DETECTION OF HEAVY METALS AND IDENTIFICATION OF MACROINVERTEBRATES IN THE SOILS OF JALLO PARK AND BALLOKI HEADWORKS

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RESEARCH COMPLETION CERTIFICATE

It is certified that Ms. Maham Khan, Ms. Nimra Tariq and Ms. Zamara Zahid of BS Hons. (Session 2018-2022), Department of Zoology have carried out this research work entitled **"Detection of Heavy Metals and Identification of Macroinvertebrates in the Soils of Jallo Park and Balloki Headworks"** under my supervision.

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ABSTRACT

The research was focused on finding and identifying the macroinvertebrates from the soils of Jallo Park and Balloki Headworks and studying their significance in regard to their ecological contribution. Moreover, the concentration of heavy metals in soils of the study areas was also detected. Methods like sweep netting, and litter extraction were used for the collection of macroinvertebrate samples from the study areas, which were later on identified with the help of identification guides. After that the ecological linkages were studied and their diversity was calculated using Simpson's Index. For heavy metal detection the soil samples were digested with HNO_3 and analyzed with atomic absorption spectroscopy and then values were compared with standard stock solution values. The metals under consideration included; Cadmium (Cd), Chromium (Cr), Copper (Cu), Cobalt (Co), Nickel (Ni) and Manganese (Mn). The analyzed values were then matched with standard limits recommended by WHO. The results showed that 26 species were found from Jallo Park in which 8 species were found to be pollution tolerant, 7 species were pollution indicator, and 11 species were sensitive to pollution. 13 species were found from Balloki Headworks in which 4 species were found pollution tolerant, 9 were found to be pollution sensitive and no indicator species was found there. Based on Simpson's Index of Diversity, Jallo Park species were found to be more diversified as compared to species of macroinvertebrates collected from Balloki Headworks. Simpson's Diversity Index in Jallo Park came out to be 0.96, whereas it was 0.95 for the diversity of Balloki Headworks. Therefore, it was deduced that Jallo Park is enriched with greater species diversity in comparison to Balloki Headworks. Experimental results further showed that all the metals were present within the permissible limits except Cadmium, Cobalt and Manganese which indicate that the soil was in average condition and with sensible use of fertilizers, good sewage treatment practices and soil nutrient management it can be made more sustainable.

LIST OF ABBREVIATIONS

AAS	Atomic Absorption Spectroscopy
D_S	Simpson's Diversity Index
EDXRF	Energy dispersive X-ray fluorescence spectrometry
PERI	Potential Ecological Risk Index
PGRs	Plant Growth Regulators
PLI	Pollution Load Index
QBS	Soil Biological Quality Index
WHO	World Health Organization

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CHAPTER 1

INTRODUCTION

Macroinvertebrates are cold blooded animals lacking a backbone and large enough to see with the naked eye. They can be aquatic or terrestrial and can vary greatly in body and shape. Today a variety of macroinvertebrates species are known which include annelids (isolated worms), mollusks, arthropods, arachnids, crustaceans, odonate (mayflies, dragonflies and damselflies), stone flies, caddisflies bugs and beetles etc.

Aquatic macroinvertebrates are predominately found in freshwater and marine habitats. Examples include insects, worms, snails, mollusks and crustaceans. They are considered as an integral part of the food chain and are known to feed on living organisms like leaves and mosses. While some of the top order organisms such as birds, fish and large insects then feed on them [1].

Soil macroinvertebrates, including earthworms, terrestrial insects, myriapods and isopods are known for their role as ecosystem engineers in which they transform habitats and aid in resource distribution. Earthworms are large mud dwelling worms, numerous in numbers and having significant effects on decay, cycling, water infiltration and also on the restoration of structural processes of degraded environment. In addition, earthworms are considered to be biological engineers, who contribute to the body's transformation of soil, usually in the form of bioturbation. Isopods such as millipedes, consists mainly of fresh and marine species. Seven pairs of walking legs are present in isopods. Millipedes and terrestrial isopods contribute to the natural processes in particular by cracking the leaf litter, leading to increased rotting and nutrient cycling [2, 3].

Soil invertebrates perform a variety of functions that contribute to the health of the ecosystem with nutrient cycling conservation, water conservation and basic production. Invertebrate soils directly or indirectly affect organic rot, soil retention and can have a direct impact on plant communities by feeding on the roots, leaves or seeds. As trophic chains of the earth are supported by basic autotrophic production, the degradation of dead underground species by soil organisms, including decomposers and detritivores, contributes to the interaction between nutrients and energy of soil processes. The soil has the ability to accumulate nutrients and energy through decay, therefore soil communities are increasing and becoming more complex. In addition, the positive interactions between groundless invertebrates and microorganisms contribute to this complexity [4, 5].

Soil and organisms present in it are most important earth resources, but in the efforts of restoring nature their role has been ignored. In recycling of nutrients, some vital groundwater processes are used and are very commonly adapted to disturb natural habitats. Since macroinvertebrates are considered as important monitors of these processes in many cool and tropical environments and also because ecosystems aim to restore their functions, therefore the biodiversity of the soil can play a significant role in restoring programs. Large spinal cordless detritivores are known to have significant implications for fatigue and other imperfect processes in natural systems [2].

Heavy metals are naturally occurring elements of the earth's crust having very high densities. Some metals are important for the body in limited quantities and these are known as trace elements, but the toxic effects of these metals cannot be ignored if used in inappropriate quantities by humans and if given to plants and animals unchecked. Studies have provided evidence that these metals leach into environment from both manmade and natural sources. Industrial activities and mining are one of them. Metals after entering the ecosystem become part of the underground water or accumulate in soil causing water and soil pollution. These metals penetrate animal and plant bodies by transfer mechanisms and can react with the biomolecules of the body hence rendering them inefficient [6].

Heavy metal pollution is considered as slow, long lasting and irreversible and can affect the atmosphere, hydrosphere and health of plants and animals. It has adverse effects on the food chains as well. Cadmium is taken up by plant roots through soil or water and it starts accumulating in roots and shoots which can lead to oxidative and metabolic stress. Heavy metals are present in atmosphere and soil naturally, but socio-economic development has increased the amounts by many folds within last two centuries. This includes agricultural activities, mining and unprocessed smoke and leftovers of industries. Studies have shown that these anthropogenic sources are much more significant than natural sources. A research was conducted by government of China and it was found out that use of sewage water in agriculture and mining are two most important factors of heavy metal pollution [7].

Soil contains billions of microorganisms which are responsible for a variety of microbial processes. When heavy metal content of soil is increased it affects the microorganisms in soil. Some of the important roles of soil microorganisms include mycorrhiza formation which is the direct link between soil and plant roots and is beneficial for both of them. This mycorrhiza becomes the major transporter of toxicity and heavy metals from soil to root. Researchers have studied the interactions of these metals with fungi; like the occurrence and tolerance level of fungi for different metals and their effects on the growth and development of plants. The fungal hyphae (mycorrhiza) are also used for bioremediation and as indicators of metal pollution in the soil [8].

Chromium is a heavy metal which exists in different forms in the environment with different oxidation states like: chromium (III) and chromium (VI). These two forms are interconvertible. Chromium (III) is more stable in environment so the common reaction that happens in environment is reduction of chromium (VI) to chromium (III). Chromium enters in cells by crossing the cell membranes. Chromium is used as a nutrient for some metals but to bacteria, some plants and animals it is considered toxic. Higher amounts of chromium in humans can cause cancers of the lungs and kidneys. It can also damage the skin, but studies show that not all the chromium containing compounds are toxic for animals and plants [9].

Nickel is an important metal and is needed in bodies of many animal species. Lack or deficiency of nickel in animals can cause stunted growth, infertility and changes in lipid and glucose levels in the body. Nickel is used in the formation of nickel iron alloys. Nickel makes bonds with many other atoms to form useful compounds. Nickel carbonyl is a compound that decomposes into carbon monoxide and nickel when present at room temperature. Most of the body's nickel concentration is taken through food. Nickel toxicity is mainly caused by nickel compounds and most important of them is nickel carbonyl. It affects the respiratory tract and gastrointestinal tract. Sometimes it affects the brain and cause cerebral edema which in turn leads to death [10].

Cobalt is a rare element with magnetic properties same as that of nickel and iron. Cobalt form bonds with oxygen and other compounds and exist in the form of oxides. It is used to make super alloys and hard metals. In humans it enters the body through ingestion mostly. Cobalt enters the environment during the production of cobalt powders. It is essential for proper functioning of body but when it increases from required amount it becomes toxic for the body. Like, the normal amount of cobalt in the body is important for the formation of vitamin B_{12} but excessive amount of cobalt can cause goiter and other thyroid problems. Cobalt pollution affects lungs and can causes fibrosis and asthma [11].

Copper is a trace element that is important for the human body because it is necessary for the production of hemoglobin and plays a role in absorption of iron. It is mostly used in electrical appliances and in contraceptive devices which release copper in the uterus of women for the contraceptive effects. The half-life of copper is 1 to 30 days and is excreted through bile after this time. Copper is an irritant in body which destroys the lining of gastrointestinal tract. Chronic toxicity from copper causes liver damage. 60 to 70 percent of copper intake is from diet. Accumulation of copper in liver causes Wilson's disease and other liver diseases [12]. Copper is a metal which is important for the growth and development of plants, but it becomes a problem when it is present in excess. It acts as a cofactor for proteins in plants, but the excess copper inhibits the growth of plants by altering the normal physiological processes [12, 13].

Manganese is naturally present in the Earth's crust. Main sources of manganese include volcanic eruptions, forest fires, organic waste of plants and animals and reduction of manganese oxide. Deficiency of manganese can result in retarded growth and poor functioning of skeletal and reproductive system. High intake of manganese can cause problems in nervous system. It also affects the respiratory and reproductive system [14, 15].

Cadmium is a notorious carcinogenic heavy metal. Studies show that the high levels of cadmium are associated with increased rates of lung cancer. Moreover, it is also related to kidney problems and prostate cancer. In the human body, cadmium directly affects the liver, pancreas and stomach. While in animals, cancer is caused by the accumulation of cadmium at various sites as it depends on the route of entry of metal. Researchers have shown that it can cause damage to testicles, liver, pituitary and prostate gland. It has low magnetic effects and may act by altering genetic products or DNA or by suppressing the process of apoptosis (programmed cell death) [16].

Therefore, the purpose of the study was to assess the quality of soils of Jallo Park and Balloki Headworks by determining the presence of heavy metals in the soils of the areas and to identify the different types of soil macroinvertebrates found there.

1.1 Study Area

The study areas comprise of Jallo Wildlife Park in Lahore and Balloki Headworks in Kasur District.

Jallo Park: Jallo Park is rich in providing socio economic benefits, ecological services and recreational amenities and is also famous as a Wildlife Breeding Centre. Jallo urban park is located on the east of Lahore District, Punjab at a distance of 20 km from Lahore city. Jallo Wildlife Park which is also a captive breeding center covers an area of 461 acres. It is located at 31°34´21" North and 74° 28´38" East. The minimum temperature at Jallo varies between 9-14^{o}C while the maximum varies between 34-38^{o}C, whereas the rainfall recorded is 663.9 mm annually [17, 18, 19, 20, 21, 22].

