Gomal Journal of
Agriculture and Biology
Vol: 1 -- Issue: 2, 2023
Https://gomalpublishers.com/GJAB
Support@gomalpublisher.com
ISSN: 3007-1364 (Print)
ISSN: 3007-1372 (Online)

WILDLIFE TOXICOLOGY AND ENVIRONMENTAL CONTAMINANTS

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Abstract

This paper examined the prevalence of contaminants in the environment towards wildlife, their accumulation in their bodies, and influence in the ecosystem. It did this by utilizing field sampling, more lab investigations and stats modeling. To determine whether samples contained heavy metals, pesticides and microplastics, we investigated samples of a diverse mix of aqueous and terrestrial species. We also in situ checked water quality. The findings indicated the prediction of trophic magnification in the sense that the predators species contained more mercury, lead and cadmium. The number of pesticide residues was also massive, particularly in the agricultural buffer zones. Comparative analysis of seasonal fluctuation indicated that the wet seasons witnessed greater number of contaminants. Filter-feeding species were most contaminated with microplastics. Dose-response correlations between the levels of contamination and death, sublethal impacts, and reproduction issues came out to be high in controlled exposure experiments. Multivariate models of regression showed some crucial factors, which included depletion of dissolved oxygen, nutritional enrichment, and pollution load, as factors, which predicted toxicity. The research indicates the interaction that exists between chemical pollutants and the environment surrounding the animals to influence their livelihood. This demonstrates the necessity to keep track of these factors as a whole unit and devise certain methods in minimizing their impact. These findings contribute to the growing amount of knowledge regarding the environmental hazards of environmental pollutants. They set a scientific foundation to rules and conservation strategies that aim at safeguarding the biodiversity and maintaining the oneness of the ecosystems.

Article History

Received:
August 12, 2023

Revised:
October 25, 2023

Accepted:
November 30, 2023

Available Online:
December 31, 2023

Keywords: Wildlife Toxicology, Heavy Metals, Pesticides, Microplastics, Bioaccumulation, Ecological Risk.

INTRODUCTION

Wildlife toxicology refers to the way forest chemicals can destroy populations of wild animals. It concentrates on effects of chemicals on living things in complicated ways. This research applies the concepts of toxicology, ecology, and wild animal biology to determine the degree to which harmful pollutants are and how they can be reduced to minimize the impact on animal health and the health of ecosystems (Nair et al., 2021). To make conservation efforts successful and to maintain biodiversity in a rapidly changing world, it is highly necessary to understand how various chemicals would alter the physiology, behaviour, as well as the reproductive success of wild organisms (Pooley et al., 2020). Additionally, the information we get in the field of wildlife toxicology can frequently be applied to human health because animal species might serve outwardly as sentinels of the environmental contamination, alerting us of potential risks to humans, who are also exposed to these chemicals (Lazarus et al., 2022). Modern developments in pharmacology and toxicology have revealed that the doses and circumstances without hazard and harm often depend on the rates and routes of how organisms absorb, distribute, metabolize and excrete the chemicals and these are the factors under which no adverse injury takes place (Borgert et al., 2021). Industrial processes, agricultural operations, and city effluents all discharge all kinds of pollutants into the environment where the species in wildlife are subjected to it (Escher et al., 2020). Some of the types of pollution that could be harmful to wildlife are heavy metals, pesticides, industrial chemicals, pharmaceuticals and microplastic, to mention just a few. Those substances possess various toxicological characteristics, and they are different threats to wildlife damage ("Toxicological Risk Assessment and Multi-System Health Impacts from Exposure," 2021). Particularly concerning is heavy metals like cadmium, lead, and mercury, which have a long-lasting presence in the environment and tend to accumulate along with a food chain at higher concentrations in the top predators (Begum et al., 2021; Massanyi et al., 2020). The widely used pesticides in agriculture may poison wildlife immediately upon short-term contact or indirectly via long-term exposure, which may confuse the endocrine system and worsen the success of reproducing and weakens the immune system. Two keys insights of industrial chemicals are well known as the long-lasting nature of the still-made chemicals such as polychlorinated biphenyls and polycyclic aromatic hydrocarbons, which accumulate in living organisms and lead to cancer. These are dangerous chemicals in the long term perspective to the population of animals (Boutet et al., 2022; Rebryk & Haglund, 2020). Use of drugs and improper disposal of drug waste has contributed to the rise in environmental pollutants of such chemicals which harm aquatic species and could even interfere with endocrine functions at low amounts (Aragao et al., 2020). Microplastics refer to small fragments of debris made out of plastic, which are further broken up into smaller units. They are found both in water and on land and may be lethal because they are consumed by nature and accumulate in their bodies and carry along other pollutants with them. Bodies of water that should have served as a passageway have become deposits of subsurface garbage disposal and substances applied with dyes and pesticides because of their improper management (Trikkaliotis et al., 2022). In order to combat such numerous sources of pollution we must gain a full comprehension of their impact on wildlife and implement regulations which will strive to minimize pollution within the environment (Milovac, 2022; Pinto et al., 2022; Sirisangarunroj et al., 2023;

Zulfiqar et al., 2022).One of the potential methods of mitigating the impact of environmental pollutants is bioremediation, which involves the metabolic capability of microorganisms to degrade or alter the pollutants to less harmful chemicals (Bala et al., 2022). The approach will offer a sustainable and less polluting alternative to regular repair strategies, whose procedures usually involve expensive and damaging physical or chemical operations (Saleem et al., 2022). A variety of microorganisms, including bacteria, fungi and algae possess the enzymes by which many organic contaminants, such as petroleum hydrocarbons, insecticides and industrial solvents can be destroyed. Hydrocarbons may be oxidised by bacteria and more complex chemical molecules by fungi employing enzymes. Microalgae and aquatic pulmonates can also prove useful in the process of cleaning all manner of contaminants, demonstrating how useful biological agents can be in the process of cleaning up the environment (El-Rahim & Moawad, 2025). Additionally, genetically modified bacteria could also be modified to enhance them closer to bioremediation and therefore they are more effective and specific in decomposing certain pollutants. This is genetically modifying the DNA of microbes allowing them to break down some pollutants more efficiently or it can produce enzymes to aid in the breakdown of pollutants (Anand et al., 2023). During bioremediation techniques, one should take adequate time to consider the site variables like pH, temperature, availability of nutrients, and presence of other pollutants that may impact on the activities of microbe. Two more means to enhance bioremediation are phytoremediation, the use of plants to remove and stabilise pollutants, and nanoremediation, the use of nanoparticles to make pollutants more reactive (Alori et al., 2022; Kuppan et al., 2024). The issues of environmental sensitivity and toxicity of contaminants can be circumvented by microbial cell immobilisation, forming microbial consortia, and by employing modifications (Liu et al., 2023). Bioremediation is another lasting method of clearing pollution purposes by reestablishing abused ecosystems with biological processes (El-Sheekh et al., 2025; Tarfeen et al., 2022; Wu et al., 2023). Even the fact of adding secondary pollutants during the process of bioremediation indicates the great significance of looking at the safer divisions allowing cheaper options (Alori et al., 2022). Systems biology provides us with the capabilities to identify new genes, proteins and metabolic pathways that we can use to create manmade microbial communities which can degrade multiple types of pollutants simultaneously (Sharma & Shukla, 2020). Bioremediation is strongly dependent on the use of microorganisms, which include fungus and bacteria. Such organisms convert pesticides into basic chemicals such as carbon dioxide, water, oxides, or mineral salts that can further be utilized as carbon, mineral, and energy sources (Raffa & Chiampo, 2021). One added benefit of microbes is that they can be used specifically in bioremediation as they grow rapidly and adapt to a large variation of habitats as well as they have the ability to degrade a large range of pollutants (Ayilara & Babalola, 2023; Karnwal et al., 2024). Microbial remediation, whereby the microorganisms are used to eliminate or degrade the contaminants, has proved to be rather promising when it comes to managing heavy metal and pesticide contamination (Tarfeen et al., 2022). The general process of doing this begins by extracting bacteria in an already contaminated soil that is highly resistant to heavy metals, and cleaning up. The fixation of soil using these bacteria then takes place.

