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Heavy Metal Concentrations in Soil from a Contaminated Swat Shooting Range, Khyber Pakhtunkhwa, Pakistan

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Abstract
Current study aims to find the concentration of heavy metals (Cd, Cr, Zn and Pb) in the soil of shooting range Kanju (village located on bank if river Swat), Swat, Khyber Pakhtunkhwa Pakistan. Kanju shooting range is located in Kanju town ship, where the army and police trainees' practice and shoot targets with pistols and rifles and use open area as shooting range. Samples were collected from eleven different points to analyse soil texture, electric conductivity (EC), pH and concentration of heavy metals, Cadmium (Cd), Chromium (Cr), Zinc (Zn) and Lead (Pb). The results revealed that soil was silty loamy and samples were basic to neutral ranging from 7.78-8.23. The EC ranged from 766µS/cm to 976µS/cm. The concentrations of these heavy metals were reported different at different positions i.e., Cd was highest at target top soil, while Zn was highest in 100ft form shooter point towards target at 30 cm depth. Pb-concentration was more at mid-point right side 24ft top soil and Cr was higher at the point of 50ft from

shooter towards target top soil 15cm. The presence of heavy metal in soil of shooting range affects the soil quality of not only that specific area but also the contaminants travel through different soil layers.

Keywords: Soil, Quality, heavy metals, contamination, shooting range, environment

Introduction

Soil-contamination especially in shooting ranges is a global concern for many researchers in the recent decade (Barker *et al.*, 2020; Pozza & Bishop, 2019). Metals exists naturally everywhere i.e., air, water, organisms and water in optimum amount, the denser than 5 mg/cm3 like Cadmium (Cd), Chromium (Cr), Cobalt (Co), Mercury (Hg), Nickle (Ni), Zinc (Zn), Arsenic (As) and lead (Pb) are known as heavy metals (Duffus, 2002; Li *et al.*, 2017). Despite the devastating effects and toxicity, some of heavy metals like Cr, Cu, Magnesium (Mg), and Ni are essential nutrients for organisms causing harmful effects as a result of deficiency (WHO/FAO/IAEA, 1996). Two important sources of contamination of soil via heavy metals are anthropogenic (mining, automobiles and firings in shooting ranges) and natural events like weathering and erosion of bed rocks plus ore deposits (Bayouli *et al.*, 2020; Busby *et al.*, 2020).

Shooting activities stand second after battery industries for contaminating soil with heavy metals especially Pb (Ahmad *et al.*, 2012; Sehube *et al.*, 2017). Pb was found to be exceeded the optimum range, while contamination factor was high for both Zn and Cd in shooting range of Frontier Corps Centre in Warsak, Khyber Pakhtunkhwa (Shoukat *et al.*, 2020). Also, shooting range of Nowshera cantonment revealed highest level of Pb accumulated in plants species (Khan *et al.*, 2021). The contaminants i.e., Pb and Cu in the Terningmoen military shooting range in Norway was greatest source of polluting under surface water (Okkenhaug *et al.*, 2017). Pb is the main component of bullets (> 90%), but various amounts of other heavy metals are also found in bullet mass (antimony (Sb), As, Bi, Ag, Cu, and Ni) (Sanderson *et al.*, 2014; Fayiga and Saha, 2016). Soil from post-military areas may be due to the corrosion of alloy steels used for the production of military equipment and weapons (Magaji *et al.*, 2018), that of Cd may be due to its use in bearing alloys and as a protective coating for other heavy metals and in Ni/Cd batteries, and that of Pb, Cu, and Zn may be due to their use in the production of ammunition (Clausen *et al.*, 2004). The presence of Cr, Ni, and Zn could also be due to their use as outer layers protecting steel from corrosion. Sources of heavy metals in soils used by military units also include paints containing Cr, Pb, and Cd, as well as fuels and greases (Kokorite *et al.*, 2008).

Humans may directly get in contact with heavy metals by consuming contaminated food stuffs, sea animals, and drinking of water, through inhalation of polluted air as dust fumes, or through occupational exposure at workplace (Yu and Tsunoda, 2004). The contamination chain of heavy metals almost usually follows this cyclic order: from industry, to the atmosphere, soil, water and foods then human (Krishna and Mohan, 2016). Cd is a dangerous element because it can be absorbed via the alimentary tract, penetrate through placenta during pregnancy, and damage membranes and DNA. Once in the human body, it may remain in the metabolism from 16 to 33 years (WHO, 2004). High Pb concentrations observed in many vegetables, although they do not pose a risk to human health, may be attributed to crops located near roads of heavy traffic. The

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main sources of this element to humans are inhalation of airborne Pb from vehicle emissions and from direct atmospheric deposition on soils, water, and crops, constituting the gateway into the food chain (Baird, 2002). Cr is an important element for the insulin activity and DNA transcription. However, an intake below 0.02 mg per day could reduce cellular responses to insulin (Kohlmeier, 2003). Zn has been reported to cause the same signs of illness as does Pb, and can easily be mistakenly diagnosed as Pb poisoning (McCluggage, 1991). Zn is considered to be relatively non-toxic, especially if taken orally. However, excess amount can cause system dysfunctions that result in impairment of growth and reproduction (INECAR, 2000). The clinical signs of Zn toxicosis have been reported as vomiting, diarrhoea, bloody urine, icterus (yellow mucus membrane), liver failure, kidney failure and anaemia (Fosmire, 1990).

