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Investigation of Heavy Metals in the Surface and Groundwater and its Health Risk Assessment in the Parts of Gudiyattam Region, Tamilnadu, India

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ABSTRACT

Health risk assessment and heavy metals analysis was carried out for 8 lakes water samples and 8 open well water samples in Gudiyattam region. Metal Index(MI), Adult Infusion(AI), and Hazardous Quotient(HQ) were determined to know the health risk in all locations using ingestion and dermal pathway. MI values are greater than 1 in all lakes as well as in well water for the location S1 to S3 and in S6 which indicates this water is unfit for drinking purposes. Based on $HQ_{ingestion}$ and HQ_{dermal} value, the location S1 to S4 are more polluted for the lake water. Among all the well locations S4 is the most polluted. Considering the Hazard Index (HI) of these metals was found to be greater than 1. Carcinogenic Index(CI) exceeded the acceptable limit of 1.0x $10^{(-06\ to\ -04)}$ in 5 locations for lake water and 1 location for well water. Especially the location S4 in lake water as well as in well water have direct proportionality in pollution load. The water sample previously said location can pose a serious risk to living beings.

Keywords: ground water, lake, risk assessment, metals.

INTRODUCTION

All of the organisms in the environment depend on water for life (Khan and Ansari, 2005). For domestic, industrial, potable, and cattle feed uses, freshwater is used. Freshwater lakes have recently become much more toxin-contaminated as a result of several variables, including socioeconomic development, industrial activity, human activities, and a rapidly rising population (Iqbal et al., 2012). By causing different human health issues, improper discharge of untreated home sewerage, industrial discharges, and solid waste has polluted lakes (Darapu et al., 2011; Thambavani and Mageswari, 2014; Nasirian, 2007; Simoes et al., 2008; Bodrud-Doza et al., 2020; Shams et al., 2020). According to estimates, more than 1.8 million individuals from developing nations pass away each year from diseases associated with contaminated water (WHO, 2004). It is claimed that the concentration of heavy metals such as Cadmium (Cd), Lead (Pb), and Mercury is increasing as a result of industrial activities (Hg) (Kang et al., 2016; Schuster et al., 2002).

Continuous access to these metals leads to bioaccumulation in all living things owing to their neurotoxic and cytotoxic properties and leads to gastrointestinal problems (WHO, 2011). 40×10^3 tonnes of waste is generated for a year from one tannery unit (Galina-Aleixandre et al., 2011). Studying the quality of surface and groundwater is crucial to determining the extent of pollution due to the increased industrialization and urbanization in and around the town of Gudiyattam. Numerous leather factories are operating in the town of Gudiyattam, processing the leather to create footwear components for export to different nations. In 2007–2008 and 2016–2017, respectively, the output of leather components fit for export increased from 250 to 5893 square meters (Thiripurasundari, K et al., 2018). These leather processing industries have the potential of contaminating the lakes by discharging effluent. The health of others around may suffer if unwanted trash is dumped into fields without being properly treated. To understand the health concerns in the ecosystem, many studies have been done in the past (Tajudeen et al., 2022).

Hence, to understand the risk factor associated with humans, a health risk assessment analysis is needed. The USEPA model assists in identifying and analyzing potential risk sources for the transmission of hazardous chemicals to people. In our study, the risk factor was evaluated using the USEPA model for health risk assessment. To examine the health risks associated with metals via ingestion and skin absorption for adults, this research project was undertaken to quantify the quantities of heavy metals in the lake water over a year. Gudiyattam taluk has 185,562 people as of the year 2011. There are a total of 99 villages in this Taluk (Vellore District-statistical-hand-book-2016-17). The Gudiyattam region was the site of the earlier investigations on lake water quality. The findings showed that the existence of significant industrial and agricultural activity in the major lakes had resulted in pollution of the lakes. All lakes can be identified as having Lead, Chromium, Zinc, and Copper at different times of the year (Hemath Naveen, K.S and Brijesh Nair, 2022). This is the first investigation into health risk assessment in the Gudiyattam region in aspects of lake water and groundwater.

METHODOLOGY

Study area

Gudiyattam town is located in the Vellore district in the state of Tamil Nadu. The geographical coordinates are Latitude 12.93972°N and Longitude 78.8644°E. The lake water sample locations are S1 (Thattaparai), S2 (Nellorepet), S3 (Yeripattrai), S4 (Thattankuttai), S5 (Valathur), S6 (Pakkam), S7 (Parasuramanpatti) and S8 (Pallikonda).

