# Studies on physico-chemical characterization of sediments in the Budha Nallah, Punjab (India)

Dissertation submitted in partial fulfillment for the requirement of degree of

**Master of Technology**
**in**
**Environmental Science and Technology**

by


**Nikita Rajpal**

(Roll No. 601101019)


Under the supervision of


Dr. Pramod K. Bajpai
Distinguished Professor
Department of Chemical Engineering

Dr. Haripada Bhunia
Associate Professor
Department of Chemical Engineering

Dr. Babu Ram
Member Secretary
Punjab Pollution Control Board
Vatavaran Bhawan, Nabha Road, Patiala



SCHOOL OF ENERGY AND ENVIRONMENT
THAPAR UNIVERSITY
PATIALA-147004


June 2013

# DECLARATION

I hereby declare that the work embodied in dissertation entitled **"Studies on physico-chemical characterization of sediments in the Budha Nallah, Punjab**" submitted in the **"School of Energy And Environment"**, Thapar University, Patiala, is a record of the work carried out by me under the guidance of Dr. Pramod K. Bajpai (Distinguished Professor, ChED), Dr. Haripada Bhunia (Associate Professor, ChED) and Dr. Babu Ram (Member secretary, PPCB). The matter presented in this dissertation has not been submitted in part or full, to this or any other University/Institute for any degree or diploma.

Date: ______________

Nikita Rajpal
(Roll No: 601101019)

## CERTIFICATE

This is to certify that the Dissertation titled **"Studies on physico-chemical characterization of sediments in the Budha Nallah, Punjab"**, is an authentic record of my own work carried out as requirements for the award of degree of Master of Technology in Environmental Science and Technology from Thapar University, Patiala, under the guidance of Dr. Pramod K. Bajpai (Distinguished Professor, ChED), Dr. Haripada Bhunia (Associate Professor, ChED) and Dr. Babu Ram (Member secretary, PPCB) during July 2012 to June 2013.

Date: 8/7/13

Nikita (18/6/2013)
Nikita Rajpal
(Roll No: 601101019)

It is certified that the above statement made by the student is correct to the best of our knowledge and belief.

Dr. Pramod K. Bajpai
Distinguished Professor
Department of Chemical Engineering
Thapar University, Patiala

18/06/2013
Dr. Haripada Bhunia
Associate Professor
Department of Chemical Engineering
Thapar University, Patiala

Dr. Babu Ram
Member Secretary
Punjab Pollution Control Board
Vatavaran Bhawan, Nabha Road, Patiala

**Countersigned by**

Dr. A. S. Reddy
Head, School of Energy and Environment
Thapar University, Patiala

Dr. S. K. Mohapatra
Dean of Academic Affairs
Thapar University, Patiala

# ACKNOWLEDGEMENTS

I express my sincere gratitude and regards to my supervisor Dr. Pramod K. Bajpai, Distinguished Professor, Department of Chemical Engineering, Thapar University, Patiala for his valuable guidance and suggestions. Without his encouragement and guidance this dissertation would not have been materialized.

I feel privileged to offer my sincere thanks and owe an enormous deal of gratitude to my co-supervisors Dr. Haripada Bhunia, Associate Professor, Department of Chemical Engineering, Thapar University Patiala and Dr. Babu Ram, Member Secretary, Punjab Pollution Control Board, Patiala for their guidance and encouragement at every step of my work. They guided me and gave me full time to understand the minute details of each and every step, for the successful completion of my dissertation work.

I would like to express my gratitude to Dr. A. S. Reddy, Head of School of Energy and Environment, Thapar University, Patiala for his kind cooperation and encouragement which helped in the completion of this work.

I would like to thank Dr. Rajeev Mehta, Head of Chemical Engineering Department, Thapar University, Patiala for supporting me and providing an environment to complete my work successfully.

I am thankful to Gaurav Madhu (Research Associate), Chitrakshi Goel (Inspire Fellow), Kimi Jain (Research Scholar), Nipun Dogra (JRF, ChED), Lippi (Student, SEE) and Kumar Uddipto (Student, ChED) for their constant help and support at various stages of my dissertation.

The generous support of all the staff members of Chemical Engineering Department is greatly appreciated.

I am thankful to PPCB for providing financial support in completion of this work.

Technical Education Quality Improvement Programme (TEQIP) Phase-II, Thapar University, Patiala for financial support in presenting the published papers.

Above all, I express my indebtedness to the "**ALMIGHTY**" for all His blessings and kindness.

**(Nikita Rajpal)**

Roll No.: 601101019

# ABSTRACT


Today Budha Nallah has become a major source of pollution in the region, as it gets polluted after entering the highly industrialized Ludhiana city, turning it into an open drain. Physical and Chemical analysis of sediments were done for sludge quality assessment, also helpful in analyzing an approximate level of the soil contamination. The objective of this study was to investigate the pollution of sediments in Budha Nallah. The basic sequence of measurements includes three steps: sampling (at 8 locations), sample preparation and chemical procedures for analysis based on standard methods and reference materials. All of these steps are vital in maintaining the sediment quality. The further steps of refinement are in accordance to the specific purposes like characterization of sediment samples for various important parameters such as organic carbon, nitrogen, phosphorus contents and heavy metals (e.g. Fe, Na, K, Mn, Zn, Pb, Cu and Cr) etc. Quite higher concentration of heavy metals and nutrients were measured in the sludge, this can be attributed to the discharge of industrial effluents in the past, domestic and agricultural waste and other anthropogenic activities around the Nallah. It is feared that in the long run it might prove harmful to ground water and ultimately to human beings and animals.

This dissertation seeks to give a method to study the various pollutants present in the sediment samples collected from different locations of Budha Nallah and their possible causes.

The 1st **chapter** is an introduction, giving an overview of the situation, its sources and impacts.

The 2nd **chapter** describes the review of literature based on Budha Nallah and other related studies on sediments pollution.

The 3rd **chapter** describes the materials and methods used in this work.

The 4th **chapter** describes the results and discussion related to the results.

The 5th **chapter** describes the conclusion of the study.

The 6th **chapter** describes the future recommendations and conservative measures.

# CONTENTS

# LIST OF FIGURES

## LIST OF TABLES

## ABBREVIATIONS

| | |
|---|---|
| AAS | Atomic Absorption Spectrometer |
| ASTM | American Society for Testing and Materials |
| APHA | American Public Health Association |
| APEX | Agricultural Policy/Environmental Extender |
| ANSP | *Air Navigation Service Provider* |
| BOD | Biochemical Oxygen Demand |
| COD | Chemical Oxygen demand |
| ChED | Chemical Engineering Department. |
| EPA | Environmental Protection Act |
| EC | Electrical Conductivity |
| ICP-MS | Inductively Coupled Plasma Mass Spectrometry |
| MLD | Million Litres per Day |
| MoEF | Ministry of Environment and Forests |
| ON | Organic Nitrogen |
| SEF | Sediment Enrichment Factor |
| STP | Sewage Treatment Plant |
| PERI | Potential Ecological Risk Index Method |
| PGIMER | Post Graduate Institute of Medical Education and Research |
| PPCB | Punjab Pollution Control Board |
| TN | Total Nitrogen |

# CHAPTER 1
# INTRODUCTION

## 1.1 Overview

Sediment contamination leading to toxic effects is a worldwide problem, especially in those nations with a long industrial history. The Environmental Protection Agency (EPA) lists sediment as the most common pollutant in rivers, streams, lakes and reservoirs. Natural erosion produces nearly 30 percent of the total sediment in the India, accelerated erosion from human use of land accounts for the remaining 70 percent **[1].**

The most concentrated sediment releases come from construction activities, industrial activities, domestic discharge, residential discharge, and surface runoff etc. Sediment pollution causes billions in environmental damage annually. Sediment entering storm water degrades the quality of water for drinking, wildlife and the land surrounding streams in the following ways: it fills up storm drains and catch basins to carry water away from roads and homes, which increases the potential for flooding. Water polluted with sediment becomes cloudy, preventing animals from seeing food. Murky water prevents natural vegetation from growing in water. In stream beds disrupts the natural food chain by destroying the habitat where the smallest stream organisms live and causing massive declines in fish populations **[2].** It increases the cost of treating drinking water and can result in odour and taste problems. It effects nearby soil and ground water. Sediment can clog fish gills, reducing resistance to disease, lowering growth rates, and affecting fish egg and larvae development. Nutrients transported by sediment can activate blue-green algae that release toxins and can make swimmers sick. The deposits in rivers can alter the flow of water and reduce water depth, which makes navigation and recreational use more difficult.

Sediment particles are classified by size, with smallest being clay and the largest being boulders. Smaller or fine particles are usually carried in suspension while the larger materials are moved along the channel bottom by rolling sliding, or bouncing. Fine particles are the most chemically active part of soil and carry more adsorbed nutrients than larger particles. Most deposited sediment contains high proportion of fine particles (silt, clay, organic matter) than the parent soil from which it was derived. So it generally contains higher concentration of phosphorus and pesticides.

Chemicals such as some pesticide s, phosphorus and ammonium are transported with sediment in an adsorbed state. Changes in the aquatic environment, such as decreased oxygen concentrations in the overlying waters or the development of anaerobic conditions in the bottom sediments, can cause these chemicals to be released from the sediment **[3].** Adsorbed phosphorus transported by the sediment may not be immediately available for aquatic plant growth but does serve as a long term contributer to eutrophication.

Sediments are considered to be major sink for, and also a secondary source of pollutants **[4].** If the equilibrium between sediments and the overlying water body is broken, sediments would transfer most pollutants into water **[5].** Due to their environmental persistence and biogeochemical recycling and ecological risks, heavy metals are of particular concern worldwide. The spatial distribution of heavy metals in marine and lake sediments are of great importance in clarifying the history of pollution in aquatic systems (figure 1.1). Heavy metals, unlike other pollutants, are not biodegradable and can accumulate in sediments over time. The contamination of metals in sediments can reach a level that is toxic to aquatic life **[6].**

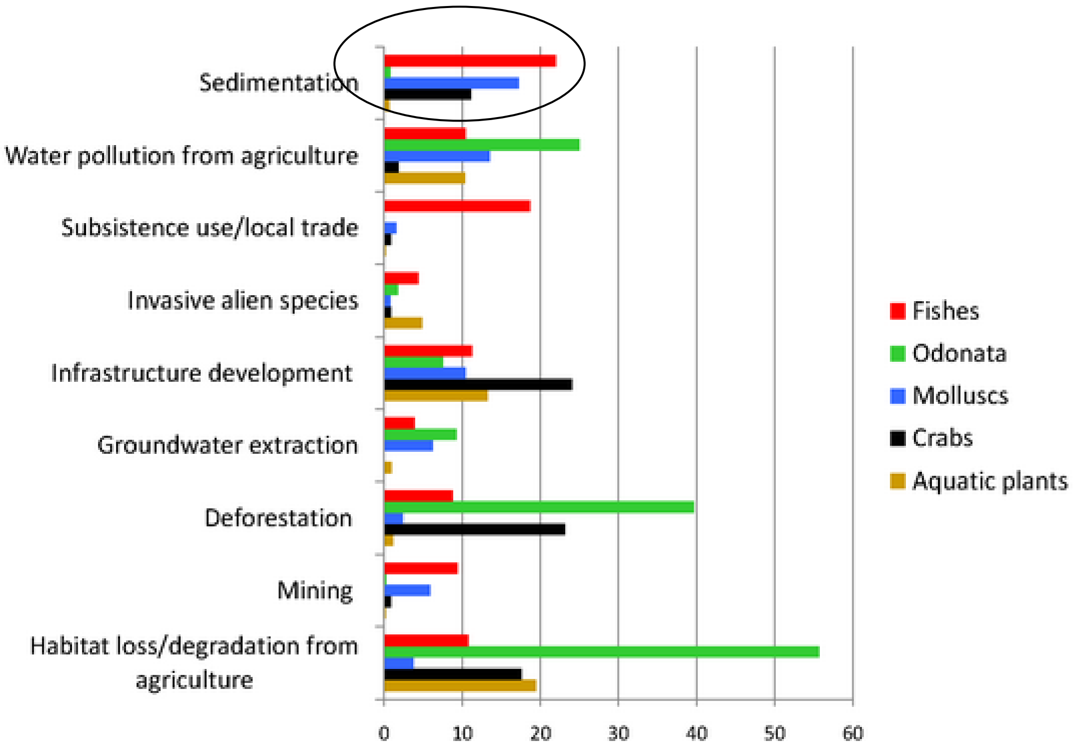


**Figure 1.1**: Major threats caused by sediment pollution

## 1.2 Description of Study Area and its Sediment Quality

Budha Nallah, a narrow unlined canal, is the Ludhiana city's sole surface water resource. It originates near Chamkaur Sahib town and merges in the River Sutlej. It is an important drainage line of Ludhiana district which passes through Ludhiana and carries the sewage and industrial sludge of the city (figure 1.2). In the late nineteenth century, it was a clean water stream with 56 types of fish species prior to 1964. Now it has no fish because of high level of toxicity in the water.

