Trends of heavy metals contamination in various micro-environments of district Peshawar

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This dissertation is submitted in candidature to the Department of Environmental Science in partial fulfillment of the requirement for the degree of Master of Philosophy.

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In the name of ALLAH, the Lord of heavens and the earth, His help we seek and ask for His forgiveness. Whoever ALLAH guides none can misguide. There is none worthy of worship but ALLAH Alone, and Salawaat for MUHAMMAD (صَلَّى اللهُ عَلَيْهِ وَسَلَّمَ) who is His servant and the seal of His Messengers.

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ABSTRACT

Understanding trends of heavy metals contamination in the dust of different micro-environments is significant for health risk assessment, urban planning in cities and pollution control. Concentrations of six heavy metals were measured by taking n=5 dust samples from twenty micro-environments and their further amalgamation forming four zones on the basis of similarity. All the samples were air-dried, ground, passed through 30 mesh sieve and digested with aqua regia and HF. The samples were analyzed in atomic absorption spectrometry for Pb, Zn, Cr, Cu, Cd and Ni. Assessment of contamination in each zone was done by various methods: Zone composition of heavy metals, Analysis of Variance, geo-accumulation index and health risk assessment for each trace metal. Geo-accumulation index was of the class 1 for all the elements of all the four zones i.e. the dust was uncontaminated to moderately contaminate. Health risk via. Ingestion to children was evaluated and found to be non-significant for most of the heavy metals. Zinc read as the highest concentration trace metal in all the four zones.

Chapter 1

Introduction

Dust is transported and is accumulated in different micro-environments having high loads of trace metals which are noxious to human health. In such micro-environments the contaminant level at a definite interval is constant and has uniform statistical properties. Twenty micro-environments i.e. Bus Terminals (BT), Rail Road (RR), Streets (ST), Heavy Traffic Roads (HT), Filling Stations (FS), Auto Workshops (AW), Carpet Industries (CI), Pharmaceutical Industries (PI), Steel Industries (SI), Electronic Shops (ES), Electrical Shops (EL), Brick Kilns (BK), Urban Homes (UB), Rural Homes (RH), Hospitals (HP), Playgrounds (PG), Agricultural Fields (AF), Schools (SCH), Scrap Facilities (SF) and Landfills (LF) were studied as significant micro-environment, to monitor the concentrations of heavy metals. These twenty micro-environments were further categorized into four zones i.e. Transport Facility (TSPF), Industrial Zone (INDZ), Residential Zone (RSDZ) and Waste Dumping Zone (WDZ) to present the findings of the study in a concise way. One micro-environment shares its boundary with numerous others micro-environments and contaminants are regularly transported in between these micro-environments, each micro-environment showing different trends of contamination which are sometimes altogether different from a micro-environment of the same stature. Contamination varies from micro-environment to micro-environment due to condition and location of the micro-environment. These contaminants are non-biodegradable, ubiquitous and stay in a micro-environment for an unknown period of time (Wu et al., 2016). Heavy metals contamination is one type of contamination in these micro-environments.

Elements having a mass density more than 4.5g/cm^3, and in a chemical reaction they have a tendency to discharge electrons and make simple cations are known as heavy metals. Heavy metals are challenging environmental contaminants with well-known deadly effects on living beings. They are good conductors of both heat and electricity and are opaque and glossy. The problem with them is that they are completely unaffected during degradation of organic waste and when passing a certain concentration they have noxious effects on living systems. Due to their contribution to the Earth’s crust, heavy metals are a part of our environment. As heavy metals are natural ingredients of the Earth’s crust, they stick in outdoor dust that has settled in indoor conveniences; both contribute to human experience to heavy metals (Hivert, Coquet, Glorennec, & Bard, 2002). The occurrences of heavy metals in dust even if they occur in traces have the ability to cause grave complications to all beings and its bio magnification in food chain specifically can pose great threat to human health (ul Islam, Yang, He, & Mahmood, 2007). Urban dust is an impending risk to humans, because of the probability of its direct and indirect contact with humans due to their insignificant particle size and its suspension in atmosphere (Xiaoyan Li, Zhang, & Yang, 2014).

Dust is a solid matter composed of natural biogenic components, soil and anthropogenic metallic ingredients (Ferreira-Baptista & De Miguel, 2005). Heavy metals in the dust particles are in the form of very fine particulates. The dispersion of these heavy metals in the atmosphere is with respect to the size and density of these heavy metals particulates. Being a substantial environmental media dust provides information about distribution pattern, fate and level of the pollutants existing in the surface environment. Due to the fact that last decades witnessed speedy urban sprawl and rapid industrialization, heavy metals were greatly intensified due to traffic exhausts, construction of building and their renovation and heating systems (Wei, Jiang, Li, & Mu, 2009). Heavy metals contained in the particulate dust emission which come from industrial waste is the motive behind environmental pollution and health risks (Jia, Huang, Al-Ansari, & Knutsson, 2011). Settled dust is often used as an indicator of atmospheric suspended particulates because the composition of both dusts are similar (Salim Akhter & Madany, 1993).

Human exposure to heavy metals has amplified exponentially epidemically because of the use of these heavy metals in several facilities. Their widespread circulation in the environment is because of their multiple applications in agricultural, industrial, medical and technological sectors which pose and cast great effects on the environment and human health. Heavy metals like copper (Cu), nickel (Ni), chromium (Cr), zinc (Zn) are also vital nutrients and they are needed for multiple physiological and biochemical roles (Tchounwou, Yedjou, Patlolla, & Sutton, 2012). The exposure to urban dust environment for long time that comprises high concentrations of trace metal would cause health complications. In dusty environment 100 mg of dust per day ingestion by adults has been calculated. The rate of exposure of children to dust is higher than adults because of their play and pica behavior (Yang, Ge, Lu, & Long, 2015). Potential health risk of heavy metals in dust micro-environment can be predicted by the exposure risk evaluation strategies (Rout, Masto, Ram, George, & Padhy, 2013). The estimation of health hazard of any heavy metal can be assessed by the level of exposure and can be quantified via routes of exposure of a contaminant to the target entity. There are a number of promising paths for such exposures (S Khan, Cao, Zheng, Huang, & Zhu, 2008). The heavy metals concentrated in dusts can be gathered in anthropoid body straight through Ingestion, inhalation and absorption through dermal contact.

Four of the studied heavy metals are termed as priority metal because of their public health significance. They have the ability to cause damage to multiple organs and are believed systemic toxicants even if the exposure level is low. They are also known to cause cancer in humans (Tchounwou et al., 2012). Lead (Pb) is found in all fragments of our environment which is set free to the environment due to mining, manufacturing and burning of fossil fuels (Martin & Griswold, 2009). Lead (Pb) toxicity is known for thousands of years. Lead (Pb) is naturally found in the environment and has been used from time immemorial. It was bio accumulated in the ecosystem with very high concentrations after its excessive practice in the industrial revolution (Yu, Tsunoda, & Tsunoda, 2011) Albeit lead (Pb) is not required in the diet still it is there in the tissues and organs of humans. Lead (Pb) is known as systemic poison. Lead (Pb) thwarts hematopoiesis, damage kidneys, cause anemia and its effects on gastrointestinal tract are nausea, and constipation linked with abdominal cramps. Asthma, pneumonia, bronchitis, joint pain, muscle aches and difficulty in breathing are connected with lead (Pb) poisoning. The growth of skeleton and immune system is also impaired because of lead (Pb) poisoning. Central nervous system (CNS) is also chiefly target by lead (Pb) (Yu et al., 2011). Smoking, airborne emissions and eating of polluted foods expose humans to cadmium (Cd) poisoning. The exposure of smokers to cadmium (Cd) is significantly higher than non-smokers (Martin & Griswold, 2009). Lung cancer, lung damage, high blood pressures are the hostile health effects related to ingestion and inhalation of cadmium (Cd). Cadmium (Cd) causes cancer in humans. Skeletal damage is also related with cadmium (Cd) poisoning. Itai-itai-byo episode in Japan was because of cadmium (Cd) poisoning(Yu et al., 2011). Nickel is widely distributed in the environment which has multiple commercial and industrial uses (Cempel & Nikel, 2006). Diseases in humans like lung Sino nasal and laryngeal carcinomas are because of the inhalation of nickel (Ni) related compounds. Other nickel (Ni) poisoning related diseases are Pneumoconiosis and emphysema. Kidney cancer is also associated with the reabsorption of Ni in the kidney. The most lethal of all nickel (Ni) compounds is $Ni(Co)_4$ gas which is responsible for the death of workers in refineries in the U.S (Yu et al., 2011). Copper is an important nutrient which is there in multiple metalloenzymes which helps in the creation of hemoglobin and in the metabolism of carbohydrates. The exposure of human to extreme copper has been related to cellular damage which causes Wilson disease (Tchounwou et al., 2012). The role of copper (Cu) is critical in infants liver damage after 2 to 3 mg/l of copper is consumed by infants in water. Some gastrointestinal effects are also associated with copper (cu) consumption. Neurological diseases in humans are directly linked to copper (Cu) toxicity (G. Georgopoulos, 2001). Zinc (Zn) is very significant trace element which is enormously bio accumulated in living systems (Cuajungco & Lees, 1997). When zinc (Zn) is compared to other heavy metal ions, we find zinc (Zn) comparatively harmless. Nausea, vomiting and abdominal pain are because of ingesting zinc (Zn) in toxic amounts. Supplementary effects of consuming zinc (Zn) in toxic amounts are dizziness, lethargy and anemia (Plum, Rink, & Haase, 2010). Zinc ingestion directly affect gastrointestinal tract before its distribution through the body. Orally taken food and drink directly from galvanized zinc containers cause gastrointestinal symptoms (Plum et al., 2010). Chromium (Cr) is found in three states, it can be a solid, a liquid or in gas phase which is found in soils, plants, rocks and animals. Chromium (Cr) is used in magnetic tapes, metal alloys, metal coatings, cement, rubber and paper (Martin & Griswold, 2009). The uptake of toxic amounts of chromium VI (Cr VI) causes acute glomerular and tubular damage. Kidney damage has been known due to the exposure of chromium (Cr) in lower toxic amounts. Toxic ulceration of the skin is among other effects of chromium (Cr) exposure. Chromium (Cr) being a carcinogenic agent causes cancer of the respiratory tract in the workers of chrome pigment industries who are exposed to chromium (Cr) toxicity (Goyer & Clarkson, 1996).

Peshawar which is a provincial capital city of the province Khyber Pakhtunkhwa (K.P) is an important city with an area of about 77 Km^2 and with a population of more than one million (Jan et al., 2010). The micro-environments of Peshawar city were never studied in such a detail; only a few studies have been conducted keeping hardly two to three micro-environments in focus. Recently the world health organization (W.H.O) conducted a survey and issued a report in which the city of Peshawar was ranked the second most polluted city in the world (Kanwal, 2016). Peshawar city is that polluted that Particulate matter ($PM_{2.5}$) has surpassed the National Environmental quality Standards (NEQs) which enhances the risk of age specific mortality. The

PM 2.5 in the air of Peshawar is four fold higher than the required standards which reduces visibility and is dangerous for human health. The soaring of this level of PM 2.5 in air is tied to a number of factors which are exhaust from vehicles, burning of waste, debris dust, broken roads, poor collection of waste, construction and demolition work and smoke discharged from brick kilns (Ali, 2016). To my knowledge there is no study conducted in which about twenty micro-environments were studied to know the trends of heavy metal contamination in Peshawar district of Khyber Pakhtunkhwa province, Pakistan.

However this study is designed;

- To monitor the concentrations of trace metals in the dust micro-environments of Peshawar, Pakistan.
- To estimate health risks to population via, ingestion, inhalation and dermal contact of dusts having heaving heavy metals.
- To provide baseline information on the extent of trace metals in the dust micro-environments of Peshawar district.

An industrial estate of Karak, Jorden was studied for the determination of heavy metals content in its dust samples. Elevated concentrations of heavy metals were observed in the study. Industrial activities and anthropogenic sources are the reasons of this high metal content in Karak industrial estate. The concentration of heavy metals was not that high to yield any health effect in humans but proactive measures should be taken to handle the situation (Omar A Al-Khashman, 2004). Residential dust of Istanbul, Turkey was observed for heavy metals concentration. The concentration of most of the heavy metals were in the range of the values available in the literature however Cr and Ni showed a deviation of 15% and 2.6% respectively from Turkish safety limits for ingestion and dermal contact of humans with dust. No significant carcinogenic risk for children and adults is associated with the studied residential dust (Kurt-Karakus, 2012). Road dust can be a good indicator for the determination of heavy metals concentrations related to heavy traffic. Extreme level of Cu and Zn pollution in traffic related dust was evaluated in the study. The high concentration of Cu implies to brake wear while high concentrations of Zn was because of zinc-plated road furniture (Swietlik, Strzelecka, & Trojanowska, 2013). (Fujimori et al., 2012) conducted a study on the impacts of toxic metals from electronic waste and the spread of these toxic metals to other environments. Cu, Ni, Pb and Zn were highly loaded in the dust samples from this waste dump; dust was moderately polluted with Cd. There can be high health risk for children ingesting dust from e-waste recycling sites.

One of the main sources of environmental pollution is transport sector. Elemental composition of the dust related to transport facility in this study was lower than given in other literature. The variation for LADD for carcinogenic metals was ranged as Cr> Ni> Cd >. Highest Hazard Index (HI) was found to be associated with Cr and Pb in road dust via ingestion (Faiz, Siddique, & Tufail, 2012). (Mohmand et al., 2015) worked on the dust from industrial zone for heavy metals determination. The famous Lahore industrial estate was been assessed for this study. The descending order of metals occurrence in the dust samples were of the order Zn >Pb> Cu > Cr > Ni > Cd. Human exposure to dust and its bioaccumulation pattern into human body is more likely by Pb, Cd and Cr while Zn, Cu and Ni exposure is tied to dietary sources. The work of (Aiman, Mahmood, Waheed, & Malik, 2016) revealed concentrations of heavy metals in the dust from MehmoodBoooti dumping site in the order of Pb (0.2-79.66) > Zn (4.85-60.41) > Cu (1.46-5.48) > Ni (0.031-4.14) > Cd (0.67-2.41) > Cr (0.46-2.5). Human health is being affected from the air currents from a landfill site which contains contaminated dust. Areas in the vicinity of a dumpsite are affected and high contaminations of heavy metals are notice. High concentrations of heavy metals were observed in residential dust in the study conducted by (Jabeen, Ahmed, Hassan, & Alam, 2001) as compared to road dust. House ventilation and dustiness of the house are the main factors behind loadings of Pb, Cd, Zn, and Cu in house dust. Interior as well as exterior sources of Pb, Cd, Zn and Cu are behind contamination in residential facilities.

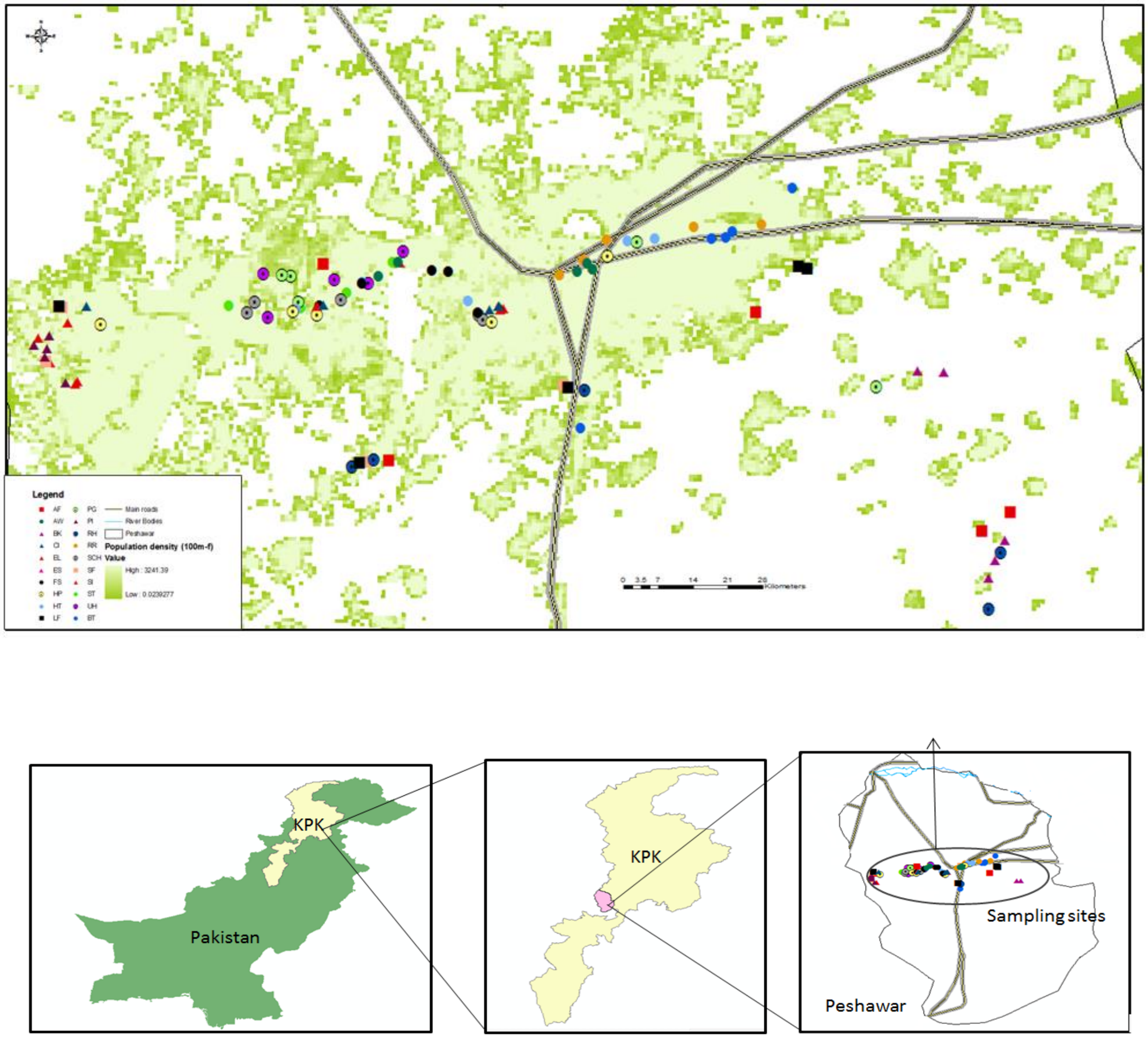
Chapter 2

Materials and Methods

2.1. Study Area:

This study was carried out in Peshawar district which is the provincial center of the Khyber Pakhtunkhwa (KP) province of Pakistan. Peshawar city is located adjacent to the eastern side of the Khyber Pass (Aslam, 2009). Peshawar district of the province Khyber Pakhtunkhwa (KP) Pakistan is situated in the North-West end of Pakistan, laying 160 Km West of the federal capital, Islamabad. Geographically Peshawar is located at northern latitudes 34° 1' 33.3012" and eastern longitudes 71° 33' 36.4860"laying at an altitude of 317 m above the sea level. Peshawar is the 7^{th} biggest cities of Pakistan (Sardar Khan, Khan, & Khan, 2002). Peshawar is the greatest populous city of the Khyber Pakhtunkhwa (KP) province having an area of 1257 sq. Km i.e. 485 sq. mi. Peshawar is mainly distributed into four towns, where there are 92 union councils, of which 43 union councils are urban while the rest are in rural parts (Khattak, Khan, & Ahmad, 2009).The population of district Peshawar according to 1998 census was 2,019,000 persons. 983,000 persons out of 2,019,000 is the urban population of Peshawar, which is 48.69% of the whole population, the remaining 1,036,000 persons live in rural areas which make up 51.31% of the population. It illustrates that half of the population lives in the urban parts (Khattak et al., 2009). Peshawar is a wild budding city with 3.29% of current population growth rate per year. This population growth rate is greater than other cities of Pakistan. 3.56% is the mean annual growth rate of Peshawar.

