Environment and Ecology 42 (2) : 498—508, April—June 2024
Article DOI: https://doi.org/10.60151/envec/MYMQ5982
ISSN 0970-0420

Monitoring of Water Quality to Assess Seasonal Color Changes of Lunar-Lubha River in East Jaintia Hills, Meghalaya (India)

R. R. Lyngskor, Arnab Mandal, Adelene Pyngrope, A. D. Blah, M. K. Choudhury

Received 23 August 2023, Accepted 4 February 2024, Published on 5 April 2024

ABSTRACT

The Lunar-Lubha River is a significant river in Meghalaya, India, flowing through the Jaintia Hills and eventually reaching Bangladesh's Surma valley. During winter, the river undergoes a remarkable transformation, changing its color from turquoise to a vibrant sky-blue hue. This study investigated the reason behind this color change by examining the physicochemical characteristics of the river water during pre-monsoon, post monsoon and winter season of the year 2020 to 2022. Chemical properties of the white-powdery sediment (which acts as light reflecting media) found on the riverbed of the color-changing stretches of the river were also investigated. The analysis revealed the presence of high levels of Iron (Fe) and Alumina (Al) in sediments of the Lunar-Lubha River beds. The water quality in stations located at Lunar River can be designated below-E as per Central Pollution Control Board (Govt. of India) guidelines as the water in those stations is not fit for drinking, bathing, propagation of marine life as well as irrigation or agricultural uses. The blue coloration is more prominent in the deeper sections of the river compared to the shallow stretches. This observation aligns with the argument that shorter wavelengths of light scatter more as the depth increases. The presence of light scattering effect due to variation in water depth and the white-colored sediments at the riverbed could explain the intensified blue color in the river. The apparent blue color of the Lukha River is most likely an illusion induced by the scattering effect rather than the genuine blue color of the water.

Keywords Lunar-Lubha River, Physico-chemical scattering, Turquoise, White color sediment, Winter.

INTRODUCTION

Water is essential for sustenance of lives on the Earth. Almost Two-thirds of the Earth is covered with water, comprising of 2.5% fresh water and 96.5% sea water and the rest are locked in the atmosphere and ice capped mountains. Although, majority of the Earth is made up of water, freshwater in liquid form in the

R. R. Lyngskor[1], Arnab Mandal[2]*, Adelene Pyngrope[3], A. D. Blah[4], M. K. Choudhury[5]

[1]Executive Engineer, [3]Research Fellow, [4]Chief Engineer
[1,3,4] Department of Water Resources, Government of Meghalaya, Agriculture Complex, Cleve Colony, Meghalaya, Shillong 793001, India

[2]Scientist, Central Pollution Control Board, Regional Directorate Shillong, BSNL NE-I Circle, Telecom Circle, CTO Building, Ground Floor, Shillong 793001, Ministry of Environment, Forest and Climate Change, Government of India

[5]Regional Director, Central Pollution Control Board, Regional Directorate Shillong, BSNL NE-I Circle, Telecom Circle, CTO Building, Ground Floor, Shillong 793001, Ministry of Environment, Forest & Climate Change, Government of India

Email : mandalarnab.cpcb@gov.in
*Corresponding author

surface only makes up 0.3% of the total water which is available to human-kind, the fact that only 0.06% is accessible for usage. Presently, worldwide several countries suffer from acute water shortage due to mis-management, over exploration, deforestation, etc (Somendro and Singh 2015). In addition to adequate quantity of water, the quality of water resources is also equally important. Monitoring water quality is crucial to maintaining the sustainability of nature and health of the world. Different quality of water sustains different ecosystems on the Earth. In India, Central Pollution Control Board (CPCB) has already classified the Water bodies for Designated-Best-Uses based on the water quality parameters like- fitness for drinking water source, bathing, fishery and agriculture uses. Monitoring of water quality on a regular basis is essential to know the current status and trend of water environment in terms of quality that may lead to the cause of health and environmental problems or may emerge in future.

It is a general fact that pure water is colorless, different types of water in different environments display a variety of shades. Due to suspended particulate matters, the water in oceans appears blue to turquoise while the water in rivers appears light olive to dark sea-green; whereas streams, lakes and ponds may appear green due to the presence of blue-green algae (Samal *et al.* 2020) and soil run-off in water results in a variety of colors (Lamare and Singh 2016). One of the most significant rivers in Meghalaya (India) Lunar-Lubha River, often known as "The Serene River," flows through the Jaintia Hills, which falls into Bangladesh's Surma valley. The river's color turned to a vivid sky-blue in January 2007 and several dead fish were observed floating on the surface. The next winter, the same thing occurred and it is being observed since then (Lamare and Singh 2016). Every year during the winter, the river shifts from turquoise to a brilliant sky-blue color. On the day the river's color changes, fish are found floating dead and no macro aquatic life has been observed in the river afterwards. Physico-chemical properties of water do not clearly explain the cause for the color-changing phenomenon in rivers.

