ALGAL BIODIVERSITY BASED RECONSTRUCTION OF THE PAST LOCAL AND REGIONAL ENVIRONMENTAL CONDITIONS OF RIVER YAMUNA IN DELHI REGION

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Dedicated to My Great Grand Mother "Janaki Chopra"

CERTIFICATE

This is to certify that the Ph.D. thesis entitled "**Algal Biodiversity Based Reconstruction of the Past Local and Regional Environmental Conditions of River Yamuna in Delhi Region**" submitted to Delhi Technological University, Delhi, for the award of Doctor of Philosophy is based on the original research work carried out by me under the supervision of **Prof. Jaigopal Sharma,** Department of Biotechnology, Delhi Technological University, Delhi, India. It is further certified that the work embodied in this thesis has neither partially nor fully submitted to any other university or institution for the award of any degree or diploma.

Vivek Chopra
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This is to certify that the above statement made by the candidate is correct to the best of our knowledge.

Prof. Jaigopal Sharma
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DECLARATION

I, Vivek Chopra, certify that the work embodied in this Ph.D. thesis is my own bonafide work carried out under the supervision of **Prof. Jaigopal Sharma,** Department of Biotechnology, Delhi Technological University, Delhi, for a period of July 2014 to August 2020 at the Department of Biotechnology, Delhi Technological University, Delhi. The matter embodied in this Ph.D. thesis has not been submitted for the award of any other degree/diploma.

I declare that I have devotedly acknowledged, given credit and refereed to the research workers wherever their work has been cited in the text and the body of thesis. I further certify that I have not wilfully lifted up some other's work, paragraph, text, data, results etc. reported in the journal, books, reports, dissertations, thesis etc., or available at websites and included them in Ph.D. thesis and cited as own my work.

Date: 19/08/2020 **Vivek Chopra**

Place: Delhi Enrolment No. 2K14/Ph.D/BT/08)

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Date: 19/08/2020 **Vivek Chopra**

Place: Delhi

ABSTRACT

River Yamuna is one of the most essential river of India originating from the Yamunotri glacier in Himalayas from a height of 6387 meters and travelling a total length of 1,376 kilometres before it merges in river Ganga. A majority of population depends on river Yamuna for their daily needs. Yamuna enters in Delhi at Palla village covering a stretch of 48 kilometres. This is where it receives huge amount of pollutants as sewage and industrial disposals.

However, it is assumed that river Yamuna was clean and in good health during earlier times. Therefore, the present research is the first attempt to study the paleolimnological conditions of river Yamuna using river bed sediments for radioactive Carbon-14 dating and using diatom diversity as an indicator of paleolimnological conditions . Two sites were selected for the research work, SITE A Palla village of Delhi where Yamuna enters in Delhi and SITE B was near Okhla barrage which is present almost at the last stretch of Yamuna in Delhi. SITE A, Palla village is present far from urban population of Delhi and surrounded by agricultural fields while Okhla barrage is located in vicinity of a outsized human population where it receives a massive amount of pollution through sewage and industrial wastes. A total of 18 river sediment samples were taken at different depths from both the sites in which 9 samples were from SITE A and 9 samples from SITE B.

Diatoms have been an essential component of paleolimnological assessments for a variety of reasons, which includes their well-preserved siliceous frustules, their ability to respond swiftly to variations in the environment and their distribution among a varied range of water quality gradients. Therefore, diatom assemblage of particular

sediment from river bed was used to reveal ecological conditions of a particular time frame observed by radiocarbon ^{14}C analysis. A total of 31 species of diatom was observed from the riverbed sediments. Each sample revealed almost different diversity of diatoms. The ecological indicators like pH, trophic state, Nitrogen uptake, oxygen and moisture requirements which are very unique for every diatom taxa were used to reveal environmental conditions of the river Yamuna in prehistoric times using the sediments collected from river bed. Other experiments like SEM-EDAX, CHNS analysis, XRD and XRF analysis were also performed to study the geochemical nature of sediments. Different elements like Si, O, Al, Nb were recorded from river sediments by EDAX analysis, while CHNS analysis helped in analyzing the concentrations of Carbon, Hydrogen, Nitrogen and Sulphur. The nature of mineral composition is studied with the help of XRD which revealed Quartz as the major mineral present at both the Sites. XRF revealed most of the oxides, trace elements and some heavy metals from the riverbed sediments. Various oxides and trace elements which are found in XRF analysis are Al_2O_3, CaO, Fe_2O_3, K_2O, MgO, Na_2O, P_2O_5, SiO_2, TiO_2, Th, MnO, Sc, V, Cr, Co, Ni, Cu, Zn, Rb, Sr, Zr, Ba, Pb. The correlation of these oxides and trace metals is an efficient way to study chemical nature of river Yamuna sediments. Paleolimnological and geochemical data revealed from sediments could be of great significance for understanding complex nature of river sediments components, diatom diversity and ecology and hence in conservation of river.

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LIST OF ABBREVIATIONS

^{14}C	Carbon 14
AGE	Automated Graphitization Equipment
AIIMS	All India Institute of Medical Science
AMS	Accelerator Mass Spectrometry
Approx	Approximately
BC	Before Christ
BOD	Biological Oxygen Demand
BP	Years Before Present
CHNS	Carbon, Hydrogen, Nitrogen, Sulphur
cm	centimeter
CPCB	Central Pollution Control Board
g	Gram
HCL	Hydro Chloric Acid
IUAC	Inter-University Accelerator Centre
JNU	Jawaharlal Nehru University
l	Liter
M	Molar
mg	milligram
MQ	Milli Q
N	Number of Samples
OC	Organic carbon
OSL	Optically Stimulated Luminescence

Pg	Picogram
SAIF	Sophisticated Advanced Instrument Facility
SEM	Scanning Electron Microscope
SEM-EDAX	Scanning Electron Microscope - Energy Dispersive X-Ray Analysis
t	tone
TC	Total carbon
TN	Total Nitrogen
USIC	University Science Instrumentation Centre
WD	Wavelength Dispersive
XRD	X-Ray Diffraction
XRF	X-ray fluorescence
Yr	Year
µm	micro meter

Chapter 1
Introduction

CHAPTER 1
INTRODUCTION

"A river is more than an amenity, it is a treasure."

Oliver Wendell Holmes

1.1. INTRODUCTION

Water is central to our existence and so vital to life. One of the most important sources of water are our rivers. India is a land of many such rivers providing valuable goods and services. The pivotal point of my thesis is one of the most crucial rivers of India, river Yamuna. Historically river Yamuna has been mentioned in numerous hymns, ancient scriptures, folk songs and also in the National Anthem of the country which expresses its value as a significant cultural heritage besides a natural treasure. The river Yamuna is the longest and second largest tributary of river Ganga whose origin is from the Yamunotri glaciers situated at a height of 6,387 meters on the uppermost region of the lower Himalayas in Uttarakhand. Its 48 kilometers stretch which passes from Delhi is a major source of drinking and potable water for the 70% population of Delhi (CPCB, 2006). It shows the importance of river Yamuna as a major source of water and an indispensable part of ecosystem.

Delhi is one of the major contributors to the pollution of river Yamuna and maximum part of complete stretch passing through Delhi is under high anthropogenic pressure which contributes to 76% of the total pollution received by Yamuna despite being just the 2% of the total length (Said and Hussain 2019). It's an interesting curiosity that today we see Yamuna as the most polluted river of India which is tolerating heavy sewage, industries and other sources of pollutants but does this river was always in such a bad situation where it has almost lost its identity of being a river. Therefore, the present study is the first attempt to reveal the prehistoric environmental conditions of river Yamuna to get an idea about environmental and limnological conditions of the river which might be completely different from the present situation. Although several studies have been undertaken on various aspects of the river like water quality, soil analysis, floral and faunal diversity of the river but no evidence has been available about the paleolimnological environmental conditions of the river Yamuna. Therefore, the aim of the present study is to reveal the archaeological profile of the river bed sediments using carbon dating studies and diatom diversity as an ecological indicator of the environmental conditions of a particular time to reconstruct the prehistoric environment of river Yamuna in Delhi region. The diatom record from river Yamuna can show a trajectory of assemblage changes that may be related to the environmental conditions. The present study will draw an inference about the limnological and environmental changes in river Yamuna from diatom species composition and geochemical analysis of the river soil sediments.

A very significant assemblage of eukaryotic, siliceous algae that play a critical role in ecosystem health are diatoms. They contribute roughly between 20 to 25 % of global primary production which is equivalent to the combined production of the terrestrial rainforests (Falkowski et al. 1998; Saade and Bowler 2009). These diatoms are present across a widespread spectrum of limnological or ecological conditions. However, variations in Physical and chemical parameters within the aquatic ecosystems can remarkably change the composition of diatom (Julius and Theriot 2010). It should not be a matter of surprise that diatoms react very sensitively to a varied range of environmental changes in their aquatic environment. Because of their well-defined preferences for a given micro-habitat type, many diatom taxa have the potential to track environmental and climate-mediated changes in water bodies (Smol 1988; Smol and Stoermer 2010).

The species composition of diatoms is specifically affected by fluctuations in ecological process and climate which have shown by the studies conducted worldwide (Catalan et al. 2002; Smol et al. 2005; Pannard et al. 2008; Winder and Hunter 2008; Rühland et al. 2008; Smol and Stoermer 2010). The factors that control diatom species composition like climate or environmental induced ecological factors are essential to grasp the knowledge how environmental changes affect the aquatic ecosystems.

Each diatom species represents a special type of environmental conditions. Therefore, in the present study, a myriad of ecological indicators like pH, nitrogen uptake, oxygen requirement, saprobity, trophic state and moisture requirements were used for diatom assemblages to elucidate the prehistoric environmental conditions of river Yamuna. The emphasis of the study was to observe whether subfossil diatom assemblages which are preserved in the soil sediment of the river bed responded to past limnological changes. The underlying hypothesis was that the composition and ecological guilds of the diatom diversity shifted in reaction to the changes in the environment and reflect environmental conditions of the river at a particular time.

1.2. OBJECTIVES OF THE STUDY

- To identify diatom diversity assemblage of river Yamuna from the river bed sediments which are related to prehistoric age.
- To reveal the archeological profile and ecological condition of the river using algae (Diatoms) as an ecological indicator of the environmental conditions of a particular time.
- The diatom record from river Yamuna can show a trajectory of assemblage changes that may be related to environmental alterations.
- To help in creating the data related to biological and geochemical features of river Yamuna which will help in conservation of the river.

1.3. STRUCTURE OF THE THESIS

Beside radioactive carbon dating with Accelerator Mass Spectrometry (AMS) and diatom analysis of river bed sediments, some other experiments like XRD, SEM-EDAX, CHNS and XRF analysis were also performed to elucidate chemical nature of the sediments. While talking about thesis structure it has been divided into six chapters for easy understanding and better interpretation. Chapter 1 is related to introduction and an outline of the present research work, Chapter 2 explains about the similar previous work done so far in many parts of the world and in India. Chapter 3 explains about study site, collection of sediment samples and other material and methods used in the research work. All results have been explained in Chapter 4 while discussion related to all observations and results explained in Chapter 5. A crisp summary and conclusion are included in Chapter 6.

Chapter 2
Previous Work

CHAPTER 2
PREVIOUS WORK

In this chapter, review of various related studies has been explained.

2.1. EARLY DAYS RESEARCH WORK

In late 19^{th} century Antonie Van Leeuwanhock observed the diatoms using his bead-like lenses but, he was unable to convincingly argue about diatoms in his published illustration but in 1703 a paper was submitted to Royal Society of London by unknown author Mr C which was published in philosophical transaction. But the historical research by John Dolan revealed his identity as Charities king a hitherto unrecognized microscopist proto-biologist born in 1654. Monograph of 1844 was published by Kutzing in 1844 and he classified all diatoms as algae. In the starting years emphasis was on the explanation of new species later on it was turned to the systemization of known diversity and the later it was about the objectification of the diatom. Certainly, the development of computation tools, multivariate statistics and various indices helping to understand the ecological conditions of our water bodies.

Few decades back diatoms studies were restricted to just represent water quality in the water bodies but with time diatoms from sediments have emerged as a potential indicator of prehistoric environmental conditions of the water bodies which is a breakthrough to understand the complex changing conditions of environment. The lakes and rivers have been studied around almost every part of the world. In last few decades many research works have been done throughout the world on the paleolimnological conditions or reconstructing the prehistoric environment of the rivers and lakes using diatom as an important criterion but till date no such information is available for any river in India.

2.2. PALEOLIMNOLOGICAL STUDIES IN ABROAD

To name a few research works done on the diatom diversity using sediments of the water bodies. Fluin et at. (2010) studied paleolimnological record of lake Cullulleraine connected to Murray river in Australia and analysed the age of core by ^{210}Pb and studied diatom community. Grundell et al. (2012) studied the paleolimnological reconstruction of river wetlands by taking sediment core and analysing them for diatom diversity and isotopic age in Murray river flood plains. Kattel et al. (2017) studied Palaeoecological evidence from a 94 cm long core taken from floodplain areas of Murray River. They analysed a span of 90 years and found *Cocconeis, Cyclotella, Nitzschia, Gyrosigma, Eunatia* and *Pseudostaurosira* as a major taxa.

In North American region, Abbott and Stafford (1996) studied chronologies from sediments core taken from Meech, Avataq and Tuktu lake systems in Arctic region in Canada using ^{14}C measurements. Galloway et al. (2011) studied post glacial hydrological changes with the diatom diversity. From sediment of lake Felkar, British Columbia and observed radiocan age of the sediments using AMS technique. Voit et al. (2014) inferred post glacial aquatic changes using diatom in Sicamous Greek lake, British Columbia, Canada. They took 410 cm long core and analyzed it for AMS 14 Carbon dating and diatom assemblages at regular interval. Important diatom taxa observed was *Achnanthes, Amphora, Aulacoseira, Cocconeis, Cyclotella, Cymbella, Eunotia, Fragilaria, Frustulia, Navicula, Nitzchia* etc. Chipman et al. (2009) explained 2000 years record of climate change using sediment cores from ^{210} Pb and ^{14}C dating and chemical, diatom assemblages and statistical analysis of Ongoke lake southwest Alaska. Another significant attempt was done by Bird et al. (2009) in glacial fed blue lake northern Alaska using ^{14}C dating techniques on sediments.

Fayo et al., (2018) studied Holocene hydrological changes from a 172 cm core and 138 texa of diatoms from Colorado river floodplain chronology based on ^{14}C dating (^{14}C yr BP) using AMS technique. The oldest age recorded from core was 4132 ± 35 ^{14}C yr BP (4510-4714 cal yr BP). While most representative diatom taxa were *Hantzschia, Cyclotella, Luticola, Epithemia, Pinnularia and Pseudostaurosira*.

Similar researches have been done on various lakes and rivers of Southern American continent. Kuerton et al. (2013) studied about the holocene environmental conditions of the Nabileque river floodplain in Brazil using sponge spicules from a 550 cm core below the surface. Ruwer et al. (2018) explained the diatom assemblage response to the environmental changes for the last 1000 years in the floodplains of Parana River, Brazil. Bere and Tundisi (2011) examined water quality using diatoms Monjolinho river in Sao Carlos, SP Brazil. Enters et.al. (2010), studied Holocene environmental dynamics of lake Lago Alexio in Brazil with the help of diatoms, sedimentological analysis using XRF and carbon dating techniques. Castineira et al. (2013) studied the prehistoric conditions of river Parana in Argentina using ^{14}C studies in the core of sediment and analysing major diatom species *Aulacoseira, cyclotella, Gomphonema, Eunatia, Pinnularia* and *fragilaria* were the important taxa recorded. Velez et al. (2013) explained about late holocene history of the floodplain lakes of Cauca river in Colombia. He observed 4500 years old records from sediments using Accelerator Mass Spectrometry (AMS) and diatoms assemblages from sediments in which they found different diatom species in different time zone. Lozano-Garcia et al. (2010) studied lake Holocene palaeoecology of lake Lagovade in Mexico. They observed diatoms in sediments with major taxa *Achnanthidium, Luticula, Aulacoseira, Fragilaria* etc. Ortega et al. (2010) studied core of lake Zirahuen in Central Mexico using diatom diversity and time scale based on AMS ^{14}C dates.

Rusanov et al. (2012) studied the environmental and anthropogenic effect on the algal assemblages in the rivers of the lake Laduga basin in Russia. Biskaborn et al. (2013) studied limnological changes in Thermokarst Lake in western lena river Delta in Siberia using ^{14}C dating by AMS and with the help of diatom assemblages. Important diatom taxa observed was *Navicula, Staurosira, Gomphonema* etc. Fedotov et al. (2014) analyzed sediment core of Lake Mountain in Siberia and revealed 850 years record of climate and vegetation changes. Core sediments were analyzed for ^{210} Pb and ^{137}Cs dating and diatom assemblages.

Extensive work has been done on the river and lakes of all over Europe. Prieto et al. (2016) studied benthic diatoms from the river bed sediments of Anllons river in Spain. Main taxa recorded in the study was *Nitzschia, Achnanthesis, Pinnularia, cocconeis, Melosira* and *Surirella.* Moreno et al. (2011) revealed last 13,500 years environmental history records of lake Lago Enol in Spain. ^{14}C dates of sediments were constructed using AMS. Important taxa observed from sediment sub sample were *Amphora, Cyclotella, Naviculla* and *Fragilaria*. Scussolini et al. (2011) studied lake Holocane climate change and human impact using diatom and radiocarbon dates on the sediments of the lake Montcortes of Catalonia, Spain. Major diatom observed was *Cyclotella, Cymbella, Cyclostephanos, Fragilaria, Gomphonema* and *Pseudostaurosira*. Morellon et al. (2011) studied sediment core recovered from lake Estanya, Spain and revealed complex environmental hydrological and anthropogenic interactions occurring in the area since medieval times. Using diatoms and calculating chronological age by AMS radiocarbon dating. Selby and Brown (2007) studied Holocene environmental conditions of lake lough Kinale and Derragh Lough in Ireland by using AMS ^{14}C dating on the sediments core and co-relating it with the diatom diversity. Danielsen (2010) studied the recent histories of two lakes, vela and Bracas in Portugal by taking help of algal diversity and ^{14}C dating on sediments core collected from lakes. Resende et al. (2010) studied benthic diatoms as biological indicators to assess water quality of the UL river in Portugal. Bragee et al. (2013) explored sediment spanning the last 800 years from two lakes in Sweden using XRF and ^{14}C AMS techniques and other methods. Luoto et al. (2017) studied limnological history of lake Hiidenvesi, Finland using diatom diversity and radioactive ages calculated from sediment core of the lake. Tavernini et al. (2011) started the effect of physico-chemical factors on community structure of diatoms in Po river Italy. Dahm et al. (2013) used diatom species to study the effect of physico-chemistry on the biodiversity of riverine organisms in Germany and Austria. Enters et al. (2010) analyzed climate change and human impact on Sacrower See Lake in Germany with the help of diatom diversity and time scale provided by AMS ^{14}C dates from the sediments taken from lake bed. Kienel et al. (2013) studied sediments of lake Hotzmaar in Germany with the help of diatoms, XRF and carbon isotopes to reveal; the climate modification in response to human activities.

Many waterbodies have been studied from African continent. Riedel et al. (2014) explained about hydromorphological and Limnological changes in makgadikgadi basin in Botswana using diatom diversity and studying chronological age using AMS radiocarbon dating. Nguetsop et al. (2011) studied the past environmental and climatic changes during the last 7200 cal yr in Lake Mbalang, Cameron, Africa. They performed ^{14}C dating using AMS technique. Major diatom taxa recorded were *Aulacoseira, Fragellaria, Cyclotella, Amphora, Cocconeis, Gomphonema, Eunotia* and *Pinnularia*. Brauneck et al. (2013) studied early to middle Holocene environmental change from sediments of Paleolake in central Sahara NE Niger with the help of diatoms, XRF and AMS ^{14}C dating. Lee et al. (2018) studied lake Holocene climate changes from diatom records in the Gonggeomji reservoir, Korea. Age of the sediments were analyzed using AMS ^{14}C dating. Dominant diatom genera observed was *Cymbella, Eunotia, Gomphonema, Gyrosigma, Navicula* and *Pinnularia*. Krstic et al. (2012) explained about lake quaternary environmental changes in lake Ponch Pokhari, Nepal using diatom from sediment core dominant taxa found in study was *Navicula, Pinnularia, Cyanbopleura, Nitzchia, Aulacoseira. Tabelloria* and *Fragillari.*

2.3. PALEOLIMNOLOGICAL STUDIES IN INDIA

Almost no data is available on paleolimnological studies of river Yamuna or any other river in India using diatom as an environmental indicator and radioactive carbon for geological age calculations. But many studies have been done to analyse water and soil quality of river Yamuna and other rivers. Jha et al. (1993) studied mineral composition of the river Yamuna sediments at different cities like Baghpat, Delhi, Mathura, Agra, Chambal, Etawah and Allahbad. Dalai et al. (2004) studied sediments geochemistry of Yamuna river system in Himalayan region. Sehgal et al. (2012) studies contamination of heavy metal in Delhi segment of Yamuna from Wazirabad to Okhla barrage. Parween et al. (2014) studies about organochloride pesticides in fluvial sediments of the Yamuna river in Delhi. Sharma et al. (2017) Studied about microbial community composition in contaminated soil samples of Yamuna River in Delhi region. A very preliminary study revealing the inorganic elements and pollutants in the Yamuna River bank soil in Delhi was studied by Farago et al. (1989). Das et al. (2018) explained about the available Nitrogen and Sulphur by using K-jeldahl method in River Yamuna in Allahabad city. Organic Carbon and available nitrogen in different horizons of Yamuna River Bank at Prayagraj was studied by Dogo et al. (2019).

The Present study is a pioneer work to reveal the Paleolimnological profile of the river using diatoms as a biological indicator of the environmental conditions of a particular time. Knowledge about the changes in environmental history of the river can be of great significance for the conservation of the river.

Chapter 3
Materials and Methods

CHAPTER 3

MATERIALS AND METHODS

In this chapter, study sites, materials and methods used for the present study has been discussed.

3.1. STUDY SITE

3.1.1 Physiography, geology and climate

The longest and second largest tributary of river Ganga is river Yamuna. This river originates from the Yamunotri glaciers at a height of 6,387 M on the uppermost region of the lower Himalayas in Uttarakhand. Travelling a total length of 1,376 kilometers it merges with river Ganga at city Prayagraj, river Yamuna has a drainage system of 366,223 square kilometers. Its 48 km stretch which passes from Delhi is a major provider of drinking and potable water for the 70% population of Delhi (CPCB, 2006). It shows the importance of river Yamuna as a major source of water and an indispensable part of ecosystem. Delhi contributes a pollution load of 76% into the Yamuna river, despite the fact that it is just 2% of the entire stretch (Said and Hussain, 2019)

Delhi (28°37′N, 77°12′E) is inhabited by around 16,787,941 people and Density of 11,312/km^2 .It is spread over an area of 1,484 km^2 and the average elevation is 200–250 m above sea level. Annual temperatures in Delhi usually range from 2 to 47 °C and the average annual rainfall is approximately 886 mm. 80 % of the rainfall is received during the monsoon season (July to October). The wind direction is predominantly from the north and northwest, except during the monsoon season that is typified by easterly or southeasterly winds.

3.1.2 Description of Study Area and sampling

A total of 18 samples were collected from two sites (Fig.3.1) of river Yamuna in Delhi region. Pit method (Rai et. al., 2019) was used to collect sample and a fresh pit were made and samples were collected at different depths excluding the top 2 cm. SITE A (Fig 3.2) was Palla village (28°85'61.7''N 77°20'80.2''E) which is located at north of Delhi and the point where river Yamuna enters in Delhi. Palla village is rural area of Delhi with the total geographical area of 377.7 hectares and a total population of only 4,221 peoples.

Most of the area is occupied by agricultural fields where the major crops produced are wheat, Rice, strawberries, different kind of vegetables and flowers like marigolds. These agricultural fields extend till the banks of river Yamuna. Some parts of the dried river beds are also used by farmers for the production of Watermelons and Muskmelons in summer. In monsoon most of the agricultural area is submerged under flood caused by high levels of water in river Yamuna. River bank has a good diversity of grasses (*Phragmites karka*), herbs (*Solanum nigrum*), shrubs (*Zizyphus mumularia*) and trees (*Acacia nilotica, Eucalyptus globules*) while species like *Eichhornia crassipes* and *Hydrilla verticillata* predominates the aquatic habitat of the river. SITE A is comparatively free from pollutants and other anthropogenic activities beside agriculture in vicinity. Multiple samples were collected for better and authentic interpretation of results. 9 samples as shown in Table 3.1, were collected at SITE A (Palla village) from 3 different locations on river and from each location 3 samples were taken at different depths of river bed. At location 1 samples were taken from surface (0-2 cm) and at the depth of 30-32 cm and 78-80 cm depth of the river bed. Again 3 samples were taken from location 2 and location 3 at the surface (0-2 cm) and depths of 30-32 cm, 74-76 cm and 26-28 cm, 59-61 cm respectively.

Same set of sampling was done at SITE B (Okhla barrage) with 9 samples in total from three different locations i.e. location 4, 5 and 6 at the surface (0-2 cm) and various depths of 30-32 cm, 76-78 cm and 30-32 cm, 67-69 cm and 26-28 cm and 62-64 cm respectively as shown in Table 3.2. SITE B (Fig 3.3) was near Okhla barrage (28°32'10.5"N 77°19'29.6"E) which is almost located at the last stretch of river Yamuna in Delhi. One of the oldest villages in Delhi near the bank of Yamuna river is Okhla. However, now it is a suburban colony which is located near Okhla barrage in South Delhi. It is surrounded by area which is heavily industrialized and densely populated. The Okhla barrage was developed by British in 19th sanctuary since than it is playing very important role in distribution and controlling the flow of water. SITE B was comparatively very much polluted as compared to SITE A. Foul smell and blackish colour of river water was recorded which is because of the addition of sewage and industrial wastes in to the river. Less vegetation with high anthropogenic activities in vicinity was recorded. Collected samples were packed in airtight zipper polybags and processed for further experimental studies in laboratory.

The geographical location was taken by Garmin GPSMAP 76CSX global positioning system.

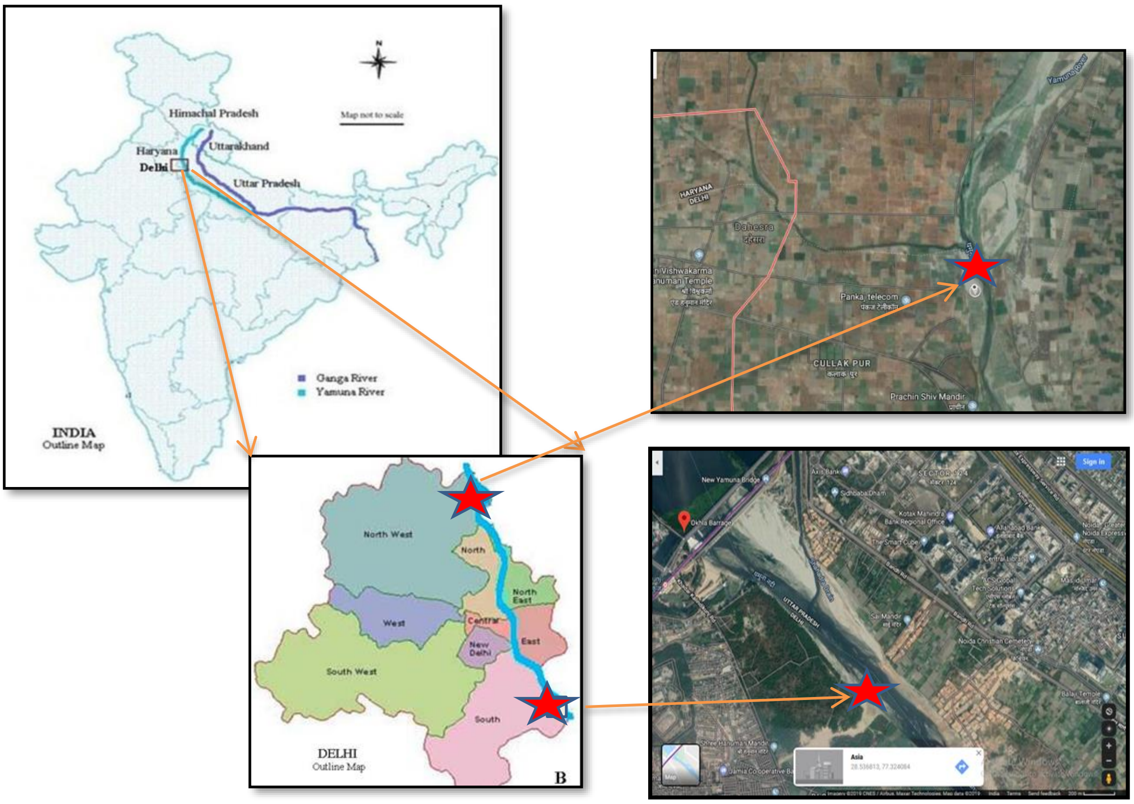

Fig. 3.1: Location of collection SITE A Palla village and SITE B Okhla barrage in Delhi.

Fig. 3.2: (a) SITE A Palla Village, Yamuna river bed, (b) sample collection from river bed.

Table 3.1. Depths of three locations at SITE A (Palla Village)

Depths of location 1		
0-2 cm	30-32 cm	78-80 cm
Depths of location 2		
0-2 cm	30-32 cm	74-76 cm
Depths of location 3		
0-2 cm	26-28 cm	59-61 cm

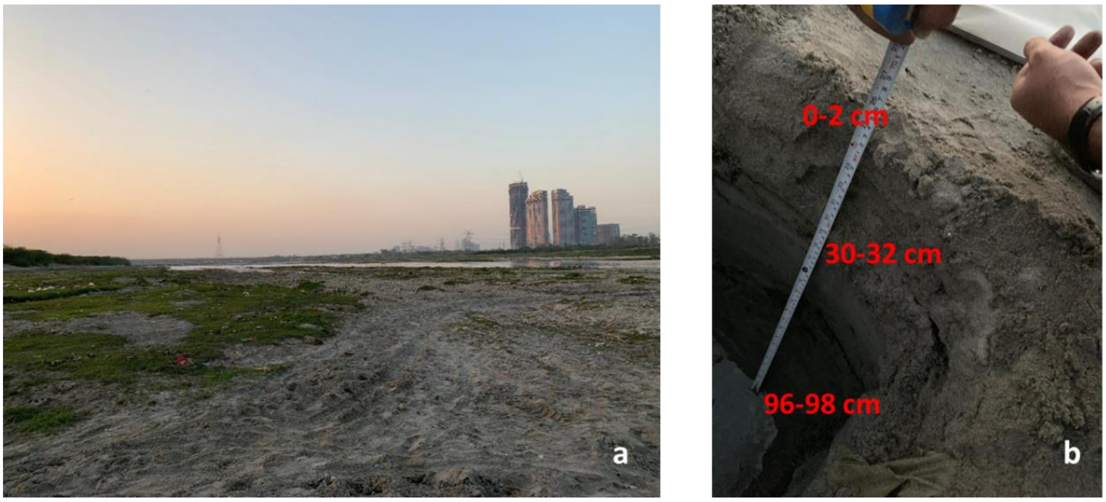

Fig. 3.3: (a) SITE B Okhla barrage, Yamuna river bed, (b) sample collection from river bed.

Table 3.2. Depths of three locations at SITE B (Okhla)

Depths of location 4		
0-2 cm	30-32 cm	96-98 cm
Depths of location 5		
0-2 cm	30-32 cm	67-69 cm
Depths of location 6		
0-2 cm	26-28 cm	62-64 cm

3.2. CARBON – 14 (Radiocarbon age) Analysis

Samples were taken to Inter University Accelerator Centre (IUAC), New Delhi for AMS carbon-14 dating experiments.

The following pre-established sample preparation procedure was followed:

3.2.1 Physical pretreatment

Contaminations like twigs, rootlests, threads, hairs or any other unnecessary materials were removed manually. Soil sediments were homogenized and covered with aluminum foil to avoid any contamination and sun dried to remove initial moisture and later was dried at 50 °C in oven till complete moisture was lost.

