Carcinogenic and non – carcinogenic health risks of heavy metals in drinking water of district Mahendergarh, Haryana, India

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Abstract

In the present research work, the study has been carried out on carcinogenic and non-carcinogenic toxic effects for inhabitants due to exposure to heavy metals through dermal and ingestion of drinking water. Present research data assessment has been carried out for the first time; no record has been collected earlier. The maximum concentration of heavy metals was evaluated for Nickel and Arsenic metals, respectively. The average concentration values of heavy metals were found in increasing order as: Ni > As > Cr > Hg > Mn > Cu > Fe > Cd > Zn > Co = Pb 15.36 > 10.3 > 4.73 > 3.32 > 1.43 > 0.27 > 0.246 > 0.068 > 0.06 mg/l respectively. Also, the highest value of incremental lifetime cancer risk was evaluated due to chromium metal. The Hazard Index > 1 was recorded, concluding that non-carcinogenic health risk via ingestion of water, and the Hazard Index < 1 for dermal contact of water, concluded the low risk of non-carcinogenic health risk. These results disclose a new avenue for the removal of these hazardous metals from drinking water. Also, assist future researchers to plan for a healthy life for living things and the present work can be useful for the development of ideas for potential risk control and management.

Introduction

Groundwater aquifers are the worldwide water supply requirement for drinking, irrigation, and industrial purposes. However, due to the presence of contamination sources i.e.; natural and anthropogenic sources that have toxic effects on human health, has been challenging to use active wells water in residential areas, fields, and for other purposes. Herein, the concentration of toxic metals like Cd(cadmium), Fe(iron), Hg(mercury), Pb(lead), As(arsenic), Mn(manganese), Ni(nickel), Cu(copper), Cr(chromium), Co(cobalt), and Zn(zinc) were detected in 50 samples, which were collected from ponds and tube well supplies of Mahendergarh, Haryana, India in the year of 2021 by using Atomic Absorption Technique. Water pollution by heavy metals has led to global problems in the past few decades (Li, Wen-Wei, et al., 2012). High needs for toxic metals i.e., Pb, Cu, As, Hg, Zn, Fe, Cd, Ni, Co, Mn, and Cr in water could induce toxicity to plants, animals, and human beings also, and thus accumulation of toxic metals in human tissues can cause health issues including cancer, abnormalities, gastrointestinal disorder, acrodynia disease, etc., Heavy metals are those metals which possess a specific density of more than 5g/cm3 and enormous effects on living organism (Järup, L., 2003). Heavy metals are non-degradable i.e., act like a polluted source, and are non-reversible (Tang, W. W., et al., 2014). The limited concentration of heavy metals is essential for metabolism in living beings, but the excess concentration of these metals can cause non-carcinogenic and carcinogenic risks (Pratush et al., 2018). Rapid industrialization in the world leads to contamination of surface and ground water (Rattan et al., 2005; Mohammadi et al., 2019; Rashed et al., 2010; Chowdhury et al., 2016; Qasemi et al., 2019; Esmaeilzadeh et al., 2019). According to the central groundwater Board Ministry of Water Resources Government of India, groundwater deterioration is due to two main sources: 1) Geogenic sources mainly occur through host rocks (depending on the geology of the area), and volcanic activities. 2) anthropogenic sources (Rizwan et al., 2021; Kumar et al., 2014) caused by manmade activities like industrialization, urbanization, mining, agriculture, and open land dumps, among others (Schwartz et al., 2007). These activities have contaminated extensive areas of the world such as China, Indonesia, and Japan with Cu, Cd, and Zn (Herawati, et al., 2000); Pb and Cu in Greece (Zantopoulos et al., 1999); Ni, Pb, Cd, Cu, and Zn in Australia (Smith et al., 1996). Industrial wastewater has been used for irrigation purposes resulting, in the presence of non-biodegradable heavy metals in water and vegetable tissues (Gemeda et al., 2021; Aschale et al., 2021). In animals, toxic metals plunge through green fodder, feeds, drinking water and medicines, etc. Contamination of the aquatic environment is a major threat to human health and contaminated water affects the aquatic ecosystem and fauna, heavy metals which enter the food chain and affect the human body (Adesiyan et al., 2018). Some heavy metals are essential nutrients like zinc, iron, and cobalt but some heavy metals are poisonous like Cd, Hg, Pb, As, etc. (Obasi et al., 2020). According to the toxicology profile for heavy metals, many effects were observed like neurological, Renal effects, Cardiovascular, Reproductive effects (male and female), Musculoskeletal (bone loss), Endocrine effects (alteration in serum of thyroid hormones), etc., During mining, the wastewater is generated results in contamination of water in regional and local areas. So, it is essential to identify these heavy metals in water. The hazard index (HI), hazard quotient (HQ), non -carcinogenic risk, carcinogenic risk, and incremental lifetime cancer risk (ILCR) terms were used to evaluate the potential health hazard risk.

