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Degradation in Water Quality due to Limestone Mining in East Jaintia Hills, Meghalaya, India

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Abstract

Meghalaya possesses 9% of the country total limestone reserves. Of which, East Jaintia Hills district has the maximum deposits. Limestone rock mining in the district started about a decade ago to meet the requirements of the cement plants of the area. In recent years, number of cement plants and quantum of limestone mining have increased drastically leading to severe environmental problems ranging from deforestation and degradation of land to water pollution and water scarcity. This study reports the impact of limestone mining on water quality based on analyses of various physico-chemical parameters of water samples of the area and its comparison with the results of unaffected water body. Analysis was done during the Pre-monsoon and Post-monsoon seasons of 2013, from five different locations in the vicinity of the mining area. The water samples from Myntdu river headwater were selected as a control. It was found that water samples analysed from the vicinity of limestone quarry and cement plant showed an elevated levels of pH, EC, TDS, total hardness, alkalinity, calcium and sulphate concentrations etc. with reference to those of control samples. The study revealed that open cast mining of limestone rock's and direct contact of wastewater from the cement plants into the water bodies does have a negative impact on the physico-chemical characteristics of the waters of the area. Thereby, indicating a serious problem on availability of clean water in the area.

Keywords: Limestone mining, cement plants, water quality, Jaintia hills, Meghalaya.

Introduction

Meghalaya is geographically characterized by an Archaean gnessis complex. Hence, the state has rich deposits of mineral resources such as coal, limestone, Sillimanite and Uranium etc[1]. Meghalaya possess 9% deposits of the total limestone resources of the country[2]. It is mainly distributed along the southern fringe of the state. Extensive mining of limestone began about a decade ago to meet the requirements of cement manufacturing plants, which grew exponentially in the recent past in Jaintia Hills area of Meghalaya. Limestone is the second most important mineral extracted in the state after coal.

Mining of natural aggregates whether in small/large scale are unsurprisingly destructive to the environment[3]. Limestone mining is progressively growing at present due to the escalating numbers of cement plant industries. Preliminary observations reveal that limestone mining has tremendously degraded the ecosystem of the area causing severe environmental impact such as deforestation, removal of top fertile soil, disturbances of the surrounding ecosystem near the mining sites as well as contamination of the water in the nearby area. Coal mining impact on water quality of the region has been adequately investigated[4-6]. Limestone rock mining and its probable impact on water quality has not been studied in Meghalaya. Hence, we have undertaken the study to analyze the impact of limestone mining on different components of environment of Jaintia Hills. In this paper we report the impact of limestone mining on the water quality of the area.

Material and Methods

Study Area: Limestone mining in East Jaintia Hills District starts from Nongsning village to Lumshnong along the NH.44 which is at a distance of approximately 130 Km from the Shillong city (State Capital). The area has the richest limestone deposits in the state. At present, limestone mining is being carried out extensively by eight cement plant factories (companies' own quarrying sites) as well as by the private land owners of the area.

Sample Collection: Water samples was collected during the Pre-Monsoon (April-May) and Post-Monsoon (October-November) seasons of 2013, from five different sampling stations in the vicinity of limestone mining area and from Myntdu River Headwater as control, by Grab sampling method. Of the five sampling sites (Table-1), three sampling stations S1, S2 and S3 were near the limestone quarry sites whereas S4 and S5 were from the water bodies contaminated by the wastewater from cement industries. The latter sources are now no longer used for drinking and other domestic purposes due to their contamination by the waste from cement plant.