3.2.2 Chemical pretreatment

15ml centrifuge tubes were taken and cleaned with soap solution, then with tap water, then with elix water and finally with MQ water. Tubes were rinsed 5 to 6 times with elix and MQ water and dried by keeping in inverted position on clean paper. 5-10 gm of sample was taken in cleaned and dried centrifuge tube and was marked by lab id. Acid-Base-Acid pretreatment was given. In each tube 10ml of 0.5 M HCL was added and sample was completely submerged in acid to remove carbonates. Sample tubes were kept on thermo shaker at 60 degree centigrade at 750 rpm for overnight. Centrifuge tube lid was kept slightly open to escape any gases formed during heating. In next step samples were centrifuge for 1 minute @ 3000 rpm and washed with MQ water. Excess water was decanted by pipettes. This washing step was repeated until pH 6-7 was retrieved. Samples were dipped in the 10 ml of 0.1 M NaOH base and kept on thermo shaker at 60 degree centigrade at 750 rpm for 3 hrs. The next acid wash (0.5M HCL, 60 °C) helped to remove CO_2 absorbed from atmosphere through base wash.

3.2.3 Graphitization

For graphitization process Automated Graphitization Equipment (AGE) attached with elemental analyzer, industrialized by Ionplus AG and ETH, Zurich was used.

3.2.4 Radiocarbon ^{14}C measurements

Radiocarbon was measured by means of AMS facility.

3.3 SEM-ANALYSIS FOR DIATOM COMPOSITION

3.3.1 Acid treatment, washing and cleaning

Three dimensional structures of diatoms are observed using SEM. After collection the diatom sample were allowed to settle down. Diatom suspension was mixed properly and 5-10 ml were taken in a beaker, 20ml 30% H_2O_2 was added and heated for 1-3 hours at 90°C and beaker was left to cool down after addition of few drops of 10% HCL. Once samples were cool down they are rinsed using distilled water and centrifugation at 2500 rpm for 10 minutes. Supernatant is decanted after centrifugation the and the washing is repeated around 4 times to wash away acids and any other impurities (Taylor et al. 2007).

3.3.2 Preparation for SEM

A drop or two of cleaned diatom suspension is poured over a small round coverslip and left to dry in a desiccator for 24 hours to ensure it is totally dehydrated (Taylor et al. 2007). After drying the coverslip is mounted over round microscopic stubs and plated with gold (Au) for further SEM analysis. SEM images were taken at different magnifications using Scanning Electron Microscope model Zeiss EVO 18 research and JEOL JSM-6610LV at SAIF, AIIMS, Delhi and USIC, Delhi University, Delhi.

3.3.3 Identification and classification

The algal species examined under microscope were identified with the help of standard books and monographs ("The Diatoms: Biology and Morphology of the Genera" by Round et al. 1990, Krammer and Lange-Bertalot 1986, 1991; Lange-Bertalot and Metzeltin 1996, "An Illustrated Guide to Common Diatom of Peninsular India" Karthik et. al. 2013 and Algaebase, 1996-2020) and an extensive comparison with other published research work.

3.4 SAMPLE PREPARATION FOR SEM-EDAX ANALYSIS

5-10 mg sub samples were homogenized, sun dried and sieved out to remove excess unwanted debris later it was dried in an oven at 60ºC for three days to remove moisture completely (Das and Mondal 2011, Tan 2005). Dried samples were mounted and microstructure was analyzed using Scanning Electron Microscope model Zeiss EVO 18 research. The elemental constituents were observed by an EDAX spectroscopy instrument attached to Scanning Electron Microscope at Sophisticated Advanced Instrument Facility (SAIF), AIIMS, Delhi.

3.5 SAMPLE PREPARATION FOR CHNS ANALYSIS

5–10 mg sub-samples were homogenized and dried in an oven at 105ºC (Relic et al. 2010) and processed for analysis of concentration Percentage of Carbon, Hydrogen, Nitrogen and Sulphur by elementar EL cube CHNS elemental analyzer at University Science Instrumentation Centre (USIC), University of Delhi, North Campus, Delhi.

3.6 SAMPLE PREPARATION FOR XRD ANALYSIS

5–10 mg sub-samples were homogenized and dried completely and disintegrated up to silt size using ball mill to determine mineralogy of different soil samples using X rays diffractometry (Maiti and Maiti, 2018) analysis using a EMPYREAN X rays diffractometer in the range $2\theta = 5^{\circ}$-80° Manufactured by PANalytical was used at IUAC, New Delhi. XRD peaks have been analyzed by using the "Match" software.

3.7 SAMPLE PREPARATION FOR WD-XRF ANALYSIS

Pre-cleaned soil samples were grinded to minute powder size using a ball mill at National facility for OSL dating, JNU, New Delhi. Grinded soil samples were taken to IUAC, New Delhi for pellet making using a pellet press made of Kameo Systems Pvt. Ltd. Pellet Press- 40 Tons – PPSA-1.040. An AXIOSmAX sequential wavelength dispersive (WD) Xrays fluorescence spectrometer contrived by PANalytical was used for analysis at IUAC, New Delhi.

Chapter 4
Results

CHAPTER 4
RESULTS

In this chapter, results of all the experiments conducted have been documented.

4.1. RESULTS ^{14}C RADIOCARBON AGE

The radiocarbon age of all the 18 samples were observed and calibrated age and median age was calculated using CALIB REV 7.1.0 (Stuiver and Reimer, 1993) software. 2 sigma values are taken for calibrated age and median age was taken under consideration for the present study. All different radiocarbon ages observed from the samples taken from different depths from location 1, 2 and 3 of SITE A and location 4, 5 and 6 of SITE B has been mentioned in Table 4.1. Oldest age of 17020 BC years was observed in case of sample taken from SITE B, location 6, depth of 0-2 cm while youngest age of 85 BC was observed from sample taken at depth of 30-32 cm at location 5 of SITE B.

Comparison of the carbon ages with geological time scale revealed most of the samples belongs to two Epoch i.e. Holocene which ranges from 11,700 years to present time and Pleistocene ranged from 2.588 million years to 11,700 years, Era Cenozoic (65.5 million years to present) and Eon Phanerozoic (542.0 million years to present). At SITE A most of the samples belongs to Epoch Pleistocene which is older as compared to samples collected from SITE B, mostly of which belongs to Epoch Holocene (11,700 years to present) whose range of age is younger as compared to pleistocene.

Table 4.1. Radiocarbon ages observed from the samples taken from different depths of various locations of SITE A and SITE B.

S. No.	SITE A & B Locations (Depth)	Lab ID	Radiocarbon Age (BP)	CALIBRATION using CALIB REV 7.1.0	
				Calibrated range (BC)	Median range (BC)
1	Location1 (0-2 cm)	IUACD#19C2421	16002 ± 112	17152- 16662	16899
2	Location1 (30-32 cm)	IUACD#19C2422	16021 ± 147	17270-16620	16924
3	Location1 (78-80 cm)	IUACD#19C2423	13716 ± 106	14355-13745	14058
4	Location2 (0-2 cm)	IUACD#19C2424	15514 ± 159	16750-16024	16404
5	Location2 (30-32 cm)	IUACD#19C2425	Sample could not be graphitized because of less carbon content		
6	Location 2 (74-76 cm)	IUACD#19C2426	12059 ± 216	12052-11157	11584
7	Location 3 (0-2 cm)	IUACD#19C2427	15930 ± 268	17497-16238	16841
8	Location 3 (26-28 cm)	IUACD#19C2428	6789 ± 76	5492-5212	5366
9	Location 3 (59-61 cm)	IUACD#19C2429	12621 ± 111	12740-11888	12205
10	Location 4 (0-2 cm)	IUACD#19C2430	8848 ± 135	7967- 7228	7575
11	Location 4 (30-32 cm)	IUACD#19C2431	11290 ± 208	10964-10683	10811
12	Location 4 (76-78 cm)	IUACD#19C2432	3912 ± 46	2103-1803	1943
13	Location 5 (0-2 cm)	IUACD#19C2433	10156 ± 65	9342-9033	9206
14	Location 5 (30-32 cm)	IUACD#19C2434	2258 ± 32	13 BC -177 AD	85
15	Location 5 (67-69 cm)	IUACD#19C2435	11921 ± 62	11560-11297	11426
16	Location 6 (0-2 cm)	IUACD#19C2436	16114 ± 132	17362-16739	17020
17	Location 6 (26-28 cm)	IUACD#19C2437	13185 ± 79	13620-13027	13283
18	Location 6 (62-64 cm)	IUACD#19C2438	9474 ± 63	8542-8240	8377

4.2. RESULTS SCANNING ELECTRON MICROSCOPY – DIATOM DIVERSITY

In present study a total of 31 diatom species was observed from 18 different genuses found in the present study *Achnanthidium, Cyclotella, Nitzschia, Fragillaria, Eunatia, Gomphonema, Plagiotropis, Pleurosira, Cocconis, Neidium, Stauroneis, Tryblionella, Stephanodiscus, Synedra, Navicula, Pantocsekiella, Mallomonas and Amphora* which all belongs to three classes, Coscinodiscophyceae, Fragilariophyceae and Bacillariophyceae.

Total 31 species observed in the present study from location 1, 2 and 3 of SITE A and location 4, 5 and 6 of SITE B are *Cyclotella atomus, Cyclotella meneghiniana, Cyclotella pseudostelligaria, Cyclotella striata, Cyclotella stelligera, Stephanodiscus parveus, Stephanodiscus minutulus, Stephanodiscus binderanus, Pleurosira indica, Pleurosira laevis, Fragillaria capucina, Fragillaria rumpens, Synedra acus, Eunatia faba, Gomphonema parvulum, Cocconeis placentula, Achnanthidium hoffmannii, Achnanthidium minutissimum, Achnanthidium eutrophilum, Neidium iridies, Navicula cryptotenella, Plagiotropis Lepidoptera* var. *proboseidea, Amphora pediculus, Tryblionella brunoi, Nitzschia acicularis, Nitzschia fonticola, Nitzschia palea, Nitzschia recta, Pantocsekiella costei*, *Mallomonas* sp., and *Stauroneis* sp. All the observed species has been listed in Table 4.2.

Table 4.2. Observed diatom species from different locations of SITE A and SITE B, Yamuna river, Delhi.

Class	Subclass	Order	Family	Genus name	Species name
COSCINODISCOPHYCEAE	Thalassiosirophycidae	Thalassiosirales	Stephanodiscaceae	*Cyclotella, Stephanodiscus,*	*Cyclotella atomus* *Cyclotella meneghiniana* *Cyclotella pseudostelligaria* *Cyclotella striata,* *Cyclotella stelligera* *Stephanodiscus parveus* *Stephanodiscus minutulus* *Stephanodiscus binderanus*
	Biddulphiophycidae	Triceratiales	Triceratiaceae	*Pleuosira,*	*Pleurosira indica* *Pleurosira laevis*
FRAGlLARIOPHYCEAE	Fragilariophycidae	Fragilariales	Fragilariaceae	*Fragilaria, Synedra*	*Fragillaria capucina* *Fragillaria rumpens* *Synedra acus*
BACILLARIOPHYCEAE	Eunotiaphycidae	Eunotiales	Eunotiaceae	*Eunotia,*	*Eunatia faba*
	Bacillariophycidae	Cymbellales	Gomphonemataceae	*Gomphonema,*	*Gomphonema parvulum*
		Achnanthales	Cocconeidaceae	*Cocconeis,*	*Cocconeis placentula*
			Achnanthidiaceae	*Achnanthidium,*	*Achnanthidium hoffmannii* *Achnanthidium minutissimum* *Achnanthidium eutrophilum*
		Naviculales	Neidiaceae	*Neidium*	*Neidium iridies*
			Naviculaceae	*Navicula,*	*Navicula cryptotenella*
			Stauroneidaceae	*Plagiotropis,*	*Plagiotropis Lepidoptera var. proboseidea*
		Thalassiophysales	Catenulaceae	*Amphora*	*Amphora pediculus*
		Bacillariales	Bacillariceae	*Tryblionella, Nitzschia,*	*Tryblionella brunoi* *Nitzschia acicularis Nitzschia fonticola grunow* *Nitzschia palea* *Nitzschia recta*

* *Pantocsekiella costei, Mallomonas* sp.and *Stauroneis* sp.are not mentioned in above table.

4.2.1.SYSTEMATIC ENUMERATION OF DIFFERENT TAXA

The general pattern of arrangement of algal species collected from different sites of Yamuna river in Delhi is based on the well accepted classification given by Round et. al. (1990).

Kingdom PROTISTA
Subkingdom CHROMISTA
Phylum BACILLARIOPHYTA
Class COSCINODISCOPHYCEAE
Subclass THALASSIOSIROPHYCIDAE
Order THALASSIOSIRALES Glezer & Makarova 1986
Family STEPHANODISCACEAE Glezer & Makarova 1986
Genus *Cyclotella* Kutzing 1883 Brebisson 1838

***Cyclotella pseudostelligera* Hustedt** (Plate 1 Fig.1)

Description: Frustule discoid, valves having flat, convex or concave centre. Valves with a central area having a stellate ornamentation is sometimes absent in smaller individuals. The central area is surrounded by marginal radial striae. Sometimes ribs bifurcate the radiate striae or may have an irregular radiate pattern.

Dimensions: Valve diameter 3-4 μm

Ecology: Freshwater

Collection SITE: Location 1 (30-32cm), Location 2 (0-2cm) SITE A.

Remarks: Circumneutral i.e. occurs at pH values about 7, Nitrogen autotrophic taxa, can tolerate small elevated concentrations of organically bound nitrogen, it requires moderate amount of oxygen (50% saturation) α-mesosaprobous, Eutraphentic and occurs in water bodies, Its very rare to occur outside waterbodies (Kobayasi and Mayama, 1982, Lobo et al. 2016).

***Cyclotella atomus* Hustedt** (Plate 1 Fig.2)

Description: Frustule in the girdle view is rectangular, valve surface is circular with a radially striate marginal zone less than one third the radius of the valve and smooth central zone with one isolated pore. The taxon has a flat, unornamented central area which is not clearly distinguished from the peripheral fascicles. The marginal coastae thicken at varying intervals of striae from 2 to 5.

Dimensions: Diameter - 5µm.

Ecology: Freshwater

Collection SITE: Location 1 (78-80cm) SITE A.

Remarks: Alkaliphilous i.e. occurring at pH>7 Nitrogen- autotrophic taxa, tolerating elevated concentrations of organically bound nitrogen. Fairly high oxygen requirement, α-mesosaprobous, eutraphentic conditions are favourable. It never occurs outside water bodies or occurs very rarely. This presence suggests stable water column with little mixing of water therefore and high water availability (Sienkiewicz et al. 2017).

Cyclotella meneghiniana **Kutzing** (Plate 1 Fig.3)

Description: Striae thick, margins strong, valves discoid. Frustules in girdle view drum shaped clearly undulate. Marginal zone is well defined by striae, extending more or less equal to the radius. Central zone is characterised by rough furrows and elevations and also two isolated pores.

Dimension: Diameter 5-22µm.

Ecology: freshwater.

Collection SITE: Location 4 (0-2cm) SITE B.

Remarks: Requires pH>7 i.e, alkaliphilous, It is facultatively nitrogen heterotrophic taxa which needs sporadically elevated concentrations of organically bound nitrogen, Oxygen requirement is fairly high, α-mesosaprobous, eutraphentic trophic state and mainly occurs in water bodies and sometimes on wet places.

Cyclotella stelligera **(Cleve & Grunow) Van Heurck** (Plate 1 Fig.4)

Description: Valve circular with a striate marginal zone extending to less than half the radius of the valve. Central zone of valve surface is characterised by a central areola surrounded by a row of radius linear areolae described as alveolar by Houk and Klee, 2004.

Dimension: Diameter 5-10µm

Ecology: Fresh Water

Collection SITE: Location 4 (30-32cm) and Location 6 (26-28cm) SITE B.

Remarks: It never occurs outside water body or occurs very rarely. *Cyclotella* sp. Has a wide tolerance to different environmental parameters and it usually dominates in mesotrophic water.

Cyclotella striata **(Kützing) Grunow** (Plate 1 Fig.5)

Description: Valve circular, undulate. Frustules discoid. Valve surface divided into the striate marginal zone and a central zone of furrows and elevations, with a strong diametrical fold. Striae radial.

Dimension: Diameter - 15μm

Ecology: Fresh Water

Collection SITE: Location 1 (30-32 cm) SITE A.

Remarks: Alkaliphilous i.e. mainly at around pH>7. It mainly occurs in waterbodies and on wet places.

Genus - *Stephanodiscus* Ehrenberg, 1845

Stephanodiscus parveus (Plate 1 Fig.6)

Description: Valves are disc shaped with a shallow mantle and undulate face. It is characterised by the presence of areolae crossways the valve face, weakly organized into rows at the centre of the valve. There is presence of small spines on each interfascicle, at the valve margin.

Dimension: Diameter **-** 6.5 μm

Ecology: Fresh Water

Collection SITE: Location 4 (0-2cm) SITE B.

Remarks: It is Alkalibiontic i.e. exclusively occurring at pH >7. Prefers hypereutrophic condition. It can sustain greater Nitrogen concentration (Winder et al. 2009) and its presence indicates increased phosphate concentration (Anneville et al. 2004, Kasperoviciene and Vaikutiene 2007).

***Stephanodiscus minutulus* (Kutzing) Cleve & Moller** (Plate 1 Fig.7)

Description: There are small valves in the shape of a disc with a concentrically undulate valve face. The valve faces are complementary, with scutate (raised) and lacunate (depressed) valves. Areolae are scattered in the middle of the valve and arranged in multiseriate fascicles towards the margin. Areolae number 2-3 per fascicle near the margin, but in many specimens, the areolae may not be resolvable at the margin.

Dimension: Diameter - 6 µm

Ecology: Fresh Water

Collection SITE: Location 5 (30-32cm) SITE B.

Remarks: It is Alkalibiontic i.e. exclusively occurring at pH >7. Nitrogen autotrophic taxa tolerating elevated concentrations of organically bound nitrogen, moderate oxygen requirements, α – mesosaprobous, Prefers hypereutrophic condition mainly occurring in water bodies, sometimes on wet places. The planktonic species *S. minutulus* is generally found in meso- to eutrophic lakes and large rivers of North America (Cumming et al. 1995, Reavie and Smol 1998, Reavie and Kireta 2015). There is an increased abundance of *S. minutulus* in paleolimnological records and this strongly indicates about cultural eutrophication (Reavie et al. 2000).

***Stephanodiscus binderanus* (Kutzing) Kreger** (Plate 1 Fig.8)

Description: Colonies are often preserved in samples. Frustules are in the shape of barrel-shaped cells in the girdle view. The faces of the valve of neighbouring cells may be linked in short to long chains by marginal spines. The face is round and flat in the valve view with a deep mantle. Areolae at the centre of the valve are arranged in a weak annulus. Uniseriate striae radiate from centre to the valve margin. Areolae number 15-17 in 10 µm.

Dimension: Diameter - 8 µm

Ecology: Freshwater

Collection SITE: Location 5 (30-32cm) SITE B.

Remarks: It is α-mesosaprobous, shows eutraphentic trophic state. It occurs only inside water bodies and very rarely occurs outside.

Subclass BIDDULPHIOPHYCIDAE Round & Crawford 1990

Order TRICERATIALES Round and Crawford 1990

Family TRICERATIACEAE (Schutt) Lemmermann 1899

Genus *Pleuosira* Menegh 1848

***Pleurosira laevis* (Ehrenberg) Compère** (Plate 1 Fig.9)

Description: Circular to elliptical in shape and slightly hemispherical. Oppositely placed ocelli are present. The ocelli are the same size. Striae indistinct.

Dimensions: Diameter - 3 μm.

Ecology: Fresh water

Collection SITE: Location 4 (0-2 cm) SITE B.

Comment: Alkalibiontic occurs around pH>7, Oligosaprobous in nature, require eutraentic conditions and mainly occurs in water bodies, also on wet and moist places.

***Pleurosira indica* B.Karthick & Kociolek** (Plate 2 Fig.10)

Description: Circular to elliptical in shape and slightly hemispherical. Three Ocelli 3 and ocelli not exactly opposite one another. Circular groove present. Striae indistinct.

Dimension: Diameter - 3.5 μm

Ecology: Fresh Water

Collection SITE: Location 2 (0-2cm) SITE A, Location 4 (96-98 cm) SITE B.

Remarks: Pleurosira laevis diatom taxon from Cauvery river in India is identical with the features like valve reported by Karthick and Kociolek, (2011) from the Western Ghats, South India.

Class FRAGLLARIOPHYCEAE Round 1990
Subclass FRAGILARIOPHYCIDAE Round 1990
Order FRAGILARIALES Silva 1962
Family FRAGILARIACEAE Greville 1833
Genus *Fragilaria* Lyngbye 1819

***Fragilaria rumpens* Kutzing Lange-B** (Plate 2 Fig.11)

Description: Valve linear slightly attenuated towards the capitates apices. Axial area linear, narrow. Central area forming a fascia reaching the margin, slightly inflated. Striae, parallel.

Dimension: Length 30-46µm, Width 2-3µm

Ecology: Fresh Water

Collection SITE: Location 1 (30-32 cm) SITE A.

Remarks: Circumneutral i.e. It primarily occurs at pH values about 7. It is a Nitrogen autotrophic taxa and can tolerate elevated concentrations of nitrogen which is organically bound, oligo-mesotrophic in nature. They have an affinity to colonise in continuous changing and disturbed system. (Lotter and Bigler, 2000).

***Fragilaria capucina* Desmazières** (Plate 2 Fig.12)

Description: It is a variable species with several varieties described and sometimes with overlapping characteristics. Frustules having narrowly linear to linear-lanceolate valves. The central area is well defined and usually reaches to the valve margins. A well-defined hyaline area is present at the centre of the valve and which is unilaterally or bilaterally inflated.

Dimensions: Valve length: 17.8-97.6µm (Aprrox.)

Ecology: It is benthic and cosmopolitan taxa found in circum neutral, oligo to mesotrophic waters with moderate electrolyte content.

Collection SITE: Location 1 (30-32cm) SITE A.

Remarks: Circumneutral i.e. mainly occuring at pH values about 7, β-mesosaprobous and requires mesotraphentic conditions.

Genus *synedra* Ehrenberg 1830

***Synedra acus* Kützing** (Plate 2 Fig.13)

Description: Long cells with needle-like appearance occur singly or in colonies, areole and raphe are present.

Dimension: length - 20 µm breadth - 1 µm (Approx.)

Ecology: Fresh Water

Collection SITE: Location 4 (0-2 cm) SITE B.

Remarks: It is an indicator of anthropogenic pollution in lakes of Mandya district, Karnataka (Devi and Murthy 2017)

Class Bacillariophyceae
Subclass Eunotiophycidae
Order Eunotiales
Family Eunotiaceae
Genus *Eunotia* Ehrenberg, 1837

***Eunatia faba* Ehrenberg** (Plate 2 Fig.14)

Description: This is characterised by the asymmetric valves which are discreetly arched with dorsal margins. Ventral margins are uncertainly concave. There are largely rounded apices. Terminal raphe fissures are very short. Striae are radiate and very finely punctate. In some specimens, there is an occurrence of forked, or short, costae along the dorsal margins.

Dimension: length - 16µm, breadth - 4.5µm (Approx.)

Ecology: Fresh Water

Collection SITE: Location 1 (0-2cm) SITE A.

Remarks: It is acidophilous i.e. mainly occurring at pH <7. Nitrogen-autotrophic i.e. tolerating very small concentrations of organically bound nitrogen. Requires high oxygen concentrations. Oligosaprobus, shows oligo-mesotraphentic trophic level. It mainly occurs in water bodies, sometimes on wet places. It suggests presence of low pH and Nitrogen and phosphorous concentrations (Velez et al, 2005)

Subclass Bacillariophycidae

Order Cymbellales

Family Gomphonemataceae

Genus *Gomphonema* Ehrenberg, 1832

***Gomphonema parvulum* Kutzing** (Plate 3 Fig.15)

Description: Cells box shaped in girdle view with pseudosepta visible. Apices rounded. Striae coarse and frequently parallel. This species is very variable.

Dimension: Length 11-30µm, Width 3.5-8µm.

Ecology: Freshwater

Collection SITE: Location 1 (0-2cm) SITE A.

Remarks: It is circumneutral i.e. mainly occurring at pH values around 7 facultatively nitrogen-heterotrophic taxa and needs sporadically higher concentrations of organically bound nitrogen, oxygen requirement is low, α-meso-polysaprobous, eutraphentic trophic level mainly occurs in water bodies and frequently on wet and moist places.

Order Cocconeidales

Family Cocconeidaceae

Genus *Cocconeis* Ehrenberg, 1836

***Cocconeis Placentula* Ehrenberg** (Plate 3 Fig.16)

Description: Valves are elliptical in outline. Valve has raphe with radial arrangement, fine. Raphe straight, thread like with closely placed central pores. Elliptical, narrow axial area with indistinct striae.

Dimension: Length - 10µm, Width - 5µm

Ecology: Fresh water

Collection SITE: Location 2 (30-32cm) SITE A.

Remarks: It is alkaliphilous, mainly occurring at pH >7, It is a nitrogen autotrophic taxa can requires moderate oxygen saturation, β-mesosaprobous, Eutraphentic trophic level, mainly occurs in water bodies ,sometimes on wet places.

Family Achnanthidiaceae

***Achnanthidium* Kützing, 1844**

***Achnanthidium Minutissima* (Kützing) Czarnecki** (Plate 3 Fig.17)

Description: Valves are narrow, linear lanceolate with broadly rounded ends. Striae fine. Central area somewhat wider on the raphe valve.

Dimension: Length 8-10µm, Width 3-4 µm

Ecology: Fresh Water

Collection SITE: Location 1 (30-32 cm) SITE A and Location 6 (62-64 cm) SITE B.

Remarks: Sensitive to organic pollution (Kwandrans et al. 1998) and considered as good indicator of disturbance.

***Achnanthidium Eutrophilum* (Lange-Bertalot) Lange-Bertalot** (Plate 3 Fig.18)

Description: Valves are rhombic lanceolate. Presence of linear raphae valve and straight fissures, middle portion of the valve axial area widens slightly.

Dimension: Length: 5µm, Width: 2µm.

Ecology: Fresh Water

Collection SITE: Location 1 (0-2cm and 78-80 cm) and Location 2 (30-32 cm) SITE A.

Remarks: Benthic and mainly dwells in the bottom of water bodies.

***Achnanthidium hoffmannii* Van de Vij., Ect., A. Mert. & Jarl.** (Plate 3 Fig.19)

Description: Valves are rhombic lanceolate. The edges of valves are somewhat circular and body appears like a cavity. Presence of linear raphe valve.

Dimension: length - 7 µm breadth - 2 µm (Approx.)

Ecology: Fresh Water

Collection SITE: Location 1 (30-32cm) SITE A.

Remarks: *Achnanthidium* sp. are found in high flow velocities and are characteristic of good water quality (Kwandrans et al. 1998)

Order Naviculales

Suborder Neidiineae

Family Neidiaceae

Genus *Neidium* Pfitzer, 1871

***Neidium iridies* (Ehrenberg) Cleve** (Plate 3 Fig.20)

Description: The genus Neidium comprises a large group of diatoms with an extensive array in structural and morphological forms. Valve shapes varying from elliptical to linear. It is a large species with somewhat curved margins.

Dimension: length - 20.3 µm breadth - 6 µm (Approx.)

Ecology: Fresh Water

Collection SITE: Location 2 (30-32cm) SITE A.

Remarks: Circumneutral i.e. mostly happening at pH about 7. Nitrogen autotrophic taxa can tolerate very small concentrations of organically bound nitrogen and need very high oxygen saturation. β-mesosaprobous, represents mesotraphentic trophic state and It occurs only in water very rarely occurs outside.

Suborder Naviculineae

Family Naviculaceae

Genus *Navicula* Bory, 1822

***Navicula cryptotenella* Lange-Bertalot** (Plate 3 Fig.21)

Description: Valves more or less narrowly lanceolate. Apex rounded. Raphe filiform to slightly oblique, with proximal endings returning towards the centre. Radiate striae, becoming parallel to convergent at the ends, difficult to resolve in light microscope.

Dimensions: length-25.8-27.4µm, breadth-5.6-5.9 µm

Ecology: Freshwater

Collection SITE: Location 5 (30-32cm) SITE B.

Remarks: It is alkaliphilous i.e. mainly occurring at pH >7, β-mesosaprobous, prefers oligo-to eutraphentic (hypereutraphentic) conditions. Occurs in water bodies, sometimes on wet surfaces.

Family Plagiotropidaceae

Genus *Plagiotropis* Pfitzer, 1871

***Plagiotropis lepidoptera* var. *proboseidea* (Cleve) Reimer** (Plate 3 Fig.22)

Description: Valves are lanceolate. Valve face is arched. The valve face is marked by longitudinal folds and apices are apiculate. The narrow axial area and raphe are positioned on the apex of a raised keel, which run along the apical axis. The central area is asymmetric. Parallel striae at the centre which become increasingly radiate towards the apices. The striae may appear wavy because of the presence of valve contours.

Dimension: Length - 27.3 μm, Breadth - 6 μm (Approx.)

Ecology: Fresh Water

Collection SITE: Location 1 (30-32cm and 78-80cm) SITE A and Location 6 (0-2cm and 26-28cm) SITE B.

Remarks: It has been observed at pH around 8.3 and *Bacillaria*, *Navicula peregrina, Nitzschia siliqua* and *Tryblionella compressa, Navicula namibica,* (diatoms.org, USA) are its common diatom associates.

Order Thalassiophysales

Family Catenulaceae

Genus *Amphora* Ehrenberg ex Kützing, 1844

***Amphora pediculus* (Kützing) Grunow** (Plate 4 Fig.23)

Description: Valves are moderately dorsiventral, semi elliptical to semi-circular. Straight to slightly concave ventral margin; raphe is straight and with proximal raphe ends straight. Distinct dorsal and ventral fascia present and extending to valve margins. Dorsal striae distinctly punctate, ventral striae composed of a single row of areolae.

Ecology: Cosmopolitan species which is found in waters with moderate electrolyte contents and tolerating critical levels of pollution. This species may be epiphytic on other algae, including diatoms.

Dimensions: Length - 19.8 μm, Breadth - 4.4μm

Collection SITE: Location 6 (26-28 cm) SITE B

Remarks: Mainly occurring at pH>7 i.e. alkaliphilous, Nitrogen-autotrophic taxa can tolerate elevated concentration of organically bound nitrogen, requires fairly high amount of oxygen concentration, β-mesosaprobous and present in eutraphentic trophic conditions. Mainly happening in water bodies, can be found on wet & moist places (Van Dam et al.1994).

Order Bacillariales

Family Bacillariaceae

Genus *Tryblionella* W.Smith, 1853

***Tryblionella brunoi* (Lange-Bertalot) Cantonati & Lange-Bertalot** (Plate 4 Fig.24)

Description: Valves are typically linear-lanceolate to elliptical in some species and possess an eccentric raphe. The raphe systems within a frustule are positioned on opposite, in the manner of nitzschioid symmetry. A distinct longitudinal undulation on the face of valves.

Dimension: length - 35 μm breadth - 5 μm (Approx.)

Ecology: Fresh Water

Collection SITE: Location 5 (67-69 cm) SITE B.

Remarks: T. brunoi is found in abundance in carbonate-rich waters (Lange-Beralot and Metzeltin 1996). The species is more commonly found in mesotrophic or oligotrophic waters, though it has been found in a slightly less quantity in eutrophic waters.

***Nitzschia* Hassall, 1845,**

***Nitzschia palea* var. debilis (Kutzing) Grunow** (Plate 4 Fig.25)

Description: Valves are lanceolate, gradually tapered apical ends with more or less parallel sides. Apices are rounded and fibulae number about 12-15 in 10 µm. Striae are not visible with light microscope.

Dimensions: Length-23.7, Breadth-2.2µm

Ecology: Freshwater

Collection SITE: Location 3 (59-61 cm) SITE A.

