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Health risk assessment and levels of heavy metals contaminated drinking water used by both adults and children from Nawanshahr town

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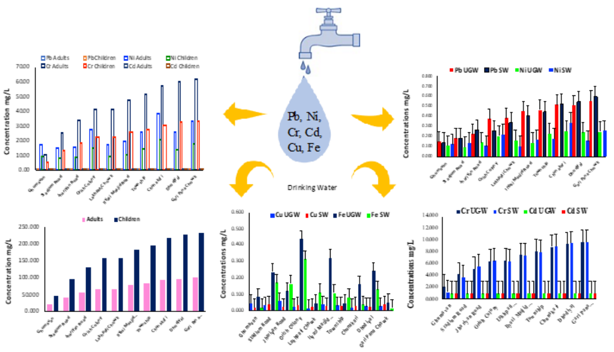
Graphical abstract



Abstract

Heavy metal ions are very toxic to human and can be introduced into the water through numerous sources such as industry wastes, coal mining, agriculture activity and human-caused activities. The current study was conducted to quantify Pb, Ni, Cr, Cd, Cu, and Fe in drinking water (surface and subsurface water) from Nawanshahr Town, Abbottabad, Pakistan, and to evaluate the associated threat to the health of the inhabitants. An atomic absorption spectrometer (Perkin Elmer, AAS-700) was utilized to quantify the metals and compare them to the threshold level set by Pak EPA. Ni, Pb, Cr, Cd, and Cu levels were higher than Pak-EPA permissible limits, so they were unacceptable. Considering the HM level, health risk assessments such as Consumers' Daily Intake (CDI), Hazard Quotient (HQ), Health Index (HI), and Targeted Cancer Risk (TCR) were calculated. The order of CDI values in both adults and children was Cr > Cu > Pb > Fe > Ni > Cd and the values of HQ were higher than 1 for all HMs in water samples, indicating non-carcinogenic risk to the residents except for Ni. The HI values >1 for all metals of each site indicate adverse non-carcinogenic health effects. Moreover, the TCR results for all metals were high in all locations, indicating the carcinogenic risk. The present study can be helpful for residents and government officials to take protective measures and minimize contamination of drinking water with heavy metals.

Keywords: Heavy metals, drinking water, health risk index, Abbottabad, cancer risk

1. Introduction

The water from lakes, ponds, rivers, streams, and underground water (hand pumps and tube wells) are two natural sources. Still, the increasing population causes water contamination, which is difficult to reinstate. Hence, there is a need to protect water quality (Nawaz *et al*. 2015).

Earth's crust has heavy metals (HMs) with molar masses ranging from 63.5 to 200.6 grams per mole and a density of more than 5 g/cm^3 (Charlesworth *et al*. 2011). These metals enter the human body via the mouth, air passage, and skin. Volcanic eruptions, forest fires, and leaching from soil and rocks, are natural sources and mining, fertilizers and pesticides, industrialization, and urbanization, are anthropogenic sources of HMs pollution in water resources (Jyothi *et al*. 2020), which is a major concern for water safety, human health, and quality assurance (Shaheen *et al*. 2016). Metals are among the environmental contaminants of special involvement due to their noxiousness and bioaccumulation. Some heavy metals, such as Cr, Fe, Cu, Pb, Cd, and Ni, are potentially dangerous in their combined or elemental forms (Gaur Sandeep *et al*. 2012). Lead occurs in the earth's crust and many common home items. The most frequent lead sources in drinking water are waterworks and lead pipes (Duff, 2002). Power plants, waste incinerators, nickel-cadmium batteries, fertilizers, and the metallurgical industry all cause nickel to enter water sources. According to Ahmed *et al*. (2020), the chromium leaching from rocks and above-ground soils is the main natural source in aquatic ecosystems. The effluent from the electroplating, leather, and textile industries adds chromium to the water bodies (Ali *et al*. 2019). Galvanized water pipes allow cadmium to enter the water, and cadmium also finds its way into water through sewage sludge, manure, contaminated groundwater, and mines (Duff, 2002). Copper can get into drinking water directly through contaminated well water or by causing damage to copper piping. It takes up copper leaks from plumbing components, including pipes, faucets, and brass faucets that taint the water. According to Kamboj *et al*. (2019), frequent sources of iron (Fe) in water are rock erosion, industrial effluents, acidic mining effluents, and landfill leachates.

