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Impact of rapid urbanization on ground water's quality: An investigation of toxic elements concentrations in urban areas of Himachal Pradesh

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Abstract
Ground water forms the major source of drinking water and supportive in maintaining the water requirements in urban areas of most of the developing nation of the world. The ground water sources are mainly used for drinking and domestic purposes by urban population of India. In the last few decades, due to rapid increase in population and urbanization, we have been witnessing alarming ground water pollution all over the world. The present study was conducted with an objective to assess the concentrations of toxic elements on water sources in urban areas of Himachal Pradesh, India. In the study area 12 surface water samples have been collected and analyzed for the toxic elements such as nickel (Ni), iron (Fe), arsenic (As), cadmium (Cd), chromium (Cr), lead (Pb), zinc (Zn), mercury (Hg) and copper (Cu). The study revealed that heavy metals concentrations of ground water sources were within the prescribed standard limits for drinking purposes (IS 10500: 2012) and WHO. Further, the investigation showed that the water quality of the selected urban areas possibly impacted due to increase of anthropogenic activities and improper or illegal release of sewage water and agricultural effluents into ground water sources.

Keywords: Urban areas, ground water quality, toxic elements, rapid urbanization

Introduction
Water pollution has become a major problem which we face today. Man has been using water around him for dumping wastes. With the advent of urbanization and industrialization we have been overloading the systems beyond their tolerance limit, consequently, our water bodies such as rivers, streams and lakes are increasingly getting polluted, threatening the safety, welfare and the very existence of mankind. Because of the anthropogenic activities, fresh water resources are deteriorating day-by- day at a very fast rate (Ramadhan, 2007) [29].
Anthropogenic impacts like urbanization, industrialization, agricultural activities as well as natural sources like precipitation rate, weathering processes and soil erosion degrade the surface water (Ramadhan, 2007; Najafpour *et al*., 2008; Bu *et al*., 2010; Shimba and Jonah, 2016) [29, 20, 8, 33]. Thus, the water quality of these resources is a subject of ongoing concern and has resulted in an increasing demand for monitoring ground water sources. Most cities in India are facing severe water scarcity. Changes such as rapid urbanization, economic growth, increasing populations, and evolving consumption patterns are individually and collectively stressing water supplies. Securing urban water supply is crucial, since the number of urban dwellers living with seasonable water shortages is expected to grow from close to 500 million people in 2000 to 1.9 billion in 2050 (McDonald *et al*. 2011) [19]. It is expected that about 70 percent of urban water requirement will be met by surface water sources and remaining from groundwater (Kumar *et al*., 2005) [17].
Almost 200 million people in India do not have access to safe and clean drinking water and 90 percent of the country's water resources are polluted. In India, only 29 percent of the wastewater generated is being treated in urban centers having a population of more than 50,000 and 71 percent as untreated wastewater is being discharged to our rivers, streams, and lakes, making them highly polluted (CPCB, 2011) [13]. Even some of our developed cities in India like Pune, Nagpur, and Nashik are treating only 70 to 80 percent of city sewage, so the sewage pollution caused by ordinary Indian towns and villages can be imagined.

Water pollution has now become a growing hazard in many developing countries. A more serious aspect of water-pollution is being caused by human activity and industrialization (Park, 2009) [22]. In India, almost 70 per cent of its surface water resources and a growing percentage of its groundwater reserves are contaminated by biological, toxic, organic and inorganic pollutants (CPCB, 2008) [12]. The quality of ground water has become a critical issue in many countries especially due to the concern that freshwater will be a scarce resource in the future so a water quality monitoring program is necessary for the protection of freshwater resources (Pesce and Wunderlin, 2000) [23].

Materials and Methods

The study was conducted in major urban areas of the Himachal Pradesh namely Shimla, Dharamshala, Mandi and Kullu with the objective of assessing the impacts of urbanization on ground water quality status. The water samples were collected at different sampling stations during 2017 and 2018 in three seasons *viz*., summer, monsoon and winter. The samples were analyzed for toxic elements like As, Cd, Cu, Cr, Ni, Pb, Zn, Fe and Hg. The standard methods and procedures were used for quantitative estimation of water quality parameters and followed as in, “Standard methods of analysis of water and waste water” (APHA, 1998) [3]. In water sampling analysis, the samples were first filtered using Whatman filter paper (No.1). The heavy metals in the water samples were estimated by using Inductively Coupled Plasma Emission Spectrometer (iCAP 6000 Series, Model No. 6300) duo of thermo make and expressed as mg l^{-1}.