Most of the researches are conducted to study the effects of toxic metals on water, food, plants and soil. In Pakistan, numerous recent researches (Khan *et al.*, 2010; Masood *et al.*, 2019; Tabassum *et al.*, 2019) have concentrated on the rice toxicity, soil toxicity due to ill-practices. Many studies have been conducted on heavy metals contamination due to shooting practices (Khan *et al.*, 2021; Shoukat *et al.*, 2020), i.e., Shoukat *et al.*, (2020) have studied the risks of potentially toxic metals in soils of shooting range of Frontier Corps Centre in Warsak, Khyber Pakhtunkhwa, and effect of heavy metals on plants in shooting range of Nowshera Cantonment, Peshawar (Khan *et al.*, 2021). But none of the study has focused on contamination of soil due heavy metals as a result of shooting practices in Kanju Township, Swat, KP. Therefore, present study has intended to focus on the heavy metal's contamination not only in the top-soil but also sub soil, both near shooting point and away from it in military and police training area Kanju, Swat.

Objectives

As we know that shooting activities plays a very important role in the contamination of our environment, which is highly neglected. This research will highlight the important aspect of environment degradation through the contamination of soil due to shooting activities. The main objective of the study was;

- To analyse the soil texture of shooting range of Kanu township, Swat.
- To analyse heavy metals (Cd, Cr, Zn and Pb) concentrations in the soil of army and police training centre town-ship Kanju, Swat.

The contamination of soils with these metals has driven researchers to analyse the effects of these metals on soil composition and other living things. Therefore, the present study aims to analyse the concentration of these heavy metals in the soil of shooting range of Kanju township, Swat.

Material and Methods

Study Area

Kanju is a village situated on the bank of the river Swat in swat district, KP Pakistan (Ali *et al.*, 2024a). It is considered as central heart of Nekpikheil. Kanju lies between 34 degree 48' 0" N and 72 degree 21' 0" E. Kanju is 3 km away from Mingora, the main city of swat district and about 5km from Saidu Sharif, the

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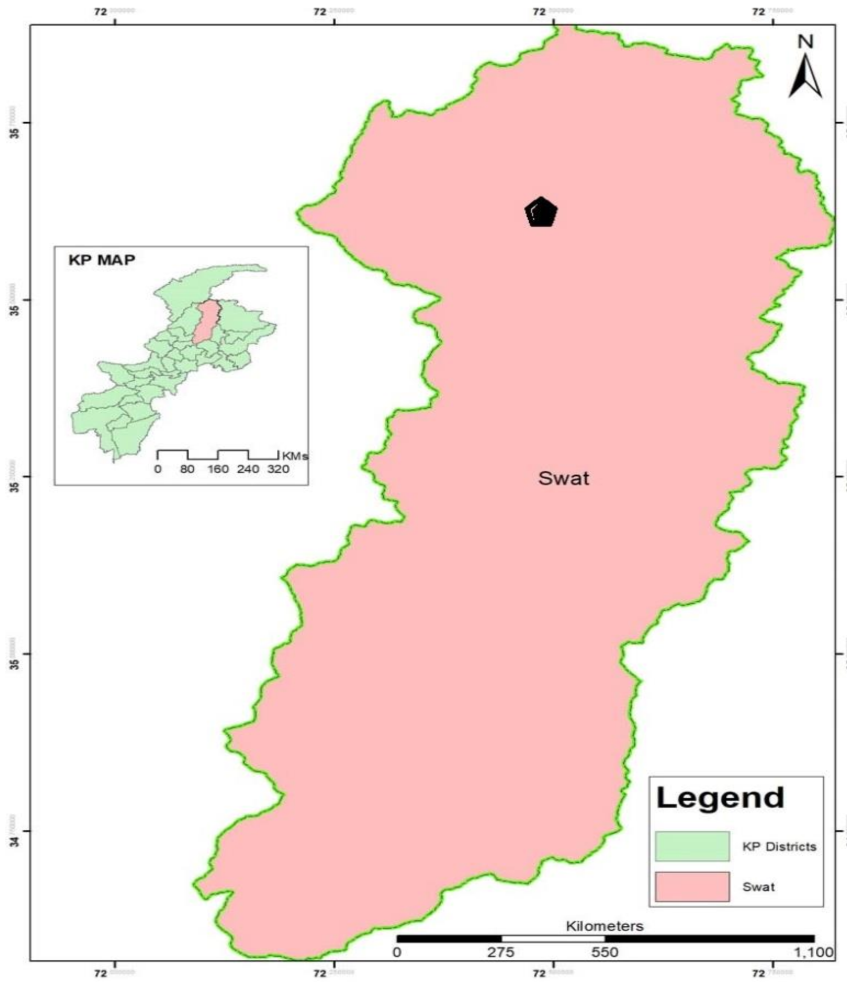
district headquarters (Ali *et al.*, 2024b). It is the first entry point to Nekpikheil (Nek Bibi Khel) area shown in Figure 1.

Figure 1: Location map showing shooting range in Kanju township Swat,



Khyber Pakhtunkhwa

Soils

The soils of the valley are alluvial/colluvial and have sedentary types. The foothills generally have deep soils composing of sand and stones, while hilltops have shallow and eroded profiles. The soil types range from sandy loam, loam sand, clay loam and sandy clay.

