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The Cause and Effects of a Sudden Blackening of the River Kameng/Jiya Bharali in October 2021

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Abstract: A disastrous sudden blackening of the river Kameng in Arunachal Pradesh, known as the river Jiya Bharali in Assam, was studied to find its cause and effects. The water of the river suddenly turned turbid and black on October 29, 2021, causing a large-scale death of fish for several days creating panic among the surrounding people. Samples of water and sediment were collected from different locations of the river and were analysed. The results indicate an increase in TSS consisting of aluminosilicates and oxides of Fe, Mn, Co, Ni, etc., mixed with water due to landslides. Coloured metal oxides were found to cause the blackening while toxicity and suffocation due to excess of suspended microscopic particles may have led to the death of fish. Preventive and curative measures for the disaster have been suggested.

Key words: The river Kameng/Jiya Bharali, blackening of river, death of fish, disaster, landslide.

Introduction

Surface water, although present in a lesser amount, is vital for the sustainability of ecological systems. Industries, urban waste effluents, and agrochemicals significantly contribute to the increase in pollution of surface water at an alarming rate (Sangani et al., 2021). This poses a serious threat to aquatic organisms as well as fish species (Islam et al., 2016). Studying the water quality, which determines the level of pollution and the viability of diverse aquatic creatures, enables one to gain knowledge about the many physicochemical properties of water (Muyen et al., 2016; Woods et al., 2012). Another serious concern in recent years is heavy metal pollution (Vernet, 2014). Aquatic systems are affected directly, as the majority of living species inhabit them as well and those living on the ground are dependent on them (Bilgili et al., 2021; Mamun and An, 2020). Another cause of the remobilisation of metal from sediment is changes in environmental conditions like pH, redox potential, etc. (Pallavi et al., 2015).

The river Jiya Bharali, a major tributary of the Brahmaputra, originates in the upper ridges of the Himalayas in Arunachal Pradesh, India (Khound and Bhattacharyya, 2018). Jiya Bharali is known as the river Kameng and as the river Warrying Bung at the top upstream in Arunachal, which touches the Arunachal town of Seppa and the Assam-Arunachal border point at Bhaluk Pung (Das and Sarmah, 2015; Das, 2016) (Figure 1). In Assam, it flows through the Nameri Wildlife Sanctuary in the Sonitpur district, then flows just a couple of kilometers east to the Tezpur University campus and finally to the river Brahmaputra.

Manmade pollution of urban rivers characterised by the blackening of water and unpleasant odour are reported where abundant metals like Fe and Mnare reported contributing to black urban rivers (Li et al. 2003; Liang et al. 2018). However, report of natural

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blackening of mountainous or rural rivers is rare. The water of the mountainous river Kameng and the rural river Jiya Bharali turned highly turbid and black suddenly on October 29, 2021, which also affected the Brahmaputra downstream from the confluence with the Jiya Bharali and the Brahmaputra (Narain, 2021; Hindustan Times, 2021). The blackening was a disaster with large-scale death of fish and other aquatic life leading to a chain of ecological consequences, e.g., suffocation of insects and plants due to a possible oxygen depletion, subsequent destabilization of food chain, breeding of aquatic animals, etc. Toxins introduced into our food through fishing in the contaminated water and using the water for livestock and crops also pose indirect threats to our health (Li et al., 2003; She et al., 2013). Considering the environmental implications, it was thought worthwhile to explore the reasons for the blackening disaster of the river. Water samples were collected from the river on November 6^{th} and 8^{th}, 2021 when the river water was intensely black. In the meantime, in early November 2021, the district authority of East Kameng of Arunachal Pradesh, after an aerial investigation, suggested the blackening to be caused by a landslide in the Warrying Bung, at the high upstream of the Kameng.

Materials and Methods

AR grade hexamethylenetetramine $(CH_2)_6N_4$, hydrazine sulphate $(N_2H_6SO_4)$, nitric acid, and hydrochloric acid were obtained from Merck, Mumbai and used without purification. The stock solutions were always prepared freshly in double-distilled water before use. Three locations were chosen for the collection of samples of water and sediment. The utmost care was taken while collecting these samples from the mainstream as far as possible. Water samples from the Kameng (KW) were

Figure 1: Map showing the courses of the Kameng/Jiya Bharali and the Bisom.

collected at Seppa, from Nicham Sonam Bridge before its confluence with the river Bisom, where there was no blackening of water. Sediment samples (KS) were collected along the riverside as far as the surface water was wadable. Water samples from the Jiya Bharali (JW) were collected from the Tou Bhanga bridge on National Highway 37. Reference water samples were collected from the Bisom, before its confluence with the Kameng. Water samples (GB) were collected from the Brahmaputra at Ganesh Ghat in Tezpur on November 27 after the disappearance of the blackening. The sample details are described in Table 1.