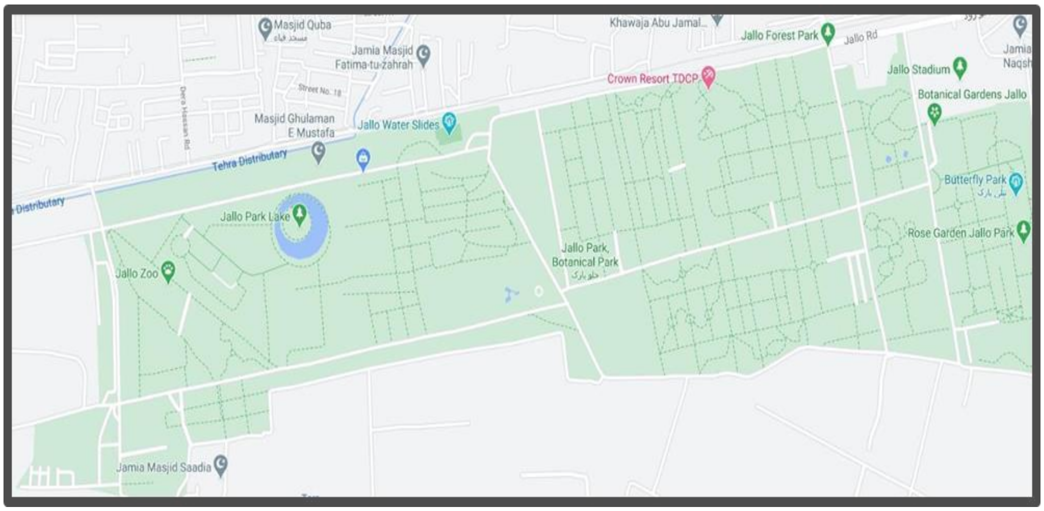


Figure 1.1: Map of Jallo Wildlife Park.

The soil of Jallo Park is mainly composed of water, air, minerals and organic matter. It is fertile, has consistent texture and a pH ranging from 6.0-6.8. Jallo Wildlife Park has great diversity of fauna and flora. Many species of aves, mammals and reptiles are found in Jallo Wildlife Park. The Park is not only popular for the species of plants and animals it sustains, but has a butterfly house as well [21, 23].

Balloki Headworks

Balloki Headworks is located around 65 km from Lahore, at River Ravi near the town of Bhai Pheru on Multan Road. Balloki Barrage was constructed when the upper Chenab joined the lower Ravi. Its coordinates are 31°13'10" N and 73°51'35" E and it is well known for its fishing and outdoor hunting location and having a design flood capacity of 225,000 cusecs [24].

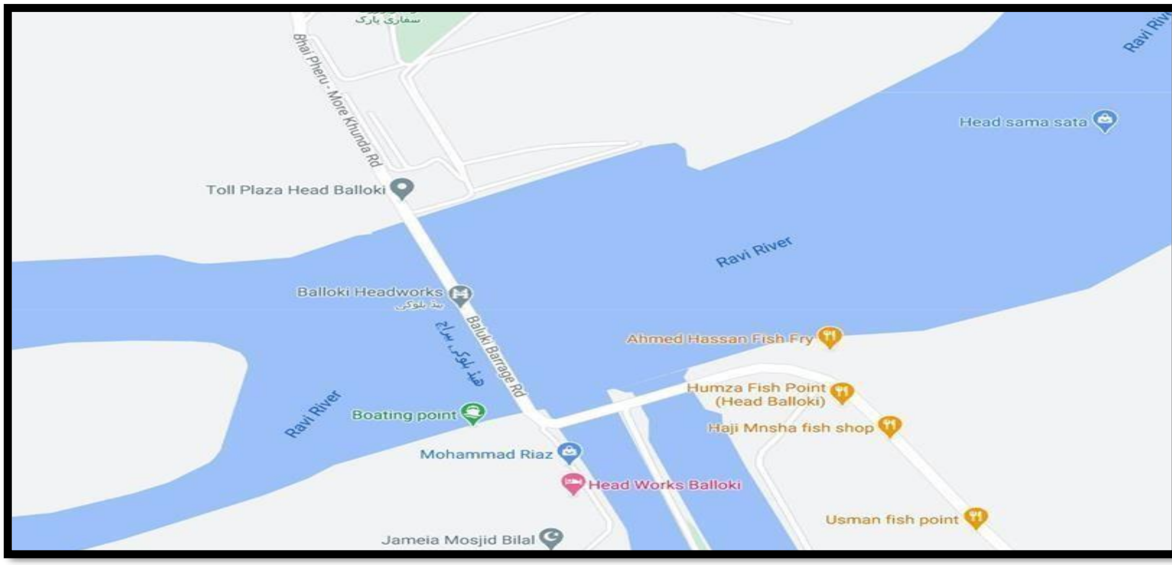


Figure 1.2: Map of Balloki Headworks

The temperature of the area varies between 16˚C-32˚C. The site surface comprises of medium grained sand with salts and clay. It has medium to large stones embedded in sand that serve as habitat for macroinvertebrates. The area which is distant from water surface is fertile and has a rich diversity of fauna and flora. Species of Water Hyacinth, Water Primrose, and Water Lilly can be found. Different avian species can be seen flying above the waterfall. Flying and crawling insects can also be found. Both the study areas have rich fertile soils, high diversity of fauna and flora and have the ideal environmental conditions to house a large number of soil macroinvertebrates [25, 26, 27].

AIMS AND OBJECTIVES

The aim of the research was to:

- identify the different types of macroinvertebrates present in the soils of Jallo Park and Balloki Headworks.
- study the diversity and abundance of different species of soil macroinvertebrates present in the selected areas.
- study the ecological relationship between the soil macroinvertebrates and the other fauna and flora present there.
- determine the soil quality of the selected study areas using Heavy Metal Analysis.

RATIONALE

Macroinvertebrates are present in almost all aquatic and soil bodies. They are considered as indicators of pollution and help in assessing the quality of soil and water. The study was carried out to find the abundance and diversity of macroinvertebrates in the soils of Jallo Park and Balloki Headworks, the ecological linkages they form with the fauna and flora found there and the pollution caused by the presence of heavy metals in the soils of the areas. Since, there has been very little research done on soil macroinvertebrates, so the study was conducted to provide a baseline knowledge to future researchers about the status of macroinvertebrates in the selected areas so that it can help in making sustainable strategies for maintaining the population of soil macroinvertebrates and in reducing the heavy metal pollution there.

CHAPTER 2

LITERATURE REVIEW

Soil macroinvertebrates are the fundamental part of agricultural ecosystem, but the intensified agricultural farming is leaving a negative impact on the soil structure, soil macroinvertebrates and soil processes. Research conducted by Naureen R et al.., aimed to study deterioration of macroinvertebrates in wheat field when provided with low and high input of chemical fertilizers. Soil samples were collected from random sites and different number of specimen were found from the areas of low input fertilizers and high input fertilizers. In order to find the difference between diversity and damage in two areas t-test analysis was done. It was concluded that deterioration of macroinvertebrates was less in the areas where organic fertilizers were used instead of chemical fertilizers [28].

Taqi R et al., studied the vital role of cotton crops in Pakistan's economy. The research was performed to check the variety and richness of various insects on crops. Sampling was done from two different districts of Punjab, Pakistan. The samples were collected by using the sweep net and hand net trap method. Specimens were identified using taxonomic keys. Shannon Weiner range index was used to analyze the data. More than 30 species were recognized from one district, whereas 34 were gathered from the other. The Shannon Weiner range index value of macroinvertebrates on cotton was calculated [29].

Edaphic macroinvertebrates form an important part of the subsoil and play a significant role in the natural operation of the product and in sustainable production. As these animals respond easily to biotic and abiotic deviations in soil profiles, various land use systems have different community assemblages of macroinvertebrates. The research conducted by Majeed MZ et al., was to find out the impact of different types of land usage i.e., natural and agricultural land on soil macroinvertebrate fauna. Random sampling was performed in winter 2015 and summer 2016 using monoliths and crossing traps. The results showed that the species used in the world have a different effect on diversity and population in macro faunal communities. Generally, low chemical marine animals were on the ground in the study area as compared to other tropical and subtropical regions reported elsewhere. Therefore, in view of the important role of invertebrates in soil stability, it is recommended to minimize the negative impacts of land management practices on these important soil organisms [30].

According to the diversity and distribution, gastropods have been least studied in Pakistan. There are different ecological factors that affect the diversity and distribution of snail in the agroecosystem of Faisalabad. Total of 19290 snail samples were collected from cropland areas of 24 different villages in Faisalabad for identification and understanding the diversity of these areas. The identification was done on the basis of recent identification key and diagrammatic description was done in order to study the biodiversity. The cropland areas include sugarcane, wheat, fodder, vegetable field and ditches. The diversity index found was significant in sugarcane, wheat, and fodder vegetable field and non-significant in ditches. The relative abundance was high in sugarcane and low in ditches. The diversity index was high in all months except that of April. Due to environmental degradation and water pollution the population of snails can't be found significant in the ditches. However, in the agroecosystem of Faisalabad it is considered as a pest and can be found significantly, so the biological strategies must be done to control it as a pest [31].

The study conducted by Majeed MZ et al.., was aimed to know the diversity and abundance of edaphic arthropods and how it is affected by different land management practices and how the arthropods provide information about the prevailing soil quality. The study was aimed to know the population abundance and diversity of edaphic arthropods in different localities of Sargodha Pakistan. Soil Biological Quality (QBS) index was used to determine the quality of soil. The soil sampling was done on random land sites for four consecutive seasons from spring 2017 to spring 2018. It was concluded that the different seasons and land-use types had a significant but different effect on the abundance and diversity of edaphic arthropods. Abundance of edaphic arthropods can be seen in summers and spring whereas, minimum population is found in winter season. The abundance of arthropods was also related with soil organic matter, bulk density, total organic carbon content and moisture content of soil [32].

Duran-Bautista studied the role of termites as a tool for indicating soil condition and ecosystem service that they are providing. The study was conducted in the deforested areas of Amazon, where the termite species were identified as the indicators for soil condition. Different variables like chemical fertility, soil macro aggregation and hydrological functions of soil and the presence of macroinvertebrate population were considered at each sampling point. Indicator species of termites were searched by using indicator value index method and the indicator species were observed for soil macro aggregation, biodiversity of macroinvertebrates and chemical fertility. The results showed that some of the termite species were indicators for more than one factor. This capability of termites made them a helpful tracking tool. The study also demonstrated the negative effects of land degradation on the biodiversity and specifically termite community [33].

Macroinvertebrates present in soil play a significant role in decomposition of organic matter, chemical properties of soil and in nutrient cycling. The study showed that various abiotic factors affect the number and presence of macroinvertebrates. These factors can fluctuate at different altitudes and this can affect the macroinvertebrate diversity. Thus, diversity of fauna in soil at elevations is not steady because of varying climate and vegetation. The research emphasizes on the types of macroinvertebrates present in diverse vegetation at three altitudes. The research was conducted on Tibetan Plateau, China. The sample size consisted of 100 families of macroinvertebrates. It was observed that individual population and specie richness increased with increasing altitude. Furthermore, extraordinary seasonal fluctuations related to structure and composition of macroinvertebrates among different vegetation was also noticed. Environmental factors also played a key role in the varying composition and structure of macroinvertebrates. An analysis technique known as Structural Equation Model was used to analyze differences among structures of macroinvertebrates. According to the model, altitudes do not affect macroinvertebrate diversity directly, but can affect it indirectly by changing the climate and levels of nitrogen and carbon in soil. Similarly, vegetation also affects the population of macroinvertebrates indirectly by managing the input of organic waste of plants [34].

Macroinvertebrates affect soil in different ways by influencing the presence of a variety of microbes and their functioning. They seem to increase the populations of bacteria and fungi and the intermediate products of metabolism in soil. Bray and Natalie studied that in the presence of rhizosphere there is an increase in invertebrates and the process they perform. This happens due to spreading of microbes in soil and dispersion of spores in soil by moving invertebrates. Thus, it was concluded that macroinvertebrates influence the processes of rhizosphere, such as formation of soil organic matter and fixing of nitrogen [35].

Condition of soil is very much dependent on the presence of soil macroinvertebrates. They are known as bioengineers of the soil because of their ability to transfer soil particles from one place to another, to make space for tiny organisms for the breakdown plant organic waste. They also control the availability of resources. Macroinvertebrates can also change the composition of soil microorganisms by mixing of soil, dispersion of microorganisms and grazing in soil. In this way they do not change the composition of nutrients and microorganisms in soil, but they also change the physical structure of soil. Soil contains soil aggregates thatdecelerate the decomposition process, control nutrient cycling and water flow in soil. These soil aggregates are formed with the help of invertebrates [36].