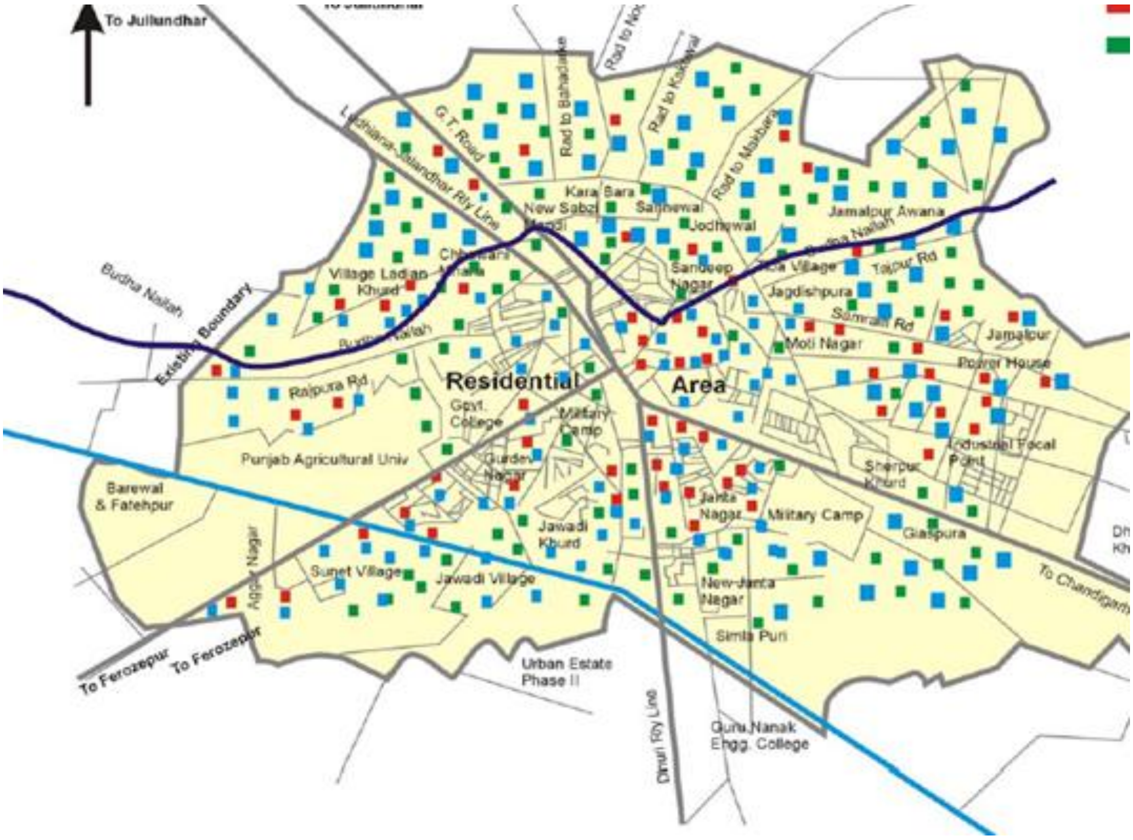


**Figure 1.2**: Map showing the coverage of Budha Nallah in Ludhiana district

Buddha Nallah is the main receptor of Ludhiana city's domestic and industrial sewage (figure 1.3). As a result of perennial flow of sewage in Buddha Nallah, it has become an open sewer. Out of 32 kilo meters of stretch of Budha Nallah, 14 kilo meters fall in the municipal limits of Ludhiana and rest 18 kilo meters in the rural vicinity upstream and downstream of the city. The rapidly increasing urbanization and industrialization have adversely affected the Ludhiana city's water resources. The Budha Nallah is polluted to the extent that self-purification mechanism does not take place even at the most downstream point where it merges in the River Sutlej. In addition, Budha Nallah is also playing an indirect key role in ground water pollution **[7].**

**Figure 1.3**: Outlets discharging effluent directly into the Nallah

Ground water in most of the industrial estate and in few residential areas is unfit for drinking. Cadmium in sewerage water is 700 times higher. Nickel and chromium are 300 times and 280 times higher in the Budha Nallah as compared to tube well water. The presence of nickel and chromium is more than the permissible limits and the Nallah water cannot be used for irrigation. The heavy metals have also polluted the shallow water close to the Budha Nallah besides impairing the soil irrigated by Nallah water. The level of chromium, nickel, cadmium and lead in the soil previously irrigated by sewerage water is 35.5, 14.3, 3.6 and 1.8 times respectively, higher than the tube-well water irrigated soil **[8]**. Right now the Budha Nallah has no dissolved oxygen and it does not recover through self purification mechanism.

The untreated domestic and industrial sewage of the city was emptied into it (figure 1.3). As a result, deposition of the sediments occurs in its bed. Presently Nallah has sludge deposition at its bed. Budha Nallah has sludge deposition at the bottom due domestic and industrial discharge. It has become an open sewer. Budha Nallah is also playing an indirect key role in ground water pollution. It is estimated that the ground water, nearby Nallah, has been polluted. The extent of which can be known after monitoring. The polluted Nallah water after covering Ludhiana district joins the Sutlej at Walipur Kalan in the north-western corner of the district (figure 1.4). The Nallah water can be easily distinguished from the river.

**Figure 1.4**: Confluence point of Budha Nallah water and river water.

The main objectives of the study are:

1) To device a sampling strategy for Budha Nallah sludge at different locations.
2) Characterisation of sludge samples for various important parameters like organic/ inorganic ratio, N&P contents, heavy metals, etc.
3) To recommend appropriate (environmental friendly) strategy for disposal/utilization of sludge.

# CHAPTER 2
# LITERATURE REVIEW

## 2.1 Studies on Budha Nallah

Studies mainly have been concentrated towards water pollution in Budha Nallah. A joint study by Post Graduate Institute of Medical Education and Research (PGIMER) and Punjab Pollution Control Board (PPCB) in 2008 **[8]**, revealed that in villages along the Nallah, calcium, magnesium, fluoride, mercury, beta-endosulphan and heptachlor were more than permissible limit (MPL) in ground and tap waters. In addition, the water had high concentration of COD and BOD, ammonia, phosphate, chloride, chromium and arsenic. The ground water also contains nickel and selenium, while the tap water has high concentration of lead, nickel and cadmium. According to PPCB, the Nallah water requires a sewage treatment capacity of at least 150 million imperial gallons (680,000 $m^3$) per day, while present sewage treatment plants at Jamlapur, Balloke and Bhattian have a combined capacity of 3,11,000 $m^3$/day **[8]**. Punjab Pollution Control Board has carried out a detailed study with regard to the pollution in Buddha Nallah. As per the study carried out by the Board from the year 2006 and 2010-11 conducted before mixing of Budha Nallah with river Sutlej water, the concentration of heavy metals has been observed as given in Table 2.1.

**Table 2.1**: Concentration of heavy metals in Buddha Nallah water

| Year | Parameter values, mg/L | | | | | | |
|---|---|---|---|---|---|---|---|
| | Zn | Ni | Total Chrome | Cr | Pb | Fe | Cu |
| 2006 | 1.71 | 5.05 | 0.53 | ND | 0.15 | 9.0 | 0.390 |
| 2008 | 1.81 | 0.46 | 0.42 | 0.44 | 0.23 | 23.3 | 0.30 |
| 7.4.2010 | 0.7 | 0.1 | 0.14 | - | - | 6.4 | 0.05 |
| 26.4.2010 | 0.8 | 0.2 | 0.19 | - | - | 7.8 | 0.06 |
| 12.5.2010 | 0.9 | 0.3 | 0.24 | - | - | 8.2 | 0.08 |
| 22.7.2010 | 1.24 | 0.10 | 0.16 | ND | ND | 13.5 | 0.07 |
| Permissible limits for drinking water as per IS : 10500 : 19991 | 5.0 | - | 0.05 | 0.01 | 0.05 | 0.3 | 0.05 |

The heavy metals are mainly contributed by the electroplating industries. The above data as tabulated above indicate that there is considerable reduction in the concentration of heavy metals, which is achieved by the continuous persuasion and concerted efforts of the Punjab Pollution Control Board which led to the installation of common effluent treatment plant at Focal Point, Ludhiana and achievement of zero liquid discharge by the said common treatment plant and also with the steps taken by large/medium scale electroplating industries by installing of RO plants.

In 2010, water samples taken from the Nallah showed that heavy metal content is quite high and the presence of uranium is 1½ times the reference range **[9]**. For example, chromium was 50 times the reference range, aluminium and iron 20 and 60 times higher respectively, while concentration of silver, manganese, nickel and lead was equally high. In June 2009, Ludhiana district administration imposed section 144 around the Nallah, banning the throwing of garbage in it, but in the following months it was scarcely implemented, despite public outcry **[10].** In the following month, the Government of Punjab allocated Rs 50 crores for the cleaning up of the Nallah. The municipal corporation in a demolition drive removed a large number of illegal encroachments from both sides of the Nallah **[11].**

### 2.1.1 Adoption of Green Bridge Technology

On April 4, 2011, Ministry of Environment and Forests (MoEF) has decided to launch "In Situ Bio-Remediation Project" on Budha Nallah in Ludhiana **[12].** In order to restore the ecology of Budha Nallah, there is also proposal to install green bridge technology (figure 2.1), which is not only a treatment system but an eco-system in itself, wherein, no machinery, electricity, chemicals and trained manpower is required but it will be a kind of horizontal filtration of wastewater through the layer of biologically activated filtration medium which absorb the contaminants. In this technology, wastewater passes through the filtering medium and biodegradable solids are degraded in series of green bridges. Biodegradable organic matter along with oil and grease will be consumed by bacteria present in the specialized top layer of filtration system and the treated water can be used for agriculture purposes.


**Figure 2.1**: Working of Green bridge technology

For assessing the status and level of contamination of surface water pollution in Budha Nallah, a detailed analysis in respect of bacteria, odour, mosquitoes, and aesthetics has been carried out. It is revealed that more than 1/4th of the population of the city and 1/7th area of the city is considerably affected by the water pollution caused in the Budha Nallah. A strip of 1000 m on either side of Budha Nallah has been affected by the water pollution. For assessing the impact of pollution, the entire area under the impact of pollution has been divided into 3 distinct zones. High bacterial contamination has been found to exist within the first 150 m strip whereas moderate contamination has been observed in the middle zone (151 to 500 m) whereas low contamination has been found to exist in the last 500 m. In this area, more than 55% population is affected by incidence of high & moderate bacterial contamination. Similar position has been found to exist in respect of the aesthetic aspect.

A study was carried out at Punjab Remote Sensing Centre in Punjab Agricultural University, Ludhiana, by Verma *et al.*, on ugly face of urbanization and industrialization: A study of water pollution in Budha Nallah **[13]**. The rapid pace of industrialization and increasing population pressure has brought in a host of environmental problems in mega city of Ludhiana. The water pollution, in Budha Nallah stream passing through the city and carrying sewage and industrial sludge to Sutlej River, is one of them. Twelve number of water samples spatially located in three different zones, zone I (upstream), Zone II (in the city) and zone III (downstream) were collected using GPS (figure 2.2). The samples were analyzed for quality parameters such as pH, EC, BOD, COD, TS, TDS, TSS, Ni, Cd and Pb. The upstream water (Zone I) has been found to be non-polluted, in contrast the concentration of most of the water quality parameters i.e. Ni, Cd, Pb, BOD, COD, TS, TDS and TSS in water of Ludhiana city (Zone II) and downstream (Zone III) exceeds the in-stream standards indicating absence of self-purification mechanism in Buddha Nallah.

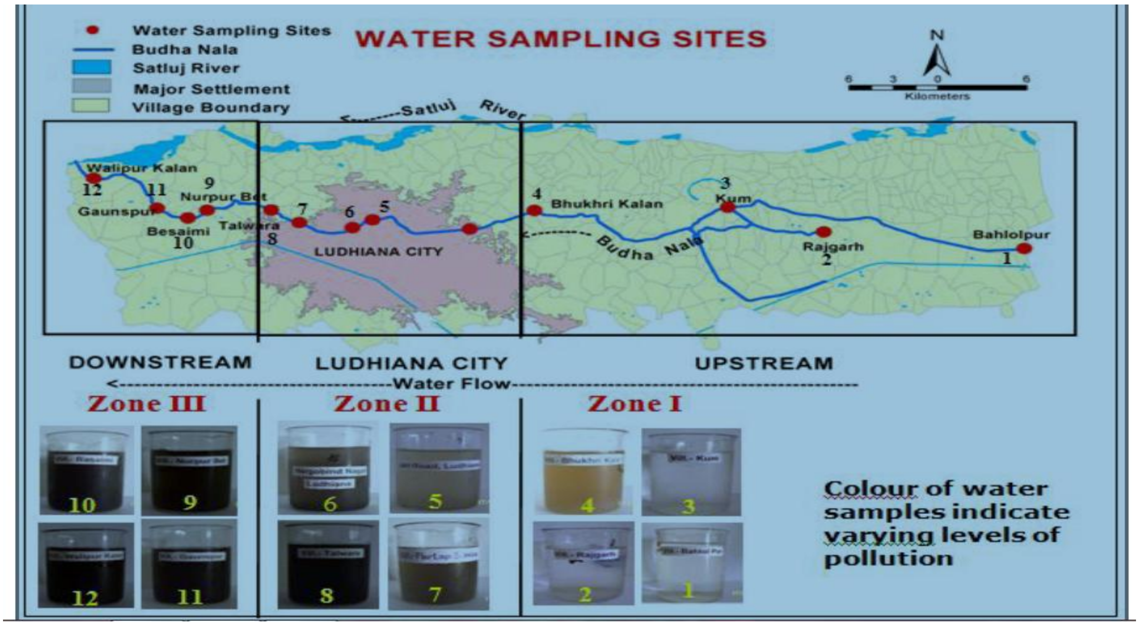


**Figure 2.2**: Water sampling locations

A study was carried out at University Institute of Law, Panjab University Regional centre, Ludhiana, by Cheema and Virk, on water pollution in the state of Punjab **[14]**. The Indian states in pursuance of their commercial development and profit have failed to internalise the environmental and social costs of their pursuits and in so failing, have neglected to take measures to preserve or reproduce the very preconditions of capitalist production. The work elaborates upon the heinous crime of water pollution in the state of India, Punjab. The studies and methodical investigations conducted on the waters of the Punjab which includes Kala Sanghian and Budha Nallah, both tributaries of the Sutlej River flowing in Punjab and the alarming rise in the cases of cancer death in Malwa region of Punjab due to underground water pollution have been analysed.