Amalgamated deposits of modern geological times of sand, silt and gravel, cover the basin of Peshawar. The basin of Peshawar is an inter-mountain basin situated in the southwestern section of Himalayas. Major cities included in this basin are Peshawar, Mardan, Charsadda and Nowshera. Flood zones are the areas in between Kabul River and BudniNala. At a depth of 400 feet (120m) there occurs confined water containing aquafers. The classes of the soil of Peshawar basin are Peshawar piedmont soil, Peshawar lacustrine soil and Peshawar flood plain. For the crucial development of plants there are some major, minor, heavy metals and trace metals in these soils.



Map of the study area showing all the micro-environments.

The climate of the studied area i.e. Peshawar varies round the year. An increase in the maximum temperature of Peshawar per year is about 0.018 ºC (Sadiq & Qureshi, 2010). The average maximum temperature of Peshawar in summer is over 40 ºC (104 ºF) and the average minimum temperature is 25 ºC (77 ºF). The average minimum temperature during winter is 4 ºC (39 ºF) and mean maximum temperature is 18.35 ºC (65.03 ºF). Yearly rainfall ranges from 2000 mm in the moist North to almost none in the dry South. Peshawar is not situated in the monsoon expanse, and only monsoon streams prompt cloudbursts in Peshawar. The city of Peshawar is more tending by winter than monsoon precipitation subsequently sub- mountainous Khyber

Pakhtunkhwa (KP) and Punjab receive lump sum equivalent share of winter and summer rainfall (Sadiq & Qureshi, 2010).

Peshawar is agonizing immensely because of inflammation population, miserable regulatory framework and unplanned growth. Speedy population growth has enhanced the speed of urbanization in developing countries which are the reasons of many environmental problems (Khattak et al., 2009). Peshawar has gigantic significance because of air pollution. World Health Organization (WHO) steered a survey and issued a report which reads Peshawar the second most polluted city in the world. According to the findings of World Health Organization (WHO) pollution has surged 8% worldwide in the past five years. They listed some of the main reasons behind this air pollution which are a lot of vehicles in which a large number are diesel fueled, waste management, cooling and heating of big infrastructures and for power generation the use of diesel and coal generators (Kanwal, 2016).

To accomplish the needs of the increasing population of a country industrial estates are established (Tariq, Ali, & Shah, 2006). Unemployment reduces due to the establishment of industrial zones. On 30th October 1963 the department of industries of the government of Pakistan established Hayatabad industrial estate (HIE). Hayatabad industrial estate (HIE) is situated in the North-West of Peshawar near Jamrud road. Hayatabad industrial estate (HIE) is the main commercial, business and industrial center of the province. Khyber Agency is present on the North bordered with Afghanistan. Warsak canal passes from the west side of the Hayatabad industrial estate (HIE). Non irrigated land surrounds the eastern and southern borders of the Hayatabad industrial estate (HIE) (Sardar Khan et al., 2002). The Hayatabad industrial estate (HIE) is encompassed of 50 industries of different types such as, textile, dying chemicals, matches, pharmaceuticals, ghee, food, rubber, drinks, steel, wood, marble and others (Tariq et al., 2006).

One of the most important sources of socioeconomic progress of the study area is agriculture as the dependence of per capita income of Pakistan is solely dependent on agriculture. This sector worked successively to strengthen our country (Syed Ali Raza, Ali, & Mehboob, 2012). The economic development of our country is centered on agriculture and after gaining independence this sector is the root cause of Pakistan’s economy (Fatima, Almas, & Yasmin, 2017). This is the key foundation of living of the people of Pakistan as it delivers food to the whole nation (Saeed & Khan, 2007). Kharif and Rabi are the cropping patterns of the study area. The main cash crops of the study area are wheat, sugarcane, maize and vegetables (Parikh, Ali, & Shah, 1995). When enhancing the productivity of the crops, farmers use pesticides and fertilizers which have toxic effects on the environment.

2.2. Micro-environments description:

All the micro-environments were selected on the basis of their pollution status to carry out a general survey of distribution of heavy metals in the dust of these micro-environments. Study area with sampling collection points are shown in fig. The micro-environments were further divided into four zones; the detailed description of each zone is listed below:

Zone 1 Zone one i.e, Transport Facility (TSPF) constitutes of six micro-environments named Bus Terminal (BT), Rail Road (RR), Streets (ST), Heavy Traffic Roads (HT), Auto-mobile Workshops (AW) and Filling Stations (FS). In auto-mobile workshops heavy metals come from a number of sources like used oil, piston rings, metal bushings, bearing wears, crankshafts wear etc(Ilemobayo & Kolade, 2008). There are hundreds of automobile workshops in Peshawar. A large number of children and adults work here in these workshops having no occupational safety measures as a result these children experience great ill health effects (H. Khan, Hameed, & Afridi, 2007). Railway transportation also causes heavy metals contamination (Wiłkomirski, Sudnik-Wójcikowska, Galera, Wierzbicka, & Malawska, 2011a). Pollution problem regarding heavy metals in streets dust is a matter of grave environmental concern in these years. Heavy metals has the power to find their way into the food chain and pose great risk to human health (Wiłkomirski et al., 2011a). Road traffic causes heavy metals pollution but the related metals are not very movable (Apeagyei, Bank, & Spengler, 2011). Zn and Cd is found in high concentrations in heavy traffic zone which indicate fragmentation of car tires as source of these heavy metals (Elik, 2003). Ni in transport facility is because of nickel gasoline and abrasion and corrosion of Ni parts (Al-Shayeb, 2001). Lead is used in industries and leaded gasoline is the reason behind high lead concentrations in transport related facilities. Lead level increases as traffic volume increases (Tüzen, 2003). Zinc and Cadmium come off tire wear and Zn is due to spills of oil on roads. The sources of Cu, Zn and Cd in road dust is associated with brass alloy while Cd is used on the surface of brass to minimize corrosion (Charlesworth, Everett, McCarthy, Ordonez, & De Miguel, 2003). According to (Al-Shayeb, 2001) chromium in the traffic dust comes from chrome plating. Bus terminals are important microenvironments as dust fragments stick to uncovered skin surfaces of humans and make their way to the human body via. Skin contact, inhalation and ingestion (Zheng et al., 2015). Workers at the filling stations are at risk due to heavy metal contamination (Xueping Li, Shi, Wang, & Li, 2017).

Zone 2

All industrial micro-environments establish Industrial zone (INDZ). Carpet Industry (CI), Steel Industry (SI), Pharmaceutical Industry (PI), Electronics Shops (ES), Electrical Shops (EL) and Brick Kiln (BK) fall in this zone. Cd in industrial area is found in high concentration near processing plants. Cd is deposited yearly about 0.25-73mg/m^3 in industrial areas. Cd and Ni come from fuel oil, coal combustions, road transport and metallurgical industry. The sources of Zn in industrial zone are fossil fuel, fertilization and metal manufacturing (Cipurković et al., 2011). The emissions from vehicles and brick kiln are the major pollution sources in Peshawar. Coal, furnace oil, wood and tires are used by brick kilns to bake bricks. The addition rate of heavy metals (Cd and Cr) to the environment from these brick kiln is 0.008 and 0.52 mg m^{-2} per month steadily (Ismail et al., 2012). Being one of the ancient and popular industries, carpet weaving was brought by Mughals to India. The practices which are done during carpet processing produces a range of wastes (Bari & Bhardwaj, 2013). These wastes are harmful for humans along with other animals' life and plants life. Steel plays an imperative part in the progress of human civilization and has extensive uses in construction and manufacturing. These manufacturing methods are accompanied with some environmental problems. Heavy metals may amass in human beings which are linked with these atmospheric particles and can cause hostile effects on the heath of humans (Dai et al., 2015). In developed countries the making of electronic and electrical instruments is a fastest developing sector of the manufacturing business. These devices become obsolete and are discarded because of the demand for effective and fresher technologies (Atiemo, Ofosu, Aboh, & Kuranchie-Mensah, 2012). These wastes are rapidly raising problems for the world to face. Humans are unprotected to the heavy metals pollution resulting from this waste (Adaramodu, Osuntogun, & Ehi-Eromosele, 2012). Heavy metals along with some other toxic ingredients are there in the patent drugs that are ended in Asian countries (Ko, 1998).

Zone 3. Residential Zone (RSDZ) has Urban Homes (UH), Rural Homes (RH), Schools (SCH), Playgrounds (PG), Hospitals (HP) and Agriculture Fields (AF). The excessive loadings of Cd, Cu and Zn in residential facility is inferred to airborne, particulate related as they are in superfluous in atmospheric particles. Cr and Ni can be attributed to stainless steel (Yoshinaga et al., 2014). The exposure of children to Pbtoxicity in residential zone is associated with ingesting Pb paint dust, leaded gasoline and other metals from vehicular emission is also main source of Pb in residential facility. Cd in residential facility is found within the range of the mean concentration of that of the crust of the Earth i.e. 0.2μg/g (Nigeria, 2012).Peshawar is the provincial capital of Khyber Pakhtunkhwa (KP) province and is home to many health facilities. These hospital receive patients from every part of the city and also from the major marginal referral facilities (Rahman, Mumtaz, Mufti, Shah, & Rahman, 2011). Hospitals can be a hotspot for heavy metals due to airborne heavy metal fall, heavy metal from paint and heavy metals due to people's movement from outside to inside. The importance of schools as micro-environments can't be neglected because of the students' experience to interior toxins, as they spend most of their time of the day in these facilities on week- days (Latif et al., 2014). Students are exposed to these toxicants which pose great bad health effects. The recognition of house dust as a major source of lead (Pb) for minors and in the United states concern was raised due to the use of lead-based points in homes (Yoshinaga et al., 2014). Source varies in case of heavy metals and depends on the location and condition of the building. Movement from outside to inside and ventilation systems are the main source of heavy metals transportation in an indoor environment (Latif et al., 2014). House micro-environment is a significant environment, whether urban or rural, humans spend most of their time in these facilities. The quantification of metal content in playgrounds dust is necessary because of the intake of this dust by children through ingestion is common (Wong & Mak, 1997). Authors are trying to evaluate children exposure to heavy metal in the play area (Kicińska & Klimek, 2015). Due to the speedy growth and industrial development heavy metal pollution in food production soil has become a somber problem during the last two decades in china (Wei & Yang, 2010).

Zone 4. Waste Dumping Zone (WDZ) is significant zone regarding its pollution potential consists of Landfills (LF) and Scrape Facility (SF). Dust production is a significant problem related with landfills. These dusts comprise of heavy metals and can yield environmental difficulties and possible health dangers (Jia et al., 2011). 2. The problems of pollution related to dust arise from huge quantity of heavy metals dumped on it through disposed waste (Akpoveta, Osakwe, Okoh, & Otuya, 2010). The leaching of heavy metals from this scrap is a big health issue for the workers. Waste dumping zone has the potential to be a source of environmental pollution and risk due to high level of heavy metals in its matrices. The higher concentration of Pb in this zone is because of e-waste (Adaramodu et al., 2012). High concentrations of Pb, Cd and Zn are found in dumping zone and their sources are anthropogenic because of their high correlation with each other and with organic matter (Ogundiran & Afolabi, 2008). Plastic contributes to Cd, scrap metal and rubber contribute to Zn (Kjeldsen et al., 2002).

2.3. Sample collection:

In this study a total of one hundred settled samples of dust were collected from twenty different microenvironments of Peshawar district in October 2016, i.e., thirty settled dust samples from transport related facilities, thirty from industrial zone, another thirty from residential zone and only ten from waste dumping zone. The purposive system of sampling was adopted for the collection of samples. This type of sampling method helps in improving representativeness of heavy metals in the dust to some extent. These dust samples were collected via plastic dust pan and a small brush. The samples were immediately transferred to an air tight polyethylene bag known as plastic zipper for transport to the laboratory. Date of collection and was noted. During this whole time special precautions were taken to avoid sample contamination during collection, transportation, laboratory analysis and metal determination via atomic absorption spectrometer (AAS). In general all sampling procedures were carried out according to the protocols and recommended standards.

2.3.1. Laboratory analysis:

2.3.1.1. Preparation:

The samples were left to dry at room temperature for five days. After five days the samples were sieved through a 30 mesh sieve to remove extraneous matter such as small pieces of brick, paving stones and other debris. Care was taken to reduce the disturbance of the fine particles which can be readily lost by resuspension.

2.3.1.2. Digestion:

Two grams of this sample was weighted and transferred to a Pyrex tube then 15 ml of aqua regia (one part of concentrated HNO_3 and three parts of concentrated HCL) and 3ml of concentrated hydrofluoric acid at room temperature was added to the sample for digestion (Razanica, Huremovic, Zero, Gojak, & Memic, 2014). NO_2 fumes will leave and after that this mixture was heated to 90°. After cooling this digest it was diluted with deionized water and made up 50ml and then filtered with Whatman[42], ash less, 90mm filter paper. Heavy metals contents (Cd, Cu, Cr, Ni, Pb and Zn) were determined using flame atomic absorption spectrometry (fast sequential atomic absorption spectrophotometer, AA240FS, VARIAN).

2.3.2. Atomic absorption spectrometry (AAS) analysis:

Dust samples were analyzed for heavy metals by VARIAN AA240FS atomic absorption spectrophotometer (AAS). Under contemplation operating limitations for heavy metals were set as suggested by the manufacturer. Atomic absorption spectrometry (AAS) data was acquired and processed by using Microsoft Excel software 2010.

2.3.3. Statistical Analysis:

Statistical analysis was executed with IBM SPSS statistics 20 for windows 10. Descriptive statistics of heavy metals concentrations in the studied zones including minimum (min), maximum (max), standard deviation (SD) and arithmetic mean were used to analyze the concentration level of heavy metals in the dust of different zones. Data were statistically analyzed by one factor analysis of variance (ANOVA) to test significant difference among the mean concentration of the heavy metals in the dust samples of the four zones followed by Tukey HSD post hoc test for multiple comparisons of metal concentrations in different zones and the statistical significance was considered at $p < 0.005$. Geo-accumulation index was determined. Pearson's correlation coefficient was used to measure the probable relationships of the studied elements concentration in four zones and the degree of correlation between logarithms of metal data of all the four zones. Principal component analysis (PCA) is the common multivariate statistical method used in environmental studies. In this study on the basis of the relationship between elements, PCA was used to explore the extents and sources of heavy metal pollution by applying Varimax rotation with Kaiser Normalization. By extracting the eigenvalues and Eigen vectors from the correlation matrix, the number of significant factors was calculated and the percent of variance explained by each factor were calculated. ADD, HQ and HI were used to assess the potential health risk.

2.3.4.1. Quality Programs

A quality control (QC) samples was set in order to measure instrumental stability. A quality control (QC) sample is the representative of all sample set and was prepared by mixing parts of each sample in a composite. Quality control (QC) sample was injected after every 10 samples. Blanks and duplicate measurements were measured to ensure the quality and accuracy of the sample pretreatment and measurement processes. The recovery rates for the six elements relative to the SRM ranged between about 95% and 103%. Replicate analysis suggested that the precision of these analyses was approximately < 5% relative standard deviation at a 95% confidence level. A mixture of internal standards was used to check the stability and sensitivity of the instrument. Accuracy and percent recovery was measured via spikes which were prepared using the same method. Spike was run after five samples. The working solutions of standard stock solution were prepared daily. Standards were prepared for each metal from their stock solutions to calibrate the instrument. Precision and accuracy of analysis were checked through repeated analysis against Standard Reference material (SRM). Stock solutions were prepared for Cd, Cr, Cu, Ni, Zn and Pb. The dilution equation is given as:

$\text{Concentration}_{(start)} * \text{Volume}_{(start)} = \text{Concentration}_{(final)} * \text{Volume}_{(final)}$

This equation is commonly abbreviated as: $C_1V_1=C_2V_2$

2.3.4.2. Quality Assurance

For the reliability of the results the quality assurance precautions and procedures were ensured. Samples were carefully handled during preparation and analysis to avoid contamination. Glass wares were washed with detergents and were rinsed properly and reagents were of analytical grids. The water used throughout the study was deionized in the laboratory. To correct the readings of instruments reagent blanks were used. The calibration of AAS was done by multi-elemental solutions.

