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Review

Facts of the main rigorous heavy metals affecting Waterfowls health, genetics, and migration habits

Humaira Aslam[1], Manel Mansour[2], Shehla Honey[1], Muhammad Ahsan Ashraf[3], Aman Ullah[4], Ali Umar[3,*], Nazia Nusrat[1], Misbah Ullah Khan[1,*], Jehanzaib Sohail[1], Muhammad Mudassar Hashim[1], Muhammad waseem Aslam[1], Mustansar Abbas[1]

[1] Centre for Nanosciences, University of Okara, Okara 56130, Pakistan
[2] Department of Chemistry, University of Picardie, 80000 Amines, France
[3] Department of Zoology, Division of Science and Technology, University of Education, Lahore 54000, Pakistan
[4] Department of Zoology, Faculty of Life Sciences, University of Okara, Okara 56130, Pakistan
*** Corresponding authors:** Misbah Ullah Khan, misbahullahkhan143@uo.edu.pk; Ali Umar, aumar2102@gmail.com

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Abstract: Swans, geese, and ducklings falling under the Anatedae group are important waterfowls to water systems. In this study, migratory birds that cover long distances are affected by some environmental stressors, especially heavy metal contamination. Al, Pb, Hg, Cd, Ni, and other similar metals are received by water structures and are natural in water, but these metals in high concentrations negatively affect the quality of water. Birds drink the polluted water and feed on polluted food, which results in the bioaccumulation of these metals in their body tissues. It leads to several diseases in body organs such as the liver, kidneys, and brain, respiratory disorders, oxidative stress, and alterations in metabolism activities. Some heavy metals known include lead and mercury, which poison the enzymes, which are crucial in the energy metabolism, hence survival. Effects of long-term exposure are DNA change, hereditary disorders, and reproductive problems such as eggshell hardness and fertility. Birds and waterfowl in particular, which may act as bioassays of the ecosystem, have experienced falls in their population because of contamination from heavy metals, which affects food chains through migration. This can only be done through concerted efforts among nations, constant monitoring of the quality of water in these habitats, and controlling water pollution with a view to preserving these birds and their habitats.

Keywords: energy metabolism; heavy metals; health effects; genetic disorders; habitats; migration; Waterfowl

1. Introduction

Contamination of environmental matrices, which include but are not limited to soil, water, and sediments, is worrisome internationally as its presence portends negative effects on ecological and human wellbeing. Environmental matrices then mean the various phases that are present in the environment where pollutants can exist, be transported, or sequestered. Such matrices include air, water, soil, and biota, all of which have unique roles of antagonism and/or affinity to the pollutants. Several researchers have reviewed different ecosystems for heavy metals, primarily the contamination levels, mobility, and risk assessment. For example, Kim et al. [1] conducted a review of the work on the source, concentration, and health impact of trace elements in fine particles. They also found out that industrial emissions, automobile emissions, and those of natural origin were the major sources of trace element contamination. It pointed to a relative risk of a worsening rate of respiratory and cardiovascular ailments, consistent with an extended presence of these fine particles. These reviews play an important role in evaluating priority polluted pollutants and policy-making for the region with serious air pollution problems. In the same year, Liu et al. [2] evaluated heavy metal pollution in surface sediment of Changjiang River Estuary and noted concentrations of cadmium (Cd) and lead (Pb) above recommended standards, thus indicating ecological hazards. These results draw attention to the constant monitoring and policing of particular measures towards the prevention of the rate of metal pollution in water bodies.

Many other researchers have also investigated the levels of heavy metal pollution in soils, especially in areas that receive massive human impacts. For instance, Han et al. [3] evaluated the concentrations of heavy metals in the soils within a reclamation project in China and the ecological risks of As and Ma et al. [4] identified human health risks of Cd uptake in rice crops that are grown in polluted paddy soils in southern China. Their research was able to show that soil contamination not only hinders plant growth but also deposits toxic elements into the food chain, hence a health hazard to man. Yang et al. [5] built on this by evaluating the concentrations of heavy metals in vegetables that have been irrigated by sewerage sludge amended soil, where they noted that a number of metal concentrations surpassed the recommended maximum limits to allow for human consumption. Altogether, these investigations underline the importance of transitioning to sustainable soil management to minimize the risks of hazardous metal pollution and preserve global food security.

In the same way, research activities have also been directed towards assessing the implications of polluted pavement on traffic safety in the towns. Zhao et al. [6] assessed heavy metal pollution and the related health risks in urban street dust of a megacity located in Southwest China and observed contamination hotspots in the areas influenced by industries and automobile exhausts. Similarly, Zhao et al. [7] pointed out the eminent ecological and human health risks due to exposure to contaminated dust and soil in urban soil samples collected from Kano City, Nigeria. In particular, such findings draw attention to the need for the use of adequate measures of pollution regulation in the territory of existing and developing megacities in developing countries where the processes of industrialization and urbanization are intensively developing. Khan et al. [8] sought to determine the concentration levels of the most dangerous metals in dust collected from the petrol stations in Nigeria, where a high presence of lead (Pb) and chromium (Cr) was established, which, if inhaled, has severe health implications for the residents.

Together, these works imply a call for better and more coherent urban planning and proper utilization of cleaner technologies in order to reduce the concentration of heavy metals in urban settings. Apart from environmental matrices, heavy metals in soil or food crops have also become an area of interest due to their impact on human health. For example, Siddeeg et al. [9] COVID-19 pandemics and their impact on the concentration of heavy metals in consumed fruits. Abdulsalam et al. [10] also analyzed the concentrations of heavy metals in vegetables that were cultivated in the contaminated soil, and they proved that long-term consumption of contaminated produce poses a threat of developing chronic diseases. Similarly, in the current study, Afolabi et al. [11] assessed the health risks of consuming vegetables grown with reclaimed water in a peri-urban region.