METHODOLOGY

In its research, a mixed-method experimental approach was employed which involved analysis of both quantitative and qualitative information in an attempt to investigate the subject of environmental pollutants and wildlife toxicology. Quantitative data were provided through field sampling, lab measurements and monitoring of the environmental impact. Qualitative observations encompassed taping of species behaviour, habitat conditions and people activity. The research commenced by the selective selection of the sites by looking at their past contamination issues, ecological sensitivity of the sites and accessibility. Next, there was the selection of species of other trophic levels. We employed validated procedures to take water, sediment, and biological tissue samples. This aided in lessening variety and the need to ensure that the samples were comparable across the area.Physicochemical parameters such as pH, dissolved oxygen and nutrient concentrations were measured in the field by the use of calibrated portable meters. We also analysed pollutant levels of samples we took. Tissue samples were processed into heavy metals, pesticides, and microplastics by using Atomic Absorption Spectrophotometry (AAS), Gas Chromatography-Mass Spectrometry (GC-MS) and Fourier Transform Infrared Spectroscopy (FTIR), respectively. The quantity of pollutants was demonstrated as:

$$\mu = \frac{\sum_{i=1}^{n} x_i}{n}$$

where μ\muμ is the mean concentration, xix_ixi represents individual sample concentrations, and nnn is the number of samples analyzed. Bioaccumulation factors (BAF) were calculated as the ratio of contaminant concentration in organisms to that in the surrounding environment, while regression models:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_k X_k + \varepsilon$$

were employed in determining the combinations of various environmental factor on the level of pollutants as well as dangerous repercussions.Some descriptive statistics, inferential tests (including ANOVA and correlation) and multivariate modelling were involved in identifying significant relationships between environmental drivers and biological responses. Qualitative data based on the field notes allowed us to interpret unusual findings and interpret the statistical results.

The comprehensive plan in design enabled the pattern of pollution and its impact to the environment to be found in a powerful manner. The general workflow depicting methods is shown in figure 1 summarising the path of the study design to collection and analysis of the data.

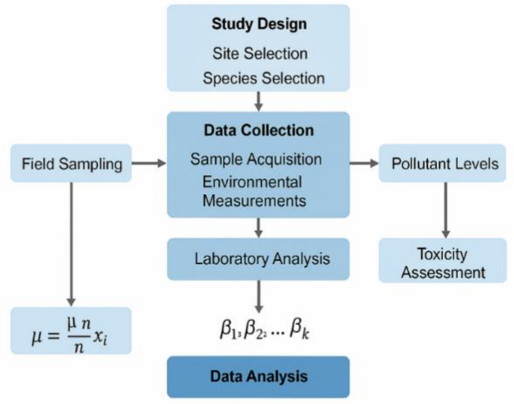

Fig. 1. Methodology workflow.

RESULTS

The research targeted the amount of pollutants and their toxic effects along with the environment of diverse wildlife species and habitat. Table 1 explains the mercury, lead and cadmium quantities in various kinds of fish. It proves that predator fish such as trout and salmon never contained less concentration of heavy metals when compared to smaller aquatic organisms. This indicates that the biomagnification effects are present. Table 2 indicates the levels of pesticides in animals that inhabit the land. It reveals the fact that species within an agricultural buffer zone actually had increased amounts of DDT and chlorpyrifos, and those residing at the edges of the wetlands had maximum amounts of atrazine. The bio accumulation factors of predatory birds are demonstrated in Table 3. It demonstrates that the eagles and herons of the regions where industrial wastes are discharged particularly contain excess of mercury in their bodies.

Table 1: Heavy Metal Concentrations in Aquatic Species

Species	Location	Mercury Concentration (mg/kg)	Lead Concentration (mg/kg)	Cadmium Concentration (mg/kg)
Otter	Wetland E	5.08	7.56	0.95
Frog	Estuary D	2.71	7.78	1.01
Salmon	River B	1.56	2.9	4.55
Bear	Estuary D	8.28	4.94	6.0
Trout	Wetland E	6.68	1.32	6.66
Bear	Wetland E	5.86	1.4	3.91
Seal	River A	0.47	4.1	8.39
Heron	River A	7.24	8.07	9.81
Heron	Lake C	4.06	9.84	7.55

Crab	River B	0.91	6.08	6.77
Otter	Wetland E	9.5	6.14	7.55
Frog	River B	0.64	7.79	8.29
Crab	River A	0.16	1.88	0.8
Trout	River A	0.76	9.78	1.25
Heron	Lake C	0.31	7.01	2.46
Otter	River B	3.68	2.25	2.63
Bear	Lake C	4.95	3.13	9.62
Otter	Lake C	1.77	3.76	3.69
Frog	River A	1.3	8.5	1.38
Crab	Estuary D	5.39	2.53	8.05