Care was taken to collect water samples from the mainstream as much as possible. Two separate water samples were collected from each location. One of them was filtered, and the filtrate and the residue were analyzed for various parameters. The other bottle was used for the determination of turbidity. Residues and sediments were digested by the standard method (Turek et al., 2019). One gram of dried sludge was digested using a mixture of 12 mL conc. HNO_3 and 4 mL conc. HCl (Rate and McGrath, 2022). Samples were boiled for 2 h in covered beakers on a hot plate. All solutions with undissolved residues were transferred into 100-mL volumetric flasks and filled to the mark with deionised water, followed by filtration.

pH of the experimental water samples was measured using a multi-parameter kit (Orion 5 Star pH.ISE. Cond.DO Benchtop). The calibration of the pH-meter was carried out with standard buffer solutions of pH 4.00, 7.00, and 10.00. Total dissolved solids (TDS) were determined by a digital TDS meter (HM Digital-TDS 3). The turbidity of the unfiltered water was determined by the nephelometric method using a turbidity meter (Systolic Nephelo-Turbidity Meter 135), and total suspended solids (TSS) were determined by filtration and expressed as mg/L. Concentrations of Al, Fe, Mn, and other heavy metals in residue and sediments after digestion in 1:3 HCl-HNO_3, and filtrate water were determined using an atomic absorption spectrophotometer (AAS, model Analyst 200, Thermo iCE 3500 series, USA) coupled with a hydride vapor generator (model VP100). Energy dispersive X-ray spectra (EDX) of residue and sediments were recorded on a Jeol Scanning Microscope (JSM 6390LV) at room temperature at an accelerating voltage of 15.0 kV. X-ray diffraction (XRD) spectra were recorded on a powder X-ray diffractometer (Miniflex, Rigaku, Japan) with graphite monochromated Cu-Kα radiation (0.15 nm) at 30 kV and 15 rnA using a scanning rate of 0.0500/s. Fourier transform infrared (FTIR) spectra were recorded on an IR spectrophotometer (Frontier MIR-FIR). Thermal analysis has been performed on a thermal analyzer (TGA-50 Shimazu). Field emission scanning electron microscopy (FE-SEM) images were captured on a Jeol Scanning Microscope (JSM 7200F).

Results and Discussions

The turbidities of water from the Kameng and the Jiya Bharali were found to be 122NTU and 100NTU, which were extremely high compared to 44.5NTU of

Table 1: Sample details – sample No. 1 and 3 were collected on 8 November 2021, sample No. 2 was collected on 6 November 2021 and sample No.4 was collected on 27 November 2021

Sample No.	*Sample location*	*Sample type*	*Sample code*	*Sample description*
1.	The Kameng near Seppa at Nicham Sonam bridge before confluence with the Bisom	Water	KWU	Unfiltered water sample
		Water	KWF	Filtrate from water sample
		Water	KWR	Residue of filtration from water sample
		Sediment	KS	Sediment from the river bed
2.	The Jiya Bharali at Tou Bhanga bridge on National Highway 37	Water	JWU	Unfiltered water sample
		Water	JWF	Filtrate from water sample*
		Sediment	JS	Sediment from the river bed
3.	The Bisom before confluence with the Kameng	Water	BWU	Unfiltered water sample
		Water	BWF	Filtrate from water sample*
		Sediment	BS	Sediment from the river bed
4.	The Brahmaputra at Ganesh Ghat, Tezpur	Water	GBU	Unfiltered water sample

*The quantity of residue was too small for analysis. Sediments were also collected for these locations.

the normal water from the Brahmaputra collected after the disappearance of the blackening. The extremely high turbidity of the Kameng followed by that of the Jiya Bharali indicates scattering of light as a cause of the blackening.