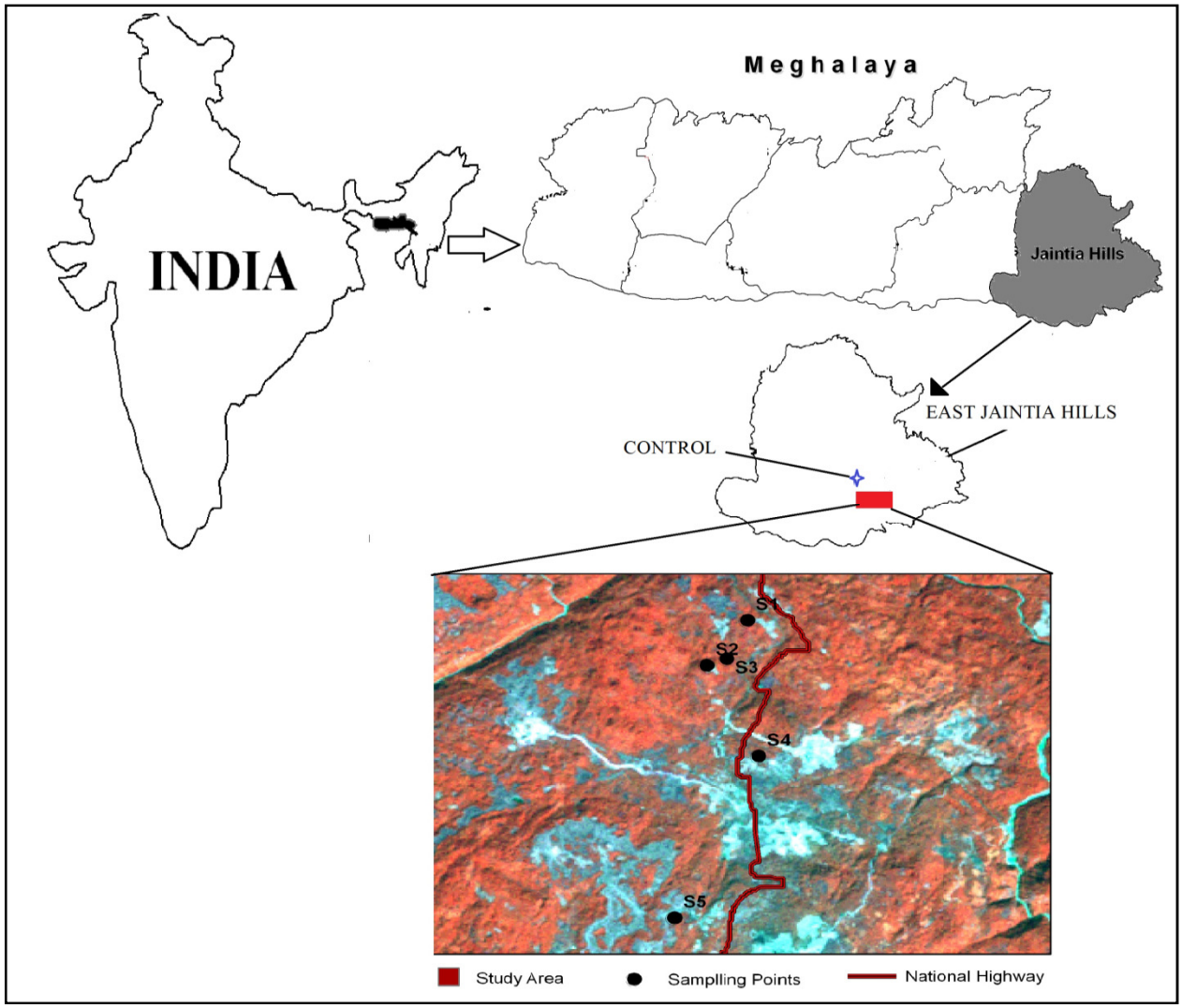


Figure-1
Map showing the study area (without scaling)

Methodology: Sampling of water was done following the standard procedures. Water quality parameter like water temperature, pH and EC was determined on the spot using EUTECH PCTestr 35. Analytical parameters like Total dissolve solids (TDS), alkalinity, total hardness, calcium, magnesium, dissolve oxygen (DO), sulphate, inorganic phosphate and chloride were analyzed in the laboratory following the standard methods[7-9]. Sodium and Potassium were estimated using Microprocessor Flame Photometer (ESICO) Model 1381.

