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A COMPARATIVE STUDY ON DIVERSITY OF ALGAE IN COAL MINE IMPACTED AND UNIMPACTED STREAMS OF JAINTIA HILLS, MEGHALAYA

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The present paper deals with a comparative study on diversity of algal communities in the AMD (acid mine drainage) impacted streams with that of unimpacted streams of Jaintia Hills, Meghalaya. A total of 113 taxa were recorded from unimpacted streams belonging to six major algal groups Bacillariophyceae (56), Chlorophyceae (42), Cyanophyceae (9), Euglenophyceae 4), Chrysophyceae (1) and Rhodophyceae (1), whereas only 34 taxa were recorded from AMD impacted streams belonging to 4 groups. Bacillariophyceae (24), Chlorophyceae (4), Cyanophyceae (4), and Euglenophyceae (2). Out of 4 Chlorophyceaen members, two filamentous green algal species belonging to Ulotrichales namely *Microspora* and *Klebsormidium* were found to form thick algal mat covering the whole stream bed in the AMD streams. Other 32 members were recorded from the rocky bottom and dead leaves and twigs. Bacillariophyceae has been found to be the most dominant group and *Navicula* was the most dominant genus. 22 members from Bacillariophyceae 4 from Chlorophyceae, 2 from Euglenophyceae and 3 from Cyanophyceae were common in both impacted and unimpacted streams. The change in diversity could be attributed to the significant differences in pH, acidity, dissolved oxygen, free Carbon dioxide and sulphate content of the water bodies of impacted streams.

Key words : Acid Mine Drainage (AMD), Jaintia hills, Species diversity.

Jaintia Hills district of Meghalaya is situated in the eastern part of the state and lies between 25° 02'N to 25° 45' latitudes, and between 91° 58' E longitudes. The area is rich in forest and mineral resources. Coal is one of the most exploited mineral in the state. Unscientific and primitive nature of coal mining has led to a variety of environmental changes especially to the water bodies. Acidic seeps and streams are prevalent throughout Jaintia Hills district. Most of the streams and rivers in these areas are affected by coloured discharge generated from active and abandoned coal mines referred commonly as AMD. Pollutants, like acid mine drainage (AMD) not only influenced stream quality but created complex problems that involved chemical pollution (Kar and Chu 1999). Since (2005) reported a decrease in diversity of micro invertebrates in the AMD impacted streams of Jaintia Hills. Algae have long been utilized as biotic indicators mainly as means for measuring and evaluating overall condition of water bodies because algae exhibit wide range of ecological tolerance and directly response to many changes in the environment (Stoemer 1998). Decrease in algal species richness and diversity with increase in acidity have been reported from different coal mine affected areas of Ohio, U.S.A. (Verb and Vis 2004). The present work was undertaken to study the diversity of algal communities from selected unimpacted steams and AMD impacted streams of Jaintia hills in relation to physico chemical characters to evaluate the status of aquatic bodies in the coal mining areas of Jaintia Hills taking algae as an indicators.

MATERIAL AND METHODS

Several streams in and around coal mining areas and streams away from coal mining areas were selected and sampled in Jaintia Hills district

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of Meghalaya.

For physico chemical analysis of water, pH, conductivity, dissolved oxygen, temperature were measured using Deluxe water and soil analysis kit (Model 191E). The mean current velocity was calculated by timing a bobbler as it moved over a distance of one meter. The mean depth was calculated from 10 randomly selected points. Water samples were analyzed in the laboratory for acidity, total hardeness, free CO_2 calcium, magnesium, nitrate, sulphate, phosphate, following the standard method prescribed by A.P.H.A. (2005) and iron was estimated by AAS (Perkin Elmer Spectrophotometer. Model 460).