This study has indicated that the levels of the heavy metal contamination differed depending on the type of water used in irrigation exercise; therefore, more frequent monitoring and assessment on the quality of water to be used in irrigation is central to enhancing the quality of produce for human consumption. Tetra's main research area is the effects of heavy metal pollution on ecosystems, including biodiversity, soil, and quality of water. Their study by Chen et al. [12] on the impact of anthropogenic impact on heavy metals in a tropical urban river investigated the sediment and also confirmed high ecological risks related to metals deposition. In the same way, Lima et al. [13] also revealed the distribution of heavy metal contamination in agricultural soils of the four mining sites in China and suggested potential ecological risk assessment needed for the identified hotspots. Their study provides good arguments for realizing the necessity of developing the integrated risk assessment that will take into consideration the aspect of the habitats' contamination and the impact of toxins on people. Zhao et al. [14] evaluated human intake and health risk of heavy metals in soil and edible food crops in a particular area of Pakistan for understanding the relation between soil pollution and food contamination. The knowledge acquired from such research helps to explain patterns of bioaccumulation of these pollutants and underscores the relevance of integrating approaches for addressing problems related to the emissions of heavy metals in different environments.

Water pollution, defined as the contamination of water in any water body, occurs when the concentrations of any foreign particles or substances within water have gone high from the set limit and have a negative impact on water quality. It encompasses all types of liquid pollution of sustainable water and thus comprises pollution in the oceans, seas, rivers, lakes, streams, groundwater, bays, and any other water residues. The term water pollution referred to aquatic contamination between two extremes. Increased and nutrient enhancement water reservoir from swage and fertilizers. Exposure through contaminated water by chemicals [15].

Specific things that cause the quality of water to deteriorate include toxic substances, those substances that need a lot of oxygen to decompose, radioactive substances, disease-causing germs, industrial wastes, domestic wastes, and all other easy-soluble substances. These Pollutants either deposit at the base of the water body or sometimes float and become distasteful for the water life; for instance, the standard of organic pollutants, algal pollutants, is more than required, and this leads to eutrophication, which means less oxygen for the water life. From the water cycle, they state that water absorbs from the soil and moves from the upstream (river) to the downstream (ocean) with organic and inorganic pollutants. The defined organic pollutant is biodegraded by the exercise of microorganisms and changed into a form that is useful for aquatic life. On the other hand, inorganic pollutants do not pose much threat to the environment because they spread widely and do not have harmful effects on nature [16].

Natural metals (elements) that have an atomic number greater than 20 and have a density greater than five times the water [17]. A heavy metal is any metal that forms toxicity in the environment. Heavy metals comprise some elements of metalloids, transition elements, lanthanides, and actinides. Heavy metals are also composed of some of the metalloids, the transition metals, the lanthanides, and actinides. Essential heavy metals are involved in pollution water pollution, land pollution. Any metal or metalloid species is called a pollutant if it is undesirable or exceeds the maximum contamination limit. Heavy metals are lead, cadmium, mercury, arsenic, chromium, copper, scandium, nickel, silver, zinc, and copper. Various kinds of organisms require a diverse quantity of these elements. However, the increased levels of these metals, as discussed below, are toxic and fatal to living organisms [18].

Heavy metal pollution in global environmental compartments and in various matrices is a major threat to both ecosystems and human health. The different studies corroborate that, therefore, the choice of an effective monitoring and management framework to tackle heavy metal pollution cannot be overemphasized. The researchers who carried out this study should consider undertaking other related studies within the future with an intention of identifying out more viable remediation strategies and policies that may help protect the environment and, by extension, the people within the society.

2. Review of literature

The present research work focused on heavy metal pollution in agricultural soils and around urban zones because they have severe impacts on the environment and human health. Some of the previous research has concerned spatial changes, distribution, and probable health implications of heavy metals in soils and plants. Similarly, analyzing the spatial characteristics and potential associated health risks of heavy metals within the agricultural soils of China, Xie et al. found considerable spatial variation along with the effect of environmental factors and human interventions [19]. Subsequently, Zeng et al. [20] built on this study through analysis of the distribution and health risk assessment of heavy metals in urban soils of a typical mining city in Hunan, China. In their study, mines were found to be among some of the principal contributors to heavy metal pollution, especially for risky heavy metals such as lead (Pb) and cadmium (CD). Likewise, Luo et al. [21] determined the level of heavy metal pollution in vegetable farming soils in Chengdu Plain, China, and this revealed that Cd and As are the most frequent heavy metal pollutants and have significantly high health risks to consumers through vegetable consumption. These findings bring into focus the importance of conducting regional risk assessments and ad hoc measures and approaches to controlling and minimizing the impact of heavy metals.

In mining regions and along the industrialized areas, soil and food crop pollution is the main challenge since there is a direct route of the heavy metals into the food chain. In a related study, Sharma et al. [22] studied the deleterious impacts of soil and food crops that are contaminated near mining lands and revealed that high concentrations of the three heavy metals of cadmium (Cd), lead (Pb), and mercury (Hg) not only affect the quality of the soil but also endanger the safety of the crops, resulting in severe health hazards to the inhabitants. Wu and colleagues, meta-analyzing the current situation of heavy metal contamination of food crops in China, discussed the general data and possibilities of health risks [23]. Consequently, it was determined that the levels of toxic heavies in food crops are equally high to the permissible level, to which close attention and well-spelled-out legislation are called for. Zhang et al. [20] analyzed selected heavy metals in the urban soil of Beijing, China, and the associated health risks and their distributions. The sources were mainly traffic emissions and industrial activities Hamid et al. [24] showed that contamination of soils and food crops by heavy metals such as cadmium, lead, and arsenic was very high in the industrial zone of Pakistan. The main sources of pollution described by participants included industrial effluent discharge, vehicle emissions, and treated wastewater used for irrigation. As the results of the Health Risk Assessment demonstrated, children and residents as a whole are potentially most endangered by non-carcinogenic and carcinogenic effects from these heavy metals, the main pathway of which is food crops soil contamination. The ecological impacts were also large, which included soil integrity and species composition/diversity within the ecosystem. The study highlighted pollution control measures, methods of soil rehabilitation, and enhancement of the general public health awareness standards which are listed in **Table 1**.

Yan et al. (2019) examined the spatial distribution and ecological risks to heavy metals in the surface sediment in the Bohai Sea, showing that heavy metals are prone to diffuse pollution through natural and anthropogenic sources and hence need horizontal management solutions [25]. Overall, these pieces of work have suggested the need for effective management and characterization of the sources and channels of heavy metals to develop intervention measures.