The study on earthworms in soil shows that they have a significant role in plant growth. Brown and Edwards mentioned different ways in which earthworms effect growth of plants in their research. There are some beneficial microbes present in soil. Earthworms help in their dispersal across the soil and also control their population. Similarly, earthworms play role in varying the population of pests and pathogens in plant soil. They also influence plant growth by amazingly playing a role in production of growth stimulating and growth regulating substances. These PGRs come from microorganisms present in the gut of earthworms. PGRs may include auxins, gibberellins, cytokinins, ethylene and abscisic acid. Moreover, they interact with plant seeds, eat parts of plant and alter soil composition and structure [37].

Students at Georgia College did a research on the role of salinity affecting the population of macroinvertebrates. They conducted their study at Sapelo Island. Soil of island contains large amounts of salt. Island supports huge population of macroinvertebrates because the tidal water carries with it a lot of organisms. The specie they studied was crayfish. Their aim was to study different factors related to soil and water quality in comparison with diversity of macroinvertebrates. For this purpose, macroinvertebrates were collected using nets. Different soil and water parameters were measured like temperature, pH etc. using multi-parameter instrument. Nitrate specific probe was used to measure its concentrations. Data showed that salinity and nitrate concentration influenced the presence of invertebrates. The areas that had low levels of salinity and nitrate concentration contained more populations of macroinvertebrates. Crayfish was mostly present in areas with low salinity. However, with global warming, sea levels are rising resulting in the flooding on island, which might cause high salinity levels in near future and will result in crayfish losing its habitat [38].

Heavy metals are toxic and non-biodegradable. They can easily be accumulated in water bodies, sediments and in bodies of fauna and flora living in the sediments. Heavy metals are released from industries into water mostly and it has become a global issue. To study the relationship between invertebrates and heavy metals and to calculate the amounts of heavy metals, researchers took 54 samples from soil with varying thickness from Weihe River Basin. Different techniques such as ecological potential risk index, pollution load index and geo accumulation index were used to calculate the risk to environment from these heavy metals. They also analyzed the habitat of macroinvertebrates and mathematically designed for them quality surrounding place with the help of above-mentioned indices. The pollution was more in deeper layer of soil which means more heavy metals were accumulated there. As for amounts of metals; cadmium, nickel and lead were much more abundant than copper and zinc. In the upper examined layer of soil, snails and slugs and biotic index were used as indicators, while in deeper layer earthworms were the bio indicators. Heavy metals especially cadmium can cause unpleasant effects on macroinvertebrate community [39].

When we talk about aquatic ecosystems, they are the ones most affected with heavy metal pollution. The most common pollutants are trace elements. Many researchers detected the presence of these trace elements in organisms living in the aquatic environment. These researchers analyzed the macrobenthic invertebrates from different water bodies in Italy. They wanted to measure the effect of these elements on macroinvertebrates. Two sites were named as “Moderate” and their percentage of metals was very high. The family of dragonflies and beetles were in positive correlation with beryllium, chromium, nickel and manganese, while the family of caddisflies was in positive correlation with copper. Mayfly was in positive correlation with beryllium, iron, manganese, lead and antimony showing that ingestion of sediments is the most common reason of uptake of these metals. Detecting the amounts of metals in freshwater invertebrates is an effective way of checking the status of water bodies. Study also suggested that predator invertebrates have greater accumulation of metals in their body [40].

A research conducted by Wandscheer AC et al., in which the point of assessment was to demonstrate the diversity and thickness of oceanic macroinvertebrates after understanding the effects of fungicides and bug sprays on the paddy rice fields. During 2012 to 2014, field experiments were carried out, which contained a single application of the fungicides and the insecticides in 10 m^2experimental plots, over rice plants in the R_3 stage. Control natural environment was created for the experiment. Soil samples were collected during the cultivation of rice for the evaluation of the macroinvertebrates present there. Physical and chemical limitations measured in the experiments were temperature, pH and oxygen dissolved in the water and pesticide presence in the water and soil. Applying a solitary measurement of the pesticides and fungicides in the defined time did not cause negative impacts over the productivity and thickness of the macroinvertebrates. Some fungicides lasted for a long time in the irrigation water of rice paddy fields. Thus, the amount and number of applications of the products in crops should be decided wisely [41].

Esenowo IK et al., observed the diversity of macroinvertebrates in the soil of Idoro and the impact of organic waste on it. Soil samples were extracted from the top layer of random locations using different tools. Macroinvertebrates were then collected and analyzed. 249 soil macroinvertebrates were identified in which thirteen invertebrate taxa belonging to nine orders from six classes and three phyla were found. In the waste sites, about 100 invertebrates were encountered, while more than 130 were discovered in the cultivated land. The abundance in percentage of the recorded taxa was (millipede--54.1%), respectively. Habitats with different diversity and richness of species were studied and it turned valuable for finding land patterns of land usage which have greatly impacted the soil microorganisms [42].

In another research conducted by Korobushkin DI et al., in 2017, the influence of forest fires on macrofauna's taxonomic richness, abundance, whole biomass and biomass of animals, going to different functional traits in 20 forests burnt five years ago and 20 respective controls plots in different areas was assessed. Definite abundance, biomass and ordered assortment of the dirt macro fauna showed noteworthy steadiness in the wake of fire and were definite to backwoods biome. Be that as it may, soil macro fauna was influenced by fire. Comparatively fixed taxa living in the topsoil of forest suffered most from the fire in the four-year period after burning. It was found that the damaged soil surface generates an obstacle in the way of the soil macroinvertebrates distribution due to their inability to quickly transit patches with harsh circumstances [43].

Koneru SL et al., examined in the study that insects are the most abundant group of eukaryotes and are hosts and predators of many other animal phyla; especially, the beetles are connected with a group of bacteria. There is very less research available on other insect-microbial relationships. To interpret complete patterns of the tritrophic beetle-nematode-bacteria connection, the researchers measured the nematode infestation outlines of scarab beetles in the area of Los Angeles for five years and discovered discrete nematode infestation patterns for certain beetle hosts. Critical contrasts in bacterial network structure were also discovered [44].

Bityutskii N et al., conducted their research on earthworms, considering them as one of the main groups of soil macroinvertebrates in many terrestrial ecosystems touching nutrient cycling and plant growth. Yet, it is not well known how earthworms can affect obtainability of silicon (Si) as a component whose valuable part in agricultural systems has been extensively known. The study was conducted to regulate the consequence of earthworms on the movement of Si in soil and to define whether earthworm induced effects on Si mobility are of significance for the accessibility of Si to plants. Two soils (a sandy loam soil and a sandy soil) with two stages of two independent actions ($\pm CaCO_3$ and ± earthworms) were used. Bioturbation of the dirty loam soil by existing earthworms were usually of main significance in refining xylem translocation of Si from roots to shoots in cucumber and maize [45].

The purpose of the research conducted by Tumuklu A et al., was to study the heavy metal concentration in a river that flows through the Nigde landfill. Soil samples are collected using the X-Ray Fluorescence Spectrometer. Traces of heavy metals were detected using mathematical programs in the analysis results. Geological observations were considered. According to the results of chemical analysis, mathematical systems provide significant accuracy. Heavy metals, which offer something unusual, vary throughout the river. The source of these heavy metals was identified as the dumping of Nigde garbage. For this reason, it was suggested that, in order to clean up the environment, a modern systematic storage system should be used instead of a waste storage system and recyclable products should be used in the industry [46].

Ata S et al., studied the most widely used medicinal plant i.e., garlic. Soil for garlic fields where heavy metals were applied, was collected from different cities of Punjab. It was considered important in protecting public health from the dangers of iron poisoning. This heavy metal toxicity in the garlic and soil samples was investigated using an Atomic Absorption Indicator. In the research, Pb and Cd were mainly found in the Gujranwala and Jaranwala garlic samples, Cu and Zn were found in samples collected from Kasur, while Cr was prominent in Sheikhupura's samples. The heavy metal concentration was within the given limits of World Health Organization (WHO) [47].

CHAPTER 3

METHODOLOGY

3.1 SOIL SAMPLING

Soil macroinvertebrates are found everywhere in soil environment and make up essential part of soil fauna. The study was conducted to determine the diversity and abundance of macroinvertebrates in the soils of Jallo Park and Balloki Headworks and the presence of heavy metals in the soils of study areas there. The following methodology was used for this purpose.

3.2 MATERIALS REQUIRED

Table 3.1: Materials used for Sampling and their Quantity Specification

Materials for Sampling	Quantity/ Specification
Plastic Jars	100
Ziploc Bags	100
Shopping Bags	50
Plastic Sheets	2
Preservatives (70% Ethanol, 30% Glycerin)	500ml
Forceps	4
Nets	2
Plastic Vials	100

Petri Dishes (Autoclaved)	5
Buckets	1
Atomic Absorption Spectrophotometer	210 A BUCK Scientific

3.3 SAMPLE COLLECTION

Two methods were used for the collection of samples: Sweep Net Method and Soil and Litter Extraction Method.

3.3.1 Sample Collection Methods:

In the Sweep Net Method, a net with 35 cm long handle and 38 cm wide net bag was used. The net was dried before sampling to prevent sticking of macroinvertebrates to the bottom of net bag. The net was swung in the air in order to collect macroinvertebrate samples. Whereas, in the Soil and Litter Extraction Method, samples of soil and litter were taken to observe the different kinds of macroinvertebrates present in them. The samples were then spread on a plastic sheet to observe various macroinvertebrates using magnifying glass and forceps. Later on, the samples of macroinvertebrates in sweep net, soil and litter were preserved in jars and kept for further identification [49, 50, 51, 52, 53].

3.4 SORTING SAMPLE AND IDENTIFICATION

After collection, the samples were placed in plastic jars and vials and were preserved in a 100% solution of ethanol and glycerin (composition: 70% ethanol and 30% glycerin). After that they were transported to Kinnaird College Laboratory where they were sorted, photographed and identified with the help of identification guides and keys and their diversity was noted. “Illustrated Guide to Major Groups of Soil Invertebrates” and “Invertebrate Identification Guide” by Robertson, T. Sargeant, B. and R. Urgellés were used for macroinvertebrate identification [54, 55].

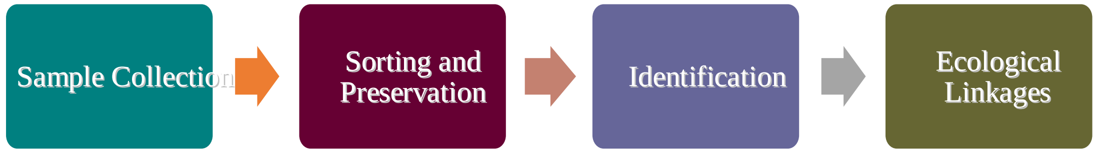


Figure 3.1: Flowsheet of Macroinvertebrates Identification

3.5 Soil Quality Analysis

Soil samples were collected from different points of Jallo Park and Balloki Headworks for heavy metal analysis. The samples were 500 g each and were collected with the help of shovels and garden trowels. They were then put in plastic bags and labeled. Larger particles of soil were grounded with mortar and pestle in laboratory after air drying the soil in order to use them further for heavy metal analysis [56].

3.5.1 Digestion of Soil Samples

In order to digest, soil samples collected from the study areas, the beakers and flasks were first autoclaved. 1g finely ground samples of soil were measured using a digital weighing machine. The weighed soil samples were transferred into separate beakers and 10 ml of concentrated HNO_3 was added in each beaker. The beakers were then covered, and the sample was allowed to stay overnight. After 24 hours, the samples were heated on a hot plate by adjusting the temperatures from 150°C to 250°C. They were then half dried and filtered using Whatman No. 42 filter paper. After that, the filtrates were transferred to 50 ml volumetric flasks and distilled water was added up to the mark. The solutions were then transferred to vials after washing the vials with distilled water [57].