Periphytonic algal samples were collected by scraping with tooth brush from various substrata such as rocks, twigs, leaves, plastic bags, pebbles etc. Phytoplanktons collected by towing plankton net and samples were kept in a sample container, allowed to sediment and preserved in 4% formaldehyde. Algal taxa present were enumerated, quantified (No. of individuals/ml) using a light microscope, drawn and photographed using phase contrast icroscope. Identification of algal taxa to the possible taxonomic level was carried out by referring standard books and monographs by Fritsch (1935), Smith (1950), Tiffany (1952), Prescott (1968), Bold and Wynne (1985), Desikachary (1988), John *et al* (2002). Diversity and richness of different algal groups had been calculated using Shannon-Weaver diversity index (Shannon and Weaver 1949). $H' = \Sigma^{ni}/N$ Pi logPi

where, H'= Species diversity, ni = Number of individuals of a particular species, N = Total number of all the individuals.

$$Pi = \frac{\text{Number of individuals of a species}}{\text{Total number of individuals of all species}}$$

OBSERVATION AND RESULTS

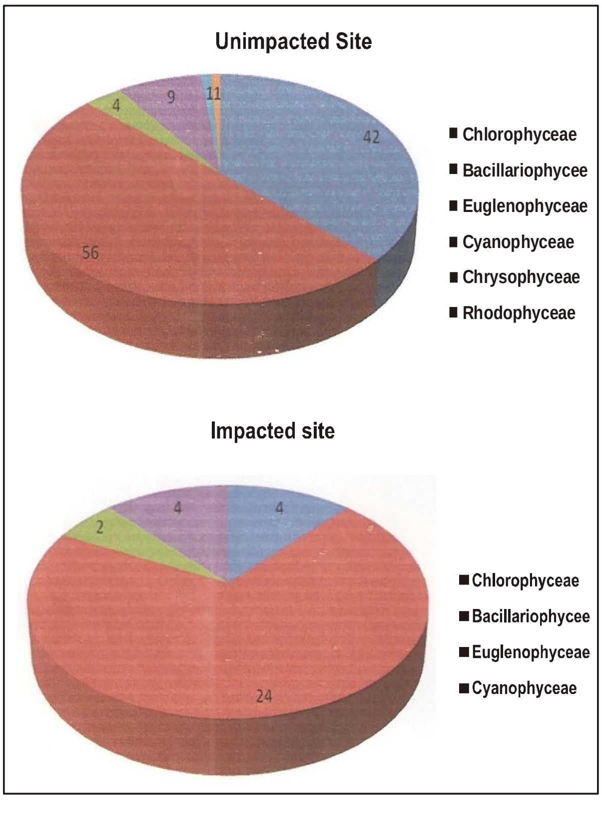
Significant differences were observed in streams impacted by AMD from that of unimpacted ones in many physico-chemical parameters. pH value ranged widely from highly acidic (3.4 to 3.7) in AMD impacted streams to nearly neutral waters in unimpacted streams (6.46), and acidity ranged from 3.5 mgl^{-1} to 21 mgl^{-1}. Not only pH and acidity, rather conductivity, current velocity, dissolved oxygen, free carbon dioxide and sulphate varied significantly between impacted and unimpacted streams. Other parameters like temperature, calcium, magnesium, total hardness, phosphate, nitrate and iron did not show significant differences (Table 1).

Table 1: Physical and chemical parameters measured from unimpacted and impacted sites

Variable	Unimpacted	Impacted
Average depth (cm)	13.5 ± 9.12a	12.75 ± 0.92a
Temperature	20.5 ± 2.12a	22.66 ± 2.35a
Current velocity ($cm\ s^{-1}$)	24 ± 1.41a	51.01 ± 16.24b
pH	6.46 ± 0.05a	3.56 ± 0.162b
Conductivity	0.02 ± 0.008a	0.45 ± 0.25b
DO ($mg\ l^{-1}$)	7.45 ± 0.77a	1.77 ± 0.01b
Free CO2 ($mg\ l^{-1}$)	7.45 ± 2.82a	17.33 ± 7.53b
Acidity ($mg\ l^{-1}$)	3.5 ± 0.70a	21 ± 1.41b
Total hardness ($mg\ l^{-1}$)	46 ± 9.59a	67.66 ± 8.95a
Calcium ($mg\ l^{-1}$)	6.72 ± 0.005a	4.48 ± 0.003a
Magnesium ($mg\ l^{-1}$)	9.58 ± 9.65a	20.11 ± 8.83a
Nitrate ($mg\ l^{-1}$)	8.3 ± 0.32a	6.8 ± 3.17a
Phosphate ($mg\ l^{-1}$)	0.04 ± 0.13a	0.03 ± 0.005a
Sulphate ($mg\ l^{-1}$)	4.40 ± 0.68a	120.95 ± 39.26b
Iron ($mg\ l^{-1}$)	0.34 ± 0.21a	1.15 ± 0.70a

*Data following the same letters are not significantly different.

A total of 114 taxa were identified from both unimpacted and impacted streams of Jaintia Hills district of Meghalaya. Streams with little or no acid pollution (pH 6.46 or higher) supported diverse algal communities consisting of 113 species belonging to six different groups. Conversely, severely polluted streams (pH 3.56 or lower) were inhabited by only 34 species (Fig. 1). Out of these 34 species, 24 belonged to Bacillariophyceae representing 68%, 4 species belonged to Cyanophyceae (11%) 2 species (6%) belonged to Euglenophyceae and two species of chlorophyceae were found occupying the rocky bottom, dead leaves and other substrata of the streams. The surface was fully covered with intermingled long filaments of two bright green chlorophyceaen algae belonging to order Ulotrichales namely *Microspora* and *Klebsormidium* species. From unimpacted stream, 56 species of Bacillariophyceae (49.55%), 42 species of Chlorophyceae (37.16%), 9 species of Cyanophyceae (7.96%), 4 species of Euglenophyceae (3.53%) and 1 species each (0.88%) of Chrysophyceae and Rhodophyceae were recorded. The genus *Navicula* was the most abundant taxa in the impacted streams and represented by the maximum number of individuals followed by *Gomphonema* and *Pinnularia* species. 4 members of Chlorophyceae, 2 members from Euglenophyceae, 3 members from Cyanophyceae and 22 members from Bacillariophyceae were found common between impacted and unimpacted sites (Table 2). As expected, diversity of algal communities mainly Chlorophyceae and Bacillariophyceae varied greatly in between unimpacted and impacted streams. In general, members of Bacillariophyceae have been found to be the most diversed group in both impacted and unimpacted streams



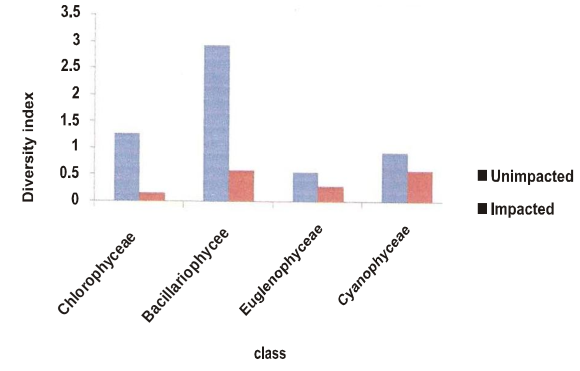


Fig. 2: Diversity of different groups in unimpacted and impacted site

DISCUSSION

Low pH, high acidity and sulphate observed in the AMD streams in the present study have also been reported as some of the most influencing parameters which separate the AMD streams of Jaintia Hills from the unimpacted streams (Singh 2005). High concentration of acidity i.e. H^+ ions (21 mg/l or greater) caused pH values to be lower than 4.0 and were inhabited by mainly species (24 species) most belonging to Bacillariophyceae. Number of Chlorophycean group reduced drastically in impacted streams but two long filamentous forms of green algae composed mainly of *Microspora* and *Klebsormidium* species covered the whole surface producing huge biomass showing their adaptability to very low pH. Much of this reduction in species diversity has been attributed due to increased hydrogen ion activity, in AMD streams and elevations in ambient metallic salt concentrations (Leatherman and Mitsch, 1978; Keating et al 1996). Singh (2005) reported significant differences in iron content in between unimpacted and impacted streams. But in the present study, differences in iron content in the water of impacted and unimpacted streams was not found to be significant but it was high in the filamentous green algae covering the surface of the impacted streams which indicated that those filaments had good iron absorbing capacity. According to Warner (1971), high levels of free carbon dioxide also played

Table 2: List of species collected from unimpacted and impacted sites

Chlorophyceae	U	I	Bacillariophyceae	U	I
Ankistrodesmus falcatus. (Corda) Ralfs	+	-	*Achnanthes inflata* Kutzing	+	-
Chlamydomonas globosa Snow	+	-	*Achnanthes lanceolata* (Brebisson) Grunow	+	-
Chlorella vulgaris Beijerinck	+	-	*Amphora elliptica* Kutzing	+	-
Chlorococcus sp	+	-	*Ampleura* sp*	+	+
Cladophora sp*	+	-	*Caloneis bacillum* Grunow	+	-
Closterium ehrenbergii Meneghini	+	-	*Cocconeis* sp*	+	-
Closterium turgidum Ehrenberg	+	-	*Cymbella affinis* Kutzing	+	-
Closterium arcuatum Brebisson	+	-	*Cymbella ventricosa* Kutzing	+	-
Closterium intermedium Ralfs.	+	-	*Cymbella cistula* (Hemprich) Grunow	+	-
Closterium lanceolatum Kutzing	+	-	*Cymbella cuspidata* Kutzing	+	+
Closterium parvulum Naegeli	+	-	*Cymbella lanceolata* (Ehrenberg) Grunow	+	-
Closterium venus Kutzing	+	-	*Cymbella naviculiformis* Auerswald	+	+
Cosmarium moniliforme (Turp.) Ralfs, formae	+	-	*Cymbella tumida* Brebisson	+	-
Cosmarium contractum Kirchn	+	+	*Diadesmis confervacea* Kutzing	+	-
Cosmarium biretum Brebisson	+	-	*Eunotia lunaris* (Ehrenberg) Grunow.	+	+
Cosmarium botrytis Meneghini	+	-	*Fragellaria biceps* Kutzing	+	+
Cosmarium pulchellum West.	+	-	*Fragellaria virescens* Ralfs	+	+
Cylindrocystis sp*	+	+	*Gomphonema abbreviatum* Agardh	+	-
Desmidium grevillei De Bary	+	-	*Gomphonema constrictum* Ehrenberg	+	-
Desmodesmus brasiliesis (Bohlin) Hegewald	+	-	*Gomphonema dichotomus* Kutzing	+	-
Desmodesmus communis (Hegewald) Hegewald	+	-	*Gomphonema gracile* Ehrenberg (Kutzing) Grunow.	+	-
Euastrum dubium Nag	+	-	*Gomphonema lanceolatum* Ehrenberg	+	-
Euastrum erosum Lund	+	-	*Gomphonema montanum* Schumann	+	-
Hydrodictyon reticulatum (Linnaeus) Lagerheim	+	-	*Gomphonema olivaceum* (Lyngbye) Kutzing	+	+
Klebsormidum sp*	+	+	*Gomphonema parvulum* (Kutzing) Grunow.	+	-
Kirchneriella obesea (W. West) Scmidle	+	-	*Gomphonema telographicum* Kutzing	+	+
Microspora sp.*	+	+	*Gomphonema vibrio* Ehrenberg	+	-
Mougetia sp.*	+	-	*Gyrosigma* sp.*	+	-
Netrium digitus (Ehrenberg)	+	-	*Melosira varians* Agardh	+	-
Oedogonium sp*	+	-	*Navicula sphaerophora* Kutzing	+	-
Pediastrum integrum Naegeli	+	-	*Navicula trimpunctata* (O.F. Muller) Bory	+	+
Pediastrum tetras (Ehrenberg) Ralfs	+	-	*Navicula borealis* Kutzing	+	+
Roya sp*	+	-	*Navicula cuspidata* Kutzing	+	+
Scenedsmus armatus (Chodat) G.M. Smith	+	-	*Navicula graciles* Ehrenberg	+	-
Scenedesmus longus Meyen	+	-	*Navicula lanceolata* (Agardh) Kutzing	+	+
Selenastrum minutum (Nageli) Collins	+	-	*Navicula major* Kutzing	+	+
Spirogyra sp.*	+	-	*Navicula microspora* Kant and Gupta	+	+
Spondylosium pygmaeum (Cooke) W. West	+	-	*Navicula pupula* Kutzing	+	-
Stigeoclonium sp.*	+	-	*Navicula radiosa* Kutzing	+	-
Straustrum gracile Ralfs	+	-	*Navicula reinhardtii* Grunow.f.gracilior Grunow	+	-
Ulothrix sp.*	+	-	*Navicula viridis* Kutzing	+	+
Zygnema sp*	+	-	*Navicula viridula* Kutzing	+	-
Chrysophyceae			*Neidium iridis* Kutzing	+	+
Dinobryon sertularia Ehrenberg	+	-	*Nitzchia amphibian* Grunow	+	-
Euglenophyceae			*Pinnularia biceps* Gregory	+	+
Euglena elongata Schewia-koff	+	+	*Pinnularia braunii* (Grunow) Cleve	+	+
Euglena gracilis Klebs	+	-	*Pinnularia brebissonii* Kutzing	+	-
Euglena oblonga Schmitz.	+	+	*Pinnularia cardinalis* (Ehrenberg) Wm.Smith.	+	+
Lepocinclis ovum (Ehrenberg)	+	-	*Pinnularia divergens* Wm. Smith	-	+
Cyanophyceae			*Pinnularia gibba* Ehrenberg	+	-
Anabaena sp*	+	+	*Pinnularia nobilis* Ehrenberg	+	+
Johannebaptistia pellucida (Dickie)			*Pinnularia viridis* (Nitzsch.) Ehrenberg	+	+
W.R. Taylor & Drouet	+	-	*Strauneis acuta* Wm. Smith	+	-
Lyngbya sp*	+	-	*Synedra tabulata* Kutzing	+	-
Merismopedia convulata Brebisson	+	-	*Synedra ulna* Grunow	+	-
Oscillatoria sp.*	+	+	*Tabellaria fenestrata* (Lyngbye) Kutzing	+	+
Phormidium sp.*	+	+	**Rhodophyceae**		
Pleurocapsa varia (A. Braun) Drouet and Daily	+	-	*Batrachospermum vagum* (Roth) Agardh	+	-
Raphidiopsis curvata Fritsch	+	-			
Spirulina nordstedtii Gomont	+	+			

U=Unimpacted site; I=Impacted site

important role in the distribution and diversity of biota and this could also be an additional factor affecting diversity in the present study. Bacillariophyceae has been found to be the most dominant group in both AMD impacted and unimpacted streams. Significant differences were observed in diatom densities in between impacted and unimpacted streams. Diatom densities i.e. individuals/ml at AMD impacted streams were more dense than those found in non impacted streams though the number of species were higher in unimpacted streams. 22 diatoms were common between unimpacted and impacted streams. Benthic diatoms have often been used as useful tool in detecting anthropogenic impacts as diatom communities react very quickly to disturbances of the water, very often by changing their species composition (Stoermer 1998, Juttner *et al* 2000, Acs *et al* 2004). *Navicula cuspidata* was the most dominant taxa in AMD streams with highest number of individuals. The occurrence of certain diatom taxa had been highly correlated with pH (Pan *et al* 1996, Verb and Vis 2000). Presence of nearly 42 species from Chlorophyta in the unimpacted streams was characteristic of lotic systems (Sheath and Burkholder 1985). Thick mats formed by two filamentous green algae namely *Microspora* sp. and *Klebsormidium* sp which covered fully the surface of impacted streams was not observed in unimpacted streams. Occurrence of conspicuous bright green algal mats composed of filamentous taxa such as *Klebosormidium, Microspora, Mougetia, Ulothrix* and *Stigeoclonium* species from AMD streams had been reported by many workers (Rai *et al* 1981, Stevens *et al* 2001, Verb and Vis 2004). According to Kelly (1988) certain algae grow best at low pH, as stimulation by pH stress, stimulate the growth. Progressive application of stress, involve almost complete suppression of biodiversity leading to the dominance of one or very few taxa (Niyogi *et al* 2002). According to Niyogi *et al* (2002) two mechanisms could account for low diversity in stressed systems (mining). Firstly, a small number of taxa and secondly, high abundance of few taxa as grazing get disrupted. Streams stressed by AMD in the present study were dominated by few tolerant diatoms found mainly on the rocky bottom and two filamentous algae belonging to Chlorophyceae on the surface. Thus, both mechanisms cited above could account for the reduced diversity at AMD stressed sites.

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