It should be noted that the general health risk of heavy metal distribution is not only inherent to agricultural soils and industrial regions but also exists in urban regions. Li et al. [26] examined the levels of heavy metals in vegetables cultivated near the closed and operating mines and established that chronic contact with polluted soil enhances the bioavailability of metals in the vegetable parts and poses serious health threats to inhabitants. Similarly, another study by Zhang and colleagues compared the distribution of heavy metals in soil and groundwater in areas with a landfill and a riverbed in Hangzhou, China, and showed how a landfill increased levels of heavy metals in soil and groundwater [27]. The study also pointed out the need to embrace better disposal methods in a bid to reduce the pollution associated with heavy metals. Wang et al. [28] studied heavy metal in urban street dust in China, and it revealed that the metals' level crossed the maximum permissible limit for both environmental and human health. Zhao et al. [29] studied the spatiotemporal characteristics and source contributions of heavy metals in agricultural soils in the Beijing-Tianjin-Hebei region, where high concentrations of metals were attributed to industrial emissions and the insufficient treatment of wastes. These results imply that the physical and social infrastructure that underpins the consumption space in the city needs to be protected from polluting our environment and threatening the wellbeing of citizens.

Furthermore, the study of heavy metal pollution has gone a notch higher, aiming at evaluating the pollution in definite contexts like paddy soils and urban soils. Sun et al. [30] analyzed the heavy metal concentrations of the agricultural soils and vegetables in Shandong, China; the results showed that Cd, Pb, and chromium (Cr) have become the dominant heavy metals with risks of threat to human health through the intake of contaminated vegetable crops. Li et al. [31] studied the distribution characteristics, sources, and risks of heavy metals in the urban soils of Shanghai, China, and concluded that industrial input and transportation emissions were the main causes of contamination. In the industrial village of Northwest China, the content of heavy metals for Zhao et al. [32] points to specific phytoremediation strategies to lower plant indicators and enhance the growth of soil. Huang et al. [33] evaluated the levels of heavy metals in paddy soil in Shouguang city, China, and pointed out both the geological and/or human origin of heavy metal pollution and called for improvement of land utilization to reduce risks of heavy metal content increase in paddy soil. These cumulative observations of the mentioned studies support the fact that an integrated approach for identification and remediation of contaminated heavy metals in varied ecosystems should take into account the specific environment of agriculture and industrializable of the region.

3. Research methodology

This work applied a systematic review of the current literature in probing the prevalence and consequences of heavy metal pollution of soil, sediments, and crops across the world. The study is a systematic and electronic search for an article that was published in the SCI with the help of ScienceDirect, SpringerLink, and IEEE Xplore in the period from January 2018 to January 2021. Article selection was done systematically using the following criteria: the studies had to be centered on heavy metal contamination, risk assessment, ecological risk, and health risk assessments. Studies that were inconclusive or that only had qualitative data on risk assessments were thus excluded from further analysis.

Contaminant data include heavy metal concentration, pollution indices, health risk assessment, and ecological impact. In order to protect the accuracy and credibility of the gathered data, the quality of the assessment procedure was established with the help of a systematic checklist. To assess the levels and distribution of heavy metals, descriptive statistics were used, while to assess danger factors within such concentrations, a qualitative approach was used.

Furthermore, the review found differences and similarities between regions of the world in order to institute areas of high risk and areas where limited information is available about heavy metal pollution. This allowed for dispassionate examination of the research questions and offered a rich source of data on the sources, distribution, and threats posed by heavy metal pollution.

4. Results and discussion

4.1. Water pollution

Figure 1, provides an idea on the water pollution, origin, and destination. It identifies two primary sources: those coming from the industries in the kind of chemicals or metallurgical products and agricultural wastes like pesticides or fertilizers that contaminate the river. It also seeped into oceans, groundwater, and other systems where they corrupted water with which they leaked. Bioaccumulation is a process that impacts the life existing in water bodies; disease is something by which people are impacted, and environmental vandalism is the other, which impacts the life in the affected region. This flow of water demonstrates how on time the issue of pollution is, especially because the effects are broader as well as sustainable.

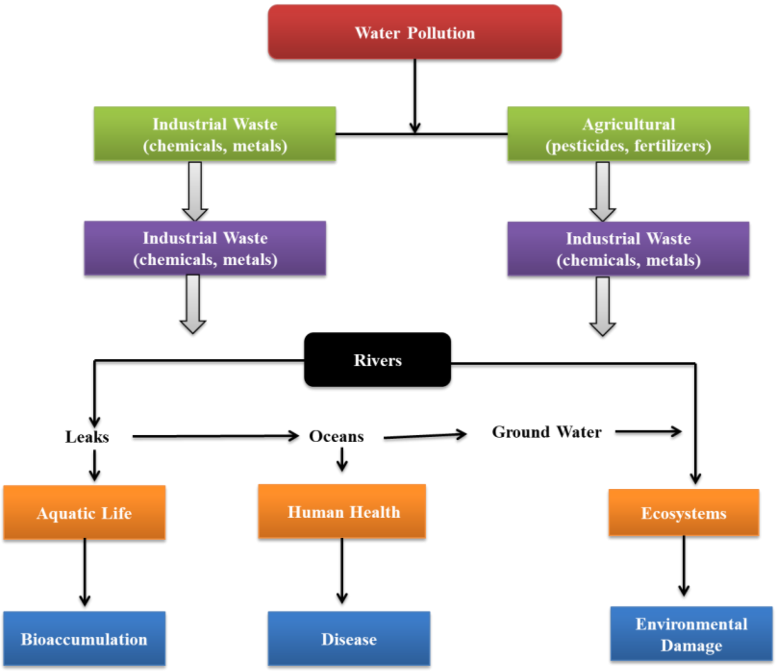

Figure 1. Schematically representation of water pollution.