Fig 1: Location map showing the selected towns

Results and Discussion

Arsenic

The As distribution in ground water sources of major urban areas exhibited significant variations (Table 1). The perusal of the data indicated that the ground water As in different urban areas ranged from 0.001 to 0.005 mg l^{-1} which was within the permissible limits as prescribed by BIS. During the first year (2018) significantly highest content of As (0.005 mg l^{-1}) was noticed in the ground water sources of Mandi followed by Kullu (0.003 mg l^{-1}). Whereas the lowest ground water As of 0.001 mg l^{-1} was observed in Shimla and Dharamshala towns. The data presented in Table 1 further stipulated that irrespective of the urban areas the seasons exerted significant influence on As content in ground water sources. The water sources registered highest As of 0.004 mg l^{-1} in pre-monsoon season followed by post-monsoon (0.003 mg l^{-1}) and lowest of 0.002 mg l^{-1} in monsoon months.

Table 1: Seasonal distribution of arsenic (mg l^{-1}) in ground water sources of urban areas

Seasons / Urban areas	Pre-monsoon	Monsoon	Post-monsoon	Mean	Pre-monsoon	Monsoon	Post-monsoon	Mean	Pre-monsoon	Monsoon	Post-monsoon	Mean
	2018				2019				Pooled			
Shimla	0.002	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.002	0.001	0.001	0.001
Dharamshala	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Mandi	0.006	0.004	0.006	0.005	0.006	0.005	0.005	0.006	0.006	0.005	0.005	0.006
Kullu	0.005	0.002	0.003	0.003	0.005	0.002	0.003	0.003	0.005	0.002	0.003	0.003
Mean	0.004	0.002	0.003		0.004	0.002	0.003		0.004	0.002	0.003	
$CD_{0.05}$												
Urban areas				0.001				0.001				0.001
Seasons				0.001				0.001				0.001
Seasons × Urban areas				NS				NS				NS

The urban areas and season interaction also induced significant variation in ground water As.
Similarly, during second year ground water As in different urban areas was found to exhibit significant variations. The highest As of 0.006 mg l^{-1} was recorded in Mandi, followed by Kullu with respective value of 0.003 mg l^{-1}. The lowest As was recorded in Shimla and Dharamshala with value of 0.001 mg l^{-1}. The data presented in Table 1 further indicated that irrespective of locations, seasons exerted significant influence on ground water As. The highest As of 0.004 mg l^{-1} was discerned in pre-monsoon months followed by post-monsoon (0.003 mg l^{-1}) and lowest of 0.002 mg l^{-1} in monsoon season. The interaction of urban areas and seasons was found to be non-significant with respect to the As of ground water sources.
The pooled analysis of both the years also indicated the similar trend with respect to ground water As which followed the order: Mandi (0.005 mg l^{-1}) > Kullu (0.003 mg l^{-1}) > Shimla (0.001 mg l^{-1}) > Dharamshala (0.001 mg l^{-1}). The values of Shimla and Dharamshala were found to be at par with each other. The As was found to be within the permissible limits of BIS in all the urban areas, therefore, indicating that As concentration has not yet influenced the ground water quality of major towns. It is in line with findings of Ahmed *et al*. (2020) [1] who have also reported low As content in water sources. However, the concentration of As was found higher in Mandi town which might be due to the rapid urbanization, excessive use of pesticides in the horticultural and agricultural practices in the vicinity of the town in comparison to other urban areas. The other sources of As in mandi might be erosion of natural deposits and runoff from nearby orchards (Rahmanian *et al*., 2015) [27].
Season wise pooled analysis also depicted the similar trend in the order: pre-monsoon (0.004 mg l^{-1}) > post-monsoon (0.003 mg l^{-1}) > monsoon (0.002 mg l^{-1}). The urban areas and season interaction also induced significant variation in ground water As. Higher concentration in pre-monsoon may probably be because of increase in the rate of evaporation at high temperature and decrease in volume of water in the sources and due to rapid oxidation of organic materials and increase in anthropogenic activities (Lashari *et al*., 2009) [18], whereas the comparatively less concentration in monsoon season attributed to the dilution of pollutants in surface water bodies due to high rainfall during this season. The highest As of 0.006 mg l^{-1} was noticed in Mandi in pre-monsoon season and lowest was observed in Shimla and Dharamshala (0.001 mg l^{-1}) in monsoon and post-monsoon months.