Location map of the study area is given in Figure 1. The Latitude and Longitude for open well for the above mentioned location are 12.97421°N and 78.83825°E, 12.94221 and 78.85074, 12.96081 and 78.82622, 12.91633 and 78.8663, 12.87958 and 78.82626, 12.9782 and 78.8759, 12.93206 and 78.91543, 12.94321 and 78.9213 for the location S1 to S8.

Sample collection

A periodic (monthly) sampling was carried out from May 2018 to April 2019. The samples were collected from eight lakes and eight open wells, which serve as the source of water for various purposes like agricultural, domestic, and drinking utilization. The sterile polypropylene containers of volume 1 liter were used for the collection of freshwater samples. Samples were added with Nitric acid (10%) for preservation and stored at 4 °C for further laboratory analysis.

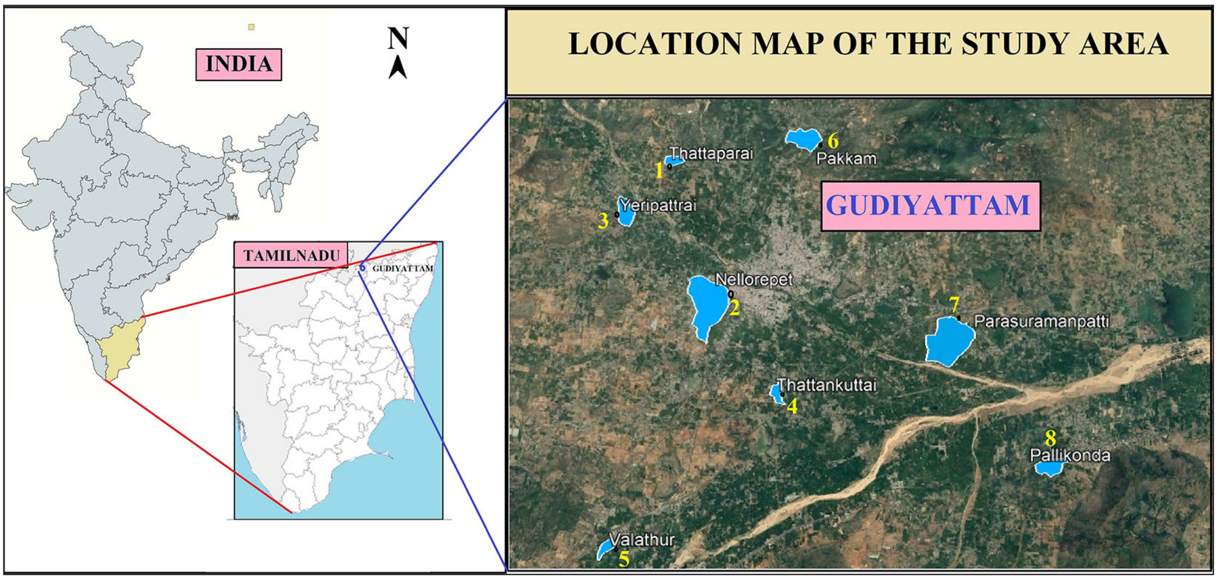

Figure 1. Location map of the Study area

Characterization of water

The American Public Health Association authorized and advised experimental approach (APHA, 2012) was used to determine the various physicochemical characteristics present in the lake water. ICP-OES was used to evaluate whether there were heavy metals in the lake's water. Cadmium (Cd), Iron (Fe), Zinc (Zn), Manganese (Mn), Cobalt (Co), Lead (Pb), Nickel (Ni), Copper (Cu), and Chromium were all tested for in the samples (Cr). To construct the Metal Index (MI) and to analyze the health risk, the mean score for heavy metals was observed.

Metal index

The most extreme allowable concentration (MAC) of metals in drinking water is based on the MI evaluation. The MI was calculated using the Equation 1 as shown below

$$MI = \sum[C/MAC] \quad (1)$$

where: C – average concentration of metal;
MAC – maximum allowable concentration of metal.

Water is termed polluted and unfit for human consumption if the MI (Metal Index) value is more than 1 (Tamasi, G, R. Cini, 2004).

