OC mine sample. Some peaks are seen around 1600-1000cm^{-1} that may be vinylic or aromatic C=C stretching. The peak at 1690-1700 cm^{-1} may be C=C or benzene ring. The functional group primarily constitute carboxylic acid, ether and carbonyl groups which might arise in mines and fly-ash sample due to breakdown of plant material (Rawat & Yadav, 2020). The peak at 1200 cm^{-1} is observed to be S=O asymmetric vibration in fly-ash CSEB. Results of FTIR analysis of all the samples were found similar with the other studies reported in the literature.

Table1: Vibration and wavenumber of FTIR Analysis

Sl no	Vibrations	Wavenumber
1.	OH vibration	3600-3000cm^{-1}
2.	NH vibration	3450cm^{-1}
3.	C=C stretching vibration	1600-1000cm^{-1}
4.	C=C or benzene vibration	1690-1700cm^{-1}
5.	S=O vibration	1200cm^{-1}

XRF analysis

XRF analysis of various fly-ash and mine samples generate peaks for certain detectable elements such as Ca, K, Cl, S, P, Si, Al, Mg and F. XRF results shows Al_2O_3 composition of gevara, kushmunda & fly-ash manikdur ranges around 25%-33%, Fe_2O_3 ranges from 3%-5.1%, TiO_2 content around 1.5%-3.8% while SiO_2 content lies in the range of 55%-62%. Different mine and fly-ash samples reveals that SiO_2 (55%-62%), Al_2O_3 (25%-33%) content found identical to portable cement and fly-ash can be used as construction material (Nordin et al., 2016).

Table 2: Composition and percentage of XRF analysis

Sl no	Composition	Percentage
1.	Al_2O_3	25%-33%
2.	Fe_2O_3	3%-5.1%
3.	TiO_2	1.5%-3.8%
4.	SiO_2	55%-62%

Physico-chemical analysis

Essential parameter to detect corrosiveness of water is pH. Lower the pH higher the corrosive nature of water. All the mine and fly-ash samples having pH ranges around 6.27-7 indicating alkalinity. Fly ash is usually alkaline because of low sulphur content and presence of calcium hydroxide, calcium carbonates, magnesium hydroxide and magnesium carbonates. pH also positively correlated with electrical conductivity and alkalinity. Electrical conductivity of mine and flyash samples indicate presence of various ions and salt content. Total dissolved solid of all samples ranged between 65 ppm-590 ppm; temperature varied from 25°C-34°C; dissolved oxygen lies around 0.40 ppm-0.49 ppm; electrical conductivity found between 140μS/cm-1390μS/cm; pressure varies from 14.250 psi-14.257 psi; resistivity found in the ranged from 0.0005-0.0015 MΩ.cm; salinity lies between 0.04-0.72.

Table 3: Analysis of physico-chemical parameters of mine samples

Sl no	Physico-chemical parameters	Range
1.	pH	6.27-7
2.	Electrical conductivity	140-1390 µS/cm
3.	Total dissolved solid	65-590 ppm
4.	Temperature	25ºC-34ºC
5.	Resistivity	14.250-14.257
6.	Pressure	0.005-0.0015Ω
7.	Salinity	0.04-0.72
8.	Dissolved oxygen	0.40-0.49 ppm
9.	Specific gravity	1.78-3g/cm^3

Specific gravity of mine and fly-ash samples

Specific gravity is one of the necessary physical properties required for the utilisation of fly-ashes for geotechnical and other applications. Specific gravity of mine and fly-ash samples ranged between 1.78 g/cm^3-3 g/cm^3.

CONCLUSION

Rising demand of metals cause continuous extraction of metals from mines depleting metal resources and posing huge threats to human health and environment. Disposal of fly-ash and overburden soil also have detrimental impact on environment. Previous studies indicate the occurrence of various major elements, trace elements and rare earth elements in fly-ash and overburden soil. Fly-ash and overburden soil as building material, soil stabiliser and construction material were usually utilised but for metal recovery still not explored properly. Utilizing fly-ash and overburden soil for metal recovery will be a promising and high-value approach as it not only will utilize to recover metals, but also to preserve mineral resources paving way to mitigate environmental risk and sustainable utilisation of resources.