The TSS of water from the Kameng was found to be 5281 ppm, which is very high compared to 2281 ppm of the Bisom and the 211 ppm of normal season water of the Kameng (Singh et al., 2020). The extremely high TSS of the Kameng may be attributed to the blackening. The TDS of water from the Kameng and the Bisom before their confluence were found to be 66 ppm and 56 ppm, respectively, both of which were in the normal range for river water and do not seem to be a cause for concern. The slightly higher TDS of the Kameng than that of the Bisom may be related to the blackening but this is unlikely to increase the absorption of light to cause the blackening as both samples have almost similar TDS.

The pH of water from the Kameng and the Brahmaputra after filtration was found to be 7.47 and 7.46, respectively, which are normal and like that of 7.40 reported for the river Kapili, another tributary to the Brahmaputra (Dutta et al., 2006). Nothing could be predicted about the blackening based on the pH of the water.

The TGA of the sediment from the Kameng riverbed and the residue of filtration of water from the Kameng were compared with the sediment of the Bisom riverbed. Barring two samples, viz., residue from Kameng water and sediment from the Bisom, showing negligibly small percent weight losses of 0.726% and 0.381%, respectively, the other sample showed undetectable weight loss. This indicates the absence of carbonaceous organic substances, no loss of any hydrated water molecules, and the absence of any decomposition or evaporation of any of the substances.

Figure 2 shows the FTIR spectra of residue from the filtration of water from the Kameng and sediments from the Kameng and the Bisom riverbeds. A medium band with the FTIR of all three samples at 535–530 cm^{-1} may be due to Fe-O (Todea et al., 2020). The band at 693 cm^{-1} is due to Si-O-Si, and that at 777.74 cm^{-1} is due to Si-O. The bands appearing at around 3437 cm^{-1} and 1630 cm^{-1} are attributed to the stretching and bending vibrations of OH in H_2O molecules, respectively, indicative of the presence of a small amount of water (Mozgawa et al., 2014). The most intense band is observed at approximately 1080 cm^{-1} which can be attributed to the asymmetric stretching vibrations of Si-O. The bands at around 462 cm^{-1} relate to the bending vibrations of O-Si-O present in the silicate tetrahedron. The band at approximately 534 cm^{-1} is due to Si-O-Al (Chabukdhara and Singh, 2016). Thus, the FTIR spectra indicate the presence of suspended iron oxide in the water of both the Kameng and the Bisom, and therefore the presence of iron oxide is unlikely to cause the blackening of the Kameng.

The XRD pattern of the sediment of the Kameng indicates the sediment to be highly crystalline (Figure 3). It shows peaks at 2θ of 20.50° and 26.63°, which can be attributed to silicon dioxide, SiO_2 (JCPDS NO.89-8951). Peaks at 2θ of 30.07° and 43.04° can be