Remarks: Circumneutral i.e. occurring at pH values about 7, It is an obligately nitrogen-heterotrophic taxa, needing continuously elevated concentrations of organically bound nitrogen, requirements for oxygen saturation is low (above 30% saturation) Polysaprobous, prefers hypereutraphentic trophic state. It mainly occurs in water bodies, and regularly on wet and moist places.

***Nitzschia acicularis* (Kützing) W.Smith** (Plate 4 Fig.26)

Description: It possesses sharp tapering end central part of the valve has nearly parallel sides. The fibulae are fine and restricted to the margin with a density 16-21 in 10 µm.

Dimension: Length 30-100 µm, Width 3-4 µm

Ecology: Fresh Water

Collection SITE: Location 6 (62-64 cm) SITE B.

Remarks: mainly occurring at ph>7 i.e. alkaliphilous, obligately nitrogen-heterotrophic taxa which requires incessantly elevated concentrations of organically bound nitrogen and low oxygen concentration,α-mesosaprobous, eutraphentic trophic state, never occurs outside water bodies or occurs very rarely outside water bodies (Van Dam et al.1994).

***Nitzchia recta* Hantzsch** (Plate 4 Fig.27)

Description: Valves are bilaterally symmetrical, linear lanceolate. Cells solitary. Frustules isopolar.Fibulae appears like short transverse ribs in valve view. Striae fine.

Dimension: Length – 38 µm, Breadth - 5µm.

Ecology: Fresh Water

Collection SITE: Location 4 (30-32 cm) and Location 5 (67-69 cm) SITE B.

Remarks: Occurs at pH>7 i.e. alkaliphilous. Nitrogen-eutrophic taxa, tolerating raised concentrations of organically bound nitrogen. Requires fairly high oxygen content β-mesosaprobous and favours olig-to entraphentic conditions never or only very rarely occurs outside water bodies.

***Nitzschia fonticola* Grunow** (Plate 4 Fig.28)

Description: Valves are broadly lanceolate, having margins that are curved tapering down to narrow ends. The apices are knob shaped and rounded. Striae are distinct and parallel.

Dimension: Length - 10.5 μm Breadth - 2.5 μm (Approx.)

Ecology: Fresh Water

Collection SITE: Location 1 (0-2cm) SITE A, Location 6 (0-2cm and 26-28 cm) SITE B.

Remarks: Mainly occurring at pH>7 i.e. alkaliphilous, Nitrogen-autotrophic taxa can tolerate higher concentration of organically bound nitrogen, requires fairly high amount of oxygen concentration, β-mesosaprobous and present in eutraphentic trophic conditions. never or only very rarely occurs outside water bodies (Van Dam et al.1994).

Subclass Thalassiosirophycidae

Order Stephanodiscales

Family Stephanodiscaceae

Genus *Pantocsekiella* K.T.Kiss & E.Ács, 2016

***Pantocsekiella costei* (J.C.Druart & F.Straub) K.T.Kiss & E.Ács** (Plate 5 Fig.29)

Description: Frustules are disc–shaped, solitary, seldom in short chains. Valves circular or slightly quadrangular, the valve face divided into a polygonal central area and a striated marginal one. Small granules are frequently observed on the interstriae near the margin and found sporadically on the whole valve face.

Dimension: Diameter – 13.3 µm

Ecology: Fresh Water

Collection SITE: Location 5 (30-32cm) SITE B.

Remarks: It is a small sized species. It is reported from modern and fossil samples with varied habitats like littoral and pelagic, Oligo- to mesotrophic and alkaline water bodies (Houk and Klee, 2004)

Class Synurophyceae

Order Synurales

Family Mallomonadaceae

Genus *Mallomonas* Perty, 1852

***Mallomonas* sp.** (Plate 5 Fig.30)

Description: The cells are elongated-ovoid to elongate-elliptical. The tripartite scale type consists of dome, V-rib and flange united by basal plate. Its exact identification is based on the fine structure of the silica sclaes and bristles. In present taxa only scale was found and observed (Siver, 1991).

Dimension: Length - 5 µm, Breadth - 3.1 µm (Approx.)

Ecology: Fresh Water

Collection SITE: Location 1 (0-2cm) SITE A.

Remarks: It's a plankton community occurs together with mesotrophic desmids and can inhabit peat bog pools in waterbodies which are usually visited by animals (Peterfi et al 2005). Many species can withstand pH variations, ranging from 4-8 and can live in slightly acidic waters.

Order Naviculales

Suborder Naviculineae

Family Stauroneidaceae

***Stauroneis* Ehrenberg, 1843**

***Stauroneis* sp.** (Plate 5 Fig.31)

Description: Valves are elliptic-lanceolate with constricted subcapitate and ends are rounded broadly. Raphe are thin, thread- like and straight. Axial area is narrow, central area is wide, and it broadens towards the sides.

Dimension: Length - 25 µm, Breadth - 6µm (Approx.)

Ecology: Fresh Water

Collection SITE: Location 3 (26-28cm) SITE A.

Remarks: *Stauroneis anceps* diatom taxon from Cauvery river in India was observed by Karthikeyan and Venkatachalapathy, 2015. It was noted in circumneutral to acidic and the specific conductivity, suspended solids and low concentrations of nutrient. (Atazadeh et al, 2014)

4.3. RESULTS SEM-EDAX

In all 18 samples EDAX analysis revealed Silicon (Si), Oxygen (O), Niobium (Nb) and Aluminium (Al) as the main elements in sediments. Si and O were present in major quantities in almost all the samples while Nb was recorded in very less amount in sample taken from surface (0-2cm) of location 1 of SITE A (Palla) similarly Al was recorded from location 5 and 6 of SITE B at the depth of 30-32 cm and 62-64 cm. Elemental weight percentage and atomic percentage distribution in all the soil samples and the various depths on which samples were taken has been elucidated in Tables 4.3-4.6 while and SEM images showing soil particles and EDAX graphs representing all observed elements are shown in Fig. 4.1-4.6 and Fig. 4.7-4.24 respectively [Gold (Au) was also shown in graphs because soil samples were plated with gold to observe diatoms, therefore Au value has been discarded in present study].

Table 4.3. Elements Atomic % of Three Locations at SITE A (Palla Village)

Elements	Depths at Location 1 (cm)			Depths at Location 2 (cm)			Depths at Location 3 (cm)		
	0-2	30-32	78-80	0-2	30-32	74-76	0-2	26-28	59-61
	Atomic %								
Oxygen (O)	57.78	0	55.09	0	58.92	95.35	0	0	91.84
Silicon (Si)	36.78	83.85	38.69	89.27	35.49	0	79.82	81.94	0
Niobium (Nb)	0.32	0	0	0	0	0	0	0	0
Aluminium (Al)	0	0	0	0	0	0	0	0	0

Table 4.4. Elements Weight % of Three Locations at SITE A (Palla Village)

Elements	Depths at Location 1 (cm)			Depths at Location 2 (cm)			Depths at Location 3 (cm)		
	0-2	30-32	78-80	0-2	30-32	74-76	0-2	26-28	59-61
	Weight %								
Oxygen (O)	30.86	27.6	0	0	31.01	62.51	0	0	47.76
Silicon (Si)	34.48	34.03	42.54	54.26	32.79	0	36.06	39.28	0
Niobium (Nb)	0.98	0	0	0	0	0	0	0	0
Aluminium (Al)	0	0	0	0	0	0	0	0	0

Table 4.5. Elements Atomic % of Three Locations at SITE B (Okhla barrage)

Elements	Depths at Location 4 (cm)			Depths at Location 5 (cm)			Depths at Location 6 (cm)		
	0-2	30-32	76-98	0-2	30-32	67-69	0-2	26-28	62-64
	Atomic %								
Oxygen (O)	86.66	92.36	0	62.31	0	92.2	95.78	94.43	56.2
Silicon (Si)	0	0	81.67	31.75	60.17	0	0	0	25.3
Niobium (Nb)	0	0	0	0	0	0	0	0	0
Aluminium (Al)	0	0	0	0	25.51	0	0	0	16.7

Table 4.6. Elements Weight % of Three Locations at SITE B (Okhla barrage)

Elements	Depths at Location 4 (cm)			Depths at Location 5 (cm)			Depths at Location 6 (cm)		
	0-2	30-32	76-98	0-2	30-32	67-69	0-2	26-28	62-64
	Weight %								
Oxygen (O)	34.54	49.54	0	32.6	0	48.98	64.86	57.94	37.24
Silicon (Si)	0	0	38.85	29.16	32.5	0	0	0	29.43
Niobium (Nb)	0	0	0	0	0	0	0	0	0
Aluminium (Al)	0	0	0	0	13.24	0	0	0	18.67

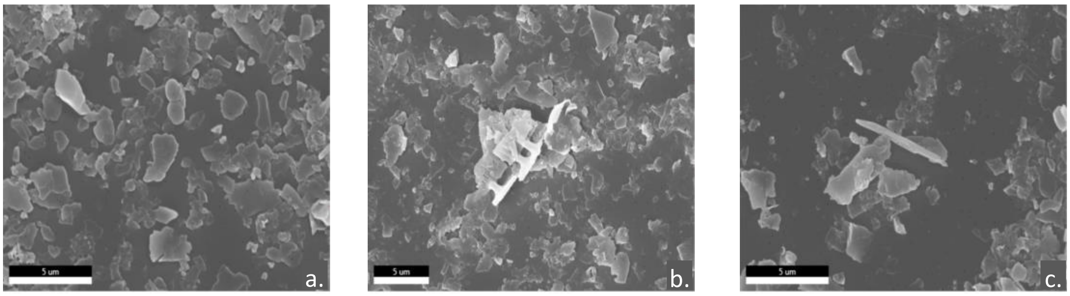

Fig. 4.1: SEM images showing soil particles of different depths (a) 0-2cm, (b) 30-32cm, (c) 78-80cm at Location 1 of SITE A (Palla Village).

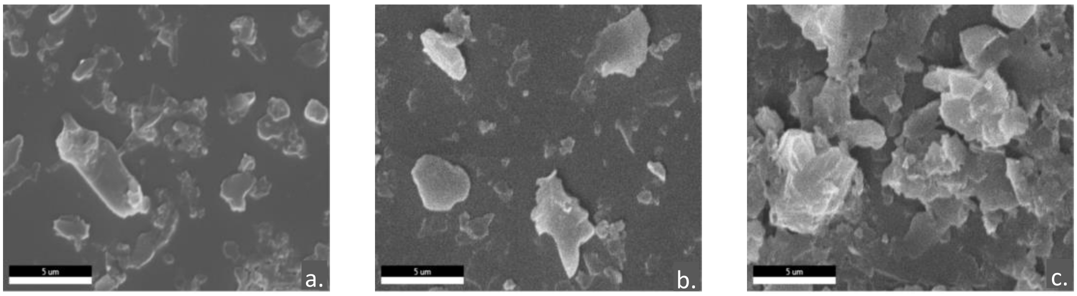

Fig. 4.2: SEM images showing soil particles of different depths (a) 0-2cm, (b) 30-32cm, (c) 74-76cm at Location 2 of SITE A (Palla Village).

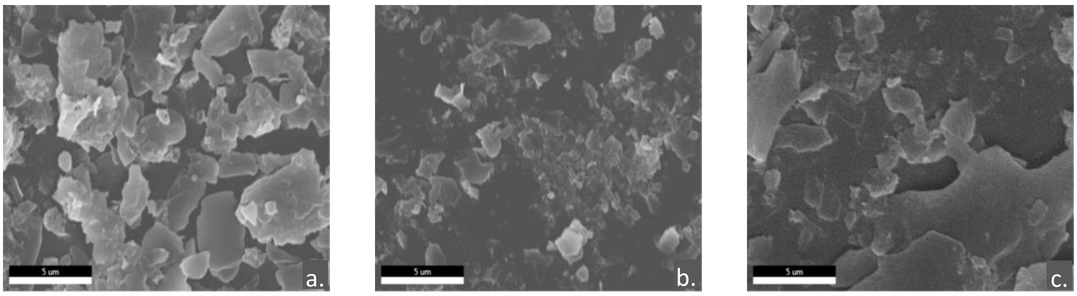

Fig. 4.3: SEM images showing soil particles of different depths (a) 0-2cm, (b) 26-28cm, (c) 59-61cm of Location 3 of SITE A (Palla Village).

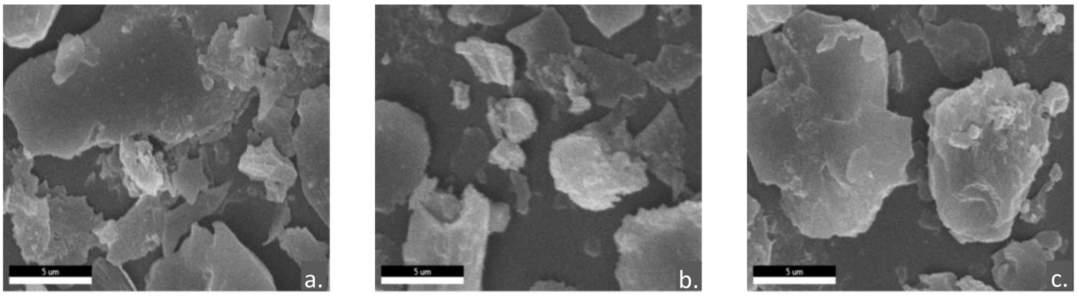

Fig. 4.4: SEM images showing soil particles of different depths (a) 0-2cm, (b) 30-32cm, (c) 96-98cm at Location 4 of SITE B (Okhla barrage).

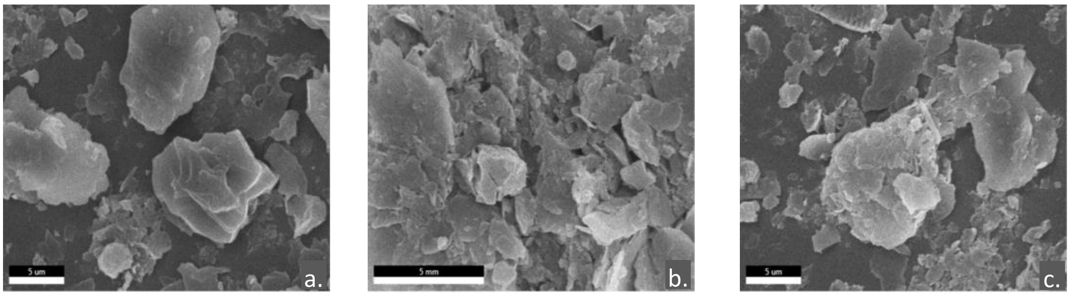

Fig. 4.5: SEM images showing soil particles of different depths (a) 0-2cm, (b) 30-32cm, (c) 67-69cm at Location 5 of SITE B (Okhla barrage).

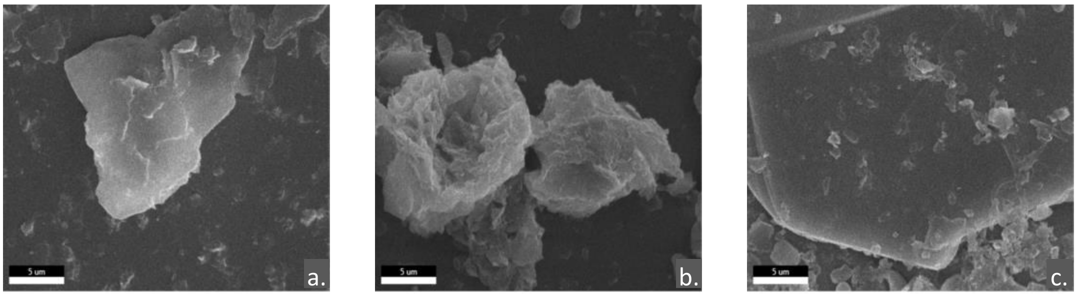

Fig. 4.6: SEM images showing soil particles of different depths (a) 0-2cm, (b) 26-28cm, (c) 62-64cm at Location 6 of SITE B (Okhla barrage).

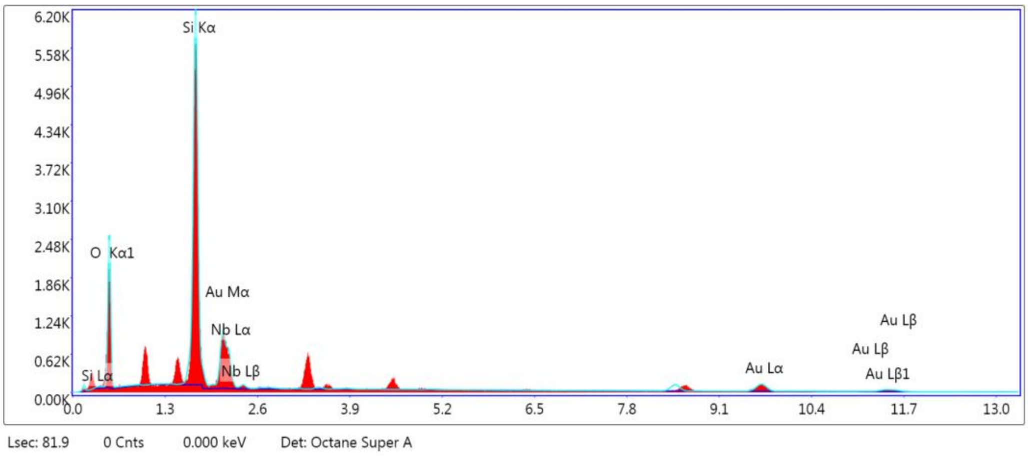

Fig. 4.7: EDAX spectrum of Location 1 (Depth 0-2 cm) at SITE A (Palla Village).

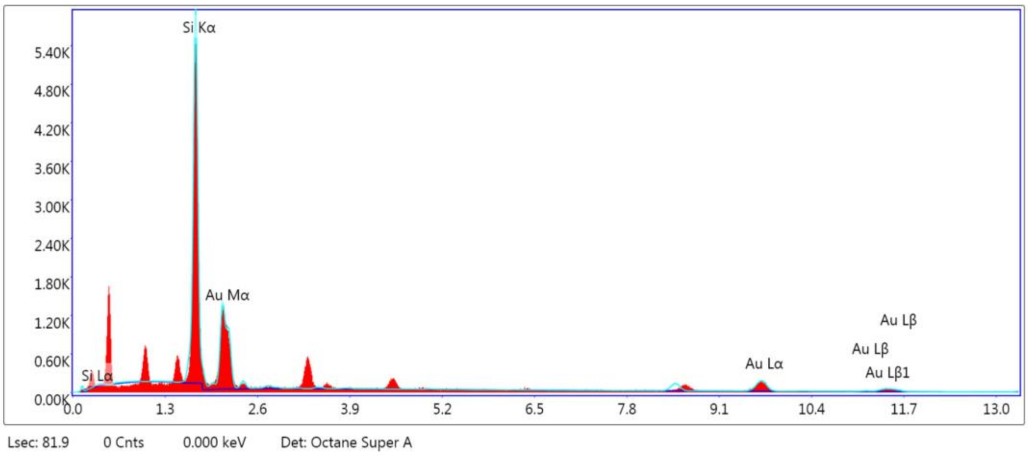

Fig. 4.8: EDAX spectrum of Location 1 (Depth 30-32 cm) at SITE A (Palla Village).

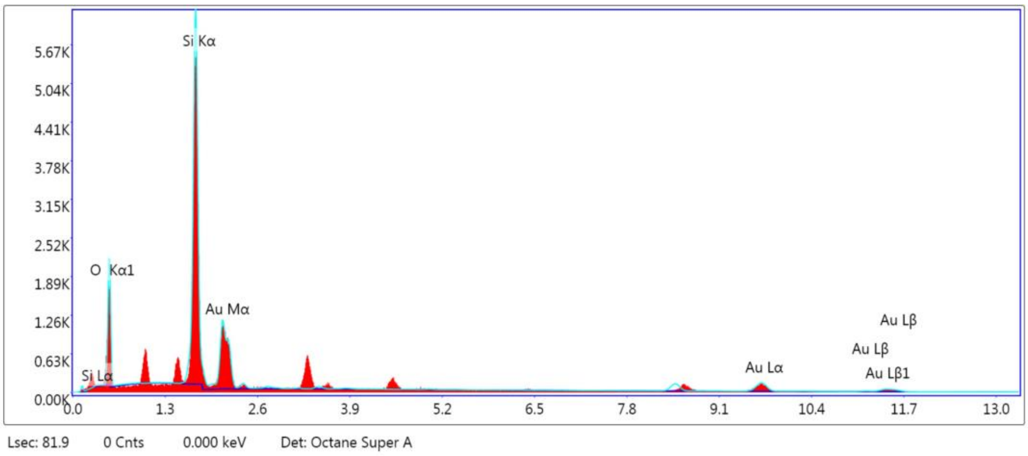

Fig. 4.9: EDAX spectrum of Location 1 (Depth 80-82 cm) at SITE A (Palla Village).

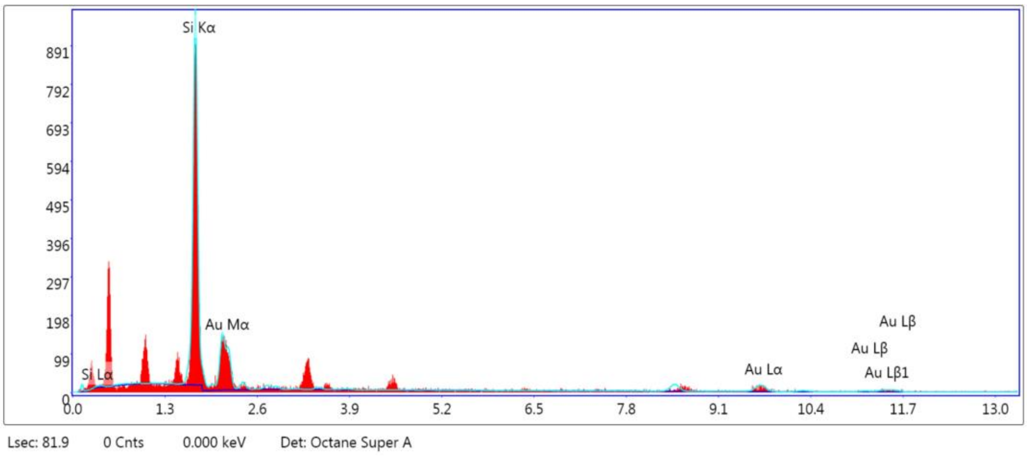

Fig. 4.10: EDAX spectrum of Location 2 (Depth 0-2 cm) at SITE A (Palla Village).

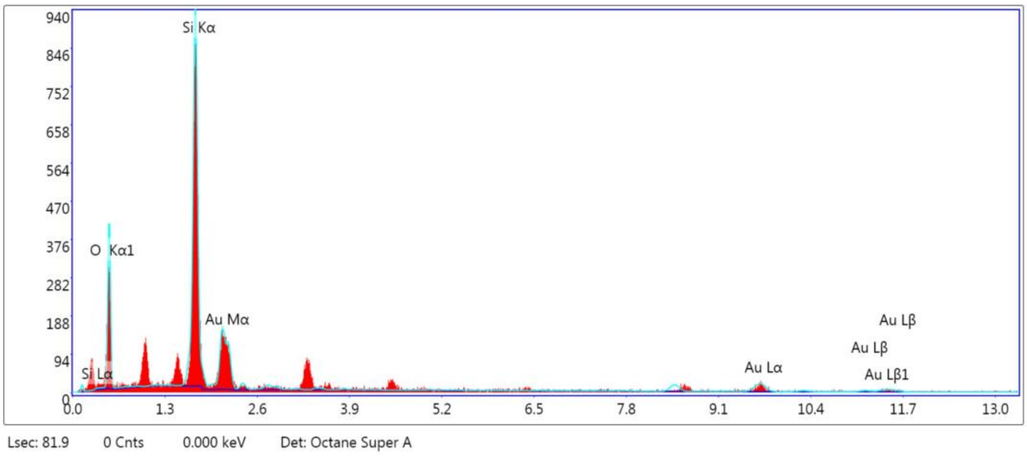

Fig. 4.11: EDAX spectrum of Location 2 (Depth 30-32 cm) at SITE A (Palla Village).

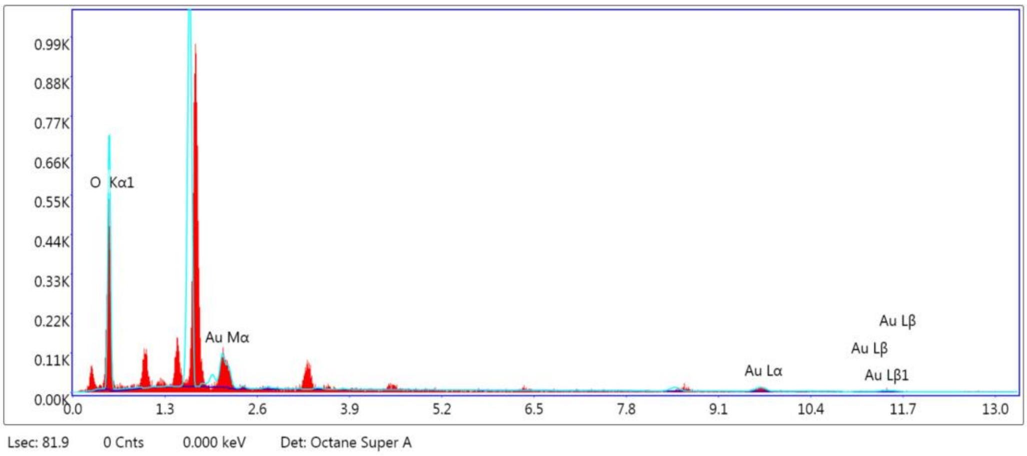

Fig. 4.12: EDAX spectrum of Location 2 (Depth 74-76 cm) at SITE A (Palla Village).

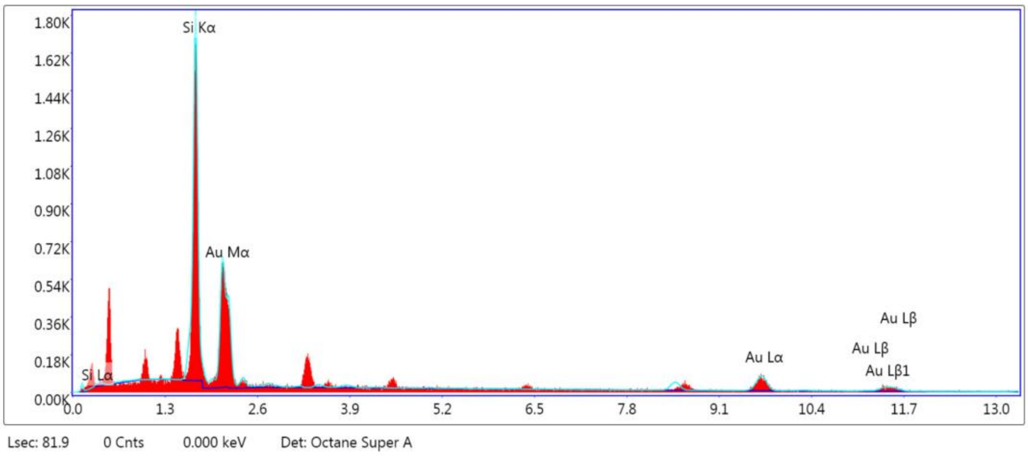

Fig. 4.13: EDAX spectrum of Location 3 (Depth 0-2 cm) at SITE A (Palla Village).

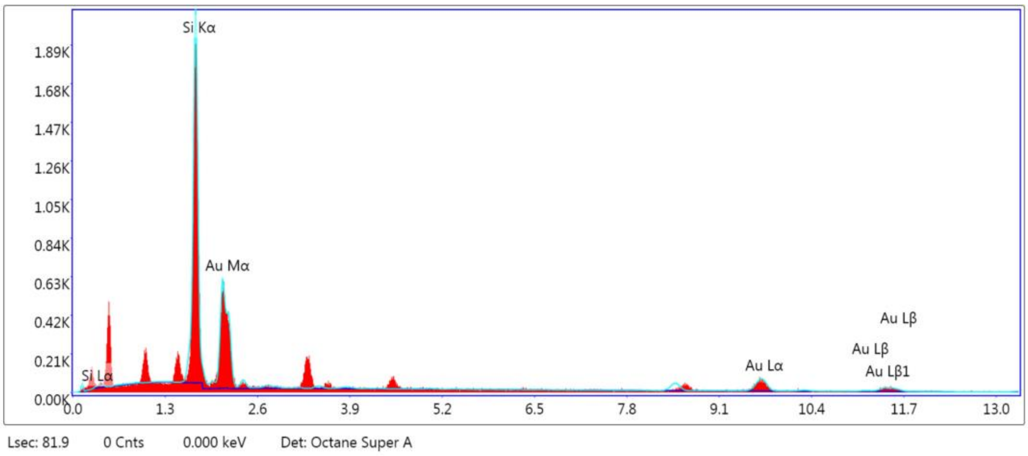

Fig. 4.14: EDAX spectrum of Location 3 (Depth 26-28 cm) at SITE A (Palla Village).

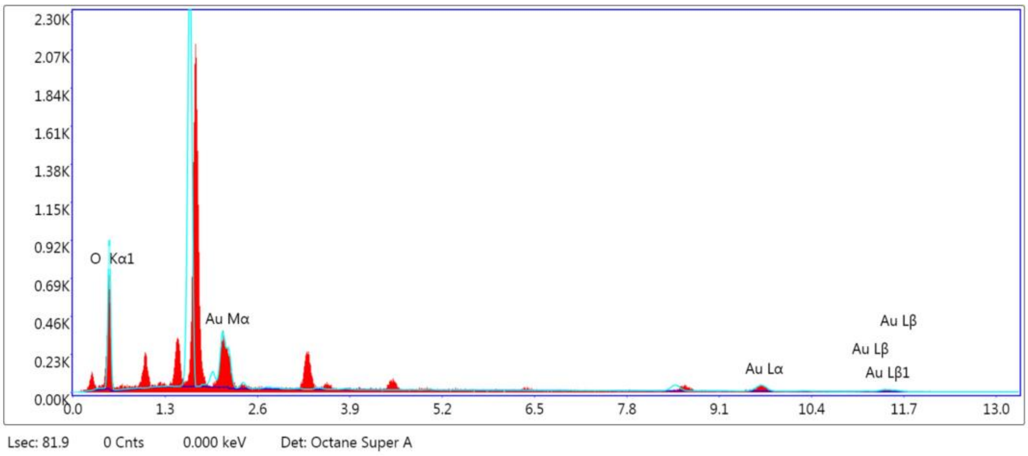

Fig. 4.15: EDAX spectrum of Location 3 (Depth 59-61 cm) at SITE A (Palla Village).

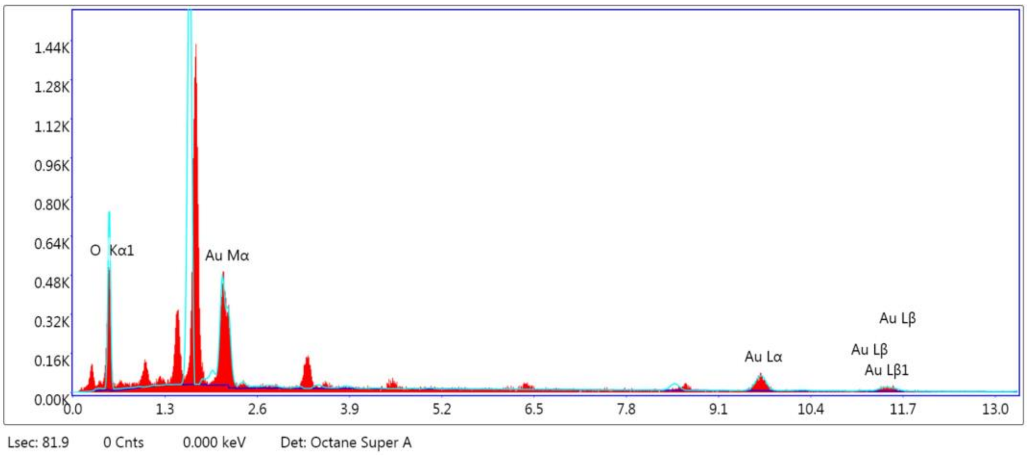

Fig. 4.16: EDAX spectrum of Location 4 (Depth 0-2 cm) at SITE B (Okhla barrage).