4.2. Heavy metals

According to the nature as well as the extent of pollution influence exerted by heavy metals, **Figure 2** indicates this in a schematic manner. It shows how industrial pollution, agriculture, and urban drainage add to the release of metals, including lead, mercury, cadmium, and arsenic, into water sources. They are discharged into rivers, lakes, and the seas, disrupting water bio environments and polluting groundwater supplies. Bioaccumulation in aquatic organism's harms human health via food chain disease and toxic effects since the heavy metals accumulate in living organisms. As shown by the schematic, efficient and immediate control of the release of heavy metals into the environment becomes crucial to the conservation of ecosystems and health for the masses.

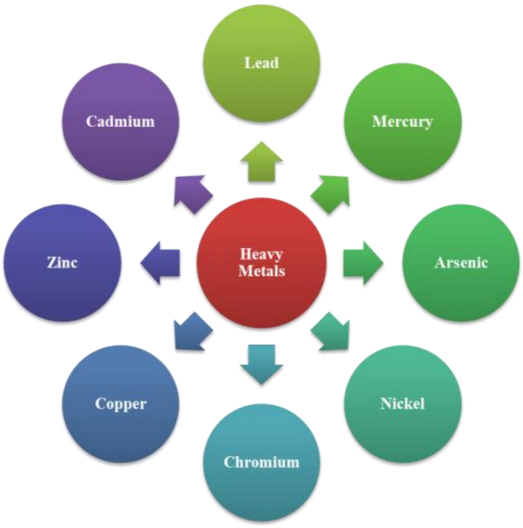

Figure 2. Schematically representation of heavy metals that are source of pollution.

4.3. Sources of heavy metals

There are a number of potential sources of heavy metals whose contribution to the concentration of these metals in different matrices, including soil, water, and air, is evident. Some/many of them can be geologically released, such as mercury (Hg), via natural ways like volcanic eruptions and weathering of rocks [34], but most of them are mobilized by human activities, including industrial processes, mining, farming, and urbanization [35]. For example, cadmium (Cd) is emitted to the environment through mining, products containing phosphate fertilizers, and other industrial wastes; lead (Pb) is primarily associated with automobile emissions, paint, and lead-acid batteries. Likewise, arsenic (As) is of both geological/geochemical origin, associated with volcanic activity, and geogenically derived or from anthropogenic sources like the use of pesticides and the burning of coal [36]. Nickel (Ni) and chromium (Cr) are often referred to as metals that are used in manufacturing and electroplating businesses. In addition, the sources of these heavy metals are not fixed since they can be flammable depending on the prevailing and other conditions coupled with the rise in human activities in certain areas. For instance, downtown evaluating higher lead and cadmium because of traffic and industrial impacts, and rural elevated arsenic and mercury because of farming and natural matter. Knowledge of these various sources is important in the formulation of effective measures to mitigate the effects of heavy metals as well as their ecological influence. (see **Table 1**).

Table 1. heavy metals and their source.

Heavy Metal	Sources
Chromium (Cr)	Chromium salts manufacturing Thermal power stations (coal-based) Steel and lead-acid battery manufacturing Leather tanning Industrial plants Chromium mining
Lead (Pb)	Bangle industry Coal-based thermal power plants Smelting operations Ceramics E-waste Paints and lead-acid batteries
Arsenic (As)	Thermal power plants Smelting operations Fuel combustion Natural and geogenic processes
Mercury (Hg)	Waste from hospitals (defective sphygmomanometers, barometers, thermometers) Electrical appliances Thermal power plants Chloroalkali plants Fluorescent lamps
Vanadium (Va)	Sulfuric acid plants Spent catalysts

Table 1. (*Continued*).

Heavy Metal	Sources
Copper (Cu)	Electroplating Mining Smelting operations
Zinc (Zn)	Smelting operations Electroplating Mining
Cadmium (Cd)	Waste batteries Paint sludge E-waste Zinc smelting Fuel consumption Incineration
Nickel (Ni)	Thermal power plants Smelting operations Battery industries
Molybdenum (Mo)	Spent catalysts (accounts for 70% of global supply)

These are various sources of different heavy metals when they cross the permissible limit in any water body and results in to water pollution. These pollutants are very toxic sometimes deadly and water quality which worsened their contribution enhance the mortality rate of water. Emission of these heavy metals: lead (Pb), cadmium (Cd), mercury (Hg), arsenic (As), chromium (Cr), copper (Cu), scandium (Sc), nickel (Ni), silver (Ag), and zinc (Zn) is associated with anthropogenic activity, which is a threat to the environmental balance. These pollutants enter ecosystems as urban and suburban drainage, industrial wastes, natural dissolutions and geochemical processes [37].

4.4. Waterfowl

There are so many classes of water birds but in relevance to this study we have chosen to work with water birds that include swans, geese and mallard which are all in the family Anatedae. Indeed, they have cosmopolitan distribution engaging in the process everywhere across the globe [38]. Floating or swimming on water surface characterize waterfowls. In some cases, they are adopted to diving in shallow waters. Water fowls comprises of 146 species in 43 genera. It requires mentioning that birds of the family Anatedae (waterfowls) are generally herbivisory, and they are known to be monogamous. It is known that the number of waterfowl species regularly performs annual migration. The majority of waterfowl species are not used for that purpose and many other waterfowl species are hunted for sport and food. 5 species of family Antares have become extinct and many more species have been threatened with extinction [39].

This **Figure 3**, sums the major life cycle and activity space events that landmark migratory birds. It is initiated by nesting in the marshes and lakes, then hatching in wetlands and ponds. Birds then make use of lakes, rivers, and wetland areas as their foraging or feeding areas. Crossings include rivers and coasts that direct migratory trajectories towards coastal or southern lakes in wintering grounds. As claimed, the cycle includes four stages: spawning in northern rivers and streams, building up in northern lakes and tundra areas, feeding on stocked fish in northern lakes and on salmon eggs in the rivers and streams throughout the year, and breeding in northern lakes and tundra areas.

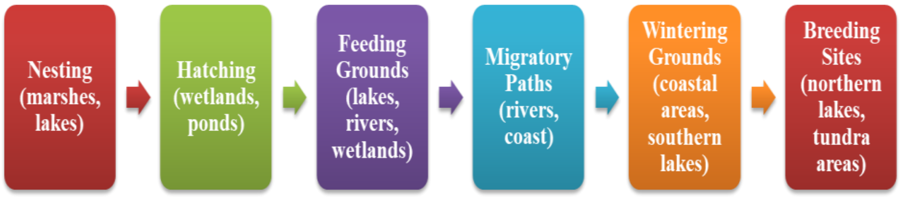

Figure 3. Schematically representation of Waterfowl.