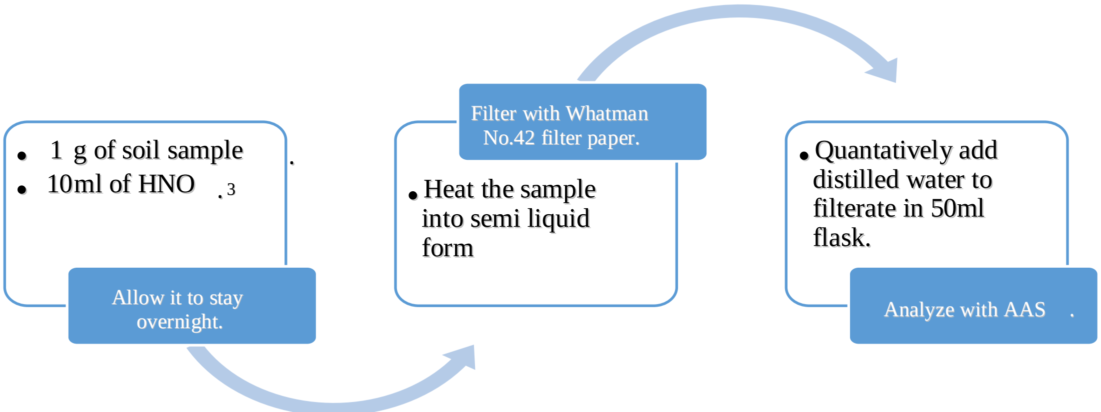


Figure 3.2: Flow Chart Demonstration of Soil Digestion Method

3.5.2 Heavy Metal Analysis

Concentration of heavy metals in soil samples were analyzed using Atomic Absorption Spectrophotometer. The before mentioned prepared solutions were used in AAS to analyze the concentration of Chromium, Cadmium, Cobalt, Copper, Nickel and Manganese. Standard stock solutions (1000, 500, 5, 4, 3, 2 and 1ppm) of the metal salts were prepared. These standard solutions were filtered and then stored in labeled vials. The samples were atomized using flame and cathode lamps. The atoms of metals were excited and particular emission spectrums for each metal were produced at various wavelengths. The concentration of heavy metals in samples of Jallo Park and Head Balloki were measured by making graphs and comparing the values obtained by AAS [58].

Table 3.2: Wavelengths of Heavy Metals

Metals	Wavelengths
Chromium	357.9
Nickel	232.0
Copper	324.8

Cadmium	228.8
Cobalt	240.7
Manganese	279.5

3.6: Data Analysis

Data was presented with the aid of graphs and charts, made via Microsoft Excel and were subjected to analysis in order to evaluate the quality of the soil in the study areas.

CHAPTER 4

RESULTS AND DISCUSSION

Samples of soil macroinvertebrates were collected from Jallo Park and Balloki Headworks and the following results were obtained from the sampling areas:

Table 4.1: Identified Species from Collected Samples

Study Areas	**Jallo Park**	**Balloki Headworks**
Black Garden Ant	✓	✓
Spotted Orb Spider	✓	-
Sun Spider	✓	-
Mealy Bug	✓	-
Centipede	✓	-
Burying Beetle	✓	-
Laurel Bug	✓	-
Bont Leg Tick	✓	-
Bluebottle Fly	✓	-
Blister Beetle	✓	-
Snowbug	✓	-
Spitting Spider	✓	-
MariposaYellow Butterfly	✓	-

Monarch Butterfly	✓	✓
Dragonfly	✓	-
Meadow Grasshopper	✓	✓
House Cricket	✓	-
Eyed Brown Butterfly	✓	✓
Ground Beetle	✓	-
Banded Apollo	✓	-
Peak White Butterfly	✓	-
Paper Wasp	✓	-
Clover Looper Moth	✓	-
Drab Looper Moth	✓	-
Hawk Moth	✓	-
Earwig	✓	✓
Housefly	-	✓
Indian Painted Grasshopper	-	✓
Golden Ringed Dragonfly	-	✓
Globe Skimmer Dragonfly	-	✓
Yellow Paper Wasp	-	✓
Field Crickets	-	✓
Tea Mosquito Bug	-	✓
Western Golden Dartlet	-	✓

(Damselfly)		

4.1: Species Collected from Jallo Park Lahore

The following species of soil macroinvertebrates were collected from Jallo Park, Lahore.

Table 4.2: Macroinvertebrate Species found in Jallo Park

Species Name	**Scientific Name**	**Type**	**No. of Species**	**Food Habitat**	**Ecological Linkages**
Black Garden Ant	Lasius niger	Highly tolerant	6	Prey on other ants and small Invertebrates.Also eat seeds and nectar.	Prey on insects and their eggs. Food source for many invertebrates.
Spotted Orb Spider	Neoscona theisi	Pollution indicator	1	They prey on flying insects.	The flying insects trap in their webs and become their prey. Birds prey on these spiders.
Sunspider	Solifugae	Pollution indicator	1	They are carnivores and prey on small	They are nocturnal and prey upon Lizards and

				invertebrates.	insects. They are solitary and are prey of birds and reptiles.
Mealy Bug	Pseudococcidae	Pollution Sensitive	1	Feed on plant matter. They have digestive enzymes in their saliva that is released on plant matter	They feed on plant sap and lay eggs on the leaves. Their predators include birds and reptiles.
Centipede	Chilopoda	Pollution sensitive Freeze sensitive	2	They feed upon insects like worms and snails.	They live mostly in gardens and under tree logs. Prey on other insects present there.
Burrying Beettle	Nictophirus	Pollution sensative	1	They prey upon dead insects mostly. Their predators are crows, foxes and raccoons.	They are scavenger species. They compete with foxes, raccoons and other

					scavengers for dead food. [63]
Laurel Bug	Lopidea major	Pollution sensitive	1	They feed on new grown, blooms and seed pots. Also feed on tree foliage.	They feed on plant sap and lay eggs on the leaves. Their predators include birds and reptiles.
Bont leg Tick	Hyalomma anatolicum	Pollution Tolerant	1	They feed on low scrubs and leaf litter but also on the blood of mammals, reptiles and birds. Ants, beetles and spiders are major predators.	As they feed on blood they cause diseases in animals and humans.
Bluebottle Fly	Calliphora vomitoria	Pollution tolerant	1	They feed on the plant nectar. Larvae feed on the dead matter. Their predators	The larva grows in human and animal remains and

				are chickens, frogs, beetles and spiders.	is known as forensic insect. The adults help in pollination [64].
Blister Beetle	Meloidae	Pollution tolerant	1	They feed on plant nectar, leaves, and flower. They prey on eggs and grasshoppers	They release a defensive agent. They are aposemetically colored.
Snowbug	Oniscidea	Pollution Tolerant	4	They feed on organic matter	They are food source for aquatic predators. i.e: Beetles
Spitting Spider	Scytodes thoracica	Pollution indicators	1	They primarily feed on insects rather than harmful garden plants.	They help control insect population and source of food for many insects.
Meriposa Yellow Butterfly	Colias croceus	Pollution sensitive	1	They primarily feed on flower nector.	Indicators for many other

					invertebrates. They help in pollination, and natural pest control.
Monarch Butterfly	Danausplexippus	Pollution sensitive	1	Larvae feed on milkweed and adults feed on Flower nector.	Indicators for many other invertebrates. They help in pollination, and natural pest control.
Dragonfly	Anisoptera	Pollution tolerant	3	They eat other butterflies, moth, flies, bees, mosquitoes and midges.	They help humans to reduce pesticides by eating insects and mosquitoes.
Meadow Grasshopper	Chorthippus parallelus	Pollution sensative	2	They feed on grass and sedges and edge of leaves.	They help in nutrient cycling. They are prey for many insects and also consume

					grassland and vegetations.
House Cricket	Acheta domesticus	Pollution tolerant	4	They feed on insects both live and dead and also feed on plants.	They help to break down decaying matter and return it to soil.
Eyed Brown Butterfly	Satyrodes eurydice	Pollution sensitive	1	They feed on sap, flower nector and birds droppings.	Indicators for many other invertebrates. They help in pollination, and natural pest control.
Ground beetle	Carabidae	Pollution indicator	2	They feed on ants, aphids, caterpillars, moth, maggots, slugs and on worms.	They are biological control agents of pests. They help in management of insect pest and weed seed banks.
Banded	Parnassius	Pollution	1	They feed on	Indicators for

Apollo	delphius	sensitive		decaying sumac leaves and on fallen leaves.	many other invertebrates . They help in pollination, and natural pest control.
Peak White Butterfly	Pontia callidice	Pollution sensitive	1	Feed on green, red cabbage and also on flower nector.	Indicators for many other invertebrates . They help in pollination, and natural pest control.
Paper Wasp	Polistes chinensis	Pollution sensitivity	1	They feed other insects, nector, flies, and caterpillars.	Help in pest control, pollination and also known as garden pests.
Clover Looper Moth	Caenurgina crassiuscula	Pollution indicator	1	They consume leaves.	Help in pollination and seed production. Food source for many

					insects and birds.
Drab Looper Moth	Minoa murinata	Pollution indicator	1	They feed on thistle flowers.	Help in pollination and seed production. Food source for many insects and birds.
Hawk moth	Agrius convolvuli	Pollution indicator	1	They extensively feed on damaged turf and also on grass leaves.	Help in pollination and seed production. Food source for many insects and birds.
Earwig	Dermaptera	Pollution tolerant	1	They eat plants and pollens.	They are known as sanitary engineers and help clear decaying mater.

4.1.1: Statistics of Species from Jallo Park Lahore

Table 4.3: Total number of Macroinvertebrate Species Found at Jallo Park

Species	No. of Species Found
Black Garden Ant	6
Spotted Orb Spider	1
Sun Spider	1
Mealy Bug	1
Burying Beetle	1
Laurel Bug	2
Centipede	2
Bont leg Tick	1
Blister Beetle	1
Bluebottle fly	1
Spitting Spider	1
Snow Bug	4
Mariposa Yellow Butterfly	1
Monarch Butterfly	1
Dragonfly	3
Meadow Grasshopper	2
House cricket	4
Eyed Brown Butterfly	1
Ground Beetle	2
Banded Apollo	1
Peak White Butterfly	1
Paper Wasp	1
Clover Looper Moth	1