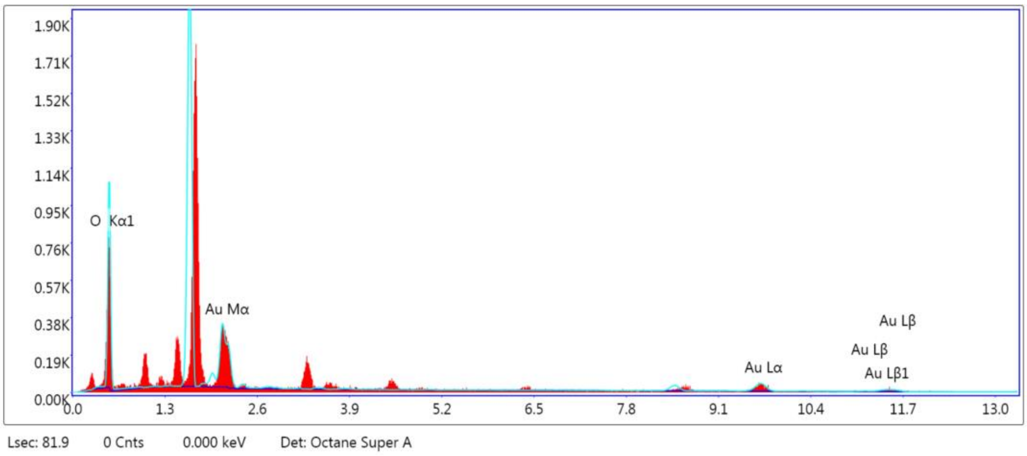

Fig. 4.17: EDAX spectrum of Location 4 (Depth 30-32 cm) at SITE B (Okhla barrage).

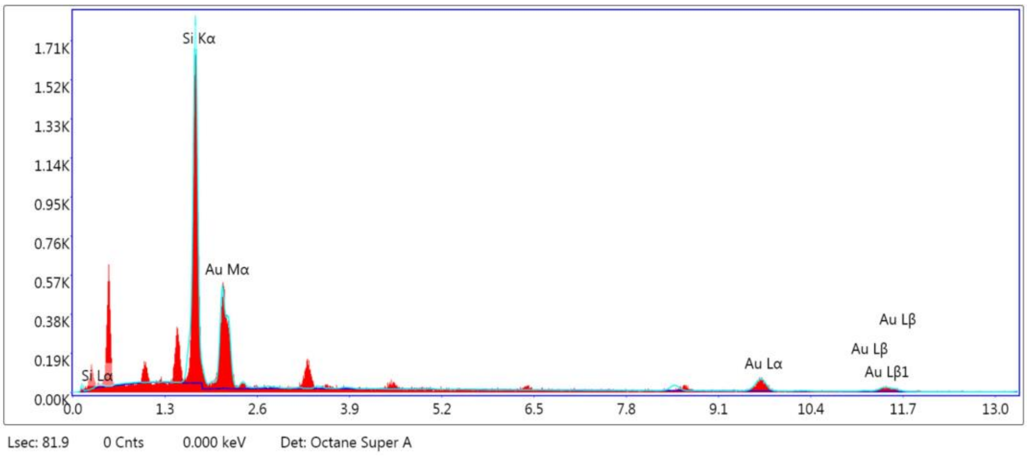

Fig. 4.18: EDAX spectrum of Location 4 (Depth 76-98 cm) at SITE B (Okhla barrage).

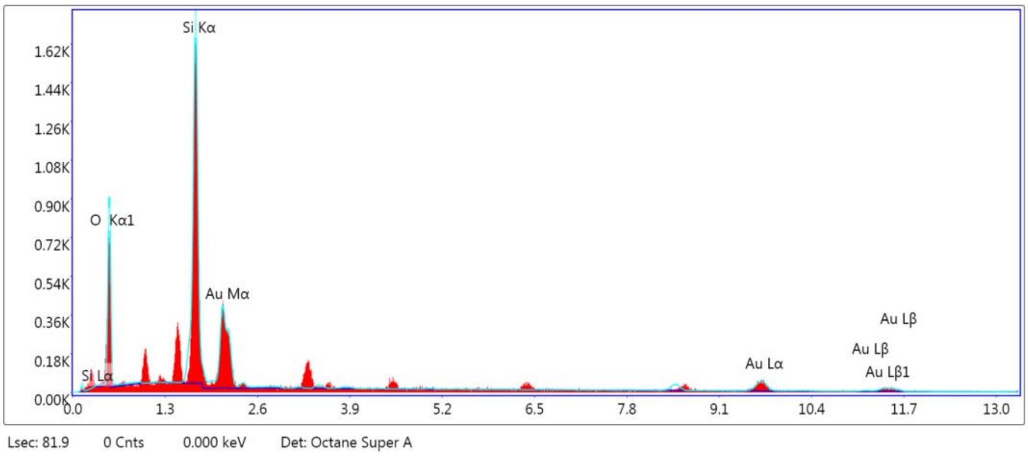

Fig. 4.19: EDAX spectrum of Location 5 (Depth 0-2 cm) at SITE B (Okhla barrage).

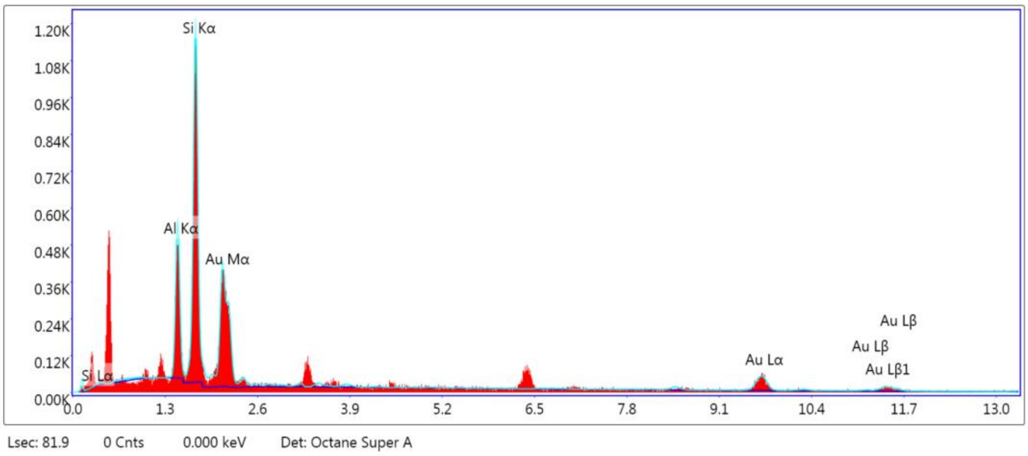

Fig. 4.20: EDAX spectrum of Location 5 (Depth 30-32 cm) at SITE B (Okhla barrage).

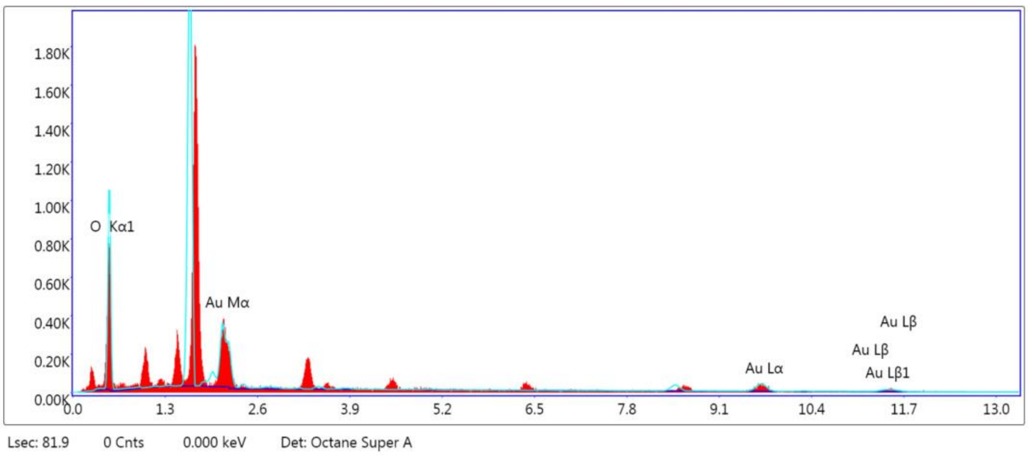

Fig. 4.21: EDAX spectrum of Location 6 (Depth 67-69 cm) at SITE B (Okhla barrage).

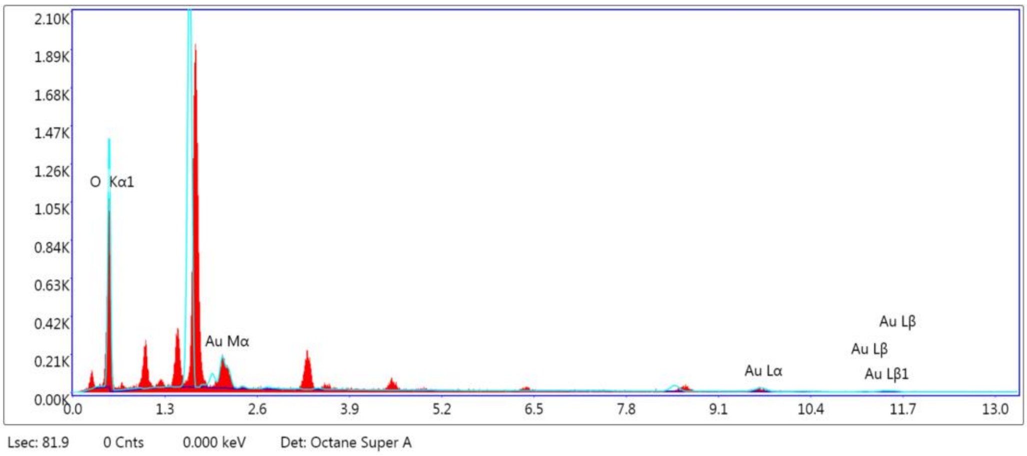

Fig. 4.22: EDAX spectrum of Location 6 (Depth 0-2 cm) at SITE B (Okhla barrage).

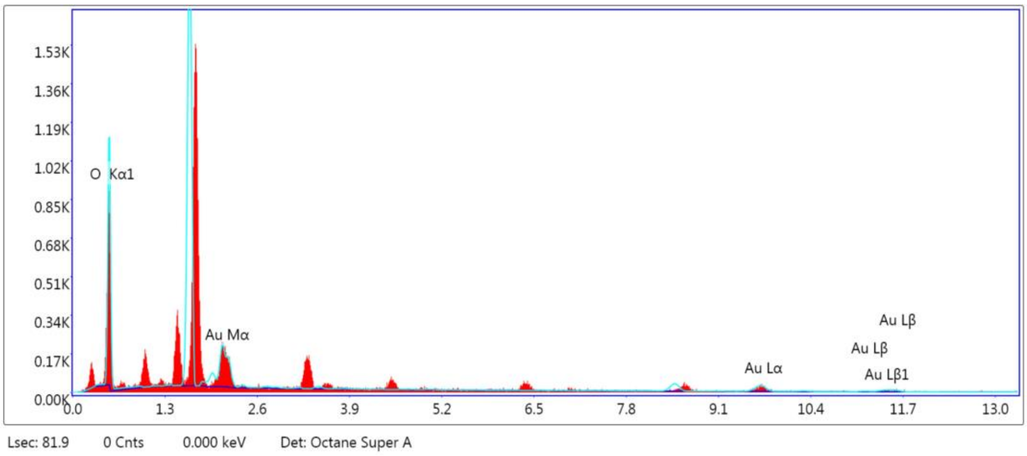

Fig. 4.23: EDAX spectrum of Location 6 (Depth 26-28 cm) at SITE B (Okhla barrage).

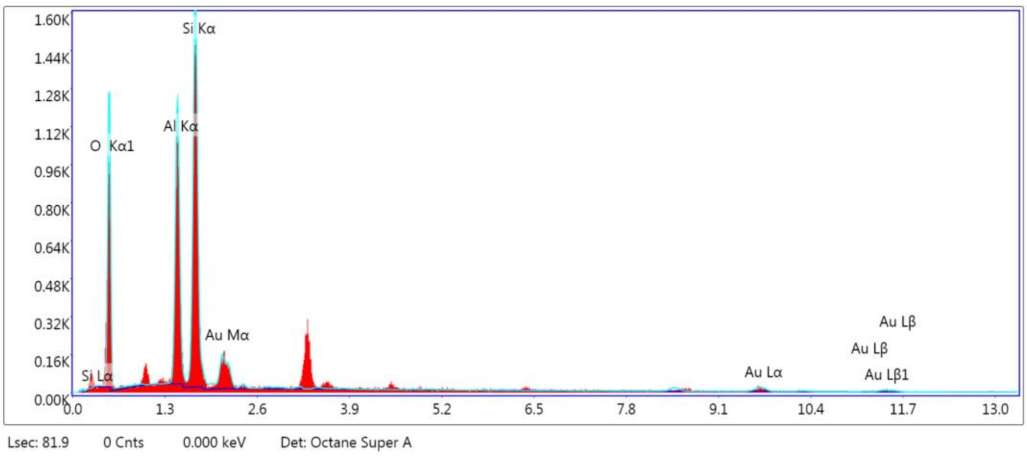

Fig. 4.24: EDAX spectrum of Location 6 (Depth 62-64 cm) at SITE B (Okhla barrage).

4.4. RESULTS CHNS

Percentage concentration of total Carbon, Hydrogen, Nitrogen and Sulphur in all 18 samples from both the sites is shown in Tables 4.7-4.8. Total Carbon at SITE A ranged from 0.11 to 0.45 % while Hydrogen, Nitrogen and Sulphur ranged between 0.132-0.299 %, 0.09-0.28 % and 0.01-0.024 % respectively. SITE B percentage range varied from 0.17 to 0.33% in case of Carbon and from 0.126-0.371%, 0.09-0.29% and 0.017-0.104% of Hydrogen, Nitrogen and Sulphur respectively. [Results of Sample taken from depth 76-78 cm at location 4 was not recorded because of technical error]

The C/N and C/H ratios of both the sites are shown in Tables 4.9-4.10. The variation between the ratio of Nitrogen and Hydrogen with Carbon has been also recorded. C/N ratio ranged from 0.494-2.1254 and from 0.433-1.7838 in case of C/H at SITE A while C/N and C/H ratio at SITE B varied from 1.0237-3.472 and 0.8223-2.7341 respectively.

Table 4.7. Elements Concentration % of Three Locations at SITE A (Palla village)

Elements	Depths at Location 1 (cm)			Depths at Location 2 (cm)			Depths at Location 3 (cm)		
	0-2	30-32	78-80	0-2	30-32	74-76	0-2	26-28	59-61
	Concentration %								
Carbon (C)	0.45	0.13	0.32	0.21	0.32	0.24	0.11	0.45	0.35
Hydrogen (H)	0.284	0.155	0.189	0.132	0.209	0.135	0.253	0.299	0.243
Nitrogen (N)	0.21	0.12	0.14	0.09	0.2	0.1	0.22	0.28	0.2
Sulphur (S)	0.013	0.007	0.011	0.01	0.024	0.01	0.013	0.03	0.011

Table 4.8. Elements Concentration % of Three Locations at SITE B (Okhla barrage)

Elements	Depths at Location 4 (cm)			Depths at Location 5 (cm)			Depths at Location 6 (cm)		
	0-2	30-32	76-98	0-2	30-32	67-69	0-2	26-28	62-64
	Concentration %								
Carbon (C)	0.26	0.32	*	0.22	1.01	0.33	0.17	0.23	0.33
Hydrogen (H)	0.202	0.153	*	0.126	0.371	0.358	0.202	0.136	0.21
Nitrogen (N)	0.18	0.1	*	0.11	0.29	0.24	0.16	0.09	0.14
Sulphur (S)	0.022	0.04	*	0.017	0.104	0.06	0.033	0.039	0.039

***Shows error**

Table 4.9. C/N and C/H Ratios of Three Locations at SITE A (Palla village)

Ratio (%)	Depths at Location 1 (cm)			Depths at Location 2 (cm)			Depths at Location 3 (cm)		
	0-2	30-32	78-80	0-2	30-32	74-76	0-2	26-28	59-61
C/N	2.1254	1.1501	2.2375	2.19	1.62	2.3089	0.494	1.613	1.7171
C/H	1.5808	0.8669	1.7143	1.5696	1.5326	1.7838	0.433	1.4954	1.4376

Table 4.10. C/N and C/H Ratios of Three Locations at SITE B (Okhla barrage)

Ratio (%)	Depths at Location 4 (cm)			Depths at Location 5 (cm)			Depths at Location 6 (cm)		
	0-2	30-32	76-98	0-2	30-32	67-69	0-2	26-28	62-64
C/N	1.4516	3.1508	*	2.0066	3.472	1.38	1.0237	2.6081	2.3696
C/H	1.2698	2.0713	*	1.7178	2.7341	0.9184	0.8223	1.7254	1.5812

***Shows error**

4.5. RESULTS XRD

Total 6 random samples were analysed from SITE A and SITE B. various minerals were identified with the help of diffractograms by analyzing the peak's position, shape breadth and intensity (Klug and Alexander 1954). The mineralogical configuration of the all soil sediment samples was analysed by diffractogram which is generated from XRD study.

The mineral having strongest peak in diffractogram in all sediment samples is quartz along with muscovite and other minerals like Melanovanadite, Gismondine, Iron, $F_{10}NaTm_3$, AlNi, $Fe_{2.87}Si_{0.99}$, $Na_{0.35}(CoO_2)(D_2O)_{1.43}$, $F_{15}Mo_5O_{15}Rb_{15}$, $Co_{1.67}Na_{0.21}(Al_4Si_8O_{24})$, $La_2Mo_2O_9$ and Co_2Feln. All the minerals found at both the sites at different depths of the location has been shown in Table 4.11 and the diffractogram of all the sites have been shown in Fig. 4.25-4.30.

Table 4.11. Compounds at different locations of SITE A (Palla village) and SITE B (Okhla barrage)

S.No.	Compound	SITE A			SITE B		
		Depth (cm)			Depth (cm)		
		0-2	30-32	78-80	0-2	26-28	62-64
1.	Silicon oxide Quartz (SiO_2)	P	P	P	P	P	P
2.	Muscovite $(KF)_2 (Al_2O_3) (SiO_2)_6$	P	A	A	A	A	A
3.	Iron (Fe)	P	A	P	P	A	A
4.	$F_{10}NaTm_3$	P	A	A	A	A	A
5.	AlNi	A	P	A	A	A	A
6.	$Fe_{2.87} Si_{0.99}$	A	P	A	A	A	A
7.	$Na_{0.35} (Co O_2) (D_2 O)_{1.43}$	A	P	A	A	P	A
8.	$F_{15}Mo_5O_{15}Rb_{15}$	A	A	P	P	A	A
9.	$Co_{1.67} Na_{0.21} (Al_4 Si_8 O_{24})$	A	A	P	P	A	A
10.	$La_2Mo_2O_9$	A	A	A	A	P	A
11.	Co_2FeIn	A	A	A	A	P	A
12.	Melanovanadite ($Ca_{1.02} H_{10} O_{15} V_4$)	A	A	A	A	A	P
13.	Gismondine ($Al_2CaH_8O_{12}Si_2$)	A	A	A	A	A	P

A-Absent, P-Present

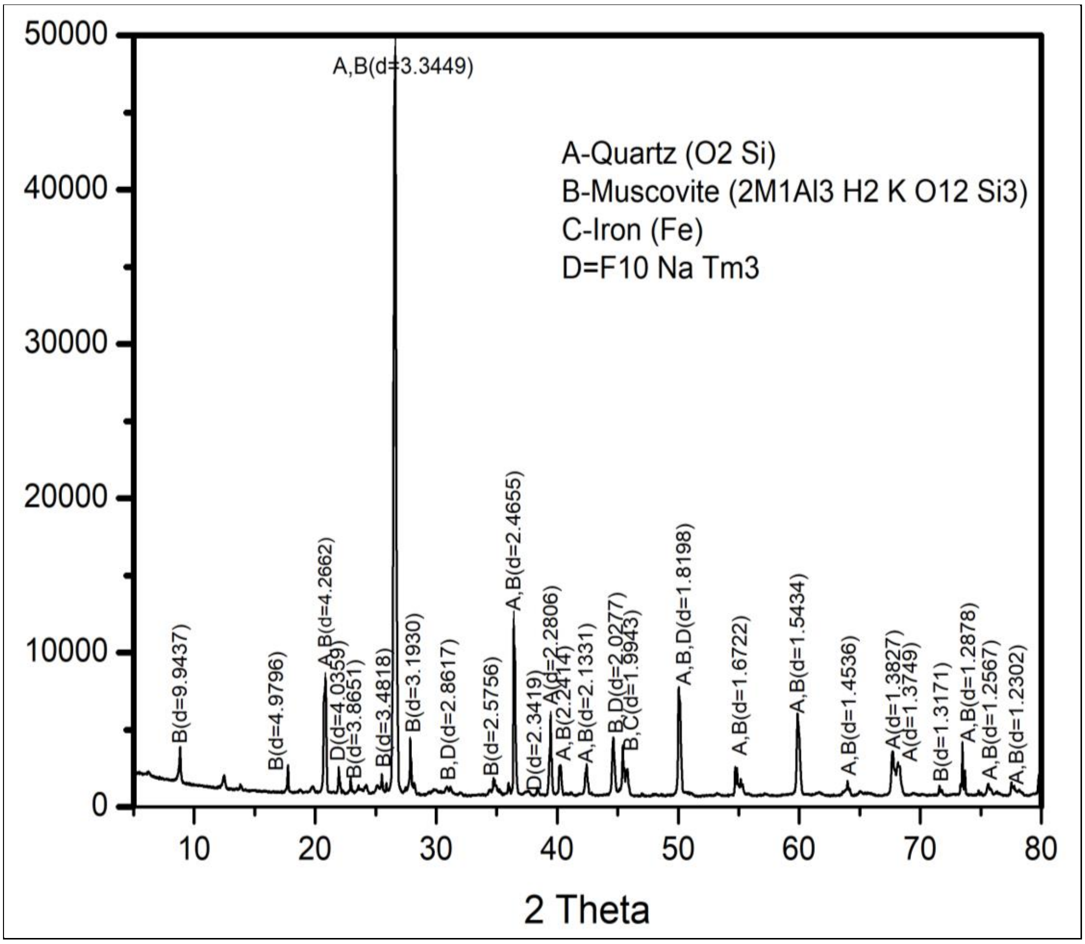

Fig 4.25: Diffractogram of soil samples at Depth (0-2 cm), SITE A

XRD analysis of sample from SITE A surface (0-2 cm) revealed following compounds:

A. Quartz- 94.6 % of the peaks matched with quartz having trigonal crystal system with unit cell parameters a = 4.210Aº, C = 5.4163 Aº
B. Muscovite – 2.8 % of peaks matched with muscovite having monoclinic crystal structure with unit cell parameters a = 5.1800 Aº, b = 9.020 Aº, c = 20.0400 Aº, β = 95.500 Aº
C. Iron- 2.0 % of the peaks matches with iron having cubic crystal system with unit cell parameters a = 2.8213 Aº
D. $F_{10}NaTm_3$ – 0.5 % of the peaks matched with $F_{10}NaTm_3$ having cubic crystal system with unit cell parameters a = 5.7400 Aº.

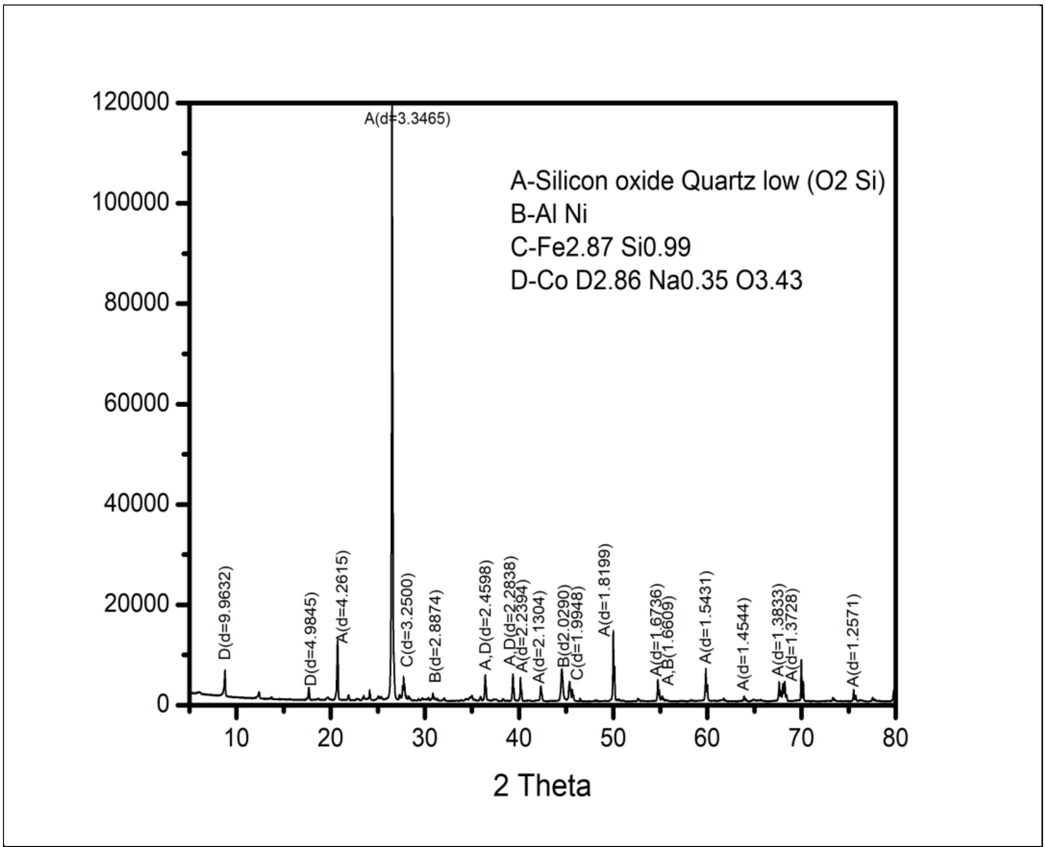

Fig. 4.26: Diffractogram of soil samples at Depth (30-32 cm), SITE A

XRD analysis of sample from SITE A depth (30-32 cm) revealed following compounds Major compounds:

A. Silicon oxide Quartz low – 94.7 % peaks matched with Quartz having trigonal crystal system with unit cell parameters a = 4.9199 A°, c = 5.4000 A°.
B. 2.5 % of the peaks matched with AlNi having cubic crystal system with unit cell parameters as a = 2.8810 A°.
C. 1.4 % of the peaks matched with $Fe_{2.87}$ $Si_{0.99}$ having cubic crystal system with unit cell parameter a= 5.6520 A°.
D. 1.4 % of peaks matched with $Na_{0.35}$ (Co O_2) (D_2 O)$_{1.43}$ having a Hexagonal crystal system with unit cell parameter a=2.8217 A° and c=19.7681 A°.

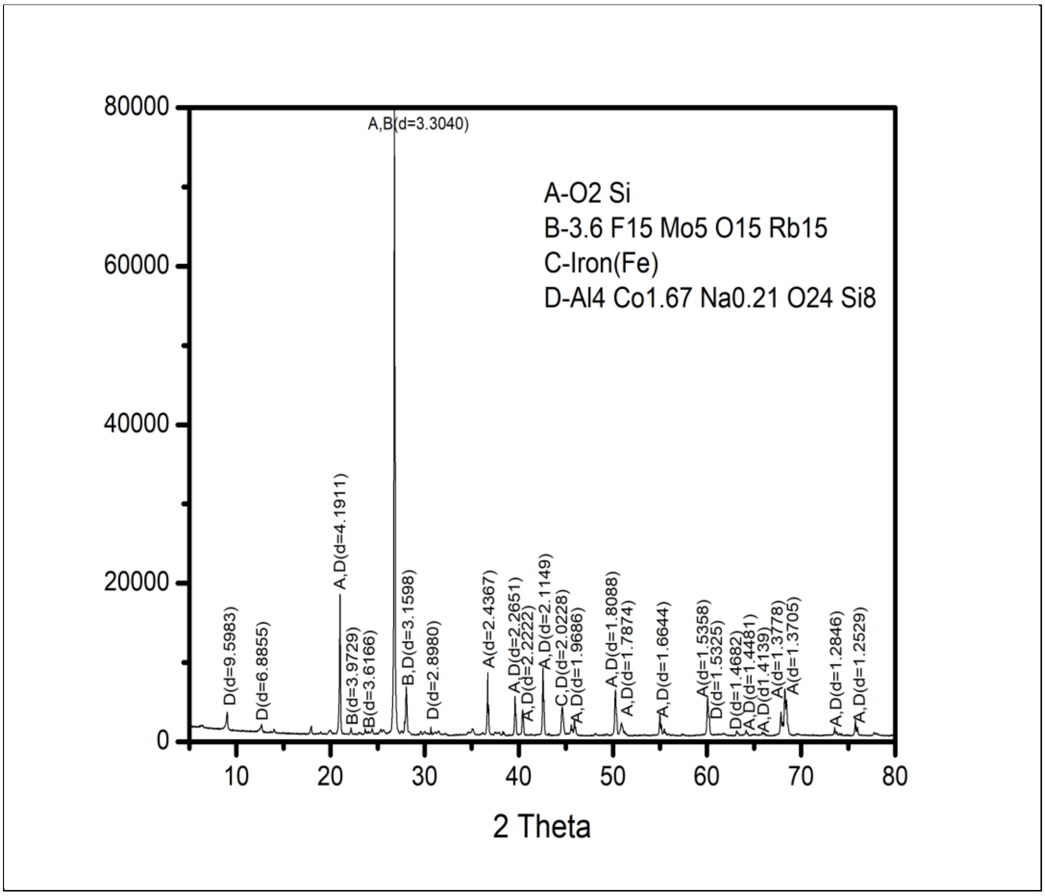

Fig. 4.27: Diffractogram of soil samples at Depth (78-80 cm), SITE A

XRD analysis of sample from SITE A, depth (78-80 cm) revealed following compounds:

A. Si O2 - 93.2 % of the peaks matched with Si O2 with cubic crystal system and unit cell parameter as a = 4.9019 Aº, c = 5.3988 Aº.

B. $F_{15}Mo_5O_{15}Rb_{15}$– 3.6 % of the peaks matched with $F_{15}Mo_5O_{15}Rb_{15}$ having a tetragonal crystal system and unit cell parameter as a = 20.0748 Aº.