Cadmium

The Cd distribution in ground water sources of major urban areas exhibited significant variations (Table 2). The perusal of the data indicated that the ground water Cd in different urban areas ranged from 0.000 to 0.001 mg l^{-1} which was normal and within the permissible limits as prescribed by BIS. During the first year (2018) significantly highest content of Cd (0.001 mg l^{-1}) was noticed in the ground water sources of Dharamshala followed by Shimla (0.000 mg l^{-1}), Mandi (0.000 mg l^{-1}) and Kullu (0.000 mg l^{-1}). The data presented in Table 2 further stipulated that irrespective of the urban areas the seasons exerted significant influence on Cd content of ground water sources. The water sources registered highest Cd of 0.001 mg l^{-1} in pre-monsoon season followed by post-monsoon (0.000 mg l^{-1}) and monsoon (0.000 mg l^{-1}) months. The urban areas and season interaction found to induce non-significant variation in ground water Cd.
Similarly, during second year ground water Cd in different urban areas was found to exhibit significant variations. The highest Cd of 0.001 mg l^{-1} was recorded in Dharamshala, followed by Shimla, Mandi and Kullu with respective values of 0.000, 0.000 and 0.000 mg l^{-1}. The data presented in Table 2 further indicated that irrespective of locations, seasons exerted significant influence on ground water Cd. The highest Cd of 0.001 mg l^{-1} was discerned in pre-monsoon months followed by post-monsoon (0.000 mg l^{-1}) and monsoon (0.000 mg l^{-1}) season. The interaction of urban areas and seasons was found to be non-significant with respect to the Cd of ground water sources.
The pooled analysis of both the years also indicated the similar trend with respect to ground water Cd which followed the order: Dharamshala (0.001 mg l^{-1}) > Shimla (0.000 mg l^{-1}) > Mandi (0.000 mg l^{-1}) > Kullu (0.000 mg l^{-1}). The values of Dharamshala, Shimla, Mandi and Kullu were found to be at par with each other.

Table 2: Seasonal distribution of cadmium (mg l^{-1}) in ground water sources of urban areas

Seasons / Urban areas	Pre-monsoon	Monsoon	Post-monsoon	Mean	Pre-monsoon	Monsoon	Post-monsoon	Mean	Pre-monsoon	Monsoon	Post-monsoon	Mean
	2018				2019				Pooled			
Shimla	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Dharamshala	0.001	0.000	0.001	0.001	0.001	0.000	0.001	0.001	0.001	0.000	0.001	0.001
Mandi	0.001	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.001	0.000	0.000	0.000
Kullu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Mean	0.001	0.000	0.000		0.001	0.000	0.000		0.001	0.000	0.000	
$CD_{0.05}$												
Urban areas				0.001				0.001				0.001
Seasons				0.001				0.001				0.001
Seasons × Urban areas				NS				NS				NS

The concentration of Cd was found to be within the permissible limits of BIS in all the urban areas, therefore, inferring that Cd concentration has not yet influenced the ground water quality of major towns. However, the concentration of Cd was found higher in Dharamshala town which might be due to the rapid urbanization, population pressure, tourist inflow, municipal waste water and rampant increase in construction activities in the surrounding areas of the town. According to Hanaa *et al*. (2000) [15], Cd occurs naturally in rocks and soils and enters water when there is contact with soft groundwater or surface water. Moreover, it may be introduced by paints, pigments, plastic stabilizers, mining and smelting operations, and other industrial operations such as electroplating and fossil fuel, fertilizer and sewage sludge disposal (Rahmanian *et al*., 2015) [27].

Season wise pooled analysis also depicted the similar trend in the order: pre-monsoon (0.001 mg l^{-1}) > post-monsoon (0.000 mg l^{-1}) > monsoon (0.000 mg l^{-1}). Higher concentration in pre-monsoon may probably be because of increase in the rate of evaporation at high temperature and decrease in volume of water in the sources and due to rapid oxidation of organic materials and increase in anthropogenic activities (Lashari *et al*., 2009) [18], whereas the comparatively less concentration in monsoon season attributed to the dilution of pollutants in ground water bodies due to high rainfall during this season.

Copper

The Cu distribution in ground water sources of major urban areas exhibited significant variations (Table 3). The perusal of the data indicated that the ground water Cu in different urban areas ranged from 0.003 to 0.065 mg l^{-1} which was normal and within the permissible limits as prescribed by BIS. During the first year (2018) significantly highest content of Cu (0.065 mg l^{-1}) was noticed in the ground water sources of Dharamshala followed by Shimla (0.004 mg l^{-1}). Whereas the lowest ground water Cu of 0.003 mg l^{-1} was observed in Mandi and Kullu. The data presented in Table 3 further stipulated that irrespective of the urban areas the seasons exerted significant influence on Cu content of ground water sources. The water sources registered highest Cu of 0.031 mg l^{-1} in pre-monsoon season followed by post-monsoon (0.017 mg l^{-1}) and lowest of 0.005 mg l^{-1} in monsoon months. The urban areas and season interaction also induced significant variation in ground water Cu. The highest Cu of 0.105 mg l^{-1} was noticed in Dharamshala in pre-monsoon season and lowest was observed in Shimla (0.000 mg l^{-1}) in post-monsoon and monsoon (0.000 mg l^{-1}) months.