4.5. Migration of Waterfowl

Pakistan is located geographically situated at 30.3753″ N 69.3451″ E in south Asia mid transit flight route of the middle voyaging flying bird migrating from West Asia to East Africa, large number of migratory birds visit wetlands in winter. This flying route is also referred to the International Migration route 4, Green route or better still Indus flyway. Some of them include water fowls, water birds and other migrant's birds from Siberia and across the Hindu Kush, Karakorum and Suleiman ranges along the Indus to delta.

This map in **Figure 4,** represents a path with an area of migration, which might be a bird's way across Central Asia. From Mongolia, Uus Nuur and Great Lakes Valley; major sites include Balkhash, Issyk-Kul, and Taukum in Kazakhstan, Kyrgyzstan, and Uzbekistan, respectively. A bridge path also passes through Afghanistan and Pakistan, including Registan, and turns back. These migration routes show important stopover and feeding grounds, which are so vital to the survival of the species.

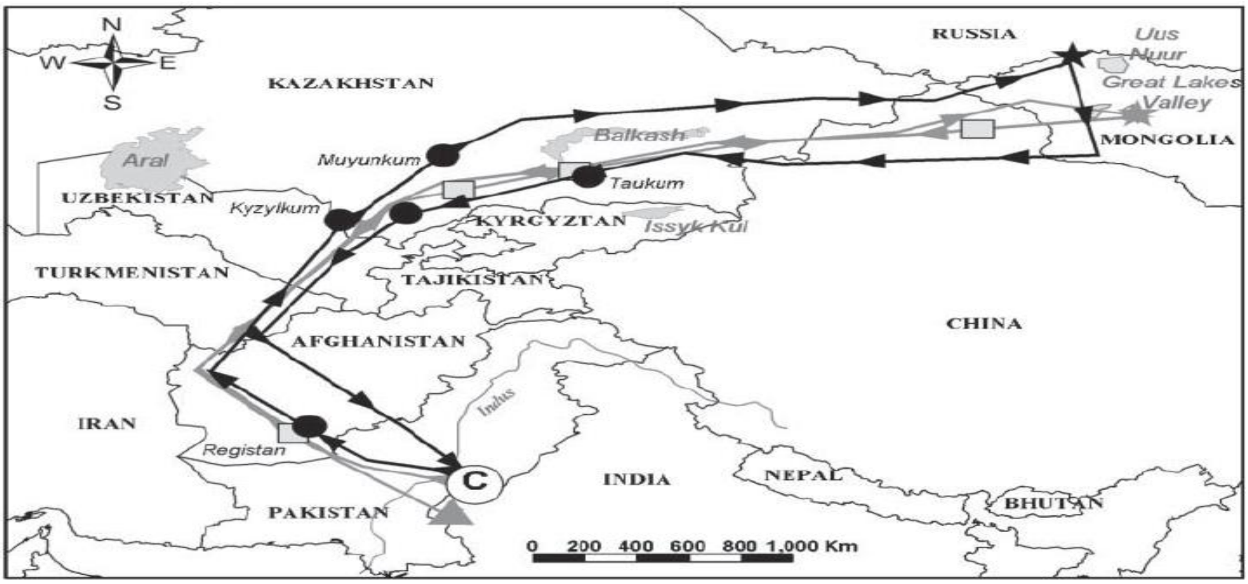

Figure 4. Map of migration route of Pakistan (Source: Google Maps).

Especially water fowls and other water birds migrating from Siberia to the wetlands and lakes of Pakistan have reduced drastically in very recent years. Some class of water birds departs its habitat in search of moderate climates where they find in India; but Pakistan is situated on their aerial course. These birds are resident at the wetlands of Pakistan [40–43]. Bird specials employ various water bodies ranging from lakes and other water bodies across the country. Tanda Dam (Kohat), Keenjhar Lake and southern parts of Punjab are other visiting places of water fowls. Over one million migratory birds from Siberia through Indus flyway with more than 100 species of waterfowls (cranes, teals, ducks, geese, mallard, gadwall etc.) travel approximately 4500 km.

4.6. Reasons of migration

One annual life cycle can be said to be accomplished through migration especially in the lives of birds and other animals. Moving from one region to another in search of favourable climatic conditions other than unfavorable weathers. For resting and breading during winter seasonife cycle of birds and other animals because it allows them to complete one annual life cycle. A number of waterfowl species engage in long-distance or local migration for a variety of reasons, including the following:

- In search of food
- In search of moderate weather to avoid harsh weather
- For resting and breading during winter season
- Due to habitat loss

This water reservoir was presumably covering 65 types of ducks in the year 1987–1988. However, the census conducted in the year 2010 shows that one is extremely fewer in number because many species of ducks and other migratory birds do not visit Pakistan due to one reason or the other. Lowered total of bird migrants can be blamed on other impacts that are either directly caused by people like land transformation with the reclamation of wetlands and decrease in forest area as well as on other effects that are precipitated by people such as change in climate and environmental degradation. Water bird-YNWSC migrants winter birds leave the breeding ground, which is Siberia in September October, and return again in end of March or start of April depending on their-YNWSC region [44–46].

This **Figure 5,** suggests the different influential aspects affecting migration. As pointed out above, movement is triggered by factors such as the appearances of heat or cold seasons and the scarcity or abundance of food. Breeding and nesting are further complements for optimal circumstances, whereas food resources dictate additional migration to regions containing more of the two. Another reason includes the need for better predator conditions, which forces the migratory species to shift to other areas with good favorable climate conditions with a view to survive and reproduce.