Soil Sampling

Eleven points were selected in the shooting range shown in Figure 2;

- Target area(150ft)
- 125ft from the shooting point towards target area
- 100ft from the shooting point towards target area
- Mid-point (75ft)
- 12 ft right from mid-point
- 24 ft right from mid-point
- 12 ft left from mid-point
- 24 ft left from mid-point

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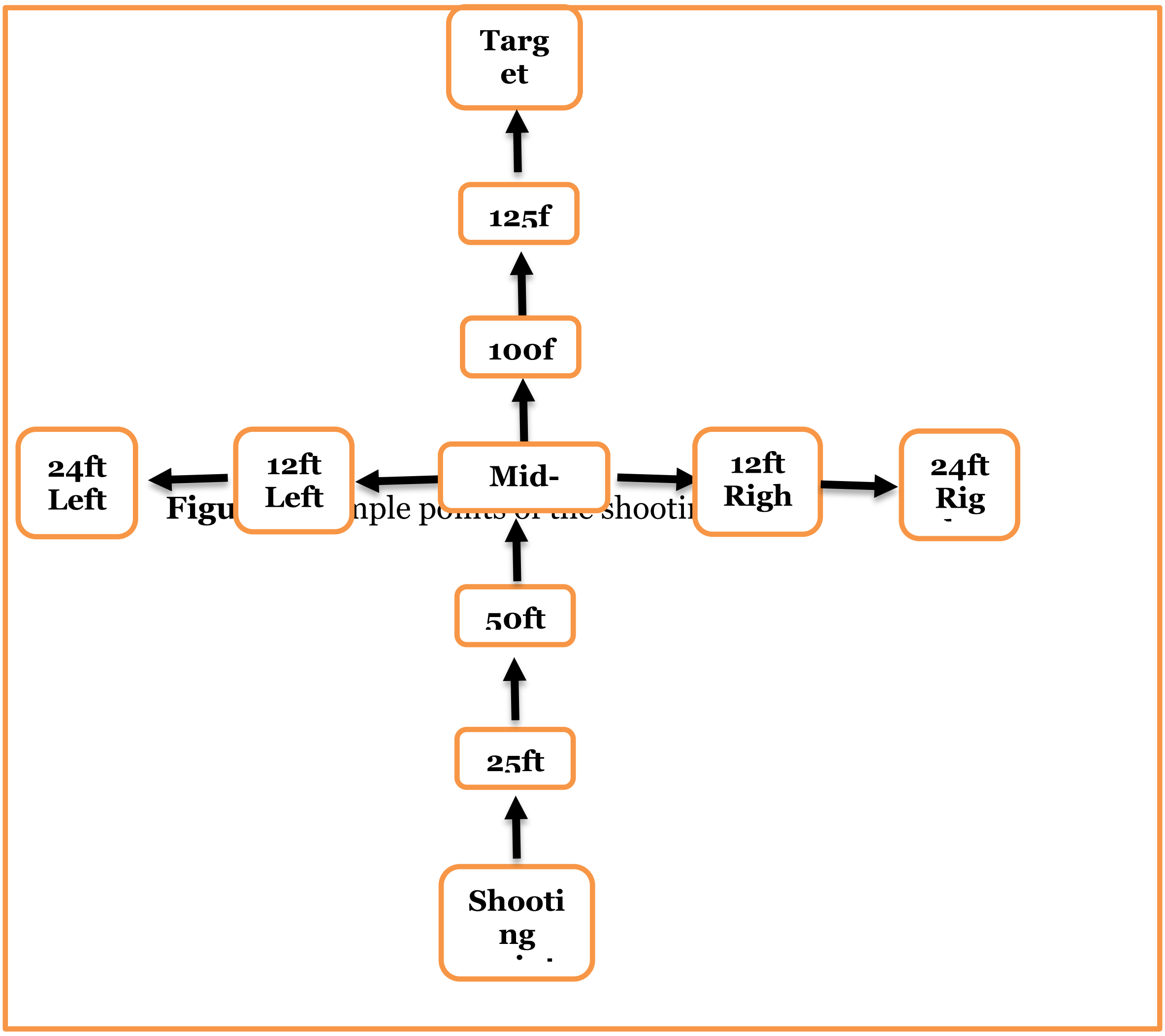
- 50ft from shooting point
- 25ft from shooting point
- Shooting point(0ft)



Two samples from each point were collected. One from 15 cm depth which is considered as top soil and the other from 30 cm depth which is considered as sub soil.

Sample Preparation
All the samples (n= 22) were kept in shade for drying for a week. Then they were grounded by using motor and pester. The samples were then sieved to get finely ground and uniformly sized soil grains. These prepared samples were kept for further analysis.

Analysis of soil parameters
Physio-chemical characteristics including EC, pH and texture were measured according to standard procedures (Khan *et al.*, 2014) (details given in supporting information (SI)).

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Heavy metals analysis

For the analysis of heavy metals, the soil samples (0.5g) were first digested using aqua regia. The digested samples were filtered through 0.22 µm membrane and the filtrate made up to 50 mL with Milli-Q water. The extract is then stored to analyse Cd, Cr, Zn and Pb. The prepared and extracted samples were used to analyse for heavy metals Cd, Cr, Zn and Pb using AAS (details given in SI).

Results and Discussion

Physio-chemical properties of soil

Different physical and chemical properties of the soil were analysed such as pH, soil texture and EC.

Sample Id

Table 1 shows points from where soil samples were collected along with its complete description.