HEALTH RISK ASSESSMENT

Average daily dose

Health risk assessment can be estimated in three ways. First way is through ingestion of metals by consumption of water, second way is by inhalation and third way is by dermal exposure. In general ingestion and dermal absorption are the most common ways. The exposure doses for both pathways were calculated using equation (2) and equation (3) respectively (USEPA, 1989; Wu et al., 2010).

$$ADD_{ing} = \frac{Cw \times IR \times EF \times ED}{BW \times AT} \quad (2)$$

$$ADD_{der} = \frac{Cw \times SA \times Kp \times \times ET \times EF \times ED \times CF}{BW \times AT} \quad (3)$$

For Cr, Pb, Cd, Cu, Co, Zn, Fe, and Mn was calculated from the standard procedure (Wu et al., 2010; USEPA, 2004; Liang et al., 2011). BW – body weight (52 kg-average value of BW for Indian man) individually was utilized for the estimations (Dang et al., 1996; Jain et al., 2009). Terms employed in Exposure Dosages was given in Table 1.

Risk categorization

Hazard Quotient (HQ), which is computed by comparing the exposure route of ingestion with the matching reference dose (RfD) utilizing an equation (4), was used to categorize risks

$$HQ = \frac{ADD}{RfD} \quad (4)$$

where: RfD originates from risk-based concentration both for ingestion and dermal absorption.

The Hazard Index (HI), which is used to evaluate the risk of numerous trace elements in lake water, measures the overall probability that several trace elements in water could result in non-cancer health issues. The following Equations 5 and 6 were used to calculate this in accordance with the USEPA recommendation for the exposure pathway. A Hazard Index (HI) score greater than 1 indicates the possibility of adverse effects on human health and the need for additional research

Table 1. Terms employed in exposure dosages

Add	Average daily dose (μg/kg /day)
Cw	Average concentration of metals in water (μg/litre)
Ir	Ingestion rate (2.5 litre/day)
Ef	Exposure frequency (350 day/year)
Ed	Exposure duration (30 years)
At	Averaging time (ED x 365 d) for non-cancer risk and (70 × 365 days) for cancer risk
Sa	Exposed skin area (18000 cm^2)
Et	Exposure time (0.6 h/d)
Cf	Unit conversion factor (0.001 l/cm^3)
Kp	Dermal permeability coefficient (cm/h)

$$HI_{ing} = \sum_{i=1}^{n} HQ_{ing} = HQ_{Mn} + +HQ_{Zn} + HQ_{Cd} + HQ_{Fe} + HQ_{Co} + +HQ_{Ni} + HQ_{Cu} + HQ_{Pb} + HQ_{Cr} \quad (5)$$

$$HI_{der} = \sum_{i=1}^{n} HQ_{der} = HQ_{Mn} + +HQ_{Zn} + HQ_{Cd} + HQ_{Fe} + HQ_{Co} + +HQ_{Ni} + HQ_{Cu} + HQ_{Pb} + HQ_{Cr} \quad (6)$$

Carcinogenic risk

The term "carcinogenic risk" refers to the likelihood that a person may develop cancer at some point in their lifetime as a result of chemical exposure (Chen and Liao, 2006). Equations 7 and 8 were used to establish the cancer index (CI), and equations 7 and 8 were used to determine the carcinogenic risk of Cr, Cd, and Pb present in lake water (9) (Miguel et al., 2007).

$$CR_{ingestion} = ADD_{ingestion} * CSF \quad (7)$$

$$CR_{dermal} = ADD_{dermal} * CSF \quad (8)$$

$$CI = CR_{ingestion} + CR_{dermal} \quad (9)$$

where: ADD – ingestion and dermal absorption; CSF – cancer slope factor (1.5mg/kg/d) (USEPA, 2005).
Here ADD is the Average Daily Dose for carcinogenic over 70 years in (mg/kg/d).

The measured value has a stable chance of an individual having any disease over a prolonged time frame due to various cancer-causing openness. The permissible limit of carcinogenic risks given by USEPA is varied from 10^{-6} to 10^{-4} for more metals (USEPA,1991).

RESULT AND DISCUSSION

Metal index (MI)

Based on Equation 1, the Metal Index(MI) values for lake water and well water were calculated and the value is listed in Table 1. For all the lakes MI value was determined to be greater than 1. MI value ranged in all the lakes from 6.1 to 221.8. Based on individual metals, the metal Cr ranged from 0.9 to 3.96. Except for the location S5 and S8, the remaining location exceeded the MI value greater than 1. For the metal Pb, except the location S7 and S8, all other sites were exceeding the MI value limit. For Cu, S1 and S2 exceed the MI value greater than 1. For the metal Cd, the MI value ranged from 0.33 to 1, for the metal Fe, the MI value ranged from 0.48 to 4.48, for the metal Zn, the MI value ranged from 0.001 to 0.71 and for the metal Mn, the MI value ranged from 0.12 to 1.3. It clearly shows that all the lakes are unfit for potable purposes and for well water sample also MI value was calculated. The result revealed that the MI value was found to be greater than 1 for locations S2, S3, S4, and S6.