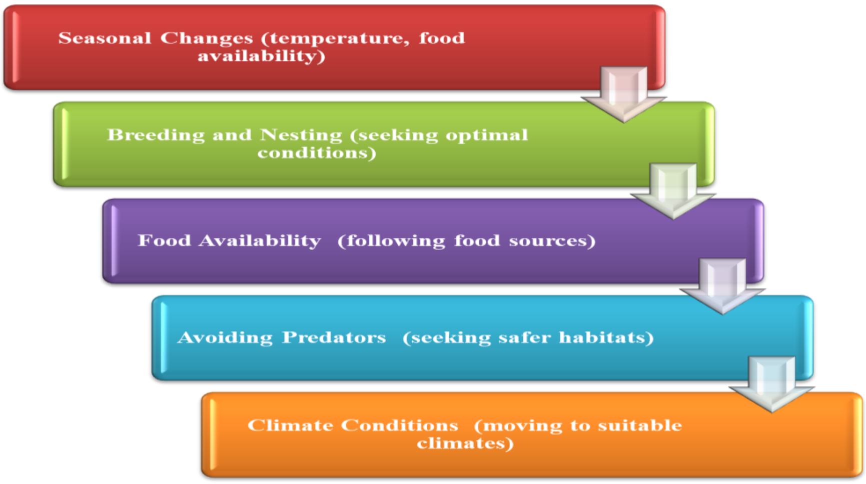

Figure 5. Schematically representation of reasons of migration.

4.7. Rout of exposure of heavy metals

Heavy metal environmental pollution has significant effects on water fowls as well as on other wild birds when they are exposed to heavy metal contamination even when they are exposed to sub lethal levels of these metals chronically [47–51]. There are various ways through which waterfowls' intake of heavy metals, these are (see **Figure 6**):

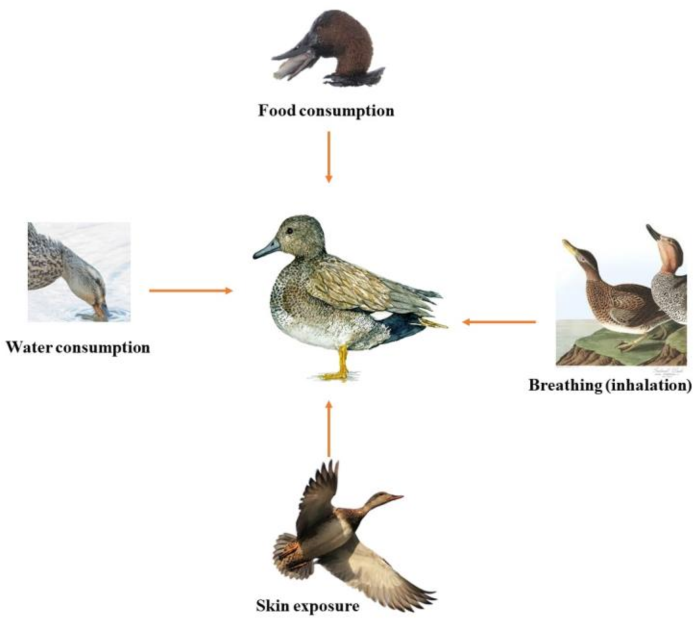

Figure 6. Rout of exposure of heavy metals.

Figure 6 represents, Birds can absorb heavy metals from contaminated food sources in the water and on the ground from various habitats they visit, such as wetlands, lakes, and agricultural fields. Another possibility is the consumption of pollutants present in the airspace through breath in the course of flying or at intermediate stopover points. These exposures can therefore build up in their bodies, having an impact on reproduction, immunity, as well as survival.

Ingestion of heavy metals through food in their diet is one of the most important routes by which solid heavy metals cumulate in the bodies of organisms [47]. Waterfowl birds's acquired heavy metals accidentally and indirectly through consumption of soil and sediments from the metal-impacted zone while searching for foods [48]. Lead (Pb) in waterfowls is also ingested from spent gunshots [49].

Bioaccumulation is not an easy process. In the following section, we establish the biotic and abiotic factors that enhance algal photosynthesis since the process is a detailed one. These two factors establish the mechanism for the accumulation of heavy metals in the environment. Route and duration of exposure and severity of metal have an impact on bioaccumulation as well as the biotic and abiotic factors. Out of the biotic factors, the food chain is the most crucial factor, but the abiotic factors, such as natural and man-made variations and fluctuations in the ppm levels of various metals in the soil, air, and water, besides abiotic factors influencing mobility and availability, and of which the physicochemical factors are said, other biotic behaviors such as foraging, migration, grit seeking, and trophic level all influence the amount of metal exposed [47–50]. This means that once heavy metals have been ingested into the system and have been incorporated into the blood, they will flow with the blood. With blood conveying oxygen and nutrients to the body tissues and organs as well as other regions of the body, metals conveyed through the blood also get to these tissues and organs. Metals have various infinities for the different tissues and organs, requiring variable affinity for lipids and solubility in a plethora of solutions, as demonstrated in **Table 1**. [37].

Besides the solubility and capacity to form the bond with the metal, there are other factors including the age of the person, his/her gender and weight and size, interaction with micro and macronutrients, moulting and reproduction, genes, and homeostatic mechanisms that define the concentration and distributions of the metal in various parts of the body [51]. From the factors cited above, age, however, remains influential when it comes to regulation of deposits of lead (Pb), mercury (Hg), and cadmium (Cd) in various organs and tissues on waterfowl. Moreover, increased levels of metals, especially mercury and cadmium, in the liver are actually linked with increased reproductive capability in waterfowls [52]. Therefore, the foraging activeness of waterfowls can be noticed in a number of sites when the birds feel that a particular place is less accommodating for feeding. There are so many varied kinds of foods that these birds feed on. The above-mentioned are some of the many varied types of foods that these birds feed on. These are stones and grits; soil; dried plant parts; grains; and vegetation that may have different metals and concentrations of metals. As is expected, habitats of waterfowl are subjected to different changes due to the variations in the factors that make up the environment. When food is scarce and their habitats have been altered, waterfowls experience indirect toxic impacts of hi Zeh metals [53].

The toxicants contaminate the water through watercourse inflow, leaching of water through the sub-surface, and air and water transfer from the rivers that are faced by the organisms of marine and estuarine water. The toxic compounds that are assimilated by the higher-trophic-level food organisms are at a higher concentration than the trophic levels below them. These toxicants are accumulated in greater concentrations in the tissues of organisms that are higher in the food chain hierarchy

[4]. In the environment, the metals are either native or incurred due to human exertions such as farming and businesses [5,6]. Sources of heavy metal pollution of soil and water are many and are always originating from one human activity or the other. The extraction of various heavy metals from mines such as Cd, Cr, Cu, Mn, Pb, and Zn has risen to 15, 18, 5, 8, 2, and 4 folds from 1930–1985, and these are emitted into the environment, and this causes some concern [7,8]. There is an alarming five-fold enrichment in the heavy metal concentrations in the wetland sediments of Northern Europe during the last century [7,9]. The birds inhabiting the polluted zones take up the metals through consuming the contaminated feed, but the direct consumption of metal-contaminated soil seems to be the main route observed in most species [7,10]. It may be ingested with feeds or deliberately as grit, which has an important role to play in the proper working of a gizzard. Hence, herbivorous ducks contain higher contents of grit in their gizzards than granivorous ducks [7,11]. Another source of metal ingestion in birds is grit, which may go along way in explaining variations in heavy metal concentrations in different species living in the same environment [7,12]. Metals are toxic in ecosystems and affect the wellbeing of wild life, and many of them get diseases. Avian species suggest the presence of environmental contaminants because they are abundant, widely distributed, occupy diverse trophic levels, and have long life expectancies [5,6]. Accounts for the use of many types of aquatic birds as biomarkers of aquatic environmental pollutants [5,13,14].

This **Table 2**, establishes that heavy metals have risen in the Pakistani soils and food crops due to industrial discharges, vehicular emissions, and irrigation using raw sewage; cadmium, lead, and arsenic are cases in point. Non-carcinogenic risks were identified in health risk assessments as being high, mainly for the children, while some vegetables had been found to contain contaminants that were above the acceptable levels in consumption. The studies focus on the pollution risks that the soil is exposed to and call for feasibility of interventions, greater constraints on industrial activities, and greater public enlightenment and education to avoid the dangers inherent in soil pollution.

Table 2. This table presents the summarized results of this study, specifically contamination level, health effects, and recommendations.

Parameter	**Key Findings**
Contamination Levels	Elevated levels of heavy metals (e.g., cadmium, lead, and arsenic) were detected in soil and food crops around industrial areas in Pakistan.
Primary Sources	Anthropogenic activities such as industrial discharges, vehicular emissions and the use of untreated wastewater for irrigation were identified as major pollution sources.
Health Risk Assessment	Health risk indices indicated both non-carcinogenic risks for residents in the affected areas, with children being at greater risk.
Dietary Exposure	Food crops grown in contaminated soils, particularly vegtables, showed significant accumulation of heavy metals,exceeding permissible limits for safe consumption.
Ecological Implications	The contamination posed significant ecological risks, threatening soil health and biodiversity in the impacted areas.
Recommended Actions	Urgent need for remediation strategies, stricter industrial regulations, and public awareness campaigns to mitigate exposure and reduce risks.

4.8. Significance of feathers as bio indictor of heavy metal pollution

It reveals that feather record lifetime integration and toxicant of heavy metals [54]. Mainly the feathers of waterfowls as well as other birds' feathers can be used in identifying and evaluating pollution by heavy metals in different parts of the world. Employment of the different forms of those feathers is very useful and important than the other parts of body of the waterfowls and other birds of similar characters. Unlike obtaining brains, kidneys, liver, hearts, gizzards and other body parts which requires killing and sometimes hurting of the waterfowls or other birds, feathers can be harvested from loving birds. They do not need to be refrigerated Bird decline is not possible on and toxicity 0f heavy metals [55]. Feathers of waterfowls and other birds are used to detect and assess heavy metal contamination in various areas. Use of different kinds of feathers is very significant and beneficial as compared to use of other tissues and organs of waterfowls and other migratory birds. There are various reasons behind this:

- Feathers can be collected from loving birds without killing or injuring the waterfowls or other birds whereas other organs and tissues such as brain, kidney, liver, heart, gizzard etc. cannot be collected from living organisms.
- Easy to collect and store
- Refrigeration is not required for their storage
- There is no risk of bird decline

Among the tissues and organs, feathers contain concentrations of various metals at a higher level than the other ones [56].

Consequently, feathers make good bioindicators of heavy metal pollution because metals may be incorporated in birds' diets or may directly affect exposed feathers. This makes them a good tool to monitor contamination indexes in birds, as well as whether they are residents or travelers through the area being evaluated. Fossil analysis is another area where feathers will have a great influence on the evaluation of ecosystem health and effects of pollution on birds in order to facilitate and inform avian conservation which is shown in **Figure 7.**

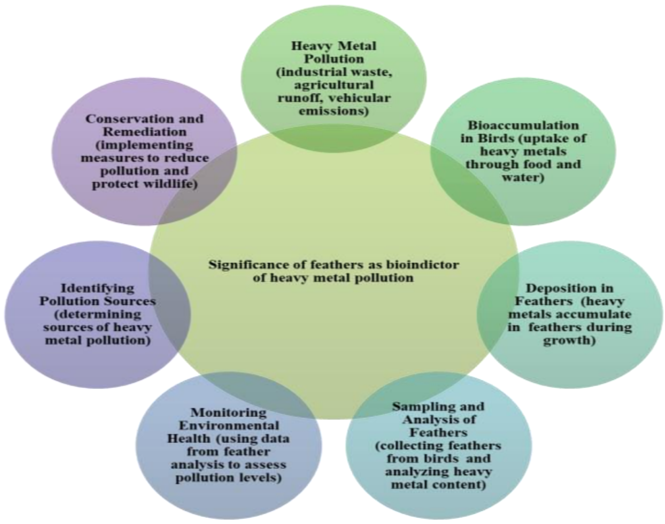

Figure 7. Representation significance of feathers as bio-indictor of heavy metal pollution.