REFERENCES

1. Authority CE (2018) Fly ash generation at coal/lignite based thermal power stations and its utilization in the country, New Delhi, India
2. Brar, K.K., Magdouli, S., Othmani, A., Ghanei, J., Narisetty, V., Sindhu, R., Binod, P., Pugazhendhi, A., Awasthi, M.K. and Pandey, A., 2022. Green route for recycling of low-cost waste resources for the biosynthesis of nanoparticles (NPs) and nanomaterials (NMs)-A review. Environmental Research, 207, p.112202.
3. Chen, L., Zhang, G., Liu, H., Miao, S., Chen, Q., Lan, H. and Qu, J., 2024. Toward Efficient Metal Recovery from Industrial Wastewater: An Electrochemical System in Potential Oscillation and Turbulence Mode. Engineering.
4. Dan, A.K., Bhattacharjee, D., Ghosh, S., Behera, S.S., Bindhani, B.K., Das, D. and Parhi, P.K., 2021. Prospective utilization of coal fly ash for making advanced materials. In Clean Coal Technologies: Beneficiation, Utilization, Transport Phenomena and Prospective (pp. 511-531). Cham: Springer International Publishing.
5. Dokania, P., Maity, S., Nayak, T., Jayantu, S. and Sarkar, A., 2023, October. Microbial and Biosorbent-Mediated Hexavalent Chromium Removal from the Tailing Waters Released from Chromite Mines. In *Asian Mining Congress* (pp. 337-344). Cham: Springer Nature Switzerland.
6. Jeong, J. and Kim, B.S., Shin, D., Park, J., 2015. A biological cyanide production and accumulation system and the recovery of platinum-group metals from spent automotive catalysts by biogenic cyanide. Hydrometallurgy, 158, pp.10-18.
7. Kinnunen, P. and Hedrich, S., 2023. Biotechnological strategies to recover value from waste. Hydrometallurgy, 222, p.106182.
8. Min, Y., Liu, C., Shi, P., Qin, C., Feng, Y. and Liu, B., 2018. Effects of the addition of municipal solid waste incineration fly ash on the behavior of polychlorinated dibenzo-p-dioxins and furans in the iron ore sintering process. Waste Management, 77, pp.287-293.
9. Nordin, N., Abdullah, M.M.A.B., Tahir, M.F.M., Sandu, A.V. and Hussin, K., 2016. Utilization of Fly Ash Waste As Construction Material. International Journal of Conservation Science, 7(1).
10. Rawat, P., Yadav, S., Kumari, S., Sharma, P., Kumar, J., Vij, A., Kumar, S., Sinha, C., Bhattacharya, J., Srivastava, C.M. and Majumder, S., 2020. A novel synthesis of the graphene oxide-silver (GO-Ag) nanocomposite for unique physiochemical applications. ACS omega, 5(10), pp.5041-5047.
11. Sahoo, P.K., Kim, K., Powell, M.A. and Equeenuddin, S.M., 2016. Recovery of metals and other beneficial products from coal fly ash: A sustainable approach for fly ash management. International Journal of Coal Science & Technology, 3(3), pp.267-283.
12. Suffia, S. and Dutta, D., 2023. Applications of deep eutectic solvents in metal recovery from E-wastes in a sustainable way. Journal of Molecular Liquids, p.123738.
13. Xing, M., Wu, X., Li, Z., Zhang, F., Wang, Y. and Zhao, L., 2023. Rare earth element recovery and aluminum-rich residue production from high alumina fly ash by alkali pre-desilication enhance the mechanochemical extraction process. Process Safety and Environmental Protection, 175, pp.60-69.

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Impact of Diamond Mining on the Environment and Human Health, Central India

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ABSTRACT

There is no doubt that diamond mining operations has brought economic prosperity to the global mining communities. Diamond mining process from discovery to delivery is an environment friendly one, Diamond mining causes less pollution as compared to mining of other minerals. They have also brought in their wake environmentally-related problems. The mining and processing of natural diamond is associated with substantial impacts on the environment as well as on human health. Internationally most of miners did not have high commitment to providing environmental safety and security as well as maintenance of environmental sanity. Negative impact of mining activities on both water bodies and on health. Most of the respondents agreed that mining had affected their communities.