Table 1: sample Id and description

Sample ID	Description	Sample ID	Description
Sample001	top soil from target area 15 cm depth	**Sample012**	target area sub soil 30 cm
Sample002	125 ft from shooter towards target area top soil 15 cm	**Sample013**	shooter area sub soil 30 cm
Sample003	mid-point left side 12 ft top soil 15 cm	**Sample014**	50 ft from shooter towards target top soil 15 cm
Sample004	mid-point left side 24 ft sub soil 30 cm	**Sample015**	mid-point left side 24ft top soil 15 cm
Sample005	100 ft from shooter towards target top soil 15 cm	**Sample016**	25ft from shooter towards target top soil 15 cm
Sample006	mid-point right side 12 ft sub soil 30 cm	**Sample017**	125 ft from shooter towards target area sub soil 30 cm
Sample007	50 ft from shooter towards target sub soil 30 cm	**Sample018**	mid-point right side 12ft top soil 15 cm
Sample008	mid-point right side 24 ft sub soil 30 cm	**Sample019**	25ft from shooter towards target sub soil 30 cm
Sample009	shooter area top soil 15 cm	**Sample020**	100ft from shooter point towards target sub soil 30 cm
Sample010	mid-point left side 12 ft sub soil 30 cm	**Sample021**	mid-point sub soil 30 cm
Sample011	mid-point right side 24 ft top soil 15 cm	**Sample022**	mid-point top soil 15 cm

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Soil texture

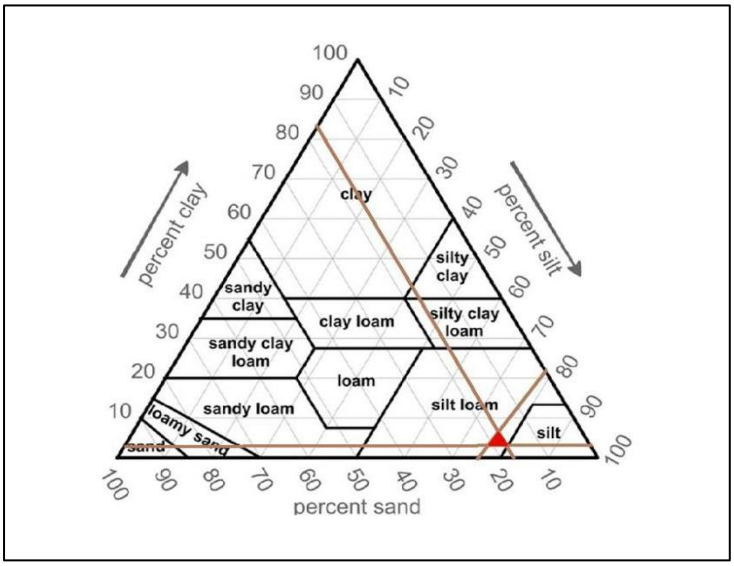
Soil texture refers to the relative proportions of different-sized mineral particles (such as clay, silt, and sand) present in the soil. These particles greatly influence the soil's physical properties, including water-holding capacity, drainage, aeration, and nutrient availability. The soil texture classification is typically based on the percentage of each particle size.

By analysing the soil texture of the shooting area as shown in Figure. 3, we found that the soil consists of 2.6% clay, which is a relatively low clay content. It has significant effects on soil properties i.e., water retention and nutrients availability. Such low clay content portrayed that the soil may likely have good drainage and adequate aeration. Also, the result revealed that soil has 19.41% sand, which is a moderate proportion showing good drainage and better aeration. The result further showed that majority of the soil is composed of 78% silt. Silt particles are smaller than sand but larger than clay particles. Soils with a high silt content generally have good water-holding capacity and moderate drainage. Silt contributes to the overall fertility of the soil and helps retain essential nutrients. Consequently, the results clearly showed that the overall texture of the soil is silty loam.

Lee *et al.*, (2011) reported 56.6% sand, 14% clay and silt 29.4% in Korean soil, which was higher than our calculated value. The soil texture was sandy loam in nature. Similarly, soil with 44.92% sand, 49.50% silt and 5.58% clay and termed as silty loamy. These values also exceeded our calculated values (Ibrahim *et al.*, 2019). Recently, Ni *et al.*, (2023) also reported that Imari shooting range, Japan has loamy sandy soil with 16.2% Silt and 83.8% sand. Additionally, two cites studies showed that the soil is overall sandy loamy in La Pampa, Argentina (Saran *et al.*, 2022). Hence, the soil of the Kanju was found to be silty loam texture, which is balanced soil with both beneficial characteristics of silt and loam. It typically has good water-holding capacity, moderate drainage, and adequate nutrient retention, making it suitable for a wide range of plants and activities (Čechmánková *et al.*, 2021).

Figure 3 Soil texture of shooting range kanju, Swat

pH of soil samples



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Soil pH is a crucial parameter that influences various soil properties and processes, including nutrient availability, microbial activity, and the solubility of heavy metals. The result revealed that the pH of soil samples collected from shooting range of Kanju township was basic to neutral ranging from 7.78-8.23. The values of soil pH are given in Table 2.

Table 2 Showing pH of the soil

Sample ID	pH	Sample ID	pH
Sample001	8.01	**Sample012**	7.93
Sample002	8.06	**Sample013**	7.89
Sample003	7.97	**Sample014**	8.21
Sample004	7.78	**Sample015**	8.16
Sample005	7.86	**Sample016**	8.02
Sample006	8.01	**Sample017**	8.22
Sample007	8.23	**Sample018**	8.06
Sample008	8.06	**Sample019**	7.98
Sample009	7.96	**Sample020**	7.94
Sample010	8.11	**Sample021**	8.14
Sample011	7.96	**Sample022**	7.81

Previous studies indicated the pH calculated in the soils of Korean soil samples from military shooting areas were 6.7 (Ahmad *et al.*, 2012) and 6.0-6.5 (Jo and Koh, 2004), which were lower than our results. They were slightly acidic in nature. Comparing these Korean soil pH values to the results of the study at hand, it is stated that the pH values obtained in the current study were higher than those reported in the Korean studies. This suggests that the soil in the current study might be less acidic or even slightly alkaline. Also, 6.7-8.6 pH was reported in five shooting ranges of Botsawana, exceeding our study results (Dinake *et al.*, 2018). These values indicate a more alkaline nature of the soil in the Botswana shooting ranges compared to the soil examined in the present study.