C. 1.7 % of the peaks matched with Iron having a cubic crystal system and unit cell valves as a = 2.8608 Aº.

D. 1.5 % of peaks matched with having rhombohedral crystal system and unit cell values as a = 2.8608 Aº, α = 92.560 Aº.

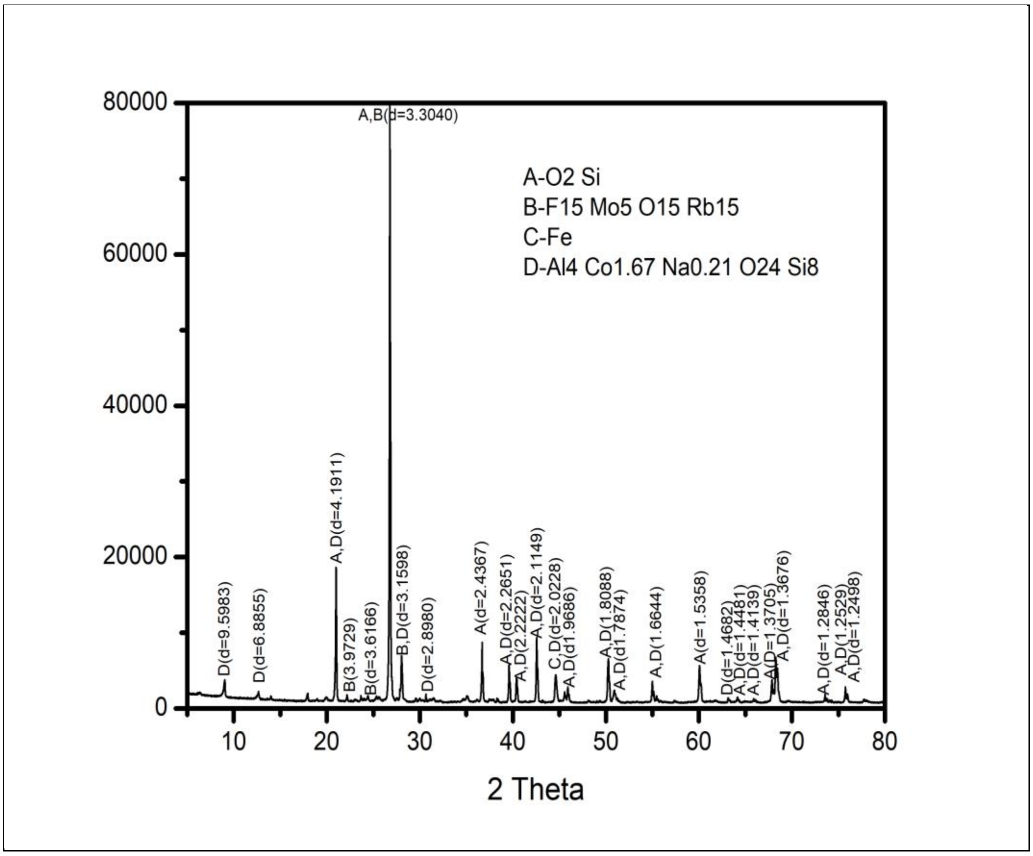

Fig. 4.28: Diffractogram of soil samples at Depth (0-2 cm), SITE B

XRD analysis of sample from SITE B, surface (0-2 cm) revealed following compounds:

A. 93.2 %of the peak matched with SiO_2 having trigonal crystal system and unit cell parameter as a = 4.9019 Aº
B. 3.6 % of the peak matched with $F_{15}Mo_5O_{15}Rb_{15}$ having tetragonal crystal system and unit cell parameter a = 20.0748 Aº, c = 36.1694 Aº
C. 1.7 % of the peak matched with Fe with cubic crystal system and unit cell dimensions as a = 2.8605 Aº.
D. 1.5% of the peak matched with $Co_{1.67}Na_{0.21}(Al_4Si_8O_{24})$ having a rhombohedral crystal system and unit cell parameter as a = 9.3510 Aº, α = 92.560 Aº.

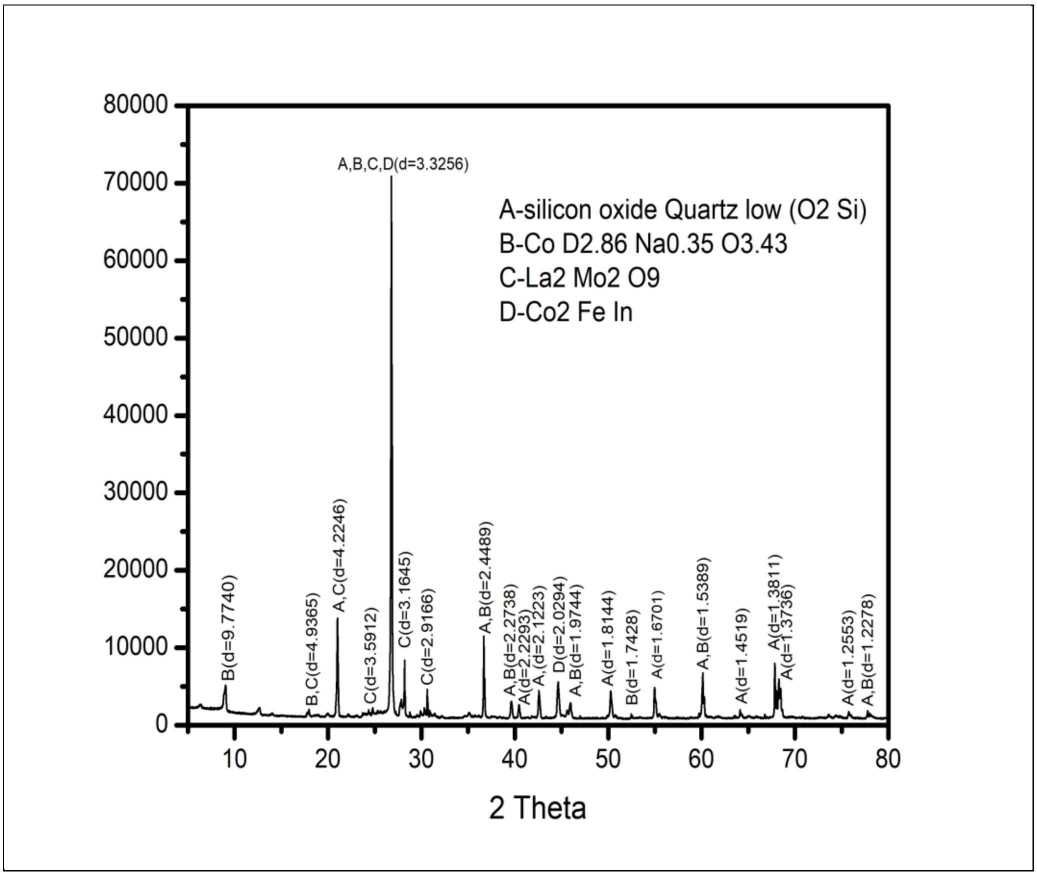

Fig. 4.29: Diffractogram of soil samples at Depth (26-28 cm), SITE B

XRD analysis of sample from SITE B, depth (26-28 cm) revealed following compounds:

A. 93.1% of the peak matched with SiO_2 with trigonal crystal system and unit cell parameter as a = 4.9100 Aº, c = 5.4000 Aº

B. 2.6 % of the peak matched with $Na_{0.35}(CoO_2)(D_2O)_{1.43}$ having a hexagonal crystal system and unit cell parameters as a = 2.8217 Aº, c = 19.7681 Aº

C. 2.1% of the peak matched with La2 Mo2 O9 with monoclinic crystal system and unit cell value as a= 14.3250 Å b= 21.4820 Å c= 28.5850 Å β= 90.400 º

D. 2.1 % of the peak matched with Co_2Feln with cubic crystal system and unit cell as a = 5.7160 Aº.

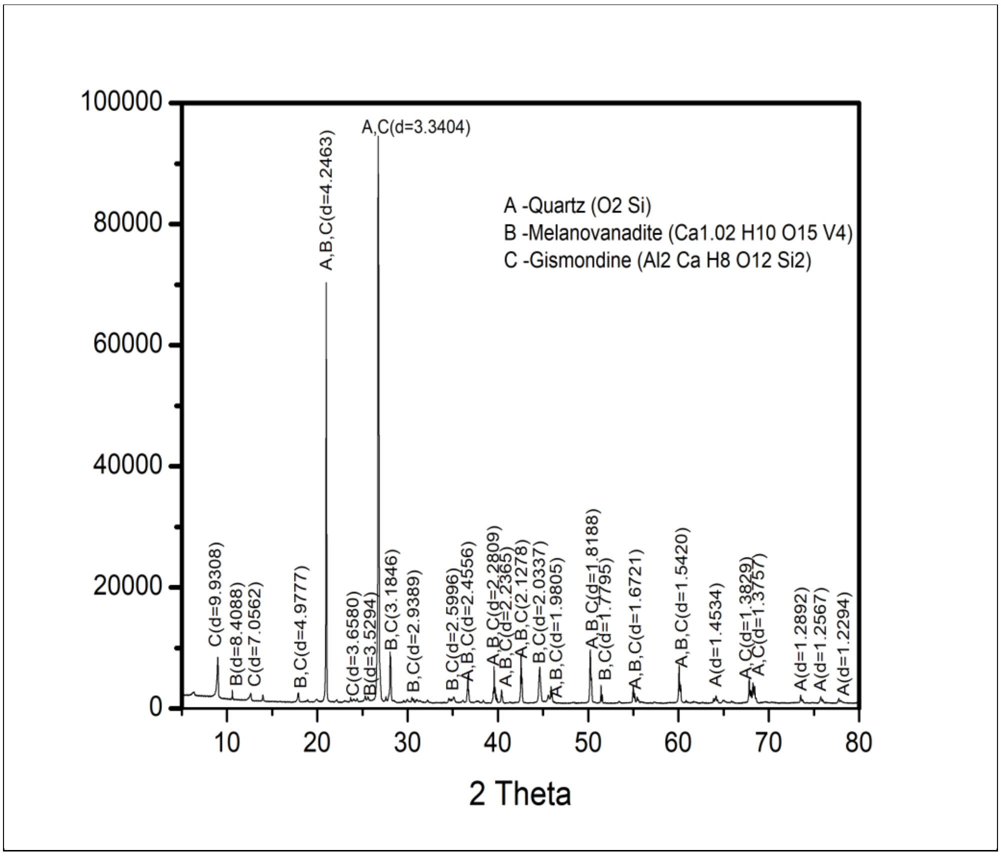

Fig.4.30: Diffractogram of soil samples at Depth (62-64 cm), SITE B

XRD analysis of sample from SITE B, depth (62-64 cm) revealed following compounds:

A. 80.7 % of the peak matched with Quartz having trigonal crystal system and unit cell dimensions as a = 4.9140 Aº, c = 5.4060 Aº

B. 12.4 % of the peak matched with Melanovanadite $Ca_{1.02}H_{10}O_{15}V_4$ having triclinic crystal system and unit cell parameter as a= 6.3600 Å b= 18.0900 Å c= 6.2760 Å α= 110.180º β= 101.620 º γ= 82.860 º.

C. 6.8 % of the peak matched with Gismondine ($Al_2CaH_8O_{12}Si_2$) with monoclinic crystal system and unit cell parameters as a= 9.9890 Å b= 10.6160 Å c= 9.8200 Å β= 92.570 º

4.6. RESULTS XRF

Various oxides and elements found in XRF analysis are, Aluminium Oxide (Al_2O_3), Calcium Oxide (CaO), Magnesium Oxide (MgO), Potassium Oxide (K_2O), Sodium Oxide (Na_2O), Hematite (Fe_2O_3), Phosphorous Pentoxide (P_2O_5), Quartz (SiO_2), Titanium Dioxide (TiO_2), Thorium (Th), Manganese Dioxide (MnO), Scandium (Sc), Vanadium (V), Chromium (Cr), Cobalt (Co), Nickel (Ni), Copper (Cu), Zinc (Zn), Rubidium (Rb), Barium (Ba), Zirconium (Zr), Strontium (Sr) and Lead (Pb).

All above elements recorded with different concentrations at different depths of all the locations at SITE A and SITE B has been shown in Table 4.12 and Table 4.13. Oxides % weight values and trace elements (ppm) concentrations at different locations of SITE A and SITE B has been shown in Fig, 4.31-4.34 respectively. Irregular distribution with no regular pattern of increasing or decreasing concentration of elements and oxides were recorded. Many heavy metals were recorded from various locations. Concentration of Al_2O_3 ranged from/recorded highest (14.69%) at depth 67-69 cm of location 5 of SITE B and lowest (8.71%) at 0-2.cm of location 2, SITE A. CaO ranged from (highest) 2.44% at depth 30-32 cm of location 5 at SITE B while (lowest) 1.2% at depths 30-32 cm and 74-76 cm of location 1and 2 of SITE A respectively. Fe203 ranged from 4.29% (highest) at surface (0-2cm) of location 4, SITE B and lowest 3.02% at surface (0-2 cm) of location 3 of SITE A. K_2O recorded 3.34% (highest) at 67-69 cm depth of location 5, SITE B while lowest 1.76% at surface (0-2cm) of location 2, SITE A. MgO recorded 3.73% (highest) at 67-69 cm depth of location 5 of SITE B and lowest 0.6% at surface(0-2cm) of location 3 of SITE A. Na_2O recorded 1.23% (highest) at depth 96-98 cm of location 4 and 67-69 cm of location 5 of SITE B respectively, while lowest value of 0.94% at surface(0-2cm) of location 1 at SITE A. P_2O_5 recorded 0.21% (highest) from 30-32 cm depth of location 5 at SITE B and lowest 0.07%at 30-32 cm depth of location 1 at SITE A. SiO_2 recorded highest,90.15%at depth of 74-76cm of location 2 of SITE A while lowest 58.55%at 67-69 cm depth of location 5 of SITE B. TiO_2 recorded highest 0.64%at 67-69 cm depth of location 5 of SITE B and lowest 0.29% at depth 30-32 cm of location 1 and surface (0-2cm) of location B of SITE A respectively. MnO recorded highest 0.09% at depth of 67-69 cm of location 5 while lowest value of 0.05% recorded from many locations at both the sites.

Distribution of various trace elements has also been recorded. The trace elements recorded in the present study are Th, Co, Ni, Cu, V, Cr, Zn, Zr, Rb, Sr, Ba, Pb. Concentration of heavy metals was higher at SITE B as compared to SITE A.

Table 4.12. Oxides and Trace Elements on different locations at SITE A (Palla Village)

Oxides and Trace Elements		SITE A (Palla Village)								
		Location 1 depth (cm)			Location 2 depth (cm)			Location 3 depth (cm)		
		0-2	30-32	78-80	0-2	30-32	74-76	0-2	26-28	59-61
Al_2O_3	%	9.23	9.38	9.37	8.71	9.92	9.23	9.15	11.98	10.34
CaO		1.5	1.2	1.37	1.37	1.68	1.2	1.16	2.22	1.61
Fe_2O_3		3.35	3.1	3.34	3.12	4	3.41	3.02	4.28	3.68
K_2O		1.79	1.9	1.88	1.76	1.97	1.91	1.89	2.41	2.11
MgO		0.72	0.65	0.7	0.64	0.86	0.65	0.6	1.52	1.05
Na_2O		0.94	0.98	1.01	0.96	1.08	1.14	1.1	1.11	1.01
P_2O_5		0.08	0.07	0.08	0.08	0.1	0.08	0.08	0.11	0.08
SiO_2		86.59	86.4	86.42	86.18	84.76	90.15	88.21	72.19	78.65
TiO_2		0.3	0.29	0.32	0.3	0.36	0.31	0.29	0.47	0.37
MnO		0.06	0.05	0.06	0.05	0.08	0.05	0.05	0.06	0.05
Th	PPM	11	9	11	11	14	10	10	15	11
Sc		6	4	4	5	3	4	4	5	3
V		33	32	36	33	41	33	31	64	46
Cr		376	340	506	398	253	574	384	424	657
Co		7	9	6	9	8	9	8	11	10
Ni		35	38	26	34	27	44	35	37	35
Cu		13	14	10	14	10	17	14	18	15
Zn		46	46	48	47	49	49	46	61	55
Rb		91	102	97	96	93	105	103	132	120
Sr		47	52	50	52	47	52	52	75	66
Zr		117	107	133	111	129	113	108	190	128
Ba		311	325	314	317	302	335	322	416	385
Pb		19	19	19	20	18	20	19	25	23

Table 4.13. Oxides and Trace Elements on different locations at SITE B (Okhla Barrage)

Oxides and Traces Elements		SITE B (Okhla Barrage)								
		Location 4, depth (cm)			Location 5, depth (cm)			Location 6, depth (cm)		
		0-2	30-32	76-78	0-2	30-32	67-69	0-2	26-28	62-64
Al_2O_3	%	10.97	10.11	10.6	9.44	12.24	14.69	9.9	11.35	10.24
CaO		1.57	1.63	2.14	1.85	2.44	1.33	1.39	1.72	1.37
Fe_2O_3		4.29	3.23	3.96	3.5	4.48	7.21	3.58	4.46	3.83
K_2O		2.27	2.02	2.07	1.89	2.4	3.34	2.06	2.33	2.09
MgO		1.32	0.89	1.17	0.78	1.71	3.73	0.87	1.42	0.99
Na_2O		1.15	1.07	1.23	1.12	1.07	0.88	0.99	1.23	1.03
P_2O_5		0.11	0.09	0.15	0.13	0.21	0.12	0.09	0.12	0.1
SiO_2		77.17	79.2	78.95	85.82	69.67	58.55	81.29	75.98	80.95
TiO_2		0.43	0.36	0.47	0.38	0.53	0.64	0.33	0.46	0.38
MnO		0.06	0.05	0.06	0.06	0.06	0.09	0.05	0.06	0.06
Th	PPM	15	12	18	15	18	8	10	14	13
Sc		1	3	6	7	5	0	3	5	5
V		57	43	61	44	75	108	40	61	45
Cr		346	306	205	202	304	242	302	263	237
Co		11	9	9	9	11	25	12	14	11
Ni		40	38	28	25	39	57	36	36	32
Cu		19	16	20	12	37	25	15	18	14
Zn		64	52	66	53	92	103	54	65	56
Rb		131	111	119	98	130	219	117	137	115
Sr		69	73	78	62	89	63	57	72	60
Zr		207	134	245	210	245	97	114	167	138
Ba		376	356	376	289	411	578	360	398	364
Pb		23	19	24	20	28	32	20	24	20

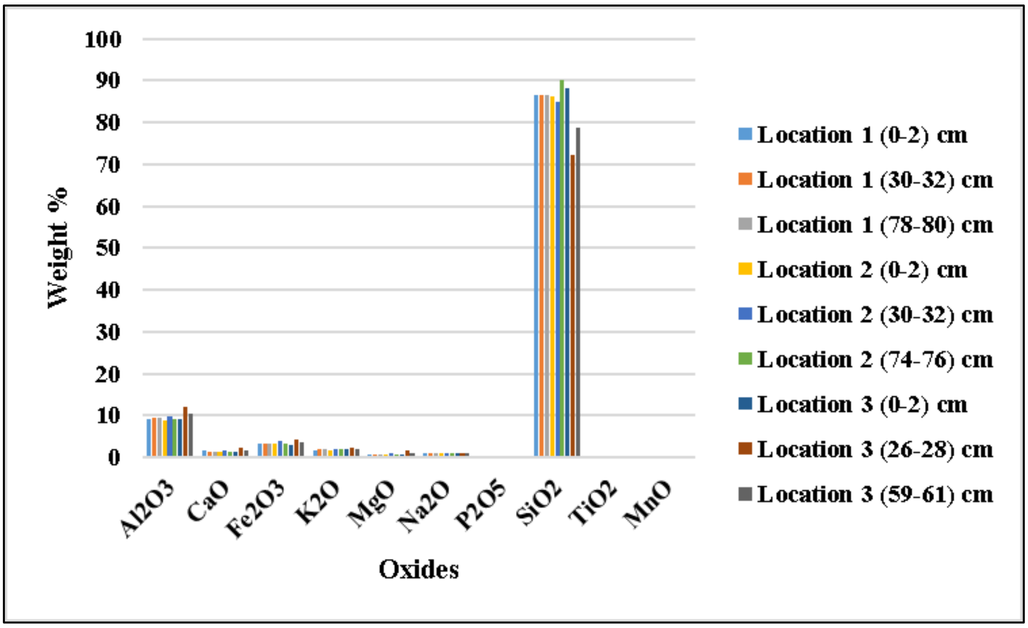

Fig 4.31: Oxides Weight (%) at different Locations of SITE A (Palla Village)

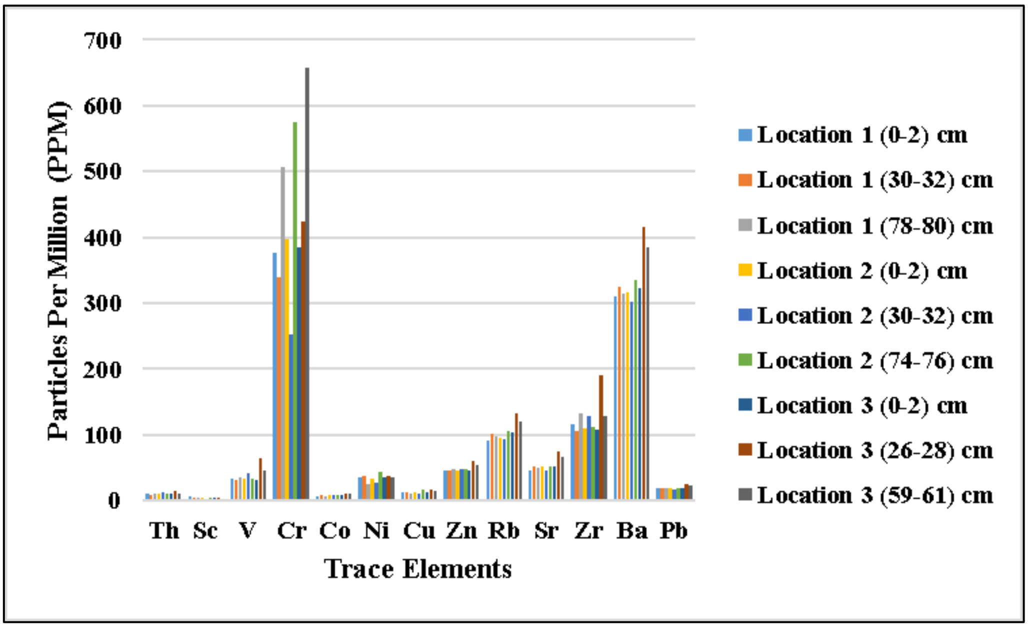

Fig 4.32. Traces Elements (PPM) at different Locations of SITE A (Palla Village)

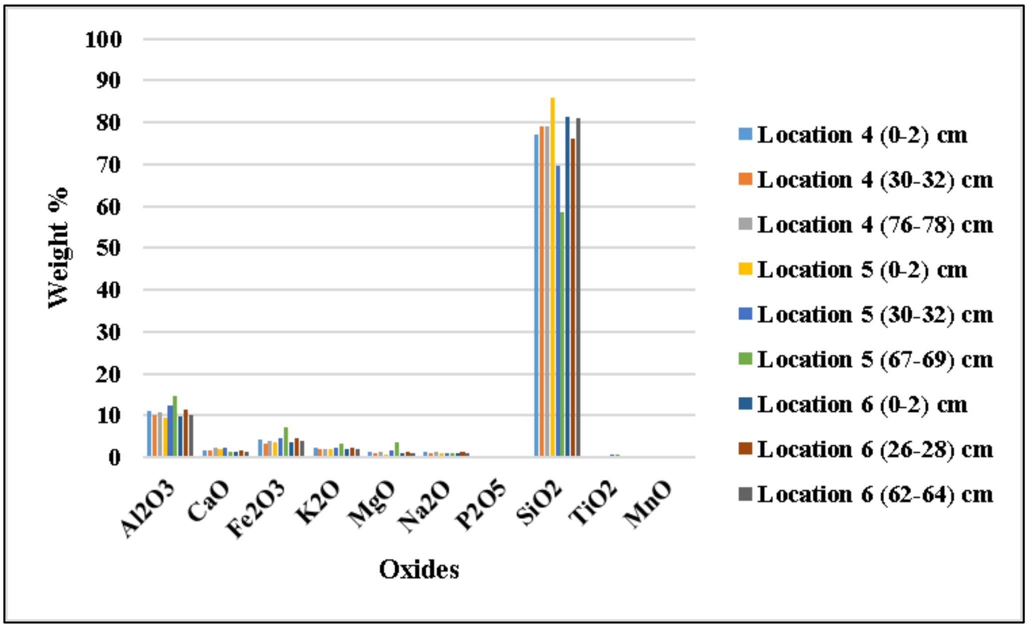

Fig. 4.33. Oxides Weight (%) at different Locations of SITE B (Okhla Barrage)

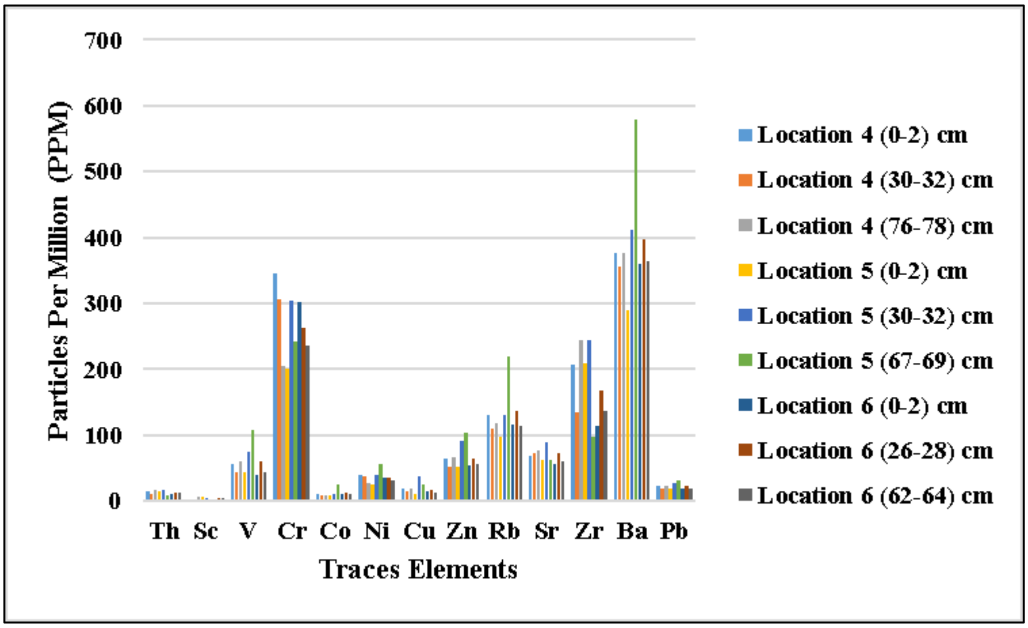

Fig. 4.34. Traces Elements (PPM) at different Locations of SITE B (Okhla Barrage)

Chapter 5
Discussion

CHAPTER 5

DISCUSSION

5.1. ECOLOGICAL INFERENCE FROM DIATOM DIVERSITY AND SEDIMENT'S RADIOCARBON AGE

In the present study SITE A and SITE B from river Yamuna were analysed for fossil diatom diversity. Ecological features of diatoms were studied on the basis of different ecological indicators like pH, Salinity, Nitrogen uptake, oxygen requirements, saprobity, Trophic conditions and the moisture preference explained by Van dam et. al (1994) and other research observations taken from water bodies throughout the world.

For a better interpretation Van dam et. al., (1994) classified above ecological indicators in subparts based on the different criteria. pH was classified in different range categories of acidobiontic (pH< 5.5), acidophilous (pH<7), circumneutral (about 7), alkaliphilous (mainly occurring at pH>7), alkalibiontic (exclusively occurring at pH>7) and indifferent (no apparent optimum). Salinity is classified on the basis of preference for freshwater or brackish water. On the basis of Nitrogen uptake metabolism diatom show preferences like nitrogen-autotrophic taxa, tolerating very small concentrations of organically bound nitrogen. Nitrogen-autotrophic taxa, tolerating elevated concentrations of organically bound nitrogen. Facultatively nitrogen-heterotrophic taxa, needing periodically elevated concentrations of organically bound nitrogen. Obligately nitrogen-heterotrophic taxa, needing continuously elevated concentrations of organically bound nitrogen. Another important criteria is oxygen requirements by diatom which requires continuously high (about 100% saturation) oxygen, fairly high (above 75% saturation), moderate (above 50 % saturation), low (above 30% saturation) and very low saturation about 10%. While saprobity classified in increasing order starting from oligosaprobous, β-mesosaprobous, α-mesosaprobous, α-meso-/polysaprobous and polysaprobous. Saprobity explains water quality class, oxygen saturation (%) and BOD mg/l. Trophic state which is a very crucial ecological indicator shows different levels starting from lower level to higher in order of oligotraphentic, oligo-mesotraphentic, mesotraphentic, meso-eutraphentic, eutraphentic, hypereutraphentic, oligo-to eutraphentic (hypereutraphentic). Trophic state represents the productivity of a water body or in other words it defines the total load of biomass in a particular water body at the time of measurement. The last ecological indicator used was moisture preference of the diatoms, which explains that some diatoms never or rarely, occurs outside water bodies, while some mainly occurs in water bodies sometimes on wet places, some diatoms mainly occurring in water bodies, also rather regularly on wet and moist places. Some occurs mainly on wet and moist or temporarily dry places and some prefers nearly exclusively occurring outside water bodies.

The diatom assemblages of 18 samples collected from various depths of all the locations of SITE A and SITE B are analyzed for ecological conditions of the river in co-relation to the age revealed by the radiocarbon-14 data. Diatom diversity of a particular sample has been listed in Table 5.1.

SITE A, Location 1, sample taken from 0-2cm revealed carbon-14 age of 16899 BC with good diatom assemblage with *Achnanthidium eutrophilum, Cyclotella pseudostelligera, Eunatia faba, Gomphonema parvulum, Mallomonas sp.* and *Nitzschia fonticola*. Considering these species as an ecological indicator of that particular area it suggests overall good water quality with high flow velocities. Acidophilous (pH<7) to Alkaliphilous (pH>7) through most of the species shows a circumneutral conditions (pH about 7). Oligotraphentic to hypereutraphentic trophic conditions that shows a distribution of nutrients which resulted in such high trophic state and this could be possible because of the waste and excreta from higher animal diversity living in vicinity. Therefore, all these ecological conditions can be a possible assumption of the condition of river Yamuna around 16899 BC years ago. While sample from depth 30-32cm shown 16924 BC years of Carbon-14 age. Diatom diversity at this depth constituted *Achnanthidium hoffmannii, Achnanthidium minutissimum, Cyclotelle pseudostelligaria, Cyclotella striata, Fragillaria capucina, Fragillaria rumpens* and *Plagiotropis Lepidoptera* var. *proboseidea.* The diatom assemblage shows an overall good water quality and high flow velocity which means the river must be flowing with enormous amount of water with high speed. Most of the species are sensitive to organic pollution. Diatom assemblage represents the pH value varied from circumneutral (pH about 7) to alkaliphilous (pH > 7). Saprobity indices varies from α to β mesosaprobous

Table 5.1. Diatom diversity at different locations and various depths of SITE A and SITE B.

SITE A								
Depths at Location 1 (cm)			**Depths at Location 2 (cm)**			**Depths at Location 3 (cm)**		
0-2 cm	30-32 cm	78-80	0-2 cm	30-32 cm	74-76 cm	0-2 cm	26-28 cm	59-61 cm
Achnanthidium eutrophilum, Cyclotella pseudostelligera, Eunatia faba Gomphonema parvulum grun, Mallomonas sp. , Nitzschia fonticola grunow.	*Achnanthidium hoffmannii, Achnanthidium minutissimum, Cyclotella pseudostelligaria, Cyclotella striata, Fragillaria capucina Desm, Fragillaria rumpens, Plagiotropis Lepidoptera* var. *proboseidea*	*Achnanthidium eutrophilum, Cyclotella atomus , Plagiotropis Lepidoptera* var. *proboseidea*	*Cyclotella pseudostelliger, Pleurosira indica*	*Achnanthidium eutrophilum, Achnanthidium hoffmanii, Cocconis placentula, Neidium iridies*	*Cocconeis placentula*	*Cyclotella pseudodtelligera, Synechocystis aquatilis*	*Achnanthidium hoffmanii, Nitzschia Stauroneis sp.*	*Achnanthidium hoffmanii, Nitzschia palea*

SITE B								
Depths at Location 4 (cm)			**Depths at Location 5 (cm)**			**Depths at Location 6 (cm)**		
0-2 cm	30-32 cm	76-98 cm	0-2 cm	30-32 cm	67-69 cm	0-2 cm	26-28 cm	62-64 cm
Cyclotella pseudostelligera, Cyclotella meneghiniana, Cyclotella cryptica, Tryblionella brunoi, Pleurosira laevis, Stephanodiscus parveus, Synedra acus	*Cyclotella stelligera, Nitzschia recta*	*Pleurosira indica*	NO SPECIES	*Navicula cryptotenella, Pantocsekiella costei, Stephanodiscus minutulus, Pleurosira laevis, Stephanodiscus binderanus*	*Cyclotella meneghiniana, Cyclotella pseudostelligera, Nitzschia recta Tryblionella brunoi*	*Nitsschia fonticola Plagiotropis Lepidoptera* var. *proboseidea Pleurosira laevis*	*Amphora pediculus, Cyclotella stelligera, Gomphonema pumilum* var. *elegans, Nitzschia fonticola, Plagiotropis Lepidoptera var. proboseidea, Synedra Ulna*	*Nitzschia acicularis*

and tropic state from oligomesotrophic to eutraphentic. All these characters favour an overall good water quality. Sediment sample from depth 78-80 cm recorded age of 14058 BC. *Achnanthidium eutrophilum, Cyclotella atomus* and *Plagiotropis Lepidoptera* var. *proboseidea* were observed in soil sediment samples which indicates occurrence of low biodiversity as compared to earlier samples and these species represent a high water flow velocities with good water quality and alkaliphilous (pH>7) and eutraphentic conditions.