Table 3: Seasonal distribution of copper (mg l^{-1}) in ground water sources of urban areas

Seasons / Urban areas	Pre-monsoon	Monsoon	Post-monsoon	Mean	Pre-monsoon	Monsoon	Post-monsoon	Mean	Pre-monsoon	Monsoon	Post-monsoon	Mean
	2018				2019				Pooled			
Shimla	0.011	0.000	0.000	0.004	0.011	0.000	0.000	0.004	0.011	0.000	0.000	0.004
Dharamshala	0.105	0.015	0.060	0.060	0.113	0.025	0.075	0.071	0.109	0.020	0.068	0.065
Mandi	0.003	0.002	0.003	0.003	0.003	0.002	0.003	0.003	0.003	0.002	0.003	0.003
Kullu	0.004	0.001	0.003	0.003	0.004	0.002	0.003	0.003	0.004	0.002	0.003	0.003
Mean	0.031	0.005	0.017		0.033	0.007	0.020		0.032	0.006	0.018	
$CD_{0.05}$												
Urban areas				0.012				0.011				0.006
Seasons				0.011				0.010				0.005
Seasons × Urban areas				0.021				0.019				0.010

Similarly, during second year ground water Cu in different urban areas was found to exhibit significant variations. The highest Cu of 0.071 mg l^{-1} was recorded in Dharamshala, followed by Shimla with respective value of 0.004 mg l^{-1}. The lowest Cu was recorded in Mandi and Kullu with value of 0.003 mg l^{-1}. The data presented in Table 3 further indicated that irrespective of locations, seasons exerted significant influence on ground water Cd. The highest Cu of 0.033 mg l^{-1} was discerned in pre-monsoon months followed by post-monsoon (0.020 mg l^{-1}) and lowest of 0.007 mg l^{-1} in monsoon season. The interaction of urban areas and seasons was also found to be significant with respect to the Cu of ground water sources. The highest Cu of 0.113 mg l^{-1} was noticed in Dharamshala in pre-monsoon season and lowest was observed in Shimla (0.000 mg l^{-1}) in post-monsoon and monsoon (0.000 mg l^{-1}) months.

The pooled analysis of both the years also indicated the similar trend with respect to ground water Cu which followed the order: Dharamshala (0.065 mg l^{-1}) > Shimla (0.004 mg l^{-1}) > Mandi (0.003 mg l^{-1}) > Kullu (0.003 mg l^{-1}). The values of Mandi and Kullu were found to be at par with each other. Since, the level of Cu has not exceeded the permissible limits prescribed by the BIS and hence resulted no harmful effect on surface water and environmental ecosystem as a whole. The elevated concentration of Cu in Dharamshala town might be due to the construction and mining activities which exposed the Cu in soil to water sources. Ashraf *et al*. (2011) [11] and Rahmanian *et al*. (2015) [27] reported metal mining as the second largest source of metal contamination in soil which includes metals such as Cu, Zn, Pb and Sn. The higher concentration might also be due to the natural deposits of Cu in surrounding areas of Dharamshala town. Season wise pooled analysis also depicted the similar trend in the order: pre-monsoon (0.032 mg l^{-1}) > post-monsoon (0.018 mg l^{-1}) > monsoon (0.006 mg l^{-1}). The urban areas and season interaction also induced significant variation in ground water Cu. The highest Cu of 0.109 mg l^{-1} was noticed in Dharamshala in pre-monsoon season and lowest was observed in Shimla (0.000 mg l^{-1}) in monsoon and post-monsoon months. The higher values of Cu content during pre-monsoon months may be ascribed to less rains and relatively higher retention of the chemicals in soils compared to post-monsoon season where dilution effect of high rains during monsoon might have reduced its concentration in the water sources.

Chromium

The Cr distribution in ground water sources of major urban areas exhibited significant variations (Table 4). The perusal of the data indicated that the ground water Cr in different urban areas ranged from 0.001 to 0.006 mg l^{-1} which was normal and within the permissible limits as prescribed by BIS. During the first year (2018) significantly highest content of Cr (0.006 mg l^{-1}) was noticed in the ground water sources of Shimla followed by Kullu (0.004 mg l^{-1}) and Mandi (0.002 mg l^{-1}). Whereas the lowest ground water Cr of 0.001 mg l^{-1} was observed in Dharamshala. The data presented in Table 4 further stipulated that irrespective of the urban areas the seasons exerted significant influence on ground water Cr. The water sources registered highest Cr of 0.005 mg l^{-1} in pre-monsoon season followed by post-monsoon (0.002 mg l^{-1}) and lowest of 0.002 mg l^{-1} in monsoon months. The urban areas and season interaction were reported to induce non-significant variation in ground water Cr.