The MI value ranged from 0.02 to 145.12. The previously mentioned location was unfit for drinking purposes due to the higher MI value. Locations S1, S5, S7, and S8 are safe for drinking purposes. By considering individual metals, Cr in location S4, Pb in location S6, Cd in location S4, and Mn in location S4 received which is above 1. Figure 2 displayed the Latitude, Longitude, and nearby industries responsible for the presence of pollution in lakes, together with the hierarchical Metal Index of the contaminants of the lakes. MI value for the lake water and well water was tabulated in Table 2.

Risk assessment analysis of health

It entails determining the type and description of negative health effects caused by human contact with toxic chemicals. According to USEPA recommendations (USEPA, 2004), the health risks associated with oral and cutaneous exposure to water that is both non-carcinogenic and carcinogenic were assessed in this investigation.

Non-carcinogenic risk (Ingestion pathway)

In this investigation, the non-carcinogenic risk from ingestion and dermal exposure was taken into account for lake water and well water.

The ADD index value varies from 6.59, 15.1, 1.42, 0.54, 1.44, 0.04, 35.6, 27.3, 3.2 $(\mu g/kg/d)^{-1}$ for Cr, Pb, Ni, Co, Cu, Cd, Fe, Zn and Mn respectively. Similarly, for well water ADD index values varies from 0.53, 0.32, 0.21, 0.19, 2.29, 25.1, 61, 1.6 $(\mu g/kg/day)^{-1}$ for the above-mentioned metals. Table 3 shows the ADD value due to ingestion for non-carcinogenic risk. For the lake water, ADD_{ing} values for non-carcinogenic risk were arranged as Fe > Zn > Pb > Cr > Mn > Ni> Cu > Co > Cd, and for well water ADD_{ing} values were arranged as Fe > Zn > Cd>Mn>Cr>Pb>CO>Cu`>Ni. It clearly shows the