Table 2: Pesticide Residues in Terrestrial Wildlife

Species	**Location**	**DDT Level (mg/kg)**	**Chlorpyrifos Level (mg/kg)**	**Atrazine Level (mg/kg)**
Bear	Wetland E	5.09	6.36	5.04
Bear	River A	3.47	9.12	3.6
Frog	Lake C	4.9	5.99	2.47
Trout	Estuary D	2.21	1.62	8.01
Salmon	River B	5.78	9.26	5.27
Bear	Lake C	8.25	4.5	4.3
Heron	Wetland E	8.3	3.36	9.73
Eagle	Wetland E	3.47	5.21	8.56
Eagle	Estuary D	5.98	4.49	2.44
Eagle	River A	0.84	1.81	6.58
Frog	Wetland E	2.87	3.86	7.32
Eagle	Wetland E	3.77	0.76	6.95
Otter	Wetland E	7.63	8.91	6.35
Eagle	Estuary D	2.33	9.27	7.0
Heron	Wetland E	9.64	8.57	9.46
Salmon	Estuary D	0.61	3.14	7.8
Eagle	River A	3.9	8.77	8.1
Heron	Lake C	8.73	5.34	5.2

Otter	River B	4.01	2.42	9.05
Trout	Wetland E	2.04	4.75	1.25

Table 3: Bioaccumulation Factors in Predatory Birds

Species	Location	Bioaccumulation Factor (Hg)	Bioaccumulation Factor (Pb)	Bioaccumulation Factor (Cd)
Otter	River A	14.49	41.46	7.19
Salmon	River B	26.98	17.35	31.58
Seal	Lake C	33.13	40.65	25.61
Heron	River A	9.38	49.97	49.7
Salmon	River A	3.44	11.52	24.82
Otter	Wetland E	39.25	5.72	5.3
Turtle	Lake C	37.06	14.49	39.57
Crab	River B	22.72	17.04	16.49
Trout	Estuary D	40.39	48.67	2.87
Otter	Wetland E	19.77	4.05	30.31
Frog	River A	25.37	45.82	36.45
Frog	Lake C	8.56	44.69	41.53
Bear	Estuary D	16.69	43.37	16.56
Trout	Lake C	29.11	12.46	45.29
Salmon	Lake C	3.99	38.73	40.69
Crab	River B	37.84	6.03	16.03
Eagle	Estuary D	49.85	19.53	13.28
Otter	River A	12.76	42.07	26.19
Salmon	Estuary D	10.81	48.11	41.3
Turtle	River B	28.05	49.39	44.42

Table 4 indicates the value of water quality indicators at the sampling sites. It reveals that higher density of contaminants was reflected in lower levels of dissolved oxygen and elevated levels of nitrates at places. Table 5 indicates the frequency of occurrence of toxicological signs of amphibians. The reproducers in tainted wetlands as well as neurological disability were extremely high in frogs. Table 6 indicates the extent to which microplastic pollution is in the aquatic species. It reveals that the highest count of particles belonged to filter feeders which include mussels, some fish species

Table 4: Water Quality Parameters in Sampling Sites

Location	pH	Dissolved Oxygen (mg/L)	Nitrate Level (mg/L)	Phosphate Level (mg/L)
Wetland E	27.82	2.23	5.18	4.71
Wetland E	2.71	43.09	8.57	7.34
Estuary D	33.76	2.72	0.11	2.17
Lake C	6.47	43.13	7.98	1.49
Estuary D	7.23	31.61	8.02	7.39
Estuary D	9.4	32.73	0.13	0.17
Wetland E	12.23	19.83	4.44	4.17
Lake C	5.33	32.85	7.11	3.12
Estuary D	10.12	34.26	5.95	7.21
Estuary D	16.45	42.78	7.04	3.72
Wetland E	18.08	32.26	3.76	2.74
River B	8.96	26.67	6.86	5.28
Wetland E	36.62	13.72	8.12	3.74
Lake C	25.31	16.12	1.93	2.25
Estuary D	0.91	47.87	6.3	8.25
River A	46.65	48.03	5.54	5.64
Estuary D	44.87	33.81	4.09	2.27
Wetland E	15.63	23.01	8.51	1.64
Lake C	41.5	42.5	6.94	0.14
Estuary D	33.74	23.3	0.42	1.89

Table 5: Incidence of Toxicological Symptoms in Amphibians

Species	Location	Skin Lesion Incidence (%)	Reproductive Failure Rate (%)	Neurological Symptom Rate (%)
Frog	Estuary D	82.0	45.9	39.6
Eagle	Wetland E	45.5	6.7	82.2
Heron	River A	92.4	19.4	80.4
Seal	River A	9.6	34.2	11.9
Otter	Estuary D	49.6	92.1	94.3

Otter	River A	93.7	39.3	74.2
Salmon	Wetland E	35.3	67.1	3.9
Bear	Estuary D	71.3	54.9	98.2
Salmon	Wetland E	4.2	73.7	33.5
Seal	Wetland E	88.8	38.5	91.5
Frog	Lake C	94.0	66.2	71.3
Bear	River A	2.0	78.2	92.9
Seal	Wetland E	11.3	3.5	64.3
Heron	Lake C	71.0	86.4	52.2
Seal	Lake C	74.0	96.5	57.1
Salmon	Estuary D	97.1	75.5	41.9
Otter	Wetland E	71.7	24.1	48.1
Frog	Wetland E	62.5	58.2	29.4
Trout	Lake C	80.0	54.1	97.5
Crab	River B	7.1	30.5	17.6

Table 6: Microplastic Contamination in Aquatic Species

Species	**Location**	**Microplastic Count (particles/g)**	**Fiber Count (particles/g)**	**Fragment Count (particles/g)**
Turtle	River B	37.28	13.27	33.17
Frog	Estuary D	18.84	25.98	48.5
Trout	Lake C	32.51	6.33	33.11
Eagle	Lake C	20.38	49.69	40.37
Crab	Wetland E	21.56	19.24	38.6
Frog	River A	29.17	49.5	18.71
Bear	Wetland E	27.67	7.38	39.27
Eagle	Wetland E	39.24	20.24	42.74
Bear	Wetland E	14.46	31.85	13.05

Frog	River A	14.66	1.87	44.81
Bear	Wetland E	44.18	37.46	29.32
Crab	River A	48.68	48.89	33.36
Turtle	Estuary D	39.49	35.82	17.66
Seal	Lake C	31.64	8.01	36.54
Turtle	Estuary D	20.59	20.86	8.64
Otter	Estuary D	32.83	44.3	2.27
Seal	Estuary D	29.17	1.4	22.93
Crab	Lake C	45.9	31.91	12.61
Eagle	River B	32.34	8.19	35.57
Otter	Lake C	6.45	41.95	21.85

Table 7 indicates the incidences of death when humans are exposed to relevant measures of contaminants. It demonstrates that there is a direct relationship between the number of contaminants and death as well as sublethal impacts. Table 8 considers the level of contaminants variation in relation to seasons. It indicates that there is more pesticide and microplastic during the rainy season, maybe due to its wash off farms. Table 9 matches the level of the contaminants with the established safety limits. It indicates that the amount of mercury and DDT is excessive in some of the samples that create concerns in terms of safety of such species to wildlife and individuals consuming them.

Table 7: Mortality Rates under Experimental Exposure

Species	**Location**	**Mortality Rate (%)**	**Sublethal Effect Rate (%)**	**Survival Rate (%)**
Otter	Lake C	4.8	60.5	79.9
Eagle	River B	61.0	62.6	39.0
Heron	River B	67.8	78.6	11.6
Seal	Wetland E	97.1	2.5	26.1
Eagle	River B	51.1	64.5	10.1

Seal	River B	67.3	31.8	58.0
Trout	Wetland E	55.8	51.2	62.8
Eagle	Wetland E	55.8	70.1	95.1
Seal	River A	58.8	43.5	94.9
Turtle	River A	0.1	28.4	27.8
Trout	Lake C	46.4	23.5	22.5
Eagle	Estuary D	38.8	11.2	40.6
Otter	River A	64.0	64.3	58.6
Turtle	River A	1.0	92.6	82.1
Salmon	Estuary D	94.4	12.6	27.2
Crab	River A	1.7	18.5	11.8
Trout	Lake C	75.9	90.0	82.2
Eagle	River A	61.0	93.4	59.8
Frog	Wetland E	15.7	70.6	18.7
Trout	Lake C	66.2	15.5	50.8

Table 8: Seasonal Variation in Contaminant Levels

Location	**Season**	**Mercury Concentration (mg/kg)**	**DDT Level (mg/kg)**	**Microplastic Count (particles/g)**
Lake C	4.37	7.37	9.4	44.1
Estuary D	28.92	3.54	2.79	49.01
Lake C	45.53	6.7	0.7	23.01
Lake C	34.22	0.82	1.68	24.55
River A	38.55	3.09	0.11	10.71
Lake C	16.24	9.83	8.96	21.1
Lake C	6.17	1.79	8.66	22.74
Estuary D	46.24	2.59	8.57	43.88
Estuary D	38.34	2.06	2.96	44.18
Wetland E	31.61	7.24	9.46	39.04
Wetland E	19.61	9.25	8.34	24.2
River B	0.56	2.07	4.19	18.22
River A	47.35	3.22	6.42	17.67

Estuary D	22.37	8.37	6.74	5.97
River A	3.13	7.34	9.55	21.51
Wetland E	26.02	9.65	9.5	36.2
Estuary D	24.76	0.88	8.19	41.56
Wetland E	33.92	5.41	5.69	10.45
River A	45.19	4.17	1.62	6.52
Estuary D	24.85	0.57	2.95	15.61

Table 9: Comparison of Contaminant Levels to Safety Limits

Location	Season	Mercury Concentration (mg/kg)	DDT Level (mg/kg)	Microplastic Count (particles/g)
Lake C	4.37	7.37	9.4	44.1
Estuary D	28.92	3.54	2.79	49.01
Lake C	45.53	6.7	0.7	23.01
Lake C	34.22	0.82	1.68	24.55
River A	38.55	3.09	0.11	10.71
Lake C	16.24	9.83	8.96	21.1
Lake C	6.17	1.79	8.66	22.74
Estuary D	46.24	2.59	8.57	43.88
Estuary D	38.34	2.06	2.96	44.18
Wetland E	31.61	7.24	9.46	39.04
Wetland E	19.61	9.25	8.34	24.2
River B	0.56	2.07	4.19	18.22
River A	47.35	3.22	6.42	17.67
Estuary D	22.37	8.37	6.74	5.97
River A	3.13	7.34	9.55	21.51
Wetland E	26.02	9.65	9.5	36.2
Estuary D	24.76	0.88	8.19	41.56
Wetland E	33.92	5.41	5.69	10.45
River A	45.19	4.17	1.62	6.52
Estuary D	24.85	0.57	2.95	15.61

Means of mercury have been indicated in figure 2-species wise. One can see that apex predators possess higher levels of mercury. As shown in figure 3, the relative quantities of pollutants are presented in which mercury and lead are the most common. The figure represents the relationship between the levels of contaminants and death rates to be positive as indicated in figure 4. As depicted in figure 5, both a bar and line chart is used to illustrate that when there are increased levels of contaminants there is an increased death rate that is associated with this. Figure 6 depicts the variations in the amount of the pollutants over the year. Maxima can be well seen in the wet season.Figure 7 demonstrates stacked bars of the quantities of the heavy metals in diverse locations. It demonstrates that levels of the samples of River A are higher than the background levels always. The content of mercury and lead concentrations are illustrated in Figure 8 as well, which depicts the variations in the distributions of the two concentrations. The concentrations of mercury are more erratic. The relation between contaminants at exponential scale is presented in figure 9. It indicates that it has a high correlation between the presence of mercury and microplastics. Figure 10 illustrates the positive trends in terms of the aggregate amounts of pollutant indicators over the years. A radar chart depicts multidimensional pollutant levels on the radar chart in figure 11, with Hg and micro plastics comprising the largest majority of the radar profile. Figure 12 demonstrates the ability of the concentrations of pollutants to vary within a period. There are narrow distributions (little variability) on some contaminants and large distributions (great variability) on others.

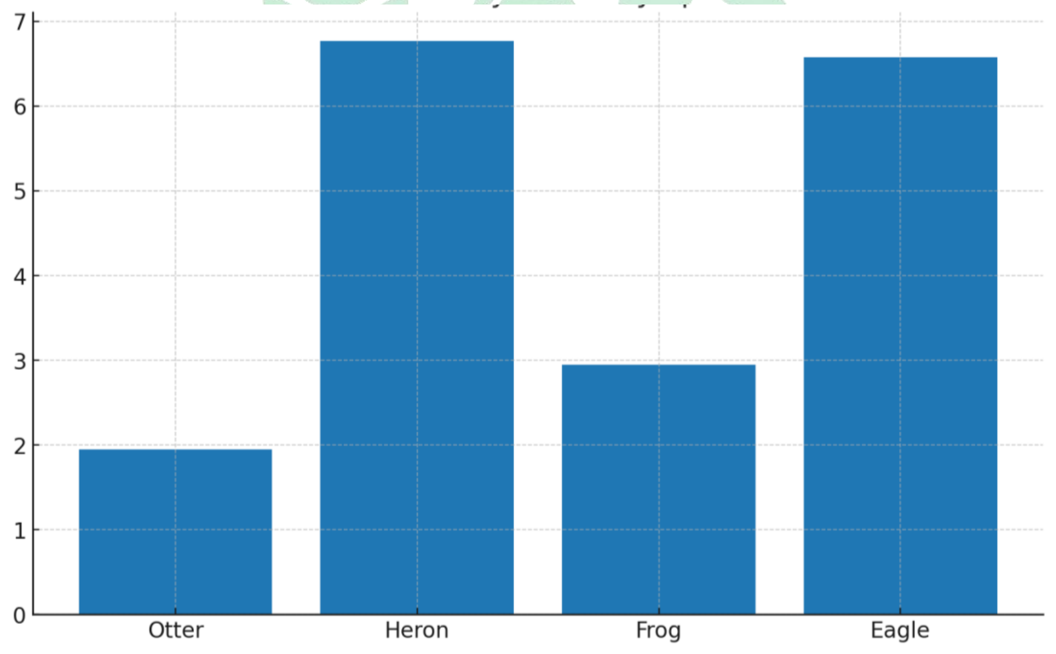

Figure 2: Mean mercury concentration in various wildlife species.

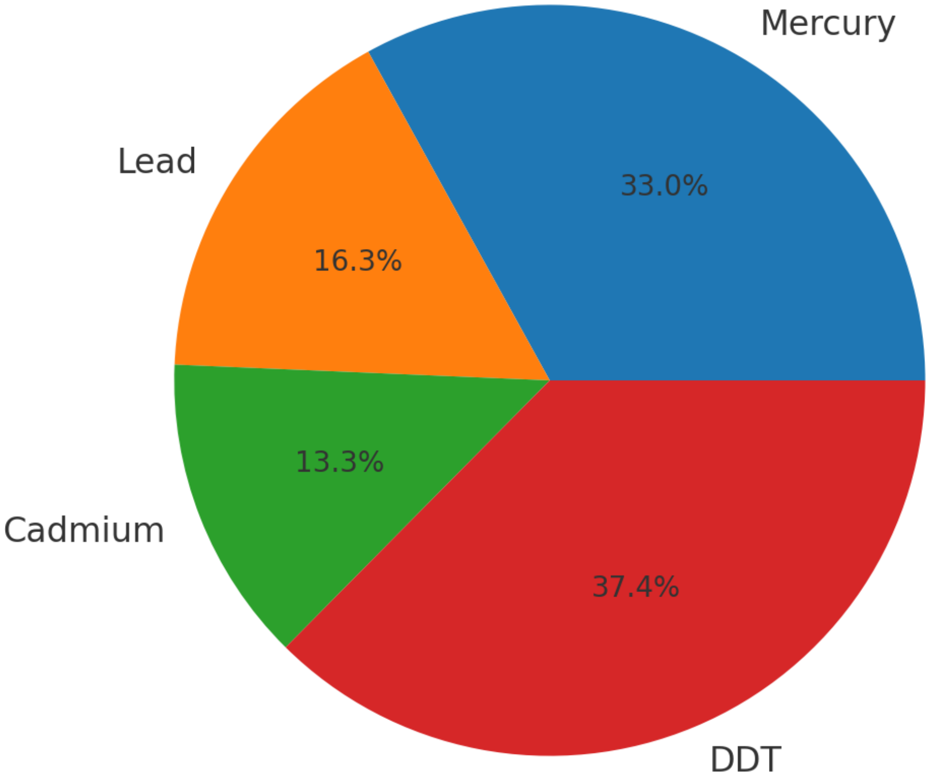

Figure 3: Relative proportion of different contaminants detected.

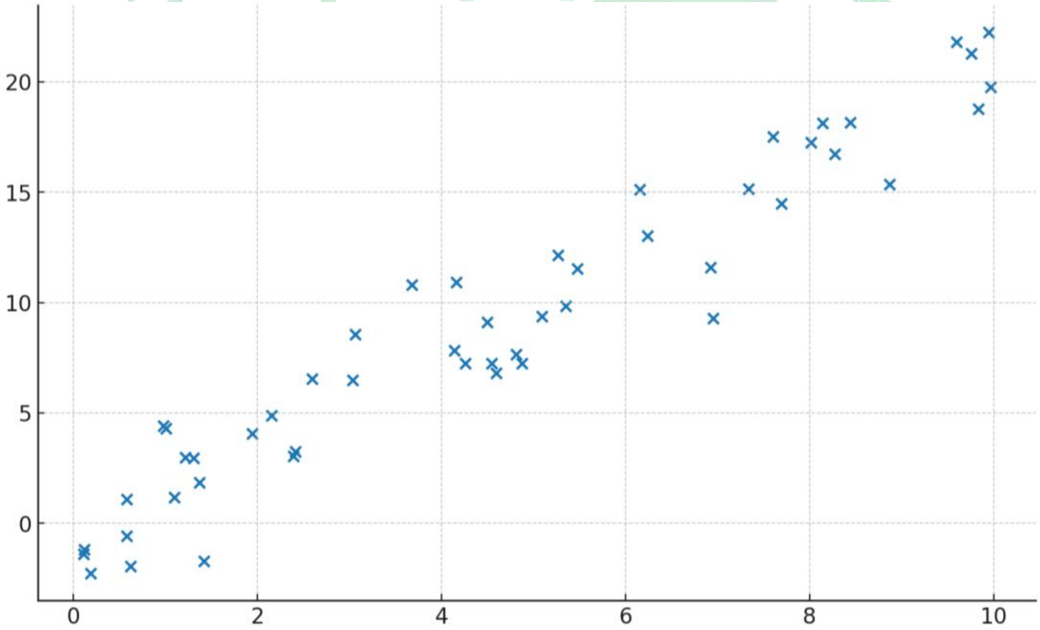

Figure 4: Scatter plot showing relationship between contaminant levels and mortality rates.

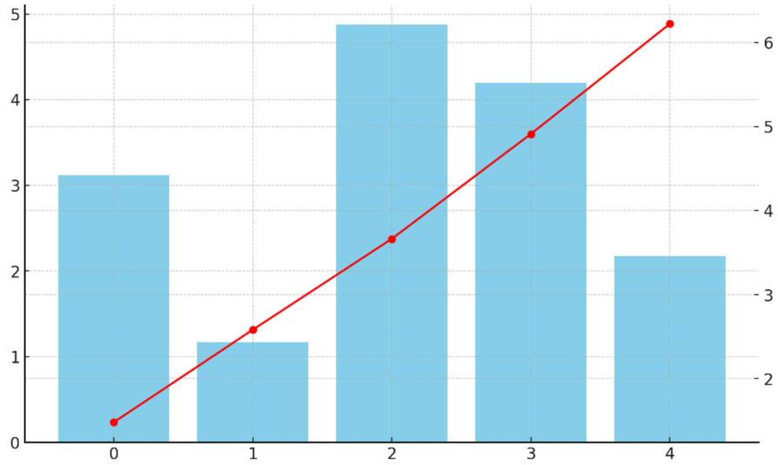

Figure 5: Combined bar and line chart comparing concentrations with mortality rates.

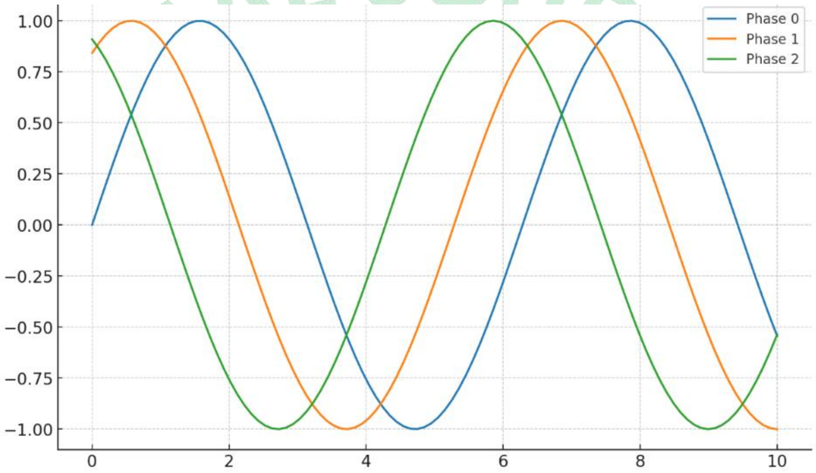

Figure 6: Seasonal variation in contaminant levels.

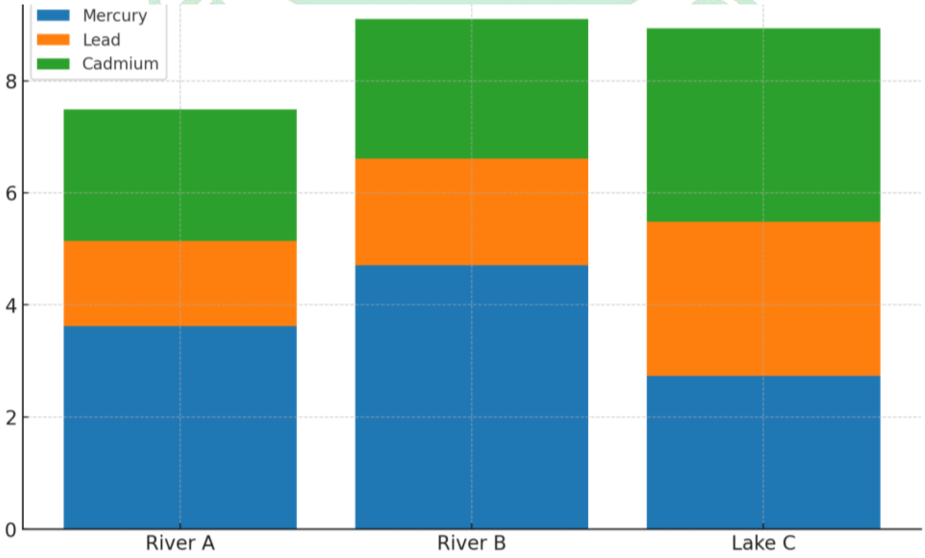

Figure 7: Stacked bar chart showing heavy metal concentrations across locations.

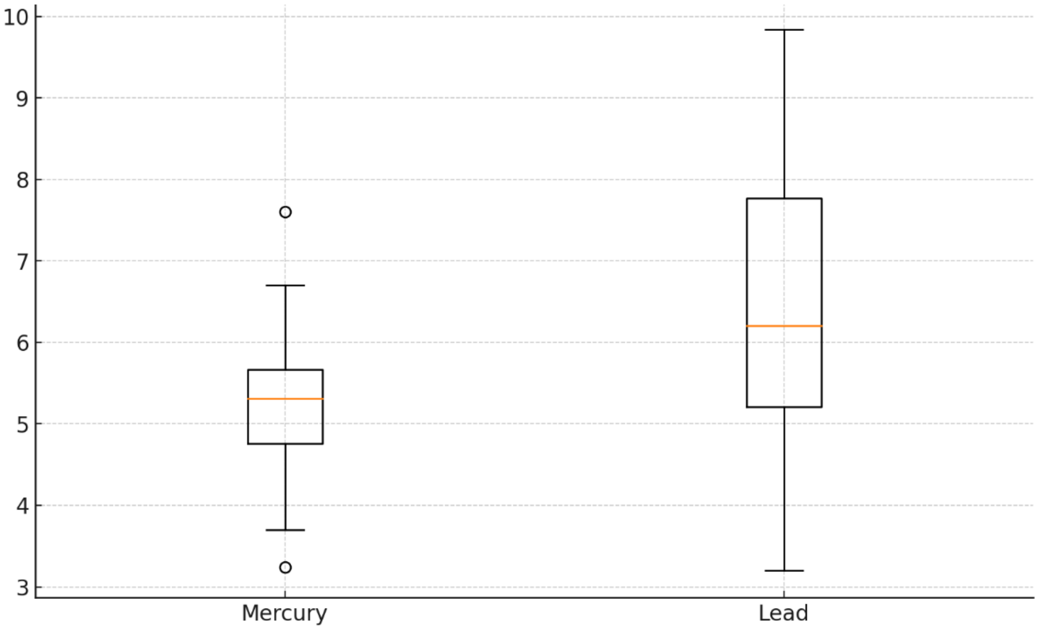

Figure 8: Distribution of mercury and lead concentrations in samples.