A study was carried out at Department of Civil Engineering, Dr. B.R. Ambedkar National Institute of Technology Jalandhar and Department of Applied Sciences, Punjab Engineering College Chandigarh, by Singare *et al.*, on textile effluent in and around Ludhiana district in Punjab. Textile industry is one of the most important and rapidly developing industrial sectors in Ludhiana city of Punjab, India **[15]**. It has a great disadvantage in terms of its environmental impact because it consumes considerably high amount of processed water and produces highly polluted discharge water. To control the polluted discharge, the textile mills in India have started to install treatment plants in the name of environmental protection. The wastewater from 7 textile mills in the woven fabric and knit fabric finishing industry and one highly polluted drain, locally known as Budha Nallah, which receives discharge from many such industrial units, were collected for the study. Performances of the treatment plants were evaluated by site inspections and analyses of influent and effluent samples were carried out. For the treatment of wastewater from textile industry, biological treatment, chemical treatment and combinations of these processes have been used. Plants utilizing biological treatment rather than chemical processes claim that their preference is due to less excess sludge production, lower operational costs and better COD removal in biological treatment. Waste water parameters in the effluent of biological treatment plants were not in compliance with the waste water and sewerage discharge standards. However, if sodium sulphate in dying process and sulphuric acid in neutralization processes are used before a biological treatment, sulphate in the effluent exceeds 1700 mg/L. This problem can be avoided by using hydrochloric acid or $CO_2$ rather than $H_2SO_4$ in neutralization and NaCl instead of $Na_2SO_4$, if the use of $Na_2SO_4$ is not necessary.

A study was carried out at Institute of Town Planners, by Rahul on built environment in Ludhiana **[16]**. Environment degradation has become one of the major problems in the metropolitan cities. This paper discusses how rapid growth of urbanization, industrialization and vehicular growth affects the environmental conditions in Ludhiana city. The results show that increase in population and changing activities from primary to tertiary in the city leads to air pollution, water pollution, land degradation, traffic congestion, mix land uses, prevalence of slums, etc. As a result, the levels of pollutants in the city are increasing day by day in comparison to the permissible limits prescribed by the Punjab Pollution Control Board.

## 2.2 Worldwide Studies on Minerals in the Sediments

Nutrients are essential for all life forms to grow and increase their biomass. The nutrients in the sediments change from one form to another by various chemical and biological processes occurring in it. Within the permissible limits, nutrients benefit the aquatic environment otherwise eutrophication occurs. Various studies on essential nutrients present in sediments have been done to know and assess their impact on aquatic environment.

A study was carried out at Institute of Food and Agricultural Sciences, University of Florida, by Arshad *et al.*, on seasonal changes in sediments and water chemistry of a subtropical shallow eutrophic lake **[17]**. A field study was conducted to develop a data base on seasonal changes of water and sediment chemistry of Lake Monroe located in central Florida, USA. This shallow eutrophic lake is a part of the St. Johns River. Quantitative samples of lake water and sediments were collected on a monthly basis from 16 stations and analysed for various physico-chemical parameters. Relatively high levels of dissolved solids prevailed in the lake water, and seasonal changes in EC were probably associated with hydrological flushing from external sources, such as incoming water from upstream as well as precipitation. Average monthly levels of total N and P during the study period were 1.82 and 0.21 mg/L, respectively. Nutrient concentrations in the water did not show any strong seasonal trends. Organic matter content of lake sediments ranged from 1 to 182 g/kg of dry sediments, reflecting considerable spatial variability. All nutrients in the sediments showed highly significant ($P<0.001$) correlations with sediment organic carbon, though little or no significant relationship appeared at any sampling period between water and sediment chemistry of the lake. Temporal trends in water and sediment chemical parameters may have been concealed by periodic hydrological flushing of the St. Johns River into Lake Monroe.

A study carried out at Cereve, faculty of Sciences and Technology, University of Paris, by Carpentier and Moilleron, on physico-chemical properties of dredged material in the river Seine basin (France) **[18]**. In rivers, sediments are frequently accumulating persistent chemicals, especially for those that are more contaminated as a consequence of pressure related to environmental pollution and human activity. The Seine river basin is heavily polluted from nearby industrial activities, and the urban expansion of Paris and its suburbs within the Ile de France region and the sediments present in the river basin are contaminated. To ensure safe, navigable waters, rivers and waterways must be dredged. Physico-chemical characteristics of the sediment itself and of the pore-water were presented. Seine basin sediments show very diverse compositions depending on the sampling site. Nevertheless, a geographic distribution study illustrated that the Paris impact is far from being the only explanation to this diversity, the quality of this sediment is also of great concern. The sediment once dredged was transported via barges to a wet disposal site, where the dredged material is mixed with Seine water in order to be pumped into the receiving site. This sort of dumping might be responsible for the potential release of contaminants to the overlying water from the significantly contaminated sediments.

A study carried out at Key laboratory of Virtual Geographic Environment, Ministry of Education（Nanjing Normal University), Key Laboratory of Poyang Lake Wetland and Watershed Research, Ministry of Education (Jiangxi Normal University) Nanchang, China, by Shuo and Shangjie, on multi-scale distributed modelling of flow, sediment, and transport Processes for nitrogen and phosphorus in Lianshui basin **[19]**. The study states that agricultural non-point Sources Pollution is one of the leading cause of water quality problems in southeast of China. It is an effective approach for ANSP control that modelling nitrogen and phosphorus transfer in a basin system by using mathematic models based on geographic processes. In this paper, the multiscale integrating distributed modelling frame was designed based on different spatial discretization units by using the (Soil and Water Assessment Tools) model and field-scale APEX (Agricultural Policy/Environmental extender) model. A large number of basic geographic data were collected for parameterization in Lianshui basin. The multi-scale distributed computer simulation for water yield, sediment yield of 1991 to 2005 and the transport processes for nitrogen and phosphorus of Oct, 2002 to Oct, 2004 were carried out in the study area of Lianshui basin. The average simulation accuracy, coefficient of efficiency (ENS) and deterministic coefficient ($R_2$) were 89.4%, 0.88 and 0.89 for annual water yield and 75.1%, 0.70 and 0.76 for annual sediment yield，respectively. The simulation results indicate that the integrating modelling has an acceptable performance in prediction of water yield and sediment loading in Lianshui basin. The predicted monthly nitrogen and phosphorus loading have larger amount difference than measured although both the predicted and measured have almost accordant trends. The reasons that caused bad accuracy for nutrient simulation should be further studied. The method of integration for multi-scale models can take the advantages effectively for each model, which can be applied in quantitative study on the geographical processes in different levels.

A study was carried out at Nanjing Institute of Geology and Mineral Resources Nanjing, China, by Nai-zheng *et al.*, on spatial distribution of organic and inorganic carbon in sediments of Tai Lake **[20]**. The sediment in lakes is the pools of material and energy, and the composition and content of organic and inorganic carbon in sediments constrain carbon cycling. This paper conducts research of spatial distribution of organic and inorganic carbon contents in sediments of Tai lake in China based on the data of geochemical survey in the early 2000s. Results show that the organic, inorganic carbon contents in surface sediments (0-20 cm) of the lake were 5.76±4.38, 1.42±1.40 g/kg and those in deep sediments (160-180 cm) are 2.30±1.39 and 2.30±1.39 g/kg respectively. The organic carbon content in deep sediments is close to that in surface sediments, but inorganic carbon content was 1.62 times of that in surface sediments. The ranges and coefficients of variation of carbon contents in deep sediments show lower spatial variability due to limited human activity. This work provides valuable information regarding accurate distribution of organic and inorganic carbon in the surface and deep sediments of lake, which may be useful to evaluate intrinsic pollution in the lake.

A study was carried out at College of Life and Environmental Science, Hangzhou Normal University, by Shan *et al.*, on characteristic evaluation for nitrogen pollution in water and surface sediments of Xixi Wetland **[21]**. Characteristics of nitrogen pollution for 11 sampling water or surface sediments (0~10 cm) in Hangzhou Xixi Wetland, and correlation analysis was conducted amongst nitrogen indexes for water and that for surface sediments. The results revealed that nitrogen nutrient loading was generally serious in water of Xixi Wetland, total nitrogen (TN) and $NH4^+$-N concentration exceeded the standard in most sampling water. Organic nitrogen (ON) was the mainly existing nitrogen forms in surface sediments of Xixi Wetland, according to evaluation criteria for organic nitrogen (ON, %) in sediments, the content of organic nitrogen in all the sampling sediments exceeded the pollution level, and TN contents showed serious biological toxicity in most sampling site based on Ontario environmental quality standards. Significantly positive correlation was found between concentration of TN or $NH_4^+$-N in water and $NO_3$--N content in surface sediments, moreover, content of $NO_3$--N in surface sediments may be attributed to the decomposition of organic matter in sediments since significantly negative correlation was found between total organic carbon (TOC) content and $NO_3$-N in sediments. Therefore, it is of great significance for controlling and reduction of organic matter and TN content existed in surface sediment of Xixi Wetland.

A study was carried out at Hydrological Department, University of Trier, Germany, by Symander *et al.*, on temporal variations of environmental pollutants in channel sediments **[22]**. The general latch of data about temporal aspects of pollutants in channel sediments seems to indicate that the situation is either considered as more or less constant, or well understood from theoretical reasoning. In three sampling periods at five stations, it could be shown that there is a dynamic behaviour of sediment associated pollutants that relates to several groups of processes. The most important processes are the removal and mixing of channel sediment layers, input and mixing of different materials, contributions of different sources of particle and pollutants and the physico-chemical properties of the pollutants. Also, some biological controlled processes play an important role, but are not well understood.

A study was carried out at School of Environmental Sciences, Jawaharlal Nehru University, New Delhi, by Subramanian**,** on geochemical factors controlling the chemical nature of water and sediments in the Gomti River, U.P **[23]**. Basic chemical parameters have been merged together which aid in interpreting a few empirical geochemical factors controlling the chemical nature of water and sediments of the Gomti River, a major Himalayan tributary of the Ganges drainage basin. Water chemistry seems to be controlled by three factors: bicarbonate, rainfall and silicate and phosphate factors. Sediments chemistry seems to be controlled by adsorption/desorption, clay, Fe-Mn hydroxide and mercury factors. These factors show spatial and temporal variability in terms of their R-scores.

A study was carried out at Jiwaji University, Gwalior, Madhya Pradesh, by Verma *et al.*, on influence of pollutants on bottom sediments of sewage collecting Kalpi (Morar) river, Gwalior, (M.P.) **[24]**. It shows the investigation of the nutrient value of bottom soil pH, conductivity, potassium, exchangeable potassium, total phosphorus, available phosphorus, organic carbon, total nitrogen, available nitrogen, calcium and magnesium were analysed from monthly samples collected from six sampling stations during two years of study.

Soil from upstream sampling station was found unpolluted due to low level of pollution load and less human activities. While sampling stations at downstream side, sewage and municipal wastes increased the amount of calcium, magnesium and other nutrient.

A study was carried out at Deparment of Chemistry, Bhavan's College, Mumbai, by Singare *et al.*, on assessment of physico-chemical properties of sediments samples collected along Mithi River of Mumbai **[25]**. The study was carried for the period of two years at three different sampling stations. It was observed that pH values observed in the second year were lower than that was in the first year of work. The pH values were lower than that reported by Maharashtra Pollution Control Board (MPCB) in 2004. Similarly the chloride, sulphate, electrical conductivity, sulphide and phosphate content also increases in second year. The values recorded were higher in the second year than that were recorded in the first year. The recorded values were also higher than that reported by MPCB in 2004. The result is a clear indication of day by day increasing pollution level of the Mithi River, which is creating negative environmental impact on biological life of the river. The results emphasize the need of regular scientific monitoring of different pollutants adversely affecting the environment and to reframe the pollution control strategies already in existence.

