IMPACT OF SANDSTONE QUARRY ON PHYSICO-CHEMICAL CHARACTERISTICS OF TLAWNG RIVER AND VEGETATION IN CATCHMENT AREA IN VICINITY OF AIZAWL CITY, MIZORAM

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DECLARATION

I, **Gurumayum Premeshowri Devi** hereby declare that the subject matter of this thesis entitled "**IMPACT OF SANDSTONE QUARRY ON PHYSICO-CHEMICAL CHARACTERISTICS OF TLAWNG RIVER AND VEGETATION IN CATCHMENT AREA IN VICINITY OF AIZAWL CITY, MIZORAM,**" is the record of work done by me, that the content of the thesis did not form basis for the award of any previous degree or to anybody else, and that I have not submitted the thesis in any other University/ Institute for any other degree.

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CERTIFICATE

This is to certify that the Thesis entitled "**IMPACT OF SANDSTONE QUARRY ON PHYSICO-CHEMICAL CHARACTERISTICS OF TLAWNG RIVER AND VEGETATION IN CATCHMENT AREA IN VICINITY OF AIZAWL CITY, MIZORAM**" submitted by **Gurumayum Premeshowri Devi** for the award of degree of Doctor of Philosophy of the Mizoram University, Aizawl, embodies the record of original investigation carried out by her under my supervision. She has been duly registered and the thesis presented is worthy of being considered for the award of the Ph.D. Degree. The work has not been submitted for any degree of any other University.

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Chapter1

INTRODUCTION

1.1. Sandstone quarry: Basic concept

India is known for natural stones, particularly granite, marble, sandstone, limestone and slate. The sandstone quarry in India is prevalent in the states namely, Arunachal Pradesh, Assam, Bihar, Gujarat, Haryana, Madhya Pradesh, Meghalaya, Mizoram, Karnataka, Orissa, Punjab, Rajasthan, Uttar Pradesh, Tamil Nadu and West Bengal.

Once the processes are complete, the stone is ready for shipping to the end user in the form of slabs, tiles, blocks, cobbles, and bricks. Quarrying activity is a necessity that provides much of the material used in traditional hard flooring such as granite, limestone, marble, sandstone, slate and even just clay to make ceramic tiles. These rocks also provide raw materials for cement and other industrial and agricultural uses.

The sandstone is extracted from underground by a process of digging, blasting or cutting. This process is known as quarrying and the pit or open excavation from which the stone is obtained is referred to as quarry. Based on the excavation methods, quarries can be divided into two broad categories: vertical quarries and horizontal quarries. In the digging process, when the stone in the form of raw material is obtained, the walls of the quarry are known as vertical quarry, whilst stone gathered from the bed or floor is known as horizontal quarry. Mining of sandstone involves both machines and manual work. The drilling and/or channeling are done using hand chisels and hammers. Many quarries now have mining machinery, such as compressors, drilling machines for drilling and blasting, cranes for lifting big blocks, and dampers and trucks for transport (Madhavan, 2005). Once the stone is obtained, it is further processed for the next stage of production. The typical processes after quarrying involve following four steps-

1. Dressing
2. Cutting/sawing
3. Surface grinding and polishing, and
4. Edge-cutting-trimming

The rapid advent of industrialization largely depends upon the judicious use of natural resources. As the demand of stone grew so did the demand of quarrying activities. Sandstone quarry is very much prevalent in the state of Mizoram. It provides employment opportunities to the people thereby improving the economy of the state and the quality of life of the people. However, the negative impacts on the environment produced by quarrying activities cannot be ignored. As a result, the study was conducted so as to assess the impact of sandstone quarry on the environment (water, and soil) and vegetation in the Aizawl district of Mizoram (Okafor, 2006).

1.2.Sandstone and its composition:

Sandstone (also known as arenite) is a sedimentary rock composed mainly of sand-sized minerals of rocks grains. Most of the sandstone is composed of quartz and feldspar because these are the most common minerals found in the earth's crust. Sandstone is clastic in origin (as opposed to either organic like chalk and coal, or chemical like gypsum and jasper. It is made up of cemented grains that may either be fragments of a pre-existing rock or be mono- minerallic crystals. The cement binding these grains together are typically calcite, clays and silica (Indian Minerals Yearbook, 2012).

Normally grain size in sand is ranged from 0.0625 mm to 2mm (0.002- 0.079 inches). Clays and sediments with smaller grain sizes are not visible with the naked eye, including siltstones and shales, and are typically called argillaceous sediments, whereas rocks with greater grain sizes including breccias and conglomerates are termed as rudaceous sediments.

The formation of sandstone involves two principle stages. Firstly, a layer of sand accumulates as a result of sedimentation, either from water (as in a stream, lake or sea) or from air (as in desert). Secondly, once it has accumulated, the sand becomes sandstone when it compacted by pressure of overlying deposits and cemented by the precimentation of minerals within the pore spaces between the sand grains.

1.3.Production of sandstone:

Carbonate rock is extracted from about 100 underground mines in the United States. Most of these mines are located in the Mid-continent and produced crushed stone. Worldwide production of carbonate rocks ranks third in terms of volume and fourth in terms of value for all non-fuel mineral commodities (Luttig, 1994). Over 70% of the crushed stone produced in the United states comes from carbonate rock, and three-fourth of that is consumed by the construction industry. During 1999, over one billion tons of crushed limestone, dolomite, and marble valued at over $ 5.5 billion were produced from about 2,200 quarries operating in 48 states. The top ten states (in decreasing order of production) each produced over 45 million tons of crushed carbonate rocks were Texas,Florida, Illinois, Ohio, Missouri, Pennesylvania, Tenessee, Kentucky, Indiana, and Alabama (Tepordei,1999).

Global production of natural stone exceeded 100 million tons in 2006. India produced 19 million tons (second only to China). The value of stone, sand and gravel exports from India rose from US$ 281,615,000 to USD$ 475,661,000 between 2001 and 2005 (International Trade Centre, 2008). India accounts for around 27% of the total natural stone production of the World.

India is one of the leading producers of dimensional stone granite, marble, sandstone, slate and quartzite in the world. The country represents for about 27% of the world's total natural stone production. The domestic consumption of dimensional stone exceeds Rs. 50,000 million per annum or $ 1.163 million.

Rajasthan is the largest producer of dimensional stone in the country and accounts for about 90% of the total natural stone production. Looking at sandstone, the state contributes about 10% of the total production in the world and around 70% of the total production in the country or 6.5 million tons per year.

Table 1. Sandstone production in Rajasthan.

Year	**In million tons**
1995-1996	4,106
1996-1997	4,781
1997-1998	4,915
1998-1999	5,679
1999-2000	8,368

Source: Revenue generation (Madhavan, 2005)

Rajasthan obtains revenue from the sandstone industry in the form of royalties and taxes, including royalties on excised and dispatched minerals, sales–tax, surcharge on finished products, road tax, and taxes on machines used by processing units. Also, the state government and the local administration obtain revenue in the form of dead rent and surface rent.

Rajasthan is a leading exporter of natural stone and has earned Rs.2,324 million ($54million) in 2000-2001 (Rajasthan State Industrial Development & Investment Corporation Ltd.). Rajasthan's sandstone conforms to the highest international standards and has been used in well-known buildings all over the world. The surge in exports in the last two decades has led to increasing numbers of sandstone quarrying and processing units in Rajasthan. The total quantity of sandstone exported from Rajasthan in 2003-2004 was 354,298 tons. Rajasthan's earnings amounted to around Rs.1,994.13 million or $46.37 million. Sandstone export from Rajasthan to the Netherlands alone has increased from Rs.24.65 million ($0.57 million) in 1999-2000 to Rs101.17 million ($2.35 million) in 2003-2004.

Table 2. Export of sandstone from Rajasthan to The Netherlands (value in million Rupees).

Sl. No.	Items	1999-2000	2000-2001	2001-2002	2002-2003	2003-2004
1	Sandstone,crude or roughly trimmed	9.08	15.71	36.44	22.88	15.74
2	Sandstone merely cut by sawing/otherwise into blocks/slabs of rectangular (inc.sq.shape)	15.57	6.34	30.87	39.91	85.43
3	Total export to the Netherlands	24.65	22.04	67.31	62.79	101.18
4	Total International Export	504.24	538.12	1,108.67	1,604.88	1,994.14

Source: Ibid 8

There was no mineral production (except minor minerals) reported from Mizoram during 2011-12. The total production value of minor minerals was estimated at Rs. 153 lakh for the year 2011-12. Occurrence of minor minerals such as lignite, sandstone and pyrites are reported from the state (Indian Minerals Yearbook, 2012)

The total sandstone and other aggregate production were still low as compared to other states in India. Most of the sandstones were hard in nature and are mainly used in construction of roads and buildings. Very few literatures are available on the production and the export of sandstone from the state of Mizoram. The table below showed the production of stone at different districts of Mizoram, recording a total production of 3, 59,812.58 (in cum) and 1, 83,909.75 (in cum) for the year 2008-09 and 2009-10, respectively for Aizawl district in Mizoram (Statistical Handbook Mizoram, 2010).

Table 3. Permits issued, production of stone with revenue collected.

Sl. No.	District	No. of Permit issued		Production from Quarry (in cum)		Revenue (Rs. In lakh)	
		2008-09	2009-10	2008-09	2009-10	2008-09	2009-10
1	Mamit	13	1	8,863.00	3600.00	1.06	0.43
2	Kolasib	10	5	21,912.41	50,231.33	2.62	6.02
3	Aizawl	31	25	3,59,812.58	1,83,909.75	43.17	22.06
4	Champhai	3	2	6,350.07	7,034.25	0.76	0.84
5	Sercchip	10	7	8,401.67	6,705.67	1.00	0.80
6	Lunglei	9	3	8,744.67	9,057.33	1.04	1.08
7	Lawngtlai	2	5	290.00	950.00	0.03	0.11
8	Saiha	-	-	-	-	-	-
	Total	78	48	4,14,375.00	2,61,488.33	49.72	31.37

Source: Statistical Handbook Mizoram (2010).

1.4.Sandstone quarry in India:

In India, there are various sandstone quarries situated in Rajasthan, Madhya Pradesh, few locations in Gujarat, Orissa, Karnataka, Tamil Nadu, Andaman and Nicobar and many more places. Mining of sandstone is generally done manually by using hammers and chisels of various shapes. At the first stage, the overburden is removed which is in the form of soil, rubble or non-splittable sandstone. The hard non-splittable sandstone is drilled and blasted to expose the underlying splittable sandstone. But, with the advent of sandstone cutting and polishing machines, this operation is also executed carefully to obtain Khandas and blocks for further processing in the form of slabs.

The sandstone quarry has also been operated at different district of Mizoram. Most of the quarries were based on small scale industries. The main uses of this rock are road construction purposes and in some cases local people are using for building materials.

Quarrying of sandstone is generally done manually by using hammers and chisels of various shapes. The hard non-splittable sandstone is drilled and blasted to expose the underlying splittable sandstone. But with the coming of sandstone cutting and polishing machines, this operation also executed carefully to obtain block of sandstone. The quarry permit issued in Mizoram is presented in the Table 4.

Table 4. District- wise number of quarry permit issued in Mizoram.

Sl.no.	District	No. of quarry permit issued during 2005-10					Total no. of permit issued
		2005-06	2006-07	2007-08	2008-09	2009-10	
1	Mamit	20	36	17	13	1	87
2	Kolasib	37	24	6	10	5	82
3	Aizawl	70	99	7	31	25	232
4	Champhai	28	8	1	3	2	42
5	Serchhip	13	19	2	10	7	51
6	Lunglei	23	3	3	9	3	41
7	Lawngtlai	1	5	1	2	5	14
8	Saiha	5	-	1	-	-	6
	Total	197	194	38	78	48	555

Statistical Handbook Mizoram (2010).

1.5. Environmental and ecological issues:

1.5.1. *Impact of sandstone quarry on water quality*:

Most of the surface water pollution is caused by human activities. The waste generated from the mining areas pollutes streams and rivers. The surface water can easily be contaminated by runoff or dust from the surrounding catchment areas where sandstone quarry is carried out. The removal of top-soil and aggregates during process may also affect the quality of water recharging of an aquifer and excavation below the water table which can lead to de-watering of adjacent water courses and wells. Different substances from wastewater, airborne fallout and rain can alter the water quality. The risk of contamination of surface water increases with the continuous exploration of sandstone and other aggregate production. The risk is mainly caused by transportation traffic and possible fuel leaks. Moreover, the runoff from the quarry areas might include nutrients and particulate minerals that can deteriorate the surface water quality.

1.5.2. *Impact on forest*:

Extensive mining for decades to meet the demand has turned large tract of forests into wastelands. Today uncontrolled sandstone mining is destroying not only the forest but also the wildlife, apart from the livelihoods of the local tribal communities. Large tract of forest is cleared so as to make way for easy transportation of trucks and vehicles into the quarrying areas. This has lead to drastic change in forest cover of the area. Besides these, noise produced from the vehicles and blasting of stones scared away the wild animals thus disturbing their ecosystem. Also mass clearing of forest leads to forest fragmentation making the wildlife homeless and loss of biodiversity. The aggregate extraction process leads to removal of vegetation and top soil from the site, resulting in the loss of natural habitats and soil productivity.

1.5.3. *Impact on soil fertility*:

The soil nutrient status is mainly depend upon the nature and extent of vegetation (Mishra and Laloo, 2006). As mentioned above, the phenomenon of mining and quarrying industry were associated with the removal of the top-soil and vegetation. As a result, there is less accumulation of biomass on the forest floor leading to nutrient depletion. Also the quarry process leads to soil erosion followed by run-off of important nutrients from the surface layer. Not only this, the solid waste generated from the quarry areas were dumped in any empty land without permission. This has drastically altered the soil characteristics including the soil microorganisms. Moreover, the unscientific quarrying activities had directly destroyed the landscape by leaving a big scar on the earth's surface. It is quite evident the quarry activities have significantly added to the degradation of forest land and development of wasteland.

1.5.4.*Others impact on Environment*:

Waste disposal is one of the common problem in aggregate mining areas. The quarrying industry particularly the sandstone quarry needs to development management strategies to tackle the air, water and noise pollution. There is a considerable amount of waste such as broken pieces, dust, irregular and odd shaped blocks were generated from the quarrying areas. This quarry waste is dumped in forest areas as well as on any empty areas without permission. This destroys the natural vegetation and ecology of the area.

The primary source of noise from extraction of aggregate and dimension stone is from earth-moving equipment, processing equipment, and blasting. The truck traffic that often accompanies aggregate mining can be a significant noise source. Noise can adversely affect wildlife by interfering with communication and masking the sounds of predators and prey, and can also result in temporary or permanent hearing loss (Fletcher and Busnel, 1978).

Likewise, dust if uncontrolled, may spread over the surroundings during dry weather, leach into the soil during storms, and create harmful conditions for the flora and fauna (Vermeulen and Whitten, 1999). When dust smothers leaf surfaces, vegetation can be damaged through the blocking of leaf stomata, thus inhibiting gas exchange and reducing photosynthesis (Howard and Cameron, 1998).

Objectives:

In Mizoram, sandstone quarry is very prevalent and most of the people get their livelihood out of it. Sandstone quarry activities leads to thinning of the forest cover of the area. The soil become infertile unable to support the plant growth including the vegetable crops along the catchment areas. Temporary construction of roadways within the forest inhibits the plant growth and the regeneration of seedlings thereby disturbing the local ecosystem of the area.

River Tlawng is one of the most important and longest river in Mizoram. The river serves as an important water supply in the state. Today, the water quality of Tlawng is being deteriorated due to many anthropogenic activities particularly the sandstone quarry. The unscientific quarry posed great threat to the water quality of the river. Prolong consumption of such water without proper treatment may cause many diseases to the people leaving in surroundings. Moreover, sandstone quarry leads to destruction of forest and loss of soil fertility. In view of the above, the present study has been carried out to assess the impact of sandstone quarry on water quality of Tlawng river, destruction of vegetation and loss of soil fertility in Aizawl district.

The major objectives of the study envisage as follow:

- To determine water quality of river Tlawng in un-mined and sandstone mining affected areas.
- To study plant community attributes, diversity and distribution of species and population structure of woody species in un-mined and sandstone mining affected areas.

- To assess the impact of sandstone quarry on water quality of Tlawng river and vegetation in catchment areas.
- To formulate appropriate management strategy.

Chapter 2

LITERATURE REVIEW

Disturbance plays an important role in ecological processes. F. Stuart Chapin and co- authors define disturbance as "a relatively discrete event in time and space that alters the structure of populations, communities and ecosystems and causes changes in resources availability or the physical environment". With the advent of human civilization, the demand for continuous exploration of rocks from the earth's surface increases which causes enormous damage to the environment.

Mining causes massive damage to the landscape and biological communities and impact of severity depends on whether the mine is working or abandoned, mining methods, and the geological conditions (Bell *et at.*,2001).

The environmental impact of mining and quarrying industry includes erosion, formation of sinkholes, damage of biodiversity and contamination of soil, groundwater, and surface water by chemicals from mining processes. Besides creating environmental damage, the contamination resulting from leakage of chemicals also affects the health of the local population. Some important relevant researches on the impact of sandstone quarry on the environment are being reviewed.

2.1. Aggregate quarry operation:

The operation of aggregate mining and quarry industry differ from one to another. Generally, starting of any large or small scale quarry operation requires many preparations to be made beforehand. First, the geologist must find a place where there is a large supply of rocks beneath the earth surface. Then the quarry can be igneous, metamorphic and sedimentary rocks. In order to get the rock beneath the surface of the earth clearing of the land is the first operation step, followed by drilling and blasting.

To undergo blasting first the hole are drilled in the earth and explosives are placed inside. The blasting results in setting off free the stone from the quarry wall. The free stone from the quarry wall is crushed and divided into different size. Now the rocks are out of the ground and move over to the processing plant to turn big rocks into little rocks. Screening comes after crushing in which the rocks are separated as larger and smaller stones (Poulin *et al*., 1994. Finally, the materials loaded into trucks for transportation to where they are needed for use (Vulcan Materials Company, 2006)

La-Touche (1891) was the pioneer worker in Mizoram, who took short traverses in the area (the then Assam-Arakan geological province) and found the area to consists of a great flysch facies of rocks comprising monotonous sequences of shale and sandstone which are folded into N-S orientation. Later Munsi (1964), Nandy, Mukherjee and Majumdar (1972), and Mukherjee and Saxena (1973) conducted a geological survey in Mizoram.

In Mizoram, commercial explosives (ANFO, Powergel) are used in mines for fragmenting the rocks from the earth's surface (Directorate of Geology and Mineral Resources, 2012). After rock blasting, the blocks of rocks and the fractured irregular stones are taken out and again made into smaller pieces with the help of stone crushers. Besides these, many labourers including women also practiced digging out of stones manually by using hammers and chisels. Then the stones are being loaded and transported either as blocks or crushed stones according to the demands.

2.2. Economic impacts of mining and quarrying:

The economic impact of Melancthon quarry generates approximately 465 permanent jobs in the state. In addition, a total of 11.5 % from every tone of aggregate removed from the Quarry would be divided among the Township of Melancthon (6 cents), County (1.5 cents), Duffer in the provincial government (3.5 cents) and the fund for the Management of Abandoned Aggregate Properties (MAAP) program (Ontario Ministry of Natural Resources, 2010). In 2010, the township recorded revenues of $ 2,513,503, and could expect to expand around 24 % in the near future (Township of Melancthon, 2010).

Construction aggregates and dimension stone are basic materials for the construction industry in Irish and contribute about $20 billion to the Irish economy each year. In addition, Irish dimension stone operators produce approximately 250,000 tonnes of cut stone annually, about half of which is exported to Europe. It also provides employments opportunities of more than 10,000 in the concrete industry.

The utilization of quarry rock dust also known as manufactured sand has been accepted as a building material in the industrially advanced countries of the west for the past three decades]. As a result of sustained research and developmental works undertaken the level of utilization of Quarry Rock Dust (QRD) in the industrialized nations like Australia, France, Germany and UK has been reached more than 60% of its total production. The use of manufactured sand in India has not been much, when compared to some advanced countries. (Missouri Department of Natural Resources, 2008).

Rajasthan obtains revenue from the sandstone industry in the form of royalties and taxes, including royalties on excised and dispatched minerals, sales–tax, surcharge on finished products, road tax, and taxes on machines used by processing units. According to the available data, sandstone quarrying in Bundi district alone generatedRs.67, 195,242 ($1, 56 million) as revenue in 003-2004 (4,25). The sales tax received by the Rajasthan Government is fixed at Rs1, 500 ($34.80) per 20 ton truck for slabs, andRs1, 400 ($32.50) per 20 ton truck for blocks. Rajasthan is a leading exporter of natural stone and has earned Rs.2, 324 million ($54million) in 2000-2001 (8,52). Rajasthan's sandstone conforms to the highest international standards and has been used in well-known buildings all over the world.

Major minerals deposits of economic importance have not been reported so far. In Mizoram there is paucity of literature on mineral exploration in the state. The massive, hard compact, grey, calcareous and stone of Lower and Upper Bhuban Formation is suitable for use as road metal and building material in different part of Mizoram (Geological Survey of India, 2011). This material is very extensively available in the state. The production value of minor minerals was estimated at Rs. 153 lakh for the year 2011-12 (Indian Minerals Yearbook, 2012). Border Road Task Force is already quarrying this sandstone for use as road metal.

2.3. Impact of quarry operation on environment:

There are wide ranges of significant environmental impact caused by quarry operation. These impacts are landscape change, change to the visual scene, erosion, habitat loss, loss of flora and fauna, and instability in the ecosystem, environmental (air, water, soil) pollution, noise, vibration, dust, security problem, are the common problem in the development of quarry operation. The detailed description of some of the impacts on environment is as follow.

2.4. Impact on water quality:

Run-off from quarry waste tips or quarry fines stockpiles can cause erosion and contaminate local watercourses. Suspended solids including acid drainage may harm freshwater ecosystem and impacts on other water users. Both surface and ground water impacts are associated with level of quarry operation. Impacts appear to be significant if the quarry operation lies near the river bank. More over the geological material being extracted easily deteriorate the adjacent water quality (Richard *et al.*, 1999). Run off from the quarry yard and dewatering of the pit can produce pollutant discharge to the surface water such as total dissolved solids, turbidity and total suspended solids (Richard *et al.*, 1999). These are leading measures to surface water pollution. The intensity of pollution also depends on the geology of the material extracted.

The surface water can easily be affected by runoff from the surrounding catchment areas. Different substances from wastewater, airborne fallout and rain can alter the water quality. The aggregate production can also change the amount and direction of surface water runoff which mainly include nutrients and particulate matter (Hasari, 2009).

Acidic mine drainage may occur especially if the bedrock is fractured and exposed. This may flows down into the river making the water acidic unfit for consumption (Bain *et al*., 2000; Amenita *et al*., 2001; Zielinski *et al*., 2001; Moncur *et al*., 2006). Contaminated water constitutes health risk, as this could result into excess accumulation of heavy metals in humans leading to phototoxic effects. About 11% of the global sulphate flux from the continent to the oceans comes from mining activities alone (Banwart *et al*., 1998).

Aggregate extraction has an adverse impact on water quality due to on site contamination from fuel storage or asphalt plants. While few impacts of aggregate operations on drinking water supplies have been documented, but concern may arise when former aggregate pits are used for landfilling or residential development (Blackport Hydrogeology, 2006)).

The geochemistry of acidic mine drainage has been the subject of numerous investigations. Some documented cases include work of Kimmel (1983), Nordstrom and Alpers

(1999), Frommichen *et al*., (2004), Geldenhaus and Ball (1998), Jenkins *et al*.,(2000), and Egiebor and Oni (2007).

Quarrying operation has economic significance but the effect they cause to the environment could be fatal. This happens when the mining activity causes pollution to soil and nearby water bodies. The main causes of this are used oils, fuels and waste metals due to the mining and transportation machinery, which get split and are dumped on the soil around the quarry site without being treated (Kirk and Morgan, 1982).

Unsustainable quarrying for over four decades has created a severe scarcity of drinking water for humans and livestock in the Budhpura quarrying area. Persistent excavation to a depth of over 30 meter has disturbed the water regime. Indiscriminate draining of deep quarries after rains, leads to siphoning of groundwater from adjoining wells. Fast depletion and degradation of the topsoil due to dumping of quarry waste has hampered water percolation leading to scarcity of groundwater in the area.

The workers Bullock and Bell, (1997); Jankowski, (2007); Jankowski and Spies, (2007); Krough, (2007); have extensively studied the deterioration of water quality through the discharge from the sandstone quarry areas. The effects of mining can have consequences that reach far from the mine site. Hydrological impacts can include lowering of the water table and pollution of catchments (Ibarra and de las Heras 2005).

In India, large scale mining operations going on in Jharkhand which have adversely affected groundwater table of surrounding with the result that yield of water from the wells of adjoining villages has drastically reduced. Further, effluents discharged from mine site shave seriously polluted the streams and under groundwater of the area. Acid mine drainage, liquid effluents from coal handling plants, colliery workshops and mine sites and suspended solids from coal washeries have caused serious water pollution problem in the region, adversely affecting fish and aquatic life (Priyadarshi, 2004).

The sandstone quarry usually generates dust particles containing silica which is not soluble and able to settle down at the bottom of the water bodies. Most of the mine workers leaving around the stored water on which mosquitoes breeds are prone to water borne malarial disease (Sinha and Rajiv,1994).

Dhiman (1990) reported that mining has reduced the annual rainfall which results in groundwater table fall by 5m in just two years between 1987 and 1989. The communities at Wagholi suffer for drinking water as there is no alternative water sources nearby except the water from the stone quarry pit. Water quality tests showed that the water is contaminated and not fit for drinking based on World Health Organisation drinking water guidelines.

A study revealed that acid mine drainage originating from coal mining area in Meghalaya had badly affected the water bodies by altering the physico-chemical properties of water (Singh, 2004). The primary cause of degradation of water quality and the declining trend of biodiversity in the water bodies of the mining area is attributed mainly to the Acid Mine Drainage (AMD), which makes water highly acidic and rich in heavy metal concentration (Pentreath, 1994) opined. The impact of coal mining on aquatic life and water quality studied by several workers like (Weed and Rutschky, 1971; Rosemond *et al.*, 1992; Brown and Sadler, 1989; Potts and McWilliams, 1989 and Kimmel, 1983).

In Mizoram, the government has permitted some license to the quarry owners (Statistical Handbook of Mizoram, 2010). Besides, this illegal mining is also practiced in the state. Such illegal and unscientific quarry may deteriorate the water quality of Tlawng river in Aizawl District (the longest river in Mizoram). Lalchhingpuii (2011) studied the assessment of the water quality in Aizawl district in Mizoram. Few literatures are found on the impact of sandstone quarry on environment in the state.

2.5. Impact on biodiversity:

There is a range of negative environmental impacts associated with extractive industries. One of the major impacts is the destruction of the habitat in the quarrying areas. The destruction and fragmentation of habitat lead to threat to biodiversity and the primary cause of species extinction.

Mining and quarrying are destructive enterprises and involve the complete destruction of the habitat of the area where they take place. In steeper areas where long wall mining occurs there is an increased change of unconsolidated surface materials moving down the slopes when cracking and subsidence occur; increasing localised soil erosion and can result in intensive sedimentation and loss of vegetation (Total Environment Centre, 2007).

The quarrying activities cause significant adverse impact on the environment (Okafor, 2006; Vitousek *et al*., 1997) dust can also have physical effects on the surrounding plants, such as blocking and damaging their internal structures and abrasion of leaves and cuticles, as well as chemical effects which may affect long-term survival.

Air pollution, especially dust from quarry sites is known to be responsible for vegetation injury and crop yield loss, and thus become a threat to the survival of plants in quarry areas (Iqbal and Shafig, 2001).