Surface (0-2cm) sediments from Location 2 dated 16404 BC revealed only 2 species *Cyclotella pseudostelligera, Pleurosira indica*. It represents circumneutral pH about 7 and alkalibiontic (pH>7) and eutraphentic trophic conditions. High flow velocities could disturb the settling of diatoms, Therefore, around 16404 BC years ago a high flow rate of water was maintained in river with good water quality. Sample taken from depth 30-32cm could not be graphitized because of less carbon content. *Achnanthidium eutrophilum, Achnanthidium hoffmanii, Cocconis placentula Neidium iridies* algal species was observed which represents high flow velocities and good water quality with pH ranging from pH = 7 to pH > 7 and mesotraphentic tropic state. Sample from depth 74-76cm revealed age of 11584 BC and only one diatom species i.e. *Cocconeis placentula*. It shows alkaliphilous (pH > 7) and eutraphentic tropic state in water bodies which represents a good quality of water but such less diversity represents very high velocities of river which opposed the settling of diatoms in the river sediments.

Sample from depth 0-2 cm of Location 3 at SITE A revealed an age of 16841 years with single species of *Cyclotella pseudodtelligera* which represents circumneutral pH values i.e. pH about 7 and Eutnaphetic trophic state. Sample from depth 26-28cm represents age of 5366 BC years and diatom diversity with *Achnanthidium hoffmanii, Nitzschia sp.* and *Stauroneis sp*. Such type of diatom assemblage shows good quality of water with high flow velocity and varying pH concentration from acidic to circumneutral to alkaliphilous. *Nitzschia* sp usually represents high organic matter or higher trophic state which could be contributed by high population of floral and faunal diversity in vicinity.12205 BC years of age revealed by sample from depth 59-61cm and observed diatoms were *Achnanthidium hoffmanii* and *Nitzschia palea.* This site again represented conditions like previous sample as it constitutes similar type of diatom diversity hence represents similar environmental conditions. SITE A, Palla village reveals a good water quality with high flow velocity of the river in maximum samples taken from different locations; Therefore, we can assume a good environmental or ecological condition of river Yamuna with during all calculated prehistoric ages. It can also be assumed that during these entire period river Yamuna was surrounded by a good floral and faunal diversity.

At SITE B sample from depth 0-2 cm of location 4 revealed radioactive age of 7575 BC years and a good diatom assemblage of *Cyclotella pseudostelligera*, *Cyclotella meneginiana*, *Cyclotella cryptica*, *Stephanodisms parvus*, *Synedra acus*, *Pleurosira lacvis* and *Tryblionella brunoi*. All these species represent circumstantial (pH~7) to alkaliphilous which mainly occurs at pH >7 to alkalibiontic which exclusively occurs at pH>7 conditions and trophic state conditions from Eutraphentic to Eutrophic. Eutrophic conditions show high nutrients and organic matter, its possible reason might be because of the good vegetation and animal biodiversity in the water and the vicinity, which could have contaminated water with excreta, wastes or dead decaying matters resulting in higher eutrophic conditions. While sample from depth 30-32cm reveled age of 10811 BC yrs with dominant diatom species of Sample constitutes three species of *Cyclotella stelligera* and *Nitzschia rect* therefore it shows mesotrophic water conditions with pH around 7 or > 7. 1943 BC yrs of age was recorded from depth of 76-78cm with low diatom diversity of two genus *Cyclotella* species and *Pleurosira indica* only. *Pleurosira* indicates good water quality and *Cyclotella* sp. prefers pH about 7.

Surface (0-2 cm) sediment sample from location 5 revealed an age of 9206 BC yrs. No diatom species was recorded from this sample. It might be because of very high flow rate of the river at that particular time which might have opposed the settlement of diatoms in the river bed. While the sample from depth 30-32 cm revealed age of 85 BC yrs and good diatom diversity with *Navicula cryptotenella Pantocsekiella costei, Stephanodiscus minutulus, Pleurosira laevis* and *Stephanodiscus binderanus.* Presence of *Navicula cryptotonella* represents alkaliphilous (pH>7) and hypereutraphentic conditions similarly other diatoms shows circumstantial (pH~7) to alkalibiontic (pH>7) and majority of genus represent hypereutraphentic conditions i.e. higher trophic productivity. Hypereutraphentic conditions shows very high productivity or high organic matter in the water bodies, This could be possible because of higher floral and faunal diversity in or around the river even keeping the recorded age (85 BC yrs) in mind anthropogenic activities could be another reason as it is the youngest age observed in the present study and it could be possible that nearby areas of the Okhla would have been colonized by human population till that time or people used to visit river regularly for their basic daily requirements of water and other activities. Sample collected from depth of 67-69 cm revealed age of 11426 BC yrs with a good diatom assemblage *Cyclotella meneghiniana, Cyclotella pseudostelligera, Nitzschia recta* and *Tryblionella brunoi.* Majority genus revealed alkaliphilous (pH>7) and eutraphentic to hypereutraphentic trophic conditions of water. Hypereutraphentic conditions show higher nutrition and the organic matter which favours high algal diversity. High nutrients could be introduced by animal wastes or other dead decaying matter present in or nearby water body.

At last location 6 of SITE B (Okhla) surface (0-2cm) sample revealed age of 17020 BC yrs which is the oldest recorded age in present study. This sample constitutes *Nitsschia fonticola, Plagiotropis Lepidoptera var. proboseidea* and *Pleurosira laevis*. Presence of this diatom diversity suggests a pH more than 7 and eutraphentic or high nutrition trophic state. Sample from depth 26-28 cm revealed age of 13283 BC yrs with main genus observed was *Amphora pediculus, Cyclotella stelligera, Gomphonema pumilum, Nitzschia fonticola, Plagiotropis Lepidoptera var. proboseidea* and *Synedra Ulna.* Alkaliphilous conditions are revealed by all the genus and eutraphentic to hypereutraphentic trophic conditions higher alkaline and eutrophic conditions might be because of excreta and waste from animals and plants which favours good biodiversity at that time. Some geochemical and climatic conditions too have altered the composition of diatoms either directly or indirectly. Sample from depth of 62-64 cm shows age of 8377 BC yrs with only one genus observed i.e. *Nitzschia acicularis.* This species represents alkaliphilous (pH>7), low oxygen concentration and eutraphentic trophic conditions of water bodies.

Most of the samples from SITE B, Okhla barrage are from epoch Holocene which reveals an overall good water quality with high flow rate of river and a good vegetation and animal diversity during many recorded radiocarbon ages.

5.2. EDAX DISCUSSION

EDAX revealed few elements like O, Al, Nb and Si from sediments and some physical parameters of soil. The concept of isotopic composition of silicon in river sediments and its relationship with climate was elucidated by Bayon et al., (2018). Discussion about the distribution and retention of Silicon in river beds and its effects on biogeochemical nature and aquatic food webs in coastal environments was conducted by Humborg et al., (2000) while distribution of biogenic silica in sediments of the Yellow river was discussed by Yang et al., (2016). Mil-Homens et al., (2013) has talked about the occurrence of silicon as aluminosilicates in the sediments of Minho river, Spain. In the present study, no specific trend is shown by spatial distribution pattern of Si in different soil samples. Silicon affects the uptake and accumulation of different plant nutrients and a large amount of silicon is bounded in inflexible silicate minerals and for the plant only a small fraction is available (Struyf et al., 2010). Silicon forms solid-phase phytoliths after it is absorbed in plants and with the deterioration of dead plant material these are recycled to the soil solution which may again be taken up by plants (Carey and Fulweiler 2012). Hydrogen bound Si–organic complexes are often found in plant tissues (Carlisle et al., 1977) which permeates the walls of vessels and epidermis and reduces fungal infections and water transpiration by strengthening the plant tissues (Kaufmian et al., 1969). The components of cell wall like lignins, proteins and polysaccharides are associated with silica (Perry and Lu 1992). The absorption, distribution and even functionality of many nutrients nitrogen (N), phosphorus (P), magnesium (Mg), potassium (K) and calcium (Ca) is affected by silicon (Wallace 1989, Miyake 1993, Brackhage et al., 2013, Neu et al., 2016, Sattar et al., 2016, Kostic et al., 2017) and strongly influence uptake of boron (B), iron (Fe), zinc (Zn) and manganese (Mn) (Nable et al., 1990, Bityutskii et al., 2014). Soil concentrations of oxygen in solution are comparatively lesser than in the soil atmosphere which is used by aerobic microorganisms as a terminal electron acceptor for the period of degradation of organic compounds and xenobiotics and Percentage volume basis of Oxygen varies in Atmosphere, Well-aerated soil surface and in fine clay or saturated soil (Pepper and Gerba, 2019). Yamada et al., (2012) explained Dissolved Oxygen concentration in sediments of downstream of rivers in Lake Biwa in japan. Similar studies on Sediment Neckar river in Germany was performed by Haag et al., (2006) which explained about oxygen fluxes in sediments. Concept of Sediment oxygen demand (SOD) and importance of oxygen was deliberated upon by Belo (2008) in Pasing river.

Rock-forming minerals such as sphene, cassiterite rutile and biotite contains traces of Niobium many trace elements and with some heavy rare earth elements while has a good negative correlation with CaO and forms some relatively rare, but economically significant minerals (Forges Geochemical Atlas of Europe). Production of steel, nuclear fuel and welding practice are some major human activities which leads Niobium in environment (Reimann and De Caritat 2012). It also carries some industrial significance like manufacturing of cutting tools, pipelines and super magnets. It is considered non-essential and there is very less knowledge about its toxicity but its existence is not denied in living organisms and in stream sediment. Astrom et al., (2008) did extensive studies on 807 streams spread over 26 countries in Europe for necessary statistics on the abundance, movement and transportation of Niobium in sediments of boreal stream water. Migani et al. (2015) studied geochemical classification of surface sediments from wetlands around the Po river delta in Italy. With this study, he came up with the suggestion that organic matter in these wetlands can have an influence on Niobium sediments. In water bodies Al can be added by industrial sources which are lethal for aquatic fauna (Hunter et al., 1980). Acidification caused by Al in water streams has inadvertently been a reason for reducing numbers of benthic and planktonic invertebrates (Okland and Okland 1986, Haines 1981). The biological significance of Al toxicity on freshwater invertebrates was divulged by (Herrmann 1987) and on fish by Driscoll et al., (1980). Aluminium traces can be located in mucilage layer on the root tips and the cell wall pectins while only a small extent is translocated to shoots (Horst et al., 1982). Physiological and biochemical implications of AI studies have been reported on both humans and animals (Siegel 1985, Trapp 1986).

The shape, size and chemical constituents of soil reserves are vastly variable (Takahashi et al., 2001). SEM images revealed the irregular, elliptical, platy and spongy structures of soil particles in almost all the samples. Similar results and such inhomogeneous nature of soil was reported by Sharma et al., (2016) in Hasdeo river basin in Chhattisgarh and by Thambavani and Kavitha (2014) in Suruli river, Karnataka in

India. Soils were sandy in nature as all the samples were collected from river bed which mainly constitutes of alluvial deposits. Sajitha et al., (2017) also used SEM EDAX to analyze mineralogical and morphological characterization of coastal soil samples of Kanyakumari district. The colour of the soil was light greyish at the SITE A while it was darker and blackish in colour at SITE B because of the accumulation of sewage pollutants from nearby drains.

Studies revealed that the type and concentration of elements varies at different depths of river bed and there is no unique pattern of occurrence of elements along the gradients of river bed. This can be understood by the fact that river ecosystem is a very dynamic system and the alluvial deposition can be easily disturbed by flow of water or floods. Though the percentage of Si and O was significantly distributed in all the sites, the occurrence of Al at SITE B proves that there is heavy load of pollution in the area. The potential source of the Al contamination is are industrial effluents. The reason for occurrence of Nb at SITE A could be depositions from weathered rocks since Nb is a vital part of many forms of rocks.

5.3. CHNS DISCUSSION

CHNS analysis revealed Carbon, Hydrogen, Nitrogen and Sulphur at both the sites. The concentration of Carbon, Hydrogen, Nitrogen and Sulphur with other trace elements is susceptible to many reactions like nitrification, denitrification, co-precipitation, sulfide oxidation. This has a direct effect on pH (Relic et al., 2010). Combined amounts of C in the atmosphere and vegetation is lesser than the total amount of 1500 Pg carbon (1Pg= 1015 g) present in top soil up to 1 m depth. The soil carbon normally falls off alongside depth of sediments (Jobbagy and Jackson 2000, Goidts and Wesemael 2007). The total organic carbon is comparatively well studied in comparison to total Carbon in sediments. Soil Organic Carbon (OC) is essential part of plant nutrients and helps in conserving the soil integrity (Solanki and Chavda, 2012). Soils with <0.20% organic carbon is indicative of very less amount; 0.21%-0.40% indicates low OC; 0.41%-0.80% as medium and > 0.80% is considered as high OC (Jaiswal, 2006). During present study, the Carbon % results at SITE A showed higher concentration of carbon at all the locations as compared to SITE B. This factor is positively correlated with Nitrogen and Sulphurwhich favours the fact that nutrient availability increases with increase in amount of organic carbon (Prusty et al 2009). Even hydrogen shows a close link between hydrogen and carbon cycles (Paul et al., 2016). The amount of Hydrogen affects not only the pH but also the accessibility of other elements in soil. At high and low pH values, nutrient deficiencies can be observed; Therefore, Hydrogen plays an important role in the development of plants. The percentage of Hydrogen kept varying with depths at both the SITE A and SITE B. SITE A has higher amount of percentage of Hydrogen at almost all the three locations as compared to SITE B. The concentration of Nitrogen of the sediments critically influences the productivity and biodiversity of an aquatic system (Kumar et al., 2012). SITE A has the higher amount of percentage of Nitrogen in soil as compared to SITE B. The percentage amount of Nitrogen kept varying with depth at both SITE A and SITE B. The organic matter present in the soil affects the amount of Nitrogen in the soil (Baruah, 1997). Due to diverse heterogeneity of soil, it is a big challenge to perceive the exact changes in the content of N and C in soil (Mitsch and Gosselink 2000). Nitrogen is one of the most important limiting element of wetland ecosystem and it plays a significant role in primary productivity (Song et al., 2012, Jobbagy and Jackson, 2000). Transport of sulphate from the water column into the sediments is influenced by Evapo-transpiration induced advection (Choi et al., 2006). Oxidation of Fe-Sulfides can lead to a decrease in the total S content in sediments (Relic et al., 2010). It could possibly be a reason for low concentration of S at SITE A. Sulphur showed advanced values at SITE B as in comparison to SITE A. This may be attributed to the accumulation of sewage and industrial pollutants at this site.

A very preliminary study revealing the inorganic elements and pollutants in the Yamuna river bank soil in Delhi was studied by Farago et al., (1989). The carbon content as well as organochlorine pesticides in fluvial sediments of river Yamuna was studied by Parween et al., (2014). Das et al., (2018) explained about the availability of Nitrogen and Sulphur by using K-jeldahl method in river Yamuna in Allahabad city. Organic Carbon and available nitrogen in different horizons of Yamuna river Bank at Prayagraj was studied by Dogo et al., (2019). Total Carbon (TC) and Total Nitrogen (TN) concentrations in dried sediment of Meenachil river basin in Kerala is conducted by George and Joseph, (2017). Comparatively less emphasis has been given on CHNS studies on Indian river sediments though it has been extensively carried out on many rivers all over the world. Discussion about organic carbon and nitrogen with C/N ratios of river sediments was carried out by Dinelli et al., (2005) in Arno river, Italy. CHN analysis on sediments of São Francisco river basin in Brazil was done by Rezende et al., (2011). Relic et al., (2010) explained the distribution of total CHNS content in relation to other heavy metals at different depths of alluvial sediments of Danube river, Serbia. The ratio of C/N and total N content in various depths of Yellow river was studied by Li et al., (2014). CHNS distribution in Sediments of the river Horna´d, Slovakia was explained by Findora´kova et al., (2017) and C and N content in comparison to Heavy-Metal from surface sediments of the Minho river Estuary, Spain was brought forth by Homens et al., (2013).

The ratio of Total Organic Carbon and Nitrogen can increase during diagenesis (Hunt et al., 2000). Sometimes, high value of Carbon and Nitrogen ratio is related with lesser N content, not because of large proportions of Carbon (Remon et al., 2005, Trembaly and Gagne 2007). Less than 1.0 % value of Hydrogen and total Organic Carbon ratio is an indicator of the aromatic character of the organic matter. On the other hand, values greater than 1.0% indicate a lesser content of organic matter and shows the aliphatic nature of organic matter. This nature possibly can be contributed by bacterial and algal organic matters (Meyers and Ishiwatari 1995). According to Steelink (1985), the presence of non-humic substances are represented by values greater than 1.3 %. Exposure to air or by inorganic oxidation can also lead to a decline in these values (Ortiz et al., 2004). In the present study, significant relationships between elements demonstrates that they have a good paragenetic association. A similar statistical analysis has been done by Li et al., (2014) in Yellow river, China and by Relic et al., (2010) in Danube river in Serbia.

5.3.1. Statistical analysis

Different descriptive statistics have been calculated as shown in Table 5.2 and Table 5.3 for SITE A and SITE B. We observed that all elements concentrations have less variations at SITE A in comparison to SITE B

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Table 5.2. Elements concentrations Descriptive Statistics for SITE A (Palla village)

Elements	Minimum	Maximum	Average	Std. Deviation	Variance
Carbon (C)	.110	.450	.287	.124	.015
Hydrogen (H)	.132	.299	.211	.063	.004
Nitrogen (N)	.090	.280	.173	.064	.004
Sulphur (S)	.007	.030	.014	.007	.000

Table 5.3. Elements concentrations Descriptive Statistics for SITE B (Okhla barrage)

Elements	Minimum	Maximum	Average	Std. Deviation	Variance
Carbon (C)	.170	1.010	.359	.270	.073
Hydrogen (H)	.126	.371	.220	.095	.009
Nitrogen (N)	.090	.290	.164	.071	.005
Sulphur (S)	.017	.104	.044	.027	.001

To reveal the correlation between different elements we have conducted Pearson correlation test is used. The correlation analysis suggests significant positive correlation between Nitrogen and Hydrogen ($p < 0.01$) and between Sulphur and Nitrogen ($p < 0.05$) at SITE A has been shown in Table 5.4.

Table 5.4. Correlations of different Elements at SITE A (Palla village)

Elements	Correlation	Carbon	Hydrogen	Nitrogen	Sulphur
Carbon	Pearson Correlation	1			
	Sig. (2-tailed)				
Hydrogen	Pearson Correlation	.617	1		
	Sig. (2-tailed)	.077			
Nitrogen	Pearson Correlation	.549	.958**	1	
	Sig. (2-tailed)	.126	.000		
Sulphur	Pearson Correlation	.568	.595	.755*	1
	Sig. (2-tailed)	.111	.091	.019	

* Correlation is significant at the $p < 0.05$ level (2-tailed)
** Correlation is significant at the $p < 0.01$ level (2-tailed)

Table 5.5 shows significant positive correlation between N and C ($p < 0.05$) and between N and H ($p < 0.01$). We also observed that S is significantly correlated with C ($p < 0.01$), N ($p < 0.05$) and H ($p < 0.05$) at SITE B.

Table 5.5. Correlations of different Elements at SITE B (Okhla barrage)

Elements	Correlation	Carbon	Hydrogen	Nitrogen	Sulphur
Carbon	Pearson Correlation	1			
	Sig. (2-tailed)				
Hydrogen	Pearson Correlation	.706	1		
	Sig. (2-tailed)	.050			
Nitrogen	Pearson Correlation	.744*	.961**	1	
	Sig. (2-tailed)	.034	.000		
Sulphur	Pearson Correlation	.920**	.832*	.787*	1
	Sig. (2-tailed)	.001	.010	.020	

* Correlation is significant at the $p < 0.05$ level (2-tailed)
** Correlation is significant at the $p < 0.01$ level (2-tailed)

5.4. XRD DISCUSSION

X-ray diffraction (XRD) is an important analytical technique which is used by many researchers for identification of crystalline materials for over a century (Tankersley and Balantyne 2010). It is used in many fields of archeology like identification clay minerals and composition of minerals of ancient pottery artifacts (Tankersley et al., 1990, 1995; Tankersley and Balantyne 2010).

Peaks revealed by diffractograms have a particular position, shape, breadth and intensity which can help to identify various minerals (Klug and Alexander 1954). The mineralogical composition of the all sediment samples was determined from XRD study.

The mineral which is observed having strongest peak in diffractogram and observed in all of the sediment samples is quartz. Other minerals like Muscovite, Melanovanadite, Gismondine, Iron, $F_{10}NaTm_3$, AlNi, Fe $_{2.87}$ $Si_{0.99}$, $Na_{0.35}$ (Co O_2) (D_2 O)$_{1.43}$, $F_{15}Mo_5O_{15}Rb_{15}$, Co $_{1.67}$ Na $_{0.21}$ (Al_4 Si_8 O_{24}), $La_2Mo_2O_9$ and Co_2Feln. All the minerals found at both the sites at different depths of the location has been shown in Table 4.10 and the diffractogram of all the sites has been shown in fig 4.26 - 4.31.

High strongest peaks of quartz is because that Yamuna (Dalai et. al, 2004). River flows past the Higher Himalaya, it drains quartzites, conglomerates, slates and carbonaceous phyllites, (Jha et.al, 1993) therefore the dominant mineral in the suspended sediments is Quartz and was found with strongest peaks in almost all the samples. Muscovite is one of the most common mineral belonging to the mica family. It is a significant rock-forming mineral which is present in igneous, metamorphic, and sedimentary rocks. Beside some physical and chemical properties of Melanovanadite and no information is available from the previous investigations of its presence in Yamuna river sediments, it is very dark greenish-black fine-grained mineral which was first observed from Peru. Similarly, no geological record has been observed for Gismondine in Yamuna river sediments. Enormous sediments loads are carried by majority of the Indian rivers in monsoon months because of the heavy rains (Subramanian 1987; Vaithiyanathan and others 1988). Most of the minerals which come from Himalaya are deposited in the river plains. The huge amount of material (13.5 x 109 t/year) is transported in the form of river sediments (Milliman and Meade 1983). The river transported sediments are mostly derived from the erosion of poorly associated rocks and from the denudation of soil horizons (Irion and Petr 1983). Therefore, all other compounds might be deposited from river sediments coming from Himalayas or the pollutants added to the river by anthropogenic activities like industrial waste, mining and sewage.

Knowledge of the mineralogical characteristics of river suspended sediments is an essential prerequisite to reveal the weathering and transport processes occurring at the continental surface. An important role is played by suspended sediments in the transport of nutrients and contaminants and influencing the river water quality (Martin and Meybeck 1979; Muller and Sigg 1990). The present study helps to elucidate the type of minerals deposited in the river bed and most probably their origin is from Himalayas.

5.5. XRF DISCUSSION

Because of the bio-accumulative nature of heavy metals they are a major concern for environment (Sehgal et al., 2012) Origin of such metals could be geological in nature and introduced in river sediments by weathering and erosion (Zhang and Huang, 1993) or by human activities like agricultural runoff, sewage disposal, industrial wastes and mining (Abbasi et. al, 1998). Higher value of heavy metals contamination can cause severe impacts on the health of living beings. A light contamination of metals in sediments was observed by comparing the concentrations with WHO standards. The concentrations of trace elements (Cr, Co, Ni, Cu, Pb and Zn) for which standard safety limits have been given by WHO (Sharma et al., 2020) have been analyzed for SITE A as shown in Fig.5.1 to Fig.5.6 and for SITE B as shown in Fig.5.7 to Fig.5.12. The concentration levels of heavy metals i.e. Ni, Co, Cu, Pb and Zn in soil samples at SITE A and SITE B were found to be lower than WHO recommended safety limits except Cr concentration levels. Fig.5.1 and Fig.5.7 show the presence of excessive Cr concentration at both the sites according to WHO recommended safety limits i.e. 400 PPM. We observed that at SITE A the enrichment of Cr varies from 253 to 657. At SITE B, Cr varies from 202 to 346. More Cr is present at SITE A in comparison of SITE B.

Presence of Pb, Zn might be because of waste introduced by coal based thermal power plant, Ni and Cr might have introduced by automobile, paint, batteries, and electroplating industrial wastes. High concentration of Cr at SITE A might be because of clothing and hosiery dyeing industries of city Panipat (Haryana) which is just few kilometers from Delhi. Similar results were reported by Sehgal et. al, 2012.