A study was carried out at Centre for P.G. and Research G.T.P. College Nandurbar, by Marathe *et al.*, on sediment characteristics of Tapti River, Maharashtra **[26]**. A baseline study of the Tapti River was conducted to determine the basic physical and chemical characteristics of the sediment. Ten stations were selected along the study area sediment characteristics revealed sandy to loamy (muddy) sand soils with pH of 7.01 to 8.05. Values of organic carbon varied from 0.16% in the study soil to 0.5454%. Electric conductivity at ten stations, sediment samples ranges from 3.11 to 5.05 dsm-1, Available nitrogen in ten samples ranges from 71.8 to 244.3 kg/ha, while phosphorus ranges from 6.7 to 20.7 kg/ha. Available potassium estimated by flame photometry varied from 13.97 to 16.07 m/gm and 20.01 to 20.40 m/gm respectively.

## 2.3 Studies on heavy metals in the sediments

The metals in the sediments are present in the bound state. Various biological processes occurring in the sediments bring them into unbound state. Some metals are essential for the sediments but within the permissible limits. Various studies on metal pollution have been done to assess the metal pollution and their hazards to aquatic environment.

A study was carried out at International Institute for Infrastuctural, Hydraulic and Environmental engineering, Netherlands, by Kelderman *et a.l*, on pollution assessment of the canal sediments in the city of Delft **[27]**. The study based on the sediments samples for (heavy) metals, PAHs, PCBs, pesticides and minerals oil. According to the pollution classes used in the Netherlands, ca, 95% of all inner city stations in Delft were in the highly polluted lasses, necessitating sediment dredging followed by disposal under strict conditions. In contrast, only 33% of the sediments samples in the Delft outer city fell into these pollution classes. Factor analysis showed that the inner and outer city sediments could be divided into two different clusters, each with their own characteristics. The chemical components mainly responsible for the sediments pollution were Cu, Zn, DDT, PAHs and Pb. For the latter two parameters, this points to traffic- related pollution loads whereas the main sources of copper and zinc were probably related to the corrosion of metal structures. Mass balance calculations for the Delft inner city canal system show that, of the accumulated heavy metals, around 65% of Zn and Pb and even 85% of Cu originates from outside the Delft inner city, viz. via open inlets with the main Rijn-Schie canal. In the view of the decreasing contents in the sediment top layer, it was anticipated that, with the various pollution abatement measures being taken, a gradual improvement of the Delft canal sediment quality will take place**.**

A study carried out at Faculty of Agricultural Engineering, Beirut Lebanese University, by Sabra and Hamieh, on sequential extraction and particle size analysis of heavy metals in sediments dredged from the Deule canal, France **[28]**. The Deule canal was one of the most polluted canals in northern France. It contains large volumes of polluted sediments. These had to be dredged and characterized before deciding about the technology suitable for their treatment. The sediments were thus subjected to a physico-chemical characterisation comprising particle size classification and heavy metals sequential extraction studies. The total metallic concentrations exceed the French standards for several metals such as cadmium, zinc, lead or copper. On average 92% of the total weight of each metal were present in the particles that were less than 53 µm in size. These particles represent about 85% of the suspended matter dry weight. The sequential extraction study revealed that most of the studied metals were strongly linked to the sediments because of their association with the sulphides and with the organic matter.

A was study carried out at Tianjin University of science and Technology, Guo *et al.*, worked on pollution and potential ecological risk evaluation of heavy metals in the sediments around Dongjiang harbour, Tianjin **[29]**. The distribution enrichment characteristics of heavy metals (such as lead, cadmium, copper, zinc, mercury and arsenic) in the sediments around Dongjiang harbour were measured and analysed in march 2009. The potential harmful elements effects of these heavy metals were evaluated by Sediment Enrichment Factor (SEF) and Potential Ecological Risk Index Method (PERI) based on considering the specially of the area and the sediment enrichment factors of heavy metals were: As>Zn>Cu>Hg>Pb>>Cd. Pb and Cd in the sediments around Dongjiang harbour were natural and did not originate from human activities. The pollution of Cu was low and from nature, which was affected by human activities slightly. Hg was polluted by human and exceeded standard much in many monitoring stations. As and Zn were affected seriously by human activities. In a word, the ecological risk levels of heavy metals in the sediments from this area were low. Potential risks indices for heavy metals were Hg>Cd>As>Cu>Pb>Zn. Hg had moderate potential risk to the ecological environment and contributed most to potential toxicity response indices for various heavy metals (RI) in the sediments around the harbour.

A was study carried out at School of Earth and Environment Science, Anhui University of Science and Technology, China, Chen and Yan, on distribution characteristics and pollution evaluation of river sediments **[30]**. 21 Sedimentary samples were taken from the river in north part of Anhui province, China. The contents of 8 heavy metal elements (Be, Cd, Cr, Cu, Pb, Ni, Mn, and Zn) were determined by ICP-MS. Organic matter contents in sediment were also tested. The results showed that the different degree enrichments of heavy metals in sediments were appearing as compared with the average values of heavy metal contents in soils in China. Moreover, organic matter concentrations were decreasing progressively from upper reaches to lower reaches in the major river. The distribution features of Be, Cr, Mo, and Zn in sedimentswere more clear in research area as compared with the others. The pollution of heavy metals was comparatively light in sediments from the river in north part of Anhui, and only two heavy metals (Cd and Mo) existed contaminating in some rivers.

A was study carried out at Netherlands, by Kelderman, on sediment pollution in the city canal of Delft, Netherlands **[31]**. The pollution was most evident for the inner city canal system, with copper, lead, zinc, and polycyclic aromatic hydrocarbons (PAHs) as main pollutants. Sediments of the outer city canals generally had a much better quality. Pollution levels, mutual correlations, and spatial variations were investigated for the various sediment parameters. Also, heavy metal binding forms onto Delft sediments were assessed with the help of sequential extraction techniques; results were found to be in line with expected sequential physio-chemical binding processes. Input of sediments into the Delft inner city canals was shown to be largely driven by busy shipping traffic on the main canal surrounding the inner city. Mass balances for the inner city were used to quantify internal and external pollution sources; 65- 85% of the heavy metal pollution can be attributed to sources outside the Delft area. As shown by factor and cluster analysis, it was highly probable that these external sources derive from river Rhine. A gradual improvement of sediment quality had set in; it's expected that, due to further pollution abatement measures, this improvement will continue in the years to come. With respect to the ship-induced sediment input into the inner city canals, it was estimated that a reduction of ship velocities to <1.5 m/s will bring down the sediment input mentioned above to about 85%.

International Conference on Future Energy, Environment, by Chen and Schorer, on copper contamination in the sediments of Salt River mouth, Taiwan **[32]**. Using the data collected at the mouth of Salt River to investigate and analyze copper (Cu) contained in the sediments, and to evaluate the accumulation of Cu and the degree of its potential risk. The results showed that samples were collected at all monitoring stations near the mouth of Salt River contain 286-895 mg/kg of Cu with average of 501± 243 mg/kg. The spatial distribution of Cu concentration is relatively high in the river mouth region, and gradually diminishes toward the harbour region. This indicates that upstream industrial and municipal waste water discharge along the river bank were major sources of pollution. The accumulation factor and potential ecological risk index indicate that the sedimentation at Salt River mouth had the most serious degree of Cu accumulation and the highest ecological potential risk.

A study was carried out at Department of Marine Environmental Engineering and Marine University Kaohsiung, Taiwan, by Dong *et al.*, on contamination and potential toxicity of heavy metals in sediment of the ocean disposal site **[33]**. This study investigates the distribution, and accumulation of heavy metals in sediments of ocean disposal site. Sediment samples which were collected from eleven locations in the ocean disposal site pre quarterly in 2009 were analyzed for metal content (e.g., Hg, Pb, Cd, Cr, Cu, Zn, Ni and Al), organic matter, and grain size. Base on the research results, the metal concentrations varied from 0.11 mg/kg for Cd to 198 mg/kg for Zn. All heavy metals concentrations excluding Hg and Ni of dumping area center in ocean disposal site were higher than other sites. Referring to enrichment factor (EF) assessment, both Cu and Cr in sediments of disposal area showed minor enrichment (EF <3) when comparing with the reference point which was located at outside of disposal site. Moreover, referring to sediment quality guidelines (SQGs), and mean ERM quotient, the dredged sediment disposal site was classified as "Medium–low contamination levels"; where most samples (97%) had a medium–low (30%) probability of toxicity pollution.

A study was carried out at Environmental Hydrology division, Jal Vigyan Bhavan, Indian Institute of Technology Roorkee, by Jain *et al.*, on metal pollution assessment of sediment and water in the river Hindon in western Uttar Pradesh **[34]**. It was assessed for Cd, Cr, Cu, Fe, Mn, Ni, Pb, and Zn. The metal concentrations in water showed wide temporal variation compared with bed sediment because of variability in water discharge and variations in suspended solid loadings. Metal concentrations in bed sediments provide a better evaluation of the degree and the extent of contamination in the aquatic environment, Santagarh and Atali being the most polluted sites of the river. The ratio of heavy metals to conservative elements (Fe, Al, etc) may reveal the geochemical imbalances due to the elevated metal concentrations normally attributed to anthropogenic sources. Metals ratio for the bed sediments of the river Hindon were used to determine the relative mobility and general trend of relative occurred Fe> Mn>Zn>Cr>Ni>Pb>Cu>Cd. The river carries natural and anthropogenic pollutants, mainly heavy metal concentration of Cd, Cr, Cu, Fe, Mn, Ni, Pb and Zn which were released from industrial effluents, agricultural return flows and domestic sewage. The heavy metals find their residence in the colloidal form in water and in 2micron clay fraction in the river bed sediments. Systematic sampling of the river bed sediments at predefined locations had revealed that the metal accumulation was very close to normal and also beyond threshold limits. Compared with the maximum background values in Kabini river sediment, Pb was the highest in terms of contamination level, especially at point of influx of paper mill effluents, followed by Zn and Cu.

A study was carried out at Department of Chemistry, University of Mumbai, by Lokhand *et al.*, on quantification study of toxic heavy metals pollutants in sediment samples collected from Kasardi River flowing along the Taloja Industrial belt of Mumbai **[35]**. The results indicates high level of pollution due to toxic heavy metals like chromium (Cr), cadmium (Cd), nickel (Ni), zinc (Zn), copper (Cu), lead (Pb), and iron (Fe). The concentration of all these heavy metals were found to be much above the acute toxicity level. It was feared that these metals may enter the food chain through bio-magnification there by creating threat to aquatic life and the surrounding population. The results of the investigation point out the need to implement common objectives, compatible policies and programmes for improvement in the industrial waste water treatment methods.

A study was carried out at Centre for Water Resource Development and Management, Kerala, by Harikumar, on distribution pattern of trace metal pollutants in the sediments of an urban wetland in the southwest coast of India **[36]**. The study was carried out to investigate the concentrations and spatial distributions of trace metals in the sediments of Kottuli wetland, which is in the south west coast of India. Eight stations were strategically positioned along the length of wetland and sampled for trace metals (Cu, Mn, Cd, Ni, Pb, Zn & Cr) content. From the analysis, it was observed that the mean concentration of all the analysed trace metals exceeded the average worldwide shale concentrations and average Japanese river sediment values. Pollution load index value (PLI) of the studied area ranged from 0.10 to 58.78 which indicated that the wetland sediments were polluted. From the study PLI of the downstream area of the wetland had the highest values of Cu, Mn, Cd, Zn & Cr. According to the index of geo-accumulation, all the sampling stations may face a severe trace metal pollution contamination problem in the future.

# CHAPTER 3

# MATERIALS AND METHODS

Sediment samples were collected from Budha Nallah, Ludhiana. Materials and methods used in this study are described in details, including the chemicals, instrument and procedures used for sampling and analysis of samples.

## 3.1 Reagents and Chemicals

The chemicals used in the study are AR grade obtained from SD Fine chemicals. Various tests have been done by using these chemicals. For determination of various forms of Nitrogen (Organic N, Ammonical Nitrogen, Nitrate- Nitrite Nitrogen, Kjeldahl N and Total N) digestion Reagent (mixture of $K_2SO_4$, conc. $H2SO4$, mercuric sulphate), Sodium Hydroxide-Sodium thiosulphate mixture, Boric acid, Borate buffer, Sulphanilamide, N-(1-Naphthyl)-ethylenediamine Di-hydrochloride (NEDA), Sodium nitrite and Sodium nitrate were used, For Phosphorus (Total P, Soluble P and Ortho P) Stannous chloride solution, Ammonium molybdate, Phosphate solution and Perchloric acid were used. For Organic Carbon potassium dichromate and sulphuric acid were used. For testing of metals standard metal solutions and Aqua Regia (mixture of Nitric acid and sulphuric acid) were used. All parameters were analysed according to standard methods.

## 3.2 Equipment

Various instruments used in the study are listed below.

### 3.2.1 pH meter

pH was measured by Thermo Scientific Orion 5-Star Plus pH meter (figure 3.1).

**Figure 3.1**: pH meter

### 3.2.2 UV-Vis Spectrophotometer

For estimation of Nitrate-Nitrite nitrogen, total phosphorus, soluble phosphorus, ortho phosphorus and organic carbon, the absorbance were measured by UV-VIS Spectrophotometer, Perkin Elmer Lambda 35 UV/VIS (U.S.A) double-beam spectrophotometer (figure 3.2).