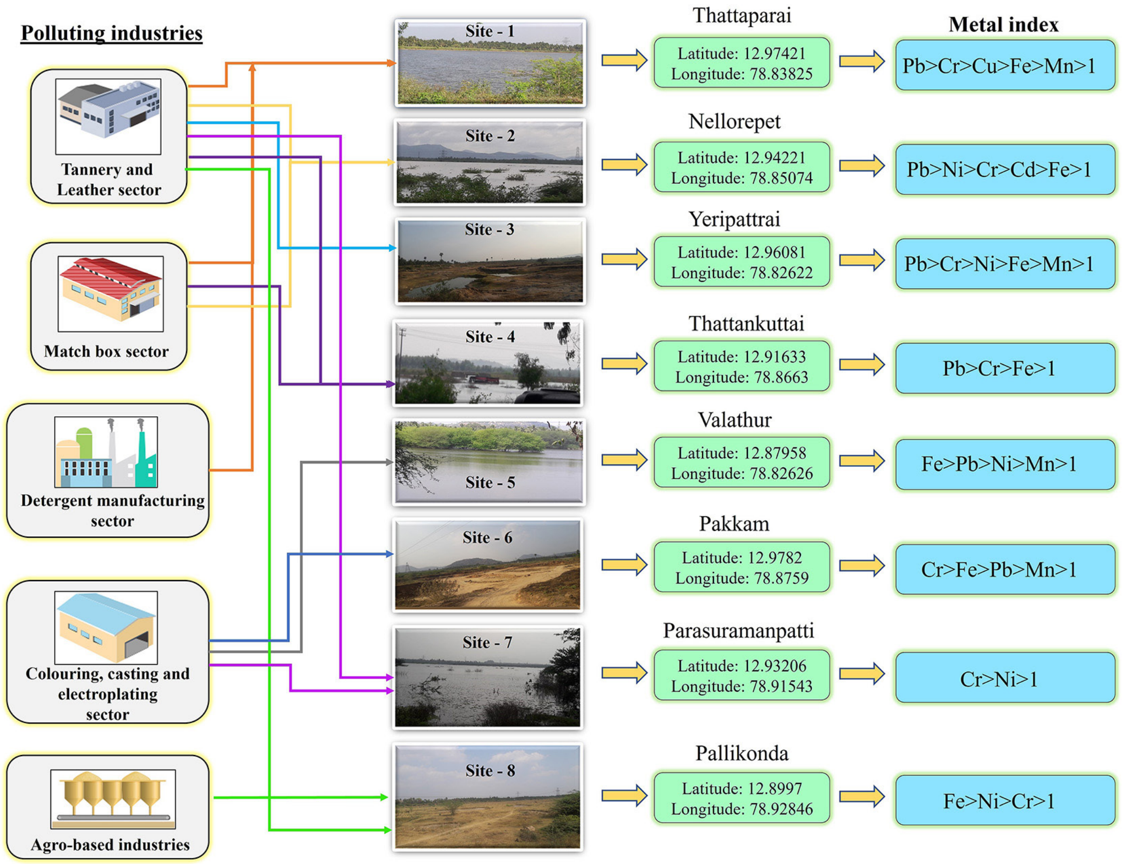

Figure 2. Polluting Industries, Latitude and Longitude and Hierarchical Metal Index of all the lakes

Table 2. Metal index for lake and well water

Maximum allowable concentration (mg/L)										
Element	Cr	Pb	Ni	Co	Cu	Cd	Fe	Zn	Mn	
MAC (mg/L)	0.05	0.01	0.02	0.05	0.05	0.003	0.3	5	0.1	
Metal index (MI) for lake water										
Location	Cr	Pb	Ni	Co	Cu	Cd	Fe	Zn	Mn	MI
S1	2.78	9.8	0.215	0.4	2.06	0.4	1.51	0.001	1.3	18.4
S2	3.78	26.5	6	0.7	1.78	1.76	1.37	0.71	0.31	42.9
S3	3.86	212.3	2.15	0.38	0.34	0	1.70	0.10	0.99	221.8
S4	1.4	11.2	0.75	0.4	0.09	0.33	0.48	0.003	0.89	15.7
S5	0.64	2	0.9	0	0.12	0	7.11	0.04	0.90	11.7
S6	5.56	1.2	0	0	0.002	0	3.23	0.03	1.01	11
S7	3.96	0	0.9	0	0.48	0	0.73	0.01	0.09	6.1
S8	0.9	0	1.45	0	0.16	0	4.48	0.03	0.12	7.1
Metal index (MI) for well water										
Location	Cr	Pb	Ni	Co	Cu	Cd	Fe	Zn	Mn	MI
S1	0	0	0	0	0	0	0.07	0.01	0	0.08
S2	0	0	0	0	0	0	1.07	0	0.02	1.09
S3	0	0	0	0	0	0	5.28	0.10	0.03	5.93
S4	1.85	0	0	0.74	0.04	132.73	7.88	0.02	1.82	145.12
S5	0	0	0	0	0	0	0.03	0.01	0	0.04
S6	0	5.58	0	0	0.12	0	0.06	0.03	0.42	6.23
S7	0	0	0	0	0	0	0.09	0.01	0.47	0.58
S8	0	0	0	0	0	0	0.02	0	0	0.02

Table 3. Average (ADD) value due to ingestion and dermal exposure of all the lake water and well water

Metals	Average ADD ing (μg/kg/day) $^{-1}$ for lake water	Average ADD ing (μg/kg/day) $^{-1}$ for well water	Average ADD dermal (μg/kg/day) $^{-1}$ for lake water	Average ADD dermal (μg/kg/day) $^{-1}$ for well water
Cr	6.592466	0.53535	0.056959	0.004625
Pb	15.15576	0.321556	0.261891	0.002778
Ni	1.425102	0	0.001231	0
Co	0.541689	0.21437	0.00936	0.001852
Cu	1.449881	0.194777	0.006263	0.001683
Cd	0.04322	2.294685	0.000187	0.019826
Fe	35.6823	25.13262	0.154148	0.217146
Zn	27.37833	6.182742	0.070965	0.053419
Mn	3.238606	1.606049	0.055963	0.013876

metal Mn occupies dominating both in lake water and in water. The mean value of HQ_{ing} for lake water is 2.19, 10.8, 0.07, 1.80, 0.03, 0.08, 0.11, 0.09, 0.16 and similarly, for well water, the mean value of HQ_{ing} for well water is 0.17, 0.22, 0, 0.71, 0.004, 4.58, 0.08, 0.02 and 0.08 for following metals such as Cr, Pb, Ni, Co, Cu, Cd, Fe, Zn and Mn respectively. The mean value is given in HQ_{ing} Table 4.