Quarrying carries the potential of destroying habitats and the species they support (Mabogunje, 1980). Again, like many other man-made activities, quarrying involves the production of significant amounts of waste that can be a great threat to biodiversity (Wang, 2007).

Blast-induced vibrations and shock waves can cause cave roofs to crack or collapse, and karst environmental conditions can be altered by just one new crack. Light may enter an otherwise dark cave or passage, or streams and ponds may suddenly drain into a new crack in the floor. Either situation can result in the death or displacement of cave communities (Vermeulen and Whitten, 1999). In general, environmental impacts associated with habitat loss, sedimentation and erosion from construction activities can be expected. Hence quarry operation can lead to Eberhards, 1990 has also reported loss of flora and fauna.

The impacts of mining on vegetation and soil properties have extensively studied by several workers in different parts of India (Pandey *et al*., 1993, Rai 2002, Sarma *et al*., 2004, Sarma 2005, Barik *et al.,* 1996).

In the Bijolia region of Rajasthan sandstone quarrying leads to change in forest area and botanical composition, resulting into loss of species with time (Sinha and Rajiv, 1994). One of the major negative impacts of quarrying on the environment was the damage to biodiversity (Anand, 2006).

The mining activity directly ruins the vegetation cover. The areas where boring and blasting have taken place, there was no plant species as the top-soil layer has been totally removed (Kumar, 2013).

Mining activities in the Western Ghats of Maharashtra has lead to loss of habit and habitat. Plant diversity, especially of Pteridophytic species reduced to a great extent (Shaikh and Dongare, 2010). Bauxite mining in the Western Ghats of south Maharashtra has caused environmental degradation due to various factors such as dust pollution, noise pollution, loss of biodiversity, vegetation loss and pressure on local resources (Lad and Samant, 2014).

The abandoned mine areas in the Meghalaya are making the fragile ecosystems more vulnerable to environmental degradation hence leading to large scale land cover/ land use changes (Tiwari 1996; Swer and Singh, 2003, 2004).

Several workers have studied the population behavior and regeneration pattern of woody plants in sub-tropical forests of Meghalaya (Barik *et al*., 1996; Jamir, 2000; Tripathi *et al*., 1989a; Mishra *et al*., 2003; Mishra and Laloo, 2006; Tripathi *et al*., 2010; Mishra and Jeeva, 2012); Arunachal Pradesh (Bhuyan *et al*., 2002 and Duchok *et al*., 2005), Assam (Borah and Garkoti, 2001); Manipur (Khumbongmayum *et al*., 2005). The available literature depicts that there is lack of such type of information with regards to the state of Mizoram.

2.6. Impact on soil nutrients:

The natural condition of the land is changed because of excavation and extraction of the minerals. This leads to unstable slope and land slide, rock fall, erosion. The slopes deteriorate and become un-structure which result sliding, plane and wedge mode of failures (OECD, 1998).

In abandoned mine areas, top-soil is totally removed and resulted into loss of soil fertility (Harris and Birch 1989; Ghose 2004), reduction in viable seed bank (Koch *et al.*, 1996), increase in soil erosion and runoff (McIntosh and Barnhisel 1993; Leavitt *et al*., 2000), reduction in nitrogen and water retention (Antonopoulos and Wyseure 1998), increase in compaction (Schwenke *et al*., 2000) and reduction in mycorrhizal density (Reddell *et al*., 1992).

Several workers (Alfred *et al*., 2008; Jung and Thornton, 1997; Kim *et al*., 1998) opined that mining deteriorates the soil quality of the area. Rapid degradation of disturbed soil with substantial macronutrient losses were recorded from karst bauxite mine in Jamaica (Harris and Samson, 2008).

The major impact of mining on the nations soil resources is due to open cast mining, which is having a very high potential for the deterioration of soil quality than underground operations (Naveen, 2012). In India, Ghose, (2004) reported that every million tone of coal extracted by surface mining method damages a surface area of about 4 ha.

Mining exploration in Jharkhand has been detrimental to the environment and has caused great soil erosion leading to several changes in the physical, chemical and microbiological properties of soil (Priyadarshi, 2004; Sendlein *et al*., 1983). In the Budhpura quarries (Rajasthan), considerable amount of quarry waste has been generated that are dumped in the forest areas that can deteriorate the soil characteristics (Madhavan, 2005).

The mining operation in Garo hills district of Meghalaya is responsible for change in landscape dynamics (Yadav *et al*., 2012). In Mizoram, Mishra and Jeeva (2012), has studied the effect of anthropogenic activities including sandstone quarries on soil characteristics and status of nutrients in the sub-tropical forest.

CHAPTER 3

MATERIAL AND METHODS

3.1. Study area and study sites

Mizoram is a mountainous region which became the 23rd State of the Indian Union in February, 1987. Earlier it was one of the districts of Assam till 1973 when it became a Union Territory. Mizoram occupies an area of great strategic importance in the north-eastern corner of India sandwiched between Myanmar in the east and south and Bangladesh in the west, with722 km international boundary.

Mizoram is interspersed with numerous rivers such as Tlawng (Dhaleshwari), Tiak, Chhimtuipui, Khawthlangtuipui, Tuirial and Tuichawng rivers having length of more than 100 km. The river Tlawng is the longest river (185 km) and is situated in the northern parts of state, flowing northwards like other rivers in this part. Aizawl ($21^o58'$- $21^o85'$ N and $90^o30'$- $90^o60'$ E), the capital of the state is 1132 meter asl. The altitude in Aizawl district varies from 800 to 1200 m asl. The climate of the area is typically monsoonic. The annual average rainfall is amounting to about 2350 mm. The area experiences distinct seasons. The ambient air temperature normally ranges from 20 to 30^o C in summer and 11 to 21^oC in winter (Laltlanchhuanga, 2006).

The district stands on a high ridge, fringed in the east by sylvan valley of river Tlawng. The Tlawng river passes through the Aizawl district and it flanks the eastern side of Aizawl city. It rises at a general altitude of 800 feet in an area having coordinate and flows towards north Mizoram and joins the Barak river in Assam. The gradient of river Tlawng is steep at some places. The catchment area of river is quite vast and is covered with forest where sandstone quarry is prevalent.

The present study was conducted in the forest patches of two villages in Aizawl district of Mizoram namely, Sairang (latitude of 23°80'E-23°58'E and longitude of 92°65'N-92°81'N) and Shimmuih (latitude of 23°48'E-23°68'E and longitude of 92°37'N-92°52'N). The study sites are located in the western part of Aizawl district which is about 26 km away from the Aizawl city.

For the present study, a total of four sampling sites were selected along river Tlawng. Of these, three stations were selected in sandstone quarry affected areas with different ages of mining. The fourth sampling station was selected in un-mined area representing control/reference site, and information procured from this site is regarded as a reference for comparison of results obtained from mine affected sites. The selection of control site was meant for assessment of impacts of mining on (i) water quality of Tlawng river and (ii) vegetation in catchment areas.

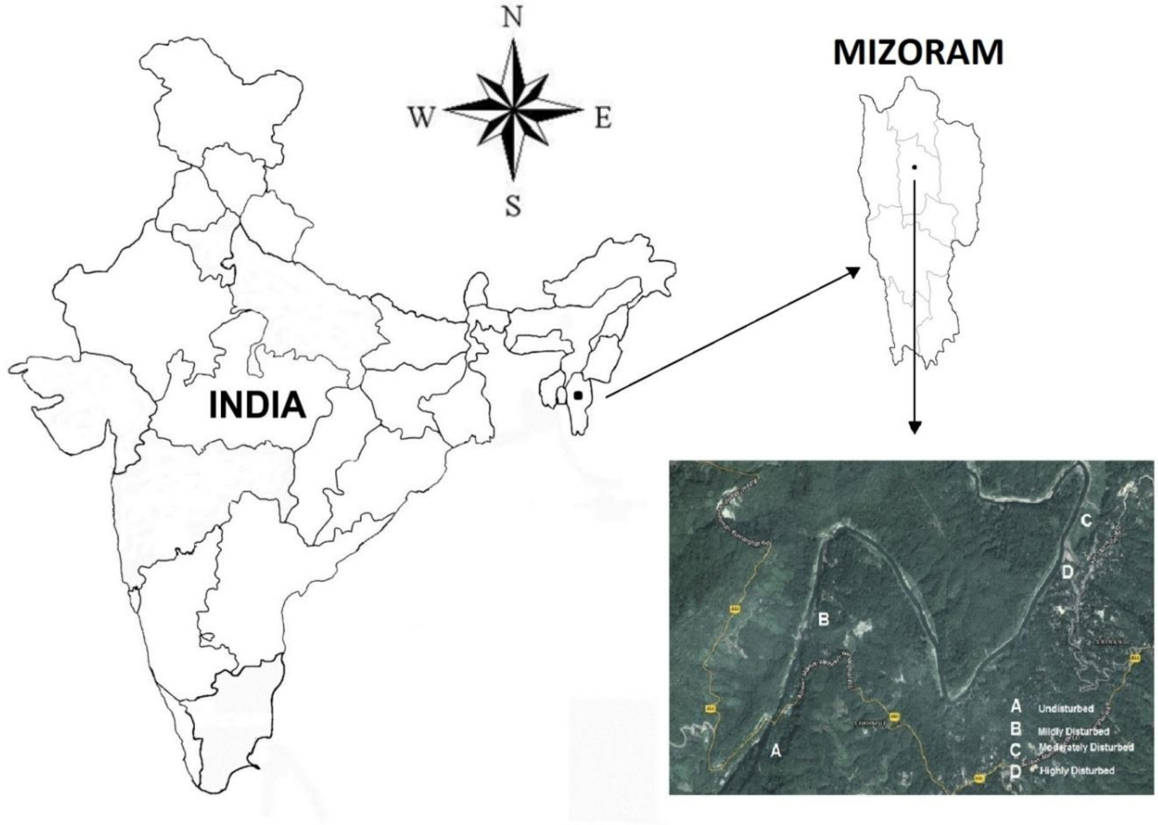
The selected study sites are as follows:

1. Undisturbed (UD): The site without mining activities.

2. Mildly Disturbed (MID): The site with mining activities 10-15 years back.

3. Moderately Disturbed (MD): The site with mining activities 5 years back.

4. Highly Disturbed (HD): The site with mining activities at present.



Map.3.1. Location map of sampling sites.

(A)

(B)

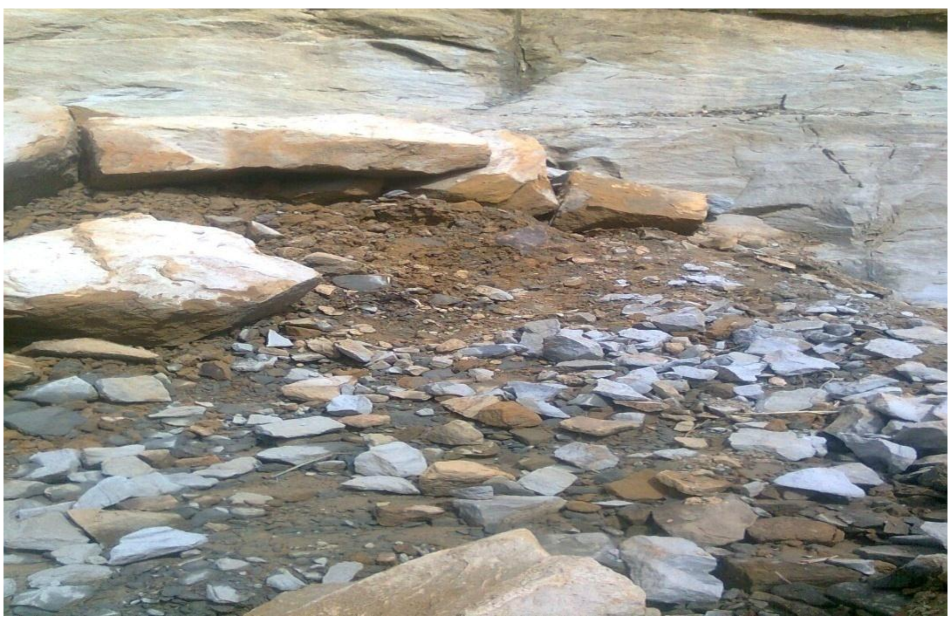
Plate 3.1. A glance of Tlawng river at undisturbed site (A) and mildly disturbed site (B)

(C)

(D)

Plate 3.2. A glance of Tlawng river at moderately disturbed site (C) and highly disturbed site (D).

(E)

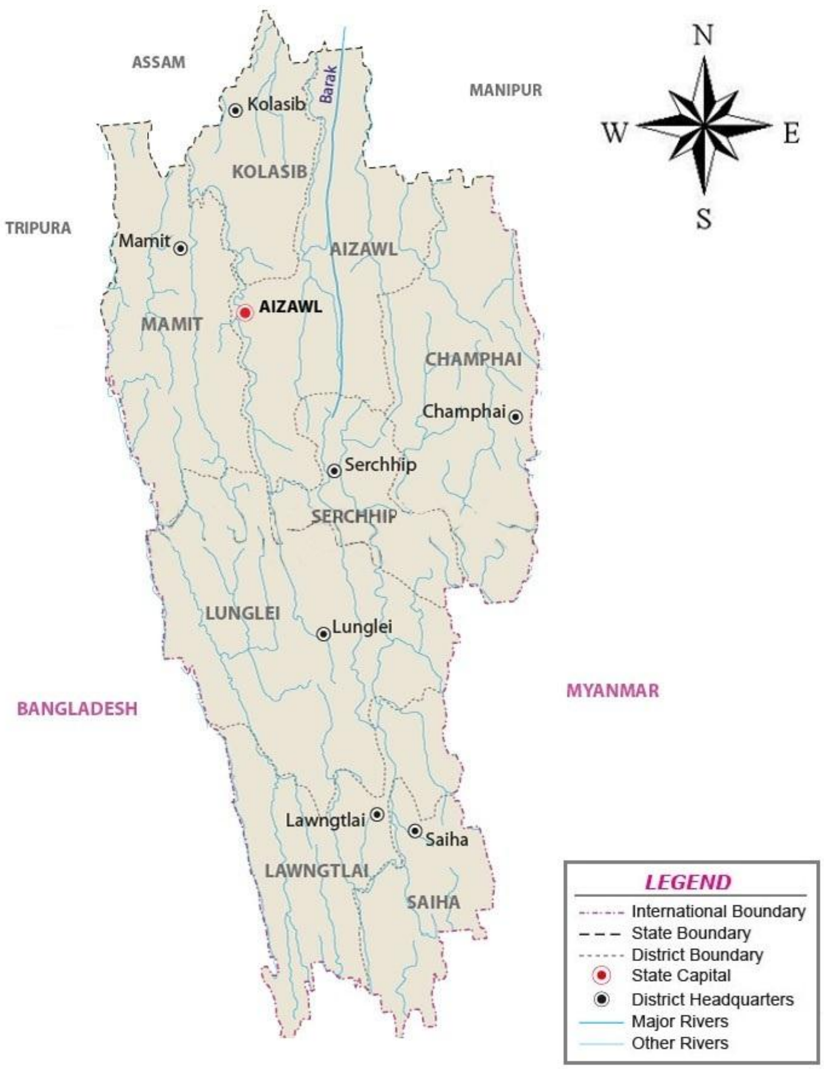


(F)

Plate 3.3. Digging out of stones from the quarry areas.

3.2. Physiography:

Aizawl has a rugged and steep topography with slopes varying from 300 ft to 450 ft. Among the two-perennial rivers draining the eastern and western flank of the town, namely Tuirial river and Tlawng river, the latter is bigger and has a considerable water discharge throughout the year. The soil formation of Aizawl, in general, is of loose sedimentary type, with high porosity and permeability. This results in the city being highly susceptible to erosion and rain induced landslides, leading to severe damages to property and lives every year.



Map 3.2. Map of Aizawl district.

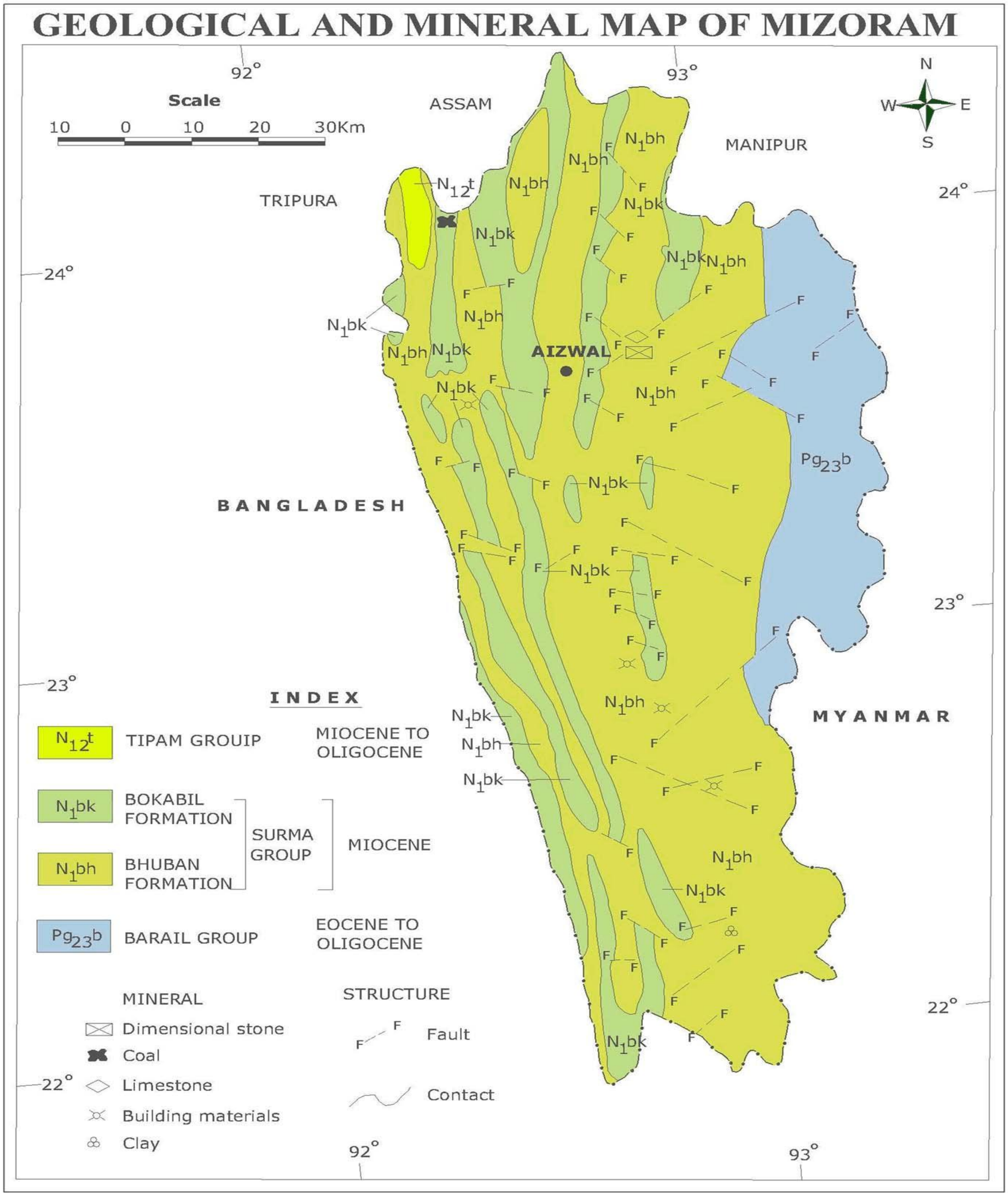
3.3. Vegetation:

The vegetation of the area can be broadly classified under: Tropical Wet Evergreen Forest, Tropical Semi Evergreen Forest and Montane Sub-Tropical Forests. The common species of natural vegetation are *Albizzia stipulata*, *Anogessus accumniata*, *Bauhinea variegate* and bamboo. The usual cultivation practice is jhumming or shifting cultivation which is primarily practiced on privately owned farms near and outside the limits of the city. The vegetation cover loss within the town can be noticed in the developed area.

3.4. Geology:

A systematic geological mapping is done only for the northern and western parts of Mizoram were covered. In the central and southern part of the state only small portion is covered. The general geology of the area exhibits repetitive succession of Neogene sedimentary rocks of Surma Group and Tipam Formation. These sequences are folded into a series of approximately N-S trending longitudinal plunging anticlines and synclines. The litho units include mostly sandstone, siltstone and shale. The topographic expression of the area often imparts fairly good indication of lithology. The arenaceous and argillaceous groups of rocks occupy relatively higher and lower grounds respectively.

Forming the small proportion of area mapped in the eastern most part of the state, knowledge of geology of this area is far from complete. Reconnaissance traverse from Aizawl to Champhai indicated the presence of Barail Group of rocks in and around Champhai subdivision, Aizawl district and Bhuban Formation exposed in the west. Barail Group comprises a monotonous sequence of shale inter bedded with siltstone and hard compact, thinly bedded, grey to khaki, fine grained sandstone. Locally they include minor bands of weathered, micaceousfelspathic sandstone.



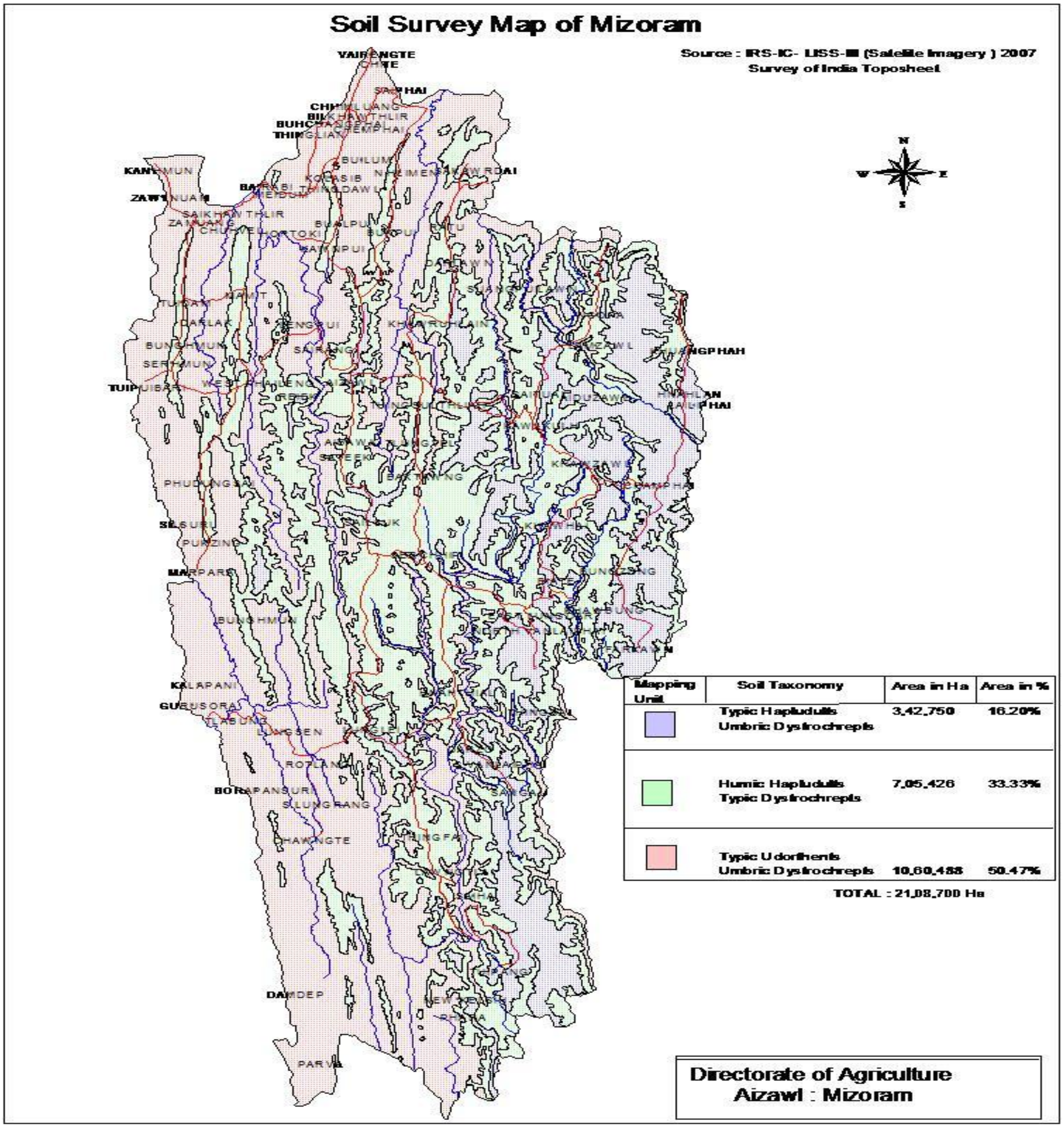
Map. 3.3. Map showing the geology of the state of Mizoram.

3.5. Soil:

The soil of Mizoram has been derived from the shales, sandstone, siltstones and mudstones of Mieocene to recent period. It is dominated by loose sedimentary formations, and is young, immature and sandy. The soil is acidic in nature and low in potash and phosphorus contents. But in an eroded soil, nitrogen content is markedly high fostered by accumulation of organic matters. The soil in the valley is heavier as it is brought down by rain water from the high altitude (Pachuau, 1994).

Generally, Mizoram soils have been classified into three orders of soil taxonomy, viz, (i) Entisols, (ii) Inceptisols, (iii) Ultisol. Entisol lacks profile development and occurs on steep, actively eroding slopes and ridges, or on flood plains that receives new deposits of alluvium at frequent intervals. It supports good vegetation, if properly managed. Inceptisols is found in sub – humid region. The soil is fine, loamy in texture with few rocks and best suited for forest space and have well developed horizon sequence. However, ultisol is commonly found on the foot slopes and have well developed horizons. It is rich in translocated silicate clays and rich in humus, if not severely drained.

In fact, the soil of Mizoram is well drained and has the capability to retain soil moisture and providing substantial oxygen supply for plant growth.



Map. 3.4. Map showing the soil survey of the state of Mizoram.

3.6. Climate and rainfall:

The area represents three distinct climatic zones- i) Sub-Tropical Hill Zone, ii) Mild- Tropical Hill Zone and iii) Temperate Sub- Alpine Zone. In the lower altitudes at the foothills and valleys, a typical tropical climate is seen, whereas the sub-tropical moist climate is observed in the mid region with large coverage, and in the upper reaches, temperate climate prevails. On the whole, the climate of the city is cool in summers and not very cold in winters. The temperature in Aizawl varies between 20^{o} celcius and 30^{o} celcius during summers and between 11^{o}celcius and 21^{o} celcius in winters. The average annual rainfall of Aizawl city is 209 cm. Pre-monsoon rains are experienced during March-May, while regular southwest monsoon commences from June till October.

3.7. Analytical methods:

The analysis work was carried out for two successive years i.e. from June 2012 to May 2014.

3.7.1. *Water analysis*:

The water samples of Tlawng river were collected at monthly intervals (in triplicates) for analysis of various physico-chemical characteristics such as temperature (Celsius thermometer), turbidity (Nephalometer) , total dissolved solids (filtration and evaporation method), dissolved oxygen and biological oxygen demand (Winkler's modified azide method), pH (total electronic pH meter), total hardness (EDTA titration method), acidity and alkalinity (potentiometric titration method), chloride (Mohr's argentometric method), nitrate (phenol-de sulphonic acid method), phosphate(stannous chloride method), and sulphate (colorimetric method).

For the above water quality characteristics the methods as described in "Standard Methods for the Examination of water and waste water" prescribed by the 'American Public

Health Association (APHA, 2005)'were adopted. The specific methods for the analysis of various physico-chemical characteristics of water are as follows.

a. <u>Temperature</u>

Temperature of water was measured by using a small centigrade thermometer with the precision of 0.1° C or by means of Digital thermometer.

b. <u>Turbidity</u>

Turbidity was measured either by its effect on the transmission of light which is termed as Turbidity or by its effect on the scattering of light which is termed as Nephalometry. Nephalometer was used for measuring turbidity.

c. <u>Total Dissolved solids (filtration and evaporation method)</u>

A Total Dissolved solid (TDS) was measured by using filtration and evaporation method.