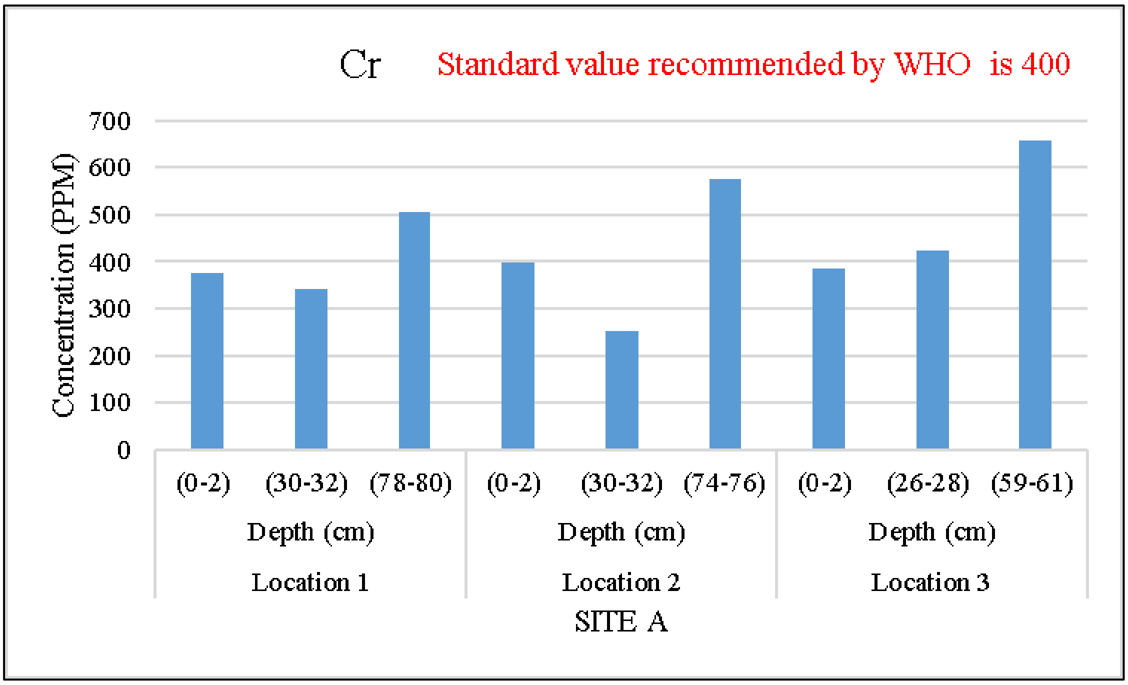

Fig. 5.1: Concentrations (PPM) of Cr at SITE A

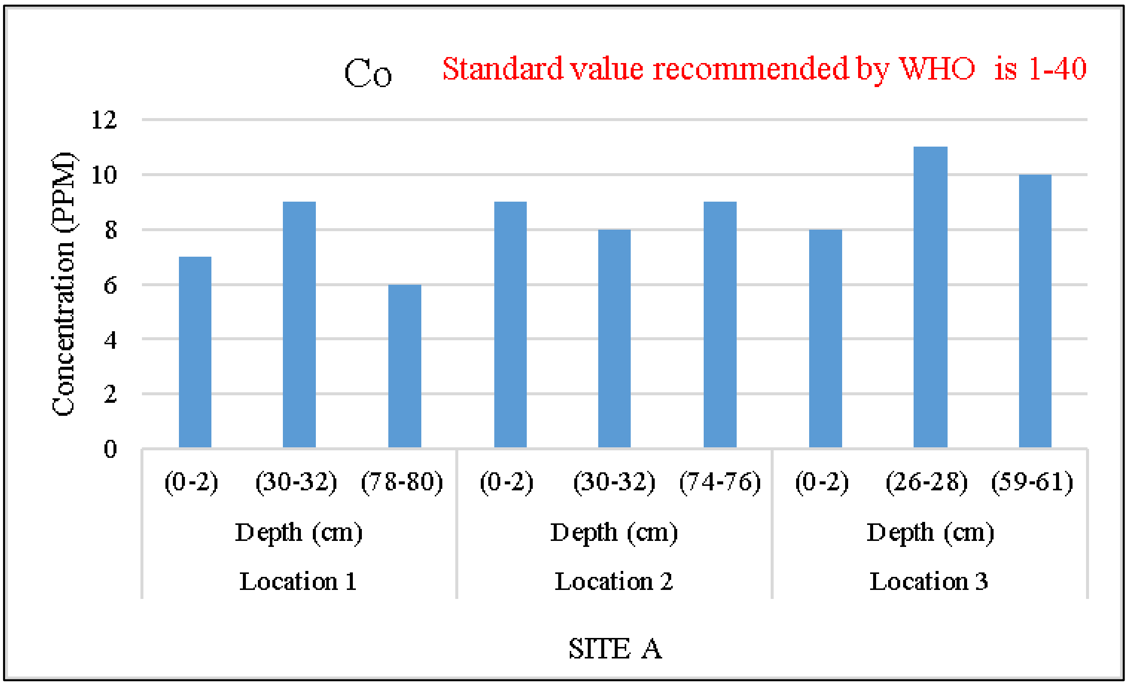

Fig. 5.2. Concentrations (PPM) of Co at SITE A

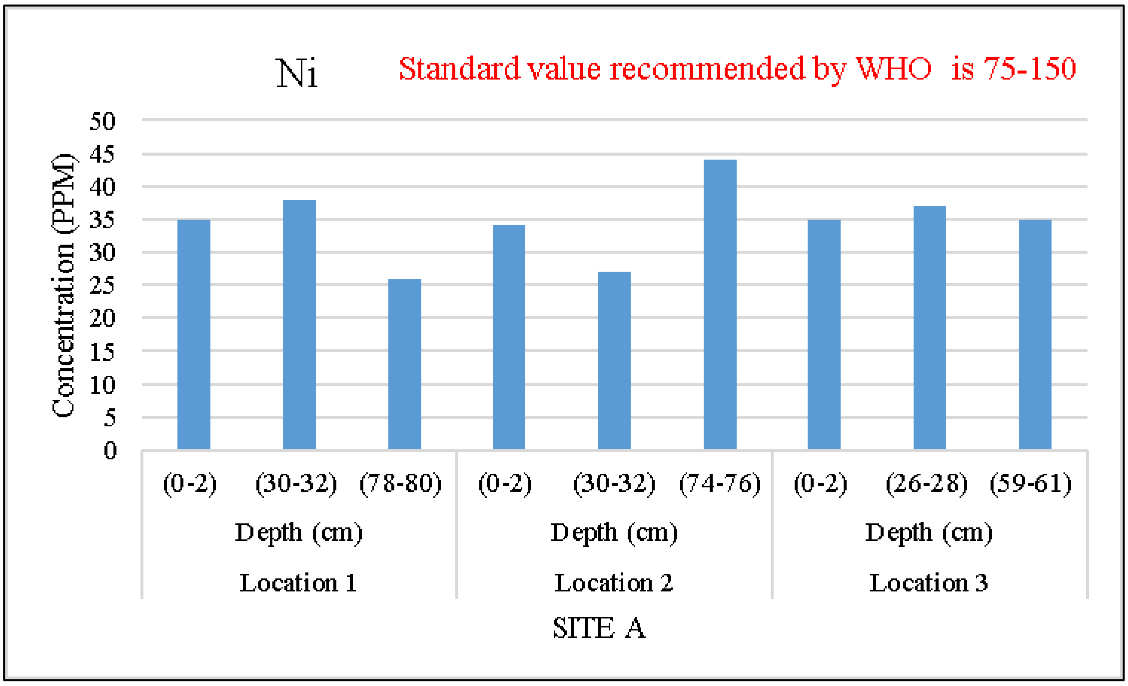

Fig. 5.3. Concentrations (PPM) of Ni at SITE A

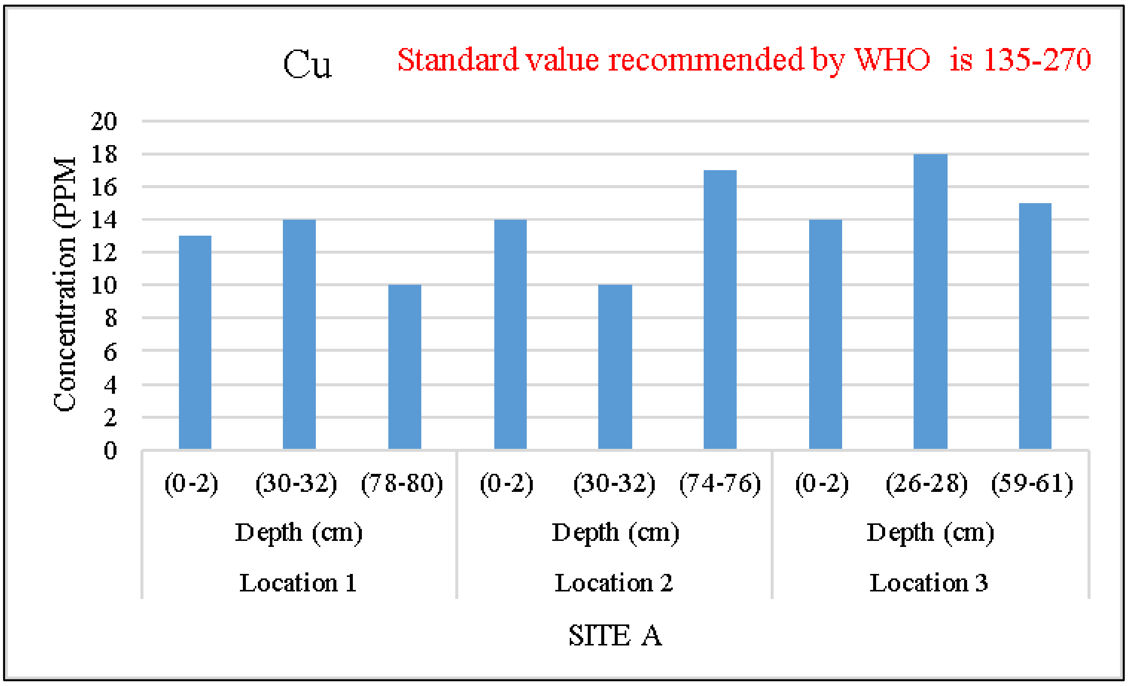

Fig. 5.4. Concentrations (PPM) of Cu at SITE A

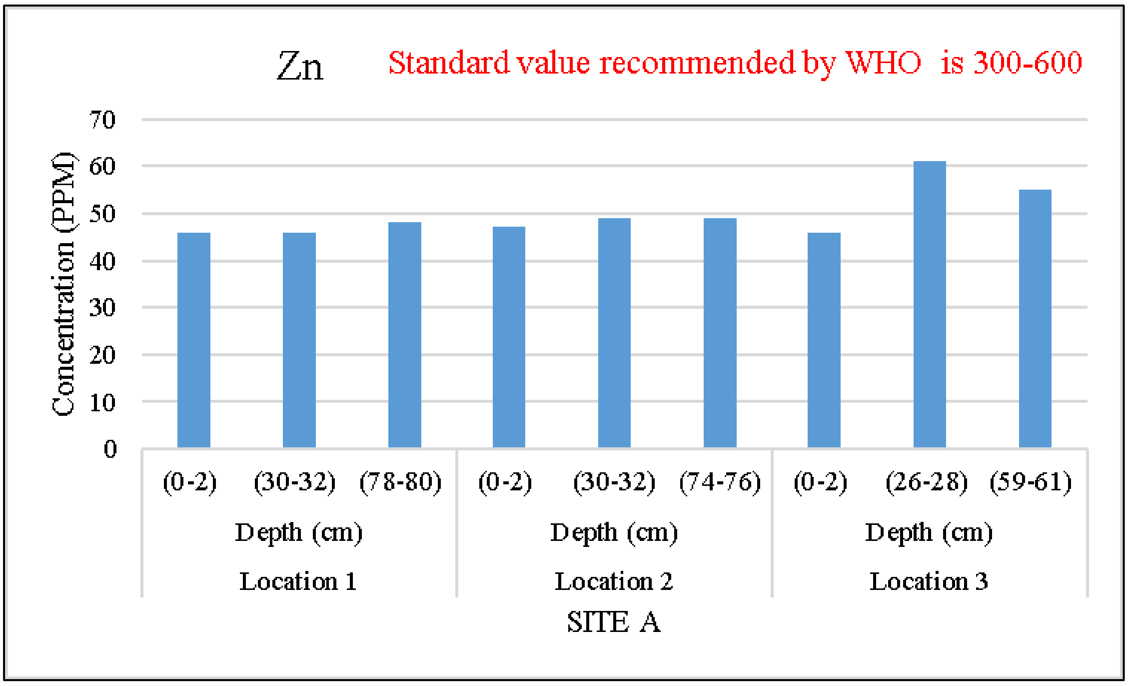

Fig.5.5 Concentrations (PPM) of Zn at SITE A

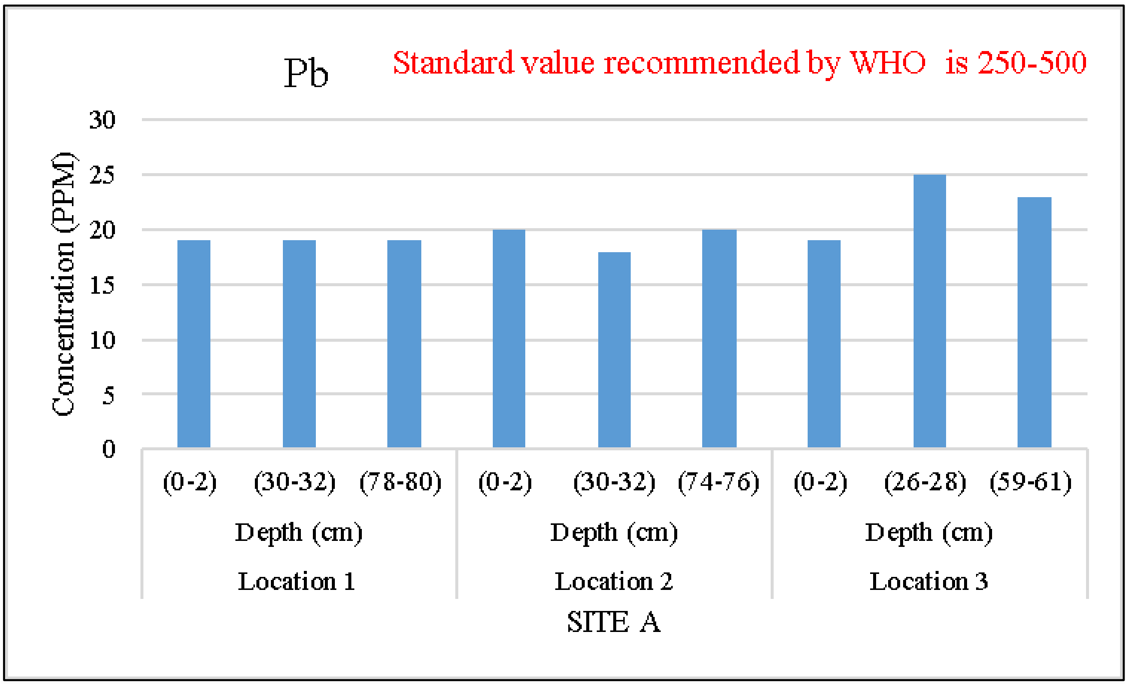

Fig.5.6. Concentrations (PPM) of Pb at SITE A

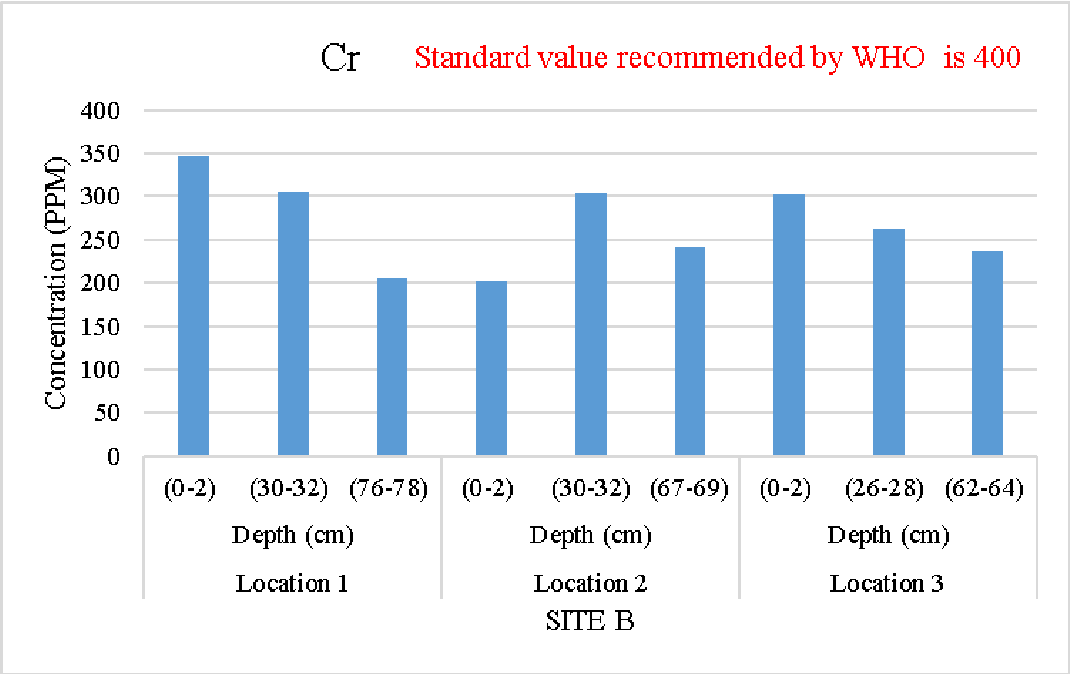

Fig. 5.7. Concentrations (PPM) of Cr at SITE B

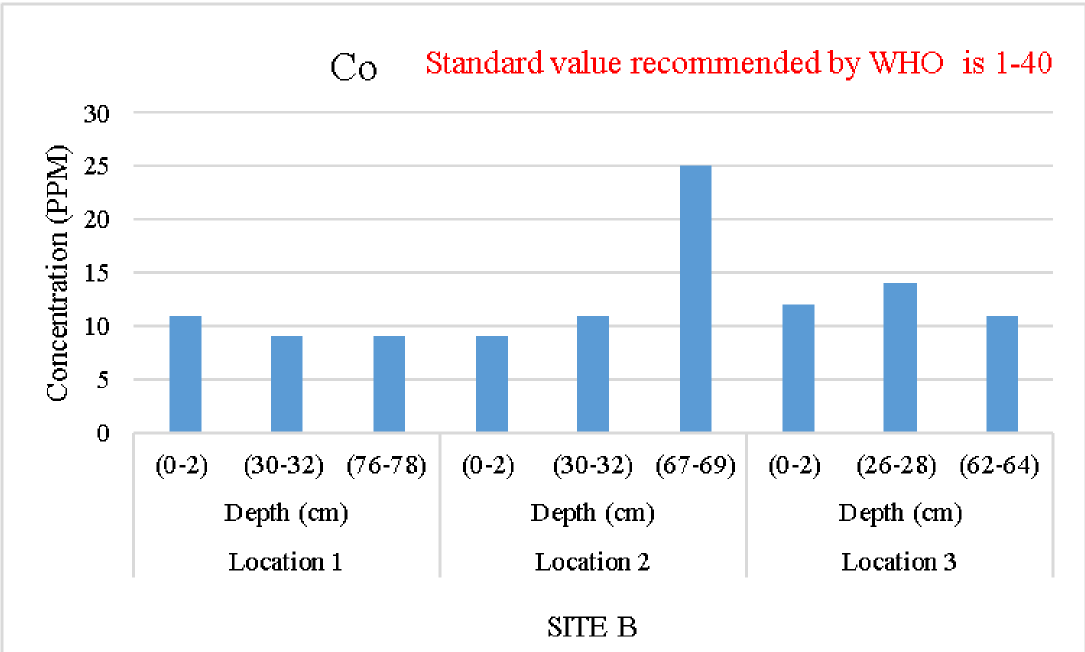

Fig. 5.8. Concentrations (PPM) of Co at SITE B

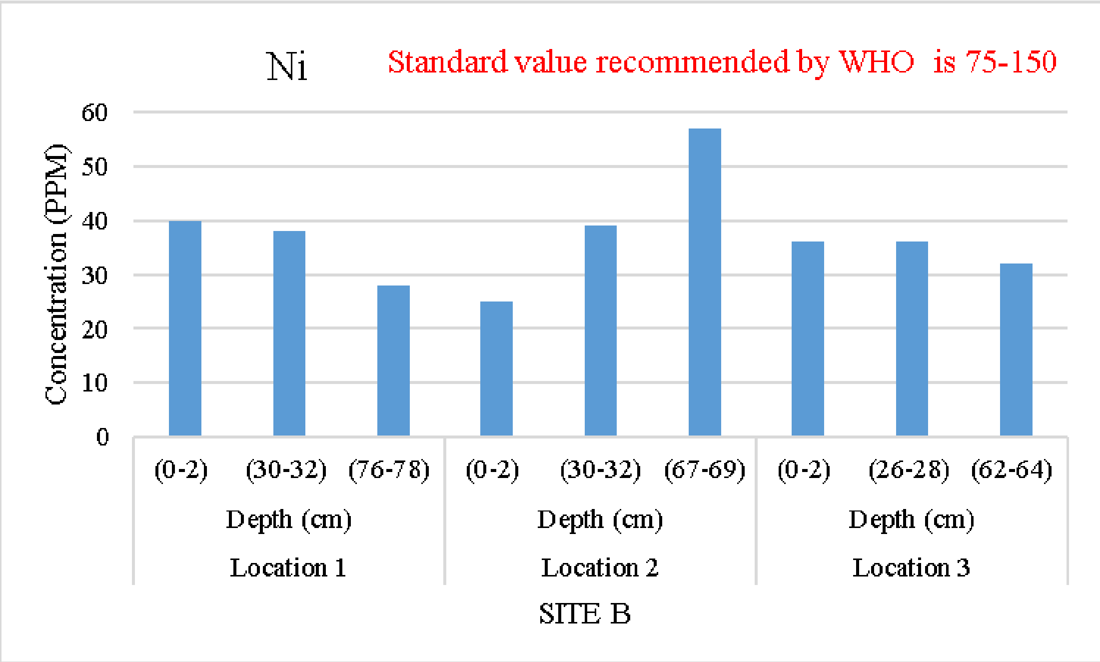

Fig. 5.9. Concentrations (PPM) of Ni at SITE B

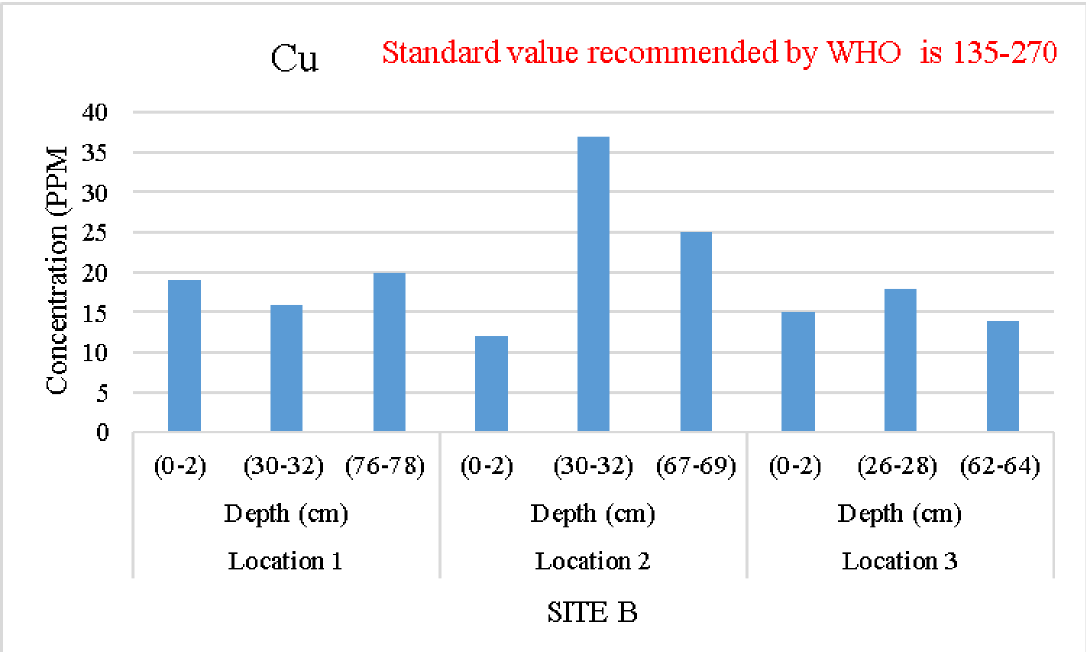

Fig. 5.10. Concentrations (PPM) of Cu at SITE B

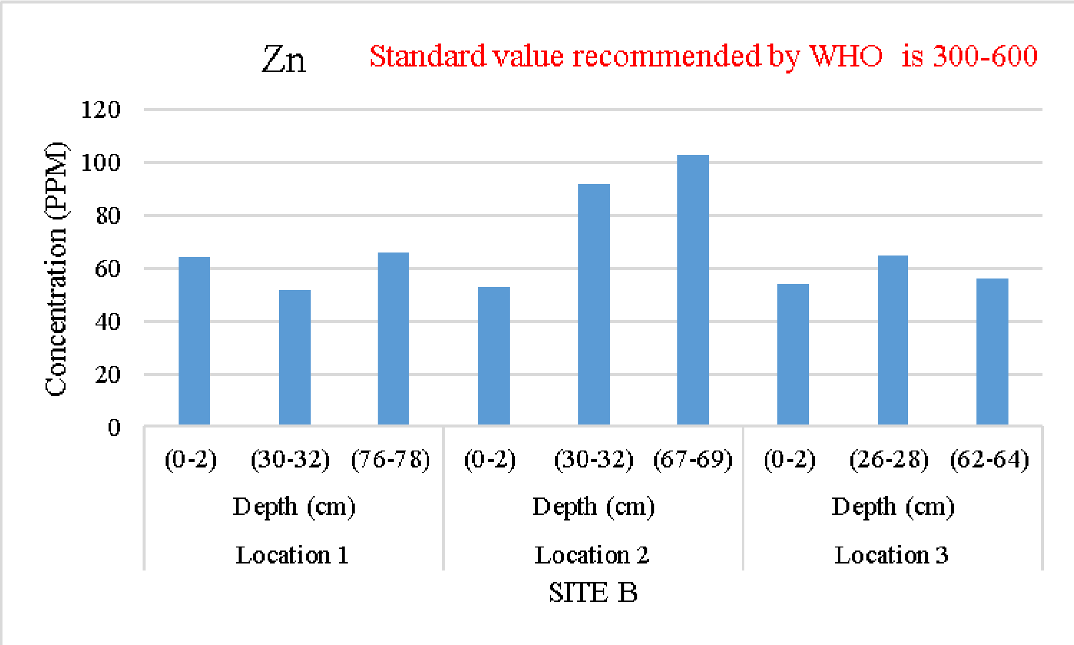

Fig. 5.11. Concentrations (PPM) of Zn at SITE B

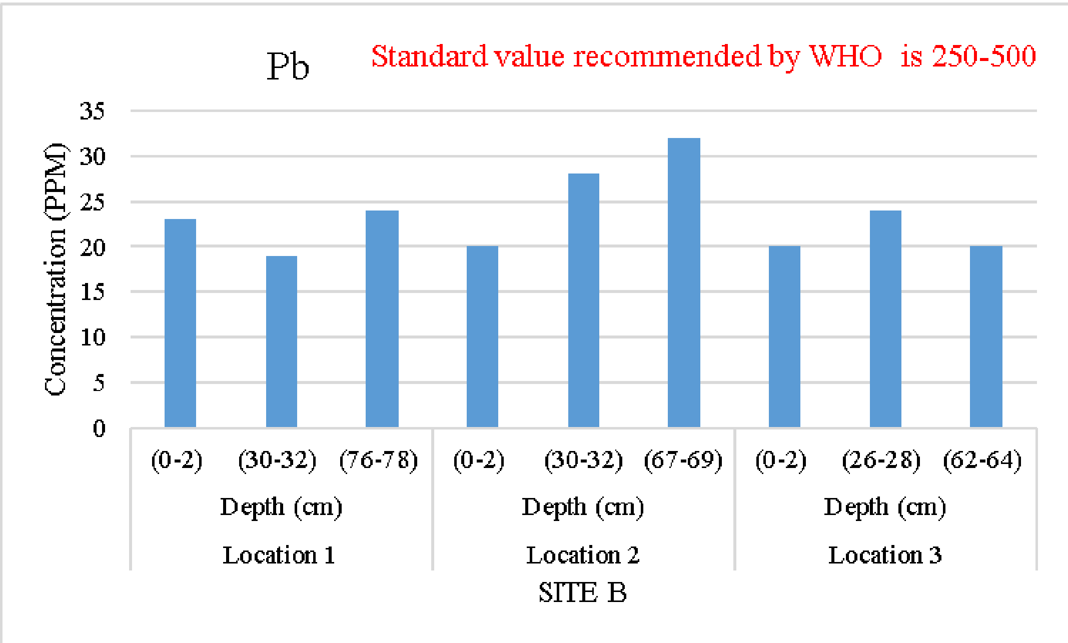

Fig. 5.12. Concentrations (PPM) of Pb at SITE B

5.5.1. Statistical analysis

Statistical Package for Social Sciences (SPSS 19.0) software package is used for statistical analysis. Different descriptive statistics have been calculated as shown in Table 5.6 and Table 5.7 for 9 soil samples (N) of SITE A and 9 soil (N) samples of SITE B for different locations respectively. Oxides and Trace Elements concentrations have fewer variations at SITE A in comparison to SITE B except in case of Chromium (Cr). To reveal the significant relationship (positive and negative) between the studied oxides and trace elements, we have conducted Pearson correlation test in SPSS.

Table 5.6. Oxides and Trace Elements Descriptive Statistics for SITE A (Palla village)

Descriptive Statistics						
Oxides and Trace Elements	**N**	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**	**Variance**
Al_2O_3	9	8.71	11.98	9.70	0.97	0.95
CaO	9	1.16	2.22	1.48	0.33	0.11
Fe_2O_3	9	3.02	4.28	3.48	0.43	0.18
K_2O	9	1.76	2.41	1.96	0.20	0.04
MgO	9	.60	1.52	0.82	0.30	0.09
Na_2O	9	.94	1.14	1.04	0.07	0.01
P_2O_5	9	.07	.11	0.08	0.01	0.00
SiO_2	9	72.19	90.15	84.39	5.54	30.74
TiO_2	9	.29	.47	0.33	0.06	0.00
MnO	9	.05	.08	0.06	0.01	0.00
Th	9	9	15	11.33	1.94	3.75
Sc	9	3.00	6.00	4.22	0.97	0.94
V	9	31.00	64.00	38.78	10.65	113.44
Cr	9	253.00	657.00	434.67	124.18	15420.75
Co	9	6.00	11.00	8.56	1.51	2.28
Ni	9	26.00	44.00	34.56	5.46	29.78
Cu	9	10.00	18.00	13.89	2.71	7.36
Zn	9	46.00	61.00	49.67	5.10	26.00
Rb	9	91.00	132.00	104.33	13.45	181.00
Sr	9	47.00	75.00	54.78	9.42	88.69
Zr	9	107.00	190.00	126.22	25.78	664.69
Ba	9	302.00	416.00	336.33	38.31	1468.00
Pb	9	18.00	25.00	20.22	2.28	5.19

At SITE A, descriptive statistics revealed the decreasing order of average percentages of the major oxides is SiO_2 > Al_2O_3 > Fe_2O_3 > K_2O > CaO > Na_2O > MgO > TiO_2 > P_2O_5 > MnO respectively. The decreasing order of average ppm of the trace elements is Cr > Ba > Zr > Rb > Sr > Zn > V > Ni > Pb > Cu > Th > Co > Sc respectively.

We observed that at SITE A the enrichment of SiO_2 varies from 72.19% to 90.15% , Al_2O_3 varies from 8.71% to 11.98%, Fe_2O_3 varies from 3.02% to 4.28%, K_2O varies from 1.76% to 2.41%, CaO varies from 1.16% to 2.22%, Na_2O varies from 0.94% to 1.14%, MgO varies from 0.6% to 1.52%, TiO_2 varies from 0.29% to 0.47%, P_2O_5 varies from 0.07% to 0.11% , MnO varies from 0.05% to 0.08% and were present in minor concentrations.

In case of trace elements, we observed that at SITE A the enrichment of Cr varies from 253 to 657, Ba varies from 302 to 416, Zr varies from 107 to 190, Rb varies from 91 to 132, Sr varies from 47 to 75, Zn varies from 46 to 61, V varies from 31 to 64, Ni varies from 26 to 44, Pb varies from 18 to 25, Cu varies from 10 to 18, Th varies from 9 to 15, Co varies from 6 to 11and Sc varies from 3 to 6.

Table 5.7. Oxides and Trace Elements Descriptive Statistics for SITE B (Okhla Barrage)

Descriptive Statistics						
Oxides and Trace Elements	**N**	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**	**Variance**
Al_2O_3	9	9.44	14.69	11.06	1.60	2.55
CaO	9	1.33	2.44	1.72	0.38	0.14
Fe_2O_3	9	3.23	7.21	4.28	1.18	1.40
K_2O	9	1.89	3.34	2.27	0.43	0.19
MgO	9	.78	3.73	1.43	0.91	0.83
Na_2O	9	.88	1.23	1.09	0.11	0.01
P_2O_5	9	.09	.21	0.12	0.04	0.00
SiO_2	9	58.55	85.82	76.40	8.00	64.05
TiO_2	9	.33	.64	0.44	0.10	0.01
MnO	9	.05	.09	0.06	0.01	0.00
Th	9	8	18	13.67	3.35	11.25
Sc	9	.00	7.00	3.89	2.32	5.36
V	9	40.00	108.00	59.33	21.52	463.25
Cr	9	202.00	346.00	267.44	49.96	2495.53
Co	9	9.00	25.00	12.33	5.02	25.25
Ni	9	25.00	57.00	36.78	9.12	83.19
Cu	9	12.00	37.00	19.56	7.57	57.28
Zn	9	52.00	103.00	67.22	18.19	330.69
Rb	9	98.00	219.00	130.78	35.12	1233.19
Sr	9	57.00	89.00	69.22	10.10	101.94
Zr	9	97.00	245.00	173.00	55.83	3116.50
Ba	9	289.00	578.00	389.78	78.40	6146.69
Pb	9	19.00	32.00	23.33	4.33	18.75

At SITE B, descriptive statistics revealed decreasing order of average percentages of the major oxides is SiO_2 > Al_2O_3 > Fe_2O_3 > K_2O > CaO > MgO > Na_2O > TiO_2 > P_2O_5 > MnO, respectively. The decreasing order of average particle per million of the trace elements is Ba > Cr > Zr > Rb > Sr > Zn > V > Ni > Pb > Cu > Th > Co > Sc respectively.
We observed that at SITE B the enrichment of SiO_2 varies from 58.55% to 85.82%, Al_2O_3 varies from 9.44% to 14.69%, Fe_2O_3 varies from 3.23% to 7.21%, K_2O varies from 1.89% to 3.34%, CaO varies from 1.33% to 2.44%, MgO varies from 0.78% to 3.73%, Na_2O varies from 0.88% to 1.23%, TiO_2 varies from 0.33% to 0.64%, P_2O_5 varies from 0.09% to 0.21% and MnO varies from 0.05% to 0.09% and were present in minor concentrations.

In case of trace elements, we observed that at SITE B the enrichment of Ba varies from 289 to 578, Cr varies from 202 to 346, Zr varies from 97 to 245, Rb varies from 98 to 219, Sr varies from 57 to 89, Zn varies from 52 to 103, V varies from 40 to 108, Ni varies from 25 to 57, Pb varies from 19 to 32, Cu varies from 12 to 37, Th varies from 8 to 18, Co varies from 9 to 25 and Sc varies from 0 to 7.

To reveal the significant relationship (positive and negative) between the studied oxides and trace elements, we have conducted Pearson correlation test in SPSS. From Table 5.8, the correlation analysis suggests significant positive correlation for Al_2O_3 with Fe_2O_3, K_2O, MgO, TiO_2, P_2O_5 and MnO and negative correlation with CaO, Na_2O and SiO_2 at SITE A. Positive correlation of Al_2O_3 was observed with all the minor traces except Sc. CaO indicates a positive correlation with all ther oxides except SiO_2. With all minor traces also, it has a positive correlation except Cr and Ni. P_2O_5 also shows the same association. Fe_2O_3 has positive correlations with all oxides except SiO_2. With all minor traces also, it has a positive correlation except Sc and Ni. Positive correlation has been observed between K_2O and other oxides except SiO_2. In case of minor traces, a positive correlation of K_2O has been found with all except Sc. Similar association we have observed for Na_2O. MgO has a positive correlation with all oxides and minor traces except SiO_2. Strong negative correlations were observed for SiO_2 with all oxides and minor traces except Ni. Conversely positive correlations were observed for TiO_2 and MnO with all oxides except with SiO_2. MnO has negative correlation with all trace elements except Th, V and Zn. V has negative correlation with Sc and Ni. Sc shows both positive and negative type of correlations with other trace elements. Pb shows a positive correlation with all other minor traces. Ba also shows same association except a negative one with Sc.

At SITE B (Table 5.9), the correlation analysis suggests significant positive correlation for Al_2O_3 with Fe_2O_3, K_2O, MgO, TiO_2, P_2O_5 and MnO and negative correlation with CaO, Na_2O and SiO_2. We observed positive correlation of Al_2O_3 with all the minor traces except Th, Sc and Zr. CaO shows a positive correlation with Na_2O, TiO_2, P_2O_5 and SiO_2. It has negative correlation with Al_2O_3, Fe_2O_3, K_2O, MgO and MnO. In case of minor traces, it has a negative correlation with Cr, Co, NI, Rb and Ba. P_2O_5 illustrates a positive correlation with all the oxides except SiO_2. Fe_2O_3 has positive correlations with all oxides except CaO, Na_2O and SiO_2. It has positive correlation with other minor traces except Th, Sc, Cr, Sr and Zr. Positive correlation has been observed between K_2O and other oxides except CaO, Na_2O and SiO_2. In case of minor traces, a positive correlation of K_2O has been found with all except Th, Sc and Zr. Na_2O shows a negative association with other oxides except CaO, P_2O_5 and SiO_2. MgO has a positive correlation with all oxides except CaO, Na_2O and SiO_2. It has positive correlation with all minor traces except Th, Sc, Cr and Zr. Negative correlations were observed for SiO_2 with all oxides except CaO and Na_2O. We observed negative correlations of SiO_2 with all the minor traces except Th, Sc and Zr. Positive correlations were observed for TiO_2 with all oxides except with Na_2O and SiO_2. In case of MnO, positive correlations were observed with all other oxides except CaO and Na_2O and SiO_2. V has negative correlation with Th, Sc, Cr and Zr. Sc shows negative correlations with all other trace elements except Sr and Zr. Pb shows a positive correlation with all other minor traces except Th and Sc. Ba also shows same association except a one more negative association with Zr.

Table 5.8. Pearson correlation matrix for Oxides and trace elements at different locations of SITE A (Palla Village)

	Al_2O_3	CaO	Fe_2O_3	K_2O	MgO	Na_2O	P_2O_5	SiO_2	TiO_2	MnO	Th	Sc	V	Cr	Co	Ni	Cu	Zn	Rb	Sr	Zr	Ba	Pb
Al_2O_3	1																						
CaO	.904**	1																					
Fe_2O_3	.877**	.914**	1																				
K_2O	.982**	.827**	.824**	1																			
MgO	.980**	.949**	.879**	.952**	1																		
Na_2O	.399	.185	.422	.501	.301	1																	
P_2O_5	.789*	.881**	.901**	.738*	.798*	.508	1																
SiO_2	-.934**	-.912**	-.779*	-.905**	-.970**	-.127	-.691*	1															
TiO_2	.970**	.950**	.928**	.947**	.983**	.403	.868**	-.930**	1														
MnO	.274	.471	.612	.154	.249	.138	.640	-.155	.349	1													
Th	.758*	.915**	.910**	.679*	.792*	.330	.975**	-.714*	.856**	.710*	1												
Sc	-.068	.132	-.160	-.160	.021	-.380	.012	-.015	-.063	-.171	.022	1											
V	.977**	.947**	.889**	.955**	.995**	.345	.825**	-.960**	.994**	.274	.816**	-.019	1										
Cr	.115	-.050	.004	.207	.148	.119	-.245	-.153	.122	-.547	-.253	-.213	.143	1									
Co	.635	.501	.465	.706*	.661	.328	.387	-.669*	.619	-.276	.314	-.095	.646	.225	1								
Ni	.037	-.164	-.145	.128	.023	.278	-.208	.043	-.048	-.649	-.351	.233	-.019	.331	.565	1							
Cu	.438	.258	.193	.525	.456	.387	.166	-.408	.389	-.568	.032	.248	.427	.407	.811**	.866**	1						
Zn	.944**	.863**	.832**	.956**	.966**	.397	.721*	-.931**	.960**	.098	.696*	-.084	.970**	.359	.726*	.129	.557	1					
Rb	.846**	.630	.575	.914**	.838**	.432	.471	-.832**	.796*	-.251	.393	-.112	.832**	.463	.815**	.373	.741*	.913**	1				
Sr	.862**	.716*	.605	.906**	.885**	.300	.514	-.905**	.836**	-.208	.471	-.021	.878**	.420	.810**	.280	.694*	.938**	.980**	1			
Zr	.929**	.926**	.848**	.889**	.938**	.349	.848**	-.879**	.953**	.338	.835**	.127	.955**	.066	.459	-.104	.336	.893**	.728*	.778*	1		
Ba	.857**	.691*	.607	.902**	.873**	.324	.480	-.874**	.818**	-.232	.428	-.016	.858**	.484	.809**	.364	.740*	.935**	.985**	.990**	.752*	1	
Pb	.819**	.721*	.597	.852**	.870**	.240	.493	-.881**	.816**	-.238	.463	.088	.857**	.490	.795*	.331	.732*	.932**	.947**	.981**	.763*	.982**	1

* Correlation is significant at the $p < 0.05$ level (2-tailed)
** Correlation is significant at the $p < 0.01$ level (2-tailed)

Table 5.9. Pearson correlation matrix for Oxides and trace elements at different locations of SITE B (Okhla barrage)

	Al_2O_3	CaO	Fe_2O_3	K_2O	MgO	Na_2O	P_2O_5	SiO_2	TiO_2	MnO	Th	Sc	V	Cr	Co	Ni	Cu	Zn	Rb	Sr	Zr	Ba	Pb
Al_2O_3	1																						
CaO	-.042	1																					
Fe_2O_3	.961**	-.212	1																				
K_2O	.978**	-.233	.987**	1																			
MgO	.975**	-.177	.990**	.993**	1																		
Na_2O	-.471	.522	-.509	-.568	-.557	1																	
P_2O_5	.328	.890**	.175	.148	.196	.209	1																
SiO_2	-.992**	.035	-.929**	-.964**	-.959**	.511	-.319	1															
TiO_2	.949**	.198	.909**	.889**	.916**	-.262	.527	-.921**	1														
MnO	.872**	-.213	.956**	.910**	.939**	-.480	.159	-.820**	.871**	1													
Th	-.309	.866**	-.425	-.479	-.437	.765*	.690*	.330	-.047	-.373	1												
Sc	-.584	.579	-.596	-.669*	-.615	.576	.367	.622	-.361	-.458	.655	1											
V	.980**	.065	.957**	.948**	.967**	-.388	.417	-.960**	.986**	.904**	-.201	-.481	1										
Cr	.040	-.097	-.100	.019	-.068	-.098	-.107	-.115	-.147	-.321	-.092	-.569	-.095	1									
Co	.881**	-.441	.950**	.955**	.940**	-.631	-.069	-.857**	.755*	.888**	-.667*	-.652	.840**	-.078	1								
Ni	.877**	-.372	.847**	.916**	.880**	-.661	-.048	-.905**	.695*	.707*	-.616	-.871**	.789*	.359	.869**	1							
Cu	.674*	.594	.480	.522	.528	-.153	.824**	-.706*	.719*	.346	.304	-.167	.675*	.266	.290	.469	1						
Zn	.952**	.214	.879**	.886**	.901**	-.415	.580	-.947**	.960**	.800**	-.089	-.412	.963**	.008	.742*	.749*	.832**	1					
Rb	.952**	-.307	.983**	.992**	.984**	-.553	.054	-.936**	.858**	.910**	-.532	-.695*	.924**	-.011	.970**	.909**	.433	.835**	1				
Sr	.212	.870**	-.023	.010	.034	.438	.797*	-.248	.369	-.108	.719*	.231	.256	.193	-.250	-.025	.751*	.382	-.062	1			
Zr	-.217	.875**	-.309	-.375	-.323	.708*	.736*	.245	.057	-.250	.969**	.567	-.086	-.096	-.571	-.531	.351	.015	-.428	.695*	1		
Ba	.967**	-.226	.956**	.980**	.970**	-.556	.130	-.968**	.872**	.859**	-.476	-.671*	.930**	.025	.929**	.912**	.536	.871**	.980**	.056	-.401	1	
Pb	.958**	.195	.909**	.899**	.915**	-.314	.545	-.938**	.984**	.833**	-.077	-.407	.982**	-.048	.770*	.730*	.772*	.983**	.864**	.358	.036	.883**	1

* Correlation is significant at the $p < 0.05$ level (2-tailed)
** Correlation is significant at the $p < 0.01$ level (2-tailed)

Chapter 6
Conclusion

CHAPTER 6

CONCLUSION

In the present research work, a total of 18 river bed sediments from the different depths of location 1, 2 and 3 at SITE A (Palla village) and location 4, 5 and 6 at SITE B (Okhla barrage) of the river Yamuna in Delhi region are studied for the paleolimnological environment of Yamuna river using diatom as a major indicator of ecological conditions of prehistoric times.

The method of radioactive carbon dating studies were performed to reveal geological age of the samples and the oldest age observed was 17020 BC years in case of sample taken from SITE B, location 6, depth of 0-2 cm while youngest age observed was 85 BC from sample taken at depth of 30-32 cm at location 5 of SITE B. Each sediment sample revealed a particular diatom assemblage which represented a particular type of environmental conditions. 32 diatom species were observed in the present study and most of the species were indicative of a good quality of water and a profuse distribution of plants and animals in vicinity of the river. Therefore, the hypothesis expounded by the present study which is the first step to reveal the paleolimnological data of river Yamuna favors that river Yamuna which is most polluted river of India was once very clean and surrounded by ample of flora and fauna. The diatom diversity revealed by the riverbed sediments at SITE A and SITE B indicates good water quality and ecological conditions of river Yamuna.

To check the chemical nature of the sediments, some other experiments were also performed like SEM-EDAX, CHNS, XRD and XRF.

In order to study the elements present in the soil and shape of sediment grains, EDAX analysis was performed on all the 18 samples. The main elements found in analysis were Si, O, Nb and Al. Out of these, Si and O were present in major quantities in almost all the samples while Nb was recorded in very less amount in sample taken from surface (0-2cm) of location 1 of SITE A (Palla). Al was recorded from only one SITE i.e. location 5 of SITE B at the depth of 30-32 cm. SEM EDAX study reveals that SITE A lacks in any type of heavy pollutant while occurrence of Al at SITE B confirms the presence of pollutants. Concentration of elements varies from the surface to the bottom of the river bed and there is no particular pattern of concentration that is followed.

The percentage of concentration of CHNS in river bed soil varies at different depths at both the sites. The river bed mainly consists of sand; therefore, there is less concentration of C, H, N, S elements as compared to any other type of soil. SITE A has higher amounts of concentration of Carbon, Hydrogen, Nitrogen except Sulphur in comparison to SITE B at various depths of river bed. This can be attributed to heavy domestic and industrial pollution at SITE B which interferes with the chemical composition of the soil and has an effect on its quality. It also adds extra amount of Sulphur in river soil through polluted water.

XRD Study helped to elucidate the type of minerals deposited in the river bed and in all probability the originating point is from the Himalayas. The mineralogical composition of all soil sediment samples was analysed using XRD. The mineral which has the strongest peak in diffractogram in all sediment samples is quartz along with muscovite and other minerals like Melanovanadite, Gismondine, Iron, $F_{10}NaTm_3$, AlNi, $Fe_{2.87}Si_{0.99}$, $Na_{0.35}(CoO_2)(D_2O)_{1.43}$, $F_{15}Mo_5O_{15}Rb_{15}$, $Co_{1.67}Na_{0.21}(Al_4Si_8O_{24})$, $La_2Mo_2O_9$ and Co_2Feln.

XRF revealed various oxides and elements, Aluminium Oxide (Al_2O_3), Calcium Oxide (CaO), Hematite (Fe_2O_3), Potassium Oxide (K_2O), Magnesium Oxide (MgO), Sodium Oxide (Na_2O), Phosphorous Pentoxide (P_2O_5), Quartz (SiO_2), Titanium Dioxide (TiO_2), Thorium (Th), Manganese Dioxide (MnO), Scandium (Sc), Vanadium (V), Chromium (Cr), Cobalt (Co), Nickel (Ni), Copper (Cu), Zinc (Zn), Rubidium (Rb), - Strontium (Sr), Zirconium (Zr), Barium (Ba) and Lead (Pb). The concentration levels of heavy metals i.e. Co, Ni, Cu, Pb and Zn in soil sediments at SITE A and SITE B were found to be lower than the WHO's recommended safety limits except Cr concentration levels which exhibited the presence of excessive amount of Cr concentration at both the sites according to WHO recommended safety limits. The presence of Pb, Zn might be attributed to the waste introduced by coal based thermal power plant. Similarly, Ni and Cr might be caused by automobile, paint, batteries, and electroplating industrial wastes. The high concentration level of Cr at SITE A might be because of clothing and hosiery dyeing industries of city Panipat (Haryana) which are just a few kilometers away from Delhi.

The extent of pollution that is faced by River Yamuna raises a severe threat to its identity as a river. Besides revealing the prehistoric environmental conditions of river Yamuna in Delhi region, the present study helps us in understanding the elemental composition and morphology of soil grains in the river bed. This further enhances our knowledge and makes our understanding better about the complexity of distribution of elements along the depths of the river bed. This can be used for conservation studies and protection of a fragile wetland ecosystem of our rivers. River Thames of London a famous and one of the most cleanest river of the world once was turned into a fermenting sewer at the time of industrial revolution but with a schematic approach and construction of efficient sewage treatment and drainage system, River Thames has become one of the cleanest rivers in the world and hailed as an international success story. In the present time River Yamuna which might be one of the most polluted rivers of India having the most polluted stretch in Delhi but the paleolimnological data from present study revealed it had a wonderful history with of clean water flowing through the Delhi region and with a scientific approach and sincere efforts it will regain its glory as one of the cleanest river of the world in future.

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List of Publications

LIST OF PUBLICATIONS

Journal Publications

1. Vivek Chopra, *Jai Gopal Sharma. Assessment of Elemental Carbon, Nitrogen, Hydrogen and Sulphur in Alluvial Sediments of River Yamuna in Delhi Region. Accepted for publication in SCOPUS indexed journal *ECOLOGY, ENVIRONMENT AND CONSERVATION*, 2020 November Supplement Issue. (Accepted).
2. Vivek Chopra, *Jai Gopal Sharma. SEM-EDAX analysis on the Soil Samples of River Yamuna in Delhi Region. Accepted for publication in SCOPUS indexed scientific research journal *Nature Environment and Pollution Technology* (pISSN 0972-6268; e-ISSN 2395-3454). The paper is likely to come in Vol. 20, No. 1 (March), Year 2021. (Accepted).

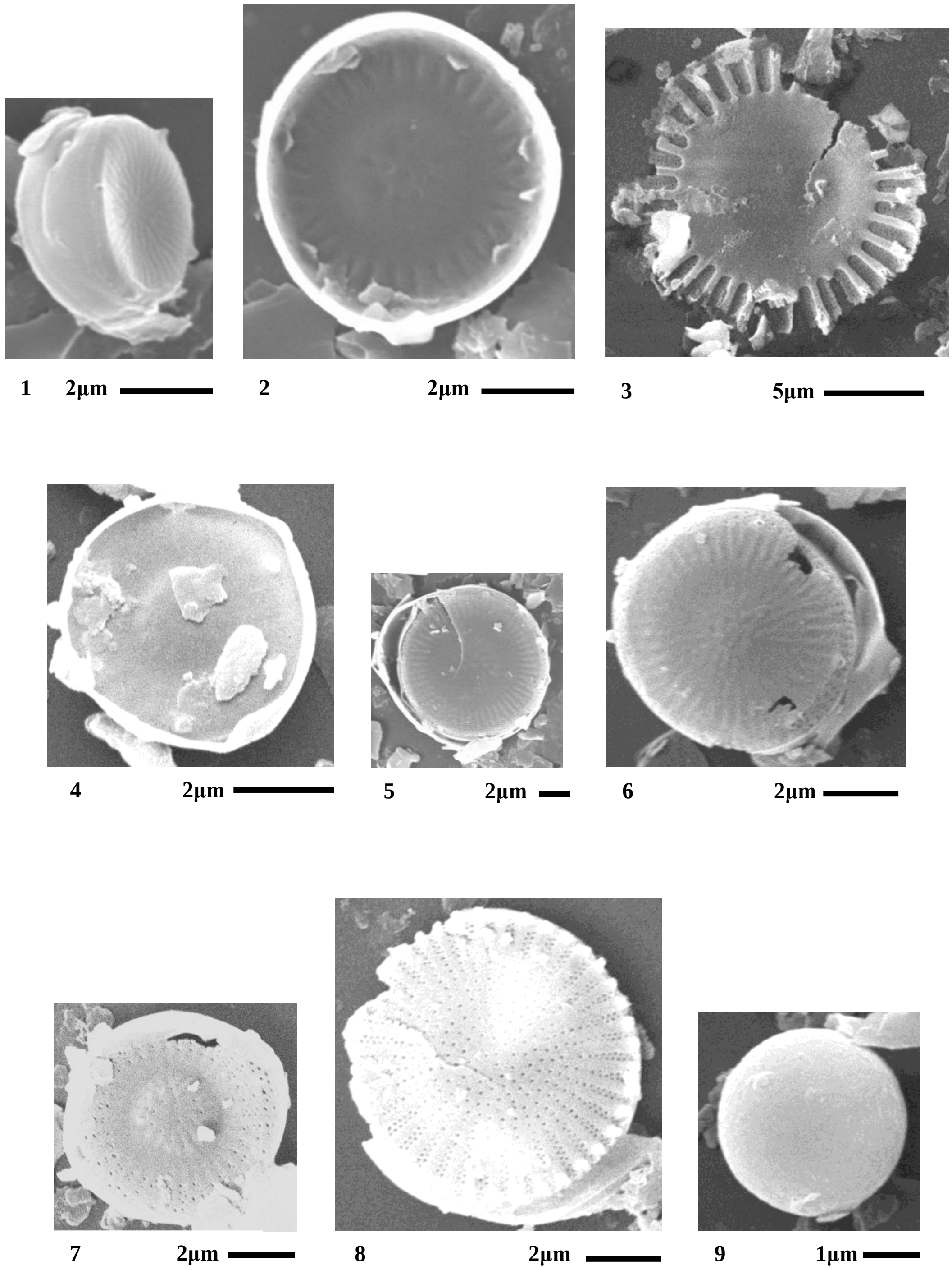
* corresponding author

Conference Presentations

1. Participated and presented Poster entitled "Analyzing *Mallomonas* sp. From river Yamuna in Delhi Region using Scanning Electron Microscopy" in International conference World Environment Summit 2020, 18-19 January, 2020 held at Delhi.
2. Participated and presented oral presentation entitled "Assesment of elemental Carbon, Nitrogen, Hydrogen and Sulphur from different soil horizons of River Yamuna in Delhi region" in international conference on Advances and Innovations in Agriculture & Allied Sciences (AIAAS - 2020) 31st January-01st February 2020 held at JNU, Delhi.

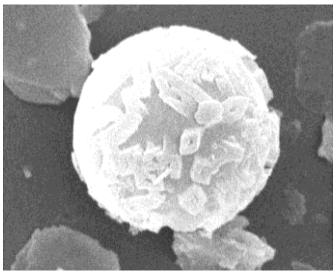
Plates

PLATE 1

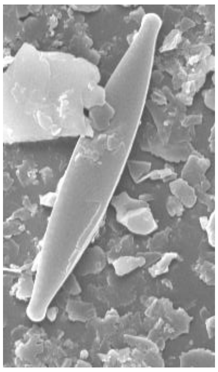


1. *Cyclotella pseudostelligera,* 2. *Cyclotella atomus,* 3. *cyclotella meneghiniana,* 4. *Cyclotella stelligera,* 5. *Cyclotella striata,* 6. *Stephanodiscus parvus,* 7. *Stephanodiscus minutulus,* 8. *Stephanodiscus binderanus,* 9. *Pleurosira laevis*

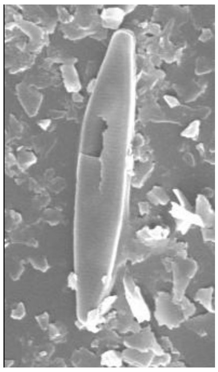
PLATE 2



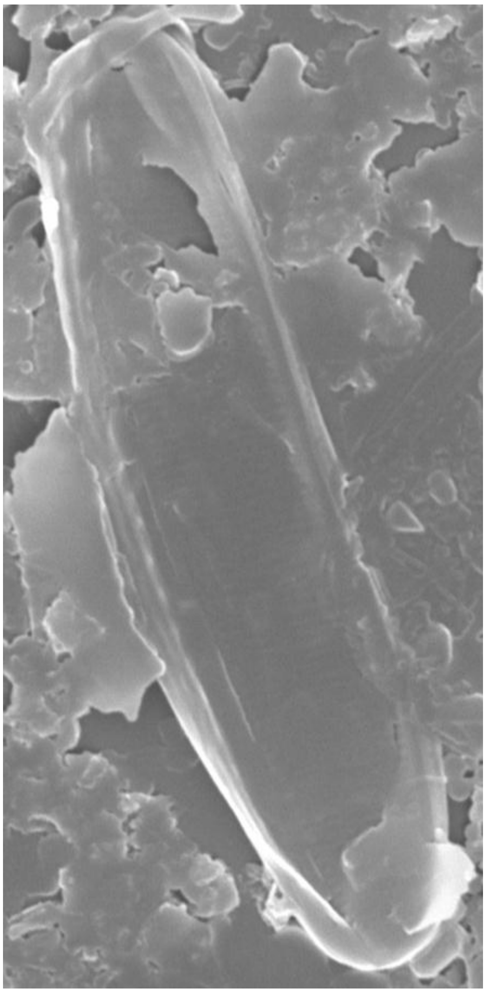
10 2µm



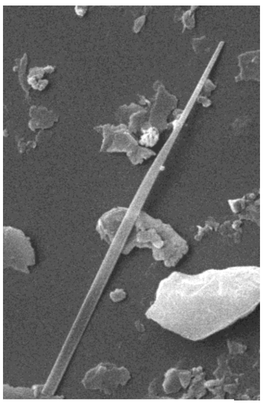
11 10µm



12 2µm



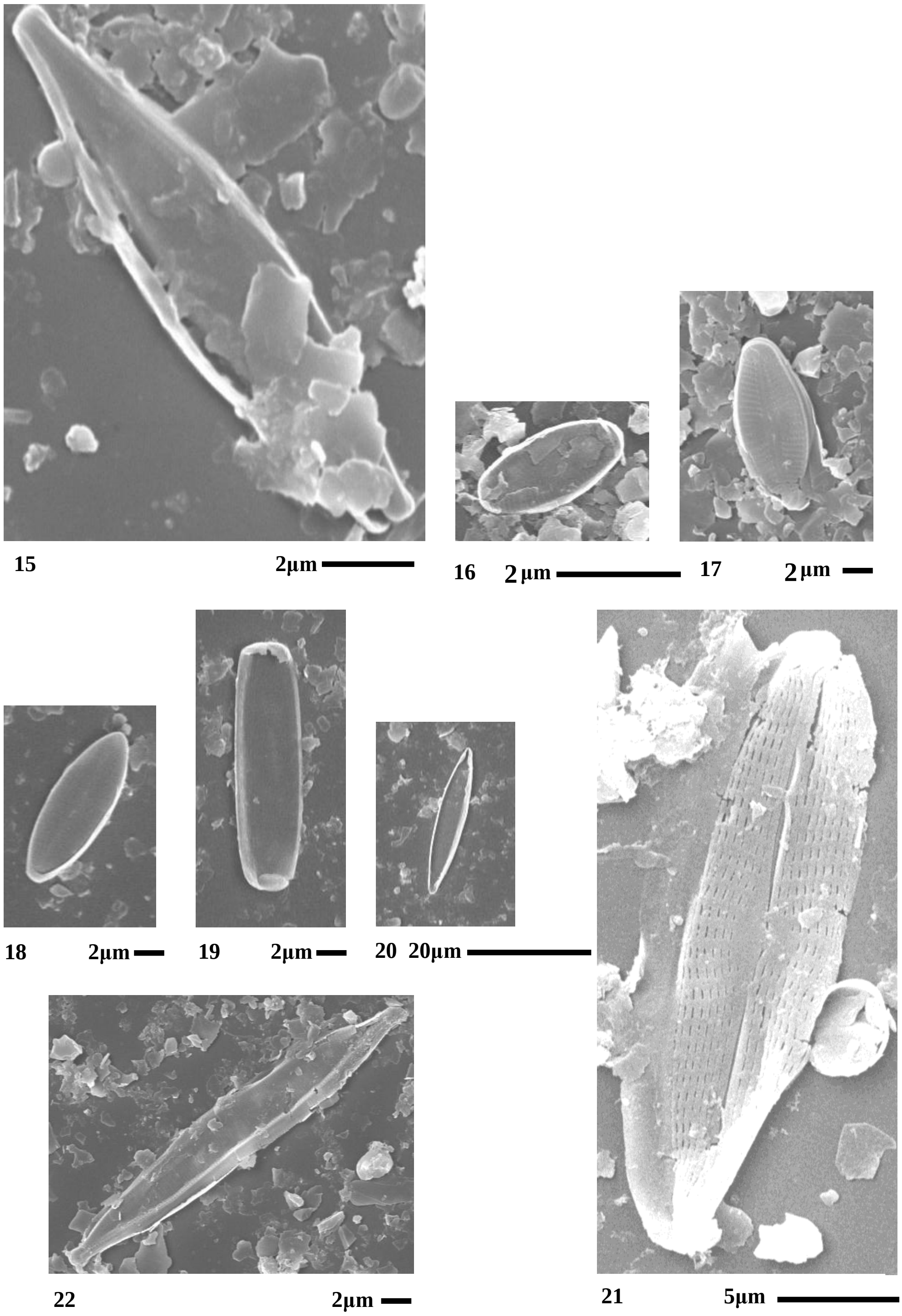
14 2µm



13 5µm

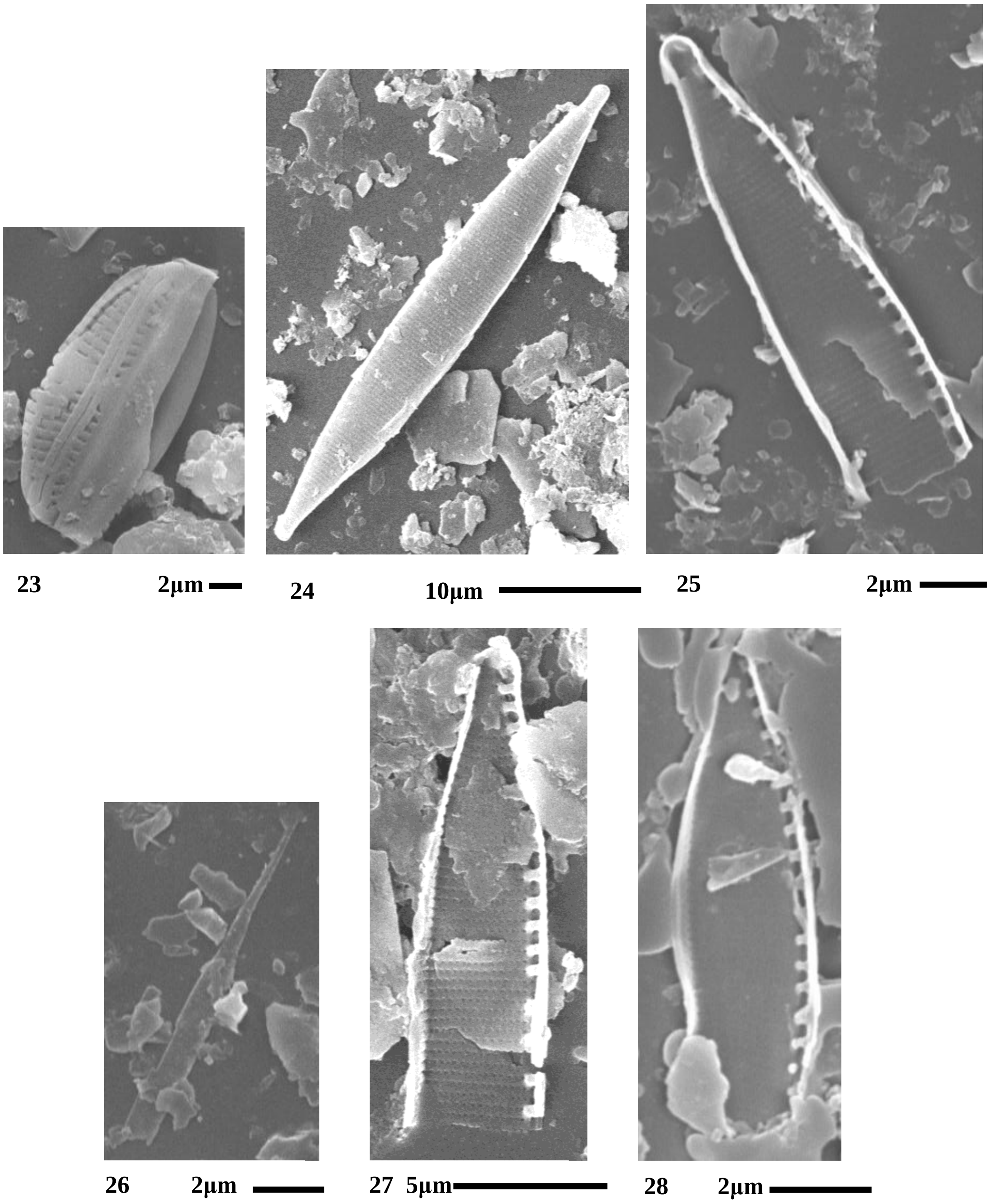
10. *Pleurosira indica,* 11. *Fragilaria rumpens,* 12. *Fragilaria capucina,* 13. *Synedra acus,* 14. *Eunatia faba*

PLATE 3



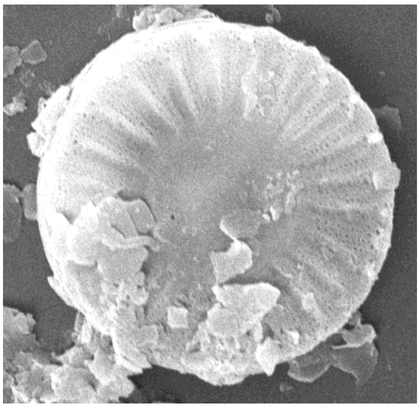
15. *Gomphonema parvulum*, 16. *Cocconeis placentula*, 17. *Achnanthidium minutissimum*, 18. *Achnanthidium eutrophilum*, 19. *Achnanthidium hoffmannii* 20. *Neidium iridis*, 21. *Navicula cryptotenella,* 22. *Plagiotropis lepidoptera* var. proboscidea

PLATE 4

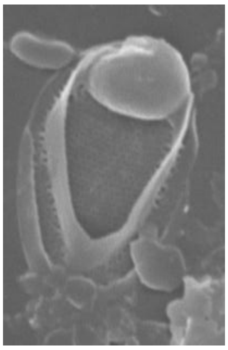


23. *Amphora pediculus*, 24. *Tryblionella brunoi*, 25. *Nitzchia palea*, 26. *Nitzschia acicularis*, 27. *Nitzshia recta* 28. *Nitzchia fonticola*

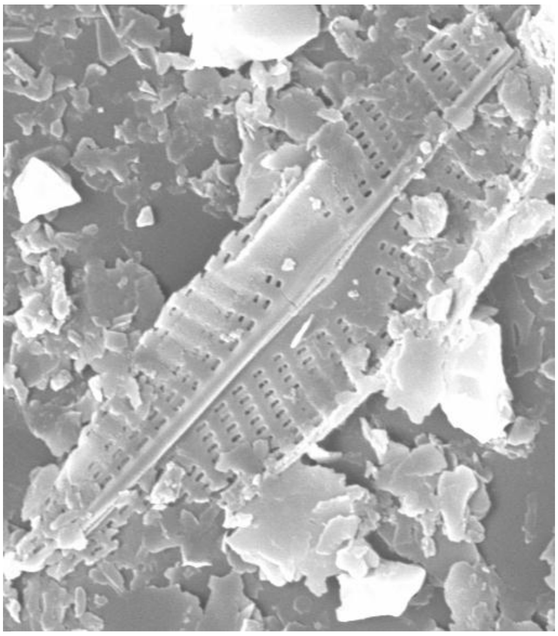
PLATE 5



29 5µm



30 2µm



31 2µm

29. *Pantocsekiella costei*, 30*. Mallomonas* sp., 31. *Stauroneis* sp

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18 to 19 January, 2020 | Delhi (India)

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Certificate of Participation

This is to certify that VIVEK CHOPRA

of DELHI TECHNOLOGICAL UNIVERSITY, DELHI

has participated in the World Environment Summit 2020 as Volunteer / Delegate and presented a Paper (Oral/Poster) entitled ANALYZING MALLOMONAS SP. FROM RIVER YAMUNA IN DELHI REGION USING SCANNING ELECTRON MICROSCOPY during the technical session.

Dr. R. K. Rana
President
ESDA, Delhi

Dr. S. K. Goyal
Head
CSIR-NEERI-Delhi Zonal

Dr. G. K. Arora
Principal
Dr. Bhim Rao Ambedkar College, DU

Prof. Jaigopal Sharma
Convener, WES 2020
DTU, Delhi

Dr. Jitendra K. Nagar
Organising Secretary, WES 2020
General Secretary, ESDA, Delhi

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International Conference

on

Advances and Innovations in Agriculture & Allied Sciences (AIAAS-2020)

31st January - 01st February, 2020

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CERTIFICATE OF PARTICIPATION

This is to certify that Prof./Dr./Mr./Ms./Mrs. Vivek chopra

has actively participated / presented a paper (Oral / ~~Poster~~) entitled Assesment of elemental - - - - - - Yamuna in Delhi region *in the International Conference held during 31st January - 01st February, 2020 at Jawaharlal Nehru University Convention Centre, New Delhi, India.*

Triveni Sharma	A. K. Mall	Dinesh Kanwar Yadav	P. K. Upadhyay
Co-organizing Secretary	Organizing Secretary	Organizing Convenor	Organizing Chairman