The present manuscript aims to assess the concentration and hazardous effect of heavy metals in drinking water by using AAS (Atomic absorption spectroscopy). Data of the present research work can be used in the future beneficially, management control risks and to aware inhabitants of the health risks of the present studied area.

Geology of Area of District Mahendergarh (Haryana)

Mahendergarh is situated in Haryana, which is an Indian state District Mahendergarh is located at 28°.28 N 76°.15 E. Mahendergarh has a total geographical area of 1899 Sq.km. This district is located in the end west-southern part of Haryana. Mahendergarh district has a boundary on the north with Districts Charkhi Dadri, Bhiwani and Jhajjar of Haryana State. In the district, Rewari and Alwar district of Rajasthan have their boundary line. On the south side, it has its boundary with the District Alwar, Jaipur & Sikar district of the state of Rajasthan and on its west side, district Sikar and Jhunjhunu district of Rajasthan state is situated. The main water streams of the district are 'Dohan' and 'Krishnawati' which flow from South to North. The annual rainfall of the district Mahendergarh is 500 mm, which is unevenly distributed over the area's normal on rainy days. The temperature of the Mahendergarh district is a maximum of 41˚C-47˚C from May to June and a minimum of 1.0˚C- 5.6˚C in January. The major soil type of the district is loamy sand. The five major crops of this district are Bajra, Mustard, Wheat, Gram and Cotton. The groundwater of the district is alkaline having a pH of 7.41 to 8.80 value. 'Madhogarh Fort' a famous tourist destination is located in the mountain range of 'Aravalli' in District Mahendergarh of Haryana state. The mountain range of Aravalli Mountain situated in the Northern-Western part of India runs approximately 670 km South-West direction, which starts from near to National Capital Delhi and it is passing through the state of south Haryana and Rajasthan. All of these villages are part of the Aravalli hill range, covered with major species like *Ziziphus jujube, Vachellia Karro, and sparse vegetation*. The high values of TDS (total dissolved solids) and pH were detected in groundwater of this area as presented in table 1. Illegal mining also takes place in this hilly area and it can generate wastes in large quantities and wastes dumped openly in the environment. Additionally, metals can percolate from these dumps and contaminate the groundwater (Punia et al., 2021). So, it may be a chance of the presence of heavy metals in the groundwater of this area and the plan of the location of the study area is shown hereunder in Fig 1.

Material And Methods Used In The Present Study

Collection and Preparation of Samples

The samples were collected from various places of district Mahendergarh, Haryana. During collection location of the particular place was noted with the help of the GPS coordinator. Then, filtration was carried out (two times) by using whatman42 having a diameter of 125µm. Electrical Conductivity (EC), pH, and Total Dissolved Solids (TDS) were measured as shown in table-1. Filtered samples were also transported to the Central Instrumentation library for toxic metal analysis. Out of 50 samples, 46 samples were collected from groundwater and 4 samples were collected from pond water in the studied area. Here, one can see that pond water has pH 7 which was within the safe limit. Ponds water is filled with water naturally i.e., by rain. Also, the pH value of the drinking water of the selected area lies between (7.93-8.8), the minimum value of pH of 7.93 was detected in village Dholi and a maximum pH value of 8.8 was found in village Jonawas of District Mahendergarh. Also, electrical conductivity (EC), is the capacity of water to conduct current, with the help of EC and TDS (total dissolved solids) one can determine the salinity of the water. Here, Electrical Conductivity (EC) is varied from (137μS/cm to 4026 μS/cm). The minimum value of EC was found in village 'Malra' of the study area having pond water and the maximum value of electrical conductivity of drinking water was detected in village 'Khatodra' of district Mahendergarh. The minimum value of EC is also found in pond water i.e., in surface water 137μS/cm. The TDS (Total Dissolved Solids) values in water are found between 134mg/l to 2480mg/l). The minimum value of TDS is found in village 'Malra' in its pond water and the maximum value was measured in village 'Khatodra' of District Mahendergarh, respectively. From the above discussion, anyone can conclude that surface water is pure in comparison to groundwater in the various locations of the studied area. The high values of EC and TDS point out that there may be chances of finding heavy metals in water in this studied area.

Detection of Heavy Metals

In the present study, the known standard protocols were used (Mohammadi et al., 2019). Here, 11 heavy metals were detected. Standards are made by using flame methods manual for Atomic Absorption for calibration of various heavy metals from which use round beakers, rinse beakers with distilled water then for dilution made heavy metal (which is detected) solutions in (ml). Add distilled water to solutions of heavy metals for making a 100ml solution, these solutions are used for calibration. Take 50 samples of water one by one and dip chalk(capillary) into it when the flame of AAS (Atomic absorption spectroscopy) gets changed we can say that element detection is going on. In AAS spectroscopy we use acetylene gas with air and the light source is a cathode lamp. From a safety point of view, we also clean the burner of AAS with the help of a burner cleaning guard. Also, with the help of AAS Spectroscopy, we get intensity absorbance. Finally, peaks of some wavelengths show in the display. Last, we get information about elements present in the water samples. Experimental conditions which are used for the determination of heavy metals in water of the studied area are presented in table 2. Results for the determination of the concentration of toxic metals are compared with (Environmental Protection Agency) USEPA 2017, European standards 1998, Romanian law 311/2004, and (World Health Organization) WHO (2008) prescribed guidelines as shown in table 3.

Health risk assessments

Non – carcinogenic risk analysis

Risk assessment is a function of exposure and is defined as the method of calculating the possibilities of occurrence of any given value of hazard health impact over a determined period (Bempah et al., 2016). The risk assessment of heavy metals depends on the evaluation of risk levels and is determined in terms of carcinogenic and non-carcinogenic health hazards (Wongsasuluk et al., 2014). The following exposure Eq (1) and Eq (2) were taken from USEPA (Environmental Protection Agency) for calculating chronic daily intake (CDI) via ingestion and dermal absorption (Mohammadi et al., 2019).

$$CDI_{ing} = \frac{C_w . DI. ABS. EF. EP}{BW. AT} \quad \text{Eq (1)}$$

$$CDI_{derm} = \frac{C_w . S. Kp . ABS . ET . EF . EP. CSF}{BW . AT} \quad \text{Eq (2)}$$

Where CDI_{ing} and CDI_{derm} are defined as daily exposure dose via ingestion and dermal absorption (mg/kg-day); C_w is defined as the estimated concentration of heavy metals present in drinking water(mg/L); SA is skin surface area; K_p is permeability coefficient; ABS is dermal absorption factor; ET is exposure time; EF is exposure frequency; EP is exposure period; CF is a conversion factor, and these parameters are represented by USEPA (1989) (Mohammadi et al., 2019). Oral reference dose (RfD) and dermal reference dose (mg/kg-day) and cancer slope factor (CSF) are used for toxicity response determination ((Mohammadi et al., 2019; Tay et al., 2019).

Also, HQ_{ing} (hazard quotient) is defined as the ratio of chronic daily exposure of contaminated water to oral reference dose via ingestion, and HQ_{derm} is defined as the ratio of chronic daily intake of contaminated water to the dermal reference dose via dermal absorption and HQ is the unitless quantity; calculated by following Eq (3).

$$HQ_{ing/derm} = \frac{CDI_{ing/derm}}{RfD_{ing/derm}} \quad \text{Eq (3)}$$

Hazard Index (HI) is the overall potential non-carcinogenic risk computed by taking the sum of all multiple toxic heavy metals present in drinking water i.e., by taking the arithmetic sum of HQs obtained value is HI; as shown in below Eq (4).

$$HI = \sum_{i=1}^{n} HQ_{ing/derm} \quad \text{Eq (4)}$$

Non-carcinogenic risk is a threshold value below which no hazardous health effects would be expected. The population is in a safe zone when $HI<1$ and at concern when $1<HI<5$ (Ogwok et al., 2014).

Carcinogenic risks analysis

The carcinogenic risk assessment aims to determine risk factors for cancer in the studied area of residents. Cancer risk assessment in the drinking water of the studied area was measured by using the ILCR (incremental lifetime cancer risk) term, defined as the production of cancer as a result of twenty- four hours per day exposure to chemical contamination to a given daily intake for seventy years. One in million (1×10^{-6}) means out of one million residents, one cancer case would be expected. According to USEPA, the acceptable limit for potential cancer risk lies within the range of (1×10^{-6}) to (1×10^{-4}) (Mohammadi et al., 2019). The carcinogenic potential risk was assessed by using the following Eq (5).

$$ILCR = CDI \times CSF \quad \text{Eq (5)}$$

Where CSF is a cancer slope factor defined as the risk produced by a lifetime average exposure dose of one mg/kg/BW and contaminates specific. Heavy metals, contamination sources, their uses, and their adverse effects on human health have been studied (WHO, 2003; Velma et al., 2010; Tchounwou et al., 2012; Hou et al., 2007; Sullivan et al., 2001; WHO, 2009; Balali-Mood et al., 2021; Pratush et al., 2018; Jaishankar et al., 2014; Obasi et al., 2020; Mahey et al., 2020).

Results

The main purpose of the present study is to find out the good quality of drinking water in the study area. Out of the total of 50 samples, 4 samples were collected from pond water and the remaining were collected from the groundwater of this region for analysis of pH, EC, and TDS. USEPA (United States Environmental Protection Agency) recommends drinking water supply should be at a pH of (6.5 to 8.5). According to table 1, out of 46 drinking water samples, 37% of pH samples were found above the permissible limit of USEPA. So, accordingly, there can be health risks. Electrical Conductivity is also having the capacity of water to conduct current. According to WHO 2006, up to a 500µS/cm limit of drinking water is good for human health having no contamination of any organic pollution. Drinking water becomes significant with EC levels up to 1500µS/cm (Abbas et al., 2013) and insignificant for irrigation when it crosses the limit above 6000µS/cm. After analysis, 35% of EC of drinking water samples were found above the limit of the world health organization (WHO 2006). Extreme value of electrical conductivity may cause kidney disease, hypertension, and stone problems in the intestines, etc. (Kormoker et al., 2022) i.e., conclude that in water salts reach a high level in this particular studied area. According to WHO, a TDS (total dissolved solids) level of less than 500mg/l is good for human beings (Kormoker et al., 2022). Here 70% of drinking water TDS samples were found above the admissible limit. Drinking water becomes objectionable when TDS is greater than 1200mg/l. Values of pH, EC, and TDS of pond water were found within the safe limit. High values of EC and TDS in groundwater may have the chance of finding contaminated heavy metals groundwater. The concentration of heavy metals (As, Cu, Co, Cd, Cr, Pb, Hg, Zn, Mn, Fe, Ni) in the drinking water of the studied area of district Mahendergarh, Haryana is presented in table3. The results demonstrated that the average concentration of heavy metals in water approaches the levels (except As, Cd, Hg, Cr, Ni, Mn metals) mentioned in World Health Organization, USEPA, and EU Standards 1998, and Romanian law. As the concentration of some heavy metals was found above the permissible limit of WHO, USEPA, and EU standards. Therefore, an improvement program for the purification of water should be taken to protect the health of the population of the Mahendergarh district of Haryana. The chronic daily intake was measured highest for Nickel and Arsenic metals. We conclude that Nickel and Arsenic are the main hazardous metals for carcinogenic risk.

The minimum, maximum, and mean values for CDI (chronic daily intake) via ingestion and dermal absorption through different pathways are shown in table 4. The exposure risk assessment was calculated by using ingestion dose, dermal exposure dose, hazard quotient, and hazard index. The minimum, maximum, and average values of non – carcinogenic health risks due to heavy metals in the water of the studied area are shown in table 5. The carcinogenic health risks via ingestion and dermal absorption into the drinking water of the study area are shown in table 6.

Conclusion

pH, EC, and TDS

A high value of pH concludes that water is alkaline in this particular region. Also, the high value of EC may cause many extreme diseases like stone deposition and hypertension and kidney failure. Here TDS values for 70% of samples were found above the permissible limit, concluding that water is very saline in this area. There was a positive correlation between pH, electrical conductivity, and total dissolved solids found in this particular studied area. High values of EC and TDS may cause findings of heavy metals in the drinking water of this district Mahendergarh, Haryana.

Concentration

According to WHO (world health organization), USEPA 2017 (Environmental Protection Agency), EU 1998 (European) standards, and Romania law no. 311/2004 guidelines as given in Table3, there were wide variations found in the mean value of the concentration of heavy metals in water of the studied area. The maximum value for the concentration of heavy metals in water was found for Ni i.e., (15.36) mg/l, and the minimum concentration for Zn with a mean value of (0.06) mg/l. The increasing order for a mean value of heavy metals concentration in water of the present studied area was: Ni > As > Cr > Hg > Mn > Cu > Fe > Cd > Zn. According to Table 3, a high value (15.36mg/l) of concentration of Nickel was detected in the village Digrota, a concentration of Arsenic was found in Jant village with a maximum value (10.306mg/l), a maximum value of Chromium concentration was found in the village Khera with (15.57mg/l) value, Hg(Mercury) heavy metal concentration was found in village Bhojawas with maximum value (6.936mg/l), For Manganese, the maximum concentration of heavy metal was detected in village Akoda with (2.994mg/l) value. Zinc, Iron, Cadmium, and Copper were detected with maximum concentration in villages Jatwas, Jant, Digrota, and in Sisoth village with values of 0.375mg/l, 0.907mg/l, 0.146mg/l, 0.566mg/l. Detection of cobalt and lead was not found in this area. It can be concluded that the mean concentration values for heavy metals cadmium, mercury, chromium, nickel, and manganese were found above the permissible limit of WHO, USEPA (2017), EU standards, and Romanian Law no. 311/2004 guidelines (Mohod et al., 2013).

Non- carcinogenic assessments

Health risks were assessed by using chronic daily intake(mg/kg-day) via ingestion and dermal absorption of contaminated water and chronic daily intake was calculated by using input parameters (Mohammadi et al., 2019). Therefore, by taking a ratio of daily intake to reference dose (RfD) via ingestion and dermal absorption values (Mohammadi et al., 2019; Tay et al, 2019), we estimated the hazard quotient (HQ) for ingestion and dermal absorption. The hazard quotient was calculated for each heavy metal toxicity present in water and from the overall non-cancer risk of heavy metals effect, we calculated the hazard index (HI). It was calculated by summing up all hazard quotients of heavy metals. In conclusion, the overall potential for non-carcinogenic risk for eleven heavy metals in increasing order as: As > Cr > Hg > Ni > Cd > Mn > Cu > Fe > Zn. The hazard index in the present research work was measured as HI > 1 for ingestion dose and HI < 1 for dermal absorption of contaminated water. So, here conclude that the present studied area has potentially non-carcinogenic risks via ingestion of water, and no potentially non–cancer hazardous health effects were observed for dermal absorption of water to residents of this particular area.

Carcinogenic risk

As toxic metals tend to transport into the body via ingestion and dermal absorption of water and enhance the hazardous effects of cancer in human beings. For cancer risk analysis, one should go for the ILCR term i.e., incremental lifetime cancer risk presented in Table 6, calculated by taking CDI (chronic daily intake) in mg/kg-day and CSF (cancer slope factor) in mg/kg-day. Here, we conclude that the potential cancer risk value observed for four toxic metals i.e., Cr, Ni, Cd, and, As, as an order for risk analysis in water observed as Cr > As > Ni > Cd mean values (6.2E-03) for Cr, (4.8E-04) for arsenic, (4.0E-04) for nickel and cadmium value as (1.2E-05). An acceptable limit is greater than 10^{-6} and less than 10^{-4}(Mohammadi et al., 2019). Hence, we conclude that chromium heavy metal has a higher value than the acceptable limit according to WHO and USEPA guidelines. According to International Agency for Research on Cancer, Cr, As, Ni, and Cd are group1 carcinogens. So, cancer risk can be observed due to heavy metals present in this particular area. According to a survey report, here inhabitants are affected by many diseases like bone cancer, and lung cancer in this studied area. Due to high pH, water is very alkaline, and observed teeth problems were found in the residents of the present area. So, conclude that it can be a high value of fluoride present in drinking water. So, the government should take protective steps for reducing heavy metal contamination in water.

Declarations

Conflict of interest

The authors declare that there is no conflict of interest in publishing the paper.

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Author contribution

Suneel Kumar and Savita Budhwar – supervision, methodology, review, editing, writing original draft, conceptualization

Amanjeet and Ranjeet Dalal- Analysis, map creation, writing original draft, data collection.

Data availability

All data has been included in the manuscript.

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Tables

Sr. No.	Address	Locations	Latitude	Longitude	Source	Depth (Feet)	pH	Electrical Conductivity (µS/cm)	Total dissolved solids (mg/l)
1	H-1	Jant	28˚21'42"	76˚09'13"	SB	450	8.63	2196	1700
2	H-2	Malra	28˚21'02"	76˚10'11"	POND	7	7.41	137	134
3	H-3	Lawan	28˚20'35"	76˚09'54"	TW	450	8.48	1639	1170
4	H-4	Bhagdana	28˚18'54"	76˚08'53"	TW	450	8.6	468	328
5	H-5	Majra Kalan	28˚18'32"	76˚09'59"	TW	450	8.51	831	640
6	H-6	Majra Khurd	28˚16'53"	76˚09'32"	SB	400	8.32	2356	1550
7	H-7	Sigri	28˚16'25"	76˚09'34"	TW	350	8.68	1013	740
8	H-8	Sigra	28˚17'6"	76˚11'19"	TW	350	8.64	1645	1180
9	H-9	Anawas	28˚16'31"	76˚12'21"	TW	400	8.72	1445	1020
10	H-10	Jhagroli	28˚18'2"	76˚12'29"	SB	380	8.5	1077	710
11	H-11	Buchawas	28˚17'27"	76˚13'50"	SB	375	8.42	3450	1980
12	H-12	Gudha	28˚18'43"	76˚15'18"	TW	380	8.34	2817	1800
13	H-13	Unhani	28˚19'50"	76˚17'07"	TW	400	8.67	888	500
14	H-14	Kanina	28˚19'49"	76˚18'31"	TW	385	8.35	1196	750
15	H-15	Chelawas	28˚18'56"	76˚17'18"	TW	450	8.61	1114	826
16	H-16	Ishrana	28˚16'56"	76˚17'46"	SB	450	8.43	1116	874
17	H-17	Partal	28˚15'38"	76˚17'37"	TW	410	8.52	1033	762
18	H-18	Bhojawas	28˚13'59"	76˚17'55"	TW	400	8.4	729	538
19	H-19	Sundrah	28˚14'49"	76˚15'50"	SB	425	8.36	1221	900
20	H-20	Bawania	28˚15'31"	76˚13'39"	SB	400	8.8	2841	1900
21	H-21	Khera	28˚15'19"	76˚12'43"	SB	400	8.74	992	722
22	H-22	Surjanwas	28˚13'25"	76˚12'58"	SB	350	8.5	926	660
23	H-23	Dulana	28˚15'30"	76˚10'47"	SB	410	8.53	2485	1600
24	H-24	Mahendergarh	28˚16'24"	76˚08'25"	TW	450	8.35	381	320
25	H-25	Jonawas	28˚13'37"	76˚07'49"	TW	425	8.8	1655	1180
26	H-26	Bhandor Neechi	28˚13'58"	76˚08'45"	TW	400	8.72	1232	880
27	H-27	Jatwas	28˚14'28"	76˚07'53"	TW	450	8.58	1627	1120
28	H-28	Jhhankhadi	28˚20'	76˚7'10"	SB	480	8.3	1103	750
29	H-29	Mandola	28˚19'54"	76˚05'41"	SB	500	8.4	572	421

30	H-30	Nangel Mala	28˚22'23"	76˚04'11"	SB	525	8.48	495	300
31	H-31	Digrota	28˚21'19"	76˚01'00"	SB	500	8.25	483	340
32	H-32	Barda	28˚19'60"	76˚00'05"	SB	510	8.67	581	400
33	H-33	Surheti	28˚20'33"	75˚58'29"	SB	525	8.46	561	380
34	H-34	Satnali	28˚22'23"	75˚57'37"	POND	25	7.47	770	500
35	H-35	Satnali	28˚22'40"	75˚57'57"	SB	510	8.65	490	400
36	H-36	Dalanwas	28˚18'24"	76˚00'41"	SB	500	8.43	454	327
37	H-37	Madhogarh	28˚18'24"	76˚01'59"	SB	480	8.27	553	400
38	H-38	Rajawas	28˚16'40"	76˚04'38"	TW	450	8.32	576	418
39	H-39	Khatodara	28˚16'50"	76˚05'24"	SB	490	8.21	4026	2480
40	H-40	Khaira	28˚15'43"	76˚07'50"	SB	425	8.27	2367	1560
41	H-41	Rewasa	28˚16'57"	76˚08'12"	TW	400	8.5	2018	1340
42	H-42	Sisoth Dhani	28˚17'37"	76˚08'41"	POND	20	7.45	288	212
43	H-43	Sisoth	28˚17'33"	76˚08'34"	TW	425	8.34	2984	1780
44	H-44	Palri Panihara	28˚19'04"	76˚07'45"	TW	450	8.3	588	452
45	H-45	Pali	28˚20'12"	76˚08'00"	POND	30	7.08	235	160
46	H-46	Dholi	28˚21'09"	76˚07'08"	TW	375	7.93	2160	400
47	H-47	Akoda	28˚25'19"	76˚08'26"	TW	250	8.41	2185	1360
48	H-48	Kharkara	28˚23'17"	76˚10'21"	TW	300	7.95	360	2100
49	H-49	Bhurjat	28˚22'42"	76˚08'53"	TW	350	8.36	505	1400
50	H-50	CUH							980
		(Central University of Haryana)	28˚21'04"	76˚08'01"	SB	450	8.39	1344	

Table 1**:** Elemental Analysis of water having Heavy metals of District Mahendergarh from various locations.

SB: Submersible, TW: Tubewell

Heavy metals	Wavelength(nm)	Slit Width(nm)	Lamp Current (mA)	Type of flame	R^2 (Correlation coefficient)
As	193.7	1.0	8.0	NitrousOxide-Acetylene	0.998
Cu	324.7	0.5	3.0	AirAcetylene(Oxidizing)	0.987
Cd	228.8	0.5	3.0	Air-Acetylene (Oxidizing)	0.970
Cr	357.9	0.2	6.0	Air-Acetylene (Highly Reducing)	0.999
Pb	217.0	1.0	5.0	Air Acetylene (Oxidizing)	0.995
Fe	248.3	0.2	7.0	Air Acetylene (Oxidizing)	0.996
Zn	213.9	0.5	5.0	Air Acetylene (Oxidizing)	0.998
Ni	232.0	0.2	4.0	Air Acetylene (Oxidizing)	0.958
Hg	253.7	0.5	3.0	Air Acetylene (Oxidizing)	0.999
Co	240.7	0.2	6.0	Air Acetylene (Oxidizing)	0.987
Mn	279.5	0.2	5.0	Air- Acetylene (Stoichiometric)	0.983

Table 2. Conditions for determination of toxic metals in water of the studied region

	Heavy metal concentration (mg/L)			WHO	USEPA	EU Standards	Romanian Law
Heavy metal	Min	Max	Mean	(2008) (mg/l)	(2017)	(1998)	311/2004
Fe	0.191	0.907	0.246	0.3	0.3	0.200	0.200
Cu	0.005	0.566	0.27	1.5	1.3	2.0	2.0
As	10.306	10.306	10.306	0.05	0.010	NM	NM
Cd	0.004	0.146	0.068	0.003	0.005	0.0050	0.0050
Hg	0.162	6.936	3.316	0.005	0.002	NM	NM
Cr	0.212	15.75	4.73	0.05	0.1	0.050	0.050
Ni	15.36	15.36	15.36	0.1	-	0.020	0.020
Mn	0.024	2.99	1.43	0.3	0.05	0.050	0.050
Co	-	-	-	0.05	-	NM	NM
Zn	0.003	0.375	0.06	5	5	NM	NM
Pb	-	-	-	0.05	-	0.010	0.010

Table 3: Concentration of heavy metals in water of the studied area

Heavy Metals	CDI_{ing}			CDI_{derm}			CDI_{total}		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Fe	6.0E-06	2.9E-05	7.7E-06	1.17E-08	5.6E-08	1.5E-08	6.0E-06	2.9E-05	7.7E-06
Cu	1.6E-07	1.8E-05	8.5E-06	3.1E-10	3.5E-08	1.7E-08	1.6E-07	1.8E-05	8.5E-06
As	3.2E-04	3.2E-04	3.2E-04	6.32E-07	6.32E-07	6.32E-07	3.2E-04	3.2E-04	3.2E-04
Cd	1.3E-07	4.6E-06	2.1E-06	2.5E-10	8.9E-09	4.2E-09	1.3E-07	4.6E-06	2.1E-06
Hg	5.0E-06	2.2E-04	1.0E-04	9.9E-09	4.3E-07	2.0E-07	5.0E-06	2.2E-04	1.0E-04
Cr	6.6E-06	4.9E-04	1.5E-04	1.3E-08	9.7E-07	2.9E-07	6.6E-06	4.9E-04	1.5E-04
Ni	4.8E-04	4.8E-04	4.8E-04	9.4E-07	9.4E-07	9.4E-07	4.8E-04	4.8E-04	4.8E-04
Mn	7.5E-07	9.4E-05	4.5E-05	1.5E-09	1.8E-07	8.8E-08	7.54E-07	9.4E-05	4.5E-05
Co	-	-	-	-	-	-	-	-	-
Zn	9.4E-08	1.2E-05	1.9E-06	1.8E-10	2.3E-08	3.7E-09	9.4E-08	1.2E-05	1.9E-06
Pb	-	-	-	-	-	-	-	-	-

Table 4: Chronic daily intake via ingestion and dermal absorption through different pathways

NM belongs to “not mention”.

Heavy metal	HQ_{ing}			HQ_{derm}			HQ_{total}		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Fe	8.6E-06	4.1E-05	1.1E-05	1.7E-08	8.0E-08	2.1E-08	8.6E-06	4.1E-05	1.1E-05
Cu	4.0E-06	4.5E-04	2.1E-04	2.5E-08	2.9E-06	1.4E-06	4.0E-06	4.5E-04	2.1E-04
As	1.1	1.1	1.1	5.1E-03	5.1E-03	5.1E-03	1.1	1.1	1.1
Cd	2.6E-04	9.2E-03	4.2E-03	4.0E-08	1.8E-06	8.4E-07	2.6E-04	9.2E-03	4.2E-03
Hg	1.7E-02	7.3E-01	3.3E-01	-	-	-	1.7E-02	7.3E-01	3.3E-01
Cr	2.2E-02	1.6	5.0E-01	8.7E-07	6.5E-05	1.9E-05	2.2E-02	1.6	5.0E-01
Ni	2.4E-02	2.4E-02	2.4E-02	1.7E-07	1.7E-07	1.7E-07	2.4E-02	2.4E-02	2.4E-02
Mn	5.4E-06	6.7E-04	3.2E-04	-	-	-	5.4E-06	6.7E-04	3.2E-04
Co	-	-	-	-	-	-	-	-	-
Zn	3.1E-07	4.0E-05	6.3E-06	3.3E-12	3.8E-11	6.2E-11	3.1E-07	4.0E-05	6.3E-06
Pb	-	-	-	-	-	-	-	-	-
HI	**1.16**	**3.46**	**1.96**	**0.005**	**0.005**	**0.005**	**1.16**	**3.46**	**1.96**

Table 5**:** Minimum, maximum, and mean values of non-carcinogenic health risk due to heavy metals in the water of the studied area.

Metals	ILCR (Incremental lifetime Cancer Risk)		
	Min	Max	Mean
Fe	-	-	-
Cu	-	-	-
As	4.8 E-04	4.8 E-04	4.8 E-04
Cd	7.32 E-07	2.8 E-05	1.2 E-05
Hg	-	-	-
Cr	2.7 E-04	2.0 E-02	6.2E-03
Ni	4.0 E-04	4.0 E-04	4.0 E-04
Mn	-	-	-
Co	-	-	-
Zn	-	-	-
Pb	-	-	-

Table 6: Carcinogenic health risk via ingestion and dermal absorption into the drinking water of the study area.

Figures

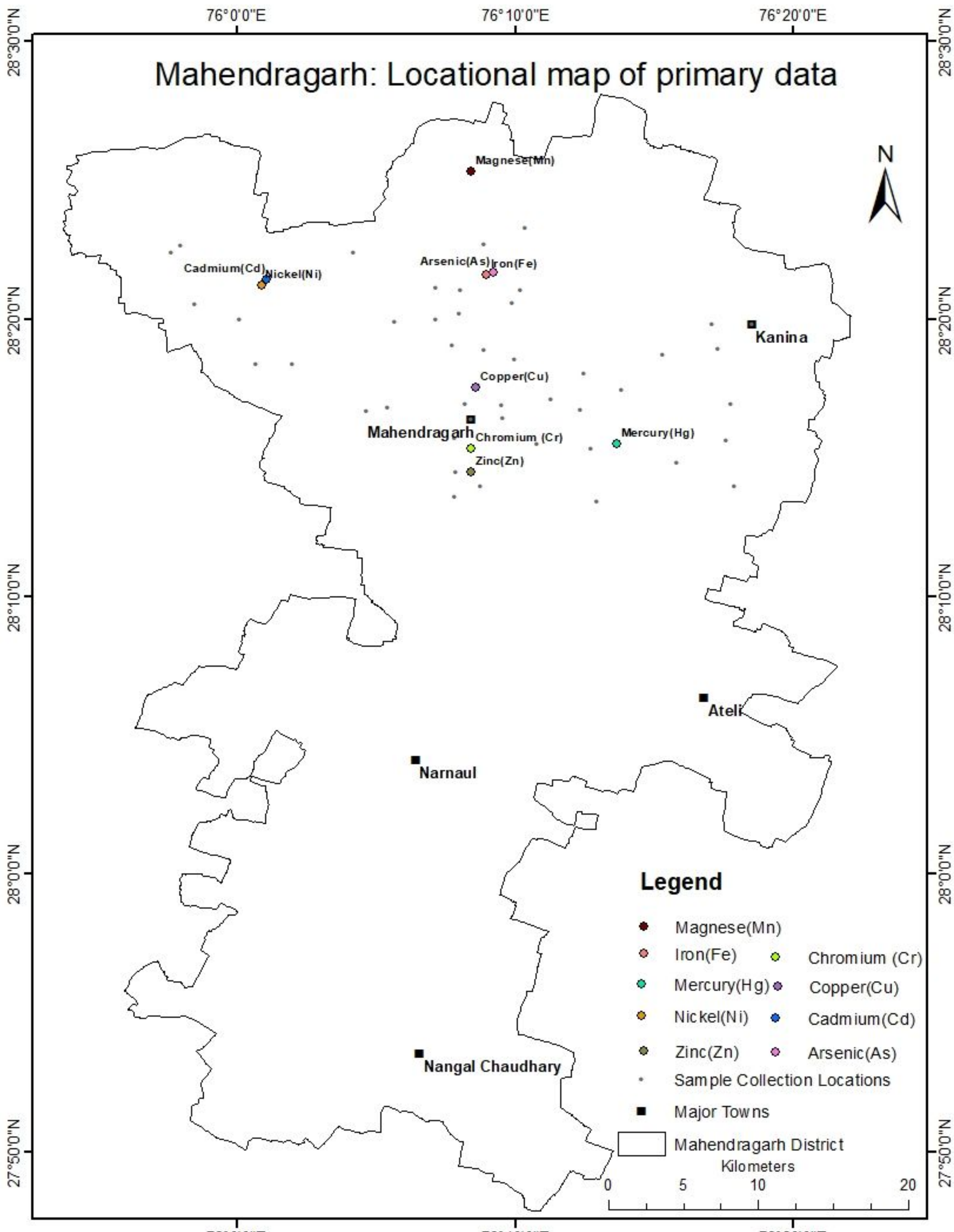

Figure 1

Map of the studied area