Total Dissolved Solids was calculated by using the formula,

$$TDS\ (g/l) = (W_1 - W_2) \times 1000/V$$

Where,

W_1 = Final weight of the crucible

W_2 = Initial weight of the crucible

V = Volume of water sample evaporated (ml)

d. <u>Dissolved Oxygen</u>

Dissolved Oxygen (DO) was analysed by Winkler's Modified Azide Method.

The value was calculated by using the formula,

$$\text{DO}\ (\text{mgL}^{-1}) = \frac{(0.2 \times 1000) \times \text{Volume of thiosulphate}}{100}$$

e. Biological Oxygen Demand

Biological Oxygen Demand (BOD) was measured by using Winkler's Modified Azide Method. Determination of BOD, DO content of water sample was measured for initial and after incubation at 20^{o}C for 5days.

Biological Oxygen Demand was calculated by using the formula

$$BOD\ (mgL^{-1}) = DO_1 - DO_2$$

Where,

DO_1= Dissolved Oxygen taken for initial sample just after collection of sample.

DO_2 = Dissolved Oxygen after incubation of the sample (at 20^{o}C for 5days incubation).

f. pH

The pH value of the natural water is an important index of acidity and alkalinity. pH was be measured by using the Digital pH meter.

g. Total hardness

The Hardness was measured using EDTA titration method. Hardness can be calculated by using the following formulae,

Total hardness

$$\text{Total Hardness as } CaCO_3 mgL^{-1} = \frac{C \times D \times 1000}{\text{Volume of sample taken}}$$

Where,

C = Vol, of EDTA required by sample.

D = mg $CaCO_3$ equivalent to 1.0 ml EDTA titrant

h. Acidity

Acidity was measured by using potentiometric titration method.

Acidity can be calculated by using the formula,

$$\text{Total Acidity} = \frac{(\text{A} + \text{B}) \times 1000}{\text{Volume of sample taken}}$$

where,

A = Acidity due to mineral

B = Acidity due to CO_2

i. Total Alkalinity

Alkalinity was measured by potentiometric titration method and value was calculated by using the formula

$$\text{Total Alkalinity } (\text{mgL}^{-1}\text{CaCO}_3) = \frac{(\text{A} + \text{B}) \times 1000}{\text{Volume of sample taken}}$$

where,

A = Alkalinity due to Phenolphthalein

B = Alkalinity due to Methyl Orange

j. Chloride

Chloride content was measured by using Mohr's argentiometric method.

It can be calculated by using the formula,

$$\text{Chloride content } (\text{mgL}^{-1}) = \frac{\text{Volume of titrant } \times 0.0141 \times 35.45 \times 1000}{\text{Volume of sample taken}}$$

k. Nitrate-N

Nitrate-N content was measured by using Spectrophotometric method.

It can be calculated by using the formula,

$$\text{Nitrate, N mgL}^{-1} = \frac{\text{Net mg nitrate, N}}{\text{ml of sample}}$$

$$NO_3 \text{ mgL}^{-1} = \text{Nitrate, N mg/l} \times 4.4$$

l. <u>Phosphate-P</u>

Phosphate content was measured by using Stannous Chloride Method.

It can be calculated by using the formula,

$$\text{Phosphate} - \text{P mgL}^{-1} = \frac{\text{mgP from the calibration curve x 1000}}{\text{ml of sample}}$$

m. <u>Sulphate</u>

Sulphate content of water was measured by using Spectrophotometric method.

It can be calculated by using the formula

$$\text{Sulphate mgL}^{-1} = \frac{\text{mg } SO_4 \times 1000}{\text{ml of sample}}$$

3.7.2. *Vegetation analysis*:

3.7.2.1. <u>Field Sampling and Identification of plant species</u>:

The phytosociological study was conducted during the peak vegetation growth, which occurred in September. The quadrat method was adopted for field data on vegetation. The size of quadrat was 10 x 10 m for trees and each 60 quadrats were laid randomly at each selected sites. The plant species were identified with the help of herbarium of the concerned University Department, herbarium of the BSI, Eastern Circle, Shillong, and counter checked with the help of flora (Kanjilal *et al*., 1934-40; Haridasan and Rao, 1985).

3.7.2.2. **Analysis of phytosociological attributes**:

The field data on vegetation was analyzed for frequency, density and abundance as proposed by Curtis and Mclntosh (1950). The basal area is regarded as the index of the dominant of species and nature of the community. The circumference/girth at breast height (1.37 m) was taken for determination of tree basal area. The importance value index (IVI) was calculated as per Phillips (1959). The ratio of abundance to frequency (A/F) for different species was determined for eliciting the distribution pattern (Whitford, 1949). Species composition and relative abundance were calculated following the methods as outlined by Misra (1968) and Mueller-Dombois and Ellenberg (1974). The population structure of trees in different girth classes was also determined. Following formulae were used for calculating various attributes.

a. Frequency:

Frequency refers to the number of sampling units in which a particular species occurs. Thus, the frequency of the species was calculated as follow:

$$\text{Frequency (\%)} = \frac{\text{Number of quadrats in which the species occurred}}{\text{Total number of sampling unit studied}} \times 100$$

b. Density:

Density is used to describe the characteristics of plant communities. Basically, it is the number of individuals per unit area, and it gives an idea of degree of competition. It was calculated as follow:

$$\text{Density (ind ha}^{-1}) = \frac{\text{Total number of individual of a species in all quadrats}}{\text{Total number of quadrats studied}} \times 100$$

c. Abundance:

Abundance is the number of individuals of a species per sampling unit of occurrence. It was calculated as follow:

$$\text{Abundance} = \frac{\text{Total number of individuals of a species in all quadrats}}{\text{Number of quadrats in which species occurred}}$$

d. Importance Value Index:

The IVI is used to determine the overall importance of a species within community. This is the sum of relative frequency, relative density and relative dominance value of a species (Phillips, 1959).

IVI of a species = Relative frequency + Relative density + Relative dominance.

e. Distribution Pattern:

The distribution pattern of species was calculated by dividing the abundance of a species by frequency (F) of the species as the method suggested by Curtis and Cottam (1956) and calculated as follow:

$$\text{Distribution pattern} = \frac{\text{Abundance of a species (A)}}{\text{Frequency of a species (F)}}$$

The distribution of a plants is said to be regular, random and contagious when the value of A/F ratio is <0.025, between 0.025 – 0.05 and >0.05, respectively.

f. Shannon diversity index:

Shannon- Weiner diversity index proposed by Shannon and Weaver (1963) was calculated by the following formula.

$$H' = -\sum f_{=1} p_i \ln p_i$$

Where,

H' = Shannon- Weiner index of diversity,

P_i = the proportion of important value of the i^{th} species.

g. Simpson dominance index:

The Simpson index of dominance (1949) was calculated as follows:

$$D = \frac{\sum_{i=1}^{S} q_i (q_i-1)}{Q (Q-1)}$$

Where,

q_i= Total number of individual of a particular species

Q = Total number of individual of all species

D = Simpson dominance index

h. Margalef's index of species richness:

The Margalef's index of species richness (1972) was calculated as follows:

$$D = \frac{S-1}{\ln N}$$

where,

D = Margalef's index

S = Number of species

N = Number of individuals.

i. Evenness index:

The evenness index (Pielou's index, 1975) was calculated as follows.

$$E = \frac{H'}{H'_{max}}$$

Where,

H' = Shannon's index value

H'_{max}= ln S, S= Total number of species.

j. Similarity index or Sorenson's index:

The similarity index (Sorenson's, 1948) was calculated as follows.

Sorenson index of similarity$S = \frac{2C}{A+B}$

Where,

C = species common in both the stands

A = species present in stand A

B = species present in stand B

3.7.3. Soil analysis:

Soil samples were collected in triplicate from selected study sites during 2012-2014 for top soil (0-10 cm) and sub-soil (10-20 cm) on seasonal basis. The soil samples were collected from the two depth i.e, top – soil (0 – 10 cm depth) sub – soil (10 – 20 cm depth). The soil samples were brought to the laboratory for analysis and air dried and then powdered with the help of mortar and pestle. The powdered samples were passed through 2 mm sieve, and used for the analysis of soil physico- chemical properties namely soil moisture content, soil pH ,soil organic carbon, total nitrogen, available phosphorus and exchangeable potassium by the methods as outlined in Allen *et al., (*1974) and Anderson and Ingram (1963).

a. Soil Moisture Content:

The soil moisture content was calculated as the difference between fresh and dried soil samples after drying in oven for 24 hours at 105°C.

b. Soil pH:

The pH was measured by a pH meter using glass electrode in the supernatant suspension of 1:2:5 ratio of soil water.

c. Organic carbon:

Soil organic carbon was determined by rapid titration method as the procedure outlined by Walkley and Black (1934).Known amount of soil (1.0 g) was added with known volume (10 ml) of 1 N solution of $K_2Cr_2O_7$ and concentrate H_2SO_4. After half an hour of digestion the remaining amount of $K_2Cr_2O_7$ by titration with ferrous ammonium sulphate solution using Diphenylamine as an indicator. Organic carbon concentration in the soil was calculated as formula given by:

$$\text{Organic Carbon (\%)} = \frac{0.003 \times 10\ (B - T) \times 100}{B \times S}$$

Where,

B = Volume of ferrous ammonium sulphate solution required for blank titration in ml

T = Volume of ferrous ammonium sulphate solution required for soil sample in ml

S = Wt. of soil in gram

d. Total Nitrogen:

Total nitrogen in soil was determined by Kjeldahl method. It involves three steps:

1. Digestion
2. Distillation
3. Titration

Total nitrogen in soil can be determined by the following formula:

$$\% \text{ of total } N_2 = \frac{14 \times \text{Normality of acid} \times \text{Titrant value} \times 100}{\text{Sample weight} \times 100}$$

e. Available Phosphorus:

Available Phosphorus was soil was determined by Oslen's method. In this method phosphorus is extracted from soil with 0.5 M $NaHCO_3$at nearly constant pH of 8.5. It can be calculated by using the following formula:

Oslen's Phosphorus (kg/ha) = R x V/v x 1/Sx (2.24 x 10^6)/10^6

Or = R x (50/5) x (1/2.5) x 2.24

Or = R x 8.96

Where,

V = Total volume of extractant

v = Volume of aliquot taken for analysis (5ml)

S = Wt. of soil

R = W. of P in the aliquot in µg (from standard curve)

f. Exchangeable Potassium:

Exchangeable Potassium in soil was determined by Flame photometer method. The readily exchangeable plus water soluble potassium is determined neutral normal ammonium acetate (1N NH_4OAc) extract of soil. It can be calculated by using the following formula:

$$\text{Exchangeable Potassium (kg/ha)} = \frac{R \times V \times 224 \times 10^6}{W \times 10^6}$$

CHAPTER 4

RESULTS

The analytical investigation for water, vegetation and soil was conducted for two years i.e, from June 2012 to May 2014, and results are expressed on monthly and/or seasonal basis.

4.1. Water Quality Analysis:

4.1.1. Temperature:

The temperature was highest (27.35 ° C) in the month of July at highly disturbed site. The lowest value (20.37 °C) was recorded in the month of December at undisturbed site. The rainy season months normally possessed high temperature. On the contrary, lower values were recorded during winter months (Fig.1.& Table.1). All the data relating to physico-chemical characteristics from different month were pooled together site wise and correlated to find the correlation coefficient between them. (Appendix I-IV).

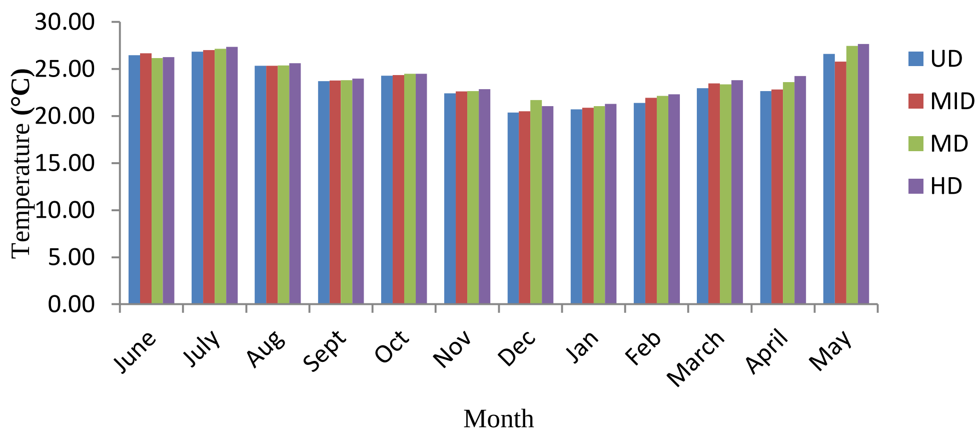


Fig.1.Monthly variation in temperature of water along disturbance gradient.

Table 5.Statistics characteristics for temperature of water.

Sampling site	Min	Max	Mean	SD
Undisturbed	20.37	26.83	23.64	2.29
Mildly disturbed	20.50	27.02	23.77	2.14
Moderately disturbed	21.05	27.14	24.08	2.10
Highly disturbed	21.04	27.35	24.24	2.17

SD = Standard deviation

4.1.2. pH:

The water ranged from 6.82 to 8.12. It was highest in the month of May (8.12) at highly disturbed site and moderately disturbed site. The lowest value (6.82) was found in the month of January at undisturbed site. Normally, the pH value was higher with increase in degree of disturbance and it was in alkaline range with few exceptions (Fig.2; Table. 2).All the data relating to physico-chemical characteristics from different month were pooled together site-wise and correlated to find the correlation coefficient between them. (Appendix I-IV).

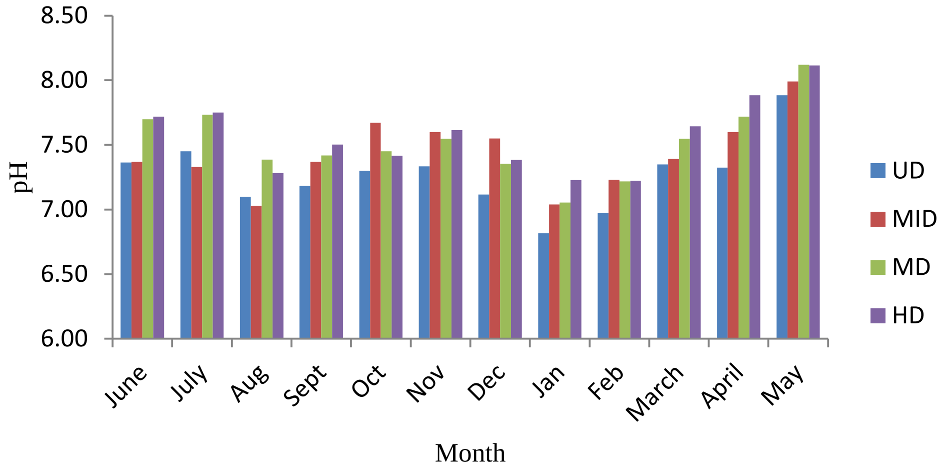


Fig.2. Monthly variation in pH of water along disturbance gradient.

Table 6.Statistics characteristics for pH of water.

Sampling site	Min	Max	Mean	SD	SE
Undisturbed	6.82	7.89	7.27	0.27	0.077
Mildly disturbed	7.03	7.99	7.43	0.27	0.079
Moderately disturbed	7.06	8.12	7.52	0.28	0.080
Highly disturbed	7.22	8.12	7.56	0.28	0.080

SD = Standard deviation

4.1.3. Electrical Conductivity:

The EC value was highest (272.24 µS) in the month of December at highly disturbed site. The lowest value (65.27 µS) was found in the month of July at undisturbed site. There was increase in value with increase in degree of disturbance, and higher value was recorded during post-monsoon season months followed by winter months (Fig. 3; Table. 3). All the data relating to physico-chemical characteristics from different month were pooled together site wise and correlated to find the correlation coefficient between them. (Appendix I-IV).

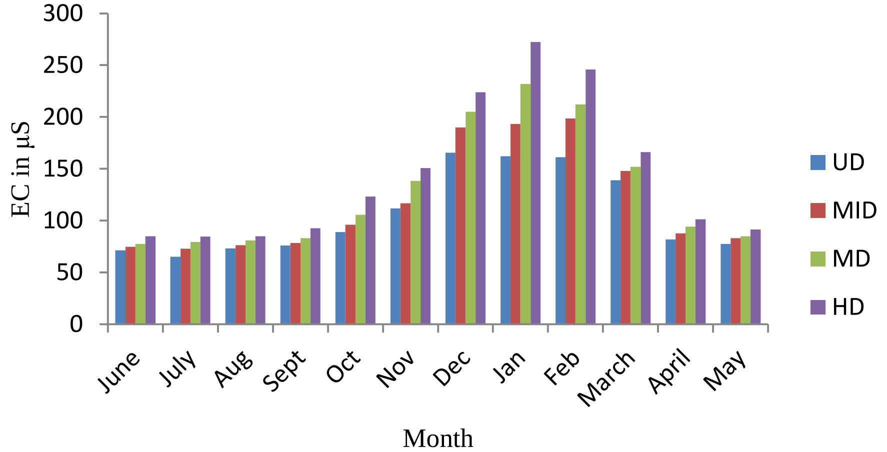


Fig.3.Monthly variation in EC of water along disturbance gradient.

Table 7.Statistics characteristics for EC of water.

Sampling site	Min	Max	Mean	SD	SE
Undisturbed	65.27	165.5	106.13	39.73	11.47
Mildly disturbed	72.89	198.5	117.94	50.51	14.58
Moderately disturbed	77.38	231.76	128.74	58.15	16.79
Highly disturbed	84.61	272.24	143.45	68.70	19.83

SD= Standard deviation

4.1.4. Total Dissolved Solids:

The TDS was highest (130.16 mgL^{-1}) in the month of June at highly disturbed site. The lowest value (40.6 mgL^{-1}) was found in the month of March at undisturbed site. The values were lower during post-monsoon season and winter months. With few exceptions, the highly disturbed site possessed maximum value.(Fig.3; Table.3). All the data relating to physico-chemical characteristics from different month were pooled together site wise and correlated to find the correlation coefficient between them. (Appendix I-IV).

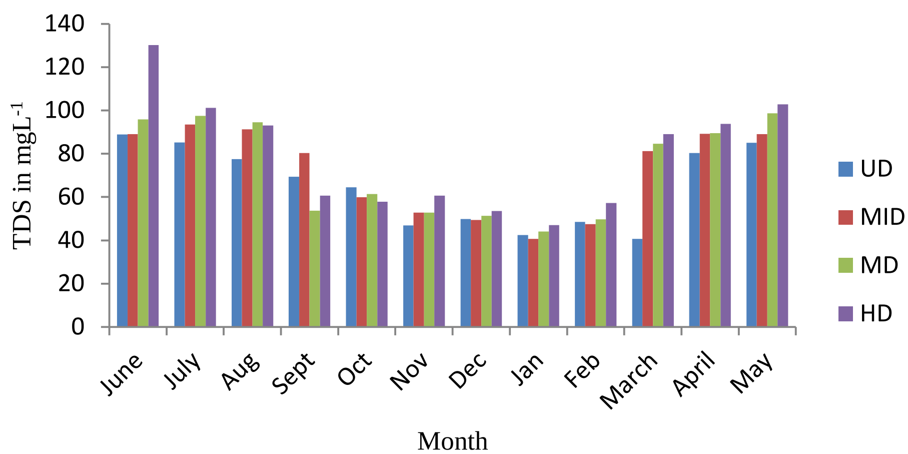


Fig.4.Monthly variation in TDS of water along disturbance gradient.

Table 8.Statistics characteristics for TDS of water. Turbidity:

Sampling site	Min	Max	Mean	SD	SE
Undisturbed	40.66	88.89	64.91	18.40	5.31
Mildly disturbed	40.68	91.25	71.96	20.17	5.82
Moderately disturbed	44.08	97.42	72.78	22.19	6.40
Highly disturbed	47.05	130.16	78.91	26.03	7.51

SD= Standard deviation

The turbidity of water was highest (6.11 NTU) in the month of July at highly disturbed site. The lowest value (0.21 NTU) was found in the month of December at undisturbed site. The highly disturbed site showed sharp increase in turbidity value as compared to other sites (Fig.5; Table. 5). All the data relating to physico-chemical characteristics from different month were pooled together site wise and correlated to find the correlation coefficient between them. (Appendix I-IV).

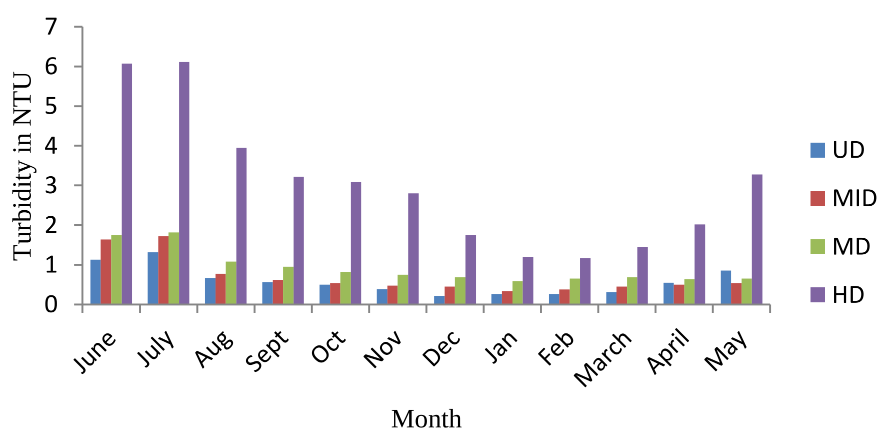


Fig.5. Monthly variation in Turbidity of water along disturbance gradient.

Table 9. Statistics characteristics for Turbidity of water.

Sampling site	Min	Max	Mean	SD	SE
Undisturbed	0.21	1.13	0.58	0.35	0.10
Mildly disturbed	0.33	1.71	0.69	0.46	0.13
Moderately disturbed	0.63	1.81	0.92	0.42	0.12
Highly disturbed	1.20	6.11	3.00	1.69	0.49

SD = Standard deviation

4.1.5. Acidity :

The total acidity was highest (72.33 mgL^{-1}) in the month of November at highly disturbed. The lowest value (14.67 mgL^{-1}) was found in the month of April at undisturbed site. The highly disturbed site showed markedly higher values. Moreover, winter season months had high values (Fig.6; Table. 6).All the data relating to physico-chemical characteristics from different month were pooled together site wise and correlated to find the correlation coefficient between them. (Appendix I-IV).

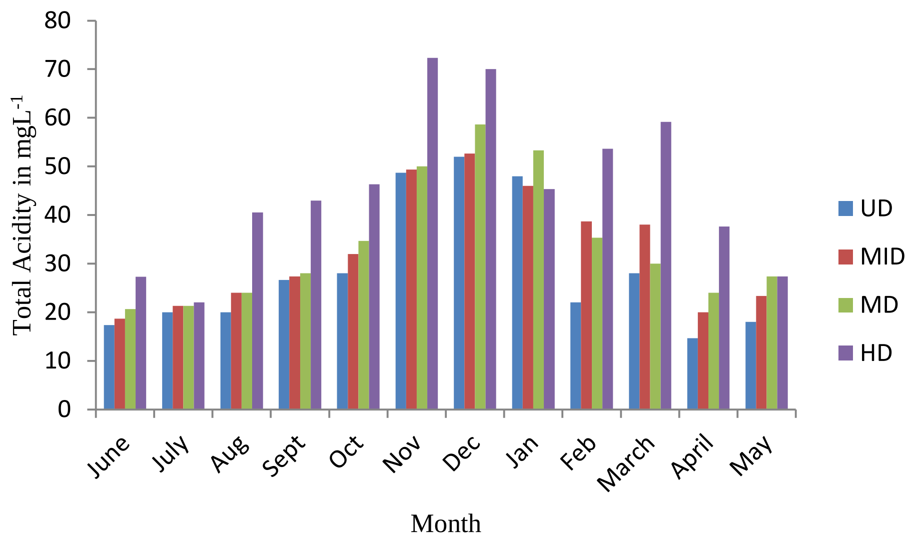


Fig.6.Monthly variation inAcidity of water along disturbance gradient.

Table 10.Statistics characteristics for Acidity of water.

Sampling site	Min	Max	Mean	SD	SE
Undisturbed	14.67	52.00	27.11	13.33	3.85
Mildly disturbed	18.67	52.66	32.61	12.04	3.47
Moderately disturbed	20.66	58.67	33.94	13.05	3.80
Highly disturbed	22.00	72.33	45.38	16.18	4.67

SD = Standard deviation

4.1.6. Total Alkalinity:

The total alkalinity was highest (44.66 mgL^{-1}) in the month of February at highly disturbed. The lowest value (12.00 mgL^{-1}) was found in the month of June at mildly disturbed site. The spring season months normally possessed higher value, and on contrary, rainy season months had lower value (Fig.7; Table. 7).All the data relating to physico-chemical characteristics from different month were pooled together site wise and correlated to find the correlation coefficient between them. (Appendix I-IV).

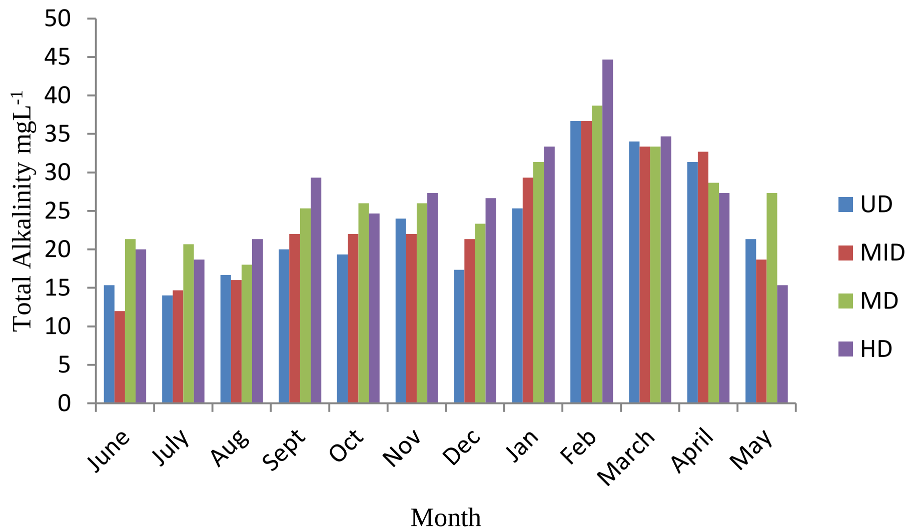


Fig.7.Monthly variation in Total Alkalinity of water along disturbance gradient.

Table 11.Statistics characteristics for Total Alkalinity of water.

Sampling site	Min	Max	Mean	SD	SE
Undisturbed	14.00	36.67	22.94	7.51	2.17
Mildly disturbed	12.00	36.66	23.38	7.91	2.28
Moderately disturbed	18.00	38.67	26.66	5.78	1.67
Highly disturbed	18.66	44.66	26.94	8.03	2.31

SD = Standard deviation

4.1.7. Total Hardness:

The total hardness was highest (162.66 mgL^{-1}) in the month of February at highly disturbed. The lowest value (30.66 mgL^{-1}) was found in the month of July at mildly disturbed site. The values were higher with increase in degree of disturbance, and highly disturbed stand possessed sharp increase in total hardness in all months (Fig. 8; Table. 8). All the data relating to physico-chemical characteristics from different month were pooled together site wise and correlated to find the correlation coefficient between them. (Appendix I-IV).