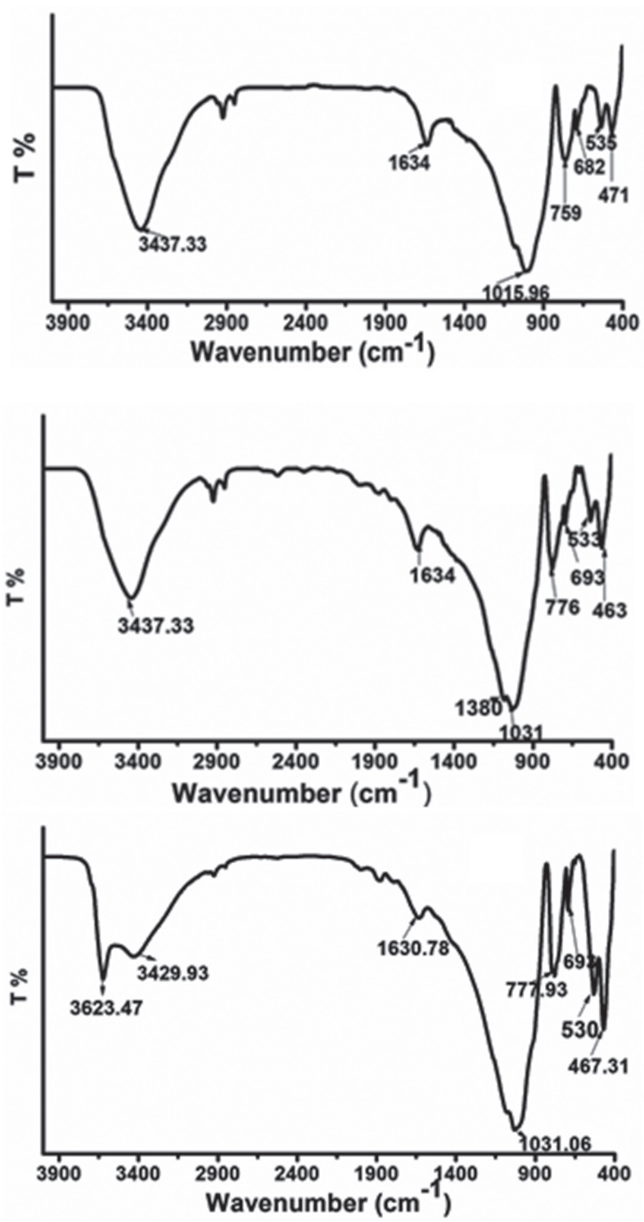

Figure 2: FT-IR spectra of residue of filtration (KWR, top) and sediment of the Kameng (KS, middle) and sediment of the Bisom (BS, bottom).

attributed to iron oxide, Fe_3O_4 (JCPDS No. 89-0950) (Bordoloi et al., 2013). Peaks at 2θ of 25.94° and 77.54° can be attributed to aluminium oxide, Al_2O_3 (JCPDSNo.03-1033). The peak at 2θ of 79.93° is due to calcium oxide, CaO (JCPDS No. 82-1691). The peak at 2θ of 46.78° can be attributed to manganese dioxide, MnO_2 (JCPDS No. 18-0802). The presence of oxides of silicon, aluminum, and calcium may be in the form of colourless or white calcium aluminium silicates. While the presence of iron oxide may produce a red-to-yellow colour, MnO_2 is intense black. Thus, the colour of the water may be due to the presence of suspended iron oxide and manganese dioxide, mostly due to the latter.

FESEM micrographs (Figure 4) indicate crystalline microparticles to be major constituents of the residue and sediment samples, which are capable of scattering light and contributing to the blackening. On the other

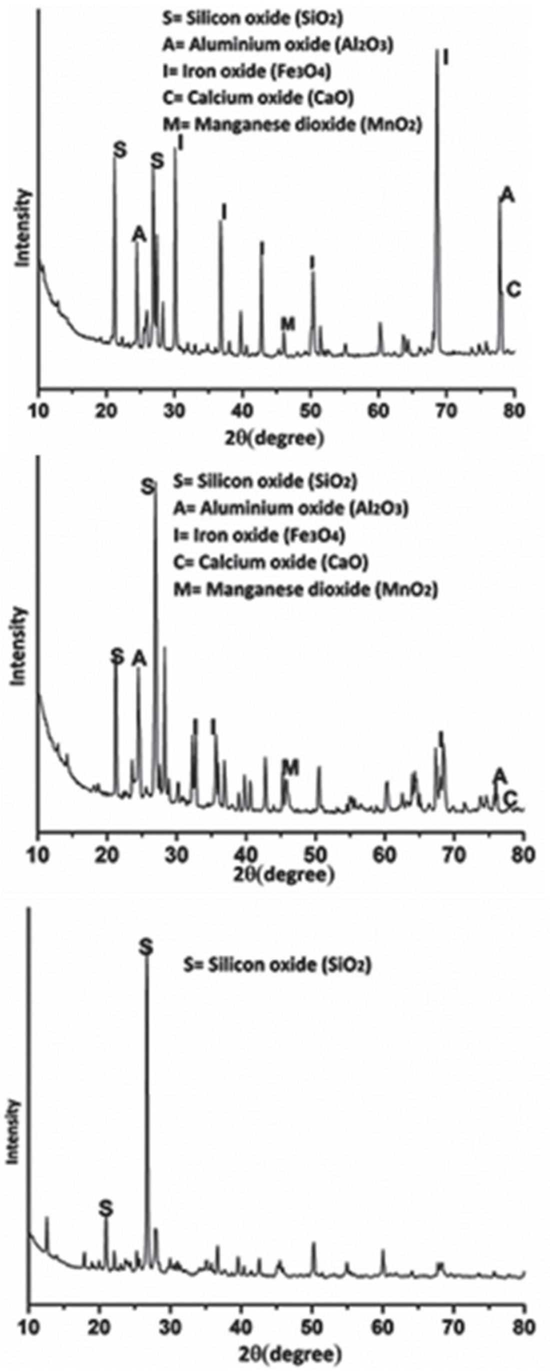

Figure 3: P-XRD spectra of residue of filtration (KWR, top) and sediment of the Kameng (KS, middle) and sediment of the Bisom (BS, bottom)