**Figure 3.2**: UV-VIS Spectrophotometer

### 3.2.3 Kjeldahl Apparatus

It is used for estimation of Kjeldahl nitrogen, Ammonical nitrogen and organic nitrogen (figure 3.3)

**Figure 3.3** Kjeldahl apparatus

### 3.2.4 Atomic Absorption Spectrophotometer

For estimation of heavy metals the absorbance were measured by GBS Avanta S with SDS 270 Atomic absorption spectrophotometer (figure 3.4).

**Figure 3.4:** Atomic Absorption Spectrophotometer

## 3.3 Methodology

It includes brief description of study area, selection of sampling sites, sample preparation and analysis according to the standard procedures.

### 3.3.1 Study Area

Ludhiana city was founded on a ridge of Budha Nallah, which once was a bed of river Sutlej. The urban area is lying between 30˚ 51' 10” to 30˚ 57’ 20” N latitude and 75˚ 46' 00” to 75˚ 56' 20” E longitude, the average sea level height above mean sea level is 247 m.

Budha Nallah, a narrow unlined canal, is the city’s sole surface water resource. It originates near Chamkaur Sahib town and merges in the river Sutlej. It is an important drainage line of Ludhiana district which passes through Ludhiana and carries the sewage and industrial sludge of the city. It has now become an open sewer and at various locations the sludge layer covers the whole Nallah from bottom to top, the surface and sediments have become so hard with time that anyone can walk over it (figure 3.5).

**Figure 3.5**: Dumped garbage accumulation in the and on the banks of Budha Nallah.

### 3.3.2 Collection of Sediment Samples

The study area was concentrated on downstream region of Nallah. Eight samples were collected from the bottom of the Nallah by Ponar grab sampler (25–30 cm depth, depending on the sediment structure) in order to assess the sediment quality before dredging (Figure 3.6). Eight samples were collected in the month of November 2012 in strategic areas determined by the Punjab Pollution Control Board, according to easy accessibility around the Nallah (Table 3.1). Out of eight samples, 2 samples were collected from the focal point of Ludhiana, 5 samples were collected from downstream and 1 sample is collected just before the confluence point of Nallah and river Sutlej. Once cored, sediments were transferred into plastic bags and were stored at 4˚C before homogenisation and analysis.

**Figure 3.6:** Collection of sediments using Ponar grab sampler

**Table 3.1:** Locations for sampling sites and contributing Sources of pollution

| Sites | Location | Contributing Sources |
|---|---|---|
| 1 | Haibowal | Dairy, domestic and industrial |
| 2 | Near Balloke STP | Dairy, domestic and industrial |
| 3 | Talwara village | Dairy, domestic and industrial |
| 4 | Jainpur village | Dairy and domestic |
| 5 | Malakpur bet | Dairy and domestic |
| 6 | Gaunspur village | Card board factory |
| 7 | Kherabet village | Dairy and domestic |
| 8 | Walipur Kalan | Dairy and domestic |

### 3.3.3 Sample collection and preparation

Eight sampling sites were selected along the Nallah to assess the quality of its sediments (figure 3.7a,b). Wet sample is passed, preferably as slurry through the sieve (stainless steel, approximately 2mm openings). After collection, the sieved material is mixed by stirring and allowed to settle for subsequent removal of supernatant liquid. The supernatant liquid from the settled sediment was decanted. Determinations were done for volatile constituents, using wet samples stored at 4˚C and non volatile constituents by drying the samples at 105 ± 2 °C **[37]**.

### 3.3.4 Physical and chemical analysis

Pollutants are largely bound to silt/clay particles of sediments. Therefore, in order to minimize the variability due to grain-size compositions and improve comparison among the stretches of the Nallah, most chemical analysis and part of toxicity tests were conducted on sediment fine fraction (<63µm). The amounts of fine fraction necessary for chemical and toxicological endpoints were collected by sieving freeze-dried samples with standard sieves. Parameters analysed on the sediment are listed in Table 3.2. Most of the parameters were measured following the APHA manual standard procedures **[38].**

**Table 3.2:** List of physico-chemical parameters and major contamination analysed in the sediment samples

| Analysis | Units | Method |
|---|---|---|
| Moisture content | % | ASTM D2936 2010 |
| pH | - | APHA, EPA 1982 |
| Nitrite, nitrate | mg/kg | APHA, EPA 1982 |
| Ammonical nitrogen | mg/kg | APHA, EPA 1982 |
| Kjeldahl N | mg/kg | APHA, EPA 1982 |
| Organic N | mg/kg | APHA, EPA 1982 |
| Total N | mg/kg | APHA, EPA 1982 |
| Total P | mg/kg | APHA, EPA 1982 |
| Soluble P | mg/kg | APHA, EPA 1982 |
| Ortho P | mg/kg | APHA, EPA 1982 |
| Organic C | mg/kg | APHA, EPA 1982 |
| Metals (Na, K, Fe, Pb, Cu, Mn, Zn and total Cr) | mg/kg | APHA, EPA 1982 |


**Figure 3.7 (a):** Location map of first four sampling locations


**Figure 3.7 (b):** Location map of last four sampling locations

## 3.4 Analysis/ Testing

Nitrite nitrogen, nitrate nitrogen, total phosphorus, soluble phosphorus, ortho phosphorus and Organic carbon were analysed using UV -VIS spectrophometer by measuring the absorbance at 543nm, 275nm, 690nm, 690nm, 690nm and 660nm, respectively. Kjeldahl nitrogen was estimated by Kjeldahl apparatus after digestion and distillation. Ammonical nitrogen was estimated by distillation process. Metals were detected using Atomic Absorption Spectroscopy by measuring the absorption at different wavelengths (figure 3.3). For all the parameters sample preparation was done by using standard procedures.

**Table 3.3** Recommended wavelengths for metal detection

| Element | Wavelength, nm |
|---|---|
| Iron | 259.94 |
| Lead | 220.35 |
| Chromium | 267.72 |
| Sodium | 330.20 |
| Manganese | 279.8 |
| Zinc | 213.86 |
| Copper | 324.75 |
| Potassium | 766.50 |

# CHAPTER 4
# RESULTS AND DISCUSSION

This chapter deals with various parameters which are analysed on the basis of standard methods. By far the most widely used method for sediment quality is a database for contaminated and uncontaminated sites based on or derived from field data and laboratory toxicity testing. There are few reliable data on sediment toxicity from which independent sediment quality guidelines might be derived, and without a financial impetus there is little likelihood that further data will be forthcoming in the immediate future. Because of this, the option selected for the sediment quality guidelines is to use the best available overseas data and refine these on the basis of our knowledge of existing baseline concentrations, as well as by using local effects data as they become available. The physical and chemical characteristics of sediments have been discussed.

## 4.1 Physical Characteristics of Sediments

The physical characteristics of sediments tested were pH and moisture content, which are discussed below.

### 4.1.1 pH

Figure 4.1 revealed that the pH value of the sediments collected from different locations of Buddha Nallah ranged from 5.7 to 7.6. The pH below 7 indicates that Nallah water is of slight acidic nature. This is probably because of anaerobic processes continuously occurring in the sediments, in which acid forming bacteria converts organic matter into volatile fatty acids (VFA) which is further converted into methane, hydrogen sulphide and carbon dioxide. The formation of VFAs could be a reason for the acidic character of the sediments. The pH range above 7 might be due to the presence of carbonates and bicarbonates in the sediments. The decrease in the pH is also because of the mixing of the domestic and industrial effluents which are mostly acidic.

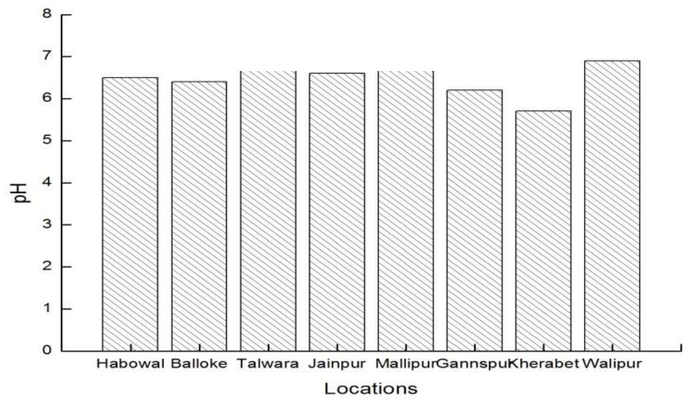


**Figure 4.1:** pH of sediment samples at various locations

### 4.1.2 Moisture content

The moisture content in Figure 4.2 shows that the value is between 19 to 47%. Haibowal area has high moisture content, due to the presence of dairy industries around it. Effluent from dairy industries has straw and hay in it which is directly discharged into Nallah. Hay absorbs water and settles down on the bed of the Nallah increasing moisture content of the sediment. Malakpur bet has highest value of moisture content which might be due to accumulation of straw and hay coming from the Haibowal region which in between meet high velocity STP effluent at Balloke, undergoes scouring and flushing which disturbs Nallah bed. The disturbed sediments settles down in the Malikpur bet region. Hay, being light and spongy, absorbs water, becomes heavier, and hence settles down with the sediments, thereby, increasing the latter’s moisture content.

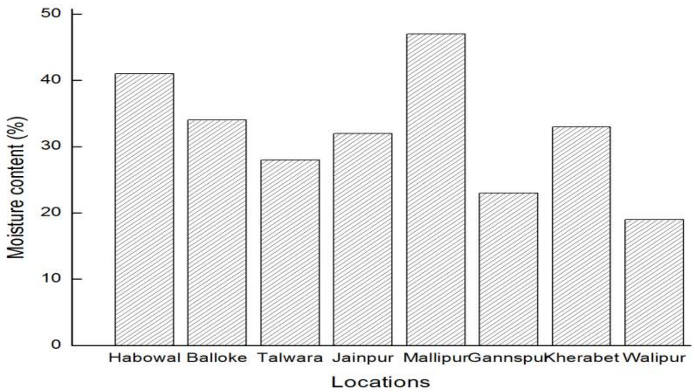


**Figure 4.2:** Moisture content of sediment samples at various locations.

## 4.2 Chemical Characteristics of Sediments

The chemical characteristics of sediments tested were all forms of nitrogen, phosphorus and carbon, which are discussed below:

### 4.2.1 Nitrite & nitrate and ammonical nitrogen

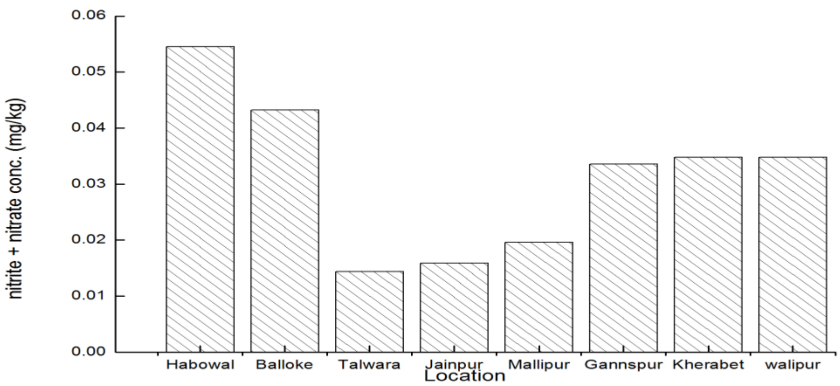


**Figure 4.3:** Nitrite, nitrate (mg/kg) in sediment samples at various locations

Figure 4.3 shows that the concentration of **nitrite and nitrate** nitrogen is between 15.8 to 144 mg/kg. Mostly domestic waste is discharged into the Nallah. Nitrite is highly unstable, it takes oxygen from water and converts into nitrate. Since the dissolved oxygen concentration is nil in Nallah water, therefore the principle nitrogen remains as nitrite and does not change. The Jainpur region has low concentration where as Talwara region has highest concentration**.**

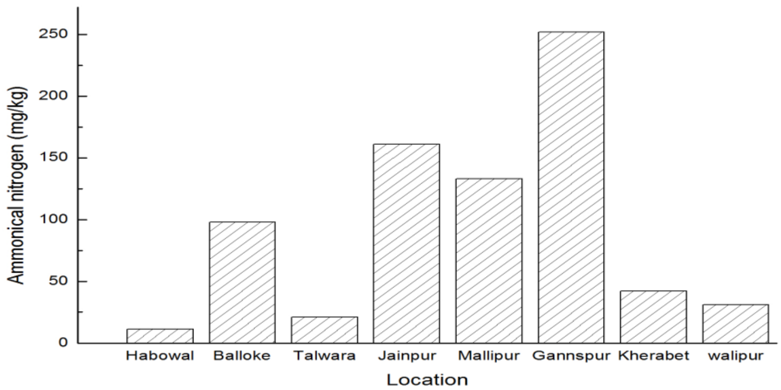


**Figure 4.4:** Ammonical nitrogen (mg/kg) of sediment samples at various locations

Figure 4.4 shows that the **ammonical nitrogen** lies in the range of 11.2 to 252 mg/kg. The concentration is high at Gaunspur region which could be due to discharge of domestic sewage from various outlets. The area around Nallah is low lying area due to which the discharge from residential areas is directly discharged into it.