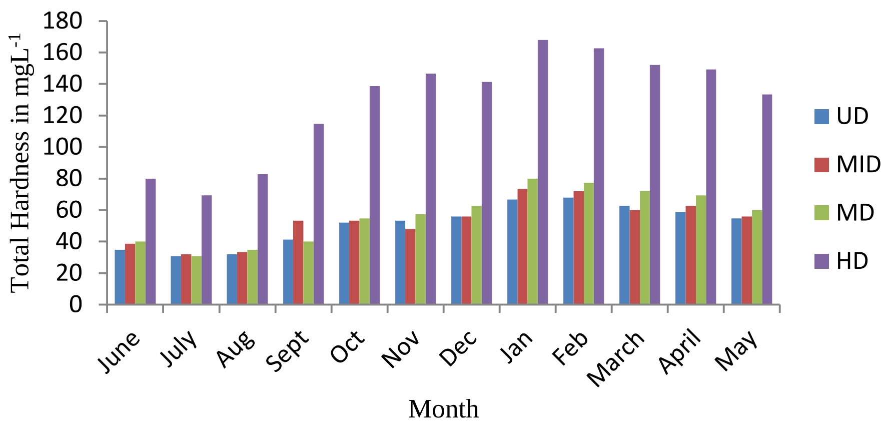


Fig.8.Monthly variation in Total Hardness of water along disturbance gradient.

Table 12.Statistics characteristics for Total Hardness of water.

Sampling site	Min	Max	Mean	SD	SE
Undisturbed	30.66	66.66	50.88	13.17	9.31
Mildly disturbed	32.00	73.33	53.22	13.45	3.88
Moderately disturbed	30.66	77.33	56.55	16.87	4.87
Highly disturbed	69.33	162.66	128.22	33.68	9.72

SD = Standard deviation

4.1.8. Chloride:

The chloride content was highest (126.66 mgL^{-1}) in the month of January at highly disturbed. The lowest value (28.00 mgL^{-1}) was found in the month of July at undisturbed site. The trend in result for chloride was similar to the total hardness with sharp increase in values at highly disturbed site (Fig.9; Table. 9).All the data relating to physico-chemical characteristics from different month were pooled together site wise and correlated to find the correlation coefficient between them. (Appendix I-IV).

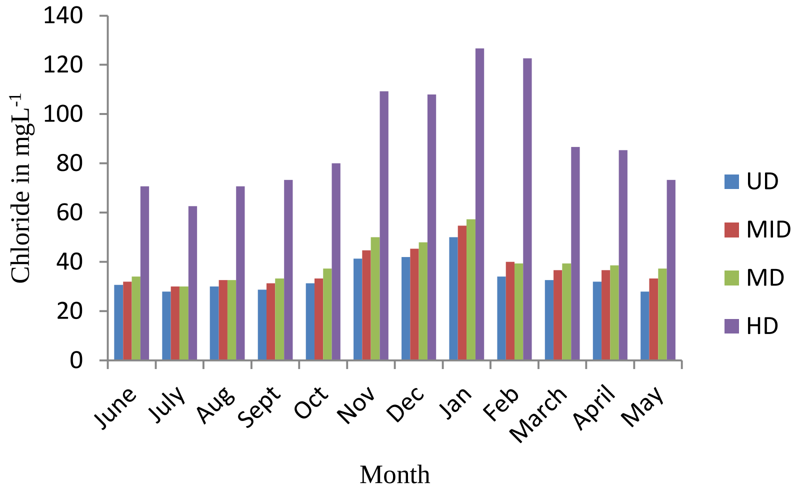


Fig.9.Monthly variation in Chloride content of water along disturbance gradient.

Table 13. Statistics characteristics for Chloride content of water.

Sampling site	Min	Max	Mean	SD	SE
Undisturbed	28.00	50.00	34.05	6.83	1.97
Mildly disturbed	30.00	54.66	37.55	7.37	2.13
Moderately disturbed	30.00	57.33	39.77	8.06	2.32
Highly disturbed	62.66	126.66	89.11	21.91	6.32

SD = Standard deviation

4.1.9. Dissolved Oxygen:

The DO content was highest(8.81 mgL^{-1}) in the month of December at undisturbed site. The lowest value (5.51 mgL^{-1}) was found in the month of May at highly disturbed site. Normally, DO content of water decreased from undisturbed to highly disturbed site (Fig.10; Table. 10).

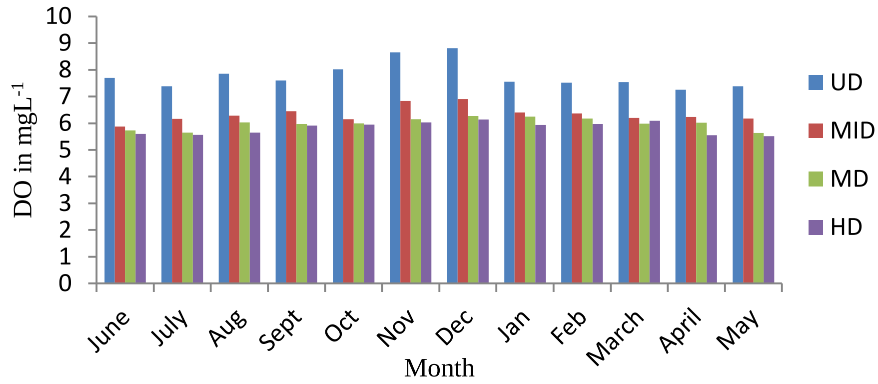


Fig.10.Monthly variation in DO content of water along disturbance gradient.

Table 14.Statistics characteristics for DO content of water.

Sampling site	Min	Max	Mean	SD	SE
Undisturbed	7.25	8.81	7.77	0.49	0.14
Mildly disturbed	5.87	6.9	6.33	0.29	0.08
Moderately disturbed	5.63	6.27	5.98	0.21	0.06
Highly disturbed	5.51	6.13	5.82	0.23	0.06

SD = Standard deviation

4.1.10. Biochemical Oxygen Demand:

The BOD content was highest (1.20 mgL^{-1}) in the month of June at highly disturbed site. The lowest value (0.80 mgL^{-1}) was found in the month of November at undisturbed site. A reverse trend in result for BOD was obtained in comparison with DO content of water (Fig11; Table. 11).All the data relating to physico-chemical characteristics from different month were pooled together site wise and correlated to find the correlation coefficient between them. (Appendix I-IV).

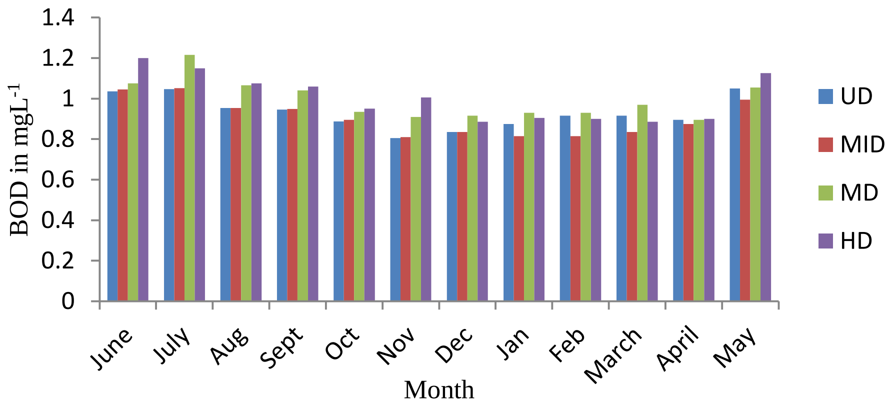


Fig 11.Monthly variation in BOD content of water along disturbance gradient.

Table 15. Statistics characteristics for BOD content of water.

Sampling site	Min	Max	Mean	SD	SE
Undisturbed	0.80	1.04	0.92	0.08	0.02
Mildly disturbed	0.81	1.05	0.90	0.09	0.02
Moderately disturbed	0.89	1.21	0.99	0.09	0.03
Highly disturbed	0.88	1.20	1.00	0.11	0.03

SD = Standard deviation

4.1.11. Nitrate-N:

The nitrate – N content of water was highest (0.51 mgL^{-1}) in the month of January at highly disturbed site. The lowest value (0.20 mgL^{-1}) was found in the month of May at undisturbed site. There was increase in value from undisturbed to highly disturbed site. The highly disturbed site had very high value in comparison to other sites (Fig.12; Table. 12). All the data relating to physico-chemical characteristics from different month were pooled together site wise and correlated to find the correlation coefficient between them. (Appendix I-IV).

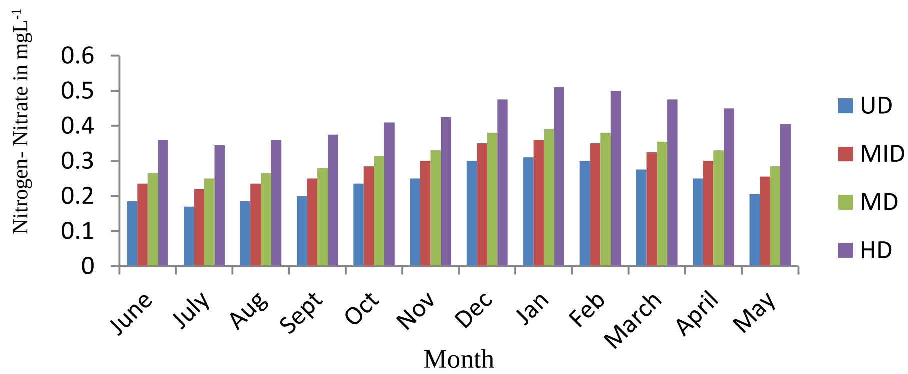


Fig.12.Monthly variation in Nitrate-N content of water along disturbance gradient.

Table 16.Statistics characteristics for Nitrogen-Nitrate Content of water.

Sampling site	Min	Max	Mean	SD	SE
Undisturbed	0.17	0.31	0.23	0.04	0.014
Mildly disturbed	0.22	0.35	0.28	0.04	0.014
Moderately disturbed	0.25	0.39	0.31	0.04	0.014
Highly disturbed	0.34	0.51	0.42	0.05	0.016

SD = Standard deviation

4.1.12. Sulphate:

The sulphate content was highest (1.33 mgL^{-1}) in the month of January at highly disturbed site. The lowest value (0.16 mgL^{-1}) was found in the month of July at undisturbed site. There was increase in value with increase in degree of disturbance. The highly disturbed possessed marked increase in the value (Fig.13; Table. 13). All the data relating to physico-chemical characteristics from different month were pooled together site wise and correlated to find the correlation coefficient between them. (Appendix I-IV).

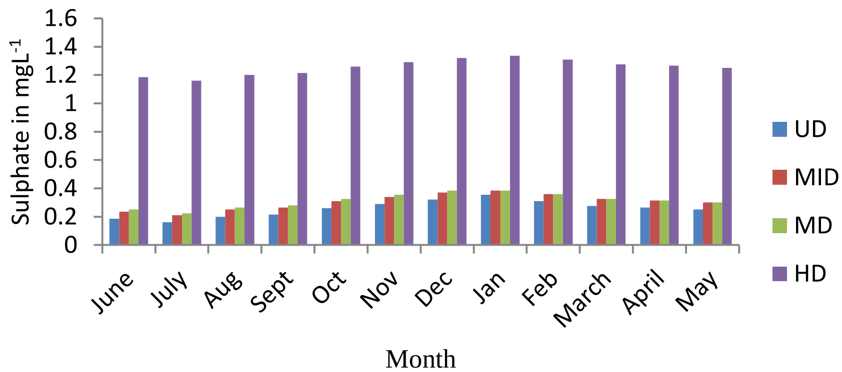


Fig.13.Monthly variation in Sulphate content of water along disturbance gradient.

Table 17.Statistics characteristics for Sulphate Content of water.

Sampling site	Min	Max	Mean	SD	SE
Undisturbed	0.16	0.35	0.25	0.05	0.01
Mildly disturbed	0.21	0.38	0.30	0.05	0.01
Moderately disturbed	0.22	0.38	0.31	0.05	0.01
Highly disturbed	1.16	1.33	1.25	0.05	0.01

SD = Standard deviation

4.1.13. Phosphate- P:

The Phosphate-P content was highest (0.52 mgL^{-1}) in the month of January at highly disturbed site. The lowest value (0.014 mgL^{-1}) was found in the month of July at undisturbed site. The winter season months generally possessed higher values. The values were decreased with degree of disturbance (Fig.14; Table. 14). All the data relating to physico-chemical characteristics from different month were pooled together site wise and correlated to find the correlation coefficient between them. (Appendix I-IV).

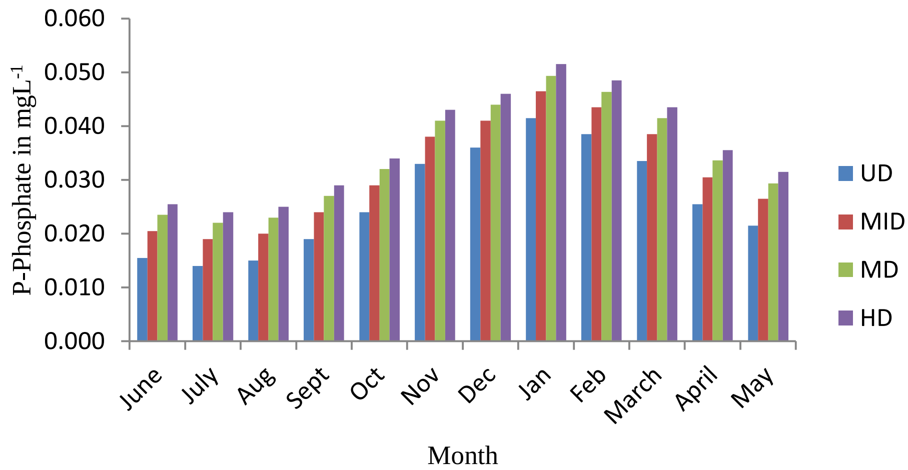


Fig.14.Monthly variation in Phosphate-P content of water along disturbance gradient.

Table 18.Statistics characteristics for Phosphate-P Content of water.

Sampling site	Min	Max	Mean	SD	SE
Undisturbed	0.014	0.042	0.02	0.009	0.002
Mildly disturbed	0.019	0.047	0.031	0.009	0.002
Moderately disturbed	0.022	0.049	0.034	0.009	0.002
Highly disturbed	0.024	0.052	0.036	0.009	0.002

SD = Standard deviation

4.2. Vegetation Analysis:

4.2.1. Tree species composition:

Altogether a total of 49 tree species belonging to 41 genera and 25 families of angiosperms were recorded from all four selected study sites. Of this, 44 species belonging to 39 genera and 22 families, 32 species belonging to 30 genera and 19 families, 21 species belonging to 19 genera and 11 families and 18 species belonging to 17 genera and 11 families were reported from undisturbed, mildly disturbed, moderately disturbed and highly disturbed sites respectively. There was successive decrease in the number of species with increase in the degree of disturbance. The species namely *Acasia concinna, Albizzia chinensis, Artocarpus heterophylla, Derris robusta., Gmelina arborea,. Phoebe goalparensis, Quercus dilata., Schima wallichii, Securinega virosa, Tectona grandis and Toona ciliata.* However, the species *Bombax ceiba, Buddleja macrostachya, Callicarpa macrophyla, Debregeasia valutina, Ficus oblongifolius, Maranta arundivaceae, Michelia doltsopa, Myrica esculenta, Parkia roxburghii, Quercus lanceofolia, Tamarindus indica and Zizyphus incurve* were present only at undisturbed site.

4.2.2. Phytosociological attributes:

There was decreased in tree density from undisturbed stand (716 ± 17.1 indv. ha^{-1}) to the highly disturbed stand (316 ± 5.83 indv. ha^{-1}). Likewise tree basal area ranged from 16.51 m^2 ha^{-1} (undisturbed) to 7.63 m^2 ha^{-1} (highly disturbed site). Shannon- Weiner diversity index was maximum (2.43) at the undisturbed site and minimum (0.85) at the highly disturbed site. On the contrary, Simpson dominance index was found to be maximum of 0.006 at highly disturbed site and minimum of 0.002 at undisturbed site. The species richness (Margalef's index) was maximum as 6.51 at undisturbed site and minimum as 2.27 at highly disturbed site. The

Evenness index (Pielou) ranged from 0.616 to 0.22 from undisturbed to highly disturbed site. (Table .no. 19)

4.2.3. Phytosociological attributes:

The findings reveal that *Tectona grandis* was the dominant species (IVI – 64.53) possessing maximum tree density (106.6) and basal area (2.65) in the undisturbed stand. The co- dominant species were *Schima wallichii* (IVI – 23.53) and *Lagerstroemia speciosa* (IVI- 21.98). However, the abundance was maximum for *Tectona grandis* (2.91) followed by *Callicarpa arborea* (2.0) and *Schima wallichii* (1.58). (Table no. 15)

In mildly disturbed site, *Tectona grandis* was the dominant species (IVI – 49.74) possessing maximum tree density (63.33) and basal area (1.44). The co- dominant species were *Schima wallichii* (IVI – 26.44) and *Lagerstroemia speciosa* (IVI- 24.71). However, the abundance was maximum for *Tectona grandis* (2.23) followed by *Schima wallichii* (1.54) and *Acasia concinna* (1.50). (Table no. 16)

In moderately disturbed site, *Citrus grandis* was the dominant species (IVI – 38.99) possessing maximum tree density (40) and basal area (0.69). The co- dominant species were *Schima wallichii* (IVI – 26.20) and *Litsea monopetala* (IVI- 26.13). However, the abundance was maximum for *Magifera indica* (3.75) followed by *Callicarpa arborea* (2.0) and *Citrus grandis* (1.50). (Table no. 17)

In highly disturbed site, *Litsea monopetala* was the dominant species (IVI – 32.70) possessing maximum tree density (20) and basal area (0.49). The co- dominant species were *Schima wallichii* (IVI – 28.89) and *Albizzia chinensis* (IVI- 28.45). However, the abundance was maximum for *Castanopsis tribuloides* (2.0) followed by *Tectona grandis* (1.75) and *Albizzia chinensis* (1.57). (Table no. 18).

Table 19.Tree community structure, dominance and distribution of species in undisturbed site.

Tree Species	Tree density	Basal area	Abundance	IVI	A/F
Acasia concinna DC	5	0.088495	1.50	3.23	0.45
Albizzia chinensis DC	25	0.600133	1.50	17.75	0.09
Bauhinia purpurea	5	0.114053	1.50	3.49	0.45
Betula alnoides Buch-Ham	1.666667	0.028079	1.00	1.26	0.60
Bombax ceiba	3.333333	0.041322	2.00	1.78	1.20
Buddleja macrostachya Benth.	3.333333	0.072718	1.00	2.69	0.30
Callicarpa arborea	3.333333	0.044068	2.00	1.81	1.20
Callicarpa macrophyla Vahl.	1.666667	0.022306	1	1.69	0.60
Castanopsis indica Roxb.	5	0.065008	1.50	3.00	0.45
Castanopsis tribuloides DC	3.333333	0.04724	2.00	1.84	1.20
Cinamomum verum Presl	1.666667	0.030573	1.00	1.28	0.60
Citrus grandis	3.333333	0.037858	2.00	1.75	1.20
Clerodrendrum bracteatum Wall	3.333333	0.020303	2.00	1.57	1.20
Cucurligo crassifolia	3.333333	0.013442	1.00	2.09	0.30
Debregeasia valutina Gaud.	1.666667	0.05268	1	1.51	0.60
Derris robusta Roxb.	3.333333	0.009687	2.00	1.46	1.20

Eleocarpus tectorius Lour	5	0.018763	1.50	2.53	0.45
Fagraea khasiana	1.666667	0.00702	1.00	1.05	0.60
Ficus oblongifolius Roxb.	13.33333	0.571258	1.14	12.98	0.10
Ficus racemosa	8.333333	0.276659	1.00	7.67	0.12
Gmelina arborea	25	0.590844	1.25	18.83	0.06
Grevillea robusta A. Cunn	3.333333	0.039504	1	1.76	0.6
Lagerstroemia speciosa	26.66667	0.747505	1.14	21.98	0.05
Litsea monopetala	26.66667	0.673917	1.23	20.65	0.06
Macaranga deticulata Roxb.	3.333333	0.023156	2.00	1.60	1.20
Macaranga indica W.	3.333333	0.095648	2.00	1.88	1.20
Magifera indica	3.333333	0.05077	2.00	1.88	1.20
Maranta arundivaceae	3.333333	0.030387	2.00	1.67	1.20
Michelia doltsopa	3.333333	0.070329	2	2.07	1.20
Murraya paniculata	8.333333	0.166162	1.00	6.56	0.12
Myrica esculenta Ham.	3.333333	0.023421	1.00	2.19	0.30
Parkia roxburghii	6.666667	0.169573	2.00	4.44	0.60
Phoebe goalparensis Hutch	13.33333	0.242633	1.14	9.67	0.10
Phyllanthus coroneria Lour	3.333333	0.073912	1.00	2.70	0.30
Quercus dialata	16.66667	0.372452	1.25	12.34	0.09
Quercus lanceofolia	3.333333	0.05495	1	2.51	0.30
Schima wallichii	31.66667	0.902017	1.58	23.53	0.08
Securinega virosa	23.33333	0.575743	1.40	17.12	0.08
Syzygium cumini (L) Skeels	1.666667	0.02569	1.00	1.24	0.60

Tarmarindus indica	3.333333	0.029007	1.00	2.24	0.30
Tectona grandis	106.6667	2.654079	2.91	64.53	0.08
Toona ciliate	3.333333	0.076659	1.00	2.73	0.30
Ulmus lancifolia Roxb.	3.333333	0.034528	1.00	2.30	0.30
*Zizyphus incurve*Roxb.	1.666667	0.02569	1.00	1.24	0.60

Table 20.Tree community structure, dominance and distribution of species in mildly disturbed site.

Tree Species	Tree density	Basal area	Abundance	IVI	A/F
Acasia concinna DC	5	0.107444	1.5	4.30	0.45
Albizzia chinensis DC	25	0.617503	1.5	22.51	0.09
Artocapus heterophylla	15	0.615897	1.125	18.01	0.08
Bauhinia purpurea	5	0.131131	1.5	4.60	0.45
Betula alnoides Buch-Ham	1.666667	0.040141	1	1.72	0.60
Callicarpa arborea	1.666667	0.017197	1	1.42	0.60
Castanopsis indica Roxb.	3.333333	0.05905	1	3.16	0.30
Castanopsis tribuloides DC	1.666667	0.049376	1	1.83	0.60
Cinamomum verum Presl	1.666667	0.054352	1	1.90	0.60
Clerodrendrum bracteatum Wall	1.666667	0.026871	1	1.55	0.60
Curculigo crassifolia	3.333333	0.019175	1	2.65	0.30

Derris robusta Roxb.	1.666667	0.02569	1	1.53	0.60
Eleocarpus tectorius Lour	3.333333	0.021497	1	2.68	0.30
Fagraea khasiana	1.666667	0.016255	1	1.41	0.60
Ficus racemosa	8.333333	0.211306	1	8.71	0.12
Gmelina arborea	21.66667	0.541189	1.3	20.50	0.08
Grevillea robusta A. Cunn	3.333333	0.075212	1	3.37	0.30
Lagerstroemia speciosa	23.33333	0.670077	1.07692308	24.71	0.05
Litsea monopetala	20	0.541419	1.2	19.98	0.07
Macaranga deticulata Roxb.	3.333333	0.066945	1.00	3.26	0.30
Macaranga indica W.	1.666667	0.074642	1	2.16	0.60
Murraya paniculata	6.666667	0.170475	0.8	7.67	0.10
Phoebe goalparensis Hutch	13.33333	0.235534	1.14285714	11.95	0.10
Phyllanthus coroneria Lour	3.333333	0.064676	1	3.23	0.30
Quercus dialata	16.66667	0.368949	1.25	15.37	0.09
Schima wallichii	28.33333	0.791083	1.54545455	26.44	0.08
Securinega virosa	20	0.504751	1.2	19.51	0.07
Syzygium cumini (L) Skeels	1.666667	0.02569	1	1.53	0.60
Tectona grandis	63.33333	1.441298	2.23529412	49.74	0.08
Tetrameles nudiflora	5	0.058028	1.5	3.67	0.45
Toona ciliate	3.333333	0.066945	1	3.26	0.30
Ulmus lancifolia Roxb.	6.666667	0.121802	1.33	5.68	0.27

Table 21.Tree community structure, dominance and distribution of species in moderately disturbed site.

Tree Species	Tree density	Basal area	Abundance	IVI	A/F
Acasia concinna DC	5	0.098899	1.50	5.07	0.45
Albizzia chinensis DC	21.66667	0.535987	1.44	24.00	0.10
Artocarpus heterophylla	13.33333	0.552468	1.14	19.63	0.10
Callicarpa arborea	3.333333	0.061385	2.00	3.03	1.20
Castanopsis indica Roxb.	10	0.139384	0.86	5.53	0.45
Castanopsis tribuloides DC	5	0.127322	1.50	19.38	0.56
Clerodrendrum bracteatum Wall	3.333333	0.036757	2.00	2.62	1.20
Citrus grandis	40	0.698013	1.50	20.58	0.10
Derris robusta Roxb.	1.666667	0.003835	1.00	1.48	0.60
Macaranga indica	4.07	4.22	2.15	10.43	0.17
Gmelina arborea	18.33333	0.463336	1.00	23.22	0.05
Grevillea robusta A. Cunn	3.333333	0.075212	1.00	4.07	0.30
Litsea monopetala	21.66667	0.566618	1.18	26.13	0.06
Macaranga deticulata Roxb.	3.333333	0.07151	1.00	4.01	0.30
Magnifera indica	25	0.429538	3.75	19.38	0.56
Phoebe goalparensis Hutch	11.66667	0.208119	1.17	12.53	0.12
Quercus dialata Lindl.	16.66667	0.353649	1.25	18.37	0.09
Schima wallichii	21.66667	0.620395	1.30	38.99	0.06

Securinega virosa	18.33333	0.451075	1.38	26.20	0.08
Tectona grandis	18.33333	0.341046	1.38	18.76	0.10
Toona ciliata	3.333333	0.093047	1.00	4.37	0.30

Table 22.Tree community structure, dominance and distribution of species in highly disturbed site.

Tree Species	Tree density	Basal area	Abundance	IVI	A/F
Acasia concinna DC	5	0.087314	1.5	6.81	0.45
Albizzia chinensis (DC)	18.33333	0.49728	1.571428571	28.45	0.13
Artocarpus heterophylla	13.33333	0.543272	1.142857143	26.83	0.10
Castanopsis indica Roxb.	3.333333	0.070714	1.00	5.57	0.3
Castanopsis tribuloides DC	3.333333	0.118007	2.00	5.47	1.2
Cinamomum verum Presl.	1.666667	0.007643	1	2.18	0.60
Citrus grandis	16.66667	0.29313	1.25	24.26	0.09
Emblica officinalis	5	0.071106	1.5	6.46	0.45
Gmelina arborea Roxb.	13.33333	0.391136	1.142857143	23.51	0.10
Grevillea robusta A.Cunn.	5	0.111093	1.00	8.46	0.2
Litsea monopetala	20	0.495559	1.2	32.70	0.07
Magnifera indica	18.33333	0.309952	1.571428571	24.37	0.13
Phoebe goalparensis Hutch	10	0.170207	1.2	14.66	0.14
Quercus dialata Lindl.	11.66667	0.250292	1.166666667	18.42	0.12

Schima wallichii	16.66667	0.505613	1.25	28.89	0.09
Securinega virosa	13.33333	0.353079	1.333333333	21.54	0.13
Tectona grandis	11.66667	0.227707	1.75	15.65	0.26
Toona ciliate	3.333333	0.080308	1	5.78	0.30

Table.23. Phytosociological attributes of tree species.