Contaminated water is to blame for up to 90% of the population's exposure to HMs, up to 50% of illnesses and 40% of deaths (Shaheen *et al*. 2016). HMs can contaminate fresh or processed water (Hajeb *et al*. 2014) and can be harmful if taken in amounts above the permitted limit (Dghaim *et al*. 2015). Bioaccumulation of HM in humans affects mutagenesis, carcinogenesis, and toxicity (Daud *et al*. 2017). Due to increased blood pressure, lead can harm the kidneys, especially in children under six years (Ahmed *et al*. 2022). Lead can also block the synthesis of hemoglobin. The symptoms of asthma, heart disease, nausea, and dizziness can all be made worse by consuming too much nickel (Ni) over the safe limit. A higher concentration of Cr has been linked to cancer, respiratory issues, allergy and asthmatic reactions, and skin hypersensitivity (Haque *et al*. 2020). According to Henson *et al*. (2013), Cd can induce lung damage, alveolar tumors, impaired fertility, early birth, and flu-like symptoms (chills, fever, myalgia). Likewise, Cu levels that are too high can lead to nose, ocular, and tongue sensitivity, as well as stomach distress and diarrhea. Overconsumption of the daily recommended amount of Fe may result in intestinal pain, hypothyroidism, depression, osteoporosis, cirrhosis, malignant tumors, cardiovascular disease, diabetes, depression, osteoporosis, infertility, hepatitis, hypogonadism, and early mortality (Tagliabue *et al*. 2014).

In Pakistan, contaminated drinking water supply infrastructure from natural and human-caused activities, such as mining, is the cause of both groundwater and tap water contamination. Poor water supply and subpar sterilizing services also contribute to the issue. The Abbottabad neighborhood's drinking water is of poor quality. HMs occurrence in Abbottabad's water resources is severe and contributes to several ailments connected to the water. Water quality surveys showed that most of the nation's regions lack water that meets Pak-EPA standards (Raza *et al*. 2017). There are few and occasional studies on drinking water contamination in the research region. However, no attention has been paid to the amount of HM in drinking water and the potential harm to Abbottabad and the surrounding communities. Thus, this was the first baseline study to investigate the drinking water contamination with heavy metals and associated health problems. Given this, the current study was to quantify the amounts of Pb, Ni, Cr, Cd, Cu, and Fe in drinking water from Nawanshahr Town, Abbottabad and the health issues.

2. Materials and methods

2.1. Research area

The research site was in Nawanshahr, a town in the Abbottabad district of Khyber Pakhtunkhwa (**Figure 1**). It is situated on Murree Road between 34°10'N and 73°16'E near the tourist spots of Thandiani and Nathia Gali (8000 feet). There are 35,737 inhabitants in Nawanshahr; 50.04% are males, and 49.96% are females. The town has a humid subtropical climate with long summers and short winters. January has the lowest temperature of 6.7 °C, while June has the highest temperature of 25.6 °C. The town has an annual mean precipitation of 166.08 mm and a literacy rate of 56.6% (Ullah *et al*. 2019).

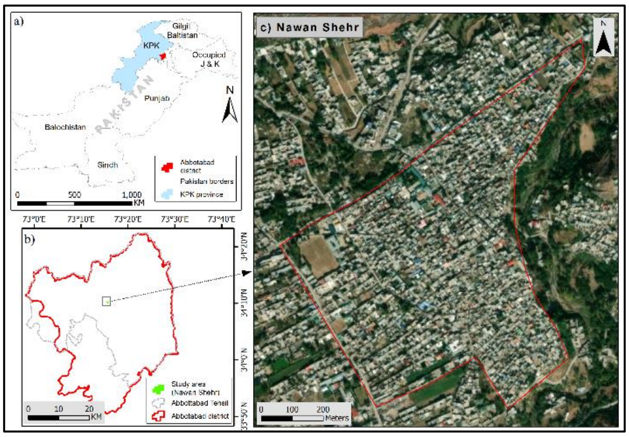


Figure 1. Map of Nawanshahr, Abbottabad

2.2. Sampling

The region under investigation, Nawanshar Town, was separated into four subzones, and 10 sampling locations were chosen: Ghumavan, Stadium Road, Jhariyan Road, Orish Colony, Lakhpati Chowk, Ilyasi Masjid Road, Township, Dhodiyal, Chunakari, and Gari Pana Chowk. 100 samples of drinking water from the underground and supplies were taken based on availability. Fresh samples were obtained from each location and put in pre-washed 100 mL plastic bottles (Parveen *et al*. 2017). The 100 ml plastic bottles were filled to the brim, and a few drops of pure HNO_3 acid were poured into each bottle. Sampling bottles were acid-cleaned with 5% HNO_3 to prevent contamination and rinsed twice with deionized water.

2.3. Digestion

The procedure outlined earlier by Parvin *et al*. (2022) was followed when digesting water samples. A mixture containing 70% HNO_3 (10 ml) and sample water (2 ml) in a conical flask was heated in a fume hood for 20 minutes at 80° C and cooled to room temperature. Then 5 ml $HClO_4$ was added to the mixture and heated at 180 °C till a clear solution. The resultant mixture was filtered off (Whatman filter paper # 42), and the filtrate was taken in a 50 mL volumetric flask and distilled water to fill up to the mark.

The same procedure was used to prepare a blank in addition to a batch of six samples.

Table 1. Heavy metals concentrations in drinking water collected from UGW and SW sources in Nawanshahr Town, Abbottabad

Sampling Sites Concentration mg/L	Pb		Ni		Cr		Cd		Cu		Fe	
	UGW	SW	UGW	SW	UGW	SW	UGW	SW	UGW	SW	UGW	SW
Ghumavan	0.144 ± 0.194	0.136 ± 0.064	0.106 ± 0.038	0.122 ± 0.064	2.106 ± 1.276	1.218 ± 1.338	0.017 ± 0.004	0.012 ± 0.001	0.600 ± 0.003	0.400 ± 0.001	0.087 ± 0.121	0.019 ± 0.018
Stadium Road	0.178 ± 0.084	0.176 ± 0.001	0.093 ± 0.013	0.131 ± 0.002	4.169 ± 0.741	3.683 ± 1.278	0.016 ± 0.001	0.018 ± 0.001	0.500 ± 0.003	0.900 ± 0.001	0.235 ± 0.082	0.171 ± 0.000
Jhariyan Road	0.220 ± 0.093	0.259 ± 0.023	0.134 ± 0.019	0.107 ± 0.062	5.144 ± 0.387	5.537 ± 0.064	0.019 ± 0.002	0.021 ± 0.000	0.100 ± 0.009	0.600 ± 0.003	0.120 ± 0.040	0.166 ± 0.058
Orish Colony	0.371 ± 0.069	0.253 ± 0.040	0.204 ± 0.066	0.218 ± 0.012	6.412 ± 0.651	6.474 ± 0.258	0.019 ± 0.002	0.023 ± 0.001	0.500 ± 0.002	0.400 ± 0.003	0.433 ± 0.080	0.313 ± 0.047
Lakhpati Chowk	0.378 ± 0.010	0.333 ± 0.054	0.161 ± 0.035	0.103 ± 0.086	6.490 ± 0.236	6.419 ± 0.549	0.019 ± 0.002	0.023 ± 0.001	0.500± 0.004	0.500 ± 0.003	0.045 ± 0.011	0.112 ± 0.108
Ilyasi Masjid Road	0.447 ± 0.034	0.405 ± 0.095	0.131 ± 0.093	0.165 ± 0.001	7.511 ± 0.249	7.373 ± 0.373	0.025 ± 0.002	0.023 ± 0.002	0.900 ± 0.006	1.100 ± 0.004	0.321 ± 0.383	0.108 ± 0.079
Township	0.459 ± 0.062	0.440 ± 0.093	0.225 ± 0.054	0.176 ± 0.085	8.112 ± 0.147	8.013 ± 0.220	0.025 ± 0.005	0.020 ± 0.004	1.200 ± 0.003	1.300 ± 0.006	0.048 ± 0.038	0.082 ± 0.036
Chunakari	0.514 ± 0.017	0.523 ± 0.045	0.253 ± 0.010	0.332 ± 0.037	8.852 ± 0.157	8.957 ± 0.119	0.025 ± 0.002	0.024 ± 0.001	1.400 ± 0.003	1.200 ± 0.002	0.162 ± 0.142	0.038 ± 0.049
Dhodiyal	0.509 ± 0.018	0.541 ± 0.024	0.236 ± 0.068	0.155 ± 0.096	9.328 ± 0.322	9.441 ± 0.004	0.025 ± 0.002	0.023 ± 0.005	1.700 ± 0.004	1.900 ± 0.001	0.241 ± 0.220	0.128 ± 0.174
Gari Pana Chowk	0.552 ± 0.040	0.593 ± 0.076	0.245 ± 0.046	0.257± 0.047	9.645 ± 0.211	9.650 ± 0.190	0.027 ± 0.003	0.025 ± 0.002	2.500 ± 0.003	0.019 ± 0.001	0.053 ± 0.036	0.016 ± 0.001

2.4. Instrumentation and data analysis

The standard solutions for each metal were prepared using stock solutions with a level of 1000 mg/L. The atomic absorption spectrophotometer (AA 700 Perkin Elmer) with hollow cathode lamps was used to quantify Pb, Ni, Cr, Cd, Cu, and Fe under optimal analytical conditions (Abeer *et al*. 2020). Descriptive statistics calculations were performed using Microsoft Excel 365 (Version 2016).

2.5. Health risk assessment

2.5.1. Consumer daily intake

The health risk was assessed by estimating the consumer's daily intake of selected metals based on the water consumption rate and comparing it to the reference dose (Muhammad *et al*. 2011; Momodu and Anyakora, 2010).

$$CDI = (C_m \left(DI / BM\right) \quad (1)$$

Where: C_m. HMs concentration (mg/L) in water samples, CDI. Consumer daily intake (2 L/day), BM. Average body mass for adults (70 kg), for children (30 kg) (Tong *et al*. 2016).

2.5.2. Noncarcinogenic risk

The ratio between the consumer's daily intake (CDI) and reference dose (R_fD) for each metal is the hazard quotient (HQ). Each metal's HRI value should be lower than 1 (Parveen *et al*. 2017). The HRI was calculated using Equation 2.

$$HQ = CDI \ / \ R_f D \quad (2)$$

Where R_fD. Reference dose of certain metals (R_fD for Pb 0.0035 mg/kg/day, Fe 0.007 mg/kg/day, Cr 0.003 mg/kg/day, Cu 0.004 mg/kg/day, Cd 0.005 mg/kg/day and Ni 0.002 mg/kg/day).

The heavy metal HQ sum is the Hazard Index (HI) and is determined using the following Equation.

$$HI = HQ_{Cd} + HQ_{Cr} + HQ_{Cu} + HQ_{Fe} + HQ_{Ni} + HQ_{Pb} \quad (3)$$

Where: HQ is Hazard quotients for metals.

2.5.3. Carcinogenic risk

When people consume heavy metals through drinking water, their exposure to cancer risk is estimated, known as the target cancer risk (TCR). The TCR in water for human consumption was calculated using Equation 4 (Parveen *et al*. 2017).

$$TCR = (MC \times DI \times CPS \times EFR \times EDTot)/(BW \times AT) \quad (4)$$

Where: The sample metal concentration (MC) was expressed in mg/L. The daily consumption is 2 L/day. EFR stands for Exposure Frequency Rate and refers to the annual exposure rate of 350 days for adults and children. CPS is Carcinogenicity Slope and values for Pb = 0.0085, Ni = 0.84, Cr = 0.041, and Cd = 0.061 mg/day. ED tot. the overall exposure period (26 years for adults and 6 years for youngsters). The body weight (BW) is 70 kg for adults and 30 kg for children. Atc is the average time carcinogen (0.6 h/day).

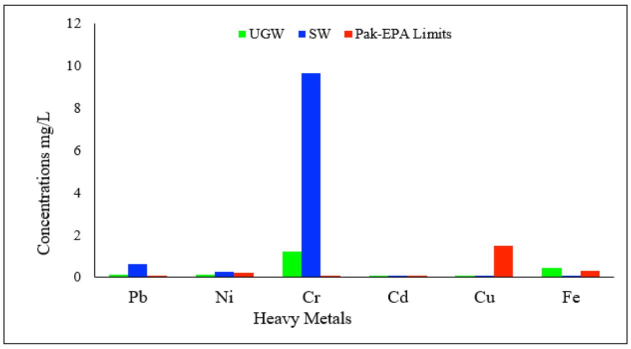


Figure 2. HMs in UGW and SW, along with Pak-EPA permissible limits

3. Results and discussion

The current investigation involved 50 samples from supply water (SW) and underground (UGW) sources. A sample of digested water was tested for Pb, Ni, Cr, Cd, Cu, and Fe. The average concentration of HMs in drinking water was tabulated in **Table 1.**

3.1. Comparison of metal concentration

Lead levels were between 0.136 ±0.064 to 0.593±0.076 mg/L and 0.144±0.194 to 0.552±0.040 mg/L in samples of groundwater and surface water, respectively. Similarly, the nickel ranges in groundwater from 0. 093 ± 0. 013 to 0. 253 ± 0. 010 mg/L in any respect locations, and surface water samples it ranged from 0. 103 ± 0. 086 to 0. 332 ± 0. 037 mg/L. Iron concentrations in groundwater ranged from 0.045 ± 0.011 to 0.433 ± 0.080 mg/L, while in-floor water samples ranged from 0.016 ± 0.001 to 0.313 ± 0.047 mg/L, respectively. However, the Ni, As, Pb, and Fe concentrations exceeded the WHO drinking water limits (Abeer *et al*. 2020). Pb in drinking water could have leaked from an outdated plumbing system. Pb poisoning impairs the brain system, the digestive tract, and the kidneys. Pb poisoning weakens memory, impairs mental clarity, and results in anemia in children, who are particularly susceptible to it (Muhammad *et al*. 2011). Cadmium ranges in groundwater from 0.016 ± 0.001 to 0.027 ± 0.003 mg/L, while the ones in floor water samples ranged from 0.012 ± 0.001 to 0.025 ± 0.002 mg /L. Copper levels in surface water and underground water samples were between 0.100 ± 0.009 and 2.500 ± 0.003, and 0.400 ± 0.001 to 1.900 ± 0.001 mg/L, respectively. Mining operations in Abbottabad City and the weathering and erosion of Cd from bedrock can be the reasons for the higher Cd concentrations in consuming water samples (Raza *et al*. 2017). Hand pumps, bore wells, tube wells, and derived offer the consuming water and different home requirements for the citizens of the studies region.

3.2. Underground water and surface water comparison

The PAK-EPA acceptable limits and mean concentrations of HM in surface and groundwater are shown in **Figure 2**. However, Pb, Ni, and Cr concentrations in surface water were higher than in underground water, and these elements' concentrations exceeded the permissible limits (0.015, 0.2, and 0.05 mg/L) established by Pak-EPA standards. Cd and Cu showed comparable mean concentrations (**Figure 2**), but the Cd level was higher than the threshold level (0.005 mg/L) set by Pak-EPA in underground and surface water. Cu contents in the underground and surface water are lower than the acceptable level (1.5 mg/L) set by Pakistan-EPA guidelines. The concentration of Fe in subsurface water was higher than in surface water (**Figure 2**). There were some in underground water because the concentration of Fe in underground water was higher than the threshold levels (0.2 mg/L) established by Pak-EPA standards.

3.3. Spatial comparison of heavy metals

The range of average lead levels was 0.593 ± 0.040 mg/L to 0.136 ± 0.064 mg/L. The area with the highest Pb level (0.593 ± 0.040 mg/L) was in surface water from Gari Pana Chowk, and the lowest (0.136 ± 0.064 mg/L) was in SW from Ghumavan. The Pb concentrations SW collected from Dhodiyal and Chunakari and UWG collected from Township, Ilyasi Masjid Road, Lakhpati Chowk, and Orish Colony were 0.541 ± 0.024, 0.523 ± 0.045, 0.459 ± 0.062, 0.447 ± 0.034, 0.378 ± 0.010, and 0.371 ± 0.069 mg/L, respectively. Many samples from Gari Pana Chowk had lead concentrations higher than the acceptable limits (0.05 mg/L). The adverse health effects of lead exposure above this threshold include anemia, high blood pressure, and kidney damage, to name just a few (Shaheen *et al*. 2016). However, according to Mostafa *et al*. (2024), adults are at risk for cardiovascular disease, particularly from lead exposure, which can cause joint and muscle pain.

Nickel concentrations ranged between 0.332 ± 0.037 and 0.093 ± 0.013 mg/L. The concentration was the highest in Chunakari (0.332 ± 0.37 mg/L) and lowest in Stadium Road (0.093 ± 0.013 mg/L). SW collected from Gari Pana Chowk had Ni level (0.257± 0.047 mg/L), followed by UWG from Chunakari, Dhodiyal, and Township (0.253 ± 0.010, 0.236 ± 0.068 and 0.225 ± 0.054 mg/L), respectively. Many samples taken from Chunakari had Ni concentrations higher than the permitted standard (0.02 mg/L). However, excessive Ni intake beyond the acceptable level (0.02 mg/L) might aggravate health issues such as nausea, vertigo, asthma, and heart disease. High concentrations of

Ni have a wide range of effects on animals, including teratogenicity and carcinogenicity (Jyothi *et al*. 2020). According to Mostafa *et al*. (2024), women are more likely than men to have a nickel allergies. (**Figure 3**).

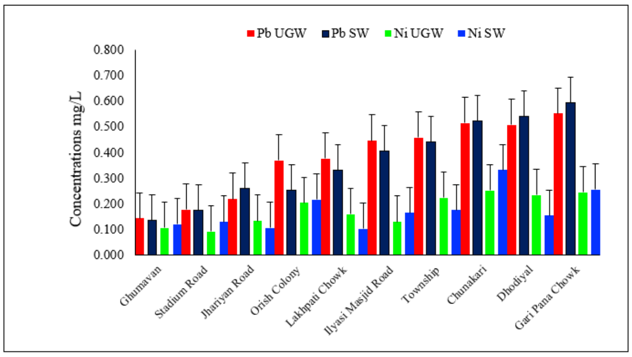


Figure 3. Average Concentrations of Pb and Ni in Water Samples

The Cr concentrations were lowest in SW and UGW Ghumavan (1.218 ± 1.338 mg/L and 2.106 ± 1.232 mg/L, respectively) and at their greatest in SW and UGW in Gari Pana Chowk (9.650 ± 0.190 mg/L and 9.450 ± 0.180 mg/L, respectively).

Most samples taken from Gari Pana Chowk had Cr concentrations higher than the allowed level of 0.05 mg/L (EPA). According to Pokhrel *et al*. (2022), levels of Cr over 0.05 mg/L) can lead to cancer, respiratory issues, allergic and asthmatic symptoms, and skin hypersensitivity. Concentrations of Cr over safe limits have been associated with gastrointestinal problems, lung cancer, and mortality in both children and adults (Georgaki *et al*. 2023) at values ranging from 4.1 to 357 mg/kg body weight (**Figure 4**).

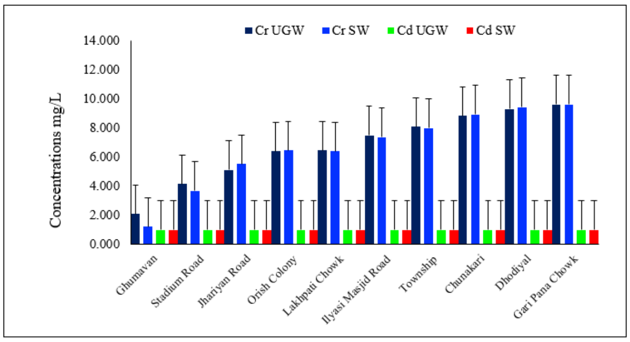


Figure 4. Average Concentrations of Cr and Cd in Different Water Samples

The average Cd concentrations were from 0.027 ± 0.003 mg/L to 0.012 ± 0.001 mg/L. Cadmium levels were highest in Gari Pana Chowk (0.027 ± 0.003 mg/L) and least in Ghumavan (0.0012 ± 0.001 mg/L) followed by UGW collected from Township, Ilyasi Masjid Road, Chunakari, and Dhodiyal (0.025 ± 0.005 mg/L), SW collected from Lakhpati Chowk, Orish Colony, Jhariyan Road and Stadium Road (0.023 ± 0.001, 0.021 ± 0.000 and 0.018 ± 0.001 mg/L) respectively. Most samples collected from Gari Pana Chowk contained the most Cd. This indicates that the metal content is not within acceptable limits. However, above the recommended limit (0.005 mg/L), Cd can cause alveolar tumors, lead to decreased fertility and premature birth, and cause flu-like symptoms (chills, fever, and myalgia) and lung damage (Henson *et al*. 2013). There is some evidence that cadmium can cause cancer when inhaled, but there is less proof that it can do so when consumed (Godt *et al*. 2006).

The average copper concentrations ranged between (2.500 ± 0.003 mg/L) to (0.100 ± 0.009 mg/L). Mean copper concentrations were highest in Gari Pana Chowk (2.50 ± 0.003 mg/L) and lowest in Jhariyan Road (0.100 ± 0.009 mg/L) Followed by SW collected from Dhodiyal (1.900 ± 0.001 mg/L), UGW collected from Chunakari (1.400 ± 0.003 mg/), SW collected from Township, Ilyasi Masjid Road and Stadium Road (1.300 ± 0.006, 1.100 and 0.900 ± 0.001 mg/L), UGW collected from Ghumavan, Orish Colony and Lakhpati Chowk (0.600 ± 0.003, 0.500 ± 0.002 and 0.500± 0.004) respectively. Most of the samples collected from Gari Pana Chowk contained the highest amount of Cu. This indicates that the metal content is not within acceptable limits. Cu (1.5 mg/L) above the permissible limit can cause nasal, eye, and mouth sensitivities, stomach upset, and diarrhea. Children under 1 year are more sensitive to copper Duff, (2002). Chronically consuming large amounts of copper can harm the liver. Signs of the digestive system (eg, abdominal pain, cramps, nausea, diarrhea, vomiting (Araya *et al*. 2003) (**Figure 5**).

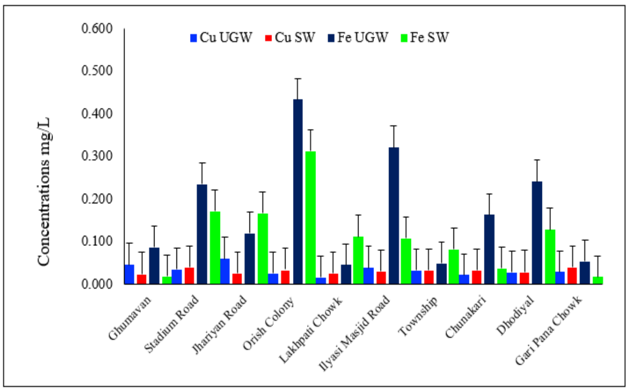


Figure 5. Average Concentrations of Cu and Fe in Different Water Samples

The average iron concentration ranged between (0.433 ± 0.080 mg/L) to (0.016 ± 0.001 mg/L). Mean iron concentrations were highest in Orish Colony (0.433 ± 0.080 mg/L) and lowest in Gari Pana Chowk (0.016 ± 0.001 mg/L) followed by UGW collected from Ilyasi Masjid Road, Dhodiyal, and stadium Road (0.321 ± 0.383, 0.241 ± 0.220 and 0.235 ± 0.082 mg/L), SW collected from Jhariyan Road (0.166 ± 0.058 mg/L), UGW collected from Chunakari (0.162 ± 0.142 mg/L), SW collected from Jhariyan Road (0.112 ± 0.108 mg/L), UGW collected from Ghumavan (0.087 ± 0.121 mg/L) and SW collected from Township (0.082 ± 0.036 mg/L) respectively. Most samples collected from the Orish Colony contained mostly Fe. The permissible lead level in drinking water is 0.3 mg/L (EPA). This indicates that the metal content is not within acceptable limits. Excess intake of the recommended daily intake (0.3mg/L) of Fe may cause liver disease (cirrhosis, malignant tumor), cardiovascular disease, diabetes, depression, osteoporosis, infertility, hypothyroidism, and intestinal pain, it may increase the risk of hypogonadism, premature death (Tagliabue *et al*. 2014).

3.4. Health risk assessment

Risk calculation is one of the most effective ways to investigate the probable hazards of heavy metal contact on human well-being, offering important evidence to communal health policymakers for protecting user health. According to the USEPA, exposure to heavy metals in drinking water, including Cd, Pb, Ni, Cr, Cu, and Fe, can lead to cancerous and non-cancerous menace to human health. The water distribution network can become contaminated with heavy metals due to various exposure routes, which can increase human health risks. Residents primarily use surface and groundwater Adults and children are separated because of their behavioral and physiological differences.

Table 2. Consumer daily intake (CDI) for adults and children in Water

Sampling Sites	Concentration mg/L/day											
	Pb		Ni		Cr		Cd		Cu		Fe	
	Adults	Children	Adults	Children	Adults	Children	Adults	Children	Adults	Children	Adults	Children
Ghumavan	0.004	0.009	0.003	0.008	0.047	0.111	0.000	0.001	0.055	0.129	0.002	0.004
Stadium Road	0.005	0.012	0.003	0.007	0.112	0.262	0.000	0.001	0.065	0.152	0.006	0.014
Jhariyan Road	0.007	0.016	0.003	0.008	0.153	0.356	0.001	0.001	0.077	0.180	0.004	0.010
Orish Colony	0.009	0.021	0.006	0.014	0.184	0.430	0.001	0.001	0.080	0.186	0.011	0.025
Lakhpati Chowk	0.010	0.024	0.004	0.009	0.184	0.430	0.001	0.001	0.079	0.185	0.002	0.005
Ilyasi Masjid Road	0.012	0.028	0.004	0.010	0.213	0.496	0.001	0.002	0.090	0.210	0.006	0.014
Township	0.013	0.030	0.006	0.013	0.230	0.537	0.001	0.001	0.084	0.196	0.002	0.004
Chunakari	0.015	0.035	0.008	0.020	0.254	0.594	0.001	0.002	0.092	0.214	0.003	0.007
Dhodiyal	0.015	0.035	0.006	0.013	0.268	0.626	0.001	0.002	0.090	0.211	0.005	0.012
Gari Pana Chowk	0.016	0.038	0.007	0.017	0.276	0.643	0.001	0.002	0.098	0.228	0.001	0.002

3.5. Noncancerous analysis

Noncancerous assessment involves identifying health effects caused by exposure to toxic substances in a polluted environment. Humans are exposed to toxic elements via ingestion, inhalation, and dermal contact (Emmanuel *et al*. 2022). The heavy metal toxicity level to human health is proportional to the CDI.

3.6. Consumer daily intake (CDI)

The calculated CDI values for drinking water consumption are summarized in **Table 2.** The highest CDI for Pb in children was measured at 0.038 mg/L in Gari Pana Chowk, and the lowest CDI for adults was 0.004 mg/L in Ghumavan (**Figure 6a**). Therefore, heavy metals CDI values in the study area were in the order of Cr > Cu > Pb > Fe > Ni > Cd. The CDI of Cr was higher than the permissible limit in many locations for adults and children. The high pollution level in the consumable water is the cause of the highest CDI values for Cr. Acute pollution from the town and effluent in the vicinity may cause higher CDI of Cr in water (Khan *et al*. 2015). The CDI for Cr in adults and children was higher than in a previous study (Hussain *et al*. 2019).

3.7. Hazard quotient

The HM hazard quotient (HQ) indices in HM are summarized in **Figure 6b**. All heavy metals studied had total HQ levels above 1, except for Ni and Fe in adults and children at each location. The mean HRI of all the samples collected from Nawansher Town, Abbottabad, indicated that the non-carcinogenic health hazards associated with Pb, Ni, Cr, Cu, and Fe are acceptable. From the HQ results, it can be deduced that the contribution of the metals to the non-carcinogenic health risk was in the order of Cr > Pb > Cu > Cd > Ni > Fe.

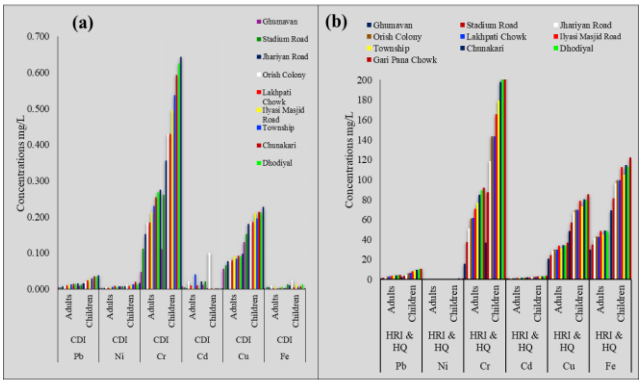


Figure 6 (a). CDI for all heavy metals in adults and children (b). HQ for all heavy metals in adults and children

3.8. Hazard Index (HI)

The study area has a health index (HI) related to drinking water consumption, as shown in **Figure 7**. The HI values for children and adults at each location ranged between 19.356 mg/L and 235.255 mg/L. Children with Gari Pana Chok had the highest HI values (235.255 mg/L), while adults with Ghumavan had the lowest HI values (19.356 mg/L). The HI values for children and adults were greater than 1. The ingestion of metals in water could pose a health risk to consumers. The HI value for all metals at each site is higher than 1, which indicates a non-carcinogenic health effect. The above-average HI values obtained in our study suggest a significant risk of non-carcinogenic health effects at each site. can occur. The concentrations can increase with time until anthropogenic sources are removed.

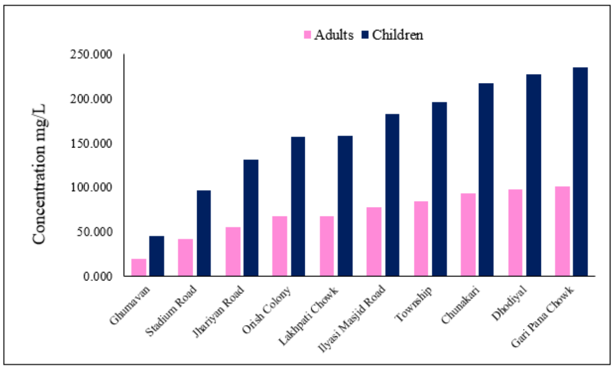


Figure 7. Concentrations of HIs for All Metals in Adults and Children

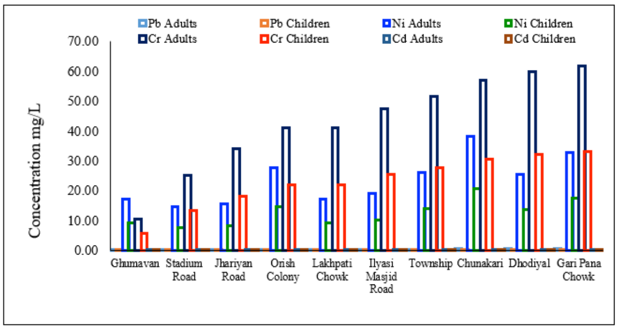


Figure 8. TCR for All Metals in Adults and Children

3.9. Cancer-causing risk assessment

Cancer-causing hazards are characterized by a term called targeted cancer risk. When an individual is exposed to low amounts of toxic metals, it has a higher chance of cancer. The carcinogenic risk assessment for adults is given in **Figure 8**.

3.10. Target cancer risk (TCR)

The target cancer risk for adults and kids is determined in addition to the contribution of each toxic metal in water. Since the EPA does not list Ni and Fe as carcinogens, we have used Pb, Ni, Cr, and Cd as the basis for carcinogenic risk calculations. The highest TCR values were found in Garipana Chowk adults (32.891 mg/L), and the lowest TCR values (7.914 mg/L) were found in Stadium Road children. The highest TCR values were found in adults with Garipana Chowk (61.71 mg/L), and the lowest TCR values were found in children with Ghumavan (5.725 mg/L). Adults are at a higher risk of developing cancer than children in the study areas because adult cancer risks were higher everywhere for all metals. According to the target carcinogenic risks (TCRs) calculated in this investigation, all metals fall below acceptable ranges. It is believed that prolonged exposure to metals (more than 70 years) increases the risk of developing cancer.

4. Conclusion

The current study aimed to quantify the heavy metals and assess health risks predominantly associated with HM concentration in ten locations in Nawanshahr Town, Abbottabad. Six metals, including Pb, Ni, Cr, Cd, Cu, and Fe, were quantified in 100 surface and groundwater samples collected from different locations in Nawanshahr, Abbottabad. The metal levels in the drinking water exceed the permitted limit specified by the Pak-EPA standards, except for Fe concentrations in UGW obtained from Orish Colony and Ilyasi Masjid Road. The high metal concentrations were suggestive of anthropogenic activity.

A human health risk assessment was undertaken where CDI and values for all metals in both adults and children were found to be > 1 at all places, indicating that the population was not within safe limits except for Ni <1, which signifies that the population was within safe limits (HQ <1). The HI values greater than one for all metals at each site imply harmful non-carcinogenic health effects. The TCR for all metals was higher in adults in all regions, indicating that adults are more likely to develop cancer. The study's findings call for extensive, continuous annual monitoring and more studies on harmful metals quantification to assess long-term consequences and protect both men and the environment.

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Conflict of interest

Authors don’t have any conflict of interest.

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