### 4.2.2 Organic nitrogen and kjeldahl nitrogen

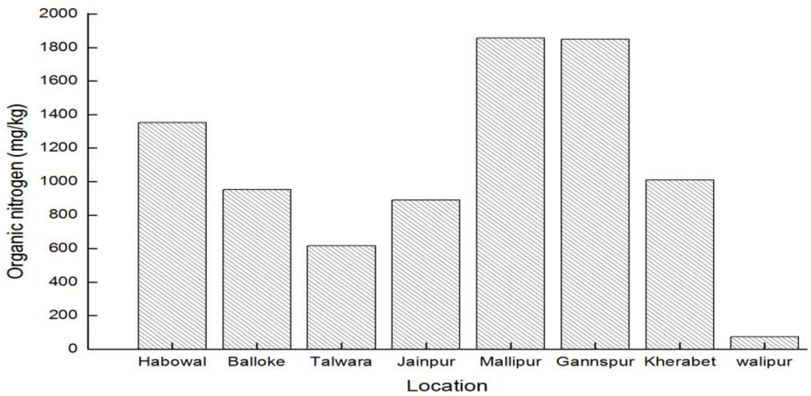


**Figure 4.5**: Organic N (mg/kg) of sediment samples at various locations

The bound form of nitrogen present in the sediments is **organic nitrogen**. The concentration of organic nitrogen varies due to action of algae and bacteria. When algae in the surface waters of puget sound take up inorganic nitrogen, they convert this nitrogen into organic forms. The algae eventually die and decompose, settling onto the floor, supplying organic nitrogen to sediments at the bed of Nallah. This organic nitrogen is further degraded by microbes in the sediment. Figure 4.5 shows that concentration of Organic nitrogen lies in between 74 to 1848 mg/kg. The concentration is high at Malakpur bet due to scouring effect occurring at Balloke region. 257 MLD of treated effluent is discharged from STP (sewage treatment plant) into the Nallah due to which a wave of disturbance is transferred to the leachate displacing the accumulated leached sediments. Therefore the concentration of organic nitrogen is high in Haibowal region and decreases upto Jainpur region and then again increases upto Kherabet region because of the same stated reason.

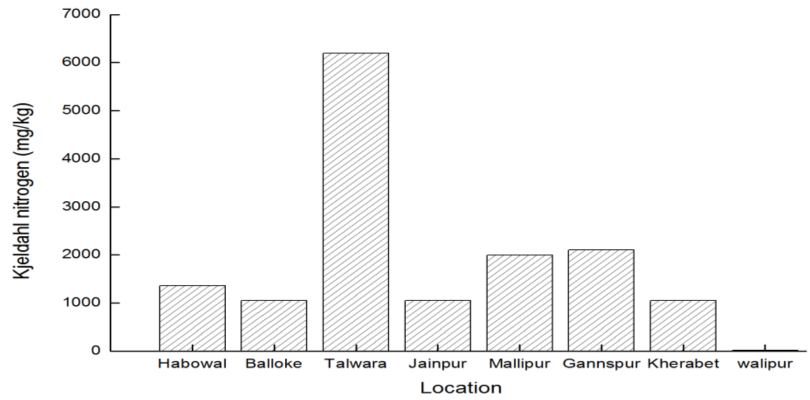


**Figure 4.6:** Kjeldahl N (mg/kg) of sediment samples at various locations

**Kjeldahl nitrogen** is the sum of ammonical nitrogen and organic nitrogen. Figure 4.6 shows that concentration is in between 11 to 6195 mg/ kg. The value is lowest in Walipur region and highest in Talwara region. This is due to discharge of effluent from residential areas. Also concentration increases due to flushing effect, which occurs when water from STP is discharged and leaching occurs. The concentration at Balloke region changes due to release of water from STP. The Nallah water gets diluted due to which pH increases.

### 4.2.3 Total nitrogen

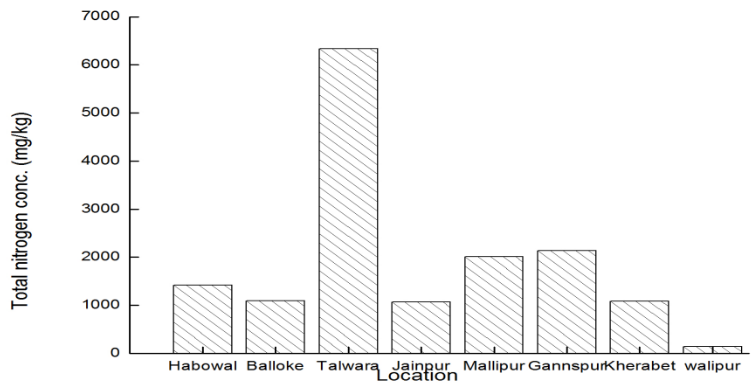


**Figure 4.7:** Total N (mg/kg) of sediment samples at various locations

**Total nitrogen** is the sum of nitrogen obtained from all sources. Figure 4.7 shows that concentration lies in between 140 to 6339 mg/kg. The concentration is highest at Talwara region due to domestic effluent discharge from residential areas and also from slaughter house. Total nitrogen is highest at Talwara region and value decreases upto Walipur kalan. STP water gives dilution effect to Nallah water and also due to scouring the Nallah bed disturbs and leaching occurs. Immediately after Balloke region, Talwara region lies and the concentration is highest. Walipur lies at the end upto which the concentration decreases.

### 4.2.4 Phosphorus (soluble, ortho and total phosphorus)

Phosphorus is often found to be the limiting nutrient in sediments. 'Limiting' here means that phosphorus is the resource in minimum supply, relative to demand, so that, increase or decrease in level of phosphorus have a direct effect on aquatic life. The excess amount of phosphorus causes blooms of the bluegreen algae, a form of cyanobacteria, which can produce neurotoxins and hepatotoxins. The same toxin can damage aquatic ecosystems and fisheries. Excess amount of phosphorus causes rapid growth of phytoplankton, creating dense populations or blooms. These blooms become so dense that they reduce the amount of sunlight available to submerged aquatic vegetation. Without sufficient light, plant cannot photosynthesize and produce the food they need to survive. The loss of sunlight can kill aquatic grasses. Algae may also grow directly on the submerged aquatic vegetation. Unconsumed algae will ultimately sink and be decomposed by bacteria in a process that depletes bottom waters of oxygen.

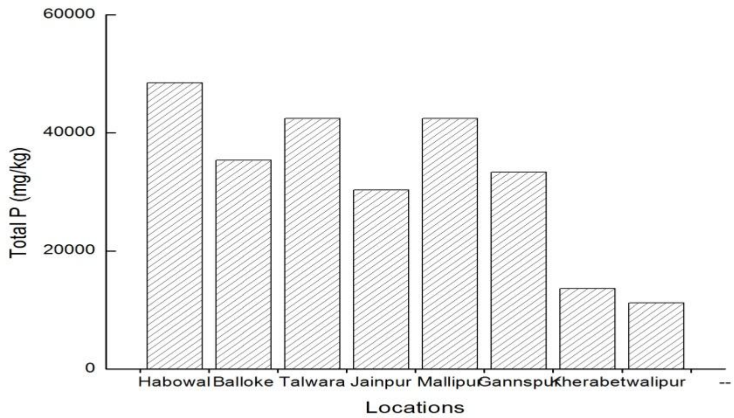


**Figure 4.8:** Total P (mg/kg) of sediment samples at various locations

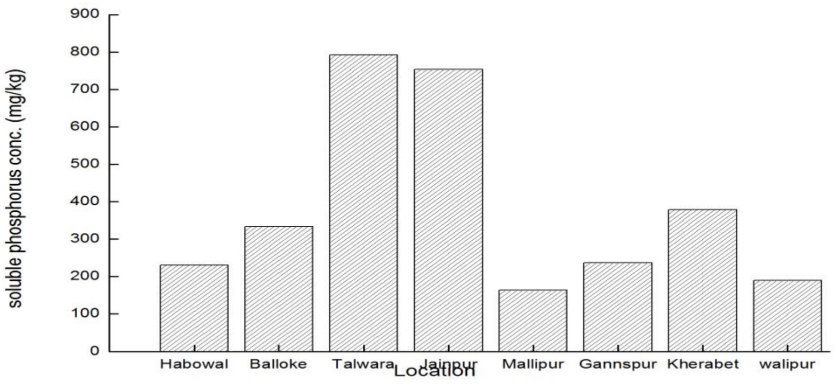


**Figure 4.9:** Soluble P (mg/kg) of sediment samples at various locations

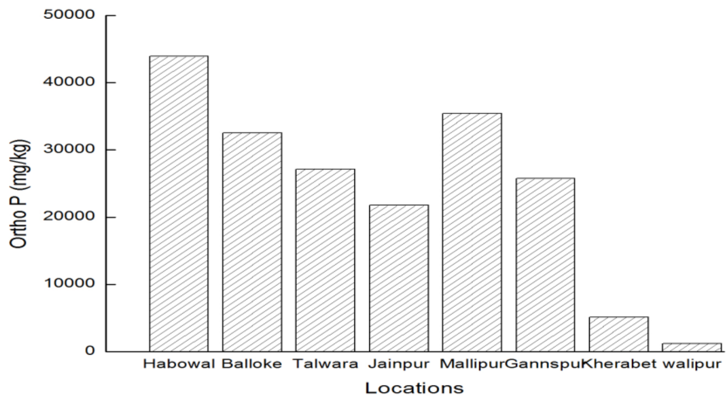


**Figure 4.10:** Ortho P (mg/kg) of sediment samples at various locations

Figures 4.8, 4.9 and 4.10 show that concentration of soluble, ortho and total phosphorus lies in between 189 to 792 mg/kg, 1212 to 43939 mg/ kg and 11212 to 48485 mg/kg, respectively. Talwara region has the highest value because of discharge of domestic effluent from low lying areas. The domestic effluent has detergents which add to phosphorus pool. The value decreases upto Walipur kalan, the last sampling site that could be a result of absence of domestic effluent and also, the relative high-plane surface near the Nallah, as opposed to the low-lying area of Talwara region. It is important here to note that such high levels of phosphate in sediments may get released in Nallah water and also may affect nearby ground water and soil. Various chemical processes occur in the Nallah bed which transforms phosphate to orthophosphate.

### 4.2.5 Organic Carbon

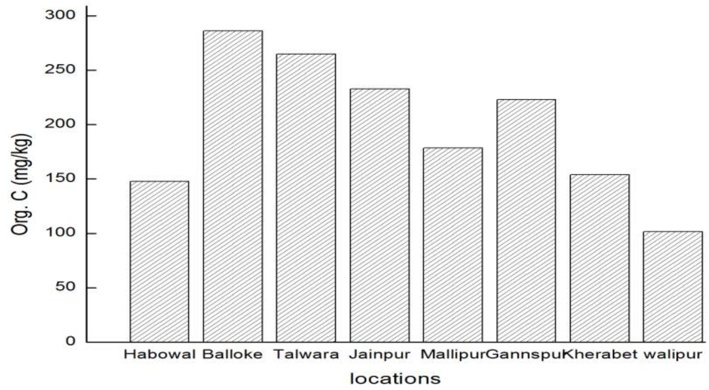


**Figure 4.11:** Organic carbon (mg/kg) of sediment samples at various locations

The organic carbon represents the organic matter in the sediments. The dead bodies of organisms buried in the sediments when undergo physical, chemical and biological processes usually contribute to organic carbon. Mineralization of organic carbon in sediments consumes left out dissolved oxygen and releases nutrient, which causes intrinsic pollution in Nallah. Fig. 4.11 shows that organic carbon lies in the range 102.0 to 286.7 mg/kg. Balloke region has highest concentration because of domestic discharge from low lying areas. Gaunspur village has dead bodies of animals buried on the Nallah bed. Due to which Nallah water is acidic and unfit for drinking. Talwara region has quite high concentration of organic carbon. This is due to deposition of carbon from the back coming water (incl. sediments) which was mixed with 157 MLD of STP discharge and causes scouring which disturbs Nallah bed and leads to deposition of sediments in Talwara region.

## 4.3 Metals (Iron, Zinc, Potassium, Copper, Manganese, Chromium, Lead and Sodium)

Nallah bed has metals which are deposited over years. Presently, according to the reports of Punjab Pollution Control Board (PPCB), no industrial outlet is discharging any effluent. Zero liquid discharge has been imposed on all the industries by PPCB. Before issue of the laws, the Nallah received directly the sewage, industrial effluents of various industries such as electroplating, woolen textile, hosiery, dyeing units, heat treatment plants, waste paper based paper mill and cycle and cycle parts manufacturing etc. Now, only domestic effluent is discharged which is because of low lying areas situated around the Nallah. The low-lying areas couldn't be connected to any STP therefore, discharges domestic effluent from residential areas directly into the Nallah. Many processes occurring in the bed of Nallah brings the chemically bound metals to unbound state. Before the rainy season, the dredging of Nallah occurs so that smooth flow of water takes place without any clogging problem. The dredging causes disturbance in the Nallah bed due to which concentration of metals and nutrients vary.

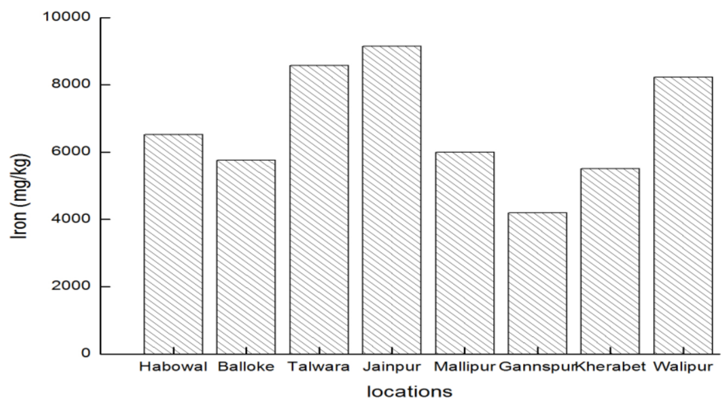


**Figure 4.12:** Fe (mg/kg) of sediment samples at various locations

Figure 4.12 shows the concentration of iron ranges in between 4191 to 52292 mg/kg in the sediment samples collected from various locations. The presence of high concentration of Fe may increase the hazard of pathogenic organisms: since most of these organisms need Fe for their growth.

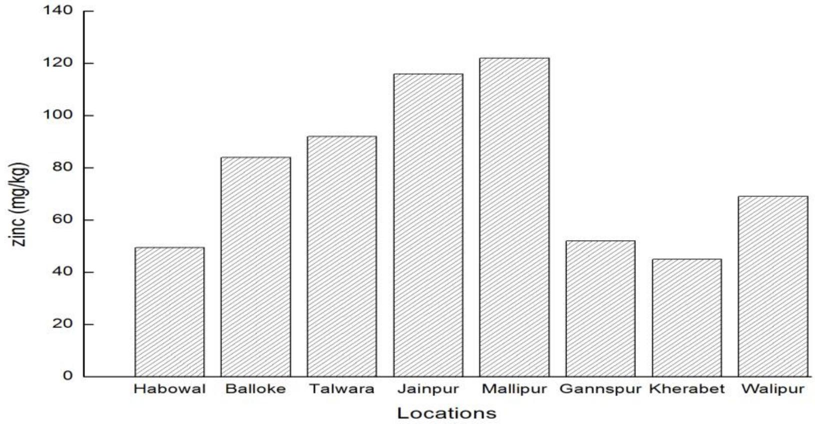


**Figure 4.13:** Zinc (mg/kg) of sediment samples at various locations

Zinc is used in coatings to protect iron and steel, in alloys for die casting, in brass, in dry batteries, in roofing and exterior fittings for buildings, and in some printing processes. The principal sources of zinc to aquatic systems include municipal wastewater effluents, zinc mining, smelting, and refining activities, wood combustion, waste incineration, iron and steel production, and other atmospheric emissions **[39]**.

Figure 4.13 shows the average concentration of Zn in sediment samples to be 50 to 122 mg/kg. High levels of Zn may result in necrosis, chlorosis and inhibited growth of aquatic plants. Zinc is an essential micronutrient and uptake in most aquatic organisms appears to be independent of environmental concentrations. It has been found to bioaccumulate in some organisms, though there is no evidence of biomagnification **[40]**.

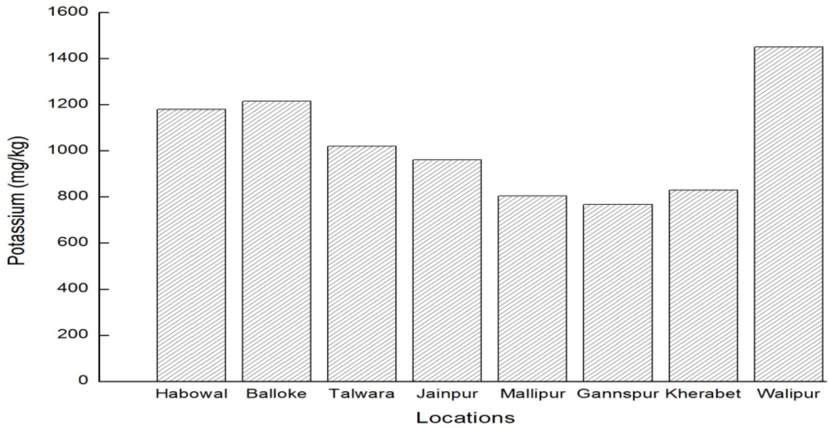


**Figure 4.14:** K (mg/kg) of sediment samples at various locations

Figure 4.14 shows that the concentration of K lies in between 767 to 1450 mg/kg. Potassium is an essential nutrient for aquatic flora and fauna. Excessive amount of potassium leads to eutrophication.

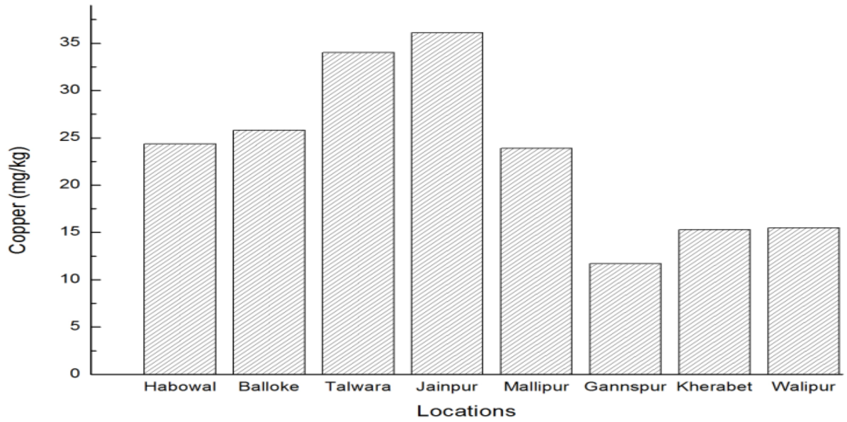


**Figure 4.15:** Cu (mg/kg) of sediment samples at various locations

Potential anthropogenic sources of copper include corrosion of brass and copper pipe by acidic waters, the use of copper compounds as aquatic algicides, sewage treatment plant effluents and runoff. Major industrial sources include mining, smelting and refining industries, copper wire mills, coal burning industries, and iron and steel producing industries **[41]**. The average concentration of Cu is shown in figure 4.15. It is in between 12 to 36 mg/kg. Higher values of Cu leads to damage to roots of aquatic plants, inhibits root growth. Hence, it damage aquatic ecosystem in the sediments of Nallah.

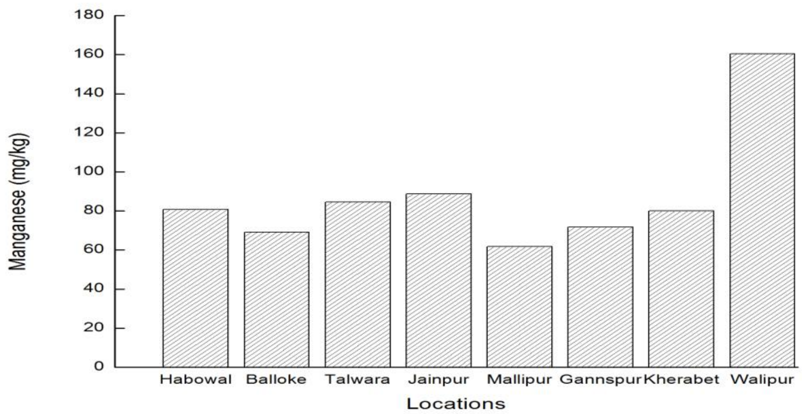


**Figure 4.16:** Mn (mg/kg) of sediment samples at various locations

Manganese is one out of the three toxic essential trace elements. Figure 4.16 shows that the Mn concentration lies in between 62 to 161 mg/kg Small amount is necessity but excess harms. The too high concentration in sediments effects nearby soil and ground water.

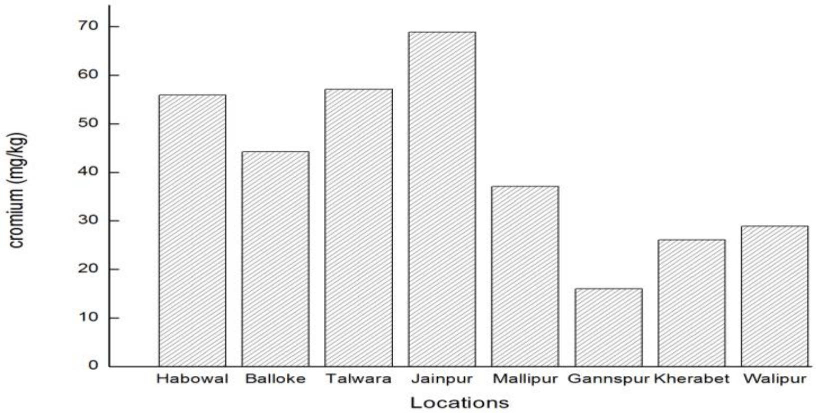


**Figure 4.17:** Cr (mg/kg) of sediment samples at various locations

Chromium is a trace metallic element widely used in industrial processes. Figure 4.17 shows that the average chrome content in sediment samples lies in between 16 to 69 mg/kg. The increased concentration of chromium in sediments is due to effluent discharged from electroplating and dyeing industries in the past when there was no installation of zero liquid discharge (ZLD). They directly discharged effluent in the Nallah water. As the time passes the Cr present in the effluent settles down thereby increasing concentration in the sediments.

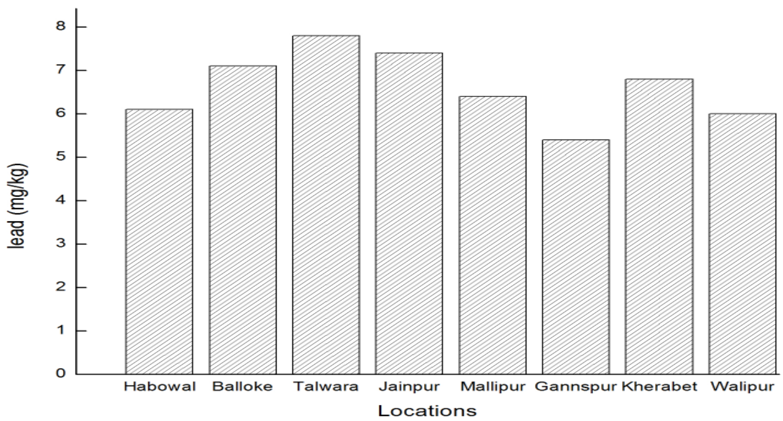


**Figure 4.18:** Pb (mg/kg) of sediment samples at various locations

Lead and its compounds are used in electroplating, metallurgy, construction materials, coatings and dyes, electronic equipment, plastics, veterinary medicines, fuels and radiation shielding. Other uses of lead are for ammunition, corrosive-liquid containers, paints, glassware, fabricating storage tank linings, transporting radioactive materials, solder, piping, cable sheathing, roofing and sound attenuators **[39]**. Figure 4.18 shows that the concentration of lead lies in between 5.4 to 7.8 mg/kg. It initially results in enhanced growth but on higher concentration leads to severe growth retardation. There are adverse effects on photosynthesis and other metabolic activities of aquatic plants.

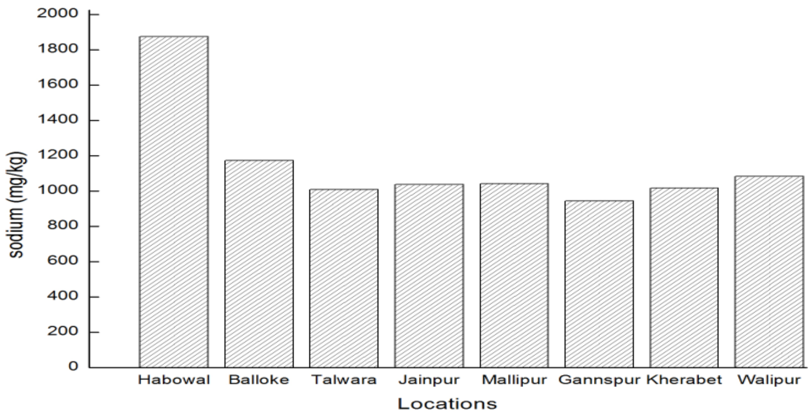


**Figure 4.19:** Na (mg/kg) of sediment samples at various locations

Figure 4.19 shows that the sodium concentration lies between 943 to 1874 mg/kg. The main source of sodium is from domestic, residential and industrial discharge.

**Table 4.1** Metal concentration at different locations

| Locations | Cr | Cu | Fe | K | Mn | Pb | Na | Zn |
|---|---|---|---|---|---|---|---|---|
| Haibowal | 55.9 | 24.35 | 6520 | 1180 | 80.75 | 6.1 | 1873.9 | 49.5 |
| Balloke | 44.2 | 25.8 | 5756 | 1214 | 69.2 | 7.1 | 1172.2 | 84 |
| Talwara | 57.1 | 34 | 8578 | 1020 | 84.6 | 7.8 | 1007.7 | 92 |
| Jainpur | 68.9 | 36.1 | 9145 | 960 | 88.7 | 7.4 | 1036.6 | 116 |
| Malakpur | 37.1 | 23.9 | 5992 | 803 | 61.7 | 6.4 | 1041.3 | 122 |
| Gaunspur | 16 | 11.7 | 4191 | 767 | 71.7 | 5.4 | 943.2 | 52 |
| Kherabet | 26.1 | 15.3 | 5503 | 830 | 80 | 6.8 | 1016.8 | 45 |
| Walipur | 28.9 | 15.5 | 8224 | 1450 | 160.5 | 6 | 1082.4 | 69 |

The unit of concentrations was mg/kg.

At various locations the increase in concentration of metals is due to old deposits. The decrease in concentration is due to dilution effect caused by STP water. The high concentration of iron and sodium is favourable because these come under the category of essential nutrients. The results on concentration of all the metals at different locations are summarized in the table 4.1. The toxicity of heavy metals also gets enhanced at particular pH. Acidic sediments also mobilize metals and can be toxic to aquatic species. Metal toxicity can cause reduced survival of fishes through chronic stress. Due to relatively high concentration of heavy metals, no aquatic life left in the sediments of Nallah. The metals like iron, potassium, sodium and magnesium being the essential metals, therefore, their concentration does not harm nearby ground water whereas the concentration of cromium, manganese, lead and copper varies differently at different locations.

# CHAPTER 5
# CONCLUSIONS

Budha Nallah is in serious need of an environmental rescue. It is the sole surface water source of the Ludhiana city. The Nallah is degrading day by day due to past on site industrial discharge of effluent. Around the Nallah, there exists the low lying area which could not be connected with any STP. Hence discharges residential and domestic effluent directly into it. The Nallah bed has accumulation of sludge and due to porous bed, seepage occurs easily there by effecting ground water quality. It has now become an open sewer and at various locations the sludge layer covers the whole Nallah from bottom to top, the surface and sediments have become hard. Dredging needs to be done to prevent ground water pollution and clogging problem. In order to assess the pollutant level of Nallah, various parameters were measured to know the extent. The concentration of minerals like nitrate and nitrite ions, ammonical nitrogen, organic nitrogen, Kjeldahl nitrogen, total nitrogen, soluble phosphorus, ortho phosphorus, total phosphorus, organic carbon and heavy metals such as Fe, Zn, K, Cu, Mn, Cr, Pb and Na are quite high and leads to problem of eutrophication, ground water pollution and damage to ecosystem. Therefore, before dredging proper treatment steps should be taken to treat it. Indeed, along the Nallah, the sediment shows a wide range of pollution level due to point and non-point sources. Depending upon these results, different treatment procedures for management of dredged material could be carried out.

# CHAPTER 6
# CONSERVATION MEASURES / RECOMMENDATIONS

In industrial city like Ludhiana it is not realistic to aim for zero sediment pollution, however a level of socio-economically acceptable pollution respecting the integrity of ecosystems can be reached. Precautionary and preventive approaches instead of end of pipe solutions need to be promoted at all decision and policy levels.

The rapidly increasing urbanization and industrialization have adversely affected the Ludhiana city's water resources which in turn affects sediments lying in the bed of Nallah. The Budha Nallah is polluted to the extent that self-purification mechanism does not take place at the most downstream points where it merges in the River Sutlej. In addition, Budha Nallah is also playing an indirect key role in ground water pollution. Ground water in most of the industrial estate and in few residential areas is unfit for drinking. Since industrial effluents contain toxic elements including heavy metals, adequate level of treatment should be ensured.

Adequate scientific investigations need to be carried out before approving the use of effluent for irrigation. Research on safe disposal methods for effluents / sludge's needs to be taken up. Recharge of freshwater through traditional as well as modern rainwater harvesting methods will help to reduce the level of pollution through dilution.

The Government should frame national policies relevant to protect freshwater biodiversity as per international agreements on water pollution. At the national and regional level, water pollution prevention policies should be integrated into non-water policies that have implications on water quality and sediment quality such as agriculture and land use management, trade, industry, energy and urban development. It is increasingly recognized that integrated sediment protection planning is suitable for the reduction of many forms of sediment pollution. The setting of standards of water quality, both for effluents and for the receiving waters, on an appropriate legal basis should become a priority, where no such standards exist.

The "polluter pays" principle should be adopted. Industry, Corporations and private offenders should be held responsible and made to pay for point source pollution.

Sediment pollution should be made a punishable offence. – with a rule to deal with minor or common use of water and the resulting pollution.

Of equal importance for the success of working programmes is the participation of stakeholders, including local authorities and local population. Partnerships can involve governments, local communities, NGOs, donors, international organizations, municipal authorities and private operators. The local communities can be empowered through knowledge and should be involved in the design and implementation of urban and rural water programs. Environmental education of farmers, industries and manufacturers as well as public discourse and access to information should be enhanced.

## References

[1] G. R. Sui (1983). Statement and evaluation of organic matter , total nitrogen and total phosphate in surface layer sediments in Taihu Lake, Journal of lake sciences, Vol. 8, pp. 319-324.

[2] L. Yang, F. Lin, X. Zheng, M. Zhang, and Y. Gao (2007). Effect of temperature on the activities of microorganism and the pollutants release in the bioremediation of the sediment, Environmental pollution & control, Vol. 29(1), pp. 22-29.

[3] X. M. Xie, M. Liao and C. Y. Huang (2004). Effects of pesticides on soil biochemical characteristics of a paddy soil, China, Journal of Environmental Science, Vol. 16 (2), pp. 252-255.

[4] X. Zhao, M. Hua, F. Wei and J. M. Sun (2005). Phytoremediation of heavy metal, organic complex in dredged sewage river sediment. Journal of Tianjin University, Vol.38 (11), pp.1011-1016.

[5] C. W. Tang, K. S. S. Paul, G. Zhang, P. Y. Qian and X. D. Li (2008). The spatial and temporal distribution of heavy metals in sediments of Victoria Harbour, Hong Kong. Marine Pollution Bulletin Vol. 57, pp. 816–825.

[6] J. Valdes, G. Vargas, A. Sifeddine, L. Ortlieb and M. Guiñez (2005). Distribution and enrichment evaluation of heavy metals in Mejillones Bay, Northern Chile: geochemical and statistical approach. Marine Pollution Bulletin. Vol. 50, pp,1558–1568.

[7] F. Zhou, H. C. Guo and Z. J. Hao (2007). Spatial distribution of heavy metals in Hong Kong’s marine sediments and their human impacts: A GIS-based chemomet approach. Marine Pollution Bulletin Vol. 54, pp. 1372–1384.

[8] “Budha Nallah (May 21, 2008). The toxic vein of Malwa” Indian Express.

[9] I.P. Singh (Jun 16, 2010). “Parts of Raj, Malwa drinking poison?” The Times of India.

[10] M. Singh (Dec 11, 2009). “Pollution in Budha Nallah on the rise” The Times of India.

[11] M. Singh (Aug 6, 2009). “Encroachment on banks of Budha Nallah cleared”. The Times of India.

[12] Ludhiana's Budha Nallah Gets In Situ Bio-Remediation Project http://abclive.in/environment/160-ludhiana-buddha-nullah-in-situ-bio-remediation-project.html

[13] V. K. Verma, R. K. Setia and M. P. Singh. (2013). Ugly face of urbanization and industrialization: A study of water pollution in Budha Nallah of Ludhiana City, India, Journal of Environmental Conservation Research, Vol. 1(1), pp, 6-11.

[14] A. Cheema and A. Virk (2012). A study of water pollution in the state of Punjab. Sacha Journal of Human Rights, Vol. 2, pp. 1- 14.

[15] S. D. Singh and S. Vasundara (2013). Study of textile effluent in and around Ludhiana district in Punjab, India. International Journal of Environmental Sciences, Vol. 3, pp. 4.

[16] S. Rahul (2011). Built environment in Ludhiana: Issues and Options, Institute of Town Planners, India Journal, Vol. 8, pp. 90-95.

[17] A. Arshad, R. Reddy and W. F. Debusk (1988).Seasonal changes in sediments and water chemistry of a subtropical lake. Hydro biologia, vol.159, pp. 159-167.

[18] S. Carpentier and R. Moilleron (2002). Quality of dredged material in the River Seine basin (France). The Science of the Total Environment, Vol. 295, pp, 101–113

[19] L. Shuo, and M. Shangjie (2001). Study on multi-scale distributed modeling of flow, sediment, and transport processes for nitrogen and phosphorus in Lianshui Basin. The Project-sponsored by SRF for ROCS, SEM. and the Opening Foundation of Key Laboratory of Poyang Lake Wetland and Watershed Research, Ministry of Education, Vol. 5, pp. 789-890.

[20] X. Nai-zheng, W. Feng and L. H. Hong-ying (2012). Spatial distribution of organic and inorganic carbon in sediments of Tai Lake, China, International Conference on Biomedical Engineering and Biotechnology, Vol. 12, pp, 978-7695.

[21] J. Shan, Z. Wei-qin, Z. Min Pan and L. Shu-ying (2013). Characteristics and evaluation for nitrogen pollution in water and surface sediments of Xixi Wetland. Third International Conference on Intelligent System Design and Engineering Applications, Vol. 12, pp, 7695-4923.

[22] W. Symader, M. Schorer and R. Bierl (1994). Temporal variations of environmental pollutants in channel sediments, Publ. no. 224.

[23] E. Subrmanium (1997). Geochemical factors controlling the chemical nature of water and sediments in the Gomti River, India, Environmental Geology Vol. 36 , pp,1-2.

[24] A. K. Verma, D. N. Saksena, A. Basavarajappa, and A. M. Qaid Saeed (2010). Influence of pollutants on bottom sediments of sewage collecting Kalpi (Morar) river, Gwalior, (M.P). Journal of Toxicology and Environmental Health Sciences， Vol. 2, pp. 38-49.

[25] P. U. Singare, R. M. Mishra and M. P. Trivedi. (2010-2011). Assessment of physico-chemical properties of sediments samples collected along Mithi River of Mumbai. Resources and Environment. Vol. 1(1), pp, 32-41.

[26] R. B. Marathe, Y. V. Marathe and C. P. Sawant (2011). Sediment characteristics of Tapti River, Maharashtra, International Journal of ChemTech Research India. Vol. 3, pp, 1179-1183.

[27] P. Kelderman, W. M. E. Drossaeri, Z. Min and L. S. Gallione (1999). Pollution assessment of the city of Delft, The Netherlands, Water Res., Vol. 34, pp, 936-944.

[28] N. Sabra, and T. Hamieh (2007). Sequential extraction and particle size analysis of heavy metals in sediments dredged from the Deûle Canal, France, The Open Environmental Engineering Journal, Vol. 4, pp, 11-17.

[29] W. Guo X. Liu and G. Liu (2010). Pollution and potential ecological risk evaluation of heavy metals in the sediments around Dongjiang Harbor, Tianjin, Journal of Environmental Sciences, Vol. 2, pp, 729–736.

[30] X. Y. Chen and P. Yan (2010), Distribution characteristics and pollution evaluation of river sediments, 2nd Conference on Environmental Science and Information Application Technology.

[31] P. Kelderman (2012). Sediment pollution, transport, and abatement measures in the City Canals of Delft, the Netherlands. Water Air Soil Pollution, Vol. 223, pp, 4627–4645.

[32] C. W. Chen and M. Schorer (2012). Copper contamination in the sediments of Salt River Mouth, Taiwan. Energy Procedia, Vol. 16, pp, 901-906.

[33] C. Dong, C. Wen and C. Feng (2011). Contamination and potential toxicity of heavy metals in sediment of the ocean disposal Site. Department of Marine Environmental Engineering National Kaohsiung Marine University, Taiwan, Vol. 8, pp, 978-4577.

[34] C. K. Jain, D. C. Singhal and M. K. Sharma (2004). Metal pollution assessment of sediment and water in the river Hindon in western U.P. Environmental Monitoring and Assessment. Vol. 105, pp, 193–207.

[35] R. S. Lokhand, P. U. Singare and D. S. Pimple (2011). Quantification study of toxic heavy metals pollutants in sediments samples collected from Kasardi River flowing along the Tajola industrial belt of Mumbai. New York Science Journal, Vol. 4(9), pp, 66-71

[36] P. S. Harikumar (2010). Distribution pattern of trace metal pollutants in the sediments of an urban wetland in the southwest coast of India. International Journal of Engineering Science and Technology. Vol. 2(5), pp, 840-850.

[37] American Society for Testing and Material (ASTM) (2010). Standard guide for sample preparation of sediments D3976-92, Vol. 11.02.

[38] American Public Health Association (APHA) (1999). Standard Methods for the Examination of Water and Waste Water Including bottom Sediments and Sludges, New York. Vol. 20.

[39] Canadian Council of Resource and Environment Ministers (CCREM) (1987). Canadian water quality guidelines. Task force on water quality guidelines. Ottawa, Canada.

[40] R. Jaagumagi (1990). Development of the Ontario provincial sediment quality guidelines for PCBs and the organochlorines pesticides. Water Resources Branch. Environment Ontario. Toronto, pp, 16.

[41] M. C. Taylor, S. W. Reeder, and S. Demayo (1979). Guidelines for surface water quality and inorganic Substances, Canada. Ottawa, Vol. I.

## Publications

Rajpal N., Bajpai P. K., Bhunia H., and Ram B. “Studies on physico-chemical characterisation of sediments in a water body” National Conference on Recent Advances in Renewable Energy & Environment Sciences, Shoolini University, Solan, June 8-9, 2013.