Parameter	**UD**	**MID**	**MOD**	**HD**
No. of Family	26	19	12	11
No. of Genera	39	30	19	17
No. of Species	44	32	21	18
Tree Density(Indv.ha$^{-1)}$	716±17.1	536±13.2	461±9.83	316±5.83
Tree basal area(m^{2}h$^{-1)}$	16.51	13.05	10.09	7.63
Shannon-Weiner index	2.43	1.7	1.19	0.85
Simpson dominance index	0.002	0.003	0.004	0.006
Margalef index (Species Richness)	6.51	4.54	3.17	2.27
Pielou index (Eveness index)	0.616	0.43	0.30	0.22

4.2.4. Girth class distribution:

The results reveal most of the tree species were confined to medium girth classes i.e. 41 to 50 cm and 51 to 60 cm at undisturbed site. Similarly most of the individuals stands were confined to the girth class 61 to 70 cm at mildly, moderately and highly disturbed stand. It was found that there was marked decrease in the number of individuals in the higher girth classes (91 to 100 cm) with increase in degree of disturbance (Fig. no. 15).

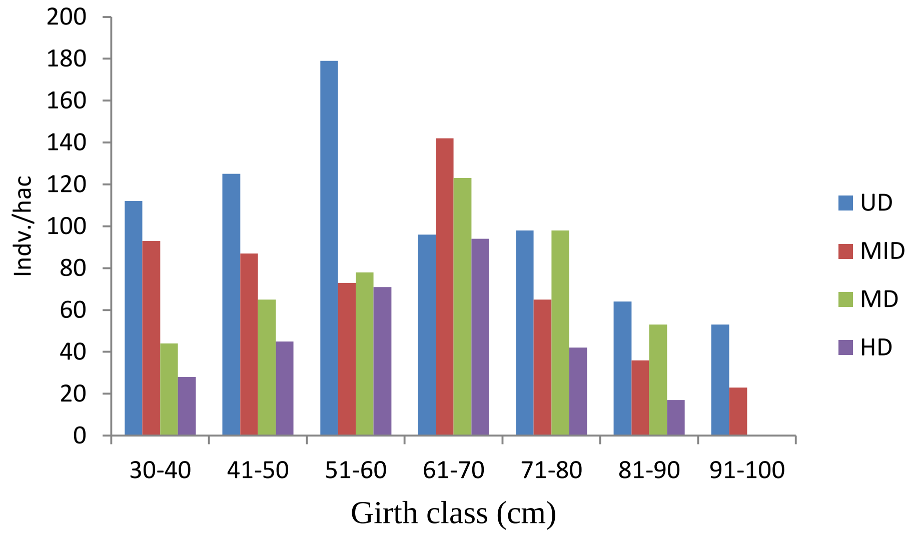


Fig.15. Girth class distribution of trees along disturbance gradient.

4.2.5.Similarity index (Sorenson's index):

The species common to all the sites were *Acasia concinna DC, Albizzia chinensis (Osb) Mer, Artocarpus heterophylla, Derris robusta Roxb., Gmelina arborea Roxb., Litsea monopetala, Phoebe goalparensis Hutch, Quercus dilata Lindl., Schima wallichii, Securinega virosa, Tectona grandis* and *Toona ciliate.* The similarity index was computed as 0.71 between UD and MID sites, 0.67 between MID and MD sites, 0.82 between MD and HD and 0.52 between UD and HD sites. Majority of the species common to all sites belonging to families Verbenaceae, Mimosaceae and Lauraceae.

4.2.6. Diversity and dominance of families:

Table presents diversity and dominance of families. A total number of 24 families were recorded from all the study sites. Of these, 22 families were reported from undisturbed site followed by 19 families from mildly disturbed site, 11 families each from moderately and highly disturbed sites. In undisturbed site Euphorbiaceae was the dominant family with 5 species and it was followed by Verbenaceae (with 4 species each), Fagaceae, Lauraceae, Mimosaceae, Moraceae (with 3 species each), Caesalpinaceae and Rutaceae (with 2 species each). And the remaining 13 families were represented by mono species.

Similarly in the mildly disturbed site, Verbenaceae was the dominating family with 4 species and it was followed by Euphorbiaceae, Fagaceae , Lauraceae (with 3 species each), Mimosaceae and Moraceae (with 2 species each). The remaining 13 species were represented by single species.

In moderately disturbed site, Verbenaceae was the dominant family with 4 species, and it was followed by Euphorbiaceae, Lauraceae, Moraceae (with 3 species each). The remaining 7 species were represented by single species.

In highly disturbed site, Lauraceae was the dominant family with 3 species, and it was followed by Euphorbiaceae, Mimosaceae, and Verbenaceae (with 2 species each). The remaining 7 species were represented by single species.

Table 24.Family-wise distribution of tree species along disturbance gradient.

Sl.No.	Family	UD	MID	MD	HD
1	Amarylidaceae	1	1	-	-
2	Anacardiaceae	1	-	1	1
3	Betulaceae	1	1	-	-
4	Bombaceae	1	-	-	-
5	Caesalpinaceae	2	1	-	-
6	Datiscaceae	-	1	-	-
7	Euphorbiaceae	5	3	3	2
8	Fagaceae	3	3	1	1
9	Lauraceae	3	3	3	3
10	Longaniaceae	1	1	-	-
11	Lythraceae	1	1	-	-
12	Marantaceae	1	-	-	-
13	Meliaceae	1	1	-	1
14	Mimosaceae	3	2	3	2
15	Moraceae	3	2	1	1
16	Myricaceae	1	-	-	-
17	Myrtaceae	1	1	-	-
18	Papilionaceae	1	1	1	-
19	Proteaceae	-	1	1	-
20	Rutaceae	2	1	1	1

21	Theaceae	1	1	1	1
22	Tiliaceae	1	1	-	-
23	Ulmaceae	1	-	-	-
24	Verbenaceae	4	4	4	2
	Total	38	30	20	15

(-) Absent.

Euphorbiaceae, Fagaceae, Lauraceae, Mimosaceae, Rutaceae and Theaceae were the familiespresent in all the study sites. The families Bombaceae, Marantaceae, Myricaceae and Ulmaceae were restricted to the undisturbed site.

4.3. Soil Analysis:

The soil samples of top-soil (0-10 cm depth) and sub-soil (10-20 cm) were analyzed for various soil characteristics and presented as below:

4.3.1. Soil Moisture Content:

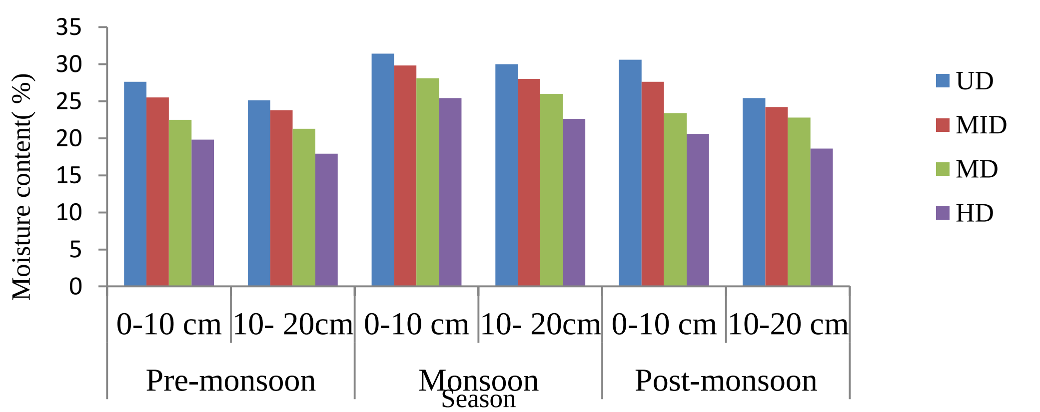


Fig.16. Seasonal variation in soil moisture content along disturbance gradient.

The soil moisture content in top soil varied from 27.6 % (UD) to 17.9 (HD) during pre-monsoon season, 25.4 % (HD) to 31.4 % (UD) during monsoon season and 20.67 % (HD) to 30.6 % (UD) during post-monsoon season. The sub-soil showed lower values than top soil. There was a decreasing trend in values from undisturbed to the highly disturbed site with respect to the both season and soil depth. All the data relating to physico-chemical characteristics from different seasons were pooled together site wise and correlated to find the relationship between them. The site and depth-wise correlation of the data generated is given in (Appendix V-XII).

4.3.2. Soil pH:

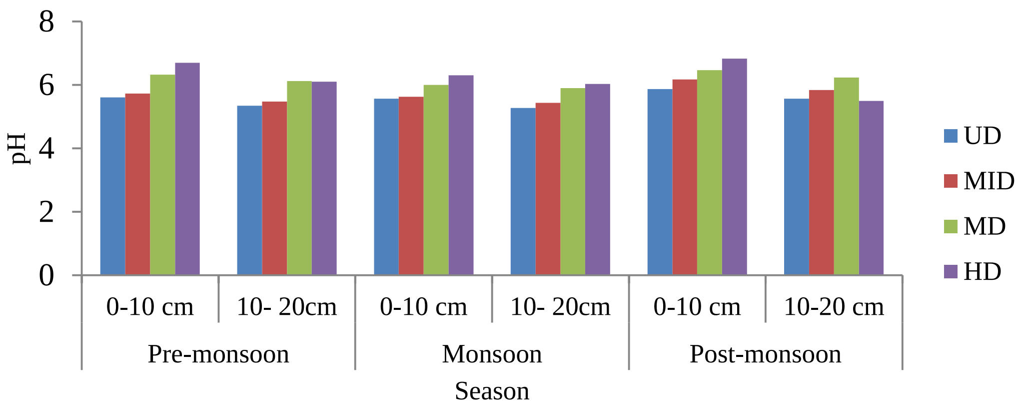


Fig.17. Seasonal variation in soil pH along disturbance gradient.

The pH of top-soil varied from 5.34 (UD) to 6.7 (HD) during pre-monsoon season, 5.57 (UD) to 6.3 (HD) during monsoon season and from 5.87 (UD) to 6.83 (HD) during post-monsoon season. The sub-soil showed lower values than top-soil. There was a increasing trend in values from undisturbed to the disturbed site with respect to the both season and soil depth with few exception. All the data relating to physico-chemical characteristics from different seasons were pooled together site wise and correlated to find the relationship between them. The site and depth-wise correlation of the data generated is given in (Appendix V-XII).

4.3.3. Soil Organic Carbon:

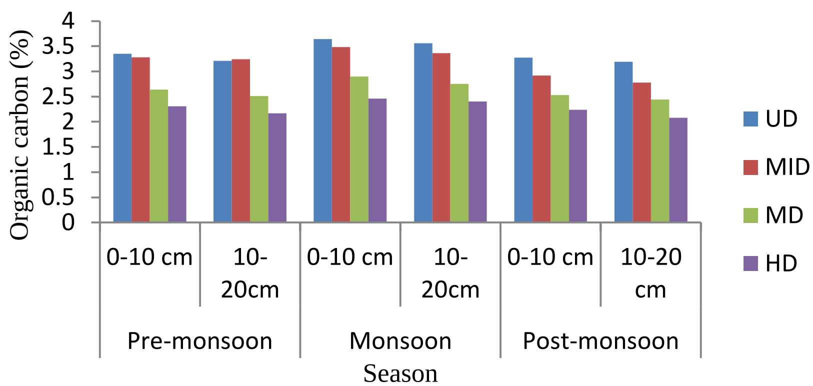


Fig.18. Seasonal variation in soil organic carbon along disturbance gradient.

The soil organic carbon of top-soil varied from 3.35 % (UD) to 2.17 % (HD) during pre-monsoon season, 2.4 % (HD) to 3.64 % (UD) during monsoon season and 2.08 % (HD) to 3.27 % (UD) during post-monsoon season. The sub-soil showed lower values than top soil. There was a decreasing trend in values from undisturbed to the disturbed site with respect to both the season and soil depth. All the data relating to physico-chemical characteristics from different seasons were pooled together site wise and correlated to find the relationship between them. The site and depth-wise correlation of the data generated is given in (Appendix V-XII).

4.3.4. Total Nitrogen:

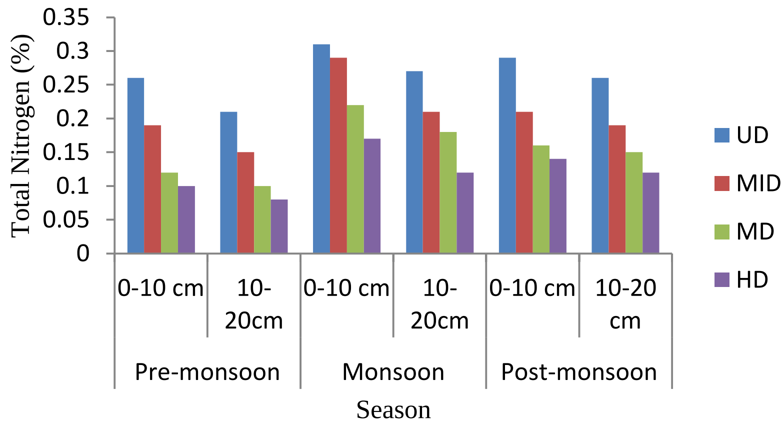


Fig.19. Seasonal variation in soil nitrogen content along disturbance gradient.

The total nitrogen content of top-soil varied from 0.26 % (UD) to 0.08 % (HD) during pre-monsoon season, 0.12 % (HD) to 0.31 % (UD) during monsoon season and 0.12 % (HD) to 0.29 % (UD) during post-monsoon season. The sub-soil showed lower values than top-soil. There was a sharp decrease in the values from undisturbed to the disturbed stand with respect to both the season and soil depth. All the data relating to physico-chemical characteristics from different seasons were pooled together site wise and correlated to find the relationship between them. The site and depth-wise correlation of the data generated is given in (Appendix V-XII).

4.3.5. Available Phosphorus:

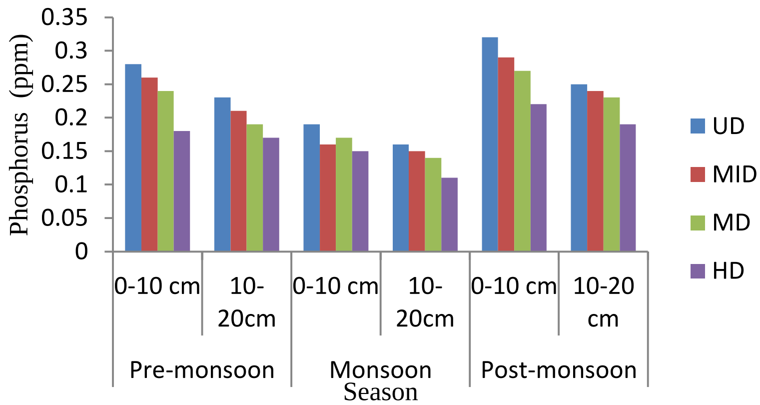


Fig.20. Seasonal variation in soil available phosphorus along disturbance gradient.

The findings reveal that soil available phosphorus of top-soil varied from 0.28 ppm (UD) to 0.17 % (HD) during pre-monsoon season,0.15 ppm (HD) to 0.19 ppm (UD) during monsoon season and 0.22 ppm (HD) to 0.32 ppm (UD) during post-monsoon season. The sub-soil showed lower values than top-soil. There was a decreasing trend in values from undisturbed to the disturbed stand with respect to both the season and soil depth. The monsoon season possessed lower values than other two seasons. All the data relating to physico-chemical characteristics from different seasons were pooled together site wise and correlated to find the relationship between them. The site and depth-wise correlation of the data generated is given in (Appendix V-XII).

4.3.6. Exchangeable Potassium:

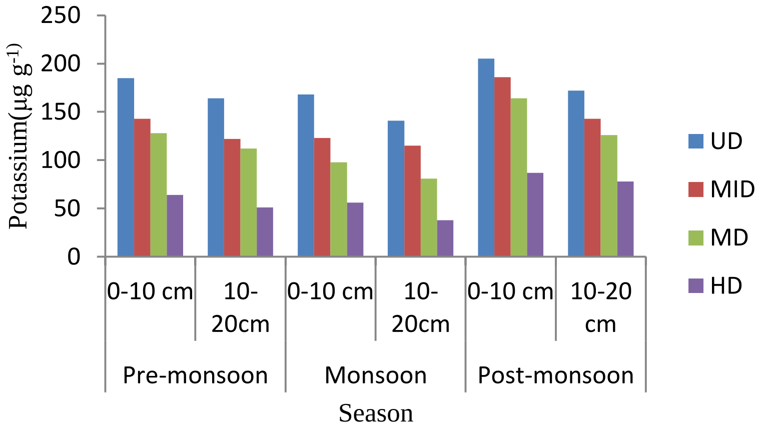


Fig.21. Seasonal variation in exchangeable Potassium along disturbance gradient.

The exchangeable potassium of top-soil varied from 185 µg g^{-1} (UD) to 51 µg g^{-1} (HD) during pre-monsoon season, 87 µg g^{-1} (HD) to 205 µg g^{-1} (UD) during post-monsoon season and 56 µg g^{-1} (HD) to 168 µg g^{-1} (UD) during monsoon season. The sub-soil showed lower values than top-soil. There was a decreasing trend in values from undisturbed to the disturbed stand with respect to both the season and soil depth. All the data relating to physico-chemical characteristics from different seasons were pooled together site wise and correlated to find the relationship between them. The site and depth-wise correlation of the data generated is given in (Appendix V-XII).

4.3.7. Carbon-Nitrogen Ratio:

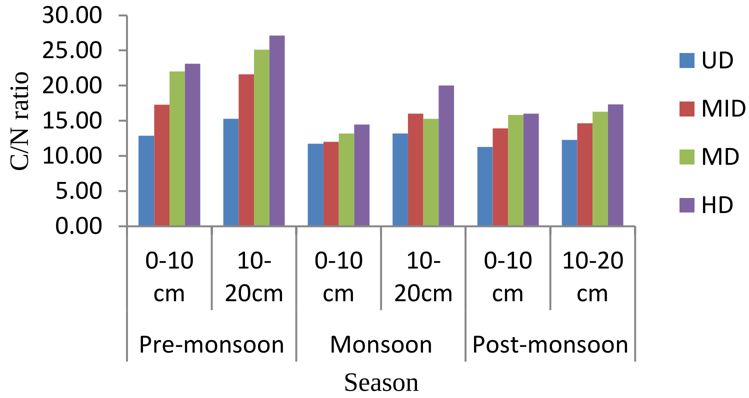


Fig.22. Seasonal variation in soil C:N ratio along disturbance gradient.

The C:N ratio of top-soil varied from 12.88 (UD) to 27.13 (HD), 11.74 (UD) to 20.00 (HD) during monsoon season and 11.28 (UD) to 17.33 (HD) during post-monsoon season. The sub-soil showed higher values than top-soil unlike other parameters. There was a decreasing trend in values from disturbed to the undisturbed stand with respect to both the season and soil depth.

CHAPTER 5

DISCUSSION

The findings of the present study reveal that the sandstone quarry operation in has badly affected the water quality of Tlawng river in Mizoram. The runoff from quarry site leads to discharge of huge amount of waste into river Tlawng, making the river water unfit for human use. The sand stone quarry also leads to destruction of vegetation and deterioration of soil at quarry site.

5.1. Water Quality Characteristics:

5.1.1. *Temperature*:

The water temperature is an important water quality parameter as most of the physical, chemical and biological characteristics of water are directly affected by it (Raney and Menzel, 1969). Water temperature has profound effects on dissolved oxygen and biochemical oxygen demand contents of water (Hasan *et al*., 2008). The present study depicts that there was not much fluctuation in water temperature either with respect to the study site. The monthly fluctuation in temperature may be due to ambient temperature and other climatic factors (Das *et al.*, 2003; Bharali *et al.*, 2008). There was direct influence of seasonal variation on water temperature. Thus, the temperature was highest during summer months and lower during winter season months. There was an increase in temperature with degree of disturbance with some exception. The discharge of pollutants from surroundings quarry area through run-off may be attributed to high temperature during rainy months, as energy is released during decomposition of waste present in water. The runoff from the surface carrying quarry waste had more suspended solids, dissolved solids and other pollutants that may also be one of the reasons for increase in temperature from undisturbed to highly disturbed site. The values are within the prescribed limits given by various scientific agencies (Appendix V). Similar trend of results were also reported by

Mishra and Tripathi (2000, 2001, 2003), Abel-Satar (2005), Zafar and Sultana (2008), Singh and Gupta (2010), Umavati and Logankumar (2010).

A positive and significant correlation was obtained between pH with temperature, total dissolved solids and BOD in all the study sites except in mildly disturbed site. On the contrary, a negative and significant correlation was procured between pH with EC, chloride and DO in all the study sites except in mildly disturbed site. Appendix I-IV.

5.1.2. *pH*:

The pH of a solution is measured as a negative logarithm of hydrogen ion concentration. Measurement of pH in one of the most important and frequently used tests, as every phase of water and wastewater treatment and waste quality management is pH dependent. The pH of natural water usually lies in the range of 4 to 9 and mostly it is slightly basic because of the presence of bicarbonates and carbonates of alkali and alkaline earth metals (ref). pH value is largely governed by the carbon dioxide/ bicarbonate/ carbonate equilibrium. It may be affected by humic substances by changes in the carbonate equilibriums due to the bioactivity of plants and in some cases by hydrolysable salts. The pH of most raw water sources lies within the range of 6.5 to 8.5 (Webber, 1963; Bulushu, 1987). Toxicity in water increases with increase in acidic content in water (Singh *et al.*, 1989).

The present study reveals that there was gradual increase in pH of water from undisturbed to highly disturbed sites. The findings indicate the river water was slightly alkaline at all the four sites and basicity was increased with intensity of pollutants. It may be due to the high content of carbonates, bicarbonates and carbon dioxide equilibrium that attributes to regular discharge of sandstone quarry waste and uptake of sand from the river basin. The higher values during rainy season could be attributed to leaching of rock materials. The values are within the prescribed limit given by various scientific agencies (Appendix V). A similar trend of results was also recorded by Puttiah and Somashekar (1985), Unni *et al.*, (1992), Singh (1995), Sivasubramani (1999) and Fakayode (2005).

A positive and significant correlation was obtained between temperature with total dissolved solids, turbidity and BOD in all the study sites. On the contrary, a negative and significant correlation was procured between temperature with EC, chloride and DO in all the study sites. Appendix I-IV.

5.1.3. *Electrical Conductance*:

EC is the numerical expression of the ability of water sample to carry an electric current. Most dissolved inorganic substances in water are in the ionized form and hence contribute to conductance. Conductivity measurement gives rapid and practical estimate of the variations in the dissolved mineral contents of an aquatic environment. Increased level of conductivity and cations are the products of decomposition and mineralization of organic materials (Abida, 2008). Higher the value of dissolved solids, greater is the amount of ions in water (Bhatt *et al.*, 2009). Electrical conductance values of water higher than the permissible limits may cause reduced yield in agricultural crops (Jothivenkatachalam *et al*., 2010).

The present study depicts that the increase in EC values from undisturbed to highly disturbed site may be attributed to the discharge of quarry waste. Higher values during winter season months may be due to low flow rate of water contributing to the subsequent increase in dissolved solids. On the contrary low values during rainy season months may be due to high volume of water. The values are within the permissible limit set by various scientific agencies

(Appendix V).The findings of the present study are in conformity with the works of Marshall and Winterbourn (1979), Patka and Azadi (1987).

A positive and significant correlation was obtained between EC with total acidity, total alkalinity, total hardness, chloride, nitrate, sulphate and phosphate in all the study sites. On the contrary, a negative and significant correlation was procured between EC with TDS and DO in all the study sites. Appendix I-IV.

5.1.4. *Total Dissolved Solids*:

In natural water, total dissolved solids are mainly composed of carbonates, bicarbonates, chlorides, phosphates and nitrates of calcium, magnesium and other particles. It is the measure of impurities of water in a dissolved state. In areas having Precambrian rocks, TDS concentration in water is generally less than 65 mgL^{-1}. The level is normally higher in the regions of Palaeozoic and Mesozoic sedimentary rock, and ranging from 195-1100 mgL^{-1} because of the presence of carbonates, chlorides, calcium, magnesium and sulphate (Rainwater *et al*., 1960; Durfor *et al*., 1972). The Indian average for TDS is 159 mgL^{-1} (Subramanian, 1983) and global average value is 115 mgL^{-1} for aquatic ecosystem (Sarin and Krishnaswamy, 1984). Higher value of TDS makes the water more turbid due to presence of silt and organic matter. The water having high TDS value cannot be used for drinking purpose.

The present study reveals that the higher values of TDS were recorded at highly disturbed sites which may be due to discharge of solids and other suspended particles from the quarry areas. The values were markedly higher values of TDS were recorded during rainy season months which may be due to heavy surface runoff and accumulation of nutrients and also evaporative loss of consequent increases in the concentration of salt present in water. The findings are in conformity with the work of Bajpal *et al.*, (1993), Patka and Rao (1997), Tiwari (2005), Bharali *et al*., (2008), Banerjee and Gupta (2010). All the TDS values recorded were within the permissible limit as given by various scientific agencies (Appendix V).

A positive and significant correlation was obtained between TDS with BOD, temperature and turbidity in all study sites. On the contrary, a negative and significant correlation was procured between TDS with DO, chloride and nitrate in all the study sites. Appendix I-IV.

5.1.5. *Turbidity*:

Turbidity of water is an expression of the optical property that causes light to be scattered and absorbed rather than transmitted in straight lines through the sample. Turbidity can be measured by its effect on the scattering light, which is termed as Nephelometry. Turbidimeter can be used for sample with moderate turbidity and nephelometer for sample with low turbidity. Higher the intensity of scattered lights, higher the turbidity value.

The present study reveals that higher turbidity values were obtained during rainy season months. This could be attributed to discharge of pollution load into the river through surface runoff from the quarry affected areas that makes the water more turbid.

A positive and significant correlation was established between turbidity with BOD, temperature and total hardness in all study sites. On the contrary, a negative and significant correlation was procured between turbidity with DO content, nitrate, sulphate and phosphate in all the study sites. Appendix I-IV.

5.1.6. ***Acidity*:**

It is an important chemical parameter of water quality and higher concentration may affect the aquatic species. Acidic water is less buffered and less productive because sufficient amount of bicarbonates are not dissolved to give CO_2 for a high rate of photosynthesis. Acid contributes to corrosiveness and influence the rate of chemical reactions, chemical speciation and biological activities. Warren (1971) argued that lowering of pH in water is result of decomposition of organic matters and finally release of CO_2.

The present study reveals that higher values of total acidity values were recorded during post-monsoon season months which may be due to high organic load received from quarry waste during monsoon months, supporting decomposition during post-monsoon season months. Similar trend of results were reported by Srivastava and Kulshreshta (1990), Dublin - Green (1990), Pahwa and Mehrotra (1996), Narain and Chauhan (2000), Ekeh and Sikota (2003), Mishra and Tripathi (2000,2001,2003), Banerjee and Gupta (2010), Shrivastava *et al.,* (2010), Singh *et al.,* (2010) and Venkatesharaju *et al.,* (2010).

A positive and significant correlation was obtained between total acidity with DO, nitrate, sulphate and phosphate in all study sites. On the contrary, a negative and significant correlation was procured between total acidity with BOD and turbidity in all the study sites. Appendix I-IV.

5.1.7. ***Total Alkalinity*:**

It is a total measure of the substances in water that have "acid-neutralizing" ability. Major portion of alkalinity in natural water is caused by hydroxide, carbonate and bicarbarbonate. The present study revealed that lower value of alkalinity was observed during rainy season months which may be due to influx of fresh water which causes dilution of water. In the contrary higher values during winter season months could be attributed to liberation of carbon dioxide during decomposition which reacts with water to form bicarbonate which is limited to low volume of water. The values recorded during present investigation were within the permissible limit as suggested by various scientific agencies (Appendix V). Similar results have also been reported by Mishra and Tripathi (2000, 2001, 2003), Zafar and Sultana (2008) and Singh and Gupta (2010), Venkatesharaju *et al.,* (2010).