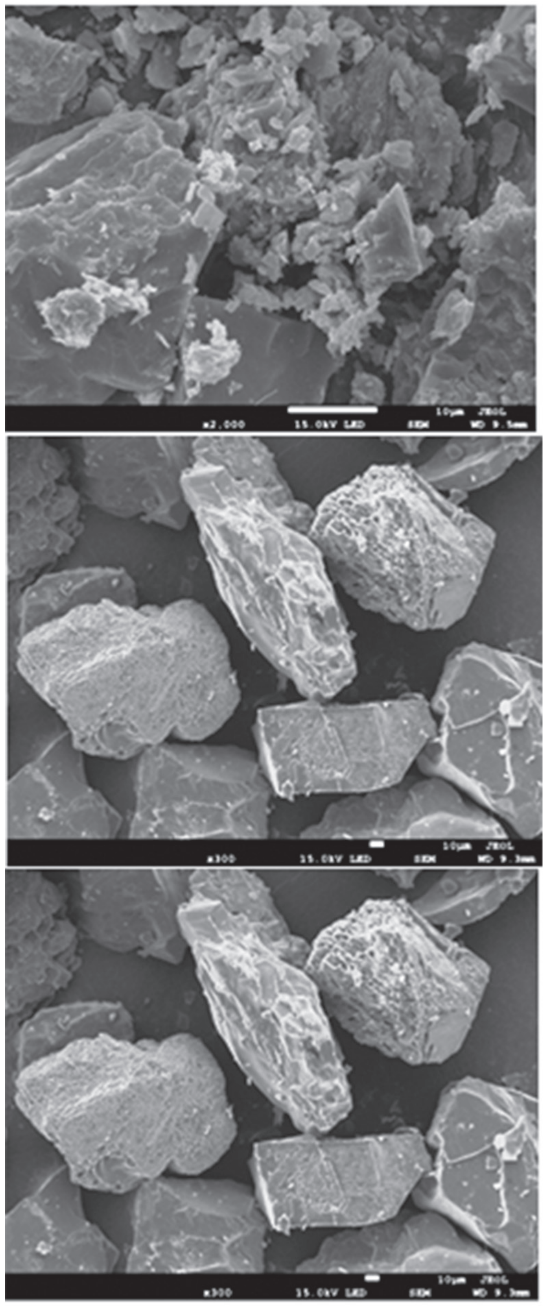

Figure 4: FE-SEM of residue of filtration (KWR, top) and sediment of the Kameng (KS, middle) and sediment of the Bisom (BS, bottom).

hand, crystalline nanoparticles seen in the samples may have toxic effects on the aquatic animals and maybe a reason for the large-scale death of the fish during the blackening.

The EDX pattern (Figure 5) shows the presence of Ca, Mg, Al, Si, Mn, and Fe in all the samples. Manganese dioxide, which was suspected to be a cause of the blackening, has been found in a small percentage, especially in the sediments from the Kameng, and in a very small amount in all other samples. The findings of EDX support MnO_2 as a cause of the blackening of water in the Kameng.

The metal ions present in the sediments and residue are shown in Table 2. The presence of Ca, Al, and Mg in the form of white microcrystalline calcium or magnesium aluminium silicates may scatter light leading to opaqueness. The presence of Mn, even in small quantities, in the form of insoluble intense black MnO_2 can cause the blackening (Briffa et al., 2020). The presence of more Mn in the residue/sediment of the Kameng than that of the Bisom suggests MnO_2 to be responsible for the blackening. The presence of more iron in the residue of the Kameng than the reported 0.72 ppm and 0.96 ppm in the water prior to the blackening (Sharma and Sarma, 2018; Singh et al., 2020) suggests reddish-brown iron oxides as a major contributor to the colour of the water. Though small, the presence of Cr, Co, and Ni in the solid samples indicates the presence of suspended light green, grey, and dark green oxides of the metals, respectively, which might have contributed to the intensity of the black colour of the water (Garbarino et al., 1984).