The current study is undertaken to investigate the cause of the water of Lukha River turning into sky-blue during winter seasons by analyzing the chemical properties of white-powdery sediment on the riverbed in the color changing stretch of river as well as the physico-chemical characteristics of the river water through field measurements and lab analysis. Following rigorous investigation and comprehensive analysis of the findings, this academic journal attempts to provide practical recommendations for implementing appropriate corrective actions.

MATERIALS AND METHODS

Study area

The river Lukha situated in Meghalaya's East Jaintia Hills' southern region is widely known for its unnatural phenomenon where occasionally the river exhibits turquoise/ blue color mostly in winter seasons. It receives water from the Lunar River, many minor streams that trickle down from the Narpuh Reserve Forest along the area's rolling hills. The river, which receives the majority of its water from monsoon rain, travels primarily in a south-westerly direction before meeting the Lubha River close to the village of Khaddum. After merging, the Lunar and Lubha Rivers form the Lukha River. This river travels through the Sonapur village, where the phenomenon occurs prominently during the lean season, before entering the

Table 1. Details of sampling stations.

Stations	Location	Co-ordinates
Station 1	Lunar at Mooblai, Byndihati	25.293159N latitude/ 92.391415E longitude
Station 2	Lunar at Urdula, Wahiajer	25.227674N latitude/ 92.422521E longitude
Station 3	Lunar at Khaddum Bridge	25.157979N latitude/ 92.437430E longitude
Station 4	Lubha at Khaddum Village	25.153651N latitude/ 92.447842E longitude
Station 5	Lukha, downstream of confluence point	25.154406N latitude/ 92.439380E longitude
Station 6	Lukha at Sonapur Bridge	25.109957N latitude/ 92.362968E longitude

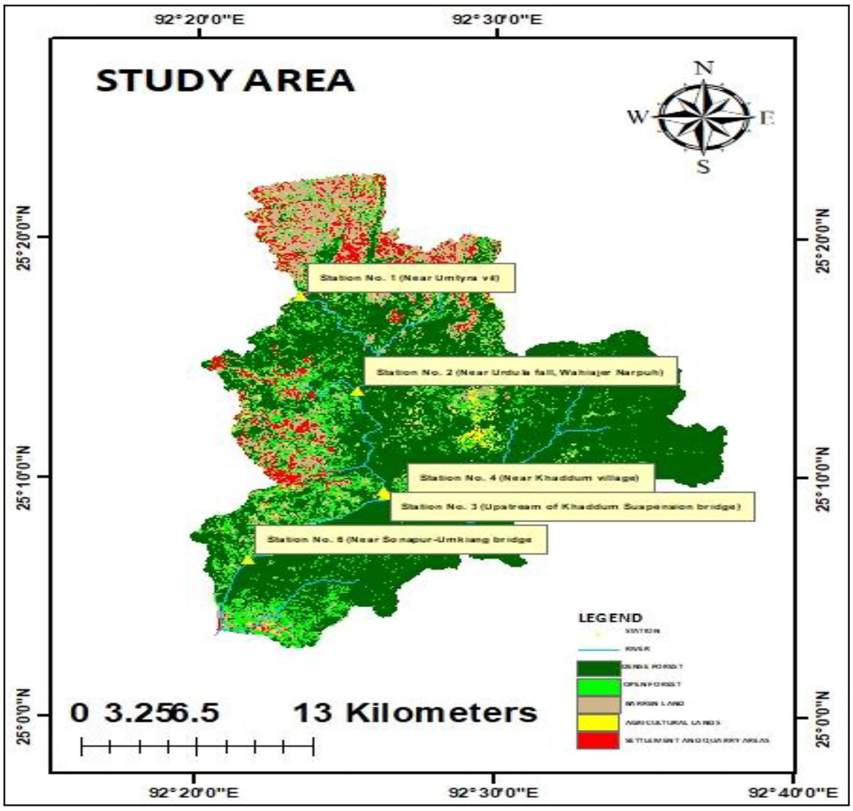

Fig. 1. Generated map of study area.

Surma valley and finally flowing into Bangladesh's flood plains. The study area lies between 25°17.590' N, 92°23.180'E to 25° 06.681'N, 92°21.855'E. For the purpose of the study, following 6 stations were selected for sample collection and monitoring (Figs. 1-8, Table 1).

Methodology

The study is qualitative in nature, where physico-chemical water quality parameters were analyzed over a certain period from 2020-2022, and spatially over the length of the river. To analyze the physico-chemical parameters of water and substrate, samples were collected from Lunar, Lukha and Lubha Rivers. Correlation of this information is analyzed.