A positive and significant correlation was obtained between total alkalinity with total hardness, nitrate, sulphate and phosphate in all study sites. On the contrary, a negative and significant correlation was procured between total alkalinity with turbidity in all the study sites. Appendix I-IV.

5.1.8. *Total Hardness*:

Water hardness is a traditional measure of the capacity of water to precipitate soap. Hardness of water is not a specific constituent but is a variable and complex mixture of cations and anions. It is caused by dissolved polyvalent metallic ions. In fresh water, the principal hardness causing ions are calcium and magnesium which precipitate soap. Other polyvalent cations also may precipitate soap, but often are in complex form, frequently with organic constituents, and their role in water hardness may be minimal and difficult to define. Total hardness is defined as the sum of the calcium and magnesium concentration, both expressed as $CaCO_3$, in mgL^{-1}. The degree of hardness of drinking water has been classified in terms of the equivalent $CaCO_3$ concentration as follows:

Water Quality	Total hardness value (mgL^{-1} C_aCO_3)
Soft	0 to <75
Moderately Hard	75 to <150
Hard	150 to <300
Very hard	300 and above

During present investigation, higher values of total hardness were obtained at disturbed sites as compared to control site which may be due to discharged of pollutants from the quarry areas and other anthropogenic activities such as washing of clothes, vehicles and bathing. Low water volume during winter months may be the reason for higher values of hardness at all the sites. A similar trend of results was observed by Saxena *et al.*, (1966), Mishra and Tripathi (2000, 2001, 2003), Zafar and Sultana (2008) and Singh and Gupta (2010). The total hardness values were within the permissible limit given by various scientific agencies (Appendix V).

A positive and significant correlation was obtained between total hardness with chloride, nitrate, sulphate and phosphate in all study the sites. On the contrary, a negative and significant correlation was procured between total hardness with BOD and turbidity in all the study sites. Appendix I-IV.

5.1.9. *Chloride*:

Chloride is one of the most stable components in water, being unaffected by most physico-chemical and/or biological processes. The major sources of chloride include natural mineral deposits, sea water intrusion, agricultural and surface runoff. Chloride content above 250 mgL^{-1} in water imparts a peculiar taste and causes corrosion in iron and plumbing metals. Average chloride concentration in Indian fresh water bodies is upto15 mgL^{-1} (Subramanian, 1983) and World's chloride concentration is amounting to 4 mgL^{-1} (Sarin and Krishnawany, 1984).

Present investigation reveals that higher values at highly disturbed site indicating presence of human excreta and organic waste from the nearby settlements. Low values in rainy months and high during winter months may be due to dilution of water with rain and discharge of municipal and agricultural waste respectively. Chloride values recorded were within the permissible limit given by various scientific agencies (Appendix V). Jana (1973), Palharya *et al.*, (1993), Kumar (2000), Mishra and Tripathi (2000, 2001, 2003), Zafar and Sultana (2008) and Singh and Gupta (2010) also reported a similar trend of results.

A positive and significant correlation was obtained between chloride with, nitrate, sulphate and phosphate in all study the sites. On the contrary, a negative and significant correlation was procured between chloride with BOD and turbidity in all the study sites. Appendix I-IV.

5.1.10. *Dissolved Oxygen*:

All living organisms are dependent upon oxygen in one form or the other to maintain the metabolic processes that produce energy for growth and reproduction. The DO content is of utmost importance for the survival of aquatic organisms and maintenance of water bodies (Mishra and Tripathi 2001). DO level in natural waters and wastewaters depend on physical, chemical and biological activities in water bodies. The solubility of atmospheric oxygen in fresh water ranges from 14.6mgL^{-1}at 0°C to about 7.0mgL^{-1} at 35°C under normal atmospheric pressure. Since it is poorly soluble gas, its solubility directly varies with the atmospheric pressure at any given temperature. Analysis of DO is a key test in water pollution control and wastewater treatment processes.

The present study reveals that there is a marked decrease in DO content with increase in degree of disturbance. Lowest DO content value at highly disturbed site may be due to arrested photosynthesis by aquatic plants as turbid water shows low photosynthetic activity. High temperature also plays an important role for decrease in DO content of water. Several workers such as Sexana *et al*., (1996), Mishra and Tripathi (2001, 2003), Rajkumar *et al.,* (2004), Singh *et al.,* (2010), Umavati and Longankumar (2010) and Venkatesharaju *et al.,* (2010); Bohra, (1977): also observed a similar trend in results. The values were within the prescribed limits as given by various scientific agencies.

A positive and significant correlation was obtained between DO with, nitrate, sulphate and phosphate in all study the sites. On the contrary, a negative and significant correlation was procured between DO with BOD and temperature in all the study sites. Appendix I-IV.

5.1.11. *Biochemical Oxygen Demand*:

The BOD can be used as a measure of the amount of organic materials present in an aquatic solution which support the growth of microorganisms. The BOD determines the strength of pollution in natural waters. The test is applied for fresh water sources (rivers, lakes), wastewater (domestic, industrial), marine water (estuaries, coastal water)

The present investigation reveals that BOD values were higher at highly disturbed site during rainy season months. This may be due to high concentration of organic waste discharged into water leading to high rate of decomposition and resulting into more consumption of oxygen by the microorganisms. All the recorded values were within the prescribed limit given by various scientific agencies (Appendix V). A similar trend in results has been reported by Mishra (1992), Mishra and Tripathi (2000, 2001), Hacioglu and Dulger (2009), Lalchingpuii *et al.*, (2012), and Mishra (2005).

A positive and significant correlation was obtained between BOD with temperature, BOD and total hardness in all study the sites. On the contrary, a negative and significant correlation was procured between BOD with DO, nitrate, phosphate and sulphate in all the study sites. Appendix I-IV.

5.1.12. *Nitrate – N*:

Nitrate – N is the stable form of oxidized nitrogen but can be reduced by microbial action to nitrite. In the process of nitrification, nitrogen changes to nitrate ion. Therefore, all sources of nitrogen (including organic nitrogen, ammonia and fertilizers) should be considered as potential source of nitrates. The maximum limit of nitrate in drinking water is 45 mgL^{-1} for human and 100 mgL^{-1} for livestock (Hasan, 2008).

The present study reveals that nitrate – N values were higher at highly disturbed site, and this could be attributed to discharge of organic waste. Higher values during winter months may be due to low water volume and high rate of decomposition. Singh *et al.*, (1980), Badge and Verma (1985), Bhowmik (1987), Rao (1987), Bajpal (1994), Mishra and Tripathi (2000, 2001, 2003), Banerjee and Gupta (2010), Deepti *et al.*, (2010) and Shrivastava *et al.*, (2010) also reported a similar trend of results. All the recorded values were within the permissible limit given by scientific agencies (Appendix V).

A positive and significant correlation was obtained between nitrate with phosphate, sulphate and DO in all study the sites. On the contrary, a negative and significant correlation was procured between nitrate with BOD and turbidity in all the study sites. Appendix I-IV.

5.1.13. ***Phosphate – P*****:**

Phosphate – P is usually derived from leaching of phosphorus rich bedrock and additionally from human wastes, synthetic detergents, industrial and agriculture waste. It is an important micro-nutrient for plants and plays an important role in plant's growth including phytoplankton. The Phosphate – P with nitrate – N may cause eutrophication in water bodies.

During present study, higher values were obtained during rainy and winter season months, this may be due to anthropogenic sources (Sand stone quarry) and sediments during rainy season months and low water table during winter months. All the recorded values were within the permissible limit given by scientific agencies (Appendix V). Similar trend of results has been reported by Shrivastava *et al.,* (2010) and Singh *et al*., (2010).

A positive and significant correlation was obtained between phosphate with sulphate, nitrate and DO in all study the sites. On the contrary, a negative and significant correlation was procured between phosphate with BOD and turbidity in all the study sites. Appendix I-IV.

5.1.14. Sulphate:

Sulphate is one of the major anions occur in natural water. It occur naturally in combination with numerous minerals including Barite ($BaSO_4$), Epsomite ($MgSO_4.7\ H_2O$) and Gypsum ($CaSO_4.2H_2O$). In excess dose of 1000 to 2000 mgL^{-1} it produces certain disease in human being including catharsis, dehydration and gastrointestinal irritation (McKee and Wolf, 1963).

During the present study, sulphate values were higher during winter season months at all the study sites which may be due to low flow of water and increased biological activity. Similar trend of results have been reported by Mishra and Tripathi (2000, 2001, 2003), Bharali *et al.*, (2008), Banerjee and Gupta (2010) and Umavathi and Longankumar (2010). All the recorded values were within the permissible limit given by scientific agencies (Appendix V).

A positive and significant correlation was obtained between sulphate with phosphate, nitrate and DO in all study the sites. On the contrary, a negative and significant correlation was procured between sulphate with BOD and turbidity in all the study sites. Appendix I-IV.

5.2. Vegetation Characteristics:

The findings on tree community attributes reveal that there was shift in position of dominant and co-dominant species along disturbance gradient. This indicates that the dominant species at disturbed site were tolerant to stress and able to survive under such harsh condition. A similar trend in results was observed with respect to families. This shifting in position of species and family could be attributed to level of anthropogenic activities including sandstone extraction (followed by clearing of forest). The species were common to all sites having high ecological amplitude. As a result of this, the number of species as well as families reduced from undisturbed to highly disturbed site. On the contrary, the species that are sensitive to the disturbance usually show poor growth or totally eliminated with increase in degree of disturbance. A similar trend in results was also reported by Thorington *et al*., (1982), Visalakshi, (1995), Parthasarathy and Karthikeyan, (1997), Kandavul and Parthasarathy, (1999), Mishra *et al*., (2003, 2004, 2005) and Mishra and Laloo, (2006).

The control and sandstone quarry affected areas have more or less similar topography and climatic condition. But altered edaphic condition may result in variation in species response and survival of the species. Species diversity measurement is one of the limiting factor of a natural community that influences functioning of an ecosystem. Higher numbers of species were recorded in the undisturbed and mildly disturbed sites as compare to moderately and highly disturbed sites. This could be attributed to the presence of favourable edapho–climatic condition such as high and prolonged rainfall, moderate temperature, high relative humidity and nutrient enriched soil that allow more species to occupy the habitat or niche (Connell and Orias,1964).

Moreover, disturbance adversely affected the girth size. The girth size was reduced from undisturbed to highly disturbed stand. As a result of this, tree density, species number and basal area were sharply reduced with increase in degree of disturbance. The results were in conformity with the works of Lyngdoh, (1995), Dasgupta, (1999), Sarma, (2002), Banerjee *et al*., (2005) and Mishra *et al*., (2003, 2004, 2005).

The nutrient deficient condition at disturbed sites also responsible for reduced basal area. Similar trend of results have been reported by Murphy and Lugo, (1986), Singh *et al*., (1991), Ravan,(1994), Verghese and Menon, (1998), Chowdhury *et al*., (2000), Fox *et al*., (1997), Khera *et al*., (2004), Ayypan and Parthasarathy, (1999), Fralish *et al*., (1993) and Parthasarathy and Karthikeyam, (1997).

Girth class distribution of trees reveals that most of the individual in the highly disturbed sites were confined to lower girth class. This could be linked with lack of proper nutrient status of soil resulting from extensive mining operation and ultimately give rise to retarded growth (Mishra *et al*., 2004). But at undisturbed site most of the tree stands were confined to medium girth class (50-60 cm) representing that the forest is well growing and continue to exist. It also adds to high basal area contribution which may be due to fast growth during adult stage. The findings are in conformity with the work of Mishra *et al*., (2004, 2005).

The findings on diversity index of show decrease in value with increase in degree of disturbance which is in conformity with the reports for tropical forest of Kodayar in the Western Ghats of Southern Indian and sub – tropical forests in Garhwal Himalaya. On the contrary, dominant index was increased with increase in degree of disturbance. This results is in conformity with the work of Knight, (1975), Tripathi *et al*., (1989 a) and Visalakshi, (1995).

Odum (1971) stated that clumped (contagious) distribution is very common in nature where the biotic and abiotic variations exist, and the species aggregate in cluster to exploit the resources in favourable conditions. Whereas, the random occurs in very uniform environment and regular distribution found where individuals are more evenly spaced than would occur by chance to avoid intraspecific competiton between the individuals. From the present study it has been recorded that most of the species showed contagious distribution pattern and few random distribution. Similar trends of findings were also reported (Greig-Smith, 1957; Singh and Yadav, 1974; Mehta *et al*., 1997).

Sorenson's index of similarity is the variation of plant species across the different study sites in the study area. The mildly disturbed site was more similar with highly disturbed site, followed by mildly disturbed site and moderately disturbed site, and undisturbed site and highly disturbed site. The high value indicates more similar stands in terms of species composition. It may be due to the transitional position of species from lower altitude to higher altitude (Jiang *et al*., 2007). Kumar *et al*., (2006) also evaluated the similarity of tree species between mildly disturbed site and highly disturbed site in the sub-tropical forest of Grahwal Himalayas.

5.3. Soil Characteristics:

Soil is one of the most important renewable natural resource. It forms the basis of all life on the earth. With advent of industrialization, the society had neglected the environment that adversely impacting soil. Abandoned mine area leads to loss of soil fertility due to continuous accumulation of small stones and fine particles without preserving the soil. During present investigation, the change in soil physico – chemical characteristics due to quarry operation is as discussed below.

The findings of the present study depict low retention of moisture content under disturbed condition could be linked with removal of vegetation and destruction of top-soil. The findings on soil moisture content were in conformity with the work of Tiwari *et al*., (1992).

The soil was slightly acidic at all the sites. This could be due to high rate of litter decomposition. Lowervalues at undisturbed site may be due to deposit of huge litter on forest floor, and subsequently more accumulation of organic matter on the soil surface. Arunachalam and Pandey (2003), Mishra (2011) and Elango *et al*., 1(992) supports the findings of the present study.

Soil organic carbon decreased from undisturbed to highly disturbed stand with respect to both the seasons and soil depth. This may be due to destruction of top-soil during mining operation. High soil organic carbon content in the undisturbed stand indicates sufficient litter accumulation on top-soil and subsequently high rate of litter decomposition. High amount of soil organic carbon in the soil is known to develop soil fertility which encourages plant growth in the long run. More organic carbon content in top-soil at undisturbed site signifies high microbial biomass which may be due to increased moisture content (Arunachalam *et al*., 1996; Arunachalam and Pandey, 2003; Mishra and Laloo, 2006; Mishra, 2011). Greater accumulation of organic carbon in the top-soil could be attributed to the accumulation of litter fall. On the contrary, low values at degraded sites may be due to the influence of sandstone extraction. It may also be attributed to the insignificant canopy cover at disturbed sites that minimizes surface runoff and resulting in loss of soil nutrients.

The anthropogenic disturbance adversely affected soil fertility as a result, a decreasing trend in values of total nitrogen from undisturbed to highly disturbed site was established with respect to both the seasons and soil depth. High nitrogen content in the soil at undisturbed site indicates greater accumulation of leaf litter and its decomposition at faster rate (Vitousek *et al*., 1997).

The decreasing trend in values of available phosphorus from undisturbed to the disturbed site with respect to both the seasons and soil depth could be linked with degree of disturbance. The findings of the present study are in conformity with the works of (Henrot and Robertson, 1994; Soave, 2003).

The C:N ratio increased from undisturbed site to highly disturbed site with respect to both the season and soil depth. The sub-soil showed higher values than top-soil unlike other parameters. Higher the C:N ratio, lower the soil fertility as this signifies the poor nutrient status of the soil at disturbed sites. A similar trend of results were also reported by Arunachalam and Pandey, (2003); Mishra and Laloo, (2006) and Mishra, (2011).

Plants directly absorbed potassium from soil solution where it is found in the most readily available form for plant absorption (Brady and Weil, 2002). The results on Exchangeable potassium reveal that potassium indicates marked reduction with increase in degree of disturbance.

The statistical analysis reveals a positive and significant correlation between nitrogen and phosphorus; nitrogen and pH; phosphorus and soil moisture content; pH and soil organic carbon. The nitrogen showed a positive and significant correlation with soil organic carbon at both the disturbed and undisturbed sites which could be attributed since organic carbon acts as main natural source for nitrogen (Brady and Weil, 2002). On the contrary, nitrogen and phosphorus were negatively correlated during post-monsoon at highly disturbed site. Likewise, other parameters such as nitrogen, pH, phosphorus, soil organic carbon showed negative and significant correlation in pre-monsoon, monsoon and post-monsoon seasons. (Appendix VI-XIV)

CHAPTER 6

MANAGEMENT STRATEGIES

Water is one among important natural resources that forms the basis of life and constitutes about 80% of the body weight. It covers about three fourth area of the earth's surface. It is evident that fresh water is only 0.9% of the total water reserves and found in the form of atmospheric water vapour, river, lakes, ponds, ground water and soil moisture (Dugan, 1972; Behura, 1984; Mishra, 1992).

Several workers (Gasim *et al*., 2007; O'Neal and Hollrah, 2007; Yillia *et al.*, 2008) have carried out researches on assessment of the quality of fresh water for different aquatic environment in India and abroad. The available literature depicts that there is paucity of information on water quality assessment in N.E. India in general and in Mizoram in particular. Lalchingpuii *et al*., (2012) have studied the impact of anthropogenic activities on water quality of Tlawng river in vicinity of Aizawl, Mizoram. In Mizoram, scarcity of potable water is very common especially during post-monsoon season as rain water is the main source of drinking water. Many rivers and streamlets drain the hill ranges which are the main source of water in the state. The river Tlawng is the longest and important river in the state having 185 km length flowing in northward direction. It is navigable by small boats upto Sairang and is regarded as the most important channel of water transport in Mizoram (Pachuau, 2009).

In the recent past, expanding human population and sandstone quarry practices have resulted into deterioration of water quality at a large. This could be attributed mainly due to discharge of waste from sandstone quarry through run off. Moreover, during quarry operation mass clearing of forest was done to make roadways to the quarry sites for easy loading and transportation of stone. This leads to the damage of vegetation and thinning of forest canopy. The contitinous extraction of sandstone results in loss of soil fertility of the sub-tropical forest of Mizoram, North East India. In fact, the disturbance is one of the major factors, which determines plant communities in natural ecosystems and status of soil nutrients (Armesto and Pickett, 1985). Destruction of forest is responsible for alteration in vegetation composition in terms of habits (Mishra *et al.*, 2004).

The water pollution problem has now become very prominent and global concern as most of the surface water bodies are getting polluted. Since water scarcity is very common in Mizoram, it is very important to conserve water resources from being polluted. Moreover, it has come into light that the people living in vicinity of the river Tlawng are directly consuming water for various purposes, as there is lack of water treatment facility in the rural areas. Prolonged consumption of such untreated water may cause many health related problems and other ophthalmic diseases in near future.

In light of the findings of the present investigation, following recommendations were made for proper management strategies:

- Scientific method for quarry should be taken up into consideration to minimize the damage on the environment (water, vegetation and soil). It is suggested that phase-wise clearing of forest and tilling of abandoned mine areas following plantation with suitable species should be adopted. Soil binding plants may be more effective to minimize deterioration of the environment.

- Reclamation of degraded land by planting the selected species that is resistant to sandstone quarry should be an effective tool for safe guard of water, vegetation and land in such areas.
- The top-soil of mining area can be transferred to the abandoned mine areas so as to increase the soil fertility.
- Proper sanitation and hygiene should be maintained by the people living nearby.
- The sandstone quarry operation should be strictly regulated to avoid further damage.
- The supply water needs proper treatment before supplying to public for drinking purpose.
- Mixed cropping of vegetables with leguminous plant to increase the soil fertility along the catchment area of the river.
- Quarry waste should not be dumped in safely.
- To educate the people for environment awareness, campaign on quarrying activities and its impacts on environment should be launched.
- For proper management of degraded areas, integrated approach involving local people, NGOs and Government organizations should be adopted.

CHAPTER 7

SUMMARY AND CONCLUSIONS

The sandstone quarry is very common in the state of Mizoram. It provides employment opportunities to the people thereby improving the economy of the state and the quality of life on one hand. However, the negative impacts on the environment (water, air, soil, vegetation) cannot be ignored. Thus, the present investigation has been carried out with following objectives.

- To determine water quality of river Tlawng in un-mined and sandstone mining affected areas.
- To study plant community attributes, diversity and distribution of species and population structure of woody species in un-mined and sandstone mining affected areas.
- To assess the impact of sandstone quarry on water quality of Tlawng river and vegetation in catchment areas.
- To formulate appropriate management strategy.

A total of four sampling study sites were selected along Tlawng river, to study water quality of river, and plant community attributes in catchment area and soil characteristics. Of these, three stations were selected in mining areas with different age of mining. The fourth station was selected in un-mined area representing control (reference) as an undisturbed site. The information procured for mine affected sites of the river and catchment areas (for vegetation and soil) was compared with the information from un-mined site to compare impact of mining on water of river Tlawng and vegetation and soil of the catchment areas. The selection of control site was meant for assessment of impacts of mining on (i) water quality of Tlawng river and (ii) vegetation and soil characteristics of the catchment area.

The description of the study sites is as follow:

1. Undisturbed : The site without mining activities.

2. Highly Disturbed : The site with mining activities at present.

3. Moderately Disturbed: The site with mining activities 5 years back.

4. Mildly Disturbed : The site with mining activities 10-15 years back.

The major findings of the present study can be summarized as below:

A. **Water quality analysis**

1. The temperature was highest (27.35 ° C) in the month of July at highly disturbed site. The lowest value (20.37 °C) was recorded in the month of December at undisturbed site.
2. The pH was highest (8.12) in the month of May at highly disturbed and moderately disturbed sites. The lowest value (6.82) was found in the month of January at undisturbed site.
3. The EC was highest (272.24 μS) in the month of December at highly disturbed site. The lowest value (65.27 μS) was found in the month of July at undisturbed site.
4. The TDS was highest (130.16 mgL^{-1}) in the month of June at highly disturbed site. The lowest value (40.6 mgL^{-1}) was found in the month of March at undisturbed site.
5. The total acidity was highest (72.33 mgL^{-1}) in the month of November at highly disturbed site. The lowest value (14.67 mgL^{-1}) was found in the month of April at undisturbed site.

6. The total alkalinity was highest (44.66 mgL^{-1}) in the month of February at highly disturbed site. The lowest value (12.00 mgL^{-1}) was found in the month of June at mildly disturbed site.
7. The total hardness was highest (162.66 mgL^{-1}) in the month of February at highly disturbed site. The lowest value (30.66 mgL^{-1}) was found in the month of July at mildly disturbed site.
8. The chloride content was highest (126.66 mgL^{-1}) in the month of January at highly disturbed site. The lowest value (28.00 mgL^{-1}) was found in the month of July at undisturbed site.
9. The DO content was highest (8.81 mgL^{-1}) in the month of December at undisturbed site. The lowest value (5.51 mgL^{-1}) was found in the month of May at highly disturbed site.
10. The BOD content was highest (1.20 mgL^{-1}) in the month of June at highly disturbed site. The lowest value (0.80 mgL^{-1}) was found in the month of November at undisturbed site.
11. The turbidity was highest (6.11 NTU) in the month of July at highly disturbed site. The lowest value (0.21 NTU) was found in the month of December at undisturbed site.
12. The nitrate-N content was highest (0.51 mgL^{-1}) in the month of January at highly disturbed site. The lowest value (0.20 mgL^{-1}) was found in the month of May at undisturbed site.
13. The sulphate content was highest (1.33 mgL^{-1}) in the month of January at highly disturbed site. The lowest value (0.16 mgL^{-1}) was found in the month of July at undisturbed site.

14. The phosphate-P content was highest (0.52 mgL^{-1}) in the month of January at highly disturbed site. The lowest value (0.014 mgL^{-1}) was found in the month of July at undisturbed site.

B**. Vegetation analysis**:

1. Altogether, a total of 49 tree species belonging to 41 genera and 25 families of angiosperms were recorded from undisturbed, mildly disturbed, moderately disturbed and highly disturbed sites. Out of these, 44 species belonging to 39 genera and 22 families; 32 species belonging to 30 genera and 19 families; 21 species belonging to 19 genera and 11 families; 18 species belonging to 17 genera and 11 families were reported from undisturbed, mildly disturbed, moderately disturbed and highly disturbed sites, respectively.
2. There was a sharp decrease in tree density from undisturbed stand (716 ± 17.1 indv. ha^{-1}) to the highly disturbed stand (316 ± 5.83indv. ha^{-1}). Likewise tree basal area ranged from (16.51 m^2 ha^{-1}) undisturbed site to (7.63 m^2 ha^{-1}) highly disturbed site.
3. Shannon-Weiner diversity index for tree species was maximum (2.43) at the undisturbed site and minimum (0.85) at the highly disturbed site.
4. The Simpson dominance index was found to be maximum of 0.006 at highly disturbed site and minimum of 0.002 at undisturbed site. The diversity index was inversely proportional to the dominance index.
5. The species richness (Margalef's) index for tree species was maximum as 6.51 at undisturbed site, followed by 4.54 at mildly disturbed site, 3.17 at moderately disturbed site and 2.27 at highly disturbed site.

6. The Eveness (Pielou's) index ranged from 0.616 to 0.22 from undisturbed to highly disturbed site.
7. The findings reveal that *Tectona grandis* was the dominant species (IVI – 64.53) possessing maximum tree density (106.6) and basal area (2.65) in the undisturbed stand. The co- dominant species were *Schima wallichii* (IVI – 23.53) and *Lagerstroemia speciosa* (IVI- 21.98). However, the abundance was maximum for *Tectona grandis* (2.91) followed by *Callicarpa arborea* (2.0) and *Schima wallichii* (1.58).
8. In mildly disturbed site *Tectona grandis* was the dominant species (IVI – 49.74) possessing maximum tree density (63.33) and basal area (1.44). The co- dominant species were *Schima wallichii* (IVI – 26.44) and *Lagerstroemia speciosa* (IVI- 24.71). However, the abundance was maximum for *Tectona grandis* (2.23) followed by *Schima wallichii* (1.54) and *Acasia concinna* (1.50).
9. In moderately disturbed site *Citrus grandis* was the dominant species (IVI – 38.99) possessing maximum tree density (40) and basal area (0.69). The co- dominant species were *Schima wallichii*(IVI – 26.20) and *Litsea monopetala* (IVI- 26.13). However, the abundance was maximum for *Magifera indica* (3.75) followed by *Callicarpa arborea* (2.0) and *Citrus grandis* (1.50).
10. In highly disturbed site *Litsea monopetala* was the dominant species (IVI – 32.70) possessing maximum tree density (20) and basal area (0.49). The co- dominant species were *Schima wallichii*(IVI – 28.89) and *Albizzia chinensis*(IVI- 28.45). However, the abundance was maximum for *Castanopsis tribuloides* (2.0) followed by *Tectona grandis* (1.75) and *Albizzia chinensis* (1.57).

11. The results reveal that in undisturbed site most of the trees fall under adult stage and confined to girth class 41 -50 cm and 51 – 60 cmin undisturbed site.
12. Overall, a total number of 24 families were recorded from all the study sites. Of these, 22 families were reported from undisturbed site, followed by 19 families from mildly disturbed site, 11 families each from moderately and highly disturbed sites.