For individual metals in lake water, the metal Cr in locations S1 to S3 and S6 was found to be greater than 1. HQ in value greater than 1 in locations S1, S2, S3, and S6 for Cr and for Pb in the location S1 to S5 HQ_{ing} value found to be greater than 1. For Co, the location S2 and S3 HQ_{ing} values are greater than 1. Cr, Pb, and Co are the metals that are dominating in locations S1 to S5 and in location S6. For well water by considering individual metal HQ_{ing} value for Cr greater than 1 in S4 as 1.42, for Pb, HQ_{ing} Value found to be 1.83 in location S6. For the metal Co, HQ_{ing} value greater than 1 in location S4.

These locations are closer to the town of Gudiyattam, which contributes to the greater HQ_{ing} value in these locations, as do the various leather manufacturing and leather finishing enterprises located at big adjacent lakes. The mentioned

Table 4. HQ_{ing} and HI_{ing} values for ingestion pathway for lake and well water

Location	Hazardous quotients (HQ_{ing}) values for lake water									HI_{ing}
	Cr	Pb	Ni	Co	Cu	Cd	Fe	Zn	Mn	
S1	2.1	3.2	0.009	3	0.11	0.11	0.06	0.00	0.29	9.04
S2	2.9	8.72	0.27	5.3	0.10	0.48	0.06	0.54	0.07	18.55
S3	2.9	69.90	0.09	2.9	0.01	0	0.07	0.07	0.22	76.30
S4	1.0	3.68	0.03	3	0.005	0.09	0.02	0.002	0.20	8.19
S5	0.4	0.68	0.04	0	0.00	0	0.32	0.03	0.20	1.76
S6	4.2	0.35	0	0	0.00	0	0.14	0.02	0.23	5.07
S7	3	0	0.04	0	0.02	0	0.03	0.01	0.020	3.17
S8	0.6	0	0.06	0	0.00	0	0.20	0.03	0.02	1.03
Mean	2.19	10.8	0.07	1.80	0.03	0.08	0.11	0.09	0.16	15.39
Location	Hazardous quotients (HQ_{ing}) values for well water									HI_{ing}
	Cr	Pb	Ni	Co	Cu	Cd	Fe	Zn	Mn	
S1	0	0	0	0	0	0	0.003	0.01	0	0.01
S2	0	0	0	0	0	0	0.04	0	0.005	0.054
S3	0	0	0	0	0.02	0	0.24	0.08	0.008	0.36
S4	1.42	0	0	5.71	0.002	36.71	0.36	0.02	0.42	44.66
S5	0	0	0	0	0	0	0.001	0.01	0	0.01
S6	0	1.83	0	0	0.007	0	0.003	0.023	0.09	1.971
S7	0	0	0	0	0	0	0.004	0.01	0.10	0.12
S8	0	0	0	0	0	0	0.001	0	0	0.001
Mean	0.17	0.22	0	0.71	0.004	4.58	0.08	0.02	0.08	5.90

industries produce and process a significant quantity of toxic waste from the leather manufacturing process due to labor availability in nearby villages. The possibility of mixing the processed waste from tanning companies into defined lakes. Similarly, for well the HQ_{ing} value in locations S1 and S6 are found to be greater than 1 which implies due to the lake water contamination, it may pollute groundwater also.

So, it causes serious damage to humans the adult. Also, HI_{ing} was calculated for each place to determine the whole anticipated non-cancer effects created by totally concentrated trace elements on people's health. HI, ingestion for lakes in all locations was found to be greater than 1 and for well water, the location S4 and S6 were found to be greater than 1 which causes more effect on humans. HI_{ing} for the lake and the well water was shown in Table 4.

Non-carcinogenic risk (dermal pathway)

The ADD index value of lakes for dermal exposure varies from 0.05, 0.26, 0.001, 0.009, 0.0001, 0.15, 0.07 and 0.05 for Cr, Pb, Ni, Co, Cu, Cd, Fe, Zn, and Mn. For well, water ADD index value for dermal exposure varies from 0.004, 0.002, 0, 0.001, 0.019, 0.21, 0.05 and 0.01 for previously stated elements. The categorization of ADD_{der} value was ranged for lake water as Pb>Fe>Zn>Cr>Mn>Co>Cu>Ni and for well water ADD_{der} value was ranged as Fe>Zn>cd>Mn>Cr>Pb>Co>Cu>Ni respectively and showed in Table 3. The calculated mean HQ_{der} for the lake are 3.7, 0.62, 0.0002, 0.15,0.0005, 0.37,0.003, 0.001, 0.06 and for the well water, the mean HQ_{der} was 0.308, 0.006, 0.02, 0.0001, 39.6, 0.004, 0.0008, 0.17 for Cr, Pb, Ni, Co, Cu, Cd, Fe, Zn and Mn respectively and the values are listed in Table 4. The categorization based on HQ_{der} for lake water as Cr>Pb>Cd>Co>Mn> Fe>Zn>Cu> Ni and well water based on HQ_{der} the metals sequenced as Cd>Cr>Co>Mn> Pb>Fe>Zn> Cu>Ni. Chromium, Lead, and Cadmium are dominating in lake water as well as in well water. This may be due to industries that are present in surrounding areas. For individual metals, the HQ_{der} value for Cr in all the lakes was found to be greater than 1. Especially the location S3 and S2 HQ_{der} value achieves higher for the metal Pb and Cd. For well water HQ_{der} value was found to be greater than 1 for Cr and Cd in location S4. Especially these metals are polluting the groundwater. HQ_{der} value for the lake and the well water was tabulated in

Table 5. HQ_{der} and HI_{der} values for dermal pathway for lake and well water

Location	Hazardous quotients (HQ_{der}) values for lake water									HI_{der} values
	Cr	Pb	Ni	Co	Cu	Cd	Fe	Zn	Mn	
S1	3.69	0.18	3.17	0.26	0.00	0.47	0.002	9.96E-06	0.12	4.75
S2	5.0	0.5	0.0	0.4	0.00	2.1	0.00	0.00	0.03	8.13
S3	5.1	4.0	0	0.2	0.00	0	0.002	0	0.09	9.5
S4	1.85	0.2	0.0	0.2	7.47E-05	0.3	0.000	2.99E-05	0.08	2.82
S5	0.84	0.03	0	0	9.96E-05	0	0.00	0.00	0.09	0.98
S6	7.3	0.02	0	0	1.66E-06	0	0.004	0.0	0.10	7.51
S7	5.2	0	0.0	0	0.00	0	0.0009	0.00	0.008	5.2
S8	1.1	0	0	0	0.0	0	0.005	0.0	0.01	1.21
Mean	3.79	0.62	0	0.1	0.0005	0.37	0.003	0.001	0.06	5.02
Location	Hazardous quotients (HQ_{der}) values for well water									HI_{der} values
	Cr	Pb	Ni	Co	Cu	Cd	Fe	Zn	Mn	
S1	0	0	0	0	0	0	0.000	0.000	0	0.00063
S2	0	0	0	0	0	0	0.002	0	0.001	0.0040
S3	0	0	0	0.16	0.000	0	0.01	0.003	0.001	0.186
S4	2.46	0	0	0.01	7.97E-05	317.2	0.02	0.000	0.09	319.81
S5	0	0	0	0	0	0	8.85E-05	0.005	0	0.0006
S6	0	0.052	0	0.04	0.0	0	0.0001	0.0010	0.02	0.1180
S7	0	0	0	0	0	0	0.0002	0.0005	0.02	0.02364
S8	0	0	0	0	0	0	7.08E-05	0	0	7.08E-05
Mean	0.30	0.006	0	0.02	0.000	39.65	0.004	0.0008	0.01	40.01

Table 5. HI_{der} values for all the lakes exceed than 1and for well water location S4 only crossed the HI_{der} above 1. Remaining all other sites are less polluted and can use for drinking purposes.

Cancer risk analysis

To determine the cancer health concerns, the carcinogenic risk of Cr, Pb, and Cd has been determined for eight lakes and also for eight well samples. Cancer risk and Carcinogenic index (CI) were determined and listed in Table 6. The calculated mean values of lake water for Cr, Pb, and Cd are 1.4×10^{-4}, 5.1×10^{-5} and 7.0×10^{-6} for the ingestion pathway and for well water the mean calculated values are 9.1×10^{-4}, 1.1×10^{-6}, 3.73×10^{-4} for ingestion pathway. The values clearly show overall mean value is an acceptable range that is specified in USEPA. In the dermal pathway, the metals Cr, Pb, and Cd, the mean value was found to be 1.2×10^{-5}, 8.9×10^{-7}, and 3.0×10^{-8} for the lakes. For well, the metals Cr, Pb, and Cd were found to be 9.1×10^{-7}, 1.1×10^{-8}, 3.23×10^{-6}. Overall mean values for individual metals show for the dermal pathway lies below the standard which is given by USEPA. The higher Cancer Index (CI) value for lakes received as 1.4×10^{-3}, 1.93×10^{-3}, 2.26×10^{-3}, 2.77×10^{-3}, 1.97×10^{-3} in the locations S1, S2, S3, S6 and S7 which higher than the referred value from USEPA. The same for well water higher Cancer Index (CI) value was received as 3.9×10^{-3} in location S4. The aforementioned value was created by adding all the metals together in one place while exposing the cutaneous and oral pathways. Due to the contaminants in the residential area through cumulative ingestion and dermal exposure, there is a chance of cancer risk in the above-mentioned location. Long-term consumption of Cr leads to liver and kidney problems and also the long-term consumption of Pb lead to lung and stomach cancer. Hence, residents of investigated region should be aware of hazards, especially in locations S1, S2, S3, S4, and S6.

CONCLUSIONS

Based on the study it is concluded that Metal Index (MI) values for all the lake water and the location S2, S3, S4, and S6 for well water are above

Table 6. Carcinogenic risk and Cancer Index for ingestion and dermal pathway for lake and well water

Carcinogenic risk and Cancer Index for ingestion and dermal pathway for lake water							
Location	Cr		Pb		Cd		$CI_{ing+der}$
	Ingestion	Dermal	Ingestion	Dermal	Ingestion	Dermal	
S1	0.001373	1.18641E-05	1.549E-05	2.67667E-07	9.00948E-06	3.8921E-08	1.40E-03
S2	0.001867	1.61317E-05	4.1886E-05	7.23793E-07	3.97919E-05	1.71901E-07	1.93E-03
S3	0.001907	1.64731E-05	0.00033556	5.79854E-06	0	0	2.26E-03
S4	0.000692	5.97471E-06	1.7703E-05	3.05905E-07	7.5079E-06	3.24341E-08	7.16E-04
S5	0.000316	2.7313E-06	3.1612E-06	5.46259E-08	0	0	3.22E-04
S6	0.002746	2.37281E-05	1.8967E-06	3.27756E-08	0		2.77E-03
S7	0.001956	1.68999E-05	0	0	0	0	1.97E-03
S8	0.000445	3.84089E-06	0	0	0	0	4.48E-04
Mean	0.001413	1.22055E-05	5.1963E-05	8.97914E-07	7.03866E-06	3.0407E-08	1.48E-03
Carcinogenic risk and Cancer Index for ingestion and dermal pathway for well water							
Location	Cr		Pb		Cd		$CI_{ing+der}$
	Ingestion	Dermal	Ingestion	Dermal	Ingestion	Dermal	
S1	0	0	0	0	0	0	0
S2	0	0	0	0	0	0	0
S3	0	0	0	0	0	0	0
S4	0.000918	7.93E-06	0	0	0.00299	2.58E-05	3.94E-03
S5	0	0	0	0	0	0	0
S6	0	0	9.37E-06	8.1E-08	0		9.45E-06
S7	0	0	0	0	0	0	0
S8	0	0	0	0	0	0	0
Mean	0.000115	9.91E-07	1.17E-06	1.01E-08	0.000374	3.23E-06	4.94E-04

the standard and these specific sites are unfit for drinking purposes. A health risk assessment study was also carried out to determine non-carcinogenic and carcinogenic effects through ingestion and dermal exposure. The result revealed that in ingestion pathway for the lake water based on HQ value S1 to S4, S1 to S5, and S1 to S4 were highly polluted in Cr, Pb, and Co. For well water based on HQ_{ing} S4, S6 are highly polluted with Cr, Pb, Co, Cu, and Cd. Locations S1 to S3 and S7 are non-polluted sites among all other locations. Similarly, the HQ_{der} of lake water especially the metal Cr in locations S1 and S2 is highly polluted. The remaining metals are lesser than the prescribed standard value, thus these sites are free from pollutants. HQ_{der} values are high in location S4 for well water. The locations S1 to S3 and S5 to S8 are free from pollutants in the well water. Regarding with Carcinogenic Index (CI), the overall CI value crossed with standard limit from S1 to S3, S6, and S7 for lake water, similarly for well water CI index crossed the standard limit in location S4. This site causes a more vulnerable effect on the public if this water will have consumed by the public for a prolonged time. All the exceeded value shows that the specific sites are highly polluted from various industries such as tannery, footwear, and improper disposal of waste from electroplating industries into surface water. Based on the health risk assessment analysis it is concluded that in specific locations lake water as well as groundwater gets polluted, which represents the pollutant that may be transferred from lake water into groundwater. Further future scope of this study is to know the interaction of surface and groundwater.

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