Monitoring was conducted on a monthly basis and data were categorized according to seasons:

Post monsoon 2021: October - November
Winter 2021-22: December – February
Pre monsoon 2022: March - April
Winter 2022: December

The acceptability of water for various uses is referred to as water quality and depends on its physicochemical, biological, and organoleptic (taste-related) characteristics. To establish an effective monitoring system and to obtain information on the quality of the river, water was tested for different physico-chemical parameters such as pH, Conductivity, Turbidity, Total Suspended Solids, Total Dissolved Solids, Total Hardness, Calcium, Magnesium, Chemical Oxygen Demand, Chloride, Alkalinity, Dissolved Oxygen, Biological Oxygen Demand, Sulphate, Nitrite, Nitrate and Phosphate. Moreover, Collected Water and sediment samples were also analyzed for metals Chromium, Copper, Alumina, Nickel, Iron, Cadmium, Zinc


Fig.2:


Fig.3:


Fig.4:


Fig.5.


Fig.6:


Fig.7:


Fig.8:

Fig. 2. Station 1- Lunar River at Mooblai, Byndihati. **Fig. 3.** Stone quarry located next to Station 1. **Fig. 4.** Station 2-Confluence of Lunar and Chyrtong. **Fig. 5..** Station 3-Lunar at Khaddum Bridge (Urdula, Wahiajer). **Fig. 6.** Confluence point of Lunar -Lubha forming Lukha River. **Fig. 7.** Station 4-Lubha at Khaddum. **Fig. 8.** Station 6-Lukha at Sonapur.

and Lead. These parameters were analyzed in the laboratories of the Central Pollution Control Board (CPCB), Shillong and Meghalaya State Pollution Control Board as per the analysis procedures recommended by the "American Public Health Association (APHA 2017)" (Mandal *et al*. 2023).

Water quality criteria

Designated best use water quality criteria Matrix as per Central Pollution Control Board, MoEF and CC, India (https://cpcb.nic.in/wqm/Designated_Best_Use_Water_Quality_Criteria.pdf) Guidelines was used to assess the water quality of the collected samples. Moreover, the tolerance limits of parameters are specified as per classified use of water depending on various uses of water by ISI-IS: 2296-1982. The tolerance limit for water quality parameters were compared as per Water Quality Tolerance and Classification matrix by Central Water Commission, Govt of India (2017-2018).

RESULTS AND DISCUSSION

Water samples

PH - The pH of pure water is naturally 7. Aquatic systems may experience an elevation in pH as a result of specific human activities and related sources, including leachate and effluents from sources related to industry and mining, as well as stormwater runoff from sources connected to agriculture (such as lime-rich fertilizers) and urbanization (such as asphalt roads).

From the Table 2 provided, it is observed that water in Station-1 and Station-2 is highly acidic in all seasons. These stations are situated in the high impact area where most of the coal mining is being practiced. Acidic Mine Drainage (AMD) from abandoned and active coal mines in the river water could be the cause of such low pH at Station 1 and Station 2. pH of the water at Station-3 is found to be slightly increased (4.3-7.6). This may be due to waste lime slurry discharge from cements factories in and around the surrounding areas of Station-3. Lubha River (Station-4) is a separate tributary of Lunar River, that confluence near Station -5 and finally flows down as Lukha River at Khaddum village (Station-6). pH of the water at Staion-4 is conforming with the permissible limits for Inland surface water (Class-A). Hence, Lubha River water from Station-4 is acting as a dilutant to the Lunar River water at the confluence point. (Station-5). The dilution effect can be confirmed by observing a slight pH increase in water at Station 6 compared to water at Station-3.

Electrical conductivity - A higher or lower concentration of dissolved ions in the water will result in a higher or lower EC. It was found that the electrical conductivity was highest in Station 1 during the winter season of 2021 with a value of 1160, whereas it displays the lowest value in Station 4 during the monsoon season of 2020 with a value of 70. Moreover, Electrical Conductivity of water at Station-1 - 3 was generally found to be higher compared to the EC of the water at Staion-4 - 6 during the study period.

Total dissolved solids - The amount of minerals, and other dissolved compounds in a specific volume of water is known as total dissolved solids (TDS), which is expressed in milligrams per liter (mg/L).It was observed that the Total Dissolved Solids (TDS) shows the highest value in Station 1 during the winter season of 2021-2022 with a value of 1542 whereas it shows the lowest value in Station 4 during the winter season of 2022 with a value of 48. Moreover, TDS of water at Station-1 and 2 is found to exceed the tolerance limits for inland surface water class-A (Limit Max: 500 mg/L) prescribed by Central Water Commission, Govt of India in majority of the seasons during the study period (2020-22).