This research paper explores strategies to mitigate environmental pollution resulting from diamond mining activities. The various environmental aspects affected by diamond mining, including land degradation, air and water quality, and biodiversity. The paper analyzes existing regulations, technological advancements, and community involvement in sustainable practices. Recommendations include implementing eco-friendly mining technologies, strengthening regulatory frameworks, promoting responsible sourcing, and fostering community engagement for sustainable development.

Water is an inherent part of all forms of life on our planet, sustaining humans, animals, and vegetation. Hence these points highlight the urgency in safeguarding it against such detrimental effects while discussing potential solutions later down the line.

Keywords: - Diamond, Mining, Environment and Human, Health, Central India

INTRODUCTION

There have been numerous descriptions of the history of diamond discovery and mining, from its inception to present day and we shall not attempt to replicate this history. The interested reader is referred to reviews by Balfour (1987), Kirkley et al. (1992), Harlow (1998), Erlich and Hausel (2002) and Wilson et al. (2007a).

The first known mining of diamonds on an economic scale occurred in the Indian alluvial deposits, in the region of the Godavari and Krishna rivers, exploited since ~ 2000 B.C., the main recognized source of the world's diamonds was from India. The second significant discovery of diamonds that led to economic mining occurred in Brazil in This discovery was followed, in 1844, by the discovery of rich alluvial deposits in Bahia State (Brazil).

The subsequent identification of diamonds in South Africa led to a third global source of diamonds. The first diamond discovery in South Africa, which prompted the exploration rush that ultimately led to the finding of diamond in a primary source rock, took place in 1866 or 1867 when a diamond was discovered on the banks of the Orange River at the farm "De Kalk" (Janse 1995). diamonds had been mined in India well before that time, from what was later recognized as the Majhgawan olivine lamproite (Wilson et al. 2007a). Latest Primary Diamond discoveries in Central India at CG and MP (CG- Behradih, Payalikhand, Kodomali, JAngra, Tmple and Kusumbura and MP-Bakswaha, etc.)

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There, at Earth's surface, diamonds are found in primary magmatic deposits of kimberlite and olivine lamproite, or secondary deposits weathered from these primary sources.

In future government of India and state government is going to auction these mines to Diamond players; The goal of this chapter is to summarise the **Impact of Diamond mining on the environment and human health,** aspects of primary and secondary diamond deposits found at the Earth's surface.

Government should prepare a common SOP for EIA In diamond mining

THE DIAMOND MINING PROCESS

The four processes for mining diamonds carry the following significant short- and long-term dangers even though there is little associated environmental harm:

Open Pit Mining: In open pit mining, the ore beneath is first blasted after layers of rock and dirt are removed. The unprocessed material is placed onto trucks and driven to a crushing facility.

Underground Mining: Deep below the earth's crust, two levels of tunnels are excavated and joined by funnels, a process is sometimes known as "hard rock mining." Ore falls and lands in the second tunnel when it is blasted in the first. It is then grabbed by the hand and brought to the top.

Marine Diamond Mining: This method of mining for diamonds, which is among the most recent mining innovations, attaches crawlers to ships to collect seabed gravel that would subsequently be processed. Naturally, this happens in Namibia with access to water.

Alluvial (Artisanal) Mining: Since alluvial diamonds are frequently discovered in numerous beds, industrial mining of them is essentially impossible. Small-scale diamond extraction is therefore often carried out by hand, frequently without regulation.

ENVIRONMENTAL IMPACTS OF DIAMOND MINING

As demand grows, mining expands to distant locations, resulting in soil erosion, deforestation, forced migration, and the extinction of numerous animal species (all of which are delicately intertwined).