Drab Looper Moth	1
Hawk Moth	1
Earwig	1

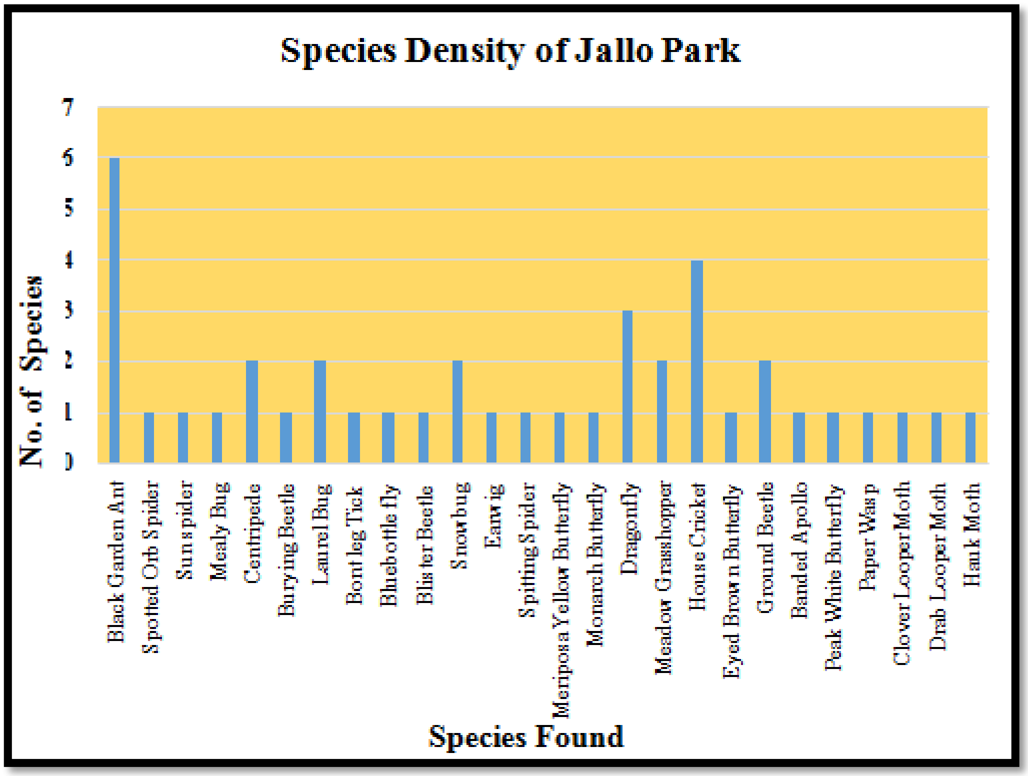


Figure 4.1: Specie Density of Jallo Park

4.1.2: Role of Macroinvertebrates in Food Web

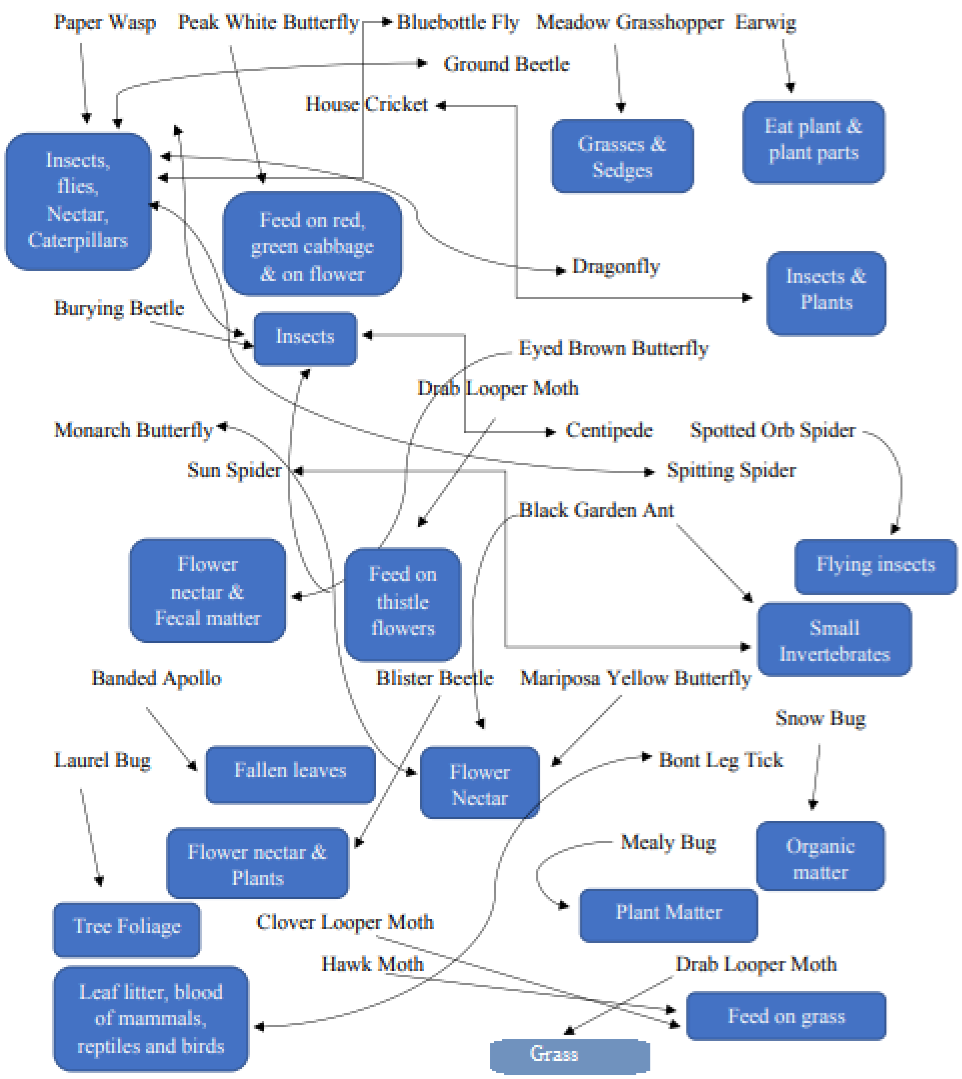


Figure 4.2: Food Web of Macroinvertebrates found from Jallo Park

4.1.3: Simpson's Index Calculation

Table 4.4: Calculations of Simpson's Index for Jallo Park Species

Species	Number(n)	n(n-1)
Black Garden Ant	6	30
Sun Spider	1	0

Centipede	2	2
Burying Beetle	1	0
Hawk Moth	1	0
Bluebottle Fly	1	0
Blister Beetle	1	0
Mealy Bug	1	0
Snow Bug	4	12
Banded Apollo	1	0
Spitting Spider	1	0
Earwig	1	0
Bont leg Tick	1	0
Laurel Bug	2	2
Spotted Orb Spider	1	0
Mariposa Yellow Butterfly	1	0
Monarch Butterfly	1	0
Dragonfly	3	6
Meadow Grasshopper	2	2
House Cricket	4	12
Eyed Brown Butterfly	1	0
Ground Beetle	2	2
Peak White Butterfly	1	0
Clover Looper Moth	1	0
Drab Looper Moth	1	0
Paper Wasp	1	0
Total	43	68

D_s= 1- [$\sum n_i$ (n_i-1)/N (N-1)]

= 1- [68/43(43-1)]

$= 1- [68/43(42)]$

$= 1- [68/1806]$

$= 1-0.03765$

$D_s = 0.96235$

4.2: Species Collected from Balloki Headworks

Table 4.5: Macroinvertebrate species found in Balloki Headworks

Specie Name	Scientific Name	Type	No. of Species Found	Food Habitat	Ecological Linkages
Meadow Grasshopper	Chorthippus parallelus	Pollution sensitive	2	Feeds only on grasses and sedges.	Feeds on valuable forage grasses, contributes to the damage caused by a heavy infestation.
Housefly	Musca domestica	Pollution sensitive	1	They eat everything from food to animal and human fecal matter.	Demolishing and regenerating living organisms. They also eat sugary foods, rotten fruits and vegetables.

Indian Painted Grasshopper	Poekiloceru s pictus	Pollution sensitive	1	The grasshopper feeds on the toxic plants.	The adults are capable of good flight. It causes considerable damage by feeding on young plants [58].
Eyed Brown Butterfly	Satyrodes eurydice	Pollution sensitive	1	Larvae feed on leaves, adults feed on feces and flower nectar.	Source of food for predators such as birds, spiders, lizards and other animals.
Monarch Butterfly	Danausplexi ppus	Pollution sensitive	1	They eat the nectar of their flowers, but they breed only where milk is available.	An important part of the food chain as predators and animals. Some species provide a natural form of insect control.
Golden	Cordulegast erboltonii	Pollution sensitive	1	They feed mainly on	It allows humans to

Ringed Dragonfly				insects such as midges to flies, butterflies and even bumblebees.	decrease the use of insecticides to kill these insects.
Globe Skimmer Dragonfly	Pantalaflavescens	Pollution sensitive	1	They feed on small midges and mosquitoes to butterflies, moths, damselflies and smaller dragonflies.	These dragonflies are used as convenient food source and requires fresh water to reproduce [60].
Yellow Paper Wasp	Polistes versicolor	Pollution sensitive	1	They eat caterpillars and other insects [61].	Besides eating butterfly larvae, beetle larvae and other insects, they can eat nectar.
Field Crickets	Grylloidea	Pollution sensitive	3	They eat dried organic matter, fresh plant material, small fruits, seeds, living and dead insects [62].	Greatly accelerates flow of energy and nutrients into the ecosystem.

Tea Mosquito Bug	Camellia sinensis L.	Pollution tolerant	1	They feed on developing apples and nuts, and cause brown sunken spots on them.	Major sucking pest of tea plant.
Earwig	Dermaptera	Pollution tolerant	3	Earwigs feed on decaying vegetation, such as leaves and other decaying plants	It can damage the vegetation of the plants or flowers and often severely damage the growth of soft fruits or silk.
Black Garden Ant	Formicidae	Pollution tolerant [64]	2	Ants are omnivorous and eat seeds, nectar and other invertebrates.	Ants eat a variety of living things and provide food for many different things
Western Golden Dartlet	Ischnurarubi lio	Pollution tolerant	1	They eat flies, mosquitoes, and other small insects	This species occupies a variety of stagnant and

(Damselfly)					slowly flowing water bodies.

4.2.1: Statistics of Species from Balloki Headworks

Table 4.6: Total Number of Macroinvertebrate Species Found at Balloki Headworks

Species	No. of Species
Meadow Grasshopper	2
Housefly	1
Indian Painted Grasshopper	1
Eyed Brown Butterfly	1
Monarch Butterfly	1
Golden Ring Dragonfly	1
Globe Skimmer Dragonfly	1
Yellow Paper Wasp	1
Field Cricket	3
Western Golden Dartlet	1
Tea Mosquito Bug	1
Earwig	3
Black Garden Ant	2

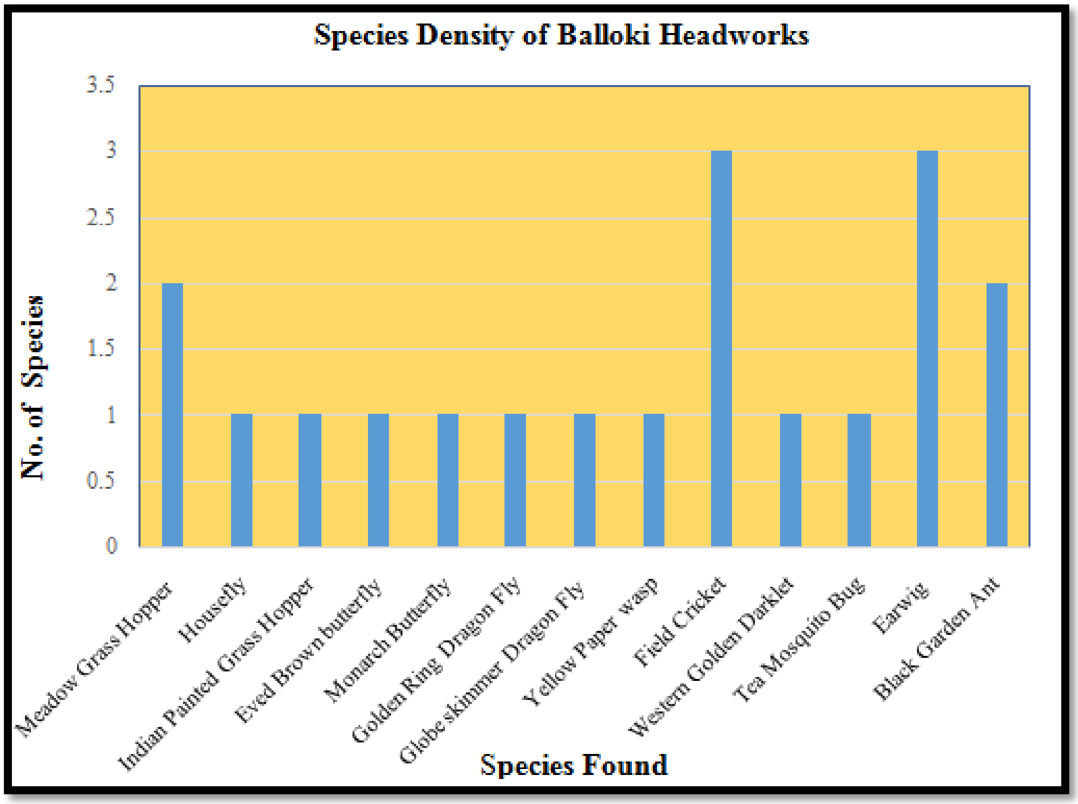


Figure 4.3: Specie Density of Balloki Headworks

4.22 Role of Macroinvertebrates in Food Web

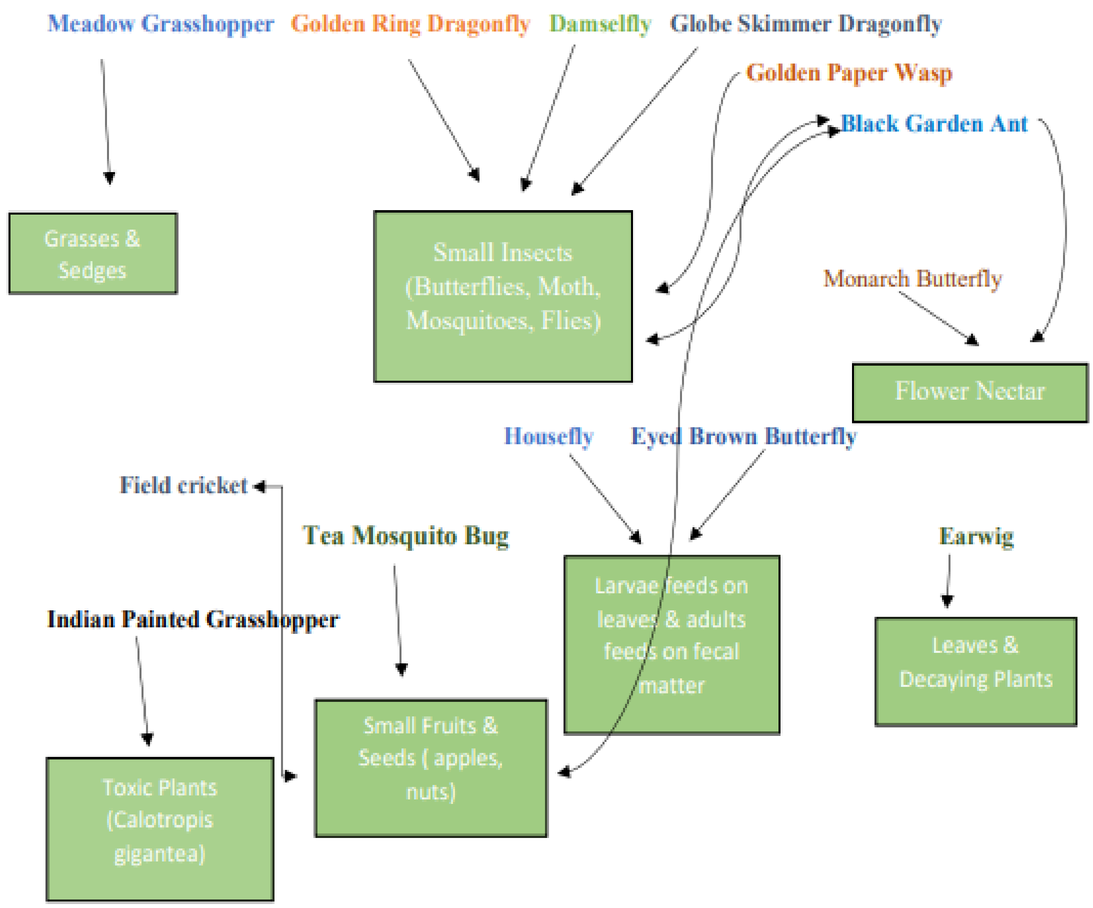


Figure 4.4: Food Web of Macroinvertebrates from the Balloki Headworks

4.2.3: Simpson's Index Calculation

Table 4.7: Calculations of Simpson's Index for Balloki Species

Species	Number (n)	n(n-1)
Meadow Grasshopper	2	2
Housefly	1	0
Indian Painted Grasshopper	1	0

Eyed Brown Butterfly	1	0
Monarch Butterfly	1	0
Golden Ring Dragonfly	1	0
Globe Skimmer Dragonfly	1	0
Yellow Paper Wasp	1	0
Field Cricket	3	6
Tea Mosquito Bug	1	0
Earwig	3	6
Black Garden Ant	2	2
Western Golden Dartlet	1	0
Total	19	16

D_s= 1- [$\sum n_i$ (n-1)/N (N-1)]

= 1- 16/19(19-1)]

= 1- [16/19(18)]

=1- [16/342]

= 1-0.0467

D_s= 0.9533

Through Simpson's index formula i.e., **D_s = 1- [$\sum n_i$ (n-1)/N (N-1)]**, the community diversity of Jallo Park and Balloki Headwork was measured. The range for Simpson's Index is 0-1, where scores close to 1 indicate high diversity and scores close to 0 indicate low diversity. Tables shown above suggest that Simpson's Diversity Index in Jallo Park is 0.96, whereas it is 0.95 in Balloki Headworks. The results show that Jallo Park shows more species diversity in comparison to Balloki Headworks.

The study was conducted to investigate the macroinvertebrate diversity and their ecological linkage in two areas of Punjab namely, Balloki Headworks and Jallo Park. The area overall was rich in diversity due to variety of fauna and flora. 15 species were collected from point 1 and 11 were collected from point 2. The area was covered by plants and soil which act as habitat for many macroinvertebrates. Many birds can be seen at the selected area which are predators of macroinvertebrates found. The graph above confirms the variety of macroinvertebrates found at Jallo Park. The second sampling area was Balloki Headworks. The samples were collected from wet soil near the shore and also from the dry land. Very few macroinvertebrates were found in the wet soil, but many were found in the dry soil. The results show species found at Balloki Headworks were more tolerant to the pollution due to excessive agricultural stress and dry season [64].

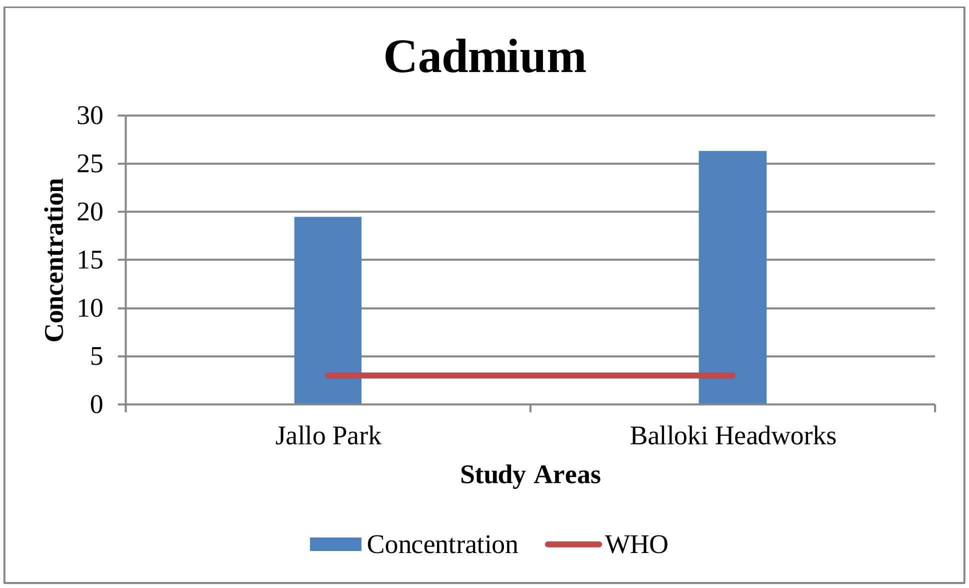
Table 4.8: International Standards of Heavy Metals Concentration in Soil by WHO

Heavy Metals	**Permissible Limit of WHO in soil [ppm]**
Cadmium	0.8ppm
Chromium	100ppm
Nickel	35ppm
Cobalt	0.05ppm
Copper	36ppm
Manganese	12ppm

4.3.1: Cadmium Concentrations

Table 4.9: Concentration of Cadmium in Soil Samples

Study Area	Concentration of cadmium
Jallo Park	19.59 ppm
Balloki Headworks	26.39 ppm



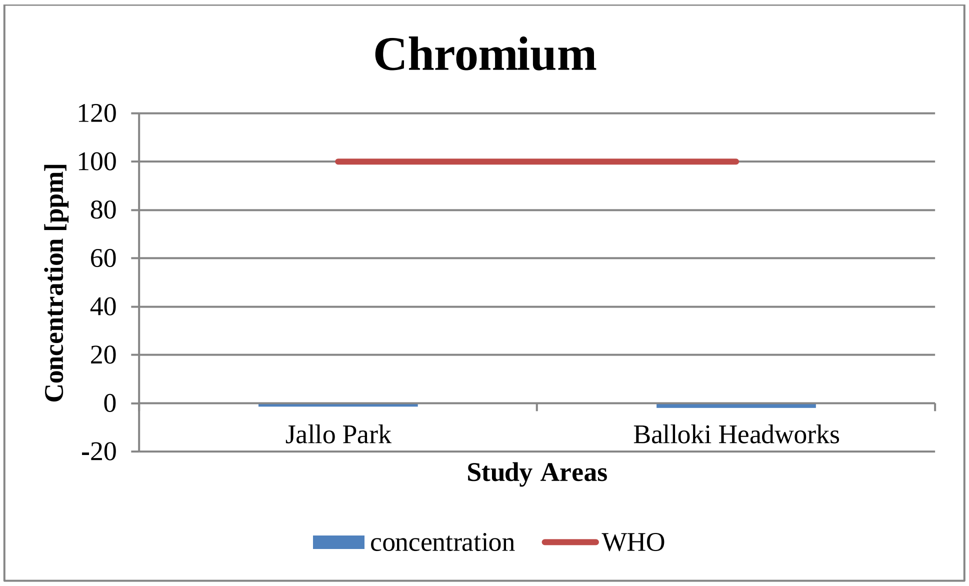
Graph 4.1: Concentration of Cadmium in Soil Samples

The graph shows that the concentration of Cadmium in soil samples of Jallo Park and Balloki Headworks is 19.59 and 26.39 respectively. Concentration of cadmium in both areas exceeds the permissible limit of WHO which is 0.8 ppm. This may be due to excessive use of phosphate fertilizers in these areas over prolonged periods of time. The other reason can be application of sewage or industrial waste [66, 67].

4.3.2: Chromium Concentrations

Table 4.10: Concentration of Chromium in Soil Samples

Study Area	Concentration of chromium
Jallo Park	0
Balloki Headworks	0



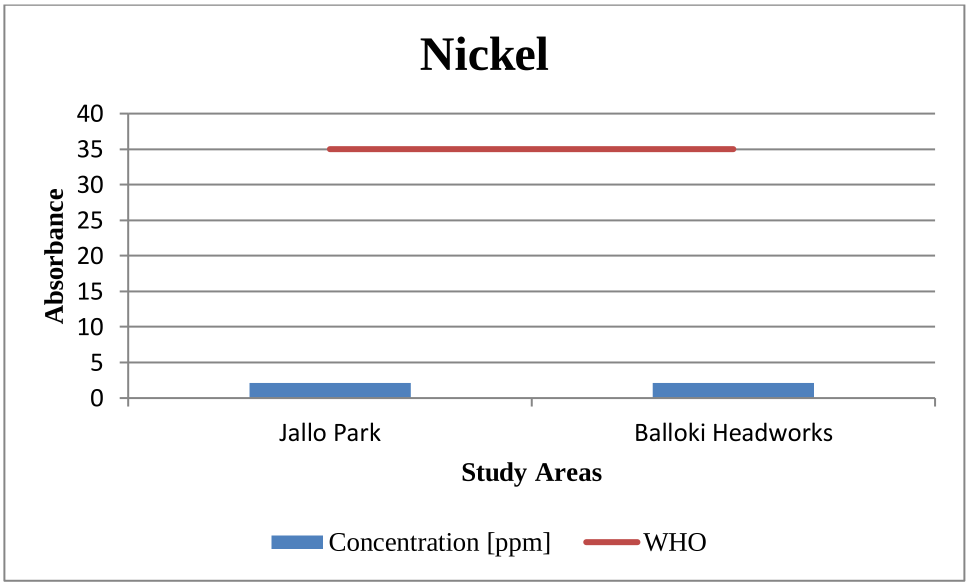
Graph 4.2: Concentration of Chromium in Soil Samples

The graph shows that the concentration of Chromium in soil samples of Jallo Park and Balloki Headworks is zero respectively. This negligible value is below the permissible limit value of WHO which is 100 ppm. Chromium becomes part of soil by disposal of Chromium containing commercial products and by coal ash [67].

4.3.3: Nickel Concentrations

Table 4.11: Concentration of Nickel in Soil Samples

Study Area	**Concentration of nickel**
Jallo Park	2.10 ppm
Balloki Headworks	2.13 ppm



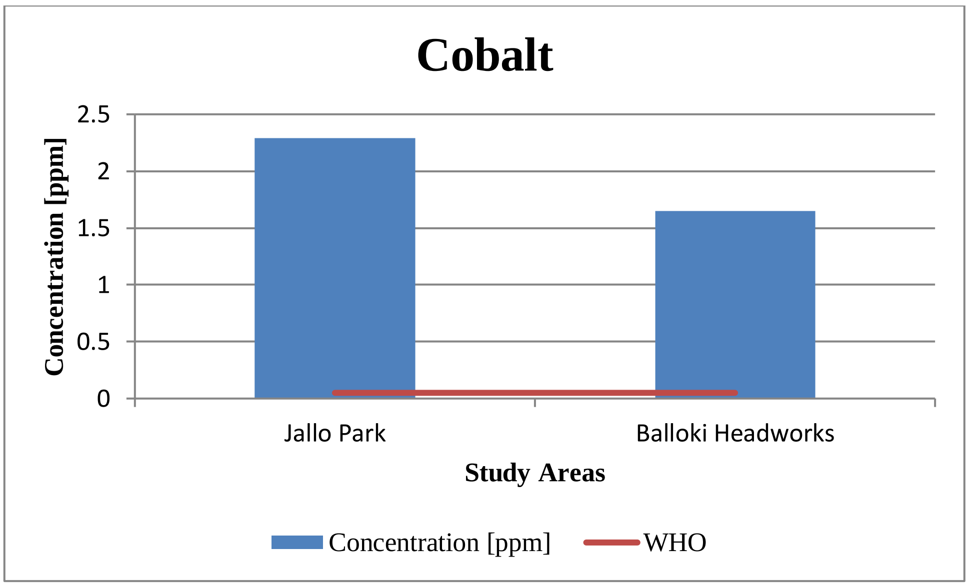
Graph 4.3: Concentration of Nickel in Soil Samples

The graph shows that the concentration of Nickel in soil samples of Jallo Park and Balloki Headworks is very low and hence less than permissible limits of WHO which is 35 ppm. Wastes disposed from vehicle and metal plating industry is a source of nickel. Combustion of fossil fuels also releases Nickel in a soil [68].

4.3.4: Cobalt Concentrations

Table 4.12: Concentration of Cobalt in Soil Samples

Study Area	Concentration of cobalt
Jallo Park	2.29 ppm
Balloki Headworks	1.65 ppm



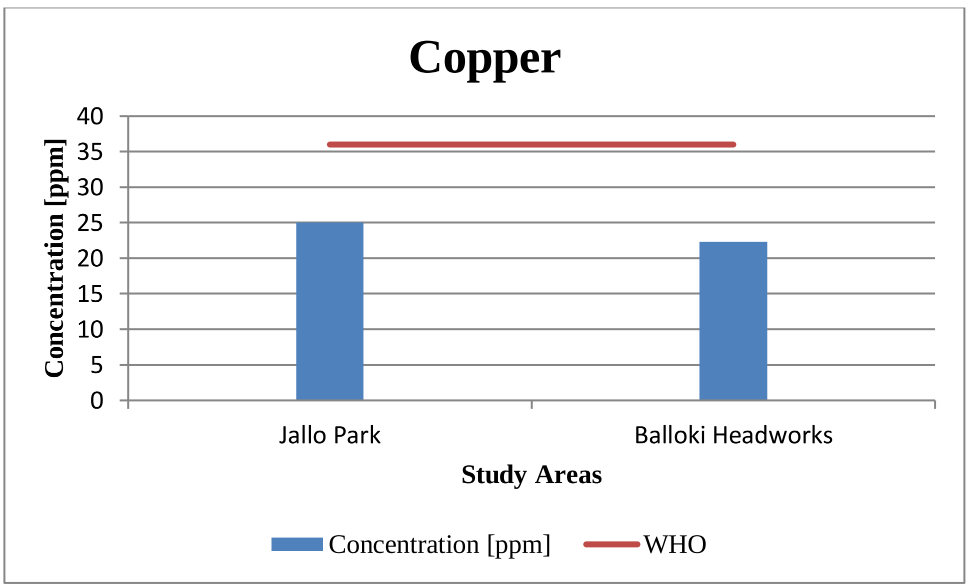
Graph 4.4: Concentration of Cobalt in Soil Samples

The graph shows that the concentration of Cobalt in soil samples of Jallo Park and Balloki Headworks is 2.29 and 1.65 respectively. The concentration is more than the permissible limits of WHO which is 0.05 ppm. It accumulates in soil by deposition of dead mater [69].

4.3.5: Copper Concentrations

Table 4.13: Concentration of Copper in Soil Samples

Study Area	Concentration of copper
Jallo Park	25 ppm
Balloki Headworks	22.3 ppm



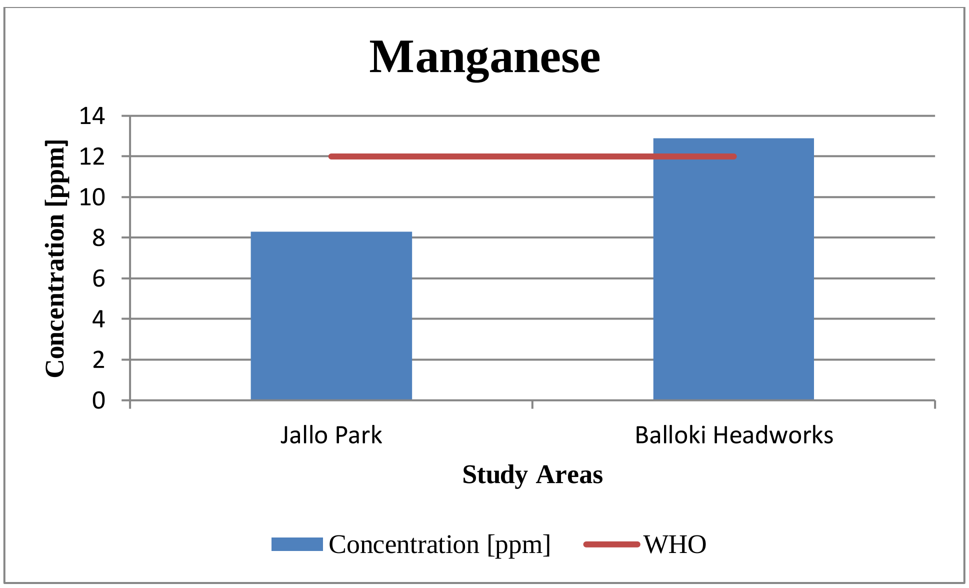
Graph 4.5: Concentration of Copper in Soil Samples

The graph shows that the concentration of copper in soil samples of Jallo Park and Balloki Headworks is 25ppm and 22.3ppm respectively which is less than the permissible limit of WHO which is 36 ppm. The main sources of copper in soil are manure, sewage, fertilizers and pesticides [12].

4.3.6: Manganese Concentrations

Table 4.14: Concentration of Manganese in Soil Samples

Study Area	**Concentration of manganese**
Jallo Park	8.3 ppm
Balloki Headworks	12.9 ppm



Graph 4.6: Concentration of Manganese in Soil Samples

The graph shows that the concentration of Manganese in soil samples of Jallo Park and Balloki Headworks is 8.3ppm and 12.9 ppm. Concentration of Manganese in Jallo Park is less than the permissible limit of WHO which is 12 ppm while in soil of Balloki Headworks it is slightly greater than permissible limit. Manganese becomes part of soil directly from atmosphere, from plant matter and from dead plant and animal material.

CONCLUSION

Soil macroinvertebrate samples were collected from Jallo Park and Balloki Headworks and were identified with the help of identification guides and keys. 26 species were of macroinvertebrates were found from Jallo Park out of which; 8 species were found to be pollution tolerant, 7 species were pollution indicators while 11 species were sensitive to pollution. Whereas, 13 species were found from Balloki Headworks in which 4 species were found to be pollution tolerant and 9 were found to be pollution sensitive. However, no indicator species was found there. Species diversity of Jallo Park and Balloki Headworks calculated using Simpson's Index was 0.96 and 0.95 respectively, which showed that Jallo Park is rich in diversity as compared to Balloki Headworks. Furthermore, soil quality of both study areas was checked using Heavy Metal Analysis and the concentration of cadmium, chromium, nickel, cobalt, copper and manganese in soil of Jallo Park came out to be 19.59, 1.32, 2.10, 2.29, 25 and 8.3 respectively. The metal concentrations in the soil of Balloki Headworks were 26.39, -2.03, 2.13, 1.65, 22.3, and 12.9. The concentrations of cadmium and cobalt in soils of both study areas were more than the permissible limit of WHO. The concentration of manganese was found to be within limits in Jallo Park but it exceeded the permissible limit of WHO in Balloki Headworks. The possible reason for the excess of these metals in Jallo Park is excessive use of sewage and manure for a long time. In Balloki Headworks it is due to excess use of fertilizers and presence of excess dead plant and animal waste in the area. Chromium, Nickel and Copper concentration was within the permissible limits specified by WHO and this is mainly due to absence of automobile and metal plating industries in the vicinity of these areas. Thus, it was deduced that the soil quality is good in both of the study areas and it should be maintained by regular monitoring, good sewage treatment practices and soil nutrient management and in case of Balloki Headworks with sensible use of fertilizers.