In contrast, the Avgrunnsdalen shooting ranges were characterized by very low pH values, specifically 3.5-4.2 (Mariussen *et a.*, 2017). These extremely low pH values indicate highly acidic soil conditions in the Avgrunnsdalen shooting ranges, which are significantly lower than the pH values observed in the current study. Additionally, studies conducted in Pakistan reported varying pH values in shooting ranges. The soil pH in the Warsak shooting range was found to be 6.5-7.1 (Shoukat *et al.*, 2020), while the Nowshera Cantonment shooting range reported a pH range of 6.34-8.31 (Khan *et al.*, 2021). These results indicate that the soil pH in these shooting ranges can range from slightly acidic to slightly alkaline.

The importance of soil pH in relation to heavy metal solubility and availability is well-documented in scientific literature. Studies by Ok *et al.*, (2008, 2010) have demonstrated the influence of soil pH on the mobility and bioavailability of heavy metals in soil. Generally, in acidic conditions, heavy metals tend to be more soluble and therefore more readily available for uptake by plants and other organisms. In contrast, in alkaline conditions, heavy metals tend to be less soluble and, thus, less available for uptake.

Electric Conductivity of soil samples

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The conductivity of soil samples is an important parameter that provides information about the ability of the soil to conduct electrical current. It is a measure of the soil's ability to transmit nutrients, ions, and water through its matrix. In this discussion, we will analyse the conductivity values obtained for different soil samples and compare them to values reported in other studies.
The given Table 3 shows the EC values of various soil samples, ranging from 766 µS/cm to 976 µS/cm. It is worth noting that these values exhibit limited variation among the samples tested. EC is typically measured in microsiemens per centimetre (µS/cm), and it reflects the concentration of total dissolved salts and other ions in the soil solution.

Table 2 Showing EC of the soil

Sample ID	EC µS/cm	Sample ID	EC µS/cm
Sample001	766	**Sample012**	930
Sample002	850	**Sample013**	856
Sample003	797	**Sample014**	797
Sample004	876	**Sample015**	827
Sample005	976	**Sample016**	945
Sample006	897	**Sample017**	962
Sample007	816	**Sample018**	805
Sample008	845	**Sample019**	913
Sample009	920	**Sample020**	796
Sample010	784	**Sample021**	782
Sample011	832	**Sample022**	872

To contextualize the results, the study refers to previous research conducted by various researchers reported different EC values for soils in different regions. Lee *et al*., (2011) found an EC value of 250 µS/cm in Korean military shooting soil, which is considerably lower than the calculated values in the current study. Similarly, Singh and Agarwal (2007) reported an EC value of 4 µS/cm in Indian soil, also significantly lower than the present findings. Additionally, Shoukat *et al*., (2020) analysed Warsak shooting range soil and reported an EC range of 0.2-0.4 µS/cm, which is extremely low compared to the values obtained in the current study.
These variations in EC values can be attributed to several factors, including differences in soil composition, geographical location, environmental conditions, and anthropogenic activities. Soil composition plays a crucial role in determining its conductivity. Soils with high clay or organic matter content tend to have higher conductivity due to the presence of more ions and enhanced water retention capacity. On the other hand, sandy soils with low organic matter content may exhibit lower conductivity because of their lower ion concentration and reduced water-holding capacity. Geographical location and environmental conditions, such as climate and rainfall patterns, can also affect soil conductivity. Regions with higher rainfall often have higher conductivity due to increased leaching of ions from the soil surface. Furthermore, human activities like agriculture, industrial processes, and the use of fertilizers and chemicals can significantly influence soil conductivity by introducing additional ions and contaminants.

Concentration of heavy metals in soil samples

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Soil samples were sent to CRL (Centralized Resource Laboratory) for determination of heavy metal concentrations. Concentrations of Pb, Cd, Cr and Zn were measured by AAS (Atomic Absorption Spectrophotometer).

Concentration of Cadmium in soil samples

Cadmium is a toxic heavy metal that is commonly found in shooting range soils due to the use of lead-based ammunition. When lead bullets or pellets strike a target, they can fragment and disperse tiny particles of lead and other metals, including cadmium, into the surrounding soil. Over time, these contaminants accumulate and pose a risk to human health and the environment. The Figure. 4 shows the Cd values in samples. Concentration of Cd at mid-point subsoil is the highest i.e., 1.2 mg/kg followed by the target area top soil i.e., 1.0 mg/kg which is lower than the permissible limit set by WHO 3 mg/kg (Chiroma et al. 2014) but at some points Cd is not detected which are midpoint left side 12ft top soil, mid-point left side 24ft top soil, and 25ft from shooter towards target sub soil (Details given in SI).

Dinake *et al*., (2018) investigated five different shooting ranges and reported 0.2-0.8 mg/kg Cd, which is less than our calculated value and also less than permissible limit of WHO (Chiroma et al. 2014). Also, Cesynaite and Sujetoviene, (2018) calculated the Cd in soil of in military shooting range in Central Lithuania was 17.42-39.07 mg/kg, which was higher than the current results. It also exceeded the WHO recommended level (3mg/kg) (Chiroma *et al*., 2014). One more finding revealed that the concentration of Cd in Kaduna (Nigeria) was reported to be 1.84 ± 0.27, which was lower than our findings. Lee et al. (2011) also reported Cd concentration (0.35 mg/kg) exceeding the background level in the soil of Korean shooting range, and observed that the metal concentrations become higher when heavy continuous shooting is practiced in the range. As Cd is considered as the most toxic element for humans (Volpe *et al*., 2009). Therefore, the soil in shooting ranges should be treated with precautionary method to control the concentration of heavy metals.