Soil Erosion& Land Disturbances (Blasting Excavation): Mining involves large volumes of earth and gravel, which are thoroughly washed during ore processing. Soil erosion is the washing away of the outermost layer of the Earth's crust, and certainly, with a process like diamond mining, in which layers of the soil is removed to reach out for the gemstone underground; soil erosion would be prevalent if not controlled. Nevertheless, soil erosion would occur if the mining site has been abandoned or no actions are taken to handle the aftereffects of diamond mining. Just like other forms of mining, diamond mining poses a threat to the land and its inhabitants. Diamond mining can lead to land disturbances like landslides, tremors, and even earthquakes. Why is that? Well, it's because the earth is being disturbed to access the precious stone.

Deforestation: Diamond mining involves clearance of land in order to mine and dig out land. This causes deforestation and the destruction of habitats. For example, trees and vegetation are removed to facilitate miners' access to areas that are abundant in diamonds. This leads to the degradation of crucial ecosystems and uprooting of trees and forests.

In Sierra Leone, areas that had previously been mined were thought to be permanently destroyed, but ecosystem restoration is becoming a more common method for repairing damaged ecosystems. On their initiative, private residents have planted trees, filled in trenches, and recovered topsoil.

Water Pollution: (Water Use& Alters the Course of Waterways, Depletion of Ground and Surface Water Sources) Diamond mining requires copious amounts of water for various activities, such as washing, and processing extracted ore. This frequently leads to the pollution of neighboring water sources with sediment, chemicals, and heavy metals. Consequently, it poses a threat to aquatic life and compromises the quality of drinking water available to local communities.

Additionally, water pollution from diamond mining may have an impact on residents' health. If the mining pits or sites are closed down, this will take place. As diamond reserves are depleted and formerly rich cropland is stripped of its topsoil, uninhabitable pits are left behind. Waterborne viruses, parasites, and mosquitoes thrive in stagnant water.

Depletion of Ground and Surface Water Sources by Acid Drainage &Toxic Chemicals: Acid mine drainage has been a problem since the beginning of the industrial age. Still, sulphuric acid remains a massive issue in areas where mining and mining waste has been historically common.

Health danger to populations during the rainy seasons. There complaints of animal deaths and human illnesses. According to environmentalists, dense medium separation procedures release the hazardous chemical ferrosilicon. When groundwater or surface water becomes contaminated from mining (like the acid mine drainage), it can cause health problems for animals that drink from these sources. In addition, if humans consume contaminated food or drink milk from cows that drink the same source, then this could lead to severe illnesses such as cancer and congenital disabilities. Acid mine drainage occurs when leftover mine material reacts with oxygen in the air, creating an acidic compound called sulfuric acid. This acid mine drainage can leech into and contaminate nearby water sources, making them undrinkable to both humans and animals. Acid mine drainage also affects soil quality, reducing crop yields and making it harder for farmers to grow food.

AIR QUALITY ISSUES ASSOCIATED WITH EXCAVATION ACTIVITIES (HARMFUL MINING DUST PARTICLES)

Air pollution is not a local problem. Once released, pollutants travel across borders causing widespread effects on human health and the global climate. Mined diamond activities involve heavy machinery and equipment, releasing pollutants into the atmosphere in the process. The use of diesel in generators and vehicles further adds to air pollution and contributes to greenhouse gas emissions.

Harmful Mining Dust Particles: Dust is one of the most harmful environmental polluting agents for human health. Mining creates a lot of dust. Delicate particle matter (pm) is especially problematic from around 2.7 pm to 10.30 pm. Fine PM is more severe due to its pulmonary effects, which may cause lung irritation. Dust also impacts visibility during the time of intense smog accumulation. In addition to increasing the risk of lung cancer and asthma in people, dust particles can affect plant life as well, decreasing crop yields and causing leaf disease in plants. To combat these issues, companies must take measures to reduce dust at their mines by using protective gear such as masks and respirators when working in dusty areas or by creating a comprehensive dust control plan for their business.

Fugitive Dust Emission monitored at Panna Diamond mining (DMP) site, Based on the activities in the mining particulate pollution was the critical pollutant. In data table Maximum level of dust were found 2 places near Dumper site and Jaw crusher and conveyer belt.