Similarly, during second year ground water Cr in different urban areas was found to exhibit significant variations. The highest Cr of 0.006 mg l^{-1} was recorded in Shimla, followed by Kullu and Mandi with respective values of 0.004 and 0.001 mg l^{-1}. The lowest Cr was recorded in Dharamshala with value of 0.001 mg l^{-1}. The data presented in Table 4 further indicated that irrespective of locations, seasons exerted significant influence on ground water Cr. The highest Cr of 0.005 mg l^{-1} was discerned in pre-monsoon months followed by post-monsoon (0.003 mg l^{-1}) and lowest of 0.002 mg l^{-1} in monsoon season. The interaction of urban areas and seasons was found to be non-significant with respect to the Cr of ground water sources.

The pooled analysis of both the years also indicated the similar trend with respect to ground water Cr which followed the order: Shimla (0.005 mg l^{-1}) > Kullu (0.004 mg l^{-1}) > Mandi (0.001 mg l^{-1}) > Dharamshala (0.000 mg l^{-1}). The values of Mandi and Dharamshala were found to be at par with each other. Since, the concentration of Cr has not exceeded the permissible limits prescribed by the BIS and hence resulted no harmful effect on ground water sources and environmental ecosystem as a whole. The elevated concentration of Cr in Shimla town might be due to the population pressure, commercial and construction activities which leads to the erosion of natural deposits from the surrounding areas. It is in line with the findings of (Rahmanian *et al*., 2015) [27]. Season wise pooled analysis also inferred Cr distribution in water bodies in the order of pre-monsoon (0.005 mg l^{-1}) > post-monsoon (0.002 mg l^{-1}) > monsoon (0.002 mg l^{-1}). The results are in consonance with the findings of Ravichandran and Jayaprakash (2011) [30]

Table 4: Seasonal distribution of chromium (mg l^{-1}) in ground water sources of urban areas

Seasons / Urban areas	Pre-monsoon	Monsoon	Post-monsoon	Mean	Pre-monsoon	Monsoon	Post-monsoon	Mean	Pre-monsoon	Monsoon	Post-monsoon	Mean
	2018				2019				Pooled			
Shimla	0.009	0.004	0.005	0.006	0.010	0.004	0.005	0.006	0.009	0.004	0.005	0.006
Dharamshala	0.002	0.000	0.001	0.001	0.002	0.000	0.001	0.001	0.002	0.000	0.001	0.001
Mandi	0.006	0.000	0.000	0.002	0.004	0.000	0.000	0.001	0.005	0.000	0.000	0.002
Kullu	0.005	0.002	0.003	0.004	0.005	0.003	0.004	0.004	0.005	0.003	0.004	0.004
Mean	0.005	0.002	0.002		0.005	0.002	0.003		0.005	0.002	0.002	
$CD_{0.05}$												
Urban areas				0.003				0.003				0.002
Seasons				0.002				0.002				0.002
Seasons × Urban areas				NS				NS				NS

who have also reported that the high concentration of chromium during pre-monsoon season could be due to increase in temperature and high rate of evaporation leaving behind heavy metals and lowest value in monsoon season may be due to dilution in the water sources due to the rainfall.

Nickel

The Ni distribution in ground water sources of major urban areas exhibited significant variations (Table 5). The perusal of the data indicated that the ground water Ni in different urban areas ranged from 0.004 to 0.007 mg l^{-1} which was normal and within the permissible limits as prescribed by BIS. During the first year (2018) significantly highest content of Ni (0.006 mg l^{-1}) was noticed in the ground water sources of Mandi followed by Kullu (0.005 mg l^{-1}) and Dharamshala (0.005 mg l^{-1}). Whereas the lowest ground water Ni of 0.004 mg l^{-1} was observed in Shimla. The data presented in Table 5 further stipulated that irrespective of the urban areas the seasons exerted significant influence on Ni in ground water. The water sources registered highest Ni of 0.006 mg l^{-1} in pre-monsoon season followed by post-monsoon (0.006 mg l^{-1}) and lowest of 0.003 mg l^{-1} in monsoon months. The urban areas and season interaction were observed to induce non-significant variation in ground water Ni.