Cadmium can be found in shooting range soils due to several factors, including the presence of cadmium-based primers in ammunition, erosion of targets and backstops containing cadmium, improper disposal of cleaning agents and maintenance materials, historical practices, and natural occurrences in certain regions. The accumulation of cadmium in the soil poses environmental and health risks, necessitating proper soil management, monitoring, and remediation to mitigate these concerns.

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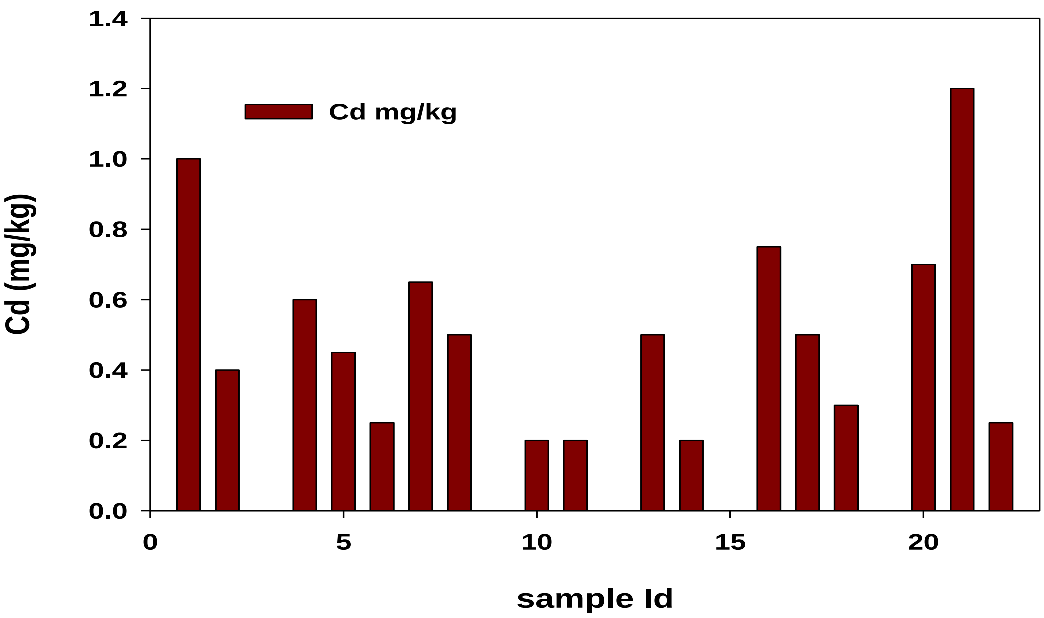

Figure 4 Concentration of Cd in soil samples

Concentration of Zinc in soil samples

Zn is an essential micronutrient required for various physiological processes in plants, animals, and humans. However, excessive concentrations of zinc in soil can have adverse effects on the environment, including potential toxicity to plants and subsequent impacts on the food chain. Human exposure to high levels of zinc through contaminated soil or water sources can also pose health risks.

The concentration values are presented in Figure 5, and there are two notable points mentioned: the highest concentration of 65.6 mg/kg at a distance of 100 feet from the shooter point towards the target, at a depth of 30 cm, and the lowest concentration of 10 mg/kg at the midpoint, at a depth of 15 cm. According to the details provided, both concentrations of zinc are below the permissible limit set by the World Health Organization (WHO), which is 300 mg/kg (Chiroma *et al.*, 2014). This indicates that the zinc levels in the mentioned area are within acceptable limits for human health.

Comparing these findings with previous studies, it is mentioned that the mean concentration of zinc calculated in the soil of Nigeria was 1.04 ± 0.32 in shooting practice zones (Magaji *et al.*, 2018). This value is considerably lower than the concentrations found in the current study. It implies that the levels of zinc observed in the current area are relatively higher compared to the shooting practice zones in Nigeria. Additionally, a study conducted in Pakistan (Khan *et al.*, 2010) claimed that the amount of zinc in the soil of Gilgat ranged from 173 mg/kg to 1194 mg/kg. These values exceed the concentrations found in the current study as well as the WHO recommended level. Therefore, it can be concluded that the zinc levels observed in the area under study are comparatively

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lower than those reported in the soil of Gilgat, Pakistan.
The variations in zinc concentrations between different areas and studies can be attributed to factors such as geological and soil composition, human activities, shooting practices, environmental conditions, and sampling methods. These factors can influence the natural presence of zinc in soils, the introduction of zinc through human activities, and the mobility and availability of zinc in the environment. Further research and analysis are necessary to fully comprehend the reasons behind the observed variations.