Turbidity - The degree of murkiness or cloudiness in the water defines its turbidity. In other words, water that contains a variety of suspended materials will have a higher level of turbidity than water that does not. Turbidity of water at all the stations is found to conform with the tolerance limits for inland surface water class-A prescribed by Central Water Commission, Govt of India during the study period (2020-22)

Total suspended solids- Turbidity and Total Suspended Solids are connected. Water that has a high concentration of total suspended solids and is murky will make it difficult for sunlight to penetrate, which will impede aquatic life growth. TSS of water at all the stations is found to conform with the tolerance

Table 2. pH 2020 - 2022 (*marked in red: Not within the permissible limits).

Station	Monsoon 2020	Post-Monsoon 2020	Winter 2021	Pre- Monsoon 2021	Monsoon 2021		Post-Monsoon 2021		Winter 2021-2022			Pre-Monsoon 2022		Post-Monsoon 2022	Winter 2022
	Sept 2020	Nov 2020	Jan 2021	Mar 2021	May 2021	Sept 2021	Oct 2021	Nov 2021	Dec 2021	Jan 2022	Feb 2022	Mar 2022	April 2022	Oct 2022	Dec 2022
1	3.1	2.7	3.2	3.2	2.8		3		3.1			3.5		3.5	3.2
2	-	3.1	3.3	3.6	-		-		3.6			4.3		-	3.5
3	7.3	5.3	4.6	4.7	5.9		6.3		5			6.5		7.6	5
4	7.8	6.8	7.6	7.1	7		7		7			7.6		7.9	7.8
5	7.3	4.8	4.6	4.7	7.1		6.1		5			7.1		7.4	4.9
6	7.4	6.7	5.9	6.4	7.1		6.5		6.4			7		7.4	6.9

Tolerance limits for inland surface waters, Class–A (ISI-IS: 2296-1982), PH (Max): 6.5 – 8.5.

limits for inland surface water class-A prescribed by Central Water Commission, Govt of India during the study period (2020-22).

Total hardness - Total hardness, which is the sum of the calcium and magnesium concentrations in water, provides an overview of how easily soap suds and scale buildup in water pipes and boilers can occur. Total hardness of water at all the stations is found to conform with the tolerance limits for inland surface water class-A prescribed by Central Water Commission, Govt of India during the study period (2020-22).

Calcium - Natural water contains calcium, an essential component. Moreover, it is a major cation responsible for the hardness of water. Total hardness of water at all the stations is found to conform with the tolerance limits for inland surface water class-A prescribed by Central Water Commission, Govt of India during the study period (2020-22).

Chloride - One of the main inorganic anions, or negative ions, in both freshwater and saltwater is chloride (Cl-). It comes from the dissociation of salts in water, like calcium chloride or sodium chloride. Chloride in natural waters can come from a variety of sources, including soil, industrial or municipal sewage, and animal waste. Chloride in the water at all the stations is found to conform with the tolerance limits for inland surface water class-A prescribed by Central Water Commission, Govt of India during the study period (2020-22).

Biological oxygen demand (mg/L) - The amount of dissolved oxygen required (i.e., requested) by aerobic biological organisms to decompose organic matter present in a particular water sample at a certain temperature over a specific time period is known as the biological oxygen demand (BOD). BOD of water at all the stations is found to conform with the tolerance limits for inland surface water class-A prescribed by Central Water Commission, Govt of India during the study period (2020-22).

Chemical oxygen demand (mg/L) - Calculating the amount of oxygen required to chemically oxidize the organic materials and inorganic nutrients, like ammonia or nitrate, that are present in water is called Chemical Oxygen Demand (COD). COD is often used to measure pollutants in water, wastewater, and aqueous hazardous wastes. COD of water at all the stations is found to conform with the tolerance limits for inland surface water class-A prescribed by Central Water Commission, Govt of India during the study period (2020-22).

Sulphate (mg/L) - All types of natural waters contain the naturally occurring anion sulphate. Sulphate is mostly a contaminant that enters our water system through waste and industrial discharge, while it can occasionally occur naturally since some soils and rocks contain sulphate minerals. Sulphate is widely produced by mines, smelters, paper mills, textile mills, tanneries, and other industrial facilities. Although sulphate in water at all the stations is found to conform with the tolerance limits for inland surface water class-A prescribed by Central Water Commission, Govt of India during the study period (2020-22) except during winter season of 2021-22 at Stations 1 - 3 i.e., upstream stations (Table 3). Sulphate is largely contributed from acid mine drainage resulting from coal mining in the adjacent areas surrounding the study area at Stations 1 - 2.

Dissolved oxygen (mg/L) - Dissolved oxygen is the amount of free, non-compound oxygen that is present in water or other liquids. It is a key element in measuring the water quality because of its effect on the aquatic life present in a body of water. First, oxygen becomes less soluble as temperature rises. The actual concentration of dissolved oxygen (measured in mg/L) is influenced by temperature, pressure, and salinity. Second, the amount of dissolved oxygen decreases exponentially as salt concentrations increase. The level of dissolved oxygen will also increase as pressure increases. DO level of water at all the stations is found to conform with the tolerance limits for inland surface water class-A prescribed by Central Water Commission, Govt of India during the study period (2020-22).

Phosphate (mg/L) - Phosphorus naturally exists in mineral deposits and in rocks. As the mineralized phosphate compounds disintegrate, the phosphorus slowly leaks out of the rocks as soluble phosphate ions during the natural weathering process. This element is

Table 3. Sulphate (mg/L) 2020 – 2022 (*marked in red- above the tolerance limit).

Station	Monsoon 2020	Post-Monsoon 2020	Winter 2021	Pre-Monsoon 2021	Monsoon 2021		Post-Monsoon 2021		Winter 2021-2022			Pre-Monsoon 2022		Post-Monsoon 2022	Winter 2022
	Sept 2020	Nov 2020	Jan 2021	Mar 2021	May 2021	Sept 2021	Oct 2021	Nov 2021	Dec 2021	Jan 2022	Feb 2022	Mar 2022	April 2022	Oct 2022	Dec 2022
1	274.32	127.2	99.02	90	316		848.5		946.3			896.5		188.9	206.2
2	-	147.57	91.98	85.03	-		-		845.6			1021		-	206.2
3	86.73	155.67	71.51	74	68.5		268.5		616.6			515		195.6	206.2
4	5.5	12.11	3.19	15	4.9		17.97		35.04			37.04		38.89	85.32
5	58.9	379.35	66.88	75.79	50.4		316.5		637.3			446.5		189.7	206.2
6	52.65	138.9	47.79	77	43.9		203		369			309.5		163.5	206.2

Tolerance limts for inland surface waters, Class – A (ISI-IS: 2296-1982).
Sulphate (mg/L) Max: 400.

used to make phosphorates PO_4^{3-}. Nutrient pollution can be brought on by rivers with high phosphate concentrations. Some plants and animals may suffer damage at concentrations higher than 0.035 mg/L. Phosphate was found to be Below Detectable Limit (BDL) in all the Stations regardless of the season after analyzing the water samples collected.

Nitrate (mg/L) – A naturally occurring chemical with numerous man-made origins is nitrate. It is a chemical that can be found in septic tank liquid waste discharge, manure, agricultural runoff, dairy lagoons, and fertilizers. Vegetables naturally contain nitrate at low amounts. Nitrate can permeate the soil and enter groundwater as a result of irrigation or rain. River water often contains nitrates in the range of 0.01-3 mg/L. Nitrate was also found to be Below Detectable Limit (BDL) in all the stations regardless of the season after analyzing the water samples collected.

Iron (mg/L) - Magnetite, hematite, goethite, and siderite are the four primary iron minerals that are found in nature. The element enters the water through weathering processes. Water that is yellow or crimson is frequently a reliable sign that iron is present.

Iron content of water at all the stations was found to exceed the tolerance limits for inland surface water class-A (Limit Max: 0.3 mg/L) prescribed by Central Water Commission, Govt of India in winter 2022 during the study period. The highest value of iron is found in Station 1 with a value of 6.9 and the lowest value in Station 4 and Station 6 with a value of 0.48 (Table 4).

Zinc – Zinc is naturally present in water. Zinc content (wt %) level of water at all the stations is found to conform with the tolerance limits for inland surface water class-A prescribed by Central Water Commission, Govt of India during the study period (2020-22).

Nickel - Nickel (Ni) is a frequently present element in soil and water systems that has the potential to be harmful. From both natural and anthropogenic sources, nickel is frequently discharged into soil and water systems. Through deposition and runoff from soil, nickel contamination can be directly transported from the air and soil to surface water bodies, or indirectly through leaching to groundwater. Nickel content (wt.%) of water at all the stations is found to conform with the tolerance limits for inland surface water class-A prescribed by Central Water Commission, Govt of India during the study period (2020-22).

Manganese – Although manganese is naturally present in groundwater and surface water, human activities like steelmaking and mining can raise its concentration. Manganese can cause the water to turn rusty or brown.

Manganese content of water at all the stations was found to exceed the tolerance limits for inland surface water class-A (Limit Max: 0.5 mg/L) prescribed by Central Water Commission, Govt of India

Table 4. Iron 2020 – 2022 (*marked in red- above the tolerance limit).

Season	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
Winter 2022	6.9 mg/L	0.64 mg/L	5.6 mg/L	0.48 mg/L	3.4 mg/L	0.48 mg/L

Table 5. Manganese 2020 – 2022 (*marked in red- above the tolerance limit).

Season	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
Winter 2022	4.74	2.37	1.72	0.92	0.86	0.63

in winter 2022 during the study period. It is observed that the manganese level is highest in Station 1 with a value of 4.74 and shows the lowest value in Station 5 with a value of 0.86 (Table 5).

***Chromium* –** Chromium is a potentially harmful metal that can be found in surface and groundwater due to anthropogenic and natural causes. The primary natural source of chromium into water bodies is leaching from rocks and topsoil. Chromium content (wt %) of water at all the stations is found to conform with the tolerance limits for inland surface water class-A prescribed by Central Water Commission, Govt of India during the study period (2020-22).

***Copper* -** Due to both natural and man-made sources, copper is frequently found in aquatic systems. Mining operations, agriculture, the production of metals and electrical equipment, the usage of pesticides, and more are examples of anthropogenic sources of copper. Chromium content (wt %) of water at all the stations is found to conform with the tolerance limits for inland surface water class-A prescribed by Central Water Commission, Govt of India during the study period (2020-22).

***Alumina* -** The common chemical element aluminum (Al), which is produced by various anthropogenic activities and the Earth's crust, is discharged into the aquatic environment. Aluminum is one of the major causes of water pollution. From the Table 6, we observe that the alumina level is highest in Station 1 during the winter season of 2021 with a value of 49, whereas it shows the lowest value in Station 6 on the pre-monsoon season of 2022 with a value of 0.5. Al, like other metals, is extremely pH dependent; its solubility rises as pH drops, (Baes *et al*. 1986). Since, water at Station-1 and Station-2 are extremely acidic, the concentration of Alumina is highest in Station-1 and Staion-2 during Winter 2021 and Pre-Monsoon 2022 Season. The solubility of Alumina is decreased at Station 5 and Station 6 (Table 6). Hence, Aluminum may have a tendency to precipitate in the river bed sediment in the downstream stations.

Sediment samples

Elemental analysis for the sediments collected in March,2021 has been performed in order to investigate the following parameters: Silicon, Iron, Aluminium, Cobalt, Phosphorus, Copper, Sulfur, Chromium, Potassium, Magnesium.

From the Table 7, the following observations have been made

Oxygen has the highest level in Station 1.
Silicon has the highest level in Station 6.
Carbon has the highest level in Station 3.
Iron has the highest level in Station 2.
Alumina has the highest level in Station 5.
Cobalt has the highest level in Station 1.
Phosphorus has the highest level in Station 1.
Copper has the highest level in Station 1 and Station 5.
Sulfur has the highest level in Station 2.
Chromium shows the highest level in Station 2 also.
Potassium shows the highest level in Station 5.

Considering the high concentration of Aluminium in Station 5, Sediment samples were collected in the color changing stretches of the river during December,2022 in order to analyze the following metals: Alumina (Al), Cobalt (Co), Chromium (Cr) and Iron (Fe).

From the Table 8, Alumina shows the highest value in river bed sediment of the color changing stretches of the river. The blue color is more noticeable in the deeper sections of the river than in the

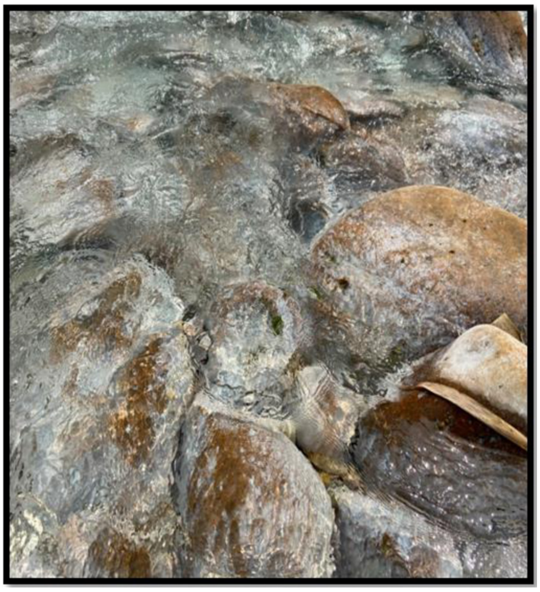

Fig. 9. White deposit on rocks in Site 5.

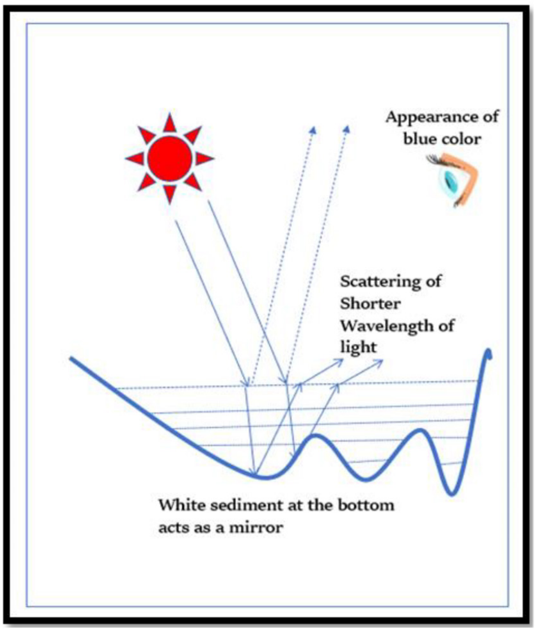

Fig. 10. Light Scattering effect for blue coloration.

shallow stretches. Slimy-jelly like white sediment that are deposited in the river-bed in the downstream stations (Station 5 and Station 6) as seen in the Figs. 9 - 10 may be responsible for acting as a mirror for reflection of the light waves. Since light of short-wave length scattering rises as depth increases. The appearance of blue color from scattering is more pronounced when there is more light scattering due to water depth. As a result, the Lukha River's apparent blue coloring is probably just an illusion caused by the scattering effect rather than it is actually due to the blue color of the water.

Flow-rate Measurement

The flow rate of the Lukha and Lubha Rivers were calculated after measurement of average depth, average width and average water velocity for the streams- a few meters upstream (Station 3) and downstream of confluence point (Station 5). As the water levels were shallow during the lean period, the measurements were done during the month of December, 2022. The flow-measurement will give us an idea about the dilution at the confluence point of the stream of Lunar River (Station 3). This flow-rate variation across the Stations 3 - 5 coupled with physico-chemical parameters of the water should depict a clear picture of "Blue Coloration Phenomena". The flow rate of streams of Lunar River at Station 3 can be found on subtracting the flow-rate of stream in Station 4 with that of stream in Station 5.

Table 6. Alumina 2020 – 2022 (*marked in red- above the tolerance limit).

Season	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
Pre-Monsoon 2021	2.14	1.55	3.45	4.32	4.32	3.35
Post-Monsoon 2021	4.1	-	2.59	2.94	1.45	1.3
Winter 2021	49	30	10	0.28	9.5	6.3
Pre-Monsoon 2022	42	25	13	0.18	9.1	0.5

Tolerance limit (IS: 2296 Class A) - 0.5 – 1.

Table 7. Sediment samples 2021.

Pre-Monsoon 2021 (March 2021) Parameters (wt%)	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
Oxygen	53.3	35.4	34.7	30.1	50.0	46.6
Silicon	25.0	0.7	1.0	7.9	13.0	28.8
Carbon	12.5	16.2	58.4	55.0	15.0	21.9
Iron	4.6	42.2	2.3	3.0	2.6	1.4
Alumina	3.1	0.9	2.3	2.7	13.6	1.1
Cobalt	0.5	-	0.1	0.4	-	-
Phosphorus	0.4	-	-	0.1	0.3	-
Copper	0.3	-	0.1	-	0.3	-
Sulfur	0.2	4.1	0.6	-	0.8	0.3
Chromium	-	0.4	-	-	0.3	-
Potassium				0.8	3.6	
Magnesium					0.5	

Table 8. Sediment sample 2022.

Parameters (wt %)	Mixed sediment sample from the color changing stretches of the river
Alumina (Al)	10.8
Cobalt (Co)	0.00118
Chromium (Cr)	0.00223
Iron (Fe)	3.4

Stations	Station-3 (Flow rate of Lukha before confluence)	Station-4 (Tributary of Lukha before confluence)	Station-5 (Flow rate of Lukha River after confluence)
Flow-rates (m^3/s)	11.30117	0.897	12.19817

It is evident from the above table that, the effect of dilution of Lubha River at Station 4 is negligible during the lean season. This dilution factor impacts the physico-chemical parameters like pH. During monsoon and post monsoon period, the dilution factor should be increased so that the impact of acidic water in the downstream stations may get nullified. As soon as, the water levels of all the streams are increased beyond a certain critical point in the months of summer or monsoon, the effect of light scattering may get nullified, hence we do not observe any blue coloration at those seasons.

CONCLUSION

From the analysis conducted, it was found that presence of Iron (Fe) and Alumina (Al) were found in high levels in the Lunar-Lubha-Lukha river water and sediment. In fact, the water quality in the Stations-1 - 3 at Lunar River can be designated below-E (CPCB guidelines) as the water in those stations is not fit for drinking, bathing, propagation of marine life as well as Irrigation or agricultural uses. The pH of the water in these stations were found to be less than 5. Variation in the pH values at a particular station in different seasons is also observed. Intermittent discharge of slurries from the surrounding cement plants could impact the pH values of the acidic water in the river. Alumina could be contributed from effluents of cement producing factories which are present in abundance across the study area. In addition to that, sulphate was also found in large quantity in upstream stations during winter season. Sulphate is largely contributed from acid mine drainage resulting from coal mining in the adjacent areas surrounding the study area. Iron could be the result of acid mine drainage as the study area is surrounded by large coal reserves where mining is taking place (Gupta *et al.* 2002 and Yu *et al.* 2020). Iron in coal is mainly associated with sulfur in the mineral pyrite and jarosite (Waanders *et al.* 2003). Increased concentrations of $SO4^{2-}$ in ecosystems affected by mining can have detrimental effects on the environment, such as acidification and the release of heavy metals and methyl mercury into aquatic systems (Cheng *et al.* 2022).

The blue color is more noticeable in the deeper sections of the river than in the shallow stretches. Slimy-jelly like white sediment that are deposited in the river-bed in the downstream stations may be responsible for acting as a mirror for reflection of the light waves. Since light of short-wave length scattering rises as depth increases. the appearance of blue color from scattering is more pronounced when there is more light scattering due to water depth. As a result, the Lukha River's apparent blue coloring is probably just an illusion caused by the scattering effect rather than it is actually due to the blue color of the water.

ACKNOWLEDGMENT

The authors are very much thankful to National Hydrology Project, Government of India for providing necessary resources & financial assistance for completion of the project.

REFERENCES

Baes CF, Mesmer RE (1986) The Hydrolysis of Cations. Robert E. Krieger. ISBN 978-0-89874-892-5.

Bwapwa J, Jaiyeola A, Chetty R (2017) Bioremediation of acid mine drainage using algae strains: A review. *South African Journal of Chemical Engineering,* pp 24. https://doi.org/10.1016/j.sajce.2017.06.005

Cheng L, Jiang C Li C, Zheng L (2022) Tracing Sulphate Source and Transformation in the Groundwater of the Linhuan Coal Mining Area, Huaibei Coalfield, China, *Int J Environ Res Public Health* 4;19(21):14434. doi: 10.3390/ijerph192114434. PMID: 36361314; PMCID: PMC9656132.

Gupta SD, Tiwari BK, Tripathi RS (2002) Coal Mining in Jaintia Hills, Meghalaya:An Ecological Perspective. In: Jaintia Hills, A Meghalaya Tribe: Its Environment, Land and People. (eds. PM Passah and AS Sarma), Reliance Publishing House, New Delhi, pp121-128.

Krishnan B, Arumugam S, Shekhar S, Thangavel B (2015) Distribution and seasonal variation of heavy metals in sediments of Muthupet lagoon, Southeast coast of India. *Journal of Ecological Engineering* 16: 49-60. https://doi.org/10.12911/22998993/2805

Lamare RE, Singh OP (2016) Seasonal Variation in Water Quality of Lukha River, Meghalaya, India. *Current World Environment* 11: 101-113. https://doi.org/10.12944/cwe.11.1.14

Mandal A, Choudhury MK, Gargava P (2023) Monitoring of Water Quality to Assess the Impact of Unscientific Sand Mining in the Catchment Areas of Umtyngar River, Meghalaya (North-Eastern India). *Biological Forum – An International Journal* 15(5): 187-196

Samal D, Krishna P, Sukla L, Pattanaik A, Pradhan D (2020) Role of microalgae in treatment of acid mine drainage and recovery of valuable metals. *Materials Today: Proceedings* 30 : 346-350. https://doi.org/10.1016/j.matpr.2020.02.165

Somendro T, Singh OP (2015) Analysis of land use/land cover dynamics using Remote Sensing and GIS Techniques: A case of Jaintia Hills, Meghalaya. *International Journal Current Research* 7 (1): 11873-11879.

Waanders FB, Vinken E, Mans A, Mulaba-Bafubiandi AF (2003) Iron Minerals in Coal, Weathered Coal and Coal Ash – SEM and Mössbauer Results. *Hyperfine Interactions* 148: 21–29. https://doi.org/10.1023/b:hype.0000003760.89706.f6

Yu H, Gui H, Zhao H, Wang M, Li J, Fang H, Jiang Y, Zhang Y (2020) Hydrochemical characteristics and water quality evaluation of shallow groundwater in Suxian mining area, Huaibei coalfield, China, *Int J Coal Sci Technol* 7: 825–835. https://doi.org/10.1007/s40789-020-00365-6