C**. Soil analysis**

1. The soil moisture content of top-soil varied from 25.4 % (HD) to 31.4 % (UD) during monsoon season, and 20.67 % (HD) to 30.6 % (UD) during post-monsoon season. The sub-soil showed lower values than top-soil. There was decreasing trend in values from undisturbed to highly disturbed site with respect to the both seasons and soil depth.
2. The pH of top-soil varied from 5.57 (UD) to 6.3 (HD) during monsoon season and 5.87 (UD) to 6.83 (HD) during post-monsoon season. The sub-soil showed lower values than top soil. There was a decreasing trend in values from undisturbed to highly disturbed stand with respect to the both seasons and soil depth.
3. The findings reveal that soil organic carbon of top-soil varied from 2.4 % (HD) to 3.64 % (UD) during monsoon season and 2.08 % (HD) to 3.27 % (UD) during post-monsoon season. The sub-soil showed lower values than top-soil. There was a decreasing trend in values from undisturbed to highly disturbed site with respect to both the seasons and soil depth.
4. The total nitrogen of to- soil varied from 0.12 % (HD) to 0.31 % (UD) during monsoon season and 0.12 % (HD) to 0.29 % (UD) during post-monsoon season. The sub-soil showed lower values than top-soil. There is a decreasing trend in values from undisturbed to highly disturbed stand with respect to both the seasons and soil depth.

5. The soil available phosphorus of top-soil varied from 0.15 ppm (HD) to 0.19 ppm (UD) during monsoon Season and 0.22 ppm (HD) to 0.32 ppm (UD) during post-monsoon season. The sub-soil showed lower values than top-soil. There was a decreasing trend in values from undisturbed to highly disturbed stand with respect to both the seasons and soil depth.
6. The exchangeable potassium of top-soil varied from 87 $\mu g\ g^{-1}$ (HD) to 205 $\mu g\ g^{-1}$ (UD) during post-monsoon season and 56 $\mu g\ g^{-1}$ (HD) to 168 $\mu g\ g^{-1}$ (UD) during monsoon season. The sub-soil showed lower values than top-soil. There is a decreasing trend in values from undisturbed to the disturbed stand with respect to both the season and soil depth.
7. The C:N ratio of top-soil varied from 11.74 (UD) to 20.00 (HD) during monsoon season and 11.28 (UD) to 17.33 (HD) during post-monsoon season. The sub-soil showed higher values than top soil unlike other parameters. There was a increasing trend in values from undisturbed to highly disturbed site with respect to both the seasons increasing and soil depth.

The findings of the present study may be a potential tool for formulation of appropriate strategy for proper management of water of Tlawng river. The generated on vegetation and soil may be helpful in suggesting suitable species for plantation at degraded/ abandoned mining sites, resulting into increase of biodiversity and reclamation of soil. *Litsea monopetala*, the dominant species followed by *Schima wallichii and Albizzia chinensis* at highly disturbed site should be included in reclamation programme of the Mizoram Government to promote the recovery of the degraded landscape.

Undoubtedly, the information on soil analysis may be useful in eco-restoration of degraded areas of the sandstone quarry affected areas.

REFERENCES

Abel-Satar and Amaal, M. 2005. Water quality assessment of River Nile from IDFO to Cairo, Egypt. *J. Aqua. Res.* 31(2): 200-223.

Abida, B. 2008. Study on the quality of water in some streams of Cauvery river. *e-Journal of Chemistry*, 5(2): 377-384.

Alfred, E. H. and Tom, V.Z. 2008. Land Cover Change and Soil Fertility Decline in Tropical Regions. *Turkish Journal of Agriculture and Forestry*, 32: 195-213.

Allen, S.E., Grimshaw, H.M., Rowland, A.P. 1976. Chemical analysis. In: Moore, P.D., Chapman, S.B. (Eds.), *Methods in Plant Ecology. Blackwell, Oxford*, 285-344 pp.

Amienta, M.A., Villusenor, G., Rodriguez, R., Ongley, L.K., Mango, H. 2001. The role of arsenic – Bearing rocks in groundwater pollution at Zimapan Valley, Mexico. *Environ. Geol*. 40: 571 – 581.

Anand, P.B. 2006. Waste management in Madras revisited. *Environ. Urbanization*, 11(20): 161-176.

Anand, P.B. 2006. Waste management in Madras revisited. *Environ. Urbanization*, 11(20): 161-176.

Anderson, J.M. and Ingram, J.S.I. 1963.Tropical Soil Biology and Fertility. *A Handbook of Methods (2nd Ed), CAB International, Wallingford, U.K.*221 pp.

Antonopoulos, V.Z. and Wyseure, G.C.L. 1998. Modeling of water and nitrogen dynamics on an undisturbed soil and a restored soil after open-cast mining. *Agriculture Water Management*, 37: 21-40.

APHA. 2005. Standard Methods for the Examination of water and Wastewater: 21st Edition as prescribed by American Public Health Association, American Water Works Association and Water Environment Federation, Washington, D.C.

Arbogast, B.F., Knepper, D.H., Jr., and Langer, W.H. 2000. The human factor in mining reclamation, U.S. *Geological Survey Circular,* 1191, 28p.

Armesto, J.J. and Pickett, S.T.A. 1985. Experiments on Disturbance in Old-Field Plant Communities: Impact on Species Richness and Abundance. *Ecology*, 66: 230–240.

Arunachalam, A. and Pandey, H.N. 2003. Ecosystem restoration of jhum fallows in northeast India: microbial C & N along altitudinal and successional gradient. *Restoration Ecology*, 11: 168-173.

Arunachalam, A., Maithani, K., Pandey, H.N. and Tripathi, R.S. 1996. The impact of disturbance on detrital dynamics and soil microbial biomass of a Pinuskesiya forest in northeast India. *Forest Ecology and Management*, 88: 273-282.

Ayyappan, N. and Parthsarathy N. 1999.Biodiversity inventory of trees in a large scale permanent plot of tropical evergreen forest at Varagalaiar, Anamalais, Western Ghats, India. *Biodiversity and Conservation*, 8: 1533-1554.

Bain JG, Bloes DW, Robertson WD, Frind EO (2000). Modelling of sulphide xidation with reactive transport at a mine drainage site. *J. Contamin Hydrol.* 23 – 47.

Bajpal, Avinash, Mishra, S.M., Tamot, Sashana and Agarwal, Akhilesh. 1993. Limnological studies to assess water quality of Upper Lake Bhopal (M.P). *Abstract in National Seminar on Conservation and development of Aquatic Resources.*

Banerjee, S.K., Mishra, T.K. and Singh, A.K. 2000. Restoration and reconstruction of coal mine spoils: an assessment of time prediction for total ecosystem development. *Advances in Forestry Research in India*, 23: 1-28.

Banerjee, U.S. and Gupta, S. 2010. Seasonal assessment of irrigation water suitability of river Damodar in West Bengal, India. *J. Crops and Weeds,* 6(1): 6-12.

Banwart, S.A., Destouni, G., Malmstrom, M. 1998. Assessing mine water pollution from laboratory to field scale. In*: Proceedings of the groundwater quality conference held at Tubingen Germany,* 307 –311pp.

Barik, S.K., Tripathi, R.S., Pandey, H.N. and Rao, P. 1996. Tree regeneration in a subtropical humid forest: effect of cultural disturbance on seed production, dispersal and germination. *Journal of Applied Ecology*, 33: 1551-1560.

Behura, B.K. 1984. *J. Water Poll. Con. Fed*., 45: 850-869pp.

Bell, F.G., Bullock, S.E.T., Halbich, T.F.J. and Lindsey, P. 2001. Environmental impact associated with an abandoned mine in the Witbank Coalfield, South Africa. *International Journal of Coal Geology,* 45: 195-216.

Bharali, Jasmine, Baruah, B.K., and Sarma, H.P. 2008. Studies on physic-chemical characteristics of water of the Wetlands in Kaziranga National Park, Assam. *Poll. Res.* 27(3): 591-597.

Bhuyan, P., Khan, M.L. and Tripathi, R.S. 2002. Regeneration status and population structure of Rudraksh (*Elaeocarpus ganitrus*Roxb.) in relation to cultural disturbances in tropical wet evergreen forest of Arunachal Pradesh. *Current Science,* 83(11): 1391–1394.

Blackport, 2006. Hydrogeology Inc. and Golder Associates, *Applied Research on Source Water Protection Issues in the Aggregate Industry.*, 55.

http://www.mnr.gov.on.ca/stdprodconsume/groups/lr/@mnr/@aggregates/documents/document/mnr_e000024.pdf

Borah, N. and Garkoti, S.C. 2011.Tree species composition, diversity and regeneration patterns in undisturbed and disturbed forests of Barak valley, South Assam, India. *International Journal of Ecology and Environmental Sciences*, 37(3): 131-141.

Brady, N. C. and Weil, R.R. 2002. The nature and properties of soil. *13rd Ed. New Jersey: Prentice-Hall, Inc. 960pp.*

Brown, D.J.A. and K. Sadler, 1989. Fish survival in acid waters. In: Acid Toxicity and Aquatic Animals. Society for Experimental Biology Seminar Series: 34, (Morris, R. et al., eds.), Cambridge University Press, pp. 31-44.

Bullock, S.E.T., Bell, F.G. 1997. Some problems associated with past mining at a mine in the Witbank coal field, South Africa. *Environ. Geol.* 33: 61-71.

Bulushu, K.R. 1987. Chemical constituents in water related treatment and management NEERI, Nagpur. 25pp.

Chowdhury, M.A.M., Auda, M.K. and Iseam, A.S.M.T. 2000.Phytodiversity of *Dipterocarpus turbinatus*Gaertn.F.(Garjan) undergrowth at Dulahazaraganjan forest, Cos'B Bazar, Bangladesh. *Indian Forester*, 126: 674-684.

Connell, J.H. and Orias, E. 1964. The ecological regulation of species diversity. *American Naturalist*, 98: 399-414.

Cottam, C. and Curtis, J. T. 1956. “The use of distance measures in phytosociological sampling.” *Ecology*, 37(3): 451-460.

Curtis, J.T. and McIntosh, R.P. 1950. The interrelations of certain analytic and synthetic phytosociological characters. *Ecology*, 31: 434-455.

Das Gupta, S. 1999. Studies on vegetal and microbiological processes in coal mining affected area. *Ph.D.Thesis. North Eastern Hill University, Shillong, India.*

Das, A.C., Baruach, B.K., Baruach, D. and Sengupta, S. 2003. Study on wetlands of Guwahati City 2, Water quality of rivers and drains. *Poll. Res.* 22(1): 117-119.

Deepti, V., Singh, R.K. and Bajpal, A. 2010. Assessment of water quality of Betwa river (M.P), India. *Poll. Res.*14(4): 447-454.

Dhiman, S.C. 1990. Hydrological Development Potential of Bhilwara District, Rajasthan: C.G.W.B.

Directotate of Geology and Mineral Resources, 2012.

Dublin-Green, C.O. 1990.Seasonal variations in some physic-chemical parameters of the Bonny Estuary, Niger Delta, NIOMR Technical papers. 59: 21-25.

Duchok, R., Kent, K., Khumbongmayum, A.D., Paul, A. and Khan, M.L. 2005.Population structure and regeneration status of medicinal tree Illiciumgriffithiiin relation to disturbance gradients in temperate broad- leaved forest of Arunachal Pradesh. *Current Science,* 89(4): 673-676.

Dugan, R. 1972. Biochemical ecology of water pollution. New York, Plenum.

Durfor, R. and Becker, E. 1972. Constituents and properties of water. In: *Water quality in a stressed environment: Reading in environmental hydrology*. (Ed: W.A. Pettyjohn). Burgess Publishing Company, Minneapolis, Minnesota.

Egiebor, N.O. and Oni, B.O. 2007. Acid rock drainage formation and treatment: a Rev. *Asia Pacific J. Chem. Eng.* 2: 47-62.

Ekeh, I.B. and Sikoki, F.D. 2003. The State and seasonal variability of some physic-chemical parameters in the New Calabar River, Nigeria. *Supp. Ad. Acta. Hydrobiol.* 5: 46-60.

Fakayode, S.O. 2005. Impact assessment of industrial effluent on water quality of the receiving Alaro river in Ibandan, Nigeria. *Ajeam-Ragee* 10: 1-13.

Fletcher, J.L., and Busnel, R.G. 1978. Effects of noise on wildlife: *Academic Press,* New York.

Fox, B.J., Taylor, J.E., Fox, M.D. and Williams, C. 1997. Vegetation changes across edges of rainforest remnants. *Biological Conservation*, 82: 1-13.

Fralish, J. S., Franklin, S. B. P., Robertson, A., Kettler, S. M. and Crooks, F. B. 1993. An ordination of compositionally stable and unstable forest communities at land between the lakes, Kentucky and Tennessee. In: Fralish, J. S., R. P. McIntosh, and O. L. Loucks (Eds.) Fifty Years of Wisconsin Plant Ecology. *The Wisconsin Academy of Sciences, Arts, and Letters*, 247-267pp.

Frommichen, R., Went-Potthoff, K., Friese, K., Fischer, R. 2004. Microcosm studies for neutralization of hypolimnic acid mine pit lake water (pH 2.6). *Environ. Sci. Technol.* 38: 1877 – 1887.

Gasim, M.B., Ismail, B.S.,Toriman, E., Mir, S.I., Chek, T.C. 2007. A physic-chemical assessment of the Bebar River, Pahang, Malaysia. *Global J. Environ. Res.* Volume-1(1), pp.7-11.

Hacioglu, N. & Dulger B. (2009) Monthlu variation of some physic-chemical and microbiological parameters in Biga Stream (Biga, Canakkale, Turkey). *African Journal of Biotechnolgy,* Volume – 8(9): 1929-1937pp.

Geldenhaus S, Ball FG (1998). Acid mine drainage at a coal mine in the eastern Transvaal South, Africa. *Environ. Geol*. 34(213): 234 – 242.

Ghose, M. K and Anjay Kumar, 2004. Mineral industries and their environmental aspects in Indian context. *Indian Journal of Engineering & Materials Sciences*. Vol. 11, October, 433-437pp.

Ghose, M.K. 2004. Effect of opencast mining on soil fertility. *Journal of Scientific and Industrial Research*, 63: 1006-1009.

Gillieson, David and Houshold, lan. 1999. Chapter 6.3 – Rehabilitation of the Lune River Quarry, Tasmanian Wilderness World Heritage Area, Australia: in Drew, David, and Hotzl, Heinz, eds. Karst hydrology and human activities – Impact, consequences and implications, A.A. Balkema, 201-205pp.

Greig-Smith, P., Kershaw, K.A. and Anderson, D.J. 1963. The Analysis of Pattern in Vegetation: A Comment on a Paper by D. W. Goodall. Journal of Ecology, 51(1): 223-229.

Gunn, John, 1993. Limestone quarrying and quarry reclamation in Britain. *Environmental Geology,* V.21: 167-172 pp.

Gunn, John, Bailey, Debra, and Handley, John. 1997. The reclamation of limestone quarries using landform replication: Department of Geographical and Environmental Sciences, University of Huddersfield, Queensgate, Huddersfield, U.K., 176 pp.

Hanief, S. M., Thakur, S.D. and Gupta, B. 2007. Vegetal profile of natural plant succession and artificially reclaimed vegetated limestone mines in Himachal Pradesh, India. *Journal of Tropical forestry*, 23(I & II): 128-135.

Haridasan, K., Rao, R.R., Forest Flora of Meghalaya. 2 Vol. Bishen Singh Mahendra Singh, Dehra Dun, India.

Harris, A.M. and Samson, O.N. 2008. Post-mining deterioration of bauxite overburdens in Jamaica: storage methods or subsoil dilution?, *Environ. Geol.* 54, 111–115.

Harris, J.A. & Birch, P. 1989. Soil microbial activity in opencast coal mine restorations. *Soil Use and Management*, 5: 155–160.

Hasan, H., Hoesien, A. 2008. Water quality, physic-chemical and biological characteristics of Tajan river. *J. of Ind. Poll. Control.* 24(2): 169-176.

Hasanzadeh, H.H. 2008. Water quality, physic-chemical and biological characteristics of Tajan river. *J. Ind. Poll. Control*, 24(2): 169-176.

Hasari, M. 2009. Thesis done as practical training for environmental engineering studies.

Hengeveld, R. 1996. Measuring ecological biodiversity. *Biodiversity Letters*, 3: 58-65.

Henrot, J. and Robertson, G.P. 1994. Vegetation removal in two soils of the humid tropics. Effect on microbial biomass. *Soil Biology and Biochemistry*, 15: 111-114.

Howard, B. and Cameron, l. 1998. Dust control: Best Practice Environmental Management in Mining. *Environment Australia*, 73p.

Ibarra, J. M. N. and de las Heras, M. M. 2005. *Open-cast mining reclamation.* In *Forest restoration in landscapes: beyond planting trees. Eds Mansourian, S.,Vallauri, D. and Dudley, N. Springer, New York.*Kershaw, K.A. 1973. *Quantitative and Dynamic Plant Ecology*. Edward Arnold LTD, London.

Indian Minerals Yearbook, 2012. Government of India, Ministry of India, Indian Bureau of Mines.

Iqbal, M.Z. and Shafig, M. 2001. Periodical effect of cement dust pollution on the growth of some plant species. *Turk J. Botany*, 25: 19–24

Jamir, S.A. 2000. Studies on plant biodiversity, community structure and population behaviour of dominant tree species of some sacred groves of Jaintia hills, Meghalaya. *Ph.D. Thesis, North-eastern Hill University, Shillong*.

Jana, B.B. 1973. Seasonal periodicity of plankton in a freshwater pond, West Bengal, India. *Int. Rev. Gev. Hydrobiol.*58: 127-143.

Jankowski, 2007. Changes of water quality in a stream impacted by longwall mining subsidence (eds. G. Li, D. Kay): *Mine Subsidence Technology Society, Wollongong*, 241-251.

Jankowski, J., Spies, B. 2007. Impact of Longwall mining on surface water – groundwater interaction and changes in chemical composition of creek water. In: *Proc. XXXV IAH Congress (eds. L. Ribeiro et al.)* Lisbon, Portugal, CD – ROM.

Jiang, N., Cox, R.D. and Hancock, J.M. 2007. A kinetic core model of the glucose-stimulated insulin secretion network of pancreatic beta cells. *Mammalian Genome,* 18(6-7): 508-20.

Jothivenkatachalam, K., Nithya, A. and Chandra, M.S. 2010. Correlation analysis of drinking water quality in and around Perur block of Coimbatore district, Tamil Nadu, India. *Rasayan J. Chem.* 3(4): 649-654.

Jung, M.C., Thornton, I., 1997. Environmental contamination and seasonal variation of metals in soils, plants and waters in the paddy fields around a Pb–Zn mine in Korea. *Sci. Tot. Environ.* 198: 105–121.

Kadavul, K. and Parthasarathy, N. 1999.Structure and composition of woody species in tropical semi evergreen forest of Kalrayan hills, Eastern Ghats, India. *Tropical Ecology,* 40(2): 247-260.

Kajilal, U.N., Kanjilal, P.C., Das, A., Bor, N.L. 1940. *Flora of Assam. 5 vol. Government Press*. Shillong. India.

Khera, N. and Singh, R.P. 2005. Germination of some multipurpose tree species in five provenances in response to variation in light, temperature, substrate and water stress. *Tropical Ecology*, 46(2): 203-217.

Khumbongmayum, A.D., Khan, M.L. and Tripathi, R.S. 2005.Survival and growth of seedlings of a few tree species in the four sacred groves of Manipur, Northeast India. *Current Science*, 88(11): 1781-1788.

Kim, K. Y., D. Jordan D. and G. A. McDonald. 1997. Solubilization of hydroxyapatite by Enterobacter agglomerans and cloned Escherichia coli in culture medium. *Biol. Fert. Soils*, 24: 347-352.

Kimmel, W.G. 1983. The impact of acid mine drainage on the stream ecosystem. In: Majumdar SK, Miller WW (eds), Pennslyvania coal: Resources, Technology and Utilization. *Acad. Sci.* Publisher, USA, 424 – 437pp.

Kirk and Morgan 1982. A new global rivers database for remote sensing programme studying climatically-sensitive large rivers. *Journal Of Great Rivers Research*, 21(3): 307-318.

Knight, D.H. 1975. A phytosociological analysis of species rich tropical forest on Barro Colorando Island, Panama. *Ecological Monograph*, 45: 259-284.

Koch, J.M., Ward, S.C., Grant, C.D. and Ainsworth, G.L. 1996. 'Effects of Bauxite Mine Operations on Topsoil Seed Reserves in the Jarrah Forest of Western Australia'. *Restoration Ecology*, vol. 4: 368-376pp.

Krough, M., 2007. Management of Longwall Coal mining impacts in Sydney's southern drinking water catchments. *Australisian J. Environ. Management*, 14: 155-165.

Kumar, A. 2000. A quantitative study of the pollution and physic-chemical conditions of the river Mayurakshi in Santhal Pargana, Bihar. In: (Trivedy, R.K. edited). *Pollution and Biomonitoring of Indian Rivers, ABD Pub. Jaipur.* 246-251pp.

Kumar, A., Marcot, B.G. and Saxena, A. 2006. Tree species diversity and distribution patterns in tropical forests of Garo Hills. *Current Science*, 91(10): 1370-1381.

La Touche, T.H.D. 1891. *Records Geological Survey of India*, Vol. 24, Part 2.

Lad, R.J. and Samant J.S. 2014. Environmental and Social Impacts of Stone Quarrying- A Case Study of Kolhapur District, *International Journal of Current Research*, 3(8), 39-42.

Lalchhingpuii, Lalparmawii, S., Lalramnghinglova H. & Mishra, B.P. 2012. Assessment of the water quality of Tlawng river in Aizawl, Mizoram. Science Vision, Volume-11(2):72-76pp.

Lalchhingpuii. 2011. Status of water quality of Tlawng river in the vicinity of Aizawl city, Mizoram. *Ph.D. Thesis, Dept. of Env. Sc.,* Mizoram University, Aizawl, Mizoram.

Laltlanchhuang, S.K. 2006. Studies of the impact of disturbance on secondary productivity of forest ecosystem with special reference to surface, sub-surface litter insect and other non-insect groups. M.Sc. dissertation. Mizoram University.

Leavitt, K.J., Fernandez, G.C.J. and Nowak, R.S. 2000. Plant establishment on angle of response mine waste dumps. *Journal of Range Management*, 52: 442-452.

Liu, C.W., Lin, K.H., Kuo, Y.M. 2003. Application of factor analysis in the assessment of groundwater quality in a black foot disease area in Taiwan. *Sci. Total Environ.* 113:77–89.

Luttig, G.W. 1994. Rational management of geo-environment – A view in favour of "geobased" planning – with special reference to aggregate resources, in Luttig, G.W., ed., Aggregate – Raw materials gaint. *Report on the 2nd International Aggregate Symposium, Erlangen,* 346p.

Lyngdoh, T. 1995. Community dynamics and edaphic changes in relation to coal mining in Jaintia Hills, Meghalaya. *Ph.D.Thesis, North Eastern Hill University, Shillong, India.*

Mabogunje, A.L. 1980. The Debt to Posterity: Reflection on a National Policy on environmental Management N.P.O. Sada and T. Odemerho (ed). Environmental Issues and Management in Nigerian.

Madhavan, P. 2005. Budhpura 'Ground Zero'. Sandstone quarry in India.

Margalef, D.R. 1958. Perspective in ecologically theory. *University of Chicago Press, Chicago.*

Margalef, R. *Information theory in Ecology*. Gen. Syst. 3: 36- 71.

Marshall, J.W. and Winterbourn, I.M.J. 1979. An ecological study of a small New Zealand stream with particular reference to Oligochaeta. *Hydribiol*. 65: 199-208.

McIntosh, J.E and Barnhisel, R.I. 1993. Erodibility and sediment yield by natural rainfall from reconstructed mine spoils. *Journal of soil science,* 156: 118-126.

Mclntosh, J.E and Barnhisel, R.I. 1996. Erodibility and sediment yield by natural rainfall from reconstructed mine soils. *Soil Science,* 156:118-126.

Mehta, M.R. Barnes, C.A. and McNaughton, B.L. 1997. Experience dependent asymmetric expansion of hippocampal place fields. Proc. Natl. Acad. Sci. USA, 94: 8918–8921.

Mishra, B. P. 1992. Ecological studies on pollution and management of river Ganga in Vanarasi. *Ph.D. Thesis,* BHU, Vanarasi, India.

Mishra, B.P. 2011. Vegetation composition and soil nutrients status from polyculture to monoculture. *African Journal of Environmental Science and Technology,* 5(5): 363-366.

Mishra, B.P. and Jeeva, A.S. 2012. Plant diversity and community attribute of woody plants in two climax subtropical humid forests of Meghalaya, Northeast India. *Applied Ecology and Environmental Research,* 10(4): 417-436.

Mishra, B.P. and Laloo, R.C. 2006. A comparative analysis of vegetation and soil characteristics of montane broad-leaved, mixed pine and pine forests of northeast India. In: P.C. Trivedi (Ed.), Advances in Plant Physiology. I.K. *International Publishing House, New Delhi*, pp. 185-197 pp.

Mishra, B.P. and Tripathi, B.D. 2000. Sewage quality analysis: pollutants removal efficiency of a sewage treatment plant. *Journal of Industrial Pollution Control*. 16(2): 239-251.

Mishra, B.P. and Tripathi, B.D. 2001. Impact of city sewage discharge in physic-chemical characteristics of river Ganga water. *Asian Journal of Microbiology, Biotechnology and Environmental Science*, 3(4): 333-338.

Mishra, B.P. and Tripathi, B.D. 2003. Seasonal variation in physic-chemical characteristics of Ganga water as influenced by sewage discharge. *Indian J. Ecol.* 30: 27-32.

Mishra, B.P., Tripathi, O.P. and Laloo, R.C. 2005. Community characteristics of a climax subtropical humid forest of Meghalaya and population structure of ten important tree species. *Tropical Ecology*, 46: 241- 251.

Mishra, B.P., Tripathi, O.P., Tripathi, R.S. and Pandey, H.N. 2004. Effects of anthropogenic disturbance on plant diversity and community structure of a sacred grove in Meghalaya, North-east India. *Biodiversity and Conservation*, 13: 421-436.

Mishra, B.P., Tripathi, R.S., Tripathi, O.P. and Pandey, H.N. 2003. Effects of disturbance on the regeneration of four dominant and economically important woody species in a broad-leaved subtropical humid forest of Meghalaya, Northeast India. *Current Science*, 84(11): 1449-1453.

Misra, R. 1968. Ecology WorkBook. Oxford and IBH Publishing Company, Calcutta.

Moncur, M.C., Ptacek, C.J., Blowes, D.W., Jambor, J.L. 2006. Spatial variations in water composition at a Northern Canadian lake impacted by mine drainage. *Appl. Geo. chem*. 21: 1799 – 1817.

Mueller-Deombois, D. and Ellenberg, H. 1974. Aims and methods in vegetation ecology. *New York: John Wiley and Sons*. 547pp.

Munshi, M.M. 1964. Geological mapping in parts of Mizo hills, Assam. Unpub. Progress Report of the GSI for F.S. 1963-64.

Murphy, P.G. and Lugo, A.E. 1986.Ecology of tropical dry forest. *Annual Review of Ecology and Systematics*, 17: 67-88.

Narian, S. and Chauhan, R. 2000. Water quality status of river Complex Yamuna at Panchnada (Etwah, U.P): An integrated management approach. *J. Poll. Res.* 19(3): 357-364.

Naveen, M.S. 2012. Environmental impact of soil and sand mining: A review. *International Journal of Science, Environment*, 1(3): 125-134.

Nordstrom, D.K., Alpers, C.N. 1999. Geochemistry of acid mine waters. In: Plumlee GS, Logsdon M.J (eds), The environmental geochemistry of mineral deposits. Part A: Processes, Techniques and Health Issues. *Rev. Econ. Geol.* 6A: 133 – 160.

O'Neal, S.W., Hollrah, D.N. 2007. Monitoring of Total Coliform and Escherichia coli Levels in a Second Order Stream in West-Central Oklahoma. *Proc. Okla. Acad.Sci.*Volume-87: 69-75pp.