Results and Discussion

General Environmental implications of limestone mining in Jaintia Hills: Extraction of limestone rocks in the region has undeniably brought employment opportunities and revenues for the local communities. But limestone mining has also brought an inevitable dilapidation to the environment of the area. The types and extent of environmental degradation varies from area to area with severe degradation in the environmental health of the area. The thick native vegetation cover has been denudated resulting great loss of the rich biodiversity of the area. Excavation has resulted in removal of the fertile top soil and generations of huge amount of spoil or overburden generally in the form of gravel, coarse sand, fragmented rock pieces etc, which has deteriorated the aesthetic beauty of the proximate landscape. A large area has become unusable due to spreading of mine spoil and overburden. Limestone rocks are disintegrated into smaller rock size using drilling machines and dynamite, causing hefty noise pollution. Heavy and daily blasting may also has resulted in crack formation on the geological rock, which in long run will certainly influence the availability of surface and ground water in and around the mines. The region at present is already facing an acute shortage of water availability, particularly during the dry season. Pollution of surface water by limestone mining and cement plants has further deteriorated the situation.

Table-1
Details of different sampling sites from where water samples was collected for the present study

Sampling Stations	Water Bodies Local Name	Location	GPS Reading	Stations Description
Control (Co)	Myntdu	Jowai	N25^{0}47′49.7″ E92^{0}20′93.7″	Situated at 200-300 m south of headwater. Rocky river bed. Away from mining activities and heavy anthropogenic disturbances
S1	Mih-Chariang	Nongsning	N25^{0}24′67.7″ E92^{0}37′71.9″	Only sources of drinking water to the nearby area. At least 50 -70 m south of one quarry sites. Large volume of mine water emanating from the mining sites can be seen contaminating the sources during rainy seasons.
S2	Wah-Rkhiang	Mynkree	N25^{0}23′56.8″ E92^{0}37′57.4″	Situated alongside the limestone quarry. Streams bed is covered with a thick sand deposition.
S3	Pom-Pa	Mynkree	N25^{0}23′06.6″ E92^{0}37′89.2″	Situated on the side of another quarry. The streams bed and bank are rugged, deposited with stone and gravel of different size.
S4	Jynrong	Wahiajer Narpuh	N25^{0}19′61.3″ E92^{0}39′11.3″	Situated inside the forest at least 1.5 Km south from one of the cement plant. Heavy sand deposition observed on stream bed. Once the source of water supply to the nearby locality.
S5	Umjri	Lumshnong	N25^{0}17′97.8″ E92^{0}36′32.2″	Situated approximately 0.5 to 1 km south of another cement plant. Once the source of drinking water to the Lumshnong locality. Dull appearances of the water body.

Degradation in water quality due to limestone mining: Water quality analysis gives us an idea about the health of the water bodies. Thus water samples from two different seasons of the year were analysed to see the changes in its quality. The pre-monsoon and post-monsoon water quality data are summarized in table-2 and table-3, respectively. The graphical representations of different physico-chemical water parameters are also presented in figure-2. The details various parameters are discussed below:

Water temperature: The minimum average temperature recorded during the study period was 21.5^{0}C ±0.56 during pre-monsoon at S1 and maximum temperature was 24.7^{0}C ± 0.27 at S2 during post-monsoon. During the study period, it was observed that water temperature during post- monsoon gradually increases as compared to pre-monsoon with the exception of the control sites. The variation in water temperature at different locations may be attributed to the altitudinal variations of the sites.

pH: The water samples from the studied area are generally neutral to moderately alkaline in nature having pH ranged from 7±0.11 to 8±0.05 during the pre-monsoon and 7.2±0.11 to 8.2±0.05 during post-monsoon. Similar studies have been done at other limestone mining sites in the country. Study at Biramitrapur limestone and dolomite mines showed slightly alkaline in nature having pH ranging from 7 to 7.9[10]. Except for S1 and S4, pH values slightly increased from pre-monsoon to post-monsoon in all sampling sites. However, this alkaline nature of water may be due to limestone mining. Since, major chemical constituent of limestone is calcium carbonate which on coming in contact with water generates alkalinity. In contrary to this, pH of water in the nearby coal mining area is highly acidic.