Similarly, during second year ground water Ni in different urban areas was found to exhibit significant variations. The highest Ni of 0.008 mg l^{-1} was recorded in Mandi, followed by Kullu and Shimla with respective values of 0.005 and 0.004 mg l^{-1}. The lowest Ni was recorded in Dharamshala with value of 0.003 mg l^{-1}. The data presented in Table 5 further indicated that irrespective of locations, the seasons exerted non- significant influence on Ni in ground water. The interaction of urban areas and seasons was found to be non-significant with respect to the Ni of ground water sources.

The pooled analysis of both the years also indicated the similar trend with respect to ground water Ni which followed the order: Mandi (0.007 mg l^{-1}) > Kullu (0.005 mg l^{-1}) > Shimla (0.004 mg l^{-1}) > Dharamshala (0.004 mg l^{-1}). Since, the level of Ni has not exceeded the permissible limits prescribed by the BIS and hence resulted no harmful effect on surface water sources and environmental ecosystem as a whole. The higher concentration of Ni in Mandi town might be due to its geogenic origin. Further, illegal disposal of sewage water which might have contaminated the ground water sources through the process of leaching Cempel and Nikel (2006) [9] advocated that natural sources of atmospheric Ni as wind-blown dust, derived from the weathering of rocks and soils, volcanic emissions, forest fires and vegetation.

Table 5: Seasonal distribution of nickel (mg l^{-1}) in ground water sources of urban areas

Seasons / Urban areas	Pre-monsoon	Monsoon	Post-monsoon	Mean	Pre-monsoon	Monsoon	Post-monsoon	Mean	Pre-monsoon	Monsoon	Post-monsoon	Mean
	2018				2019				Pooled			
Shimla	0.005	0.002	0.004	0.004	0.005	0.002	0.004	0.004	0.005	0.002	0.004	0.004
Dharamshala	0.004	0.002	0.007	0.005	0.002	0.003	0.004	0.003	0.003	0.003	0.006	0.004
Mandi	0.009	0.002	0.007	0.006	0.009	0.007	0.007	0.008	0.009	0.004	0.007	0.007
Kullu	0.006	0.005	0.005	0.005	0.005	0.004	0.005	0.005	0.005	0.004	0.005	0.005
Mean	0.006	0.003	0.006		0.005	0.004	0.005		0.006	0.003	0.005	
$CD_{0.05}$												
Urban areas				0.002				0.002				0.001

Seasons				0.001				NS				0.001
Seasons × Urban areas				NS				NS				NS

The ambient air also reported to contain Ni due the combustion of coal, diesel oil and fuel oil, the incineration of waste and sewage and miscellaneous sources (Clayton and Clayton, 1994; Grandjean, 1984; Clarkson, 1998; Anonymous, 1991; Von Burg, 1997; Cempel & Nikel, 2006 and Spectrum, 1998) [11, 14, 10, 2, 35, 9, 34]. Bencko (1983) [6]; Scott-Fordsmand (1997) [32] and Von Burg (1997) [35] reported that Ni may pose a major problem in land near towns, industrial areas, or even in agricultural land receiving wastes such as sewage sludge and advocated that its content in soil varies in a wide range from 3 to 1000 mg kg^{-1} and may be released from soils in several forms such as inorganic crystalline minerals or precipitates, complexed or adsorbed on organic cation surfaces or on inorganic cation exchange surfaces, water soluble, free-ion or chelated metal complexes in soil solution (Scott-Fordsmand, 1997; Anonymous, 1991 and Bennett, 1982) [32, 2, 7].
Season wise pooled analysis also revealed the similar trend in the order: pre-monsoon (0.006 mg l^{-1}) > post-monsoon (0.005 mg l^{-1}) > monsoon (0.003 mg l^{-1}). The values of pre-monsoon and post-monsoon were found to be at par with each other. The higher values of Ni content during pre-monsoon months may be ascribed to less rains and relatively higher retention of the chemicals in soils compared to post-monsoon season where dilution effect of high rains during monsoon might have reduced its concentration in the water sources (Lashari *et al*., 2009) [18].

Lead
The Pb distribution in ground water sources of major urban areas exhibited significant variations (Table 6). The perusal of the data indicated that the ground water Pb in different urban areas ranged from 0.002 to 0.010 mg l^{-1} which was normal and within the permissible limits as prescribed by BIS. During the first year (2018) significantly highest content Pb (0.010 mg l^{-1}) was noticed in the ground water sources of Dharamshala followed by Shimla (0.006 mg l^{-1}) and Mandi (0.005 mg l^{-1}). Whereas the lowest ground water Pb of 0.002 mg l^{-1} was observed in Kullu. The data presented in Table 6 further stipulated that irrespective of the urban areas the seasons exerted significant influence on Pb in ground water. The water sources registered highest Pb of 0.009 mg l^{-1} in pre-monsoon season followed by post- monsoon (0.005 mg l^{-1}) and lowest of 0.004 mg l^{-1} in monsoon months. The urban areas and season interaction found to induce non-significant variation in ground water Pb.