Emission of dust Panna mine site, (2022)			
Sno.	Location	Finding	Limits
1	View pont	117 μm³	1200 μm³
2	Near Dumper plateform	135 μm³	1200 μm³
3	Near HMSplant	115 μm³	1200 μm³
4	Coarse tailing Dump, Explosive magzine	106 μm³	1200 μm³
5	Majhgawan town ship	122 μm³	1200 μm³
6	Hinauta village	108 μm³	1200 μm³
7	Jaw crusher Plant, Conveyer Blt	136 μm³	1200 μm³
8	Mining electric office	114 μm³	1200 μm³
9	Mining canteen	131 μm³	1200 μm³
1 μm³ = 1 million of per Cubic meter			

Energy Use and Emissions: Mostly Fossil fuels are used in diamond exploration and mining, They released C & Co2 into the atmosphere and result in a variety of environmental issues, such as pollution and climate change, which endanger both human health and the ecosystem.

Diamond mines produce wastes similar to those of any other major industrial facility, such as oil, paper, scrap metal, batteries, tires, and minor amounts of plastic and glass.

In table: shows internationally fule consumption ratio. — [Sources: (Lord et al., 2019),(Cano Londoño, 2019), (Shah, 2014), ("Environmental performance," 2009)] (Frost & Sullivan, 2014)

Quantifying the environmental impact of mined diamonds per carat			
Sno.	Energy usage (KWh)	Emissions (CO2, kg)	Total fuel consumption (litres)
1	Canada	98	
2	Australia	58	6.88
3	Zimbabwe	15	43.88
4	South Africa	1362	1501
5	Bostwana	185	227

Occupational Health Hazards and benefits: As if the harm to delicate environmental systems and toxic waste wasn't enough. In that case, there are also significant and risky health hazards lurking on any mining site that place its workers at risk. An unsafe mine site could easily cave in due to hazardous mining processes resulting in dismemberment in death. Kimberlite is a gas rich potassic ultramafic igneous rock, kimberlite have some good Nutrients which are useful for humans, Diamond mining is more environment friendly than other minerals mining.

AVAILABLE MICRO NUTRIENTS IN THE TAILINGS		
Sno.	Test Carried out	(In PPM)
1	Zinc	0.3 to 2.7
2	Copper	0.9 to 1.3
3	Iron	7.8 to 11.3
4	Manganese	2.1 to 6.5

SUMMARY AND CONCLUSIONS

It is impossible to imagine the development of human civilization without mining, at the same time mining also causes pollution of the environment, both these words are complementary to each other, both are essential aspects of development and security of human civilization. The next generations will be prosperous and healthy i.e. with mining Along with this, it is also important to keep the environment safe, for this we should work from time to time to study, assess and take measures for the damage caused to the environment by mining.

A Meta study was conducted to evaluate the environmental impact of mined diamonds. Diamond mining has many impacts on the environment including soil erosion, deforestation, and ecosystem destruction. Without planning and environment study diamond mining can causes entire ecosystems to collapse.

The tailings obtained from the beneficiation plant, varies in size ranging from a few microns to around 20mm. These tailings are usually dark green in colour with whitish black particles in between. Microscopic studies revealed that these tailings contain minerals like serpentine, olivine, calcite, biotite, phlogophite and Garnet. Approximately 80% of the ROM feed to plant is coarse tailing, which may be utilized for other commercial purposes like in Tile Industry, Cement (with mixing of Cement), and Fertilizer Industries.

The diamond industry efforts to ensure that all types of waste are monitored and minimized (e.g., scrap metal). To guarantee proper disposal and recycling, for instance, waste materials are categorized at the mine. The recovery and recycling of oil and grease have recently received special attention. However, at Namdeb, some used oil is recycled right away at the mine site. Used oil is often transported off-site for recycling.