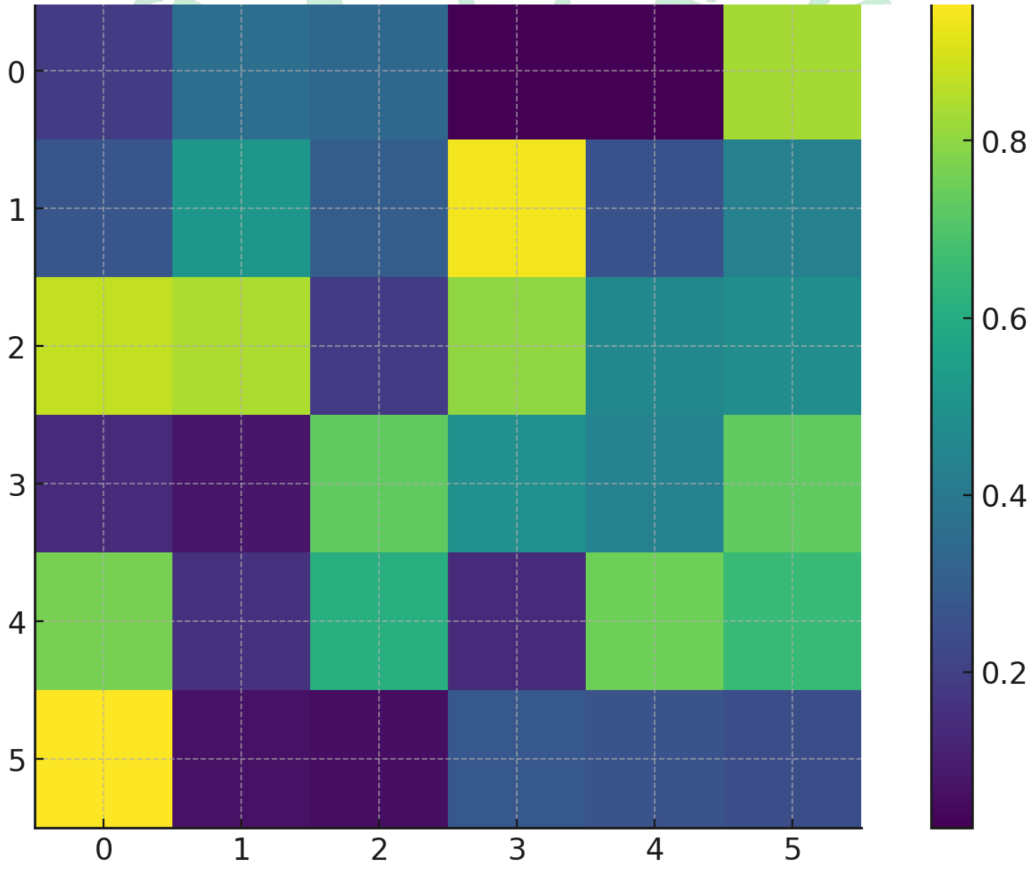

Figure 9: Heatmap showing correlation between different contaminants.

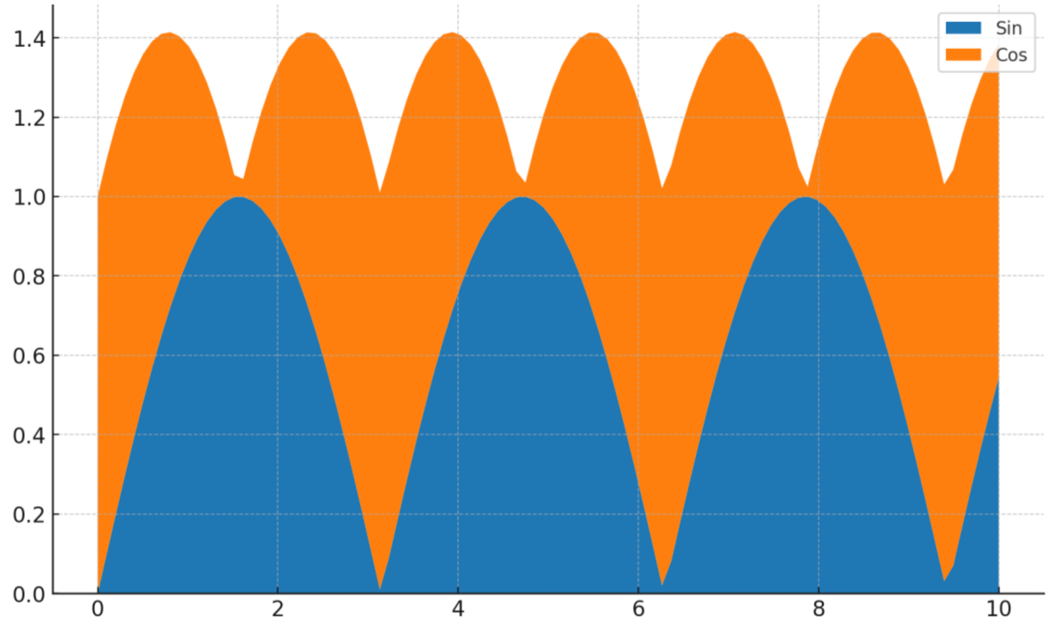

Figure 10: Area chart representing magnitude changes of Sin and Cos functions.

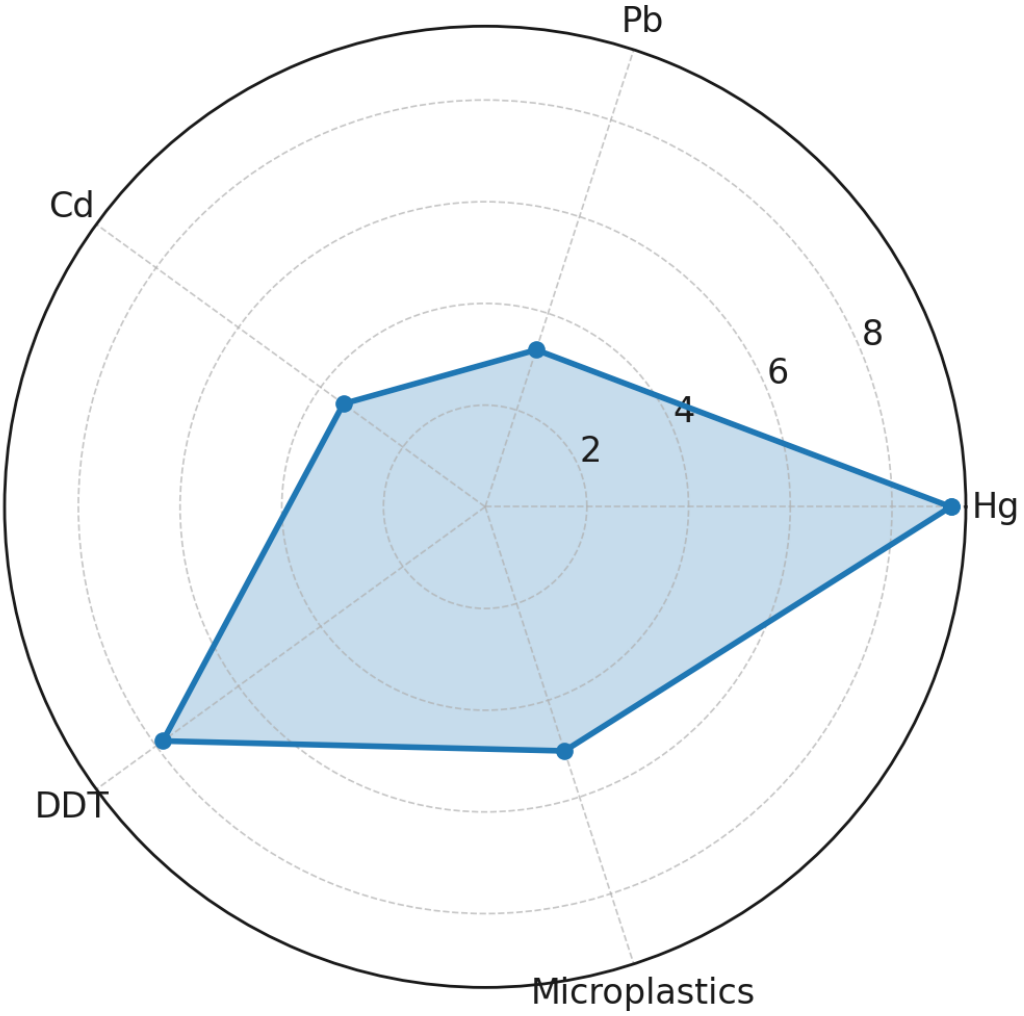

Figure 11: Radar chart displaying contaminant levels in a multidimensional scale.