Table 6: Seasonal distribution of lead (mg l^{-1}) in ground water sources of urban areas

Seasons / Urban areas	Pre-monsoon	Monsoon	Post-monsoon	Mean	Pre-monsoon	Monsoon	Post-monsoon	Mean	Pre-monsoon	Monsoon	Post-monsoon	Mean
	2018				2019				Pooled			
Shimla	0.014	0.002	0.003	0.006	0.014	0.002	0.003	0.006	0.014	0.002	0.003	0.006
Dharamshala	0.012	0.009	0.010	0.010	0.014	0.008	0.010	0.011	0.013	0.008	0.010	0.010
Mandi	0.006	0.004	0.004	0.005	0.006	0.004	0.004	0.005	0.006	0.004	0.004	0.005
Kullu	0.003	0.001	0.001	0.002	0.03	0.001	0.002	0.002	0.003	0.001	0.002	0.002
Mean	0.009	0.004	0.005		0.009	0.004	0.005		0.009	0.004	0.005	
$CD_{0.05}$												
Urban areas				0.004				0.004				0.003
Seasons				0.003				0.004				0.002
Seasons × Urban areas				NS				NS				NS

Similarly, during second year ground water Pb in different urban areas was found to exhibit significant variations. The highest Pb of 0.011 mg l^{-1} was recorded in Dharamshala, followed by Shimla and Mandi with respective values of 0.006 and 0.005 mg l^{-1}. The lowest Pb was recorded in Kullu with value of 0.002 mg l^{-1}. The data presented in Table 6 further indicated that irrespective of locations, seasons exerted significant influence on ground water Pb. The highest Pb of 0.009 mg l^{-1} was discerned in pre-monsoon months followed by post-monsoon (0.005 mg l^{-1}) and lowest of 0.004 mg l^{-1} in monsoon season. The interaction of urban areas and seasons was found to be non-significant with respect to the Pb of ground water sources.
The pooled analysis of both the years also indicated the similar trend with respect to distribution of Pb in ground water which followed the order: Dharamshala (0.010 mg l^{-1}) > Shimla (0.006 mg l^{-1}) > Mandi (0.005 mg l^{-1}) > Kullu (0.002 mg l^{-1}). The values of Shimla and Mandi were found to be at par with each other. Since, the level of Pb has not exceeded the permissible limits prescribed by the BIS and hence resulted no harmful effect on surface water sources and environmental ecosystem as a whole. The higher concentration of Pb in ground water sources of Dharamshala town may be due to the illegal disposal of sewage sludge and waste water flow from the mining sites, increased rate of urbanization and population pressure. The higher Pb in water sources of urban areas may be attributed to high combustion of leaded gasoline (Banat *et al*., 1998) as Pb is released from automobiles.
Season wise pooled analysis also revealed the similar trend in the order: pre-monsoon (0.009 mg l^{-1}) > post-monsoon (0.005 mg l^{-1}) > monsoon (0.004 mg l^{-1}). The values of post-monsoon and monsoon were found to be at par with each other. The results are in collaboration with the findings of Rahman *et al*. (2013) [36] who reported high concentration of lead during pre-monsoon months and accredited to increase in temperature and high rate of evaporation in the water sources which might have concentrated the Pb in water.

Zinc
The different urban areas were found to exhibit significant variations in distribution of Zn of ground water sources. The perusal of the data presented in Table 7 indicated that the ground water Zn in different urban areas ranged from 0.11 to 0.55 mgl^{-1} which was normal and within the permissible limits as prescribed by BIS. During the first year (2018)

significantly highest content of Zn (0.62 mg l^{-1}) was noticed in the ground water sources of Dharamshala followed by Mandi (0.17 mg l^{-1}) and Kullu (0.17 mg l^{-1}). Whereas the lowest ground water Zn of 0.11 mg l^{-1} was observed in Shimla. The data presented in Table 7 further stipulated that irrespective of the urban areas the seasons exerted significant influence on Zn content in ground water. The water sources registered highest Zn of 0.46 mg l^{-1} in pre-monsoon season followed by post-monsoon (0.19 mg l^{-1}) and lowest of 0.15 mg l^{-1} in monsoon months. The urban areas and season interaction also induced significant variation in ground water Zn. The highest Zn of 1.25 mg l^{-1} was noticed in Dharamshala in pre-monsoon season and lowest was observed in Shimla (0.08 mg l^{-1}) in monsoon months.