RECOMMENDATION

Diamond mining is causing less pollution as compared to mining of other minerals, The Mining company and Government should be investigated the diamond mining activities and discover their impacts on the relevant environments. The research was guided by the following Recommendation is below:-

1. Improvement of Worker Conditions in Diamond Mines
2. Stopping of land Degradation, vegetation, and Water, Air, Noise pollution use electric trolley to carry blasted kimberlite, Stock pile and Crushing Plant
3. Prefer to go for Underground mining for controlling of Air pollution
4. Make SOP for tailing stock piles management, Re use of weathered Tailing Kinberlites :- in Road, Tiles and Houses with mixture of Cement
5. Kinberlites have nutrients value - old Weathered kimberlite can be use as compost for plant
6. Plantation is more important, Reservoir for re use of water
7. Minimize break down time HMS plant and heavy mineral separation
8. Proper management for Re uses of FeSo4
9. Proper Acid wash and Packaging - After acid wash of **rough Diamond,** remain acid should be drain out in Sink.
10. use X-ray protective

11. Mine Waste Management

REFERENCE

1. Franklin, J. 1833. On the diamond mines of Panna in Bundelkhand. In Asiatic researches or transactions of the society instituted in Bengal. Vol. 18, 100-21. Calcutta, India: Bengal Military Orphan Press, G. H. Huttman.
2. Meyer HOA and Seal M (1998) Natural diamond. In: Prelas MA, Popovici G and Bigelow LK (eds) Handbook of industrial diamonds and diamond films. New York: Marcel Dekker,cop.
3. Aryee BNA, Ntibery BK and Atorkui E (2003) Trends in the small-scale mining of precious minerals in Ghana: A perspective on its environmental impact. Journal of Cleaner Production 11(2): 131-140.
4. Ghose, M. 2003. Environmental impacts of Indian small-scale mining industry – an overview. Minerals & Energy – Raw Materials Report 18(2): 24-33.
5. Acheampong E. Impact assessment of mining activities by Ashanti Goldfields-Bibiani Limited on the environment and socio-economic development of Bibiani. Undergraduate Dissertation, Faculty of Social Sciences, Kwame Nkrumah University of Science and Technology. 2004..
6. Yeboah JY. Environmental and health impact of mining on surrounding communities: a case study of Anglogold Ashanti in Obuasi (Doctoral dissertation). 2008.
7. Deb, M., G. Tiwari, and K. Lahiri-Dutt. 2008. Artisanal and small-scale mining in India: Selected studies and an overview of the issues. International Journal of Mining, Reclamation and Environment 22(3): 194-209.
8. Yaro JI. The Impact of mining on livelihoods of local communities: A case study of Newmont Ahafo South Mining Project of Brong-Ahafo Region of Ghana. International Institute of Social Studies, Netherlands. 2010; 10:2016.
9. Elenge M, Leveque A and De Brouwer C (2013) Occupational accidents in artisanal mining in Katanga, D.R.C. International Journal of Occupational Medicine and Environmental Health 26(2): 265-274.
10. Ali SH (2017) The ecology of diamond sourcing: from mined to synthetic gems as a sustainable transition. Journal of Bioeconomics 19(1): 115-126.
11. Furberg A, Arvidsson R and Molander S (2018a) Live and let die? Life cycle human health impacts from the use of tire studs. International Journal of Environmental Research and Public Health 15(8).
12. Gupta T (2018) The Transparent Carbon: the Diamond. In: Gupta T (ed) Carbon. The Black, the Gray and the Transparent. Springer International Publishing. Hauschild MZ, Rosenbaum RK and Olsen SI (2018) Life Cycle Assessment: Theory andPractice. 1st ed.: Springer International Publishing.
13. Clifford, M. J., R. K. Perrons, S. H. Ali, and T. A. Grice. 2018. Extracting innovations: Mining, energy, and technological change in the digital age. Boca Raton, USA: CRC Press.
14. Popplewell G (2019) Diamonds. In: Dunne RC, Kawatra SK and Young CA (eds) SME Mineral Processing & Extractive Metallurgy Handbook. Englewood, Colorado:Society for Mining, Metallurgy and Exploration.
15. Makhetha E and Maliehe S (2020) 'A concealed economy': Artisanal diamond mining in Butha-Buthe district, Lesotho. Extractive Industries and Society 7(3): 975-981.
16. World Bank (2020) Life expectancy at birth, total (years) - Congo, Dem. Rep. Available at: https://data.worldbank.org/indicator/SP.DYN.LE00.IN?locations=CD accessed 13th October 2020.
17. Government of Madhya Pradesh, Environmental Planning & Coordination Organisation. Accessed 10 January 2020 at <http://www.epco.in/epco_biosphere_panna.php>.