4.9. Effects of heavy metals on birds

Disabilities in birds due to heavy metals are numerous and extensive and affected areas are as follows. Lead (Pb), employed in hunting actions, negatively influence the ability of nestlings to survive or grow; it leads to haemolytic anaemia in avian species; affects reproduction and brings about behavioural impediments [5,15–17]. The findings of 0,5 μg g^{-1} of Hg in eggs and 9–20 μg g^{-1} in feathers are associated with decline in reproductive rates [5,18]. Hg were found to thin and have abnormalities in the eggs, decrease eggs production and it has embryo toxic effects [5,19,20]. Though mercury (Hg) has been found to experimentally cause egg shell thinning [21,22], it has been mainly ignored [4]. They also lose appetite to eat hence they starve, have complications with their legs and wings, and poor co-ordination to walk or fly; convulsions, paralysis and death [5,17]. Calcium regulating action, phosphorus metabolism is also irritated by Al. This disruptive effect leads to a slow rate of growth and muscle atrophy [5,17]. The vital components or, rather, Cu Se, and Zn at high concentrations could also exert toxic effects on the kidneys and reproductive system [5,23,24]. Cadmium belongs to trace element which is not essential for human and animal and due to its usage in industries it is found abundantly in earth crust. renal toxicity, disturbance in calcium metabolism, intestinal tissue lesions, decrease in the thickness of eggshells and decrease in the feed intake [5, 25–27].

A conceptual map of the impacts of heavy metals for birds only would represent the major ways through which birds are likely to come into contact with a heavy metal, mainly through ingestion, inhalation, and via the skin and absorption, hence bioaccumulation. They would include such effects as made negative by the toxicity, which are, for instance, reproductive capacity suppression, neurological disorders, stunted growth, immune system suppression, and behavioral shifts. The freeware map could also portray secondary effects such as loss of the biosocial community, decrease in the size of the population, and disturbance of the food chain, thus emphasizing the need to control and prevent heavy metal pollution shown in **Figure 8**.

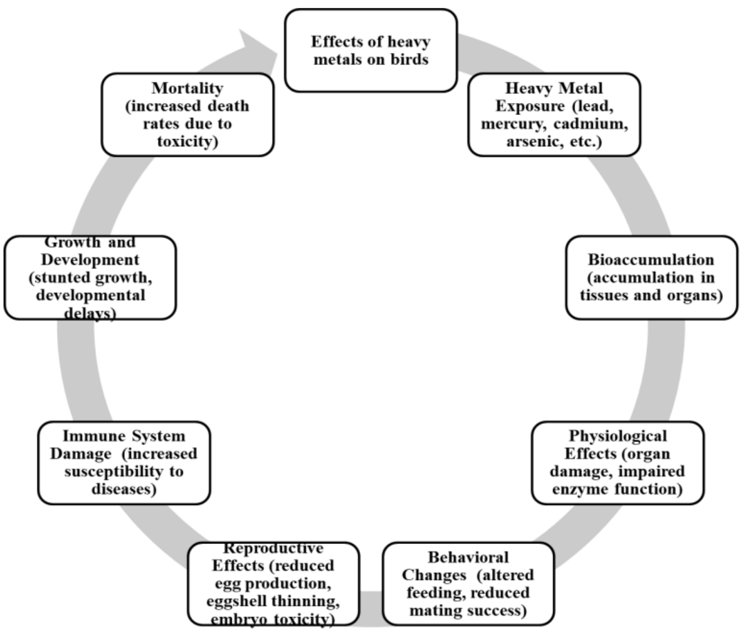

Figure 8. Scheme diagram illustrating the effects of heavy metals on birds.

4.10. Effects of heavy metals on waterfowl

Heavy metals are very necessary for normal growth and development of organisms.

- For example, iron (Fe) a heavy metal is central atom of hemoglobin (oxygen carrying protein in the red blood cell) deficiency of iron leads to low production of hemoglobin decrease oxygen storing and carrying capacity of organism's (waterfowl) blood. Heavy metals produce various adverse effects in waterfowls.
- Lead (Pb) produces adverse effects in all body organs, tissue and body systems such as liver, kidney, brain, feathers, circulatory and nervous system. Along with these effects lead (Pb) also has effects on reproduction, molting, endocrine system, migration, growth rate, psychological behavior and enzymes involving in hemoglobin formation.
- Mercury (Hg) causes weight loss and muscle weakness in wings and legs. Chromium (Cr) is associated with adverse effects on embryonic development (Kertesz and Fansci 2003).
- Copper (Cu) accumulation influence kidney and impair reproduction (Carpenter et al., 2004).
- Nickel (Ni) is associated with various adverse effects of breathing system (by causing asthma). It accumulates in feathers and damages them. It also causes birth defects, vomiting and DNA damages.
- Arsenic (As) causes genetic disorders, weight loss and is carcinogenic. Heavy metals such as Fe, Pb, Hg, CD, Ni, Si, etc. affect metabolic activities in waterfowls. There are two different ways in which heavy metals affect the metabolic activities these are
    - ➢ Accumulation of heavy metals change position of necessary minerals from their original place so these minerals stop functioning and become dangerous to organism.
    - ➢ High deposition of heavy metals disrupts functioning of some organs such as liver, bone, heart etc. [57–63].

5. Conclusion

The outcomes of this systematic data synthesis and analysis established that there are high levels of soil and crop pollution with heavy metals with much potential hazard to ecological systems and human health. An ongoing high level of accumulation of hazardous metals like Cd, Pb, As, and Hg was evident in the agricultural soils and urban sediment samples collected from China, Bangladesh, and Pakistan, where industrialization and mining activities are quite common. For instance, cadmium concentration in paddy fields was higher than the set limit, increasing the possibility of contaminated foods. Also, booms in the concentrations of lead and arsenic in sediments in the vicinity of industrialization and urbanization were found to be above ecological standards to increase the pollution indices. The findings further showed that population pressures, industrial effluent discharge, mining, and contaminated water, particularly irrigation water, were considered the main culprits of heavy metal pollution.

The risk assessment showed non-carcinogenic and carcinogenic risks from a health perspective as follows: They got direct contact with the soil and consumed crops and inhaled dust particulates in the air. Amid the COVID-19 crisis, vegetables grown in polluted soils, especially leafy vegetables, had higher bioaccumulation of heavy metals, an impact that may endanger susceptible populations' food intake. Succinctly, the kids and residents in polluted environments were at dangerous levels of the health risk index to warrant public health attention. These findings reveal the necessity of measures to control the presence of these contaminants so as to minimize risks of sick health resulting from the presence of heavy metals.

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