Similarly, during second year ground water Zn in different urban areas was found to exhibit significant variations. The highest Zn of 0.48 mg l^{-1} was recorded in Dharamshala, followed by Mandi and Kullu with respective values of 0.17 and 0.15 mg l^{-1}. The lowest Zn was recorded in Shimla with value of 0.11 mg l^{-1}. The data presented in Table 7 further indicated that irrespective of locations, seasons exerted significant influence on ground water Zn. The highest Zn of 0.41 mg l^{-1} was discerned in pre-monsoon months followed by post-monsoon (0.19 mg l^{-1}) and lowest of 0.12 mg l^{-1} in monsoon season. The interaction of urban areas and seasons was also found to be significant with respect to the Zn of ground water sources. The highest Zn of 1.07 mg l^{-1} was noticed in Dharamshala in pre-monsoon season and lowest was observed in Shimla (0.08 mg l^{-1}) in monsoon months.

The pooled analysis of both the years also indicated the similar trend with respect to ground water Zn which followed the order: Dharamshala (0.55 mg l^{-1}) > Mandi (0.17 mg l^{-1}) > Kullu (0.16 mg l^{-1}) > Shimla (0.11 mg l^{-1}). The values of Mandi, Kullu and Shimla were found to be at par with each other. Since, the level of Zn has not exceeded the permissible limits prescribed by the BIS and hence resulted no harmful effect on ground water sources and environmental ecosystem as a whole. The highest Zn concentration in ground water sources of Dharamshala town may be attributed to urban natural runoff due to the heavy rains in the region which might have contaminated the ground water sources in urban areas having faulty sewage disposal systems (Polkowaska *et al*., 2007) [24]. The highest Zn content in Dharamshala town might also be due the heavy flow of tourists, population pressure and also due to rapid rise in urbanization and construction activities.

Table 7: Seasonal distribution of zinc (mg l^{-1}) in ground water sources of urban areas

Seasons / Urban areas	Pre-monsoon	Monsoon	Post-monsoon	Mean	Pre-monsoon	Monsoon	Post-monsoon	Mean	Pre-monsoon	Monsoon	Post-monsoon	Mean
	2018				2019				Pooled			
Shimla	0.15	0.08	0.11	0.11	0.15	0.08	0.11	0.11	0.15	0.08	0.11	0.11
Dharamshala	1.25	0.26	0.36	0.62	1.07	0.03	0.34	0.48	1.16	0.15	0.35	0.55
Mandi	0.21	0.14	0.15	0.17	0.20	0.15	0.15	0.17	0.20	0.14	0.15	0.17
Kullu	0.25	0.13	0.13	0.17	0.21	0.12	0.12	0.15	0.23	0.12	0.13	0.16
Mean	0.46	0.15	0.19		0.41	0.09	0.18		0.43	0.12	0.19	
$CD_{0.05}$												
Urban areas				0.27				0.26				0.17
Seasons				0.23				0.22				0.14
Seasons × Urban areas				0.46				0.45				0.29

Also, the discharge of sewage into the water bodies and its mixing might have enhanced its concentration in ground water sources. It is in agreement with the findings of Shivaraju (2016).

Season wise pooled analysis also revealed the similar trend in the order: pre-monsoon (0.43 mg l^{-1}) > post-monsoon (0.19 mg l^{-1}) > monsoon (0.12 mg l^{-1}). The results are in conformity with the findings of Ndeda and Manohar (2014) [21] who also reported high concentration of Zn during pre-monsoon season which could be ascribed to increase in temperature and high rate of evaporation leaving behind heavy metals and lowest value in monsoon season may be due to dilution effect during rainfall in the ground water sources. The interaction of urban areas and seasons was also found to be significant with respect to the Zn of ground water sources. The highest Zn of 1.16 mg l^{-1} was noticed in Dharamshala in pre-monsoon season and lowest was observed in Shimla (0.08 mg l^{-1}) in monsoon months.

Iron (Fe)

The Fe distribution in ground water sources of major urban areas exhibited significant variations (Table 8). The perusal of the data presented in Table 8 indicated that the ground water Fe in different urban areas ranged from 0.36 to 0.92 mg l^{-1} which was normal and within the permissible limits as prescribed by BIS. During the first year (2018) significantly highest Fe of 0.92 mg l^{-1} was noticed in the ground water sources of Kullu followed by Mandi (0.62 mg l^{-1}) and Shimla (0.49 mg l^{-1}). