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Assessment of Heavy Metal Contamination in Wastewater Surrounding the Butwal Industrial Area

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ABSTRACT

Assessing heavy metal contamination in wastewater is crucial to protect environmental health, as these toxic elements can infiltrate residential areas through groundwater or soil, posing significant risks to human health, ecosystem stability, and the safety of water resources for daily and agricultural use. Quantitative determination of five heavy metals Lead (Pb), Cadmium (Cd), Chromium (Cr), Nickel (Ni) and Zinc (Zn) in six wastewater samples, collected from industries released from Butwal industrial area, was carried out by Atomic Absorption Spectroscopic method. Physicochemical properties pH, conductivity and estimation of chloride concentration were also done by using titrimetric method of analysis. The result showed the wastewater released from industries located in Butwal industrial area is highly contaminated with heavy metals. Lead and Chromium are the most prominent metals found in all wastewater sample above WHO standard limit whereas Nickel, Zinc and Cadmium contamination are within the standard limit.

***Keywords:* -** Heavy metals, pH, Conductivity, AAS, Titration

INTRODUCTION

Water makes up about 71% of the Earth's surface, but only 3% of that is fresh water we can drink. Out of this fresh water, 69% is locked away in ice at the Polar Regions. The rest is found in rivers, lakes, and underground sources that people, plants, and animals use. It's really important to manage this fresh water wisely to prevent running out of it (Yeazdani, 2016)**.** Water becomes polluted if it contains harmful substances or conditions that make it inappropriate for its intended use. According to Olaniran, water pollution happens when there are excessive amounts of harmful substances, rendering the water unusable. Pollution occurs when contaminants are introduced into the environment through sources such as industrial and commercial waste, agricultural practices, everyday human activities, and transportation.

Nepal, like many other developing countries, faces challenges with the quality and availability of drinking water, leading to health problems for many people due to water pollution (Pandey & Shakya, 2012). Urban growth and industrialization have increased levels of trace metals, especially heavy metals, in the water (Mohod & Dhote, 2013).

Heavy metals in river water are particularly concerning because they do not break down and can accumulate in the food chain, posing risks to living organisms. Heavy metals are defined as metals and metalloids with a higher density than water and are toxic even at low concentrations. They are grouped into essential and non-essential heavy metals. Essential heavy metals, like zinc, copper, iron, and manganese, are important for biochemical processes and act as micronutrients for plants. In contrast, toxic heavy metals like lead, mercury, arsenic, cadmium, and chromium are carcinogenic. Heavy metal contamination occurs when high concentrations of these metals are deposited in an area, often due to activities such as development, waste disposal, industrial work, mining, and vehicle emissions.

Several recent studies have highlighted the prevalence of heavy metal contamination in water system causes detrimental effects on human health and ecosystems. Lewis et al. (2023) conducted a comprehensive review of drinking water contamination across the United States, identifying key toxic substances such as arsenic, lead, and uranium. The result found recommended substantial investment on water resources, improved treatment technologies and strict regulatory protocols. The similar study from Punjab, India in ground water from (Chaudhary et al. (2024) have accessed the concentration of toxic metals such as arsenic, cadmium and selenium in water and linked them to carcinogenic and non-carcinogenic risk analysis. In Nepal, Shrestha et al. (2016) analyzed levels of iron, manganese, zinc, and arsenic in 41 groundwater wells in the Kathmandu Valley. Yadav et al. (2019) examined the spread, sources, and health risks of heavy metals in house dust and soil from four major Nepalese cities. This study focuses on estimating concentrations of five heavy metals Lead (Pb), Cadmium (Cd), Chromium (Cr), Nickel (Ni), and Zinc (Zn) along with physical and chemical properties (pH, conductivity, and chloride levels) in wastewater from the Butwal industrial area.

MATERIALS AND METHODS

Study area and Sample Collection

The study area is located between 27.6769° N latitude and 83.4875° E longitude. Within this area, there are over 70 registered industries, including major ones like metal, battery, soap, glass, and fiber industries.

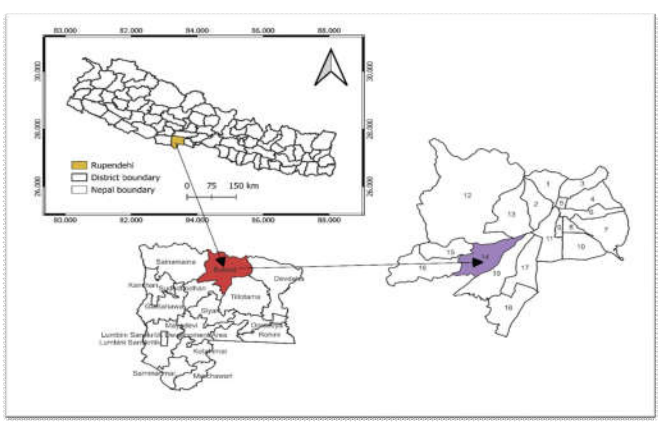

Figure 1. Map of study area

Six different locations of Butwal industrial area has been selected by using stratified random sampling for our study. Waste water sample were collected at surface level (0-10 cm in depth) by using suction pump and kept in polythene bottle with proper labelling from W1 to W6. In certain location more than one sample were collected and finally mixed in same polythene bottle, since there was high risk of heavy metals contamination. The collected waste water samples were kept in refrigerator at 4°C.

Materials and Methodology

Standard solutions (1000 ppm) for Pb, Ni, Cr, Cd, and Zn were prepared by using double distilled water. Analytical-grade reagents, HNO_3 and HCl, were used as received without additional purification. Chemicals such as silver nitrate, sodium chloride, and potassium chromate, supplied by Thermo Fisher Scientific India Pvt. Ltd., were of AR grade are used as such. The samples were subjected to pH and conductivity measurement, and is also used for chloride estimation.

Table 1: Chemical reagents and details of instrumentation.

S.N.	Chemical and Reagents	Manufacture	Instrument	Brand
1.	Conc. Nitric acid and Sulfuric acid.	Thermo Fisher Scientific India Pvt. Ltd.	pH meter	HANNA (HI98107)
2.	Silver Nitrate	Thermo Fisher Scientific India Pvt. Ltd.	AAS	AA240FS
4	Potassium chromate	Thermo Fisher Scientific India Pvt. Ltd.	Hot air Oven	S.M. Scientific Instrument Pvt. Ltd.
5	Lead Nitrate	Qualikems Fine Chem Pvt. Ltd.	Electronic balance	USA.HZ & HUAZHI
6	Potassium dichromate	Thermo Fisher Scientific India Pvt. Ltd.	Conductometer	Ri (model 215-R)

Heavy metal Analysis

3111 C, APHA, 24th EDITION method was used for heavy metal analysis by using atomic absorption spectrophotometer at Water Engineering and Training (P.) Ltd. Kathmandu. The collected 100mL waste water samples were first added in 2 mL of concentrated nitric acid (HNO_3) and 5 mL of hydrochloric acid (HCl). After mixing, 100 mL of the sample was poured into a beaker. The beaker was covered with a watch glass and heated on a steam bath or hot plate at 90 to 95°C until the volume reduced to 20 mL due to evaporation. Once the volume was reduced, the beaker was taken off the heat and allowed to cool. The beaker and watch glass were then washed with water. To remove any solid particles that could block the nebulizer, the sample was filtered, using clean using Whatman 40 filter paper. And, the volume of the sample was adjusted to 100 mL with deionized water before analyzing it using AAS. The filtrate solution was tested by AAS for the detection of heavy metals concentration. 1000 ppm stock solution of heavy metals were imported from India and from 1000 ppm stock solution, working standard solution of desired concentration were prepared. Doubly deionized water (blank solution) and accurately prepared working standard solution of known concentration was used for the preparation of calibration curve. By plotting the absorbance of working standard solution at y- axis and concentration at x- axis, calibration curve was obtained. In order to measure the concentration of heavy metals in waste water sample. Absorbance of a sample given by AAS was noted carefully. Absorbance of the sample was plotted in the calibration curve and the corresponding concentration of heavy metals was calculated. All the sample were measured in triplicates and the mean value of absorbance was taken.

Table 2: Instrumentation of Flame AAS techniques and detection limit of heavy metal.

Parameter	**Cd**	**Cr**	**Ni**	**Pb**	**Zn**
Wavelength	228.8 nm	357.9 nm	232.0 nm	217.0 nm	213.9 nm
Lamp current	4.0 mA	7.0 mA	4.0 mA	10.0 mA	5.0 ma
Flame type	Air/Acetylene	Air/Acetylene	Air/Acetylene	Air/Acetylene	Air/Acetylene
Air flow	13.50 L/min	13.50 L/min	13.50 L/min	13.50 L/min	13.50 L/min
Acetylene flow	2.00 L/min	2.00 L/min	2.00 L/min	2.00 L/min	2.00 L/min
Replicates	3	3	3	3	3
Detection Limit	0.001 mg/L	0.005 mg/L	0.01 mg/L	0.01 mg/L	0.01 mg/L

RESULTS AND DISCUSSION

Calibration Curve

Doubly deionized water (blank solution) and accurately prepared working standard solution of known concentration was used for the calibration curve. By plotting the absorbance of working standard solution at y- axis and concentration at x- axis, calibration curve was obtained. The calibration curve of Pb, Cd, Cr, Ni and Zn and their coefficient of determination value (R^2) are shown in figure below.

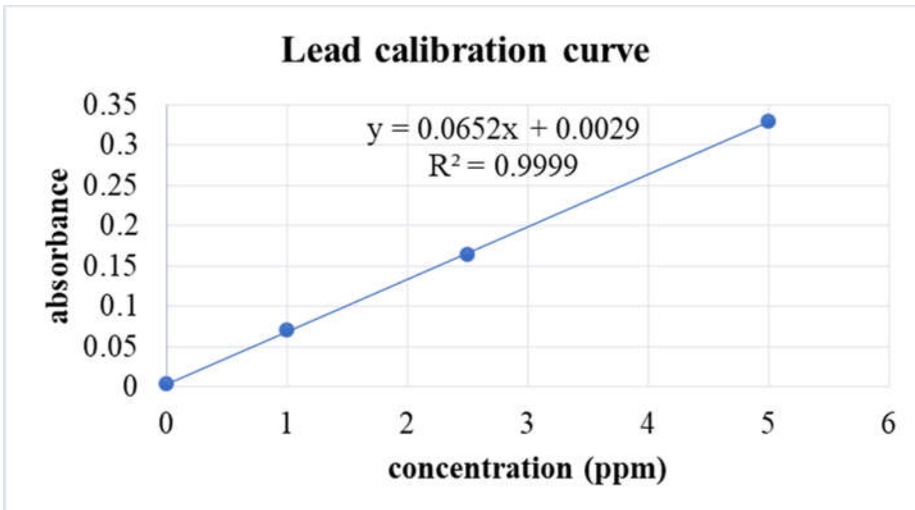

Figure 2. Calibration curve for Lead

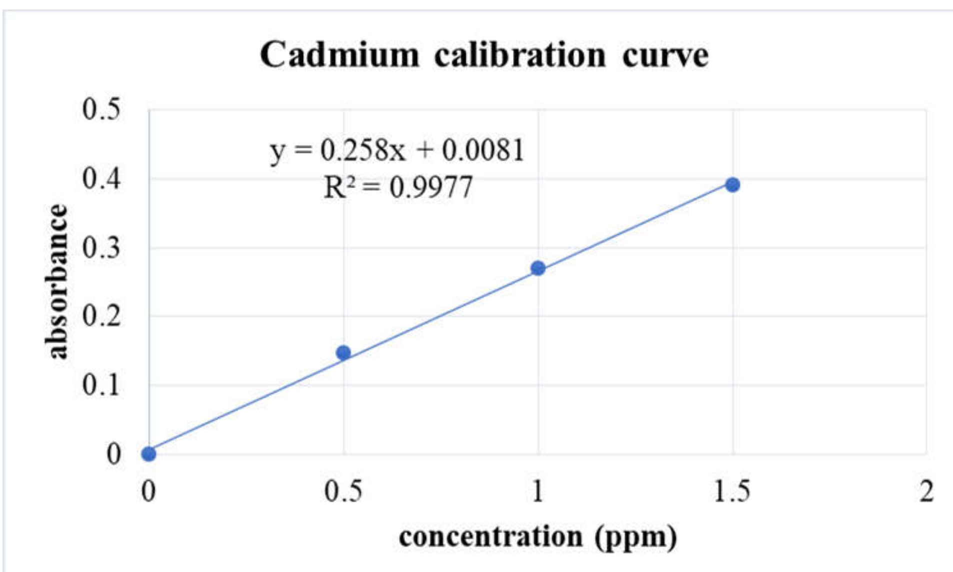

Figure 3: Calibration curve of Cadmium

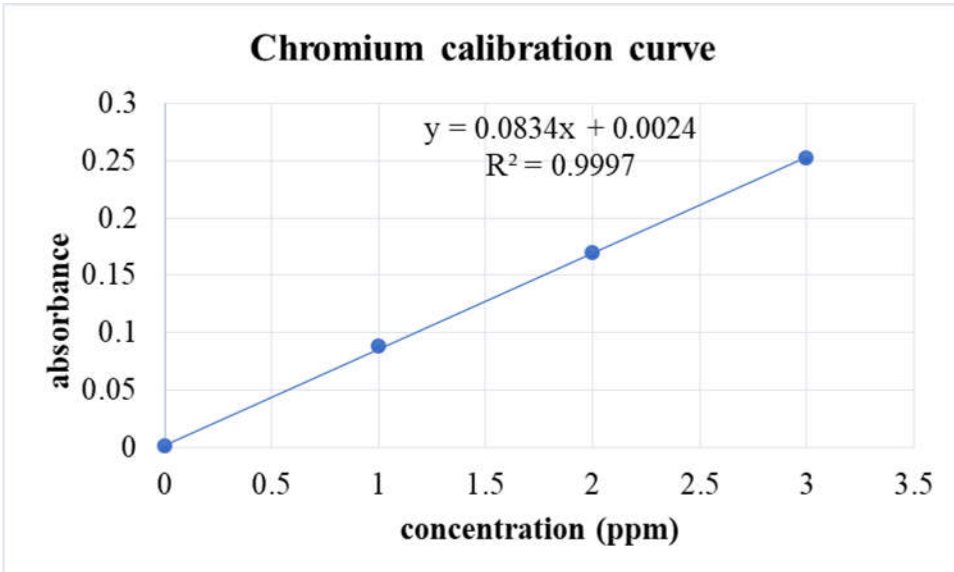

Figure 4: Calibration curve for Chromium

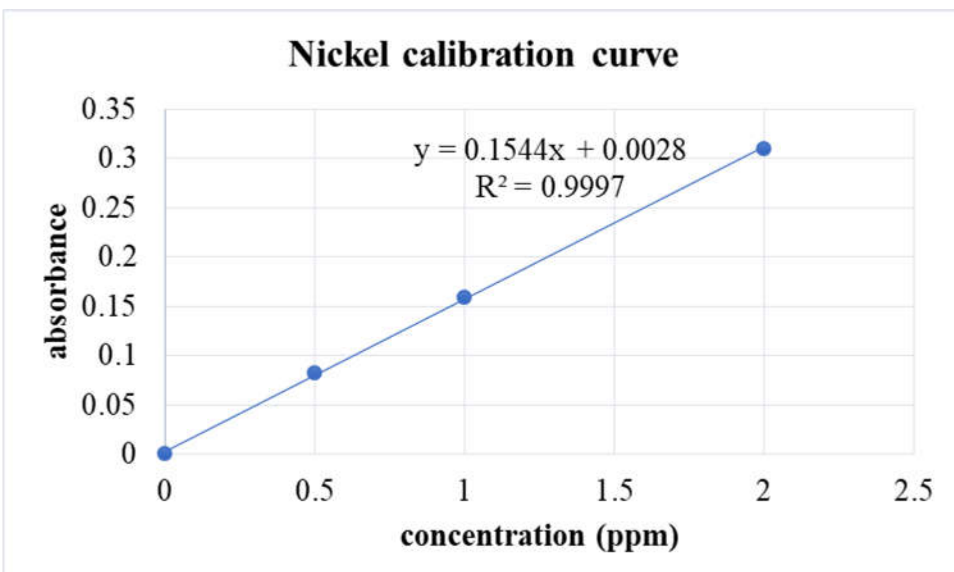

Figure 5: Calibration curve for Nickel

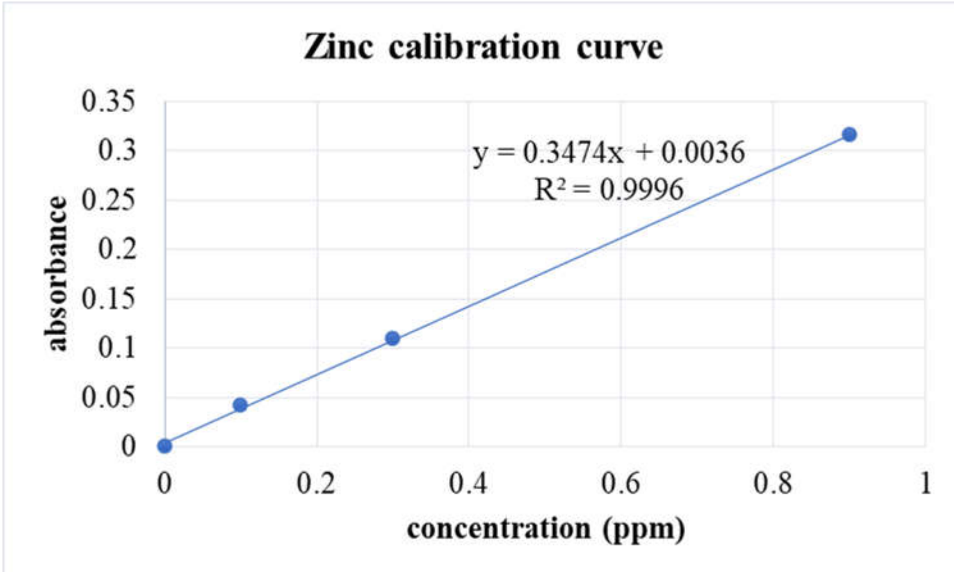

Figure 6: calibration curve for Zinc

Physicochemical Studies

The physiochemical studies on samples from W1 W6 are given in Table 3. The pH of the wastewater samples ranged from 7.1 to 8.0, with an average pH of 7.6, indicating the water is alkaline. The sample W2 had the highest pH at 8.0. For drinking water, an ideal pH range is 6.5-8.5, meaning Sample 6 falls within the WHO-recommended range. The conductivity of the wastewater samples ranged from 0.012 to 0.160 mS/cm, with an average of 0.045 mS/cm. The highest conductivity was recorded in sample W6 at 0.160 mS/cm, while the lowest was in W2 at 0.008 mS/cm. According to WHO, industrial wastewater with conductivity under 10,000 mS/cm is considered safe, and all samples met this guideline. Chloride levels ranged between 70.9 and 638.1 mg/L, averaging 283.6 mg/L. The highest chloride concentration was in sample W5 at 638.1 mg/L, and the lowest was in W6 at 70.9 mg/L.

Table 3: physiochemical parameters of waste water samples

Sample	pH	Conductivity (mS/cm)	Chloride concentration
W_1	7.9	0.012	212.7
W_2	8.0	0.008	177.25
W_3	7.5	0.020	283.6
W_4	7.9	0.014	319.05
W_5	7.4	0.057	638.1
W_6	7.1	0.160	70.9

Estimation of Heavy Metals

The estimation of heavy metal ion present in wastewater samples under investigation are shown in Table 4. Lead (Pb) levels ranged from 0.01 to 0.51 mg/L, with the highest found in sample W4 (0.51 mg/L) and the lowest in W5 (0.01 mg/L). WHO's limit for Pb in wastewater is 0.01 mg/L, indicating that all samples from the industrial area exceed this guideline, with concentrations ordered as W4>W1>W3>W2>W6>W5.

Cadmium (Cd) levels ranged from 0.005 to 0.016 mg/L, with the highest concentration in W4 (0.016 mg/L) and the lowest in W1 and W2 (0.005 mg/L). All Cd levels were below WHO's limit of 0.03 mg/L, following the order W4>W3>W6>W5>W2>W1.

Chromium (Cr) levels varied between <0.05 and 1.1 mg/L, with the highest concentration in W5 (1.1 mg/L) and the lowest in W1, W2, and W6 (<0.05 mg/L). WHO's limit for Cr is 0.05 mg/L, which was exceeded in W4 and W5. Cr levels were ordered W5>W4>W3>W1>W2>W6.

Nickel (Ni) ranged from 0.01 to 0.14 mg/L, with the highest concentration in W5 (0.14 mg/L) and the lowest in W2 (0.01 mg/L). Except for W5, all samples were within WHO's Ni limit of 0.07 mg/L, following the order W5>W3≥W4>W6>W1>W2.

Zinc (Zn) concentrations ranged from 0.071 to 2.89 mg/L, with W3 having the highest (2.89 mg/L) and W5 the lowest (0.071 mg/L). All Zn levels were within the WHO permissible limit of 3 mg/L, ordered W3>W1>W4>W6>W2>W5.

Table 4: Heavy metals concentration in waste water sample

S.N.	Heavy metals	Sample Concentration (mg/L)						WHO Permissible limit (Edition, 2011)
		W_1	**W_2**	**W_3**	**W_4**	**W_5**	**W_6**	
1.	Lead	0.37	0.02	0.05	0.51	0.01	0.02	0.01
2.	Cadmium	0.005	0.005	0.008	0.016	0.006	0.007	0.003
3.	Chromium	<0.05	<0.05	0.05	0.21	1.1	<0.05	0.05
4.	Nickel	0.02	0.01	0.05	0.05	0.14	0.03	0.07
5.	Zinc	0.561	0.116	2.89	0.284	0.071	0.156	3.00

CONCLUSION

Heavy metal assessment in wastewater samples was conducted using AAS techniques on five different samples collected from the Butwal industrial area. The analysis revealed that lead (Pb) has the highest concentration across all samples collected under investigation. In sample W4, chromium (Cr) levels is higher, while both chromium (Cr) and nickel (Ni) concentrations were notably high in sample W5. Lead was identified as the most prominent heavy metal in the wastewater samples, with the overall concentration of heavy metals following the order Pb > Cr > Ni > Cd > Zn. Physiochemical analysis further indicated that the pH and conductivity of the water were within the normal range.