2.3.5.1. Geo-accumulation index (I_{geo})

The index of geo-accumulation (I_{geo}) is the method employed widely for the calculation of pollution status of an single element by relating it with the levels of heavy metals acquired to a background level (Victoria, Cobbina, Dampare, & Duwiejuah, 2014).

The index of geo-accumulation can be calculated by means of the following equation:

$I_{geo}= \log2 (C_n/ 1.5 B_n)$

In the equation above $I_{geo}$is the index of geo-accumulation for unlike trace elements, C_n shows the trace elements concentrations in the sample. The introduction of constant i.e. 1.5 is for finding human effects and to explore the natural differences in the constant of a precise pollutant

(Ali et al., 2017). The classification of geo-accumulation index is in the Table 3 in Appendix section. Geo-accumulation (I_{geo}) values of heavy metals in the dust of studied zones are illustrated in Table 3.

2.3.5.2. Health risks assessment model

The United States Environmental Protection Agency presented this model to calculate health risk and mankind exposure to potentially toxic elements (PTEs) in dust samples. The average daily dose (ADD) (mg/kg/day) of a contaminant through three exposure pathways i.e. direct ingestion of dust, inhalation of dust and dermal contact with dust can be calculated using the following equations:

$$ADD_{ing} = \frac{c*Ring*CF*EF*ED}{BW*AT}$$

$$ADD_{inh} = \frac{c*Rinh*EF*ED}{PEF*BW*AT}$$

$$ADD_{derm} = \frac{c*SA*CF*SL*ABS*EF*ED}{BW*AT}$$

The first equation i.e. ADD_{ing} denotes average daily dose for ingestion followed by ADD_{inh} which represents average daily dose for inhalation and the third one ADD_{derm} represents average daily dose for dermal contact with dust (Ali et al., 2017). The exposure factors for these models are shown in the following Table.1 of appendix section.

The values of these factors are shared between the standards from US EPA and real actual data for Chinese. The values of ADD are calculated in the Table. 6 of Tables section.

2.3.5.3. Hazard Quotient (HQ)

After the calculation of average daily dose (ADD) for ingestion, inhalation and dermal exposure pathways, the Hazard Quotient (HQ) can be estimated by dividing average daily dose (ADD) by a definite reference dose (RfD). Hazard Quotient (HQ) is centered on non-cancer toxic risk. The equation for the estimation of Hazard Quotient is as follows:

$$HQ = \frac{ADD}{RfD}$$

The RfD value is for the estimation to know if there is hostile health effect during a life time. If the ADD value is lower than RfD value there will be no unfriendly health effect but if the ADD value is higher than RfD value then human health can be adversely effected via. exposure pathways. HQ ≤ 1 shows no adverse human health effects, while HQ > 1 indicates adverse human health effects (Du et al., 2013).

2.3.5.4. Hazard Index (HI)

We generally add HQs to create Hazard Index (HI) to calculate the risk of combined metal pollutants. The equation to calculate hazard index is as follows:

$$HI = \sum_{i=1}^{3} HQ_i$$

If multiple contaminants and multiple exposure pathways need to be estimated HI is used. Sum of HQ is equal to HI which means total non-carcinogenic risk for one element. If HI ≤ 1 then there is no significant risk of non-carcinogenic effect but if the value of HI>1 it means there is a pronounced chance of non-carcinogenic effects (Du et al., 2013). Hazard indices (HQ & HI) are summarized in the Table 4 along with RfD values.

2.3.5.5. Pearson Correlation Analysis

To measure the correlativity among heavy metals a method was employed named as Pearson Correlation Analysis. The Pearson Correlation Coefficients of heavy metals in dust from multiple zones of Peshawar, Pakistan were done and the results are illustrated in the following Table 7.

Tables

Table.1. Descriptive statistics for Heavy metals concentrations in multiple zones of Peshawar, KP, Pakistan

		Pb	Zn	Cr	Cu	Cd	Ni
RESIDENTIAL ZONE	Mean±S.D	0.6±0.7	8.4±2.1	2.4±0.3	0.8±0.4	0.1±0.1	0.5±0.3
	Range	0.0-2.8	5.0-13.3	1.4-3.0	0.5-2.1	0.0-0.2	0.0-1.3
INDUSTRIAL ZONE	Mean±S.D	1.5±1.8	15.8±2.6	1.8±0.9	1.9±1.8	0.1±0.1	1.3±2.1
	Range	0.6-7.2	9.3-19.6	0.2-3.6	0.5-8.2	0.0-0.2	0.1-7.8
WASTE DUMPING ZONE	Mean±S.D	5.0±4.1	17.8±1.4	1.8±0.5	4.2±2.6	0.2±0.3	1.2±1.4
	Range	0.5-10.4	15.7-19.6	1.0-2.7	1.5-9.6	0.3-1.0	0.3-5.2
TRANSPORT FACILITIES	Mean±S.D	6.4±5.7	13.8±3.3	1.1±0.8	2.6±2.5	0.1±0.1	0.6±0.4
	Range	0.3-17.7	6.5-19.9	0.0-2.7	0.4-8.8	0.0-0.2	0.0-1.5

Table.2. Heavy metals concentrations (mg/kg) of different zones of Peshawar, KP, Pakistan with test of significance F*(p)* and multiple comparisons (Tukey) test. n represents the number of studied micro-environments in each zone.

	n		Pb	Zn	Cr	Cu	Cd	Ni
RESIDENTIAL ZONE	6	Mean± S.D	0.6±0.7	8.4±2.1	2.4±0.3	0.8±0.4	0.1±0.1	0.5±0.3
		Range	0.0-2.8	5.0-13.3	1.4-3.0	0.5-2.1	0.0-0.2	0.0-1.3
			A	A	C	A	A	A
INDUSTRIAL ZONE	6	Mean± S.D	1.5±1.8	15.8±2.6	1.8±0.9	1.9±1.8	0.1±0.1	1.3±2.1
		Range	0.6-7.2	9.3-19.6	0.2-3.6	0.5-8.2	0.0-0.2	0.1-7.8
			A	BC	BC	AB	AB	A
WASTE DUMPING ZONE	6	Mean± S.D	5.0±4.1	17.8±1.4	1.8±0.5	4.2±2.6	0.2±0.3	1.2±1.4
		Range	0.5-10.4	15.7-19.6	1.0-2.7	1.5-9.6	0.3-1.0	0.3-5.2
			B	C	B	C	B	A
TRANSPORT FACILITIES	2	Mean± S.D	6.4±5.7	13.8±3.3	1.1±0.8	2.6±2.5	0.1±0.1	0.6±0.4
		Range	0.3-17.7	6.5-19.9	0.0-2.7	0.4-8.8	0.0-0.2	0.0-1.5
			B	B	A	B	AB	A
		F*(P)*	16.767*(<.000)*	52.941*(<.000)*	16.673*(<.000)*	9.409*(<.000)*	2.123*(.103)*	3.010*(.034)*

Table.3. Geoaccumulation (*I*geo) Values of Heavy Metal in the dust of studied zones

Zonation		Pb	Zn	Cr	Cu	Cd	Ni
TSPF	Mean	0.064012	0.029058	0.00241	0.011436	0.098872	0.001709
	min	0.003311	0.01368	0.000103	0.002002	0.012041	3.84E-05
	max	0.177307	0.042039	0.00613	0.039272	0.207711	0.004451
INDZ	Mean	0.015092	0.03335	0.004073	0.008299	0.098637	0.003983
	min	0.000602	0.019706	0.00041	0.002404	0.001003	0.000215
	max	0.071745	0.041367	0.007965	0.036356	0.203697	0.022937
RSDZ	Mean	0.005556	0.017813	0.005356	0.003763	0.078134	0.001553
	min	0.0001	0.010546	0.003115	0.002123	0.004014	4.13E-05
	max	0.027695	0.028114	0.006667	0.009187	0.219752	0.003789
WDZ	Mean	0.050001	0.037654	0.003929	0.01869	0.175099	0.003571
	min	0.004917	0.033089	0.00219	0.006761	0.033113	0.00103
	max	0.104156	0.041678	0.006085	0.042951	1.015475	0.015202

Table.4. Hazard Quotient of potentially toxic heavy metals for children and adults in TSPF, INDZ, RSDZ & WDZ.

Risk	Gender	Zonation	Pb	Zn	Cr	Cu	Cd	Ni
HQ_{ing}	Children	TSPF	0.140	0.004	0.017	0.005	0.008	0.002
		INDZ	0.033	0.004	0.028	0.004	0.008	0.005
		RSDZ	0.012	0.002	0.037	0.002	0.006	0.002
		WDZ	0.109	0.005	0.027	0.009	0.013	0.005
	Adults	TSPF	0.019	0.000	0.002	0.001	0.001	0.000
		INDZ	0.004	0.001	0.004	0.001	0.001	0.001
		RSDZ	0.002	0.000	0.005	0.000	0.001	0.000
		WDZ	0.015	0.001	0.004	0.001	0.002	0.001
HQ_{inh}	Children	TSPF	0.000	0.000	0.000	0.000	0.000	0.000
		INDZ	0.000	0.000	0.000	0.000	0.000	0.000
		RSDZ	0.000	0.000	0.000	0.000	0.000	0.000
		WDZ	0.000	0.000	0.000	0.000	0.000	0.000
	Adults	TSPF	0.000	0.000	0.000	0.000	0.000	0.000
		INDZ	0.000	0.000	0.000	0.000	0.000	0.000
		RSDZ	0.000	0.000	0.000	0.000	0.000	0.000
		WDZ	0.000	0.000	0.000	0.000	0.000	0.000
HQ d_{erm}	Children	TSPF	0.008	0.000	0.003	0.001	0.000	0.000
		INDZ	0.002	0.000	0.005	0.001	0.000	0.001
		RSDZ	0.001	0.000	0.007	0.000	0.000	0.000
		WDZ	0.007	0.000	0.005	0.002	0.000	0.001
	Adults	TSPF	0.006	0.000	0.002	0.001	0.000	0.000
		INDZ	0.001	0.000	0.004	0.001	0.000	0.001
		RSDZ	0.001	0.000	0.005	0.000	0.000	0.000
		WDZ	0.005	0.000	0.004	0.001	0.000	0.001
HI	Children	TSPF	4.195	0.106	0.497	0.159	0.227	0.067
		INDZ	0.989	0.121	0.841	0.116	0.226	0.155
		RSDZ	0.364	0.065	1.106	0.052	0.179	0.061
		WDZ	1.092	0.046	0.270	0.087	0.134	0.046
	Adults	TSPF	0.563	0.014	0.067	0.021	0.030	0.009
		INDZ	0.133	0.016	0.113	0.016	0.030	0.021
		RSDZ	0.049	0.009	0.148	0.007	0.024	0.008
		WDZ	0.147	0.006	0.036	0.012	0.018	0.006
RfD_{ing}			0.004	0.300	0.005	0.037	0.001	0.020
RfD_{inh}			0.004	0.300	0.000	0.040	0.001	0.021
RfD_{derm}			0.001	0.060	0.000	0.002	0.050	0.001

Table.5. Eigenvalues and Percentage of Explained Inertia by Each Component

Variable	PC 1	PC 2
Pb	**0.706**	**-0.626**
Zn	**0.634**	**0.766**
Cr	-0.064	0.024
Cu	**0.296**	**-0.146**
Cd	0.002	-0.001
Ni	0.094	0.013
Eigenvalues	27.318	11.809
Percentage	63.236	27.336
Cum. Percentage	63.236	90.571

Table 6 Daily dose

Risk	Gender	Zone	Pb			Zn			Cr			Cu			Cd			Ni		
			Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
ADD $_{ing}$ mg/(kg-d)	Child	TSPF	.0000	.0014	.0005	.0005	.0015	.0011	.0000	.0002	.0001	.0000	.0007	.0002	.0000	.0000	.0000	.0000	.0001	.0000
		INDZ	.0000	.0005	.0001	.0007	.0015	.0012	.0000	.0003	.0001	.0000	.0006	.0001	.0000	.0000	.0000	.0000	.0006	.0001
		RSDZ	.0000	.0002	.0000	.0004	.0010	.0006	.0001	.0002	.0002	.0000	.0002	.0001	.0000	.0000	.0000	.0000	.0001	.0000
		WDZ	.0000	.0008	.0004	.0012	.0015	.0014	.0001	.0002	.0001	.0001	.0007	.0003	.0000	.0001	.0000	.0000	.0004	.0001
	Adult	TSPF	.0000	.0002	.0001	.0001	.0002	.0001	.0000	.0000	.0000	.0000	.0001	.0000	.0000	.0000	.0000	.0000	.0000	.0000
		INDZ	.0000	.0001	.0000	.0001	.0002	.0002	.0000	.0000	.0000	.0000	.0001	.0000	.0000	.0000	.0000	.0000	.0001	.0000
		RSDZ	.0000	.0000	.0000	.0001	.0001	.0001	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
		WDZ	.0000	.0001	.0001	.0002	.0002	.0002	.0000	.0000	.0000	.0000	.0001	.0000	.0000	.0000	.0000	.0000	.0001	.0000
ADD $_{inh}$ mg/(kg-d)	Child	TSPF	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
		INDZ	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
		RSDZ	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
		WDZ	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
	Adult	TSPF	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
		INDZ	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
		RSDZ	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
		WDZ	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
ADD $_{derm}$ mg/(kg-d)	Child	TSPF	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
		INDZ	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
		RSDZ	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
		WDZ	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
	Adult	TSPF	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
		INDZ	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
		RSDZ	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
		WDZ	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

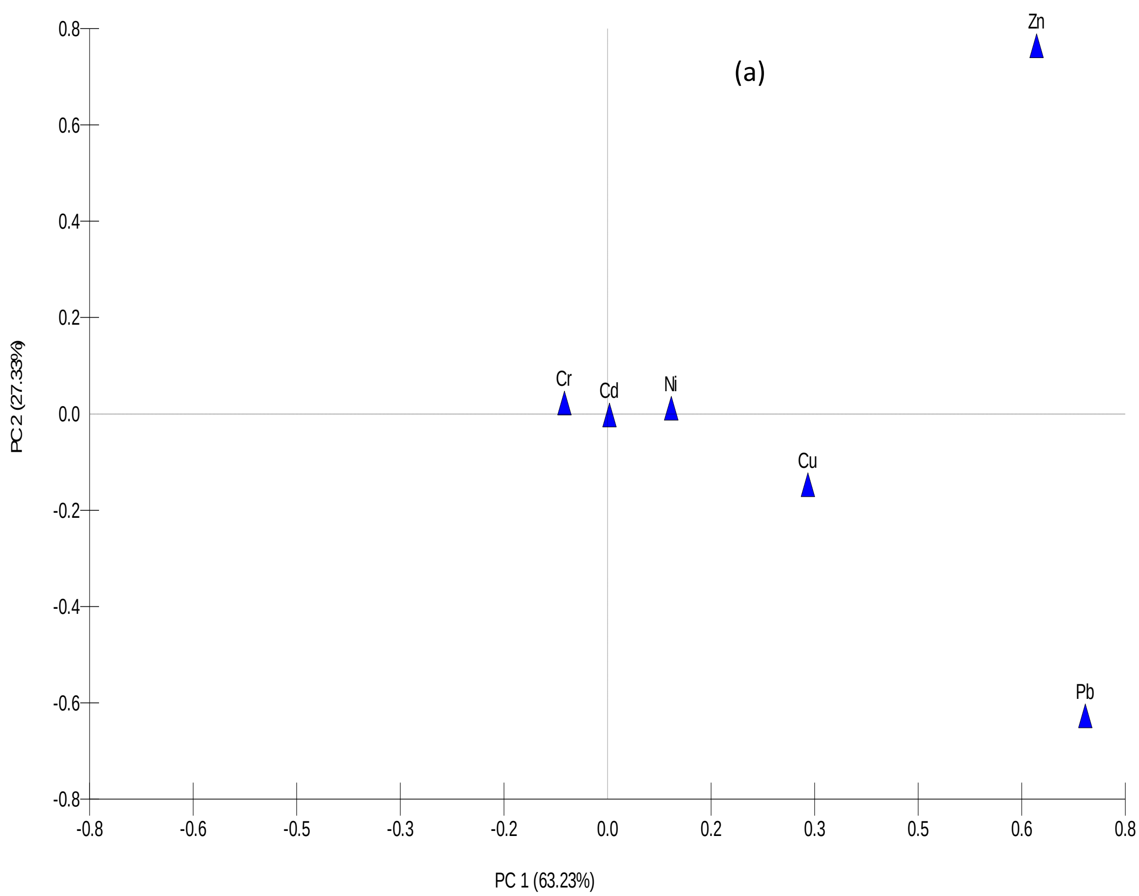
Table 7 Pearson Correlation Coefficient showing correlation among heavy metals in all the four zones

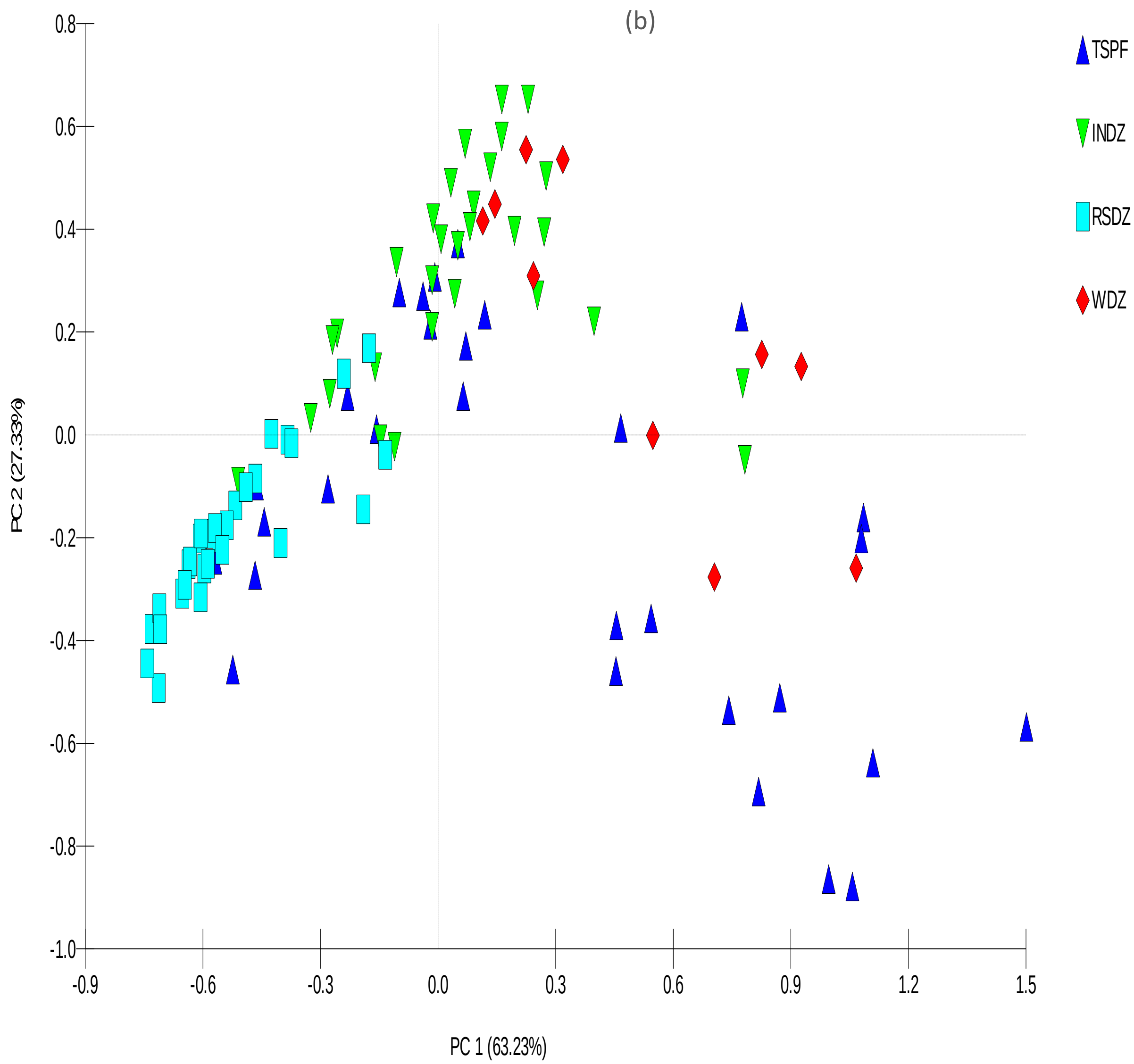
	Metals	Pb	Zn	Cr	Cu	Cd	Ni
Transport Facility	Pb	1					
	Zn	.428* (.018)	1				
	Cr	-.088 (.645)	.132 (.487)	1			
	Cu	.726** (.000)	.212 (.261)	.070 (.715)	1		
	Cd	-.441* (.015)	-.271 (.147)	-.174 (.357)	-.464** (.010)	1	
	Ni	.613** (.000)	.317 (.088)	-.010 (.958)	.800** (.000)	-.561** (.001)	1
Industrial Zone	Pb	1					
	Zn	0.24 (0.18)	1				
	Cr	0.09 (0.61)	0.03 (0.86)	1			
	Cu	.814** (4.38)	0.19 (0.30)	0.05 (0.77)	1		
	Cd	-0.10 (0.59)	-0.03 (0.85)	0.31 (0.08)	-0.21 (0.25)	1	
	Ni	.779** (4.02)	0.28 (0.13)	0.29 (0.11)	.747** (2.14)	-0.14 (0.45)	1
Residential Zone	Pb	1					
	Zn	.366* (0.04)	1				
	Cr	-0.15 (0.41)	-.362* (0.04)	1			
	Cu	0.10 (0.57)	0.33 (0.07)	-0.22 (0.22)	1		
	Cd	-0.11 (0.55)	-.449* (0.01)	.546** (0.00)	-0.23 (0.20)	1	
	Ni	0.16 (0.37)	0.26 (0.16)	-.519** (0.00)	.442* (0.01)	-0.28 (0.12)	1
Waste Dumping Zone	Pb	1					
	Zn	-0.16 (0.65)	1				
	Cr	-.863** (0.00)	0.31 (0.36)	1			
	Cu	0.45 (0.18)	0.20 (0.57)	-0.58 (0.07)	1		
	Cd	0.53 (0.11)	-0.18 (0.61)	-0.59 (0.06)	.716* (0.01)	1	
	Ni	0.61 (0.05)	-0.15 (0.66)	-0.63 (0.05)	.745* (0.01)	.982** (94.2)	1

*. Correlation is significant at the 0.05 level (2 tailed)

**. Correlation is significant at the 0.01 level (2 tailed)

Figures


(a)
Zn
Cr
Cd
Ni
Cu
Pb
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-0.8
-0.6
-0.5
-0.3
-0.2
0.0
0.2
0.3
0.5
0.6
0.8
PC 2 (27.33%)
PC 1 (63.23%)



(b)
TSPF
INDZ
RSDZ
WDZ
PC 2 (27.33%)
PC 1 (63.23%)
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
-0.9
-0.6
-0.3
0.0
0.3
0.6
0.9
1.2
1.5

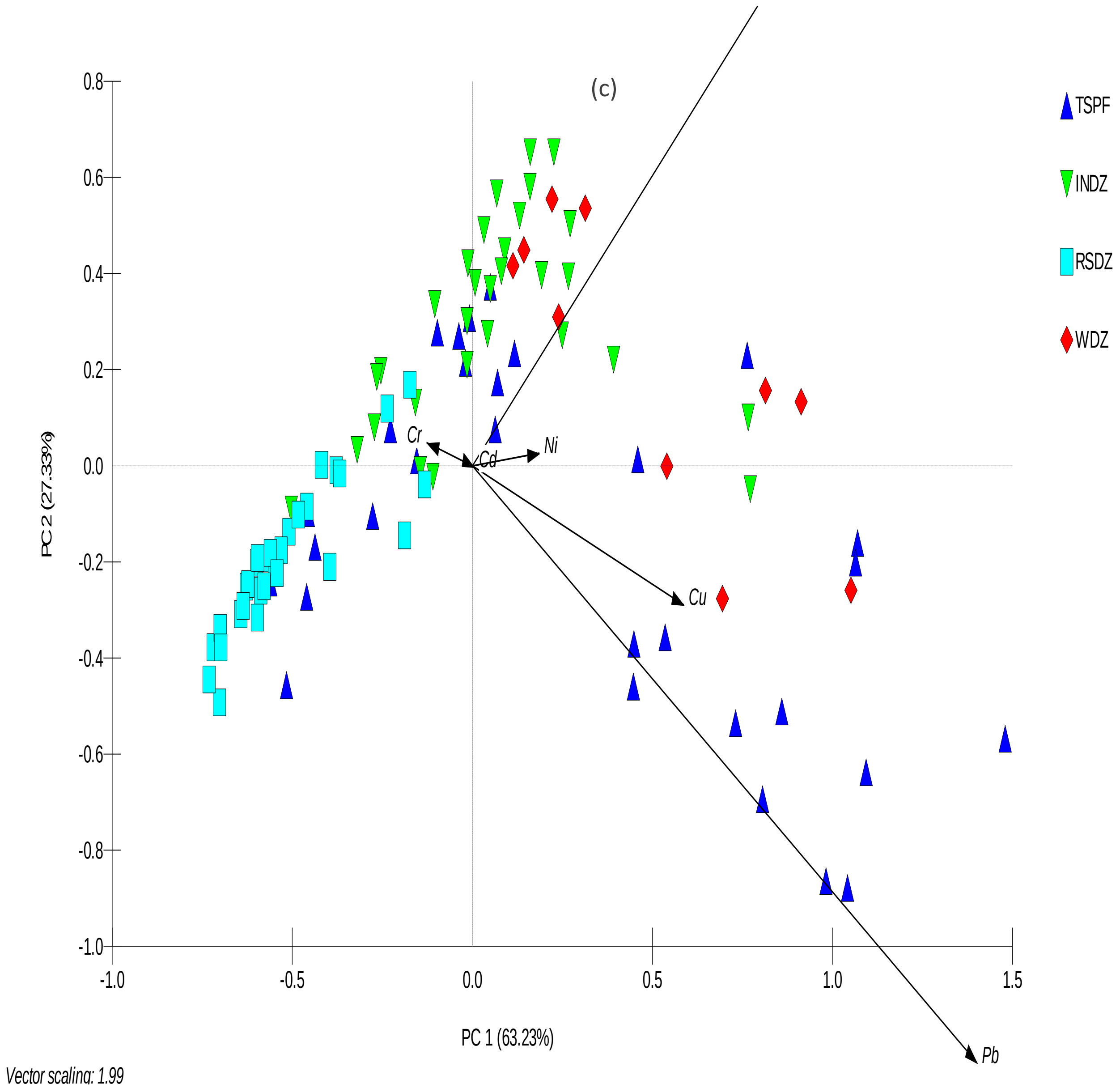
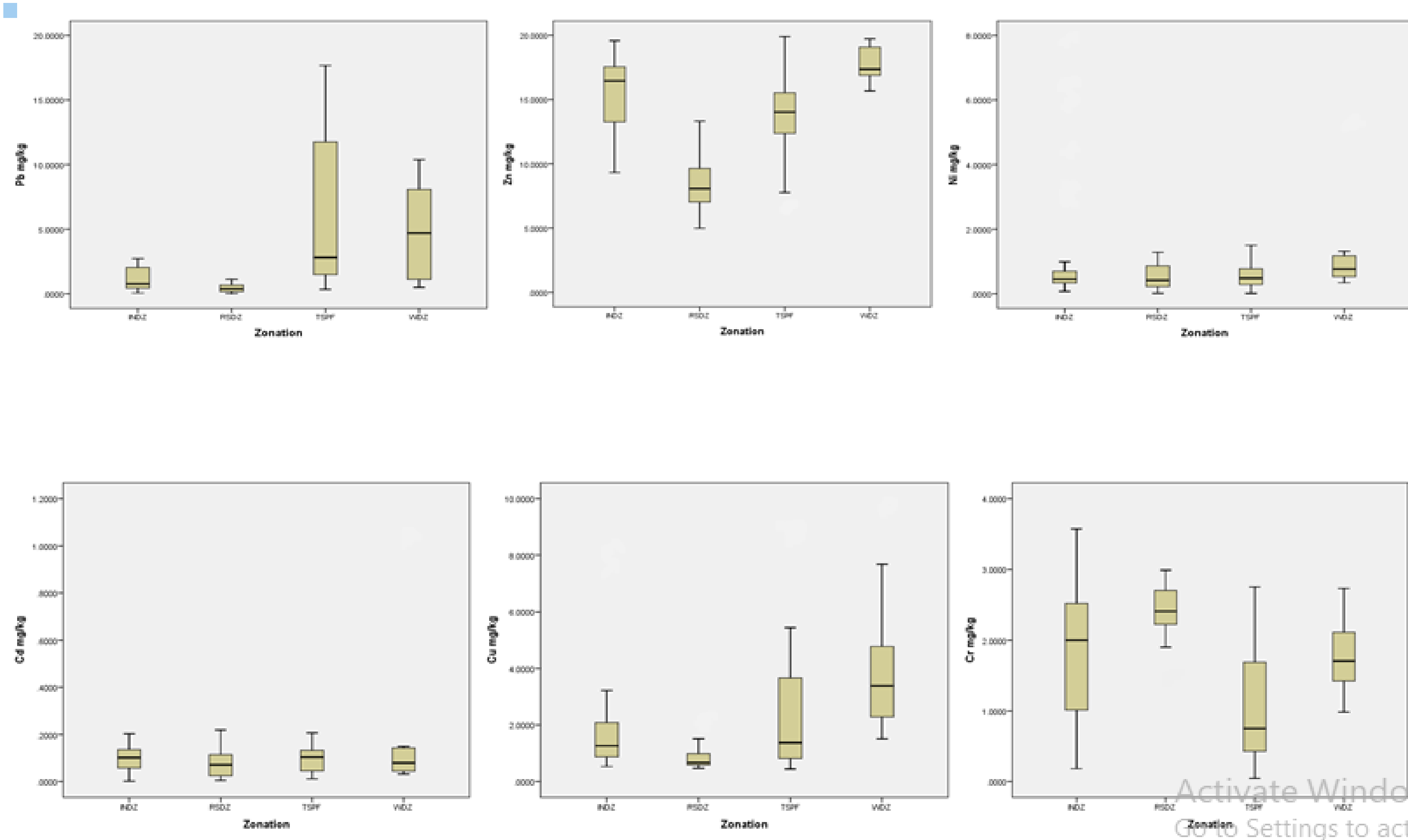


Fig 1 (a, b, c)Orientation of two axis of Principal component Analysis (PCA). Groupings obtained through plotting Factors.


Pb mg/kg
Zonation
Zn mg/kg
Zonation
Ni mg/kg
Zonation
Cd mg/kg
Zonation
Cu mg/kg
Zonation
Cr mg/kg
Zonation

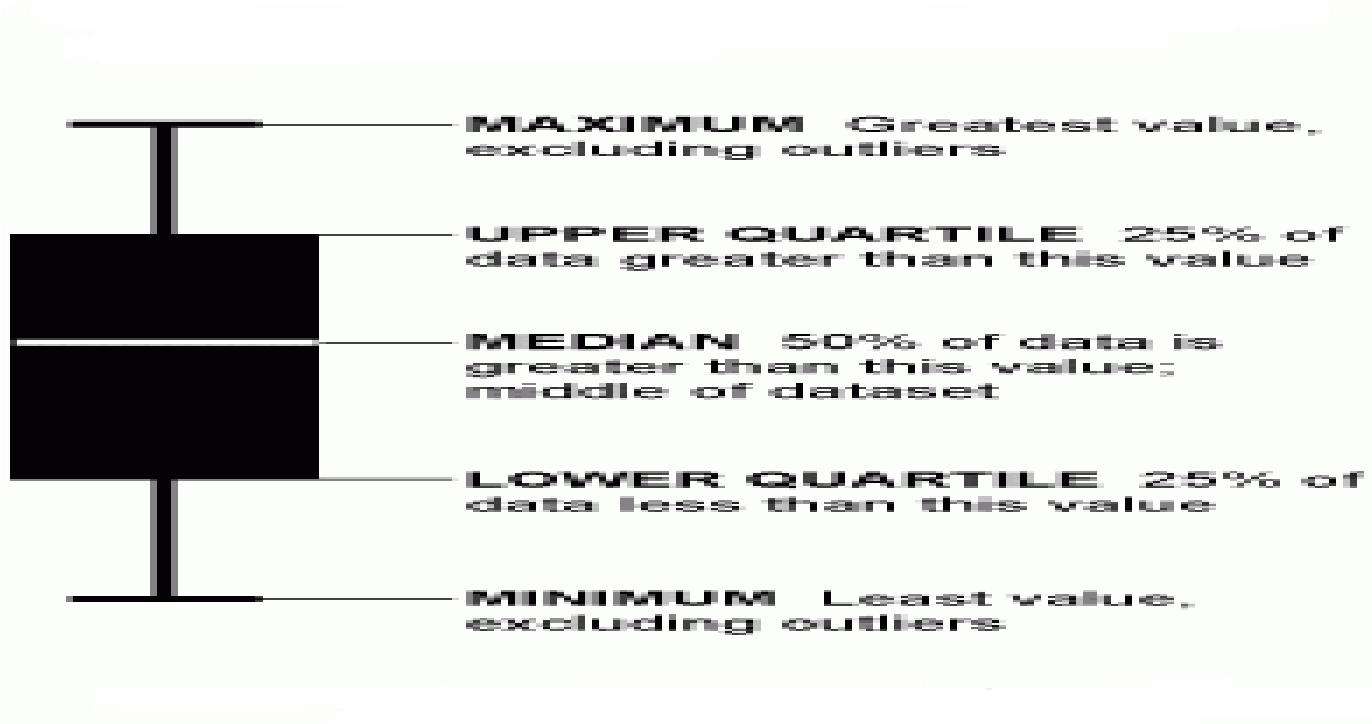
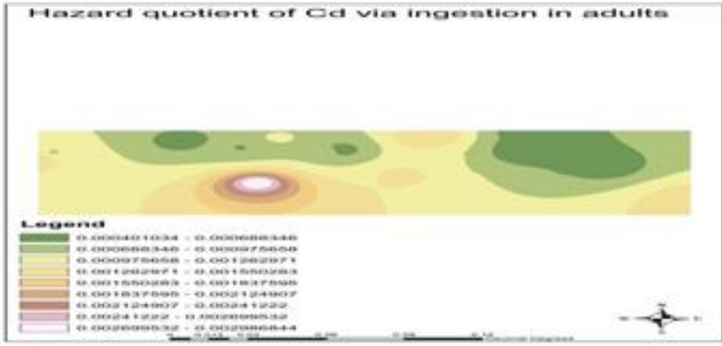
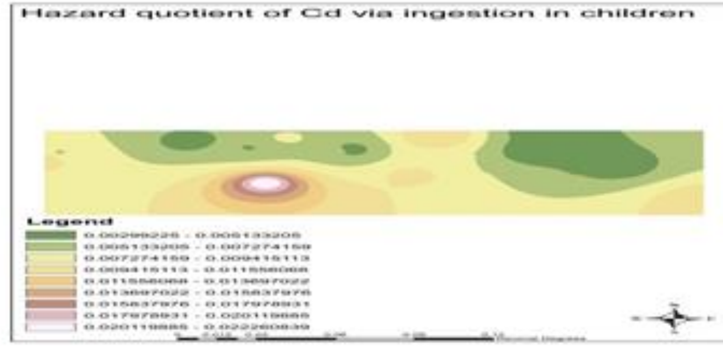
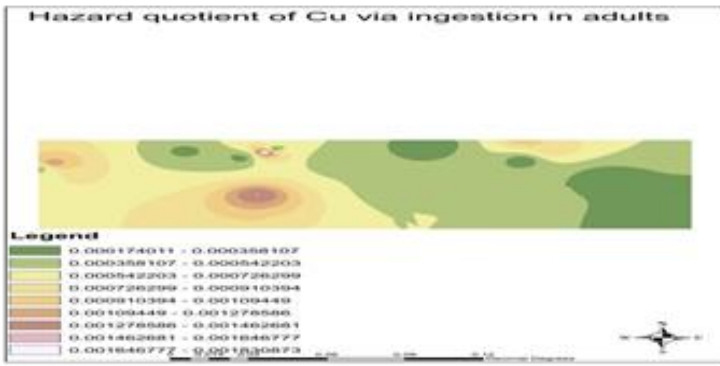
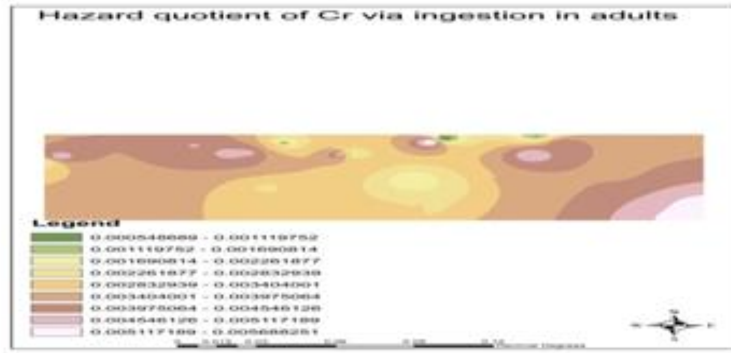


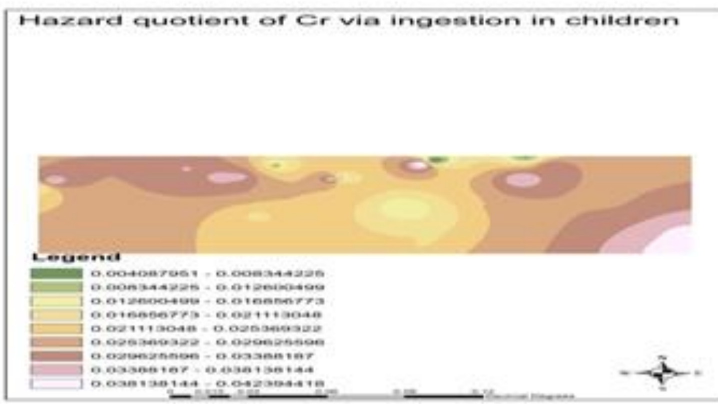
Fig. 2. Concentrations of Heavy metals in all the zones by box and whisker plot

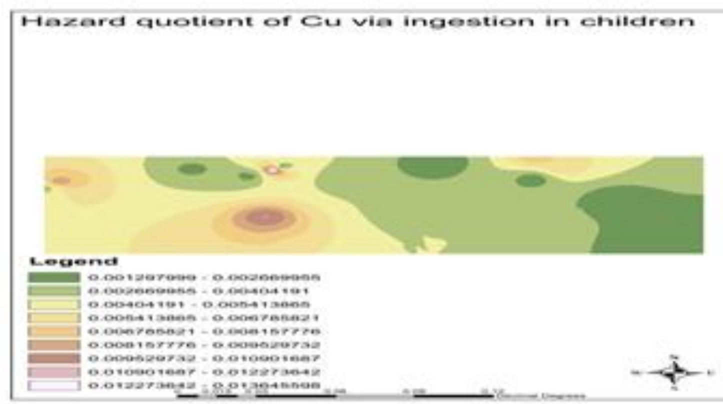

Hazard quotient of Cd via ingestion in adults
Legend


Hazard quotient of Cd via ingestion in children
Legend


Hazard quotient of Cu via ingestion in adults
Legend


Hazard quotient of Cr via ingestion in adults
Legend


Hazard quotient of Cr via ingestion in children
Legend


Hazard quotient of Cu via ingestion in children
Legend

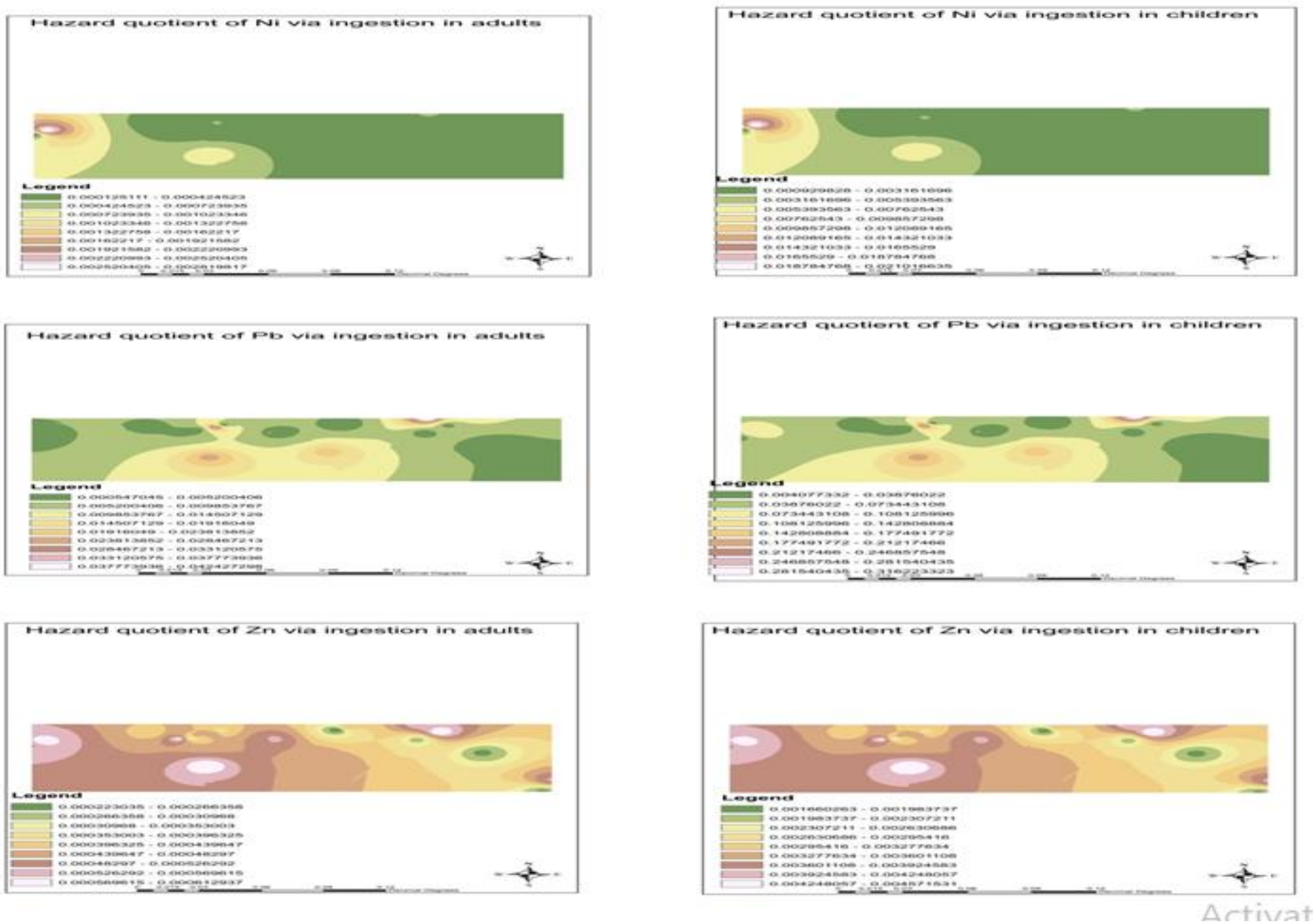
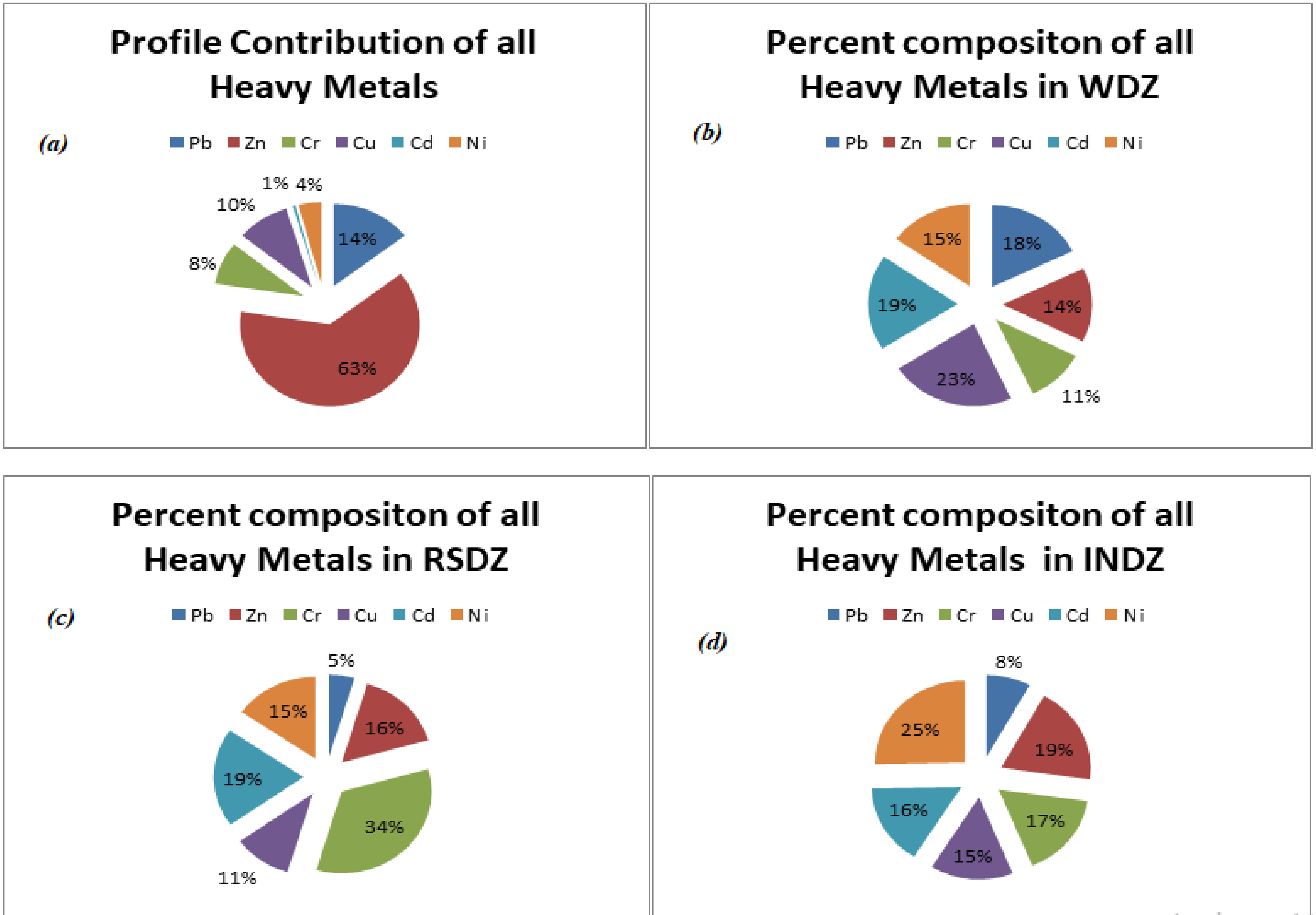
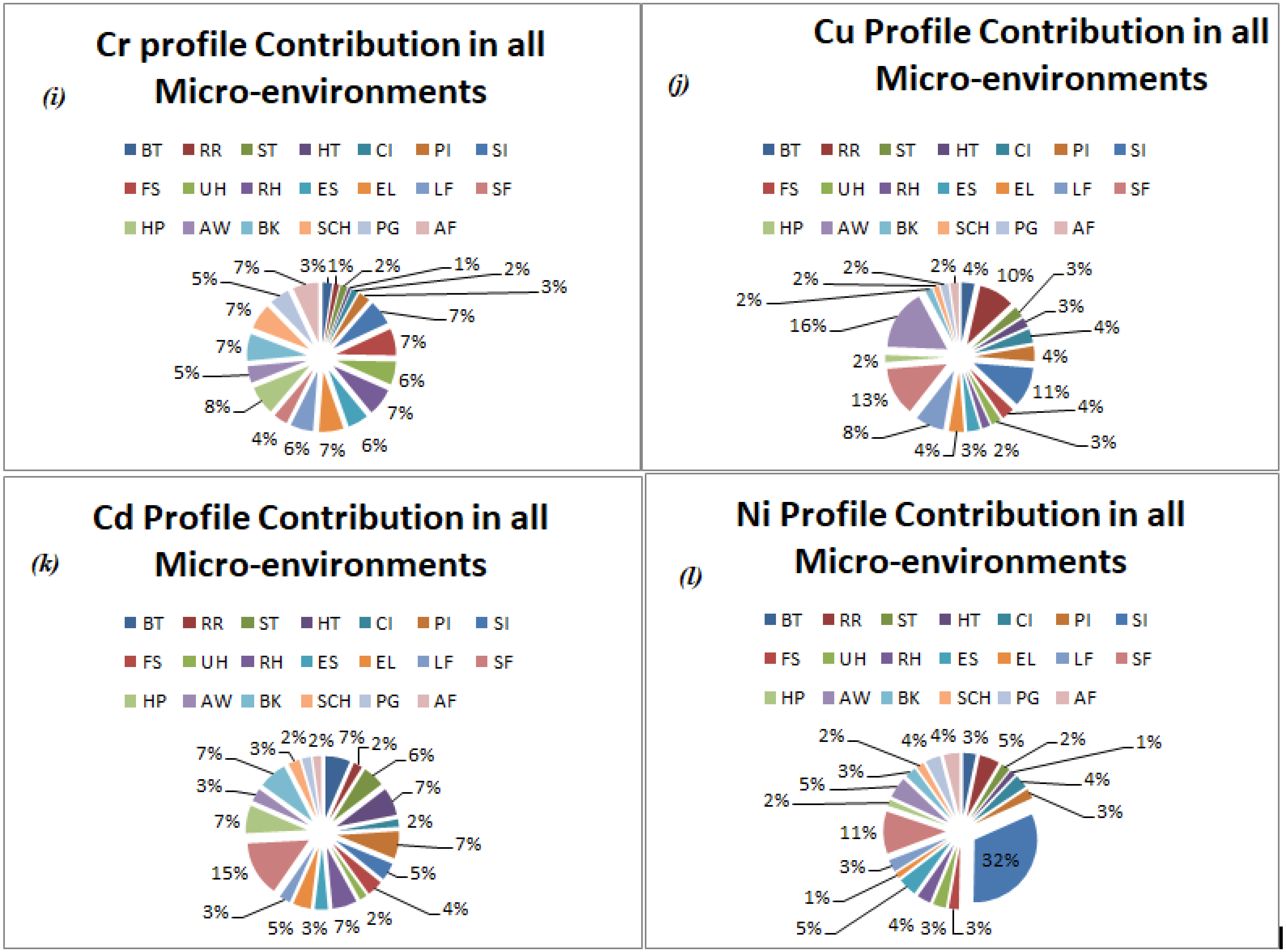


Fig.3. Hazard quotient of different heavy metals in adults and children via dust pollution is being interpolated in different zones of Peshawar Pakistan.


Profile Contribution of all Heavy Metals
(a)
Pb Zn Cr Cu Cd Ni
14%
63%
8%
10%
1%
4%
Percent compositon of all Heavy Metals in WDZ
(b)
Pb Zn Cr Cu Cd Ni
18%
14%
11%
23%
19%
15%
Percent compositon of all Heavy Metals in RSDZ
(c)
Pb Zn Cr Cu Cd Ni
5%
16%
34%
11%
19%
15%
Percent compositon of all Heavy Metals in INDZ
(d)
Pb Zn Cr Cu Cd Ni
8%
19%
17%
15%
16%
25%


(i)
Cr profile Contribution in all Micro-environments
BT RR ST HT CI PI SI
FS UH RH ES EL LF SF
HP AW BK SCH PG AF
(j)
Cu Profile Contribution in all Micro-environments
BT RR ST HT CI PI SI
FS UH RH ES EL LF SF
HP AW BK SCH PG AF
(k)
Cd Profile Contribution in all Micro-environments
BT RR ST HT CI PI SI
FS UH RH ES EL LF SF
HP AW BK SCH PG AF
(l)
Ni Profile Contribution in all Micro-environments
BT RR ST HT CI PI SI
FS UH RH ES EL LF SF
HP AW BK SCH PG AF
32%

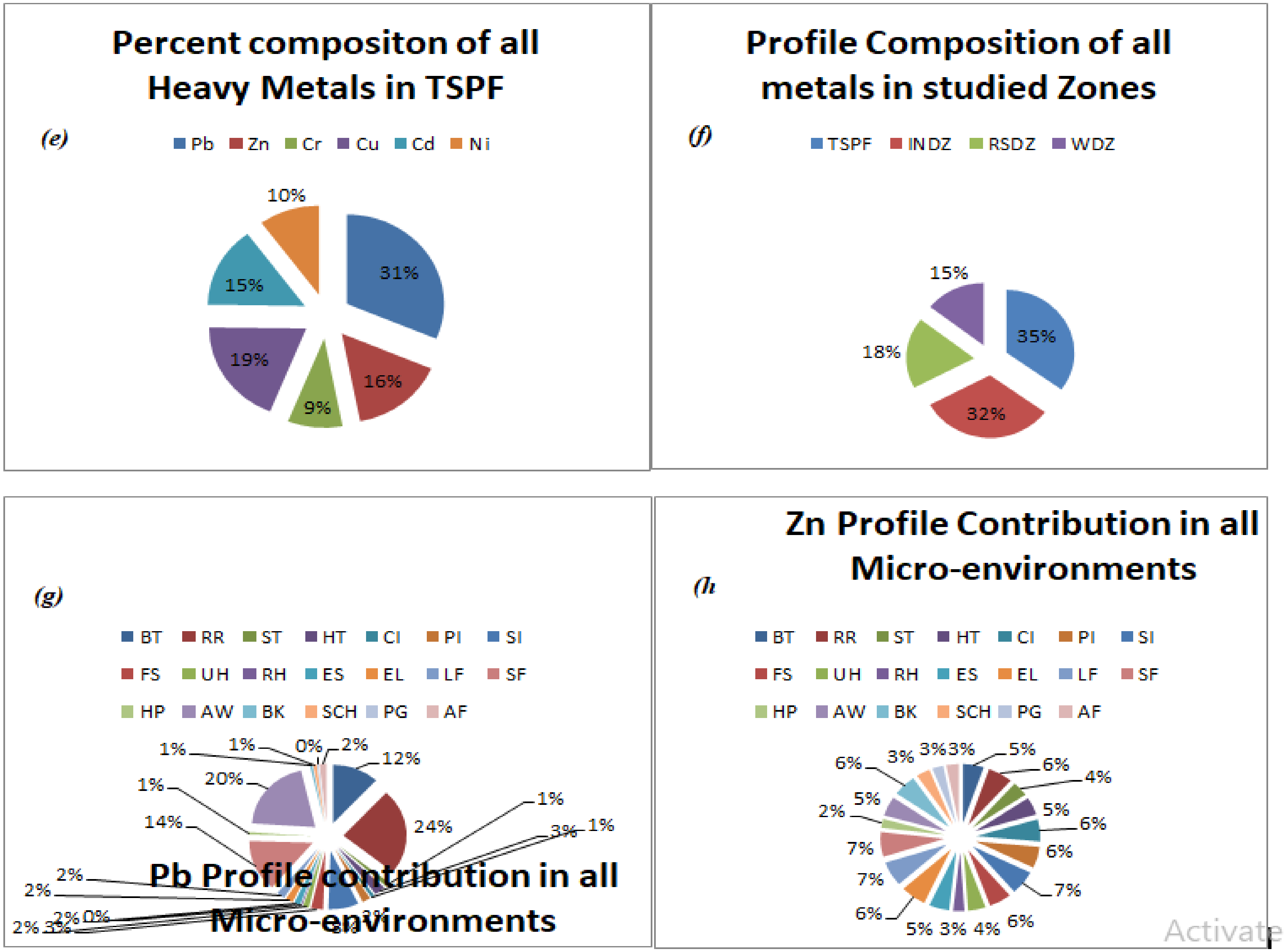


Fig 4 (a, b, c, d, e, f, g, h , I ,j ,k, l) showing Percent composition /contribution

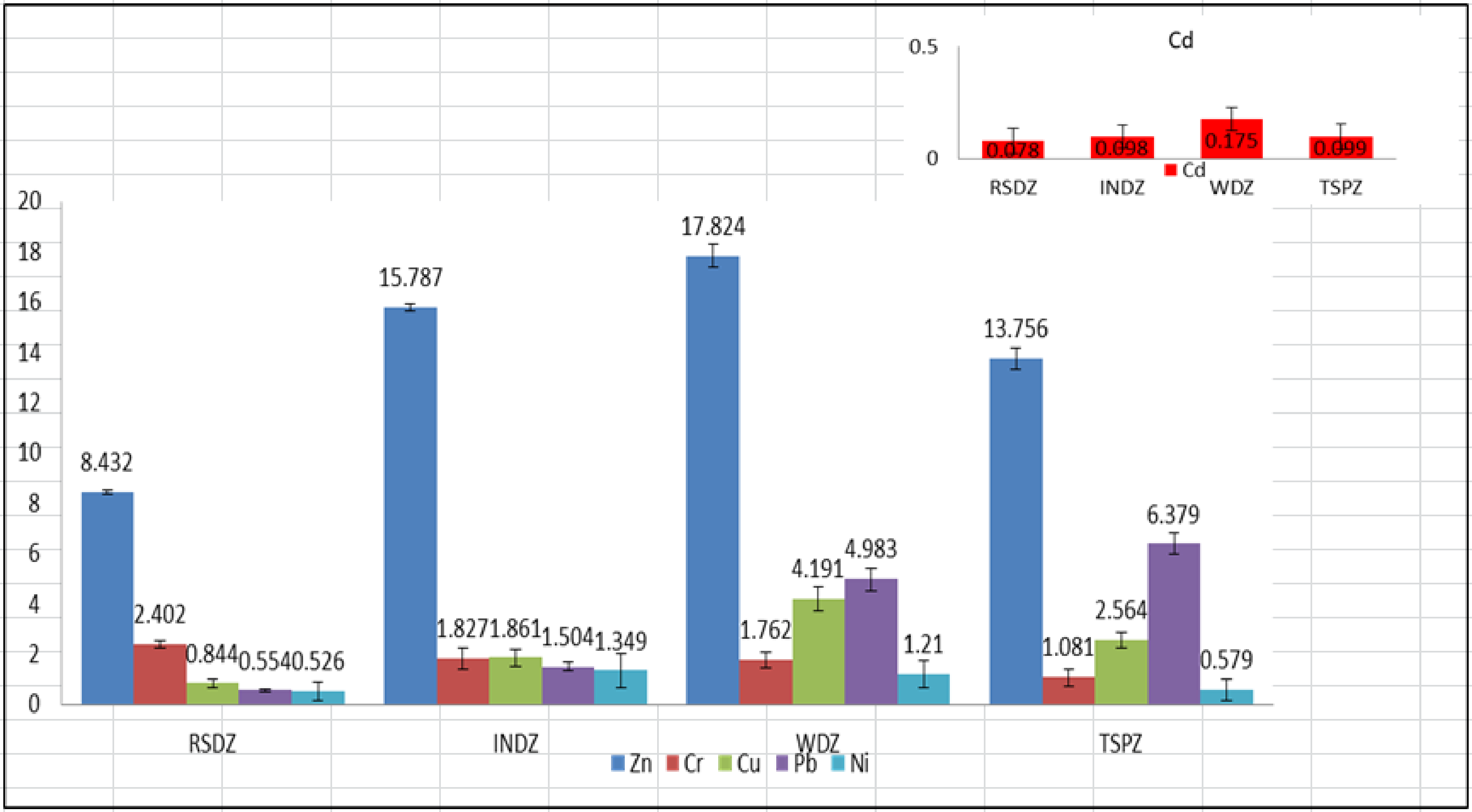


Fig.5. Bar Graph summarizing the concentrations of each heavy metal in all the four zones with error bars.

APPENDIX

Table.1. Exposure factors for dose models for both children and adults

Factor	Definition	Unit	Valure	
			Children	Adults
C	concentration of the contaminant in dusts	mg/kg		
R_{ing}	ingestion rate of soil	mg/day	200	100
EF	exposure frequency	days/year	350	350
ED	exposure duration	years	6	24
BW	average body weight	kg	15	55.9
AT	average time	days	365*ED	365*ED
CF	conversion factor	kg/mg	1*10-6	1*10-6
R_{inh}	inhalation rate	m3/day	5	20
PEF	particle emission factor	m3/kg	1.32*109	1.32*109
SA	surface area of the skin that contacts the dust	cm2	1800	5000
SL	skin adherence factor for dust	mg/cm2	1	1
ABS	dermal absorption factor (chemical specific)		0.001	0.001

Table.2 RDF

	RfD_{ing} mg/(kg-d)	RfD_{inh} mg/(kg-d)	RfD_{derm} mg/(kg-d)
Ni	0.02	0.0206	0.001
Cu	0.037	0.0402	0.0019
Zn	0.3	0.3	0.06
Cd	0.001	0.001	0.05
Pb	0.0035	0.00352	0.000525
Cr	0.005	0.0000286	0.00025

Table.3. Descriptive classes for ***Igeo*** values

Igeo value (log2 (x))	Igeo class	Designation of Dust Quality
Igeo_0	0	Uncontaminated
0<Igeo_1	1	Uncontaminated to moderately contaminated
1<Igeo_2	2	Moderately contaminated
2<Igeo_3	3	Moderately to heavily contaminated
3<Igeo_4	4	Heavily contaminated
4<Igeo_5	5	Heavily to extremely contaminated
Igeo>5	6	Extremely contaminated

Table.4.Descriptive statistics for Heavy metals concentrations in multiple micro-environments of Peshawar, KP, Pakistan

	Sites		**Pb**	**Zn**	**Cr**	**Cu**	**Cd**	**Ni**
RESIDENTIAL ZONE (RSDZ)	Hospitals (HP)	Mean±S.D	.40±.44	6.49±1.30	2.76±.23	.77±.30	.15±.05	.27±.18
		Range	.04-1.14	4.99-8.22	2.42-2.99	.56-1.29	.09-.22	.16-.59
	Urban Homes (UH)	Mean±S.D	.93±.94	11.69±1.48	2.22±.12	1.04±.59	.04±.03	.58±.22
		Range	.37-2.61	9.65-13.31	2.02-2.33	.65-2.06	.00-.09	.29-.87
	Rural Homes (RH)	Mean±S.D	.19±.14	7.47±.52	2.63±.14	.87±.42	.13±.05	.61±.25
		Range	.01-.39	6.73-8.04	2.43-2.75	.53-1.45	.09-.19	.37-.93
	Schools (SCH)	Mean±S.D	.52±.35	9.17±1.60	2.44±.26	.62±.11	.06±.04	.34±.42
		Range	.01-.89	7.04-10.80	2.06-2.76	.48-.78	.01-.12	.01-1.06
	Playgrounds (PG)	Mean±S.D	.20±.16	7.41±1.11	1.91±.31	.84±.42	.05±.03	.66±.45
		Range	.01-.44	5.87-8.82	1.40-2.20	.50-1.52	.01-.08	.20-1.28
	Agricultural Fields (AF)	Mean±S.D	1.08±1.07	8.37±2.08	2.45±.16	.92±.33	.04±.03	.70±.38
		Range	.08-2.76	5.16-10.91	2.26-2.62	.57-1.34	.02-.09	.25-1.06
INDUSTRIAL ZONE (INDZ)	Carpet Industry (CI)	Mean±S.D	.56±.18	16.11±3.05	.59±.33	1.48±.58	.04±.03	.60±.23
		Range	.33-.77	11.39-19.58	.18-1.03	.87-2.13	.02-.08	.43-.99
	Pharma Industry (PI)	Mean±S.D	1.28±.66	15.27±3.36	1.10±.20	1.63±1.07	.14±.02	.45±.08
		Range	.64-2.17	12.09-18.86	.92-1.37	.82-3.22	.12-.16	.36-.55
	Steel Industry (SI)	Mean±S.D	4.67±2.16	17.31±0.57	2.39±1.19	4.31±3.23	0.09±0.03	5.48±1.82
		Range	2.27-7.15	16.56-18.09	1.02-3.57	1.06-8.15	0.07-0.14	3.08-7.77
	Brick Kilns (BK)	Mean±S.D	.39±.37	15.47±2.52	2.58±.17	.76±.20	.15±.04	.49±.13
		Range	.06-1.03	12.98-18.10	2.38-2.84	.54-.98	.10-.20	.33-.70
	Electronic Shops (ES)	Mean±S.D	.96±.87	13.47±2.91	1.96±.48	1.37±.66	.07±.04	.83±1.30
		Range	0.6-2.30	9.33-16.38	1.15-2.41	.70-2.08	.03-.13	.16-3.15
	Electrical Shops (EL)	Mean±S.D	1.17±.79	17.07±1.40	2.34±.39	1.61±.45	.09±.06	.24±.15
		Range	.25-2.04	15.67-19.27	1.89-2.87	1.09-2.29	.00-.17	.07-.38
WASTE DUMPING ZONE (WDZ)	Landfills (LF)	Mean±S.D	1.31±.74	17.88±1.05	2.19±.33	3.11±1.32	.06±.02	.54±.16
		Range	.49-2.51	16.89-19.08	1.84-2.73	1.52-4.78	.03-.08	.35-.77
	Scrap Facility (SF)	Mean±S.D	8.66±1.62	17.77±1.82	1.34±0.24	5.27±3.20	0.29±0.41	1.88±1.84
		Range	6.90-10.38	15.66-19.73	0.98-1.57	2.28-9.63	0.05-1.01	0.76-5.15
TRANSPORT FACILITY (TSPF)	Bus Terminals (BT)	Mean±S.D	7.18±2.99	13.79±4.97	0.89±0.38	1.41±0.73	0.13±0.02	0.57±0.28
		Range	2.37-9.93	6.48-19.90	0.43-1.28	0.56-2.57	0.10-0.16	0.33-1.05
	Rail Roads (RR)	Mean±S.D	14.43±2.15	16.43±3.14	0.52±0.26	3.83±1.49	0.05±0.03	0.88±0.25
		Range	12.54-17.67	12.88-19.02	0.34-0.98	2.29-5.44	0.01-0.09	0.60-1.23
	Streets (ST)	Mean±S.D	.78±.67	10.66±2.81	.65±.30	1.15±.88	.11±.07	.39±.15
		Range	.33-1.96	7.76-14.70	.24-1.08	.53-2.68	.03-.21	.22-.55
	Heavy Traffic (HT)	Mean±S.D	1.73±0.53	12.82±3.21	0.26±0.22	1.01±0.38	0.15±0.05	0.25±0.21
		Range	1.19-2.58	8.22-15.52	0.05-0.63	0.67-1.51	0.10-0.21	0.01-0.49
	Filling Stations (FS)	Mean±S.D	1.86±0.84	14.77±1.62	2.56±0.16	1.40±1.37	0.08±0.06	0.45±0.49
		Range	1.09-3.03	12.37-16.41	2.39-2.75	0.45-3.76	0.01-0.15	0.04-1.27
	Auto Workshops (AW)	Mean±S.D	12.29±2.21	14.05±0.77	1.60±0.46	6.59±2.96	0.07±0.04	0.93±0.56
		Range	9.67-15.19	12.94-15.03	0.84-2.07	2.49-8.81	0.03-0.13	0.13-1.51

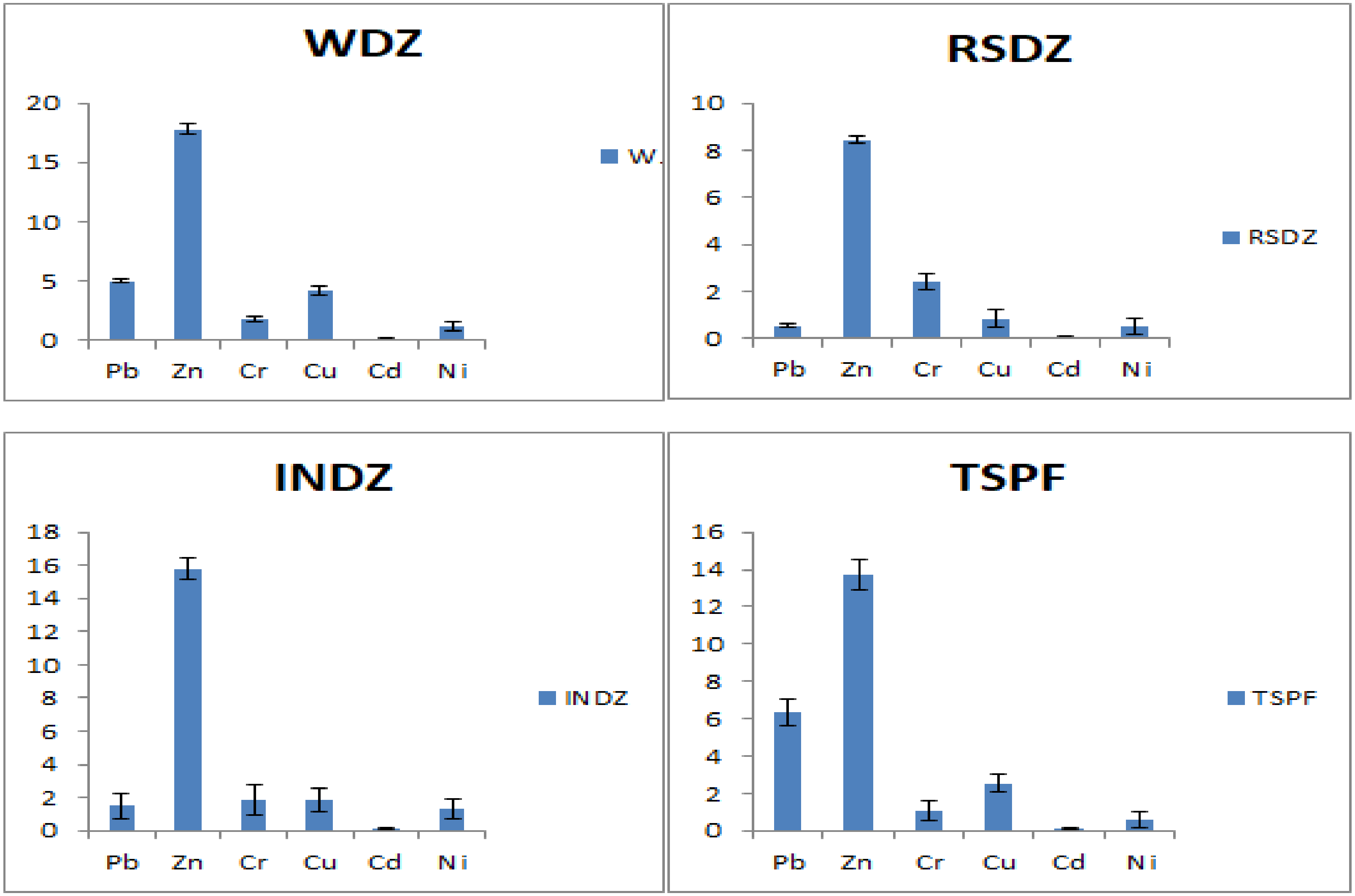


Fig.1. Bar diagram showing concentrations of studied heavy metals in all the four zones of Peshawar Pakistan

Results &Discussion

3.1. Heavy Metals Concentration in Dust Micro-environments:

3.1.1. Heavy metals concentrations in dust and their zone wise comparison

The descriptive statistics (minimum, maximum, mean and standard deviation) of the detected heavy metals i.e. (Pb, Cr, Cu, Cd, Ni, Zn) concentrations in dust at the different zones viz., INDZ, RSDZ, WDZ, and TSPF are summarized in Table.1, and Figure 2 &5. Highest overall heavy metals concentrations were recorded in TSPF followed by INDZ > RSDZ > WDZ. The overall high concentration of metals in TSPF was related to the six significant micro-environments in this zone i.e. BT, ST, HT, AW, RR and FS. The values of Cd, Cu, Pb and Zn in BT was four times higher than the background values in a study conducted by (Zheng et al., 2015). Elevated concentration of zinc at the junctions, up to 50 folds high level of lead in the siding area of Rail road, it also contains other heavy metals in large quantities (Wiłkomirski, Sudnik-Wójcikowska, Galera, Wierzbicka, & Malawska, 2011b). In a study conducted by (Xueping Li et al., 2017) the mean values of Ni, Cr, Cu, Pb, Zn and Cd in the dust of filling stations of Xi'an were 1.15, 1.19, 3.94, 4.42, 5.09, and 15.62 times higher than the background values. The concentrations of heavy metals like Cd, Cu, Pb, and Zn were higher than those in the Earth's crust, which conclude that the sources are more anthropogenic behind this metal increase (Kamani et al.). High elemental concentration was observed in the street dust in a study that was executed by (Shinggu, Ogugbuaja, Toma, & Barminas, 2010). In mechanical workshops metals like Zn and Fe are found in high concentration because of construction and bending and welding of Fe (Shinggu et al., 2010). In the Transport Facility Zone (TSPF), the studied metals showed the trend as Zn (19.900 mg/Kg) >Pb (17.670 mg/Kg) > Cu (8.806 mg/Kg) > Cr (2.749 mg/Kg) > Ni (1.508 mg/Kg) > Cd (0.207 mg/Kg). As transport facility (TSPF) encompasses BT, FS, RR, ST, HT and AW here the elemental pollution is all transport related like roads, streets etc. The high level of Zn concentration in TSPF is because of the fragmentation of car tires which is expected source of Zn in dust samples, the background value of Zinc is lower and is higher in the dust of heavy road traffic(Elik, 2003).The greatest loading of Zn can be inferred as airborne as its richness in atmospheric particles and it occurs in connection with other heavy metals like Cd and Cu (Yoshinaga et al., 2014). Zn can be mixed with dust via oil leakage as it is used in the lubricant additive Zinc diethyldithiophosphate(Cipurković et al., 2011). The high concentration of Zn in transport related facility can be attributed to metal construction works and bending and welding of Fe (Shinggu et al., 2010). In a study performed by (F. Li et al., 2016) Zn concentration in the dust related to transport was calculated as high as 171 mg/kg. Industrial Zone (INDZ), showed a concentration trend in the descending order as Zn (19.582 mg/Kg) > Cu (8.152 mg/Kg) > Ni (7.772 mg/Kg) >Pb (7.150 mg/Kg) > Cr (3.572 mg/Kg) > Cd (.203 mg/Kg). The mean concentration of Zn in the dust of an industrial zone was 514.5 mg/kg which was 6.6 times higher than the local natural soil, was the highest of the heavy metals in focus from the study of (Wan, Han, Yang, Yang, & Liu, 2016).The sources of Zn are varied in industrial zone like fossil fuels, metal manufacturing and fertilization (Cipurković et al., 2011). Waste Dump Zone (WDZ), revealed a metal concentration latter in the descending order Zn (19.729mg/Kg) >Pb (10.380 mg/Kg) > Cu (9.631 mg/Kg) > Ni (5.151 mg/Kg) > Cr (2.729 mg/Kg) > Cd (1.631 mg/Kg). In the study undertaken by (Ofudje, Alayande, Oladipo, Williams, & Akiode, 2014) the mean concentration of Zn in Ojota waste dumping zone was found to be 57.61. All the things that arise Zn pollution are thrown away in landfills which give rise to Zn pollution in these vicinities. The abundance of Zn in soil is also reported by (Hui et al, 2012). However the Residential Zone (RSDZ), depicted the similar concentration pattern in the studied heavy metals as Zn (13.309 mg/Kg) > Cr (2.990 mg/Kg) >Pb (2.760 mg/Kg) > Cu (2.060 mg/Kg) > Ni (1.284 mg/Kg) > Cd (0.219 mg/Kg). The studied samples of dust of Residential zone also presented high concentration of Zn as high as 76.2 mg/kg. The values of Zn in this study was higher than the control location which was noted the average concentration of 35.9 mg/kg (Shakya, 2013). According to the study of (Wong & Mak, 1997) Zn may come in Residential zone from atmospheric dust deposition which is resulted from wear and tear of automobile tires.

3.1.2. Heavy metals concentrations and distribution patterns in dust Micro-environments and their variations

The selected heavy metals concentrations in different dust micro-environments of Peshawar district with their descriptive summary of stats are shown (Table 4 appendix section). The overall metals trends at different dust microenvironment are: RR > AW > SF > SI > LF > BT > EL > FS > PI > BK > CI > ES > UH > HT > ST > AF > SCH > RH > PG > HP. At different dust microenvironment, the heavy metals concentrations were ranked in the order as: Zn >Pb> Cu > Cr > Ni > Cd.

3.1.2.1.Lead (Pb) concentration in dust Micro-environments:

The lead concentrations at different dust micro-environments were ranged between 0.01 (RH) to 17.67 (RR) mg/kg. Lead (Pb) in all the micro-environments followed the order rail roads (72.2 mg/Kg) > automobiles workshops (61.5 mg/Kg) > scrap facility (43.3 mg/Kg) > bus terminals (35.9 mg/Kg) > steel industry (23.4 mg/Kg) > filling stations (9.3 mg/Kg) > heavy traffic roads (8.6 mg/Kg) > landfills (6.5 mg/Kg) > pharmaceutical industries (6.4 mg/Kg) > electrical shops (5.8 mg/Kg) > agricultural fields (5.4 mg/Kg) > electronic shops (4.8 mg/Kg) > urban homes (4.7 mg/Kg) > streets (3.9 mg/Kg) > carpet industries (2.8 mg/Kg) > schools (2.6 mg/Kg) > hospitals (2.2 mg/Kg) > brick kilns (1.1 mg/Kg) > playgrounds (1 mg/Kg) > rural homes (0.9 mg/Kg). Out of all the twenty studied micro-environments lead level was the highest of all in RR measuring 72.2 mg/kg, the result was in agreement with the study of (Wiłkomirski et al., 2011b) in which the content of lead was higher many folds i.e. Pb level exceeded control level nearly 50 fold, especially in siding area.

3.1.2.2. Zinc **(Zn) concentration in dust Micro-environments:**

The concentrations of Zinc at different dust micro-environments were ranged between 4.992 (HP) to 19.9004 (BT) mg/kg. Zinc (Zn) presented the maximum concentration in the following descending order in all the micro-environments of district Peshawar i.e. landfills (89.4 mg/Kg) > scrap facility (88.8 mg/Kg) > steel industries (86.6 mg/Kg) > electrical shops (85.4 mg/Kg) > rail roads (82.2 mg/Kg) > carpet industries (80.6 mg/Kg) > brick kilns (77.4 mg/Kg) > pharmaceutical industries (76.4 mg/Kg) > filling stations (73.9 mg/Kg) > automobile workshops (70.3 mg/Kg) > bus terminals (69 mg/Kg) > electronic shops (67.4 mg/Kg) > heavy traffic roads (64.1 mg/Kg) > urban homes (58.4 mg/Kg) > street (53.3 mg/Kg) > schools (45.8 mg/Kg) > agricultural fields (41.8 mg/Kg) > rural homes (37.4 mg/Kg) > playgrounds (37 mg/Kg) > hospitals (32.5 mg/Kg). The concentration of Zn was found to be the highest in BT among all the twenty studied micro-environments, this result was in agreement with study carried out by (Zheng et al., 2015) in which the concentration of Zn was the highest among the other studied heavy metals.

3.1.2.3.Chromium (Cr) concentration in dust Micro-environments:

Chromium concentrations ranged between 0.046 (HT) to 3.572 (SI) mg/kg at different dust micro-environments of district Peshawar. Chromium (Cr) detection in the maximum concentration was noted in the following order in all the micro-environments i.e. hospitals (13.8 mg/Kg) > rural homes (13.2 mg/Kg) > brick kilns (12.9 mg/Kg) > filling stations (12.8 mg/Kg) > schools (12.2 mg/Kg) > agricultural fields (12.2 mg/Kg) > steel industries (11.9 mg/Kg) > electrical shops (11.7 mg/Kg) > urban homes (11.1 mg/Kg) > landfills (10.9 mg/Kg) > electronic shops (9.8 mg/Kg) > playgrounds (9.5 mg/Kg) > automobile workshops (8 mg/Kg) > scrap facility (6.7 mg/Kg) > pharmaceutical industries (5.5 mg/Kg) > bus terminals (4.5 mg/Kg) > streets (3.3 mg/Kg) > carpet industries (3 mg/Kg) > rail roads (2.6 mg/Kg) > heavy traffic roads (1.3 mg/Kg).

3.1.2.4.Copper (Cu) concentration in dust Micro-environments:

The concentrations of copper in different dust micro-environments stretched from 0.049 (FS) to 9.631 (SF) mg/kg. The results showed the concentration in the following descending order i.e. automobile workshop (32.9 mg/Kg) > scrap facility (26.4 mg/Kg) > steel industries (21.5 mg/Kg) > rail roads (19.2 mg/Kg) > landfills (15.6 mg/Kg) > pharmaceutical industries (8.1 mg/Kg) > electrical shops (8.1 mg/Kg) > carpet industries (7.4 mg/Kg) > bus terminals (7.1 mg/Kg) > filling stations (7 mg/Kg) > electronic shops (6.9 mg/Kg) > streets (5.7 mg/Kg) > urban homes (5.2 mg/Kg) > heavy traffic roads (5.1 mg/Kg) > agricultural fields (4.6 mg/Kg) > rural homes (4.3 mg/Kg) > playgrounds (4.2 mg/Kg) > hospitals (3.9 mg/Kg) > brick kilns (3.8 mg/Kg) > schools (3.1 mg/Kg).

3.1.2.5.Cadmium (Cd) concentration in dust Micro-environments:

The concentrations of cadmium were extended from 0.001 (EL) to 1.012 (SF) in different micro-environments of district Peshawar. The analyzed Cadmium metal was found in all the micro-environments in the following descending order i.e. scrap (1.45 mg/Kg) > brick kilns (0.75 mg/Kg) > hospitals (0.74 mg/Kg) > heavy traffic roads (0.73 mg/Kg) > pharmaceutical industries (0.72 mg/Kg) > bus terminals (0.65 mg/Kg) > rural homes (0.64 mg/Kg) > street (0.57 mg/Kg) > electrical shops (0.47 mg/Kg) > steel industries (0.46 mg/Kg) > filling stations (0.42 mg/Kg) > electronic shops (0.35 mg/Kg) > automobile workshops (0.34 mg/Kg) > schools (0.30 mg/Kg)

>landfills (0.29 mg/Kg) > playgrounds (0.24 mg/Kg) > rail roads (0.23 mg/Kg) > agricultural fields (0.22 mg/Kg) > carpet industries (0.20 mg/Kg) > urban homes (0.19 mg/Kg).

3.1.2.6. Nickel (Ni) concentration in dust Micro-environments:

The concentrations of Nickel at different dust micro-environments were ranged between 0.013 (HT) to 7.772 (SI) mg/kg. The order of the mean concentration of Nickel is as follows. Steel industries (27.4 mg/Kg) > scrap facilities (9.4 mg/Kg) > automobile workshops (4.7 mg/Kg) > rail roads (4.4 mg/Kg) > electronic shops (4.2 mg/Kg) > agricultural fields (3.5 mg/Kg) > playgrounds (3.3 mg/Kg) > carpet industries (3.1 mg/Kg) > rural homes (3 mg/Kg) > urban homes (2.9 mg/Kg) > bus terminals (2.8 mg/Kg) > landfills (2.7 mg/Kg) > brick kilns (2.5 mg/Kg) > filling stations (2.2 mg/Kg) > pharmaceutical industries (2.1 mg/Kg) > street (1.9 mg/Kg) > schools (1.7 mg/Kg) > hospitals (1.4 mg/Kg) > heavy traffic roads (1.3 mg/Kg) >electricals shops (1.2 mg/Kg).

3.2. Zones composition overview:

3.2.1. Transport Facility:

Metals in the transport facility (TSPF) were depicted in the following descending order i.e. zinc (412.665 mg/Kg) > lead (191.38 mg/Kg) > copper (76.93 mg/Kg) > chromium (32.42 mg/Kg) > nickel (17.373 mg/Kg) > cadmium (2.956 mg/Kg).

3.2.2. Industrial Zone:

Metals trend in the industrial zones is of the following category i.e. zinc (473.6068 mg/Kg) > copper (55.824 mg/Kg) > chromium (54.8 mg/Kg) > lead (45.12 mg/Kg) > nickel (40.483 mg/Kg) > cadmium (2.949 mg/Kg).

3.2.3. Residential Zone:

Residential zone revealed the concentration trend in the following descending order. Zinc (252.9671 mg/Kg) > chromium (32.06 mg/Kg) > copper (25.311 mg/Kg) > lead (16.61 mg/Kg) > nickel (15.788 mg/Kg) > cadmium (2.336 mg/Kg).

3.2.4. Waste dumping Zone:

Metals trend in waste dumping zone mimic the trend of that of Transport facility (TSPF) like, zinc (178.2445 mg/Kg) > lead (49.83 mg/Kg) > copper (41.909 mg/Kg) > chromium (17.619 mg/Kg) > nickel (12.099 mg/Kg) > cadmium (1.745 mg/Kg).

3.3. Analysis of Variance (ANOVA)

Analysis of Variance (ANOVA) was applied to all the four studied zones i.e. Residential Zone (RSDZ), Industrial Zone (INDZ), Waste Dump Zone (WDZ) and Transport Facility (TSPF). Each zone is a combination of very similar micro-environments. A total of twenty micro-environments were divided into four zones, three zones got a share of six micro-environments each on the basis of similarity while two micro-environments came under Waste Dump Zone (WDZ). Table.2 for the Analysis of Variance (ANOVA) shows if there is statistically significant difference between our zones means. In the case of Lead (Pb) the significant value is 0.00 (i.e., p= < 0.00) which is below 0.05 and therefore there is a statistically significant difference in the mean value of Lead (Pb) in the four studied zones. Same is the case with Zinc (Zn) for which the significant value is 0.00 (i.e., p= > 0.00) which is also below 0.005and there is a statistically significant difference in the mean value of (Zn) in the four studied zones. Chromium (Cr) and Copper (Cu) show same results i.e. the significant values for Chromium (Cr) and Copper (Cu) both are 0.00 (i.e., p <=0.00) and 0.00 (i.e., p <=0.00) respectively which both are below 0.05 and both show that there is statistically significant difference in the mean Chromium (Cr) and Copper (Cu) in the four zones. In the case of Nickel there was statistically significant difference between means of all zones, determined by one-way ANOVA 0.34 (i.e., p=0.34) which is also below 0.05 which illustrates that there is statistically significant difference in the means of Nickel (Ni). Only in the case of Cadmium (Cd) the significant value is .103 (i.e., p=.103) which is not below 0.05 and therefore there is no statistically significant difference in the mean of Cadmium (Cd) in different zones taken. The cause of this significant indifference of Cadmium (Cd) in the four studied zones is that Cadmium (Cd) is found in the Earth's crust and the average concentration of Cadmium (Cd) in the Earth's crust is about 0.2 µg/g (Nigeria, 2012).

3.4 Profile Contribution:

Figure 4(a) shows the overall percent contribution of all studied heavy metals at different micro-environments. Zinc contribution (63%) was reported as highest in all the micro-environment followed by Pb (14%) > Cu (10%) > Cr (8%) > Ni (4%) The order of contribution for all the studied metals at RSDZ were ranked as: Cr (34%) > Cd (19%) > Cu (11%) > Ni (15%) > Zn (16%) >Pb (5%) (Figere 4.b).). While in the WDZ, Copper (Cu) contributed to about 23% followed by Cd (19%) >Pb (18%) > Ni (15%) > Zn (14%) > (11%) (Figure 4.c). But on the other hand, Ni at INDZ has recorded highest contribution of 25% as compared to other metals that were ranked as: Zn (19%) > Cu (15%) > Cd (16 %) > Cr (17%) >Pb (8%) (Figure 4d).

The percent contribution of the selected heavy metals in TSPF and their order of % contribution were in the order of: Pb (31%) > Cu (19%) > Cd (16%) = Zn (16%) > Ni (10%) > Cr (9%) (Figure 4.e).

Zonal contribution to heavy metals indicated that TSPF is contributing 35% followed by INDZ (32%) > RSDZ (18%) > WDZ (15%) (Figure 4.f).

The contributing frequency of Lead in descending order in all micro-environments are RR (24%) followed by AW (20%) > SF (14%) > BT (12%) > SI (8%) > HI (3%) = FS (3%) > PI (2%) = UH (2%) = ES (2%) = EL (2%) = LF (2%) = AF (2%) > ST (1%) = CI (1%) = HP (1%) = BK (1%) = SCH (1%) > RH (0%) = PG (0%).(Figure 4.g).

Zinc contribution was confirmed in dust of all micro-environments in descending order where Zinc in SI, LF, SF (7%) was the highest followed by RR (6%) = CI (6%) = PI (6%) = FS (6%) = EL (6%) = BK (6%) > BT (5%) = HT (5%) = ES (5%) = AW (5%) > ST (4%) = UH (4%) > RH (3%) = SCH (3%) = PG (3%) = AF (3%) > HP (2%) (Figure 4.h)

The load of Chromium concentration in the dust of micro-environments of Peshawar contributed in the descending pattern where HP was (8%) followed by SI (7%) = FS (7%) = RH (7%) = EL (7%) = BK (7%) = SCH (7%) = AF (7%) > UH (6%) = ES (6%) = LF (6%) > AW (5%) =PG (5%) > SF (4%) > BT (3%) = PI (3%) > ST (2%) = CI (2%) > RR (1%) = HT (1%)(Figure 4.i)

The trend of Copper contribution in the dust of studied micro-environments of Peshawar was of the order AW (16%) followed by SF (13%) > SI (11%) > RR (10%) > LF (8%) > BT (4%) = CI (4%) = PI (4%) = FS (4%) = EL (4%) > ST (3%) = HT (3%) = UH (3%) = ES (3%) > RH (2%) = HP (2%) = BK (2%) = SCH (2%) = PG (2%) = AF (2%) (Figure 4.j)

Yet a different trend of Cadmium contribution was seen in the dust of micro-environments of Peshawar, SF was having Cd contribution at 15% followed by BT (7%) = HT (7%) = PI (7%) = RH (7%) = HP (7%) = BK (7%) > ST (6%) > SI (5%) = EL (5%) > FS (4%) > ES (3%) = LF

(3%) =AW (3%) = SCH (3%) > RR (2%) = CI (2%) = UH (2%) PG (2%) = AF (2%) (Figure 4.k)

However Nickel profile contributions in micro-environments of Peshawar district were of the order, SI (32%) followed by SF (11%) > RR (5%) = ES (5%) = AW (5%) > CI (4%) = RH (4%) = PG (4%) = AF (4%) > BT (3%) = PI (3%) = FS (3%) = UH (3%) = LF (3%) = BK (3%) > ST (2%) = HP (2%) = SCH (2%) > HT (1%) = EL (1%)(Figure 4.l).

3.5. Average daily dose ADD results

3.5.1. ADD $_{ing}$

The trend of Average daily dose via, ingestion in children for different heavy metals in the TSPF was Zn >Pb> Cu > Cr > Ni > Cd. In INDZ the ADD $_{ing}$ in children showed the following order Zn > Cu > Cr >Pb> Ni > Cd. However the recorded order of ADD $_{ing}$ in children in RSDZ was Zn > Cr > Cu >Pb> Ni > Cd. Last but not the least WDZ revealed ADD $_{ing}$ in children of heavy metals in the pattern Zn >Pb> Cu > Cr > Ni > Cd.

Average daily dose via, ingestion in adults in TSPF mimics the same pattern as that of ADD $_{ing}$ in children i.e. Zn >Pb> Cu > Cr > Ni > Cd. In INDZ ADD $_{ing}$ in adults was of the pattern Zn > Cu > Cr >Pb> Ni > Cd. Heavy metals were ranged in a layout for ADD i$_{ng}$ for adults in RSDZ as Zn >Pb> Cu > Cr > Ni > Cd. The stretched order of ADD$_{ing}$ in TSPF adults imitates the same as that of ADD $_{ing}$ in children i.e. Zn >Pb> Cu > Cr > Ni > Cd.

3.5.2. ADD $_{inh}$

The pattern of ADD via inhalation in children in TSPF for the studied heavy metals in descending order extended from Zn >Pb> Cu > Cr > Ni > Cd. The occurrence order of ADD $_{inh}$ in children in INDZ for heavy metals was Zn > Cu > Cr >Pb> Ni > Cd. The state of occurrence of heavy metals in RSDZ for ADD via, inhalation in children be like Zn > Cr > Cu >Pb> Ni > Cd, and in WDZ the order of distribution of heavy metals for ADD$_{inh}$ in children was Zn >Pb> Cu > Cr > Ni > Cd.

Average daily dose via, inhalation in adults occurrence structure in TSPF revealed the order Zn >Pb> Cu > Cr > Ni > Cd. For INDZ the trend of ADD $_{inh}$ in adults was Zn > Cu > Cr >Pb> Ni > Cd. Average daily dose via inhalation in adults in RSDZ showed the following stretched descending order Zn > Cr > Cu >Pb> Ni > Cd. Yet WDZ resembles the same pattern as that of TSPF i.e. Zn >Pb> Cu > Cr > Ni > Cd.

3.5.3. ADD derm

The average daily dose via dermal contact with dust in children in TSPF revealed the order Zn >Pb> Cu > Cr > Ni > Cd. In INDZ the order was a bit different i.e. Zn > Cu > Cr >Pb> Ni > Cd. In RSDZ the heavy metals were lined up in the descending order like Zn > Cr > Cu >Pb> Ni > Cd. The distribution of heavy metals for ADD_{derm} for children in WDZ was exactly the same as that of TSPF i.e. Zn >Pb> Cu > Cr > Ni > Cd.

The plan of occurrence of heavy metals for ADD via dermal contact of dust for adults, in TSPF was Zn >Pb> Cu > Cr > Ni > Cd. The lining up order of metals in INDZ for ADD_{derm} in adults be like Zn > Cu > Cr >Pb> Ni > Cd. The recorded descending order of RSDZ for average daily dose of heavy metals via, dermal contact is Zn > Cr > Cu >Pb> Ni > Cd. WDZ replicates the same order as that of TSPF for ADD_{derm} for children i.e. Zn >Pb> Cu > Cr > Ni > Cd.

Average daily exposure trend of the studied elements were regarded as by hand to mouth ingestion > dermal contact > inhalation. Because of hand-to-mouth activity of children ingestion is the main pathway to indoor dust (Lin, Fang, Wang, & Xu, 2015).

3.6. Hazard Quotient HQ

3.6.1. HQ_{ing}

The trend of Hazard Quotient via, ingestion in children for different heavy metals in the TSPF was Pb> Cr > Cd > Cu > Zn > Ni. In INDZ the HQ_{ing} in children showed the following order Pb> Cr > Cd > Ni > Zn >Cu.However the recorded order of HQ_{ing} in children in RSDZ was Cr >Pb> Cd > Zn > Ni > Cu. Last but not the least WDZ revealed HQ_{ing} in children of heavy metals in the pattern Pb> Cr > Cd > Cu > Ni > Zn.

Hazard Quotient via, ingestion in adults in TSPF mimics the same pattern as that of ADD_{ing} in children i.e. Pb> Cr > Cd > Cu > Zn > Ni. In INDZ HQ_{ing} in adults was of the pattern Pb> Cr > Cd > Ni > Zn > Cu. Heavy metals were ranged in a layout for HQ i_{ng} for adults in RSDZ as Cr >Pb> Cd > Zn > Ni > Cu. The stretched order of HQ_{ing} in adults in TSPF imitates the same as that of HQ_{ing} in children i.e. Pb> Cr > Cd > Cu > Ni > Zn. Figure 3 shows Hazard Quotient $_{ing}$interpolation of studied heavy metals in adults and children in the studied zones of Peshawar.

3.6.2. HQ_{inh}

The pattern of HQ via inhalation in children in TSPF for the studied heavy metals in descending order extended from Cr >Pb> Cd > Cu > Zn > Ni. The occurrence order of HQ_{inh} in children in INDZ for heavy metals was Cr >Pb> Cd > Ni > Zn > Cu. The state of occurrence of heavy metals in RSDZ for HQ via, inhalation in children be like Cr >Pb> Cd > Zn > Ni > Cu, and in WDZ the order of distribution of heavy metals for HQ_{inh} in children was Cr >Pb> Cd > Cu > Zn > Ni.

Hazard Quotient's occurrence structure via, inhalation in adults in TSPF revealed the same order as that for children i.e. Cr >Pb> Cd > Cu > Zn > Ni. For INDZ the trend of HQ_{inh} in adults was Cr >Pb> Cd > Ni > Zn > Cu. Hazard Quotient via inhalation in adults in RSDZ showed the following stretched descending order Cr >Pb> Cd >Zn > Ni > Cu. Yet HQ for WDZ resembles the same pattern as that of HQ for children i.e. Cr >Pb> Cd > Cu > Zn > Ni.

3.6.3. HQ derm

The HQ via dermal contact with dust in children in TSPF revealed the order Pb> Cr > Cu > Ni > Zn > Cd. In INDZ the order was a bit different i.e. Cr >Pb> Ni > Cu > Zn > Cd. In RSDZ the heavy metals were lined up in the descending order like Cr >Pb> Ni > Cu > Zn > Cd. The distribution of heavy metals for HQ_{derm} for children in WDZ was. Pb> Cr > Cu > Ni > Zn > Cd.

The plan of occurrence of heavy metals for HQ via dermal contact of dust for adults, in TSPF was exactly the same as that for children Pb> Cr > Cu > Ni > Zn > Cd. The lining up order of metals in INDZ for HQ_{derm} in adults and children were also the same i.e. Cr >Pb> Ni > Cu > Zn > Cd. The recorded descending order of RSDZ for Hazard Quotient of heavy metals via, dermal contact is Cr >Pb> Ni > Cu > Zn > Cd. WDZ replicates the same order for adults as that of HQ_{derm} for children i.e. Pb> Cr > Cu > Ni > Zn > Cd. The values of HQ and HI are given in Table.4. Both HI and HQ are having same trend for children and adults. The values of HQ for the three pathways of exposure decrease in the order of Ingestion > Dermal contact > inhalation. The primary pathway is ingestion that harms human health followed by dermal contact, inhalation ranks last in this order. HQ_{ing} contribute 80% to HI, which is consistent with other studies executed earlier (Du et al., 2013).

3.7. Geo-accumulation Index $I_{(geo)}$

The rank order for the average I_{geo} value in TSPF was Cd >Pb> Zn > Cu > Cr > Ni. In case of INDZ the decreasing order of average i_{geo} values was Cd > Zn >Pb> Cu > Cr > Ni. RSDZ showed average i_{geo} values in the descending order of Cd > Zn >Pb> Cr > Cu > Ni. In case of WDZ the i_{geo} values stretched in the following pattern Cd >Pb> Zn > Cu > Cr > Ni. The geo-accumulation index (I_{geo}) for the four zones and six studied heavy metals investigated is presented in Table.3. The results from the study show that mean of all the six heavy metals in

TSPF were of the class 1 of I_{geo} class i.e. 0 < igeo-1. The dust of TSPF was uncontaminated to moderately pollute with heavy metals. INDZ depicts the same I geo value i.e. 0 < igeo-1 and the same I geo class i.e. 1 along with RSDZ and WDZ which reveals that the dust in all these three zones were uncontaminated to moderately contaminate.

3.8. Hazard Index (HI)

3.8.1. HI children

Hazard Index (HI) occurrence pattern in children at TSPF was of the order Pb> Cr > Cd > Cu > Zn > Ni. INDZ showed HI values in children in following descending order Pb> Cr > Cd > Ni > Zn > Cu. The stretched order of HI in children in RSDZ was ranked as Cr >Pb> Cd > Zn > Ni > Cu. The lining up of Hi in decreasing order in WDZ for children was depicted as Pb> Cr > Cd > Cu > Ni > Zn. HI values of most of the heavy metals for children in all the four zones i.e. TSPF, INDZ, RSDZ and WDZ were below 1.0 indicating that there was no non-carcinogenic risk for children. Some of the heavy metals in the four studied zones were having high HI values than 1.0 indicating that there was a potential non-carcinogenic risk to children. These heavy metals having high HI values than 1.0 are Pb =4.195 of TSPF, Cr = 1.106 of RSDZ and Pb = 1.092 of WDZ. Children are more at risk of the heavy metals having HI values greater than1.0 because of their hand or finger sucking behavior, so the non-carcinogenic risk can't be ignored. Moreover local grown grains and vegetables consumption pose health risk to children (Liu et al., 2016). HI and HQ of six heavy metals for children are lower than safe level (=1) showing no risk from the metals. The decreasing order of HI for these metals is Cr >Pb> Cu > Ni > Zn > Cd. Some places have Pb concentration much higher than safe level. Lead should be given more attention to, even for HI value (HI = 0.741). Pb is widely spread in the urban environments which influence the health of children, and the ingestion of contaminated soil or dust is the main reason behind the blood Pb for children. In Shenzhen, China blood Pb accounts two third of the city children (Du et al., 2013). In case of Hazard index (HI) for adults the decreasing average values in TSPF revealed an order exactly the same in the case of children in TSPF i.e. Pb> Cr > Cd > Cu > Zn > Ni. HI in adults at INDZ imitates the order of that of Hi in children at INDZ i.e. Pb> Cr > Cd > Ni > Zn > Cu. The Hazard Index at RSDZ in adults was ranged in a layout Cr >Pb> Cd > Zn > Ni > Cu which resemble the same order as that of HI at RSDZ in children. The plan of occurrence of heavy metals at WDZ for HI in adults mimics its counterpart i.e. HI children at WDZ i.e. Pb> Cr > Cd > Cu > Ni > Zn.

3.9. Pearson's correlation Analysis (PCA)

Pearson's correlation coefficient measures correlation degree between metal data's logarithms (Omar Ali Al-Khashman, 2007).The correlation data of four zones is depicted in Table.7. A summary of the significant correlation ($p<0.01$) that was found in the heavy metals in the four studied zones is listed here: in TSPF significant correlation ($p<0.01$) was found between Pb and Cu (r = .726), Pb and Ni (r = .613), Cu and Cd (r = .464), Cu and Ni (r = 800.), and Cd and Ni (r =561). In INDZ significant correlation ($p<0.01$) was found between Pb and Cu (r = .814), Pb and Ni (r = .779) and Cu and Ni (r = .747). RSDZ shows significant correlation ($p<0.01$) between Cr and Cd (r = .546) and Cr and Ni (r = .519). 0.01 level correlations was shown in WDZ between Pb and Cr (r = .863) and Cd and Ni (r = .982). All of the above show that the pairs were strongly correlated at 99 % confidence level.

The significant correlation ($p<0.05$) was found between heavy metals in the four studied zones is summarized here: in TSPF significant correlation ($p<0.05$) was found between Pb and Zn (r = .428). In INDZ no 0.05 level correlation was calculated between heavy metals. In RSDZ level 0.05 correlation was found between Pb and Zn (r = .366), Zn and Cr (r = .362), Zn and Cd (r = .449) and Cu and Ni (r = .442). In WDZ significant correlation ($p<0.05$) was established between Cu and Cd (r = .716) and Cu and Ni (r = .745). All of the above show that the pairs were weakly correlated at 9 % confidence level. Some of the heavy metals show strong correlation which indicate similar geochemical behavior and same input sources (Boateng, Opoku, Acquaah, & Akoto, 2015).

3.10. PCA

PCA which is a method of multivariate data analysis was applied for the determination of heavy metals sources in dust samples with Kaiser's normalization and by applying Varimax rotation. As shown in Table.5. Factors loadings with a Varimax rotations as well as eigen values are calculated. The results indicated that there were two eigen values higher than 1, and these two significant factors explain 90.57% of the total variance. PC1 explains 63.23% of the total variance and loads heavily on Cu (0.296), Zn (0.634) and Pb (.706). Indeed PC1 is dominated by Pb, Zn and Cu with smaller concentrations from Cr, Cd, and Ni which suggests that the y mainly originate from anthropogenic and industrial activities. PC 2 explain 27.33% of the total variance and loadings on Cu (-0.147), Pb (-0.626) and Zn (0.766) which illustrates that they come from different anthropogenic activities related to PC1 sources. The plot of factors loadings showed the grouping of metals in PC1 and PC2 (Fig.1).

Conclusion

Taking Peshawar, Pakistan city for investigating six trace metals in the dust samples of her twenty micro-environments was the main theme of the study. In the present study the concentrations of Zn, Pb, Cr, Cu, Cd and Ni in the dust samples were measured by AAS. The dust samples were collected by dust pan and brush from multiple micro-environments of Peshawar during the period (27th September – 14th October 2016).This study gives an overall view on pollution levels and health risk posed by heavy metals in dust samples. Due to continuous increase in heavy metals and general environmental pollution globally in dust, the knowledge of risk assessment should be a priority. Increasing proper monitoring and ensuring safety of the citizens especially children who are more at risk due to heavy metal toxicity. Both the carcinogenic and non-carcinogenic health risks are within the acceptable range. For non-carcinogenic effects ingestion is the primary exposure pathway followed by dermal contact and inhalation.

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