Conductivity (EC): The EC at the control station was documented with a minimum value of 22.66±0.57 µS and 27.33±2.3 µS during pre-monsoon and post-monsoon respectively. The maximum EC was at S5 for both the seasons. The water samples S1, S2 and S3 locations show relatively low EC, implying the presence of reduced level of ionic species as compared to the other two sites. Whereas high EC value in S4 and S5 for both the seasons, may be due to elevated quantity of dissolved ions in them (sources being waste discarded into the water bodies from the cement plants).

Table-2
Pre-Monsoon season (PRM) data for different parameters of different stations from the study area

Sampling Stations / Parameters	Control (Co)	S1	S2	S3	S4	S5
Water Temp. ^{O}C	23.9 ± 0.14	21.5 ± 0.56	23.1 ± 0.07	22.5 ± 0.28	23.0 ± 0.91	22.5 ± 0.21
pH	7.0 ± 0.1	8.0 ± 0.05	8.0 ± 0.05	7.9 ± 0.05	7.3 ± 0.1	7.4 ± 0.11
EC (NTU)	22.66 ± 0.57	196 ± 4.35	129.33 ± 8.38	197 ± 5.19	443 ± 3	502 ± 5.19
TDS*	23.33 ± 5.77	76.66 ± 11.54	113.33 ± 5.77	96.66 ± 5.77	286.66 ± 20.81	386.66 ± 15.27
Alkalinity*	23 ±1.73	110.33 ±1.52	74.66 ±0.57	99.66 ± 0.57	112 ± 1	114 ± 0
Total Hardness*	12.66 ± 1.15	126.66 ± 11.54	91.33 ± 3.05	115.33 ± 2.3	264.66 ± 4.61	299.33 ± 1.15
Calcium*	2.52 ± 0.84	43.45 ± 0.97	32.8 ± 0.84	38.12 ± 1.28	98.12 ± 2.56	104.57 ± 1.75
Magnesium*	1.54 ± 0.58	4.41 ± 3.14	2.29 ±0.25	4.89 ± 1.25	4.7 ± 2.08	9.29 ± 1.27
Dissolve Oxygen*	7.18 ± 0.11	7.98 ± 0.11	6.71 ± 0.5	6.64 ± 0.4	7.44 ± 0.2	7.78 ± 0.11
Sulphate*	56.25 ± 3.12	63.54 ± 1.8	232.29 ± 6.5	162.5 ± 3.12	814.58 ± 1.8	840.62 ± 3.12
Chloride*	7.99 ± 0.49	11.66 ± 1.52	9.33 ± 0.28	10.16 ± 0.28	11.66 ± 0.57	10.66 ± 0.57
Phosphate*	2.16 ± 0.04	2.0 ± 0.12	1.94 ± 0.12	1.67 ±0.04	2.02 ± 0.12	1.97 ± 0.08
Sodium (ppm)	1.73 ± 0.05	0.46 ± 0.05	1.83 ± 0.05	1.2 ± 0.1	1.73 ± 0.05	1.93 ± 0.05
Potassium (ppm)	1.06 ±0.05	0.1 ± 0	2.36 ± 0.05	0.8 ± 0.1	1.43 ± 0.05	3.83 ± 0.05

NB: The values of all parameters marked with asterix (*) are represented in mg/l

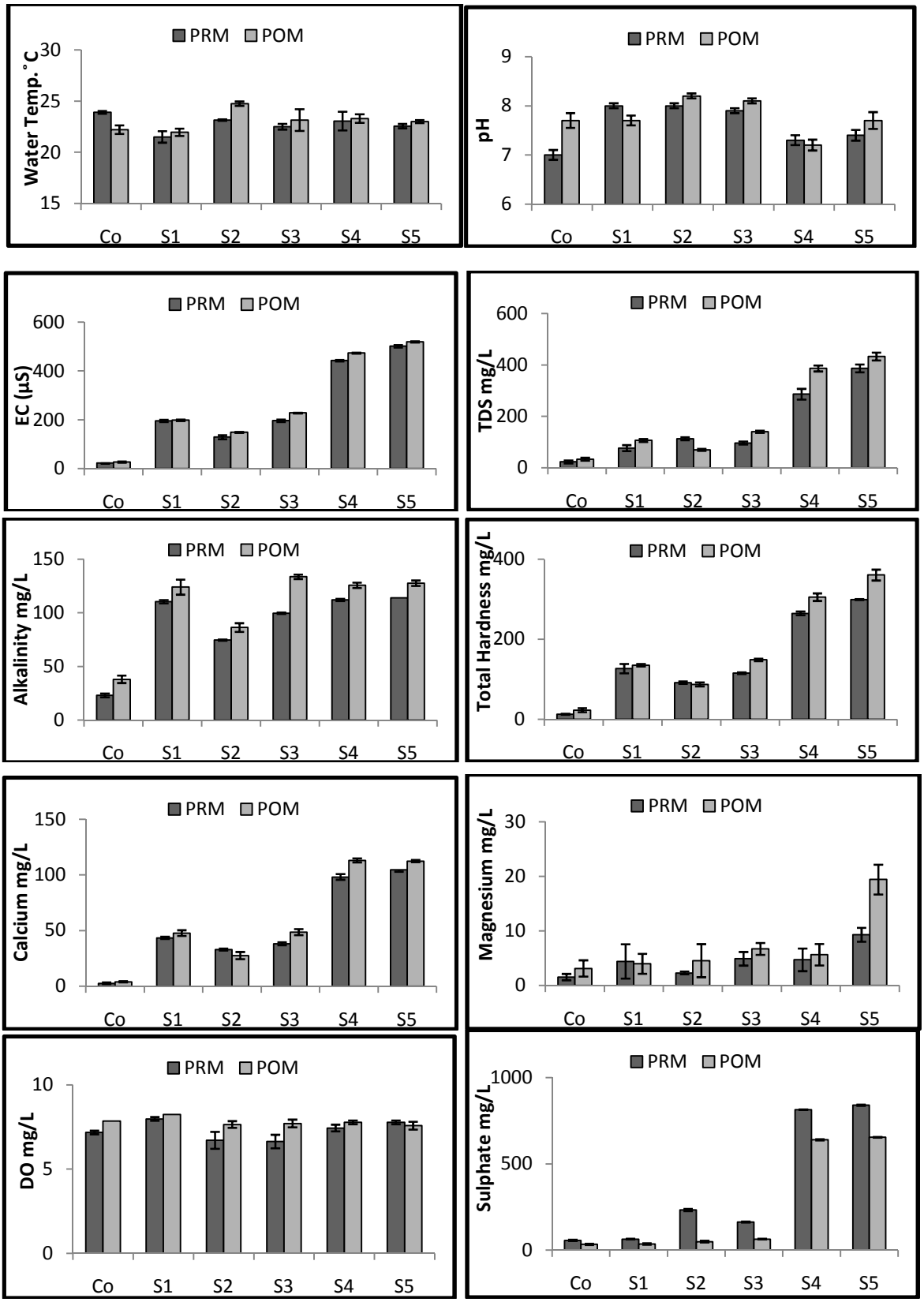
Table-3
Post-Monsoon season (POM) data for different parameters of different stations from the study area

Sampling Stations / Parameters	Control (Co)	S1	S2	S3	S4	S5
Water Temp. ^{O}C	22.2 ± 0.42	21.9 ± 0.35	24.7 ± 0.21	23.1 ± 1.06	23.3 ± 0.42	23 ± 0.14
pH	7.7 ± 0.15	7.7 ± 0.1	8.2 ± 0.05	8.1 ± 0.05	7.2 ± 0.11	7.7 ± 0.17
EC (NTU)	27.33 ± 2.3	199 ± 3	149 ± 1.73	228.33 ± 1.15	474 ± 2	519.66 ± 2.51
TDS*	33.33 ± 5.77	106.66 ± 5.77	70 ± 4.1	140 ± 4.1	386.66 ± 11.54	433.33 ± 15.27
Alkalinity*	38 ± 3.46	124 ± 7	86.33 ± 4.04	133.66 ± 2.08	125.66 ± 2.51	127.66 ± 2.51
Total Hardness*	22.66 ± 5.03	135.33 ± 3.05	87.33 ± 5.03	148.66 ± 3.05	305.33 ± 9.45	360.66 ± 13.61
Calcium*	3.92 ± 0.48	47.65 ± 2.56	27.47 ± 3.18	48.5 ± 2.7	112.98 ± 1.75	112.42 ± 0.97
Magnesium*	3.12 ± 1.49	3.97 ± 1.82	4.55 ± 3.04	6.7 ± 1.08	5.64 ± 1.96	19.43 ± 2.73
Dissolve Oxygen*	7.85 ± 0	8.25 ± 0	7.65 ± 0.2	7.71 ± 0.23	7.78 ± 0.11	7.58 ± 0.23
Sulphate*	33.33 ± 3.6	35.41 ±4.77	48.95 ± 4.77	63.54 ± 1.8	639.58 ± 3.6	654.16 ± 1.8
Chloride*	8.11 ±0.5	12.33 ± 1.05	14.7 ± 1.82	13.01 ± 1.17	13.51 ± 0.29	13.68 ± 1.34
Phosphate*	1.97 ± 0.08	1.67 ± 0.12	1.69 ± 0.12	2.22 ± 0.08	3.04 ± 0.21	2.22 ± 0.08
Sodium (ppm)	5.43 ± 0.05	1.36 ± 0.15	3.06 ± 0.89	1.83 ±0.11	6.23 ± 0.85	6.03 ± 0.57
Potassium (ppm)	1.23 ± 0.05	0.16 ± 0.05	0.4 ± 0.1	0.26 ± 0.05	1.56 ± 0.05	1.13 ± 0.05

NB: The values of all parameters marked with asterix (*) are represented in mg/l

Total Dissolved Solids (TDS): The TDS concentration in all sampling sites increases gradually, except for S2, from pre-monsoon to post-monsoon. Water samples at S1, S2 and S3 point up a comparatively little higher TDS concentration for both seasons as compared to the control stations. Limestone rock disintegration could be the reasons for these increases in dissolve ions in these water bodies. Whereas maximum concentration was found in S4 and S5, this is due to the additions of more organic and inorganic ions from the contaminated water discarded in these water bodies by the cement plants. All sampling stations were well below the set standard limit value of 500mg/l but approaching the limit in case of S5 during post-monsoon season.

Alkalinity: All the water samples analysed for alkalinity showed zero phenolphthalein alkalinity and have methyl orange alkalinity only for both the sampling seasons. This indicates that the alkalinity of the samples are due to bicarbonate only and not due to carbonate and hydroxide ions. Carbonate content has been reported to be zero in the ground water sample of Vijayraghovgarh limestone mines[11]. Carbonate were always less than bicarbonates[12]. The total Alkalinity values ranges from 23±1.73 mg/L to 114±0 mg/L during pre-monsoon and with maximum alkalinity at S5. During post-monsoon, the total Alkalinity values ranges from 38±3.46 mg/L to 133.66±2.08 mg/L and S3 possess maximum alkalinity. Alkalinity value somewhat increased during the post-monsoon as compared to pre-monsoon.


PRM
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Water Temp. ˚C
pH
EC (µS)
TDS mg/L
Alkalinity mg/L
Total Hardness mg/L
Calcium mg/L
Magnesium mg/L
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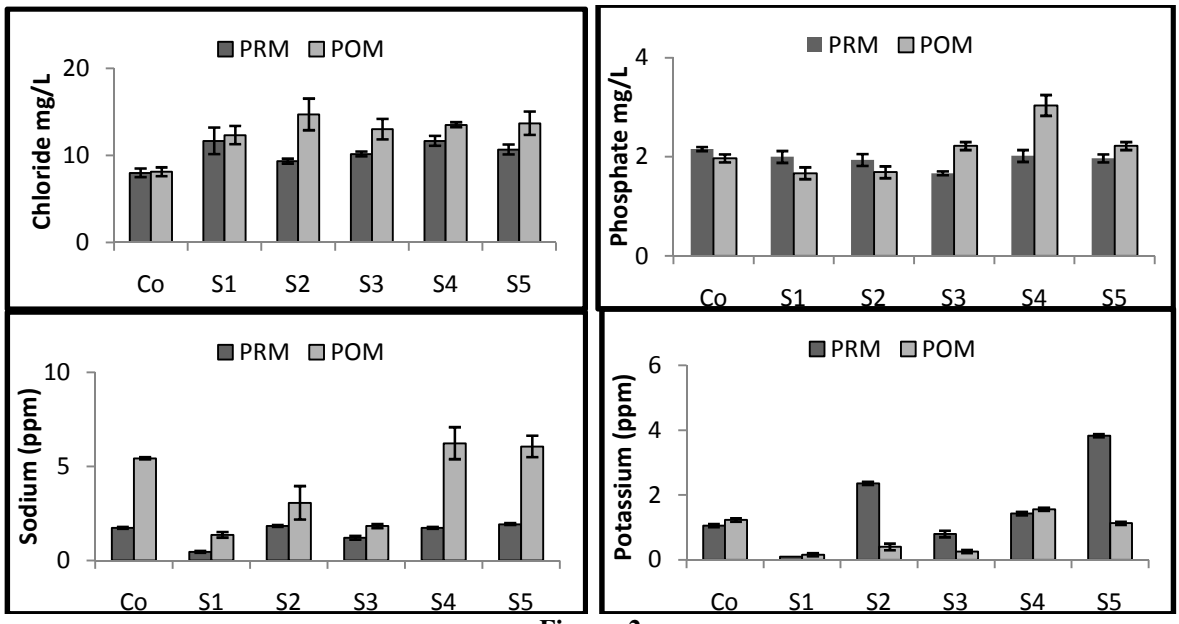

Figure–2
Graphical presentation of different physico-chemical parameter analysed during the study period

Total Hardness: As per water hardness classification; water samples having hardness (as $CaCO_3$) value ranged from 0-75, 75-150,150-300 and above 300 are classified as soft water, moderately hard, hard and very hard water. Among the investigated water samples, control stations possess soft characteristic throughout the studied period. S1, S2 and S3 are moderately hard for both the seasons. Water samples from S4 and S5 possess a hard characteristic during pre-monsoon seasons and very hard characteristic during post-monsoon seasons. Their hardness value for post-monsoon period has exceeded the prescribed limits of BIS (300mg/L).

Calcium: Calcium is a cation. The maximum calcium concentration during pre-monsoon was recorded in S5 (104.57±1.75 mg/L) and in S4 (112.98±1.75mg/L) during the post-monsoon season. Calcium concentration slightly increases in all sampling stations, excluding S2, from pre- monsoon to post-monsoon seasons. Calcium concentration for S4 and S5 has cross the standard limits (BIS: 75 mg/L) for both the seasons.

Magnesium: Magnesium concentration was reported to be lesser than the calcium values in all cases. Magnesium content investigated in all samples was found within the permissible limit of 30 mg/L. During pre-monsoon and post-monsoon period, a maximum magnesium concentration was 9.29±1.27 mg/L and 19.43±2.73mg/L at S5 respectively.

Dissolve oxygen (DO): In the present analysis it was observed that, the average DO value at all sampling stations ranges from 6.64±0.4 mg/L to 7.98±0.11 mg/L during pre-monsoon and 7.58±0.23 mg/L to 8.25±0 mg/L during post-monsoon. The high DO content in all sampling stations may be due to the shallowness of the flowing water bodies caused by the wide sand, sediment and rocks depositions on the streams bed, thus causing the water to be saturated with oxygen. Water temperature could also play an important role for high DO content in these water bodies.

Sulphate: Sulphate is a naturally occurring ion in almost all kind of water bodies. However, its concentrations of more than 200mg/L are objectionable for any domestic purposes. During pre-monsoon period, sulphate concentration at S2, S4 and S5 crossed the prescribed limits. Whereas during post-monsoon season, only S4 and S5 exceeded the standard limits. Throughout the study period, it was found that only the sulphate concentration was tumbling during post-monsoon season when compared to pre-monsoon period. The main sources of sulphate in S1, S2 and S3 may be due to dissolution of surface mineral present in limestone's rock. Limestone rock mining elevated sulphate concentration in groundwater[13]. Elevated concentration in S4 and S5 may be due to manufacturing waste discharge from the cement plants.

Chloride: Chloride concentration differs in water samples collected from different sources and it is an indicator of contamination. Encroachment of anthropogenic waste in any water bodies tends to accelerate the chlorine concentration. All water samples investigated for chloride were within the standard limits (BIS: 250 mg/l), which indicates less chloride contamination in all water samples. The minimum chloride concentration was 7.99±0.49 mg/L at control stations during pre-monsoon. The maximum concentration was during post-monsoon at S2 (14.7±1.82 mg/L). Increasing chloride concentration increases the electrical conductivity of the water[14].

Phosphate: The concentrations of phosphate in all samples investigated from limestone mining area were found to be of lowest order compared to all other ions. During pre-monsoon season, concentration of phosphate ranged from 1.67±0.04 mg/l to 2.02±0.12 mg/l whereas during post-monsoon it ranges from 1.67±0.12 mg/L to 3.04±0.21 mg/L. In limestone mining areas, higher phosphate concentration was recorded in S4 for both the sampling seasons. This may be due to the industrial pollutant (organic and inorganic form) from the cement plants discarded into the inland surface water bodies.

Sodium: Sodium concentration in water is generally found to be lower than that of calcium and magnesium concentration. Sodium concentration increases noticeably in the post-monsoon period as compared to pre-monsoon. The maximum average value for sodium concentration during pre-monsoon was 1.93±0.05 ppm at S5 and 6.23±0.85 ppm at S4 for post-monsoon. The elevated values of sodium at control station may be due to dissolution of rocks mineral caused by fast flowing water flowing over its rock bed.

Potassium: In this investigation, potassium concentration at all the sampling sites ranged from 0.1±0 ppm to 3.83±0.05 ppm during pre-monsoon and ranges from 0.16±0.05 ppm to 1.56±0.05 ppm during post-monsoon period. Concentration of potassium when compared decreases considerably at S2, S3 and S5 during post-monsoon.

Conclusion

Based on our investigation, it can be concluded that in most cases water quality as evident from elevated levels of pH, EC, TDS, Hardness, alkalinity, calcium and sulphate concentrations has deteriorated due to the mining and processing of limestone in Jaintia Hills, Meghalaya. This is true in both the seasons of study i.e. in pre-monsoon to post-monsoon seasons. The deterioration in water quality has most likely resulted due to additional accumulation, transportation, mixing and dispersion of pollutants (organic or inorganic form) from the contaminating sources into the local water bodies. Water samples, particularly collected from nearby areas of cement plants were found to be highly polluted. This may be due discharge of effluent from the cement plants into these local water bodies. The overall degradation of water quality has posed serious problem on availability of potable and irrigation water in the area. In addition, the area has experienced the loss forest and biodiversity, landscape deterioration, spreading of spoils creating wasteland, noise pollution, degradation of agricultural lands etc. due to environmental implications of limestone mining. Therefore, immediate attention towards proper management and conservation for water resources is needed by the all concerned stakeholders, particularly the mine owners and cement plant management. In order to check further deterioration, an effective plan for protection of water sources and water conservation strategy must be developed and implemented as soon as possible in the area.

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