REFERENCES

Agbaji, E., Abechi, S., & Emmanuel, S. (2015). Assessment of heavy metals level of soil in Kakuri industrial area of Kaduna, Nigeria. *Journal of Scientific Research and Reports, 4*(1), 68–78. https://doi.org/10.9734/JSRR/2015/13212

Alam, S. I., Hammoda, H., Khan, F., Enazi, R. A., & Goktepe, I. (2020). Electrical

conductivity, pH, organic matter and texture of selected soils around the Qatar University campus. *Research in Agriculture Livestock and Fisheries, 7*(3), 403–409. https://doi.org/10.3329/ralf.v7i3.51359

Bakar, M. A., & Bhattacherjy, S. C. (2012). Assessment of heavy metals concentration in some selected medicinal plants collected from BCSIR, Chittagong cultivation area in Bangladesh. *Hamdard Medicus, 55*(3), 26–32.

Bibi, M. (2023). Essential and non-essential heavy metals sources and impacts on human

health and plants. *Pure and Applied Biology, 12*(2).

Chaudhari, U., Kumari, D., Tyagi, T., Mittal, S., & Sahoo, P. K. (2024). Geochemical Signature

and Risk Assessment of Potential Toxic Elements in Intensively Cultivated Soils of South-West Punjab, India. *Minerals*, *14*(6), 576.

Edition, F. (2011). Guidelines for drinking-water quality. WHO chronicle, 38(4), 104-8.

Han, F. X., Banin, A., Su, Y., Monts, D. L., Plodinec, J. M., Kingery, W. L., & Triplett, G. E. (2002). Industrial age anthropogenic inputs of heavy metals into the pedosphere.

Naturwissenschaften, 89(11), 497–504. https://doi.org/10.1007/s00114-002-0373-4

Irfan, M., Hayat, S., Ahmad, A., & Alyemeni, M. N. (2013). Soil cadmium enrichment:

Allocation and plant physiological manifestations. *Saudi Journal of Biological Sciences, 20*(1), 1–10. https://doi.org/10.1016/j.sjbs.2012.11.004

Kayastha, S. P. (2015). Heavy metal pollution of agricultural soils and vegetables of

Bhaktapur district, Nepal. *Scientific World, 12*(12), 48–55.

Kiazai, I. (2019). Determination of heavy metals concentration in *Astragalus anisacanthus*

and *Ebenus stellata* of Balochistan, Pakistan. *Pure and Applied Biology, 8*(3).

Lewis, J. P., Cordner, M., & Fong, N. (2023). Pose space deformation: a unified approach to shape interpolation and skeleton-driven deformation. In Seminal Graphics Papers: Pushing the Boundaries, Volume 2 (pp. 811-818).

Mohammadi, A. A., Zarei, A., Esmaeilzadeh, M., Taghavi, M., Yousefi, M., Yousefi, Z., Sedighi, F., & Javan, S. (2020). Assessment of heavy metal pollution and human health risks assessment in soils around an industrial zone in Neyshabur, Iran. *Biological Trace Element Research, 195*(1), 343–352.

Raj, S. P., & Ram, P. A. (2013). Determination and contamination assessment of Pb, Cd, and Hg in roadside dust along Kathmandu-Bhaktapur road section of Arniko Highway, Nepal. *Research Journal of Chemical Sciences, 3*(9), 18–25.

Shakya, S., Baral, S., Belbase, P., Siddique, M. N. E. A., Samoh, A. N. H., Das, B., Shrestha, P. K., & Shakya, P. R. (2019). Determination and contamination assessment of heavy metals in street dust from different types of land-use in Kathmandu district, Nepal. *Journal of Institute of Science and Technology, 24*(1), 6–18.

Shrestha, S. M., Rijal, K., & Pokhrel, M. R. (2016). Assessment of heavy metals in deep groundwater resources of the Kathmandu Valley, Nepal. *Journal of Environmental Protection, 7*(4), 516–531. https://doi.org/10.4236/jep.2016.74047

Yadav, I. C., Devi, N. L., Singh, V. K., Li, J., & Zhang, G. (2019). Spatial distribution, source analysis, and health risk assessment of heavy metals contamination in house dust and surface soil from four major cities of Nepal. *Chemosphere, 218*, 11.