Odum, E.P. 1971. Fundamentals of Ecology. *Philadelphia, W.B. Sauders.*574p.

OECD, 1998: OECD Environmental Data—Compendium 1999 edition, Organization for Economic Co-operation and Development, Paris.

Okafor, F.C. 2006. Rural Development and the Environmental Degradation versus Protection: In P.O. Sada and T.Odemerho (ed.). *Environmental Issues and Management in Nigerian Development*, 150-163pp.

Ontario Ministry of Natural Resources, 2010. *State of the Aggregate Resource Ontario*. Ministry of Natural Resources. Retrieved March 13, 2012 from: http://www.mnr.gov.on.ca/stdprodconsume/groups/lr/@mnr/@aggregates/documents/document/286996.pdf

Pachuau, Rintluanga, 1994. Geography of Mizoram. *R.J. Enterprise, Venghluie, Aizawl, Mizoram.* 22-48pp.

Pahwa, D.V. and Mehrotha, S.N. 1996. Observation the fluctuation in abundance of plankton in relation to certain hydrobiological conditions of river Ganga. *Proc. Nat. Acad. Sci. India* 136B: 1597-1890.

Palharya, J.P., Siriah, V.K. and Malariya, S. 1993. Environmental impact of sewage and effluent Disposal on the River System. *Ashisj. Publ. Houses, New Delhi.*

Pandey, H.N., Tripathi, R.S., Uma, S., Boral, L. 1993. Study site, vegetation and soil. Meghalaya State Pollution Control Board. Final Technical Report. North Eastern Hill University. Shillong. 1-63.

Parthasarathy, N. and Karthikeyam, R. 1997. Plant biodiversity inventory and conservation of two tropical dry evergreen forests on Coromandal Coast, South India. *Biodiversity and Conservation*, 6: 1063-1083.

Patka, R.W. and Azadi, M.A. 1987. Ecological studies on the planktonic organisms of the Halda river, Bangladesh. *J. Zool.* 15: 109-123.

Patka, S. and Rao, Narshing, A. 1997. Interrelationship of physicochemical factors of a pond. *J. Environ. Biol.* 24(2): 125-133.

Phillips, E.A. 1959. Methods of vegetation study. *Henery Holt and co.Inc*.107pp.

Pielou, E.C. 1975. Ecological models on an environmental gradient: In Gupta, R. P. (Ed.) Proc. *Symp. Applic, of ststatics.North Holland America Elasevier.*

Potts, W.T.W. and P.G. McWilliams, 1989. The effects of hydrogen and aluminum ions on fish gills. In: Acid toxicity and aquatic animals. Society for Experimental Biology Seminar Series, v. 34, (R. Morris, et al., eds.), Cambridge University Press, pp. 201-220.

Poulin, R., Pakalnis, R.C., and Sinding, K., 1994: Aggregate resources - production and environmental constraints, *Environmental Geology*, . 23, 221 p.

Priyadarshi, N. 2004. Distribution of arsenic in Permian Coals of North Karanpura coalfield, Jharkhand. *Jour. Geol. Soc. India*, 63, 533-536.

Puttiah, E.T. and Somashekar, R.K. 1985. The ecology of desmids in lakes of Mysore city. *Proc. Sym. Recent Advance in plant Science,* 381-386.

Rai, R.K. 2002. Implication of coal mining on environment in Jaintia Hils, Meghalaya. In: Passah PM, Sarma AK (eds.), Jaintia Hiils, A Meghalaya Tribe: Its Environment, Land and People. Reliance Publishing House. New Delhi. 113-119.

Rainwater, F.H. and Thatcher, L.L. 1960. *Methods for collection and analysis of water samples.* Geological Survey Water-Supply Paper, U.S. Department of the Interior, U.S. Government Printing Office, Washington, D.C.

Rajkumar, S., Velmurugan, P., Shanthi, K., Ayyasamy, P.M. and Lakshmanaperumalasamy, P. 2004. Water quality of Kodaikanal Lake, Tamil Nadu in relation to physico-chemical and bacteriological characteristics, Capital Publishing Company.339-346.

Raney, E.D. and Menzel, B.W. 1969. Ichthyological Associates. *Bull.Ithaca.*B.Y.2.

Ravan, S.A. 1994. Ecological Analysis of Vegetation Form Satellite Remote Sensing at Madhav National park Sivapuri (M.P.). *Ph.D. Thesis, Unpublished. Srinagar: HNB Garhwal University.*

Reddell, P., Gordon, V. and Hopkins, M.S. 1992. Mycorrhizas and other specialized nutrient-acquisition strategies – their occurrence in woodland plants from Kakadu and their role in rehabilitation of waste rock dumps at a local uranium-mine. *Australian Journal of Botany,* 40: 223-242.

Richard M., Scheehan Aye, and Michelle Lawrence, 1999. Planned development of mining, Jefferson, Colorado.

Rosemond, A.D., S.R. Reice, J.W. Elwood and P.J. Mulholland, 1992. The effects of stream acidity on benthic invertebrate communities in the south-eastern United States. Freshwater Ecol., v. 27: 193-209pp.

Sarin, M.M. and Krishnaswamy, S. 1984. Major ion chemistry of the Ganga and Brahamaputra river system, India. *Nature,* 312: 538-541.

Sarma, K. 2002. Coal mining and its impact on environment of Nokrek Biosphere Reserve, Meghalaya. *Ph.D.Thesis. North Eastern Hill University, Shillong, India*.

Sarma, K. 2005. Impact of coal mining on vegetation: a case study in Jaintia Hills district of Meghalaya, India. *Thesis for partial fulfilment of the requirements for the degree of Master of Science International Institute for Geo-Information Science and Earth Observation Enschede, The Netherlands.*

Sarma, K., Barik, S.K., Rai, R.K. 2004. Impact of coal mining on Nokrek Biosphere Reserve of Meghalaya. In: Hussain Z, Barik SK (eds.), Development of Geoenergy Resources and

Its Impact on Environment and Man of Northeast India. Regency Publications. New Delhi.; 229-259.

Saxena, K.L., Chakrabarty, R.N., Khan, A.Q., Chattopadhya, S.N. and Chandra, H. 1966. Pollution studies of the river Ganga near Kanpur. *Environ. Health,* 270-285pp.

Schwenke, G.D., Ayre, L., Mulligan, D.R. and Bell, L.C. 2000. Soil stripping and replacement for the rehabilitation of bauxite-mined land at Weipa. II. Soil organic matter dynamics in mine soil chronosequences. *Australian Journal of Soil Research*, 38: 371-393.

Sendlein, V.A., Lyle, Y. H. and Carison, L. C. 1983. Surface Mining Reclamation Handbook, (Elsevier Science Publishing Co. Inc New York, NY, USA) 290.

Shaikh, S.D. and Dongare, M. 2010. Effects of mining on the diversity of the Pteridophytes from the Western Ghats of Maharastra (INDIA). *World Applied Science Journal*, 11(12): 1547-1551.

Shannon, C. and Weaver, W. 1963. The Mathematical Theory of Communication. Urbana: *University of Illinois Press.*

Shannon, C.E and Weaver, W. 1949. *The mathematical theory of communication*. Urbana,University of Illinois Press. PP.1-117.

Shrivastava, Neelish, Mishra, D.D. and Thakre, Gajanand. 2010. Water quality assessment with reference to Machna river, Betul (M.P), India. *Poll. Res.* 29(2): 371-374.

Simpson, E.H. 1949. Measurement of diversity. *Nature,* 163: 688

Singh, B.B. 1995. Pollution status of Rapti river at Gorakhpur. *J. Environ. And Poll.* 2(3): 117-120.

Singh, J.S. & P.S. Yadava. 1974. Seasonal variation in composition, plant biomass and net primary productivity of a tropical grassland at Kurukshetra, India. *Ecological Monographs*, 44: 351-376.

Singh, J.S., Singh, K.P. and Agrawal, M. 1991.Environmental degradation of the Obra-Renukoot- Singrauli area, India and its impact on natural and derived ecosystems. *Environmentalist*, 11: 171–180.

Singh, M.R., Gupta, A. and Beeteswari, K.H. 2010. Physicochemical properties of water samples from Manipur river system, India. *J. Appl. Sci. Environ. Manage.* 14(4): 85-89.

Singh, N.K., Dutta, G.R., Singh, M. and Kishore, K. 1989. Assessment of water quality of the river Subernarekha at Ghatsila with reference to heavy metal pollution. *Freshwater Biol.* 1(2): 113-120.

Sinha, and Rajiv, K. 1994. Development without Destruction. *Jaipur: Environmentalist Publishers.*

Sinha, M.K. Ghose and Singh, G., 2000. Proceedings of the National Seminar on Environment Engineering with special emphasis on Mining Environment (NSSME), *Journal of the Institution of Public Health Engineers*, India. 173-181.

Sivasubramani, R. 1999. Water quality of river Periyar (River Suruluyar) in Tamil Nadu. In: *Limnological Research in India.* (Ed. S.R. Mishra). Pp 1-15. Daya Publishing House, Delhi, India.

Soave, R. de C.F. 2003. Phytosociological studies on natural established of vegetation in an unreclaimed limestone mining. *Brazilian Archives Biology and Technology*, 46: 259-269.

Sorensen, T. 1948. A method of equal amplitude in plant sociology based on similarity of species content. Det. Kong. Danske Vidensk Vidensk, Biol. Skr. (Copenhagen), 5: 1-34.

Srivastava, U.S. and Kulshrestha, A.K. 1990. Seasonal variation in certain physic-chemical parameters in Ganga , Yamuna and Tons in Allahabad region (U.P), India . In: *Recent Trends in Limnology* (Eds: Agarwal , V. P. and Das, P.). *Society of Bioscience.* Muzaffarnagar , India. 351-364pp.

Statistical Handbook Mizoram, 2010.

Subramanian, V. 1983. Factors controlling the chemical compositions of river of India. In: *Proceeding of the Hamberg Symposium* . 141: 145-151.

Sundarpandian, S.M. and Swamy, P.S. 2000. Forest ecology structure and composition along an altituduninal gradient in the western ghats, South India. *Journal of Tropical Forest Science,* 12(1): 104-123.

Swer, S. and Singh, O.P. 2003. Coal mining impacting water quality and aquatic biodiversity in Jaintia district of Meghalaya. *ENVIS Bulletin: Himalayan Ecol*. 11:26-33

Swer, S. and Singh, O.P. 2004. Status of water quality in coal mining area of Meghalaya: In: I.N. Sinha, M.K. Ghose & G. Singh (eds.), Proceedings of the National Seminar on Environment Engineering with special emphasis on Mining Environment (NSSME), *Journal of the Institution of Public Health Engineers*, India. 173-181.

Tepordei, V.V. 1999. Crushed stone: *U.S. Geological Survey Minerals Yearbook*, 72.1 – 72.32pp.

Thorington, Jr. R.W., Tannenbaum, B., Tarak, A. and Rudran, R. 1982. Distribution of trees on Barro Colorado Island.A five hectare saple. In: Leigh, Jr. E.G., Rand, A.S. and Winddror, D.M. (Eds.). The Ecology of Tropical Forest seasonal Rhythms and Long Term Changes. *Smithsoman Institute Press, Washinton, DC.*83-94pp.

Tiwari, B.K. 1996. Impact of coal mining on ecosystem health in Jaintia Hills, Meghalaya. In: Ramakrishnan, P.S., Purohit, A.N., Saxena, K.G., Rao, K.S. and Maikhuri, R.K. (eds.), *Conservation and Management of biological Resources in Himalaya.*G.B. Plant Institute of Himalayan Environment and Development, Almora. Oxford IBH Co. New Delhi. 466-475pp.

Tiwari, M. 2005. Assessment of physicochemical status of Khanpura Lake, Ajmer in relation to its impact on public health. *Eco. Env. And Cons.* 11(3-4): 491-493.

Tiwari, S.C., Tiwari, B.K. and Mishra, R.R. 1992. Variation in some physic-chemical properties of pineapple orchard soils of north-east India. *Journal of Indian Soil Science Society,* 40: 204-208.

Total Environment Centre, 2007. Impacts of Longwall coal mining on environment in NSW.

Township of Melancthon, 2010. Township of Melancthon General Ledger Annual Budget Report Revenues and Expenses. Retrieved from; http://melancthontownship.ca/public.htm on March 22, 2012.

Tripathi, O.P., Upadhaya, K., Tripathi, R.S. and Pandey, H.N. 2010. Diversity, dominance and population structure of tree species along fragment size gradient of a subtropical humid forest of Northeast India. *Research Journal of Environmental and Earth Sciences,* 2(2): 97-105.

Tripathi, S.K., Upadhyay, V.P. and Verma, K.R. 1989a. A comparison of different indices of diversity in tree species at Kasar Devi forests in Kumaun Himalaya. *Vegetos*, 2: 86-93.

Umavathi, S. and Longankumar, K. 2010.Physicochemical and nutrient analysis of Singanallur Pond, Tamil Nadu (India). *Poll. Res.* 29(2): 223-229.

Unni, K.S., Chauhan, A., Varghese, M. and Naik, L.P. 1992. Preliminary hydrobiological studies of river Narmada from Amarkantak to Jabalpur. In: *Aquatic Ecology*. (Mishra, S.R. and Saksena, D.N. eds). Pp 221-229. Ashish Publishing House, New Delhi, India.

Venkatesharaju, K., Ravikumar, P., Somashekar, R.K. and Prakash, K.L. 2010. Physico-chemical and bacteriological investigation on the River Cauevery of Kollegal Stretch in Karnataka. Katm. Univ. *J. Sc, Eng. And Tech.* 6(1): 50-59.

Verghese, A.O. and Menon, A.R.R. 1998.Vegetation characteristics of southern secondary moist mixed deciduous forests of Agasthyamalai region of Kerela. *Indian Journal of Forestry*, 21(4): 639-644.

Vermeulen, Jaap, and Whitten, Tony. 1999. Biodiversity and cultural property in the management of limestone resources: World Bank, Washington, D.C., 120p.

Visalakshi, N. 1995. Vegetation analysis of two tropical dry evergreen forest in southern India. *Tropical Ecology*, 36: 117-142.

Vitousek, P.M., Aber, J., Howarth, R.W., Likens, G.E., Matson, P.A., Schindler, D.W., Schlesinger, W.H. and Tilman, G.D. 1997. Human alteration of the global nitrogen cycle: Cause and consequences. *Issue in Ecology No.1*.

Vulcan material company, 2006. Quarry story and helping building stranger communities, Birmingham, Alabama.

Vulcan material company, 2006. Quarry story and helping building stranger communities, Birmingham, Alabama.

Walker, L.R. and del Moral, R. 2003. *Primary succession and ecosystem rehabilitation.Cambridge University Press*. ISBN 0-521-52954-9

Walkley, A. and Black, I.A. 1934. An examination of the Degtjareff method for determining organic carbon in soils: Effect of variations in digestion conditions and of inorganic soil constituents. *Soil Science*, 63: 251-263.

Wang, A. 2007. Principle of Environmental Impact Assessment Best Practice." International Association for Impact Assessment. "Environ.Prot. China: The role of law" pp. 120-128.

Warren, C.E. 1971. Biology and Water Pollution Control. W.B. Saunder.

Webber, W.J., Jr., and Stumm, W. 1963. Mechanism of hydrogen ion buffering in natural waters. *J. Am. Water works Assoc.* 55: 1553.

Weed, C.E. and Rutschky,C.W. 1971. Benthic Macroinvertebrate Community Structure in a Stream receiving Acid Mine Drainage. *Proc. Pa. Acad. Sci*. 50:41-46.

Whitford, P.B. 1949. Distribution of woodland plants in relation to succession and clonal growth. *Ecology*, 30:199-208.

Yillia, P.T., Kreuzinger N., Mathooko, J.M. 2008. The effect of in-stream activities on the NjoroRiver,Kenya.part-II:microbial water quality. *Phys. Chem. Earth.* Volume-33: 729-737pp.

Zafar, A. and Sultan, N. 2008. Seasonal analysis in the water quality of the river Ganga. *J. Curr. Sci.* 12(1): 217-220.

Zielinski RA, Otton JK, Johnson CA (2001). Sources of salinity near a mine, a coal mine spoil pile, North – Central Colorado. J. Environ. Qual. 30: 1237 –1248.

Appendix I. Correlation coefficient within different water physic-chemical characteristics at undisturbed site.

	pH	Temp	EC	TDS	Total Acidity	Total Alkalinity	Total Hardness	Chloride	DO	BOD	NTU	Nitrate	Sulphate	Phosphate
pH														
TEMP	0.70													
EC	-0.60	-0.87												
TDS	0.57	0.84	-0.88											
Total Acidity	-0.45	-0.75	0.67	-0.74										
Total Alkalinity	-0.23	-0.55	0.53	-0.55	0.02									
Total Hardness	-0.27	-0.76	0.78	-0.72	0.43	0.81								
Chloride	-0.61	-0.78	0.77	-0.73	0.89	0.19	0.56							
DO	-0.20	-0.39	0.34	-0.42	0.73	-0.30	0.01	0.47						
BOD	0.55	0.86	-0.63	0.78	-0.80	-0.37	-0.57	-0.71	-0.64					
NTU	0.57	0.91	-0.80	0.87	-0.65	-0.61	-0.79	-0.64	-0.40	0.86				
Nitrate	-0.56	-0.93	0.95	-0.86	0.66	0.66	0.91	0.77	0.27	-0.74	-0.88			
Sulphate	-0.47	-0.89	0.88	-0.82	0.72	0.58	0.91	0.82	0.31	-0.75	-0.88	0.96		
Phosphate	-0.51	-0.90	0.95	-0.90	0.70	0.66	0.90	0.80	0.29	-0.73	-0.85	0.98	0.96	

Appendix II.Correlation coefficient within different water physic-chemical characteristics at mildly disturbed site.

	pH	Temp	EC	TDS	Total Acidity	Total Alkalinity	Total Hardness	Chloride	DO	BOD	NTU	Nitrate	Sulphate	Phosph ate
pH														
TEMP	0.14													
EC	-0.28	-0.84												
TDS	0.15	0.82	-0.83											
Total Acidity	-0.09	0.81	0.82	-0.88										
Total Alkalinity	-0.11	0.78	0.64	-0.45	0.39									
Total Hardness	0.04	0.74	0.73	-0.63	0.48	0.86								
Chloride	-0.23	0.72	0.81	-0.83	0.82	0.45	0.63							
DO	0.04	0.81	0.51	-0.63	0.81	0.18	0.23	0.60						
BOD	0.11	0.84	-0.79	0.79	-0.82	-0.78	-0.74	-0.77	-0.64					
NTU	-0.14	0.81	-0.57	0.59	-0.60	-0.70	-0.77	-0.56	-0.53	0.84				
Nitrate	-0.11	-0.69	0.94	-0.82	0.80	0.78	0.85	0.83	0.51	-0.91	-0.74			
Sulphate	0.05	-0.96	0.86	-0.84	0.82	0.71	0.85	0.86	0.59	-0.91	-0.84	0.96		
Phosphate	-0.10	-0.79	0.93	-0.85	0.85	0.75	0.83	0.87	0.56	-0.91	-0.73	0.98	0.96	

Appendix III.Correlation coefficient within different water physic-chemical characteristics at moderately disturbed site.

	pH	Temp	EC	TDS	Total Acidity	Total Alkalinity	Total Hardness	Chloride	DO	BOD	NTU	Nitrate	Sulphate	Phosphate
pH														
TEMP	0.80													
EC	-0.70	-0.85												
TDS	0.76	0.85	-0.74											
Total Acidity	-0.56	-0.78	0.81	-0.80										
Total Alkalinity	-0.29	-0.54	0.63	-0.44	0.24									
Total Hardness	-0.33	-0.70	0.78	-0.48	0.54	0.86								
Chloride	-0.49	-0.78	0.80	-0.68	0.90	0.38	0.70							
DO	-0.83	-0.95	0.78	-0.81	0.78	0.38	0.58	0.72						
BOD	0.43	0.81	-0.62	0.64	-0.64	-0.57	-0.79	-0.69	-0.80					
NTU	0.28	0.65	-0.57	0.53	-0.56	-0.64	-0.81	-0.61	-0.64	0.83				
Nitrate	-0.60	-0.89	0.93	-0.71	0.76	0.73	0.91	0.80	0.81	-0.82	-0.75			
Sulphate	-0.54	-0.87	0.87	-0.78	0.88	0.61	0.85	0.87	0.83	-0.88	-0.82	0.95		
Phosphate	-0.58	-0.88	0.94	-0.73	0.80	0.75	0.90	0.85	0.78	-0.78	-0.74	0.98	0.95	

Appendix IV.Correlation coefficient within different water physic-chemical characteristics at moderately disturbed site.

	pH	**Temp**	**EC**	**TDS**	**Total Acidity**	**Total Alkalinity**	**Total Hardness**	**Chloride**	**DO**	**BOD**	**NTU**	**Nitrate**	**Sulphate**	**Phosphate**
pH														
TEMP	0.68													
EC	-0.62	-0.85												
TDS	0.67	0.82	-0.71											
Total Acidity	-0.47	-0.81	0.61	-0.69										
Total Alkalinity	-0.60	-0.75	0.75	-0.61	0.56									
Total Hardness	-0.21	-0.72	0.73	-0.66	0.62	0.68								
Chloride	-0.55	-0.87	0.94	-0.72	0.68	0.74	0.80							
DO	-0.61	-0.82	0.69	-0.78	0.89	0.66	0.59	0.65						
BOD	0.45	0.82	-0.73	0.70	-0.70	-0.74	-0.85	-0.72	-0.68					
NTU	0.37	0.78	-0.75	0.71	-0.67	-0.74	-0.93	-0.77	-0.64	0.92				
Nitrate	-0.36	-0.80	0.90	-0.61	0.60	0.76	0.92	0.88	0.61	-0.88	-0.91			
Sulphate	-0.38	-0.84	0.87	-0.73	0.72	0.65	0.94	0.91	0.68	-0.85	-0.91	0.94		
Phosphate	-0.44	-0.86	0.94	-0.71	0.73	0.76	0.90	0.95	0.73	-0.85	-0.87	0.96	0.96	

Appendix V. Water quality standard given by various scientific agencies.

Table 16.Water quality standard given by various scientific agencies.

Parameter	Standards			
	USPH	ISI	WHO	ICMR
Temperature (◦C)	-	40	-	-
pH (nano mole L^{-1})	6 - 8.5	6 - 9	7 - 8.5	7 - 8.5
EC (µS)	300	750	-	-
TDS (mgL^{-1})	-	-	500	500 - 1500
Total Hardness (mgL^{-1} $CaCO_3$)	500	-	-	300
DO (mgL^{-1})	>4	>5	-	-
BOD (mgL^{-1})	-	<3	-	-
Chloride (mgL^{-1} $CaCO_3$)	250	600	200	250
Total Alkalinity ($mgL^{-1}$$CaCO_3$)	-	200	-	-
Nitrate (mgL^{-1})	10	50	-	20
Phosphate (mgL^{-1})	0.1	-	-	-
Sulphate (mgL^{-1})	250	-	200	200

(-) Absent

Appendix VI

Correlation coefficient within different soil physic-chemical characteristics for 0-10 cm dept at undisturbed site.

	SMC (%)	pH	SOC (%)	TN (%)	Available Phosphorous (ppm)	Exchangeable Potassium (µg g^{-1})
SMC (%)						
pH	0.20					
SOC (%)	0.49	-0.75				
TN (%)	0.98	-0.01	0.66			
Available Phosphorous (ppm)	-0.41	0.81	-1.00	-0.59		
Exchangeable Potassium (µg g^{-1})	-0.15	0.94	-0.93	-0.35	0.97	

Appendix VII

Correlation coefficient within different soil physic-chemical characteristics for 0-10 cm dept at mildly disturbed site.

	SMC (%)	pH	SOC (%)	TN (%)	Available Phosphorous (ppm)	Exchangeable Potassium (µg g^{-1})
SMC (%)						
pH	-0.19					
SOC (%)	0.36	-0.98				
TN (%)	0.95	-0.49	0.64			
Available Phosphorous (ppm)	-0.74	0.80	-0.89	-0.92		
Exchangeable Potassium (µg g^{-1})	-0.32	0.99	-1.00	-0.60	0.87	

Appendix VIII

Correlation coefficient within different soil physic-chemical characteristics for 0-10 cm dept at moderately disturbed site.

	SMC (%)	pH	SOC (%)	TN (%)	Available Phosphorous (ppm)	Exchangeable Potassium (µg g^{-1})
SMC (%)						
pH	-0.89					
SOC (%)	0.90	-1.00				
TN (%)	0.97	-0.75	0.76			
Available Phosphorous (ppm)	-0.90	1.00	-1.00	-0.76		
Exchangeable Potassium (µg g^{-1})	-0.82	-0.82	0.76	-0.94	0.50	

Appendix IX

Correlation coefficient within different soil physic-chemical characteristics for 0-10 cm dept at highly disturbed site.

	SMC (%)	pH	SOC (%)	TN (%)	Available Phosphorous (ppm)	Exchangeable Potassium ($\mu g\ g^{-1}$)
SMC (%)						
pH	-0.93					
SOC (%)	0.90	-1.00				
TN (%)	0.89	-0.66	0.60			
Available Phosphorous (ppm)	-0.74	0.93	-0.96	-0.35		
Exchangeable Potassium ($\mu g\ g^{-1}$)	-0.60	0.85	-0.89	-0.17	0.98	

Appendix X

Correlation coefficient within different soil physic-chemical characteristics for 10-20 cm dept at undisturbed site.

	SMC (%)	pH	SOC (%)	TN (%)	Available Phosphorous (ppm)	Exchangeable Potassium (µg g^{-1})
SMC (%)						
pH	-0.64					
SOC (%)	0.99	-0.71				
TN (%)	0.67	0.14	0.59			
Available Phosphorous (ppm)	-0.96	0.82	-0.99	-0.45		
Exchangeable Potassium (µg g^{-1})	-0.95	0.84	-0.98	-0.42	1.00	

Appendix XI

Correlation coefficient within different soil physic-chemical characteristics for 10-20 cm dept at mildly disturbed site.

	SMC (%)	pH	SOC (%)	TN (%)	Available Phosphorous (ppm)	Exchangeable Potassium (µg g^{-1})
SMC (%)						
pH	-0.50					
SOC (%)	0.59	-0.99				
TN (%)	0.81	0.10	0.01			
Available Phosphorous (ppm)	-0.91	0.81	-0.87	-0.50		
Exchangeable Potassium (µg g^{-1})	-0.63	0.99	-1.00	-0.05	0.89	

Appendix XII

Correlation coefficient within different soil physic-chemical characteristics for 10-20 cm dept at moderately disturbed site.

	SMC (%)	pH	SOC (%)	TN (%)	Available Phosphorous (ppm)	Exchangeable Potassium (µg g^{-1})
SMC (%)						
pH	-0.80					
SOC (%)	0.86	-0.99				
TN (%)	0.94	-0.54	0.63			
Available Phosphorous (ppm)	-0.71	0.99	-0.97	-0.43		
Exchangeable Potassium (µg g^{-1})	-0.81	-0.81	0.63	-0.56	0.99	

Appendix XIII

Correlation coefficient within different soil physic-chemical characteristics for 10-20 cm dept at highly disturbed site.

	SMC (%)	pH	SOC (%)	TN (%)	Available Phosphorous (ppm)	Exchangeable Potassium (µg g^{-1})
SMC (%)						
pH	-0.89					
SOC (%)	0.92	-1.00				
TN (%)	0.61	-0.19	0.24			
Available Phosphorous (ppm)	-0.93	1.00	-1.00	-0.28		
Exchangeable Potassium (µg g^{-1})	-0.65	0.93	-0.90	0.20	0.89	