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ANNEXURES I

Figure No.1: Sample Collection at Jallo Park

Figure No.2: Soil Sample Collection at Lahore Jallo Park

Figure No.3: Sample collection at Lahore Jallo Park

Figure No. 4: Sample Collection at BallokiHeadworks

Figure No. 5: Soil Collection at Balloki Headwork

Figure No.6: Shield backed bug

Figure No.7: Dragonfly

Figure No. 8: Spotted Orb Spider

Figure No. 9: Meadow Grasshopper

Figure No. 10: Soil Digestion

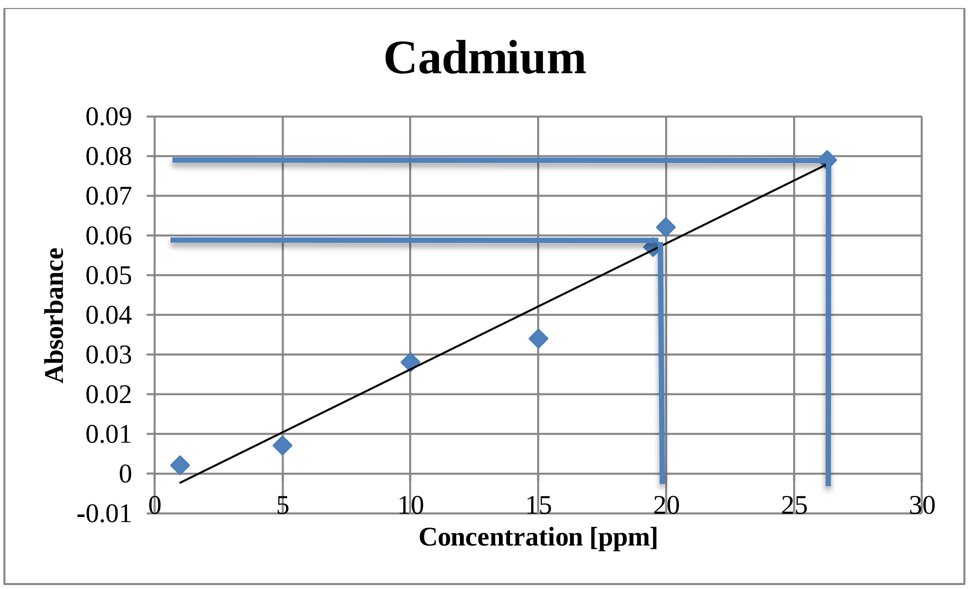
Figure No. 11: Soil Digestion

Figure No. 12: Preparation of cobalt stock solution

ANNEXURES II

Table No.1: Absorbance and Concentration of Cadmium

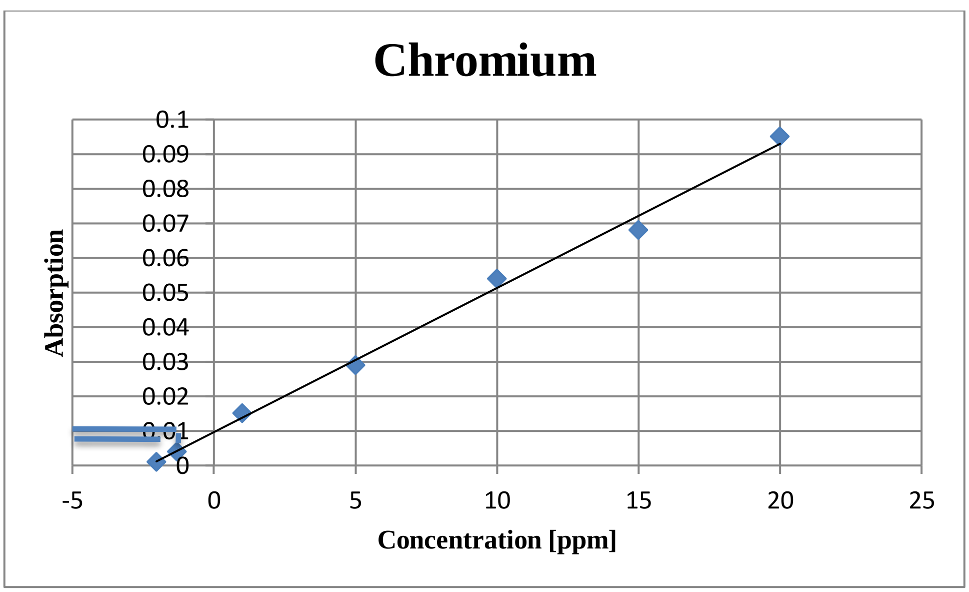
Absorbance(Au)	**Concentration [ppm]**
0.002	1
0.007	5
0.028	10
0.034	15
0.062	20



Graph No.1: Standard Concentration Graph of Cadmium

Table No.2: Absorbance and Concentration of Chromium

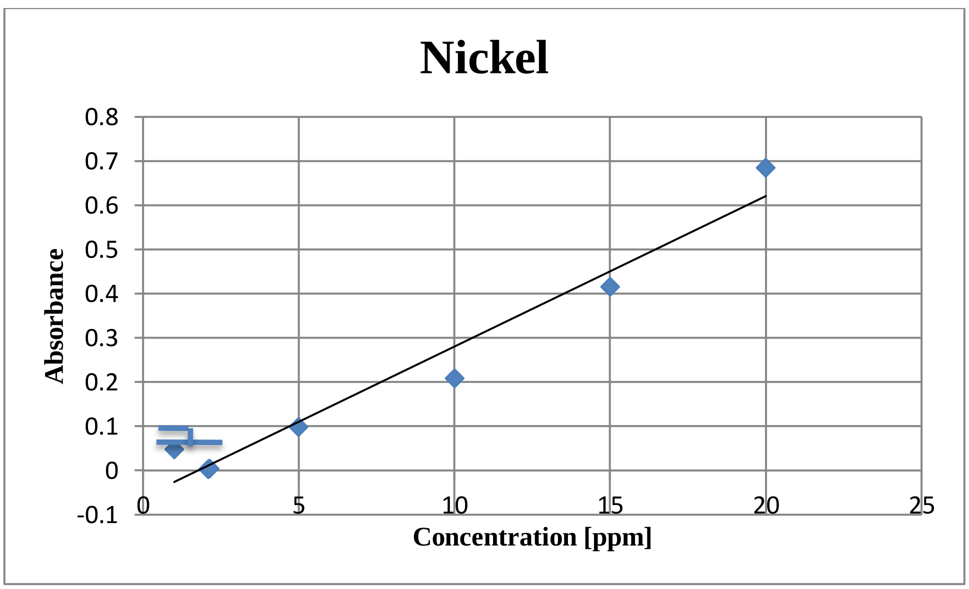
Absorbance (Au)	Concentration [ppm]
0.015	1
0.029	5
0.054	10
0.068	15
0.095	20



Graph1.2: Standard Concentration Graph of Chromium

Table No.3: Absorbance and Concentration of Nickel

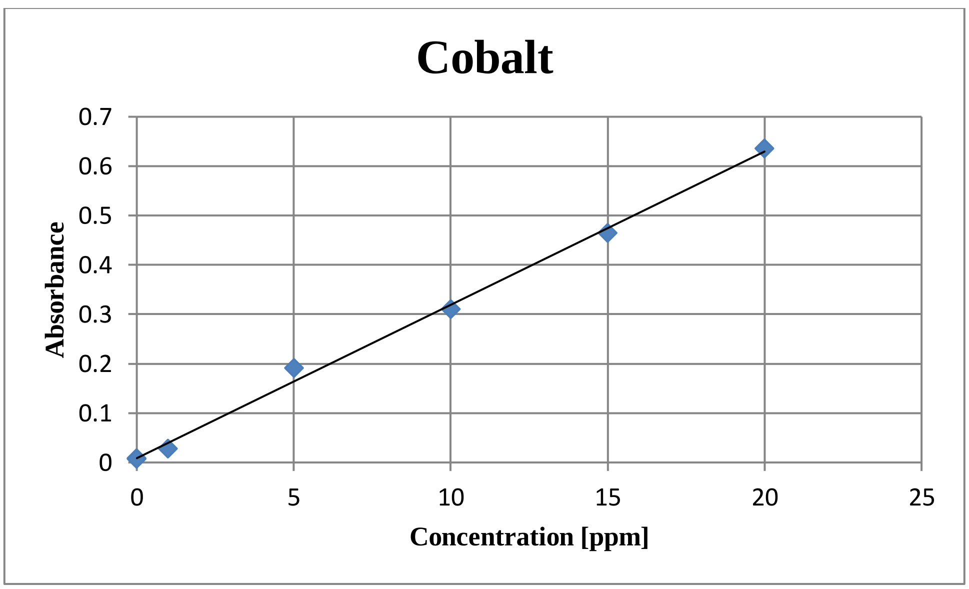
Absorbance (Au)	**Concentration [ppm]**
0.047	1
0.098	5
0.208	10
0.415	15
0.685	20



Graph No.3: Standard Concentration Graph of Nickel

Table No.4: Absorbance and Concentration of Cobalt

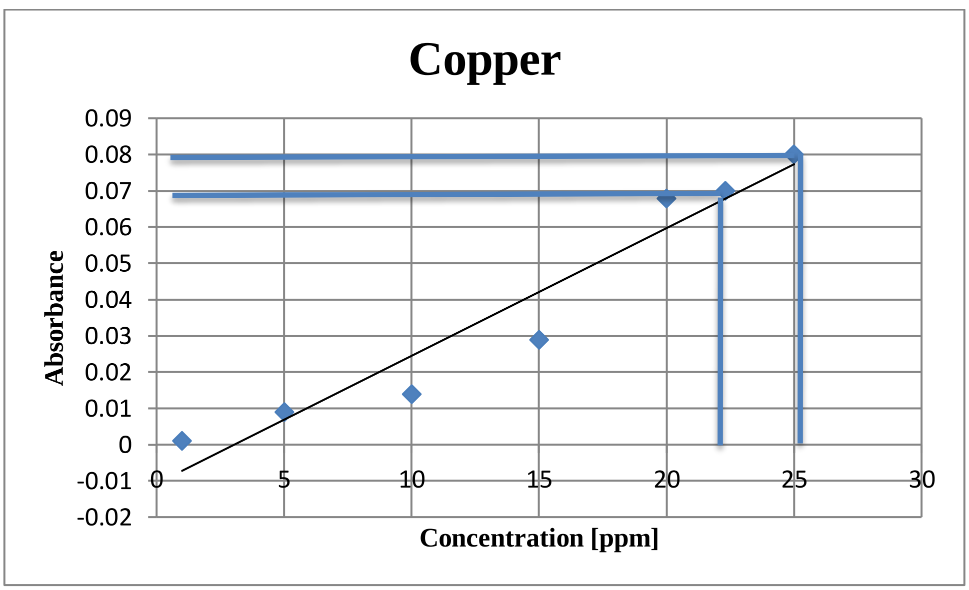
Absorbance (Au)	**Concentration [ppm]**
0.028	1
0.191	5
0.310	10
0.465	15
0.635	20



Graph No.4: Standard Concentration Graph of Cobalt

Table No.5: Absorbance and Concentration of Copper

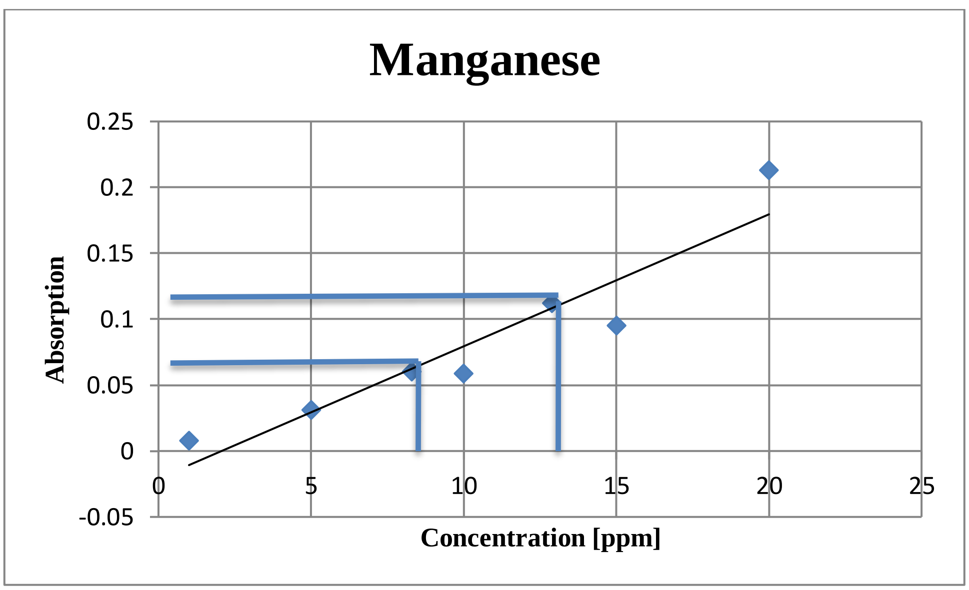
Absorbance (Au)	**Concentration [ppm]**
0.001	1
0.009	5
0.014	10
0.029	15
0.068	20



Graph No.5: Standard Concentration Graph of Copper

Table No.6: Absorbance and Concentration of Manganese

Absorbance (Au)	**Concentration [ppm]**
0.008	1
0.031	5
0.059	10
0.095	15
0.213	20



Graph No.6: Standard Concentration Graph of Manganese

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