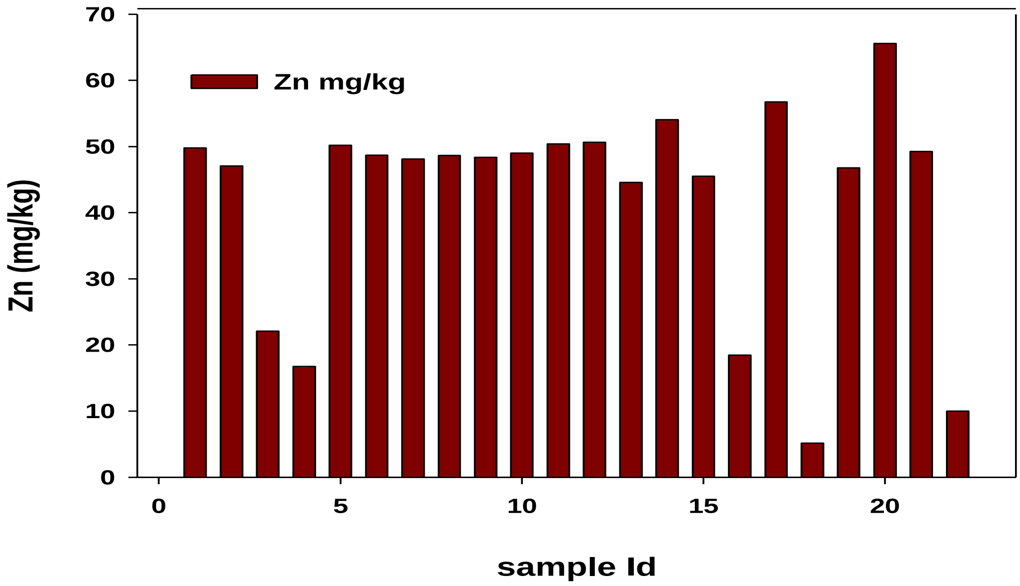

Figure 5 Concentration of Zn in soil samples

Concentration of Lead in soil samples

Lead contamination in soil poses a significant risk to human health and the environment. Even though the measured levels were within acceptable limits, it is important to note that any presence of lead in the soil can have detrimental effects, especially in the long term. Continuous monitoring, preventive measures, and remediation efforts should be undertaken to minimize the potential hazards associated with lead exposure.
By analysing the concentration of Pb in all soil sample it was found that Pb was more at mid-point right side 24ft top soil i.e., 25.05mg/kg and less at mid-point right side 12ft top soil i.e., 3.55mg/kg as shown in Figure 6 (Details given in SI). Both the levels are within the permissible limit set by WHO i.e., 100 mg/kg (Chiroma *et al.*, 2014).
In Southern Italy, the soil collected from shooting range of Acerra portrayed Pb of 1575 mg/kg, which not only exceeded our findings but also surpassed the WHO recommendations (Porfido *et al.*, 2022). Also, the average Pb calculated in the soil of Nigeria contaminated by shooting practices was 14.85 ± 6.78, which was lower than our calculated value in soil of Kanju, Swat (Magaji *et al.*, 2018).

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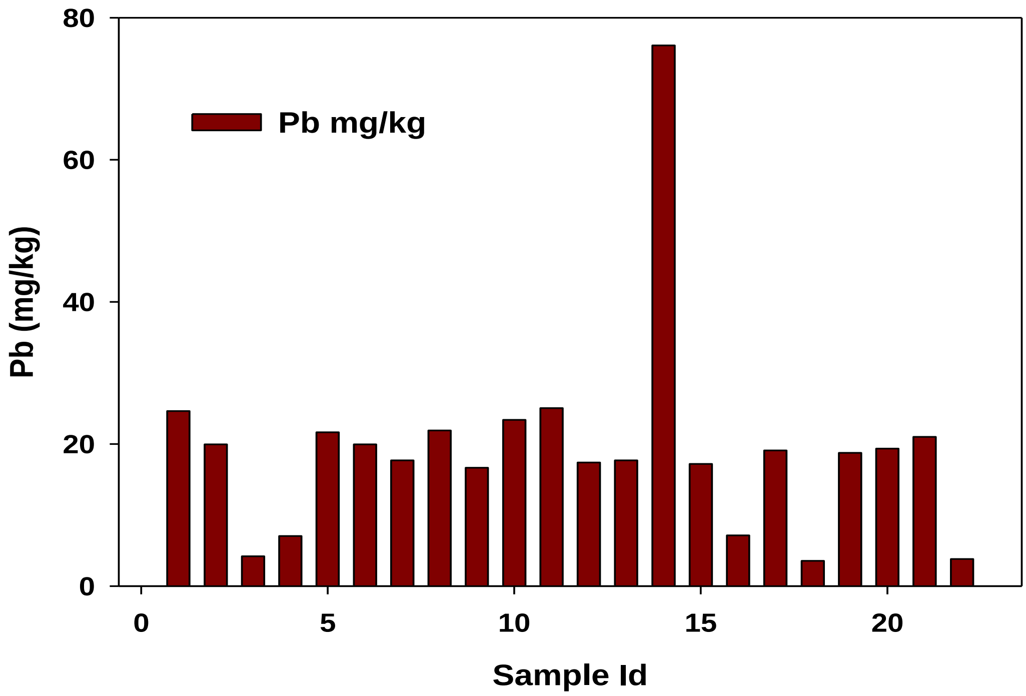

Figure 6 Concentration of Pb in soil samples

The shooting ranges contribute to Pb-contamination in soil through the use of Pb-based ammunition and human activities. The deposition of Pb particles directly into the soil, inadequate containment measures, and the accumulation of Pb dust are common factors. Soil composition and characteristics can affect the extent of contamination, and Pb in soil can have negative impacts on ecosystems and potentially contaminate groundwater. Proper management practices and containment measures are necessary to mitigate Pb contamination from shooting ranges and protect the environment.

Concentration of Chromium in soil samples

Cr is an essential element that plays a significant role in various biological processes. It is important for insulin activity, assisting in the regulation of blood sugar levels and promoting glucose metabolism. Additionally, chromium is involved in DNA transcription, supporting the replication and repair of genetic material.

The highest concentration of Cr is found at the point of 50ft from shooter towards target top soil 15cm which is 234.6mg/kg which is higher than the permissible limit set by WHO i.e., 100mg/kg (Chiroma *et al.*, 2014). The lowest concentration of Cr is found at mid-point left side 24ft top soil 15cm but at some point, the concentration is not detected like 125ft from shooter towards target top soil 15cm, mid-point left side 12ft top soil 15cm, mid-point left side 24ft sub soil 30cm, 25ft from shooter towards target top soil 15cm, mid-point right side 12ft to soil 30cm, and mid-point top soil 15cm as shown in Figure 7 (Details given in SI). The concentration of Cr in Switzerland military shooting range was 99mg/kg, which is lower than our calculated result (Evangelou *et al.*, 2012). Similarly,

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Magaji *et al.*, (2018) reported 14.55 ± 1.45 mg/kg of Cr in Nigerian soil contaminated by shooting practices, which is also less than our calculated value. Cr is an important element for the insulin activity and DNA transcription. However, an intake below 0.02 mg per day could reduce cellular responses to insulin (Kohlmeier, 2003).

The presence of chromium (Cr) in shooting range soils can be attributed to factors such as ammunition containing chromium, surface coatings on firearms and ammunition, metal fragmentation from bullet impacts, cleaning agents used on equipment, and weathering and transport processes. These factors contribute to the introduction and accumulation of chromium in shooting range soils, highlighting the importance of monitoring, proper waste management, and remediation efforts to mitigate potential risks.

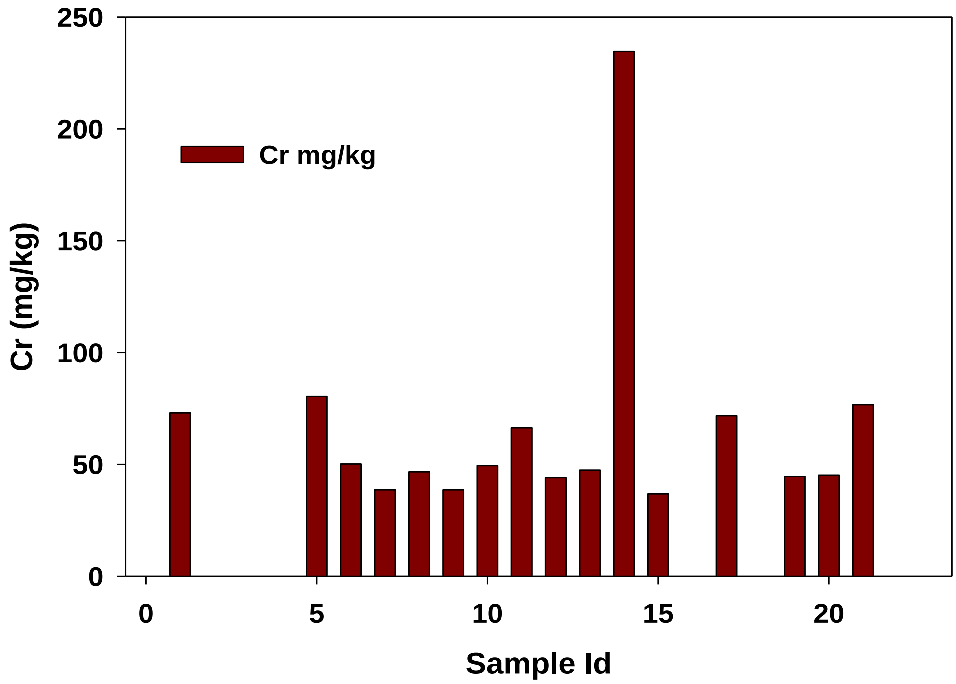

Figure 7 Concentration of Cr in soil samples

Conclusion

The objective of the study was to analyse heavy metals concentrations in the soil of army and police training centre town ship Kanju, Swat. The results of the study concluded that the soil of Army and police training centre township Kanju, is not much contaminated with heavy metals: Pb, Cd, Cr, and Zn. Only the Cr concentration was found above the permissible limit at some points and all others were within the permissible limits. In Pakistan, the environmental perspective of shooting range soils is overlooked and there is a need to take steps to avoid such contamination of soils because in the long term these heavy metals can leach underground and can contaminate the aquifer as well. Heavy metals are toxic to soil biota, so for the protection of soil biota, the shooting range soils must be safe and non-toxic.

Recommendations

Increasing the number of shooting ranges would provide a more comprehensive understanding of the heavy metal distribution in the soil of these ranges. Considering a broader range of heavy metals and pollutants would provide a more comprehensive assessment of soil contamination. Future studies could examine the effects of heavy metal contamination on the surrounding ecosystem, including the potential for bioaccumulation in plants and the transfer of contaminants through the food chain. Furthermore, other researches could incorporate an assessment of exposure pathways, such as the consumption of locally grown produce or the inhalation of dust particles, to determine if there are any potential health risks for individuals in the area. The study you described focused solely on the concentration of heavy metals in the soil of the shooting range. However, to fully understand the potential risks and impacts, it would be valuable to study the plants grown in the area for heavy metal accumulation. Future research could involve collecting plant samples from the shooting range and analysing them for heavy metal concentrations. This would provide insights into the uptake and bioaccumulation of heavy metals by plants, which could have implications for food safety and human exposure if the plants are consumed by humans or animals.

Novelty Statement

Heavy metals' effects have been studied in relation to water, food, plants and soils texture (Khan *et al.*, 2010; Masood *et al.*, 2019; Tabassum *et al.*, 2019). In Pakistan, to our knowledge only 2 studies (Khan et al., 2021; Shoukat et al., 2020) have studies shooting range practices and its impacts i.e., (Shoukat *et al.*, 2020) have studied the risks of potentially toxic metals in soils of shooting range of Frontier Corps Centre in Warsak, Khyber Pakhtunkhwa, while,(Khan *et al.*, 2021) analysed the effect of heavy metals on plants in shooting range of Nowshera Cantonment, Peshawar. Kanju shooting range in Swat has not been studied yet, so the present study has intended to focus on the heavy metal's contamination not only in the top-soil but also sub soil, both near shooting point and away from it in military and police training area.

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