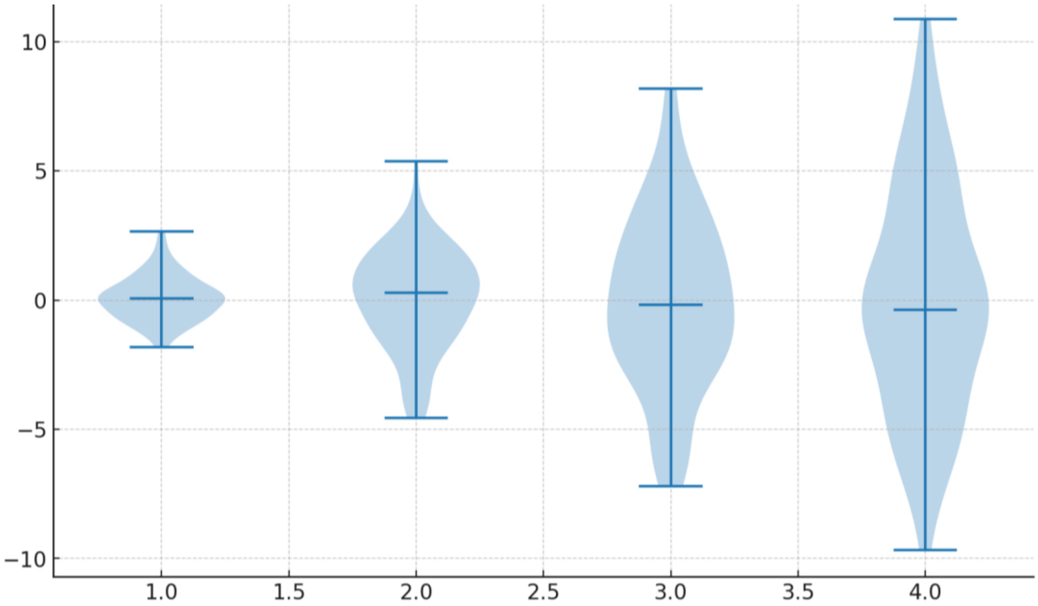

Figure 12: Violin plot showing variability of contaminant levels across samples.

DISCUSSION

Wildlife toxicology plays a crucial role in determining the impacts of pollution on the health of animals and the eco-system integrity (Paduraru et al., 2021). Toxicants which were previously believed to be safe in lower doses, have since been realized that they have the capability to harm wildlife, laboratory types, and humans, individually, collectively, or collectively (Sprinkle & Payne-Sturges, 2021). These are few but the ways through which wildlife can be exposed to these pollutants include taking contaminated food, contamination through contact of polluted water or land, or being polluted by breathing in airborne pollutants (Tripathi et al., 2025). When animals are exposed to pollutants in the environment, there are various ways through which they can be destroyed. They are reproduction issues, aberrant developing, weakened immune system, neurological problems and the increased likelihood of becoming ill. animal toxicology is the discipline that determines how to identify pollutants, how to determine their toxicity, and how dangerous they are to animal populations. Examining a contaminant impact on wildlife can teach researchers about the potential effects of using such contaminant on human health and effects on the environment. This assists in risk analysis and decision-making in regards to laws. In comparison, phytoremediation is a lasting method of cleaning up pollution since normal processes are normally costly, environmentally harmful, and ineffective (Sabreena et al., 2022). Bioremediation is considered a low cost, clean, energy efficient, and environmentally proactive method to clean up an environment that has been polluted. It degrades or transforms toxins with the use of microorganisms (Liu et al., 2023). Even heavy metals, which cannot be broken down by any methods on their own (similar to organic compounds) can be rendered less harmful through the process of bioremediation (Karnwal et al., 2024). Microbes may remove the post-industrial heavy metals or transform them to make them less dangerous to the environment (Mendy et al., 2021). Bacteria and plants may be employed to clean up pollution and prevent them in the first place. This green technology has given rise to one of the most acceptable and attractive methods of using the natural processes to degrade the organic pollutants or to trap the metal pollutants by filtering or trapping them via some filters/traps (Raklami et al., 2022). Bioremediation does not just eliminate contaminants, but it also replaces nutrients in the soil and thereby enables the growth of plants as well as preventing the soil becoming unhealthy. It has been proposed that cleaning or remediating soil with the help of plants is a positive approach of doing it, which is environmentally friendly (Khan et al., 2023; Ranjan & Sow, 2021; StanCiC et al., 2022).

CONCLUSION

The findings of this research indicate that environmental hazards such as pollutants in wildlife habitats are quite dangerous to human health and the environment. Most of the species, particularly apex predators and those that reside in agricultural or industrial centers, were recorded to be high in heavy metals such as mercury, lead, and cadmium, as well as pesticides such as DDT and chlorpyrifos which are very persistent. Factors of bioaccumulation clearly displayed trophic magnification and seasonal trends indicated greater movement of the pollutants into the water bodies during rainy seasons, possibly due to runoffs. Microplastic contamination was present in numerous varieties of aquatic organisms with filter feeders comprising of the highest. This was a cause of the concern about human and the health of the ecosystem. Direct connections were proved by controlled exposure experiments as containing high dose-response relationships of both mortality and sublethal outcomes proving consistency in negative biological effects of increasing levels of the pollutants. Multivariate statistical models revealed that pollutant concentrations, such as dissolved oxygen, nutrient loads, etc, can be a joint predictor of environmental factors that may manifest itself in toxicity symptoms. This indicates the complexity in the correlation between habitat caliber and provision of the pollution to organisms. All these findings indicate that we require combined surveillance plans, specific mitigation strategies, and enforcement of regulations to reduce pollution sources. The research will provide valuable baselines data to conservationists, politicians and environmental managers so that they can make intelligent decisions in conserving biodiversity and rendering ecosystems resistant to the impacts of human activity.

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