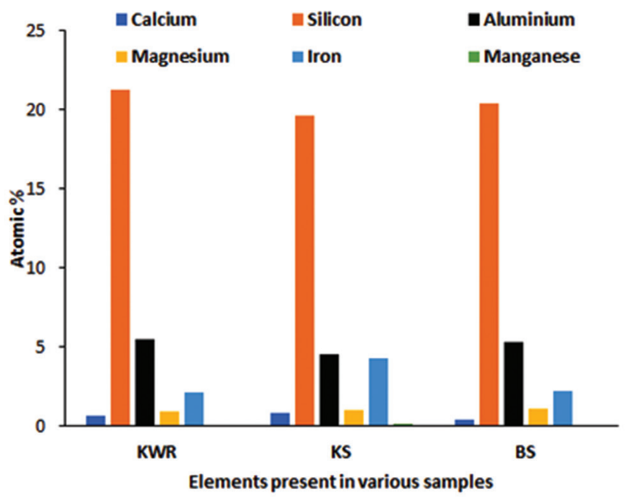

Figure 5: EDX analysis of residue of filtration (KWR, left) and sediment of the Kameng (KS, middle) and sediment of the Bisom (BS, right).

The filtrates of the water samples were also examined by AAS for the presence of some metal ions, and the results are shown in Table 3. The concentrations of Na, Ca, and Mg in the filtrates are in the normal range in river water (Dutta et al., 2006; Subramanian, 2004). Coloured ions were not detectable in the samples except for only 0.13 ppm of iron in the water from the Brahmaputra. This indicates that dissolved ions were not responsible for the blackening.

Recurrence of disasters like the blackening of rivers with ecological impact may be avoided by preventing landslides in mountainous rivers through erosion management techniques such as reforestation, creation

Table 2: Metal ions in ppm measured by AAS in the sediments and residue of the riverbeds

Sample description	*Mg*	*Ca*	*Al*	*Cr*	*Co*	*Fe*	*Mn*	*Ni*
Residue of water from the Kameng	37	12	62	0.06	0.06	176	2.0	0.14
Sediment from the Jiya Bharali riverbed	47	20	73	0.21	0.04	178	2.6	0.13
Sediment from the Bisom riverbed	46	25	24	0.17	0.04	114	1.8	ND
Color of the oxides of metals	White	White	White	Light green	Grey	Reddish-brown	Black	Dark green

ND: Not detectable

Table 3: Concentrations of metal ions in ppm measured by AAS in the filtrates of river waters

Sample description	*Na*	*Mg*	*Ca*	*Al*	*Cr*	*Co*	*Fe*	*Mn*	*Ni*
Filtrate from water from the Kameng	2	1	8	ND	ND	ND	ND	ND	ND
Filtrate from water from the Bisom	2	2	8	ND	ND	ND	ND	ND	ND
Filtrate from water from the Jiya Bharali river	2	2	7	ND	ND	ND	ND	ND	ND
Unfiltered water from the Brahmaputra	3	2	9	ND	ND	ND	0.13	ND	ND

of retaining walls, installing erosion control structures or construction of small dams (Poff and Hart, 2002). Chemical remediation of the blackening of rivers using low-cost coagulation of alum or ferric chloride together with a pH adjuster may facilitate sedimentation from the water (Bora et al., 2019).

Conclusions

The present study reveals that it was the TSS of the water and not the TDS that caused the blackening and fish deaths in the Kameng. The blackening was caused by excess suspended inorganic solids of mainly calcium-magnesium aluminosilicate clays, iron oxide and manganese, and traces of cobalt, nickel, and chromium. While the absorption of light by intense black manganese dioxide was mainly responsible for imparting black colour to the water, high amounts of reddish-brown iron oxide and a smaller presence of other metal oxides of various colours added to the blackening. Another cause of the blackening was the scattering of light by suspended microparticles with a size greater than the wavelength of visible light. The nature of the suspended inorganic solid contaminants in the river as such does not point towards any possibility of a decrease in dissolved oxygen due to the chemicals. Thus, the study also indicates suffocation of the respiratory system of the fish due to the excess microscopic solids in the water as the possible cause of the deaths of fish in the river during the blackening. Finally, the findings confirm the cause of the sudden blackening of the river water to be a landslide somewhere in the Warrying Bung at the upstream of the Kameng, as suggested by the district authority, leading to a sudden heavy load of suspended solids in the river water. Preventive measures like afforestation, small dams, and corrective measures like chemical sedimentation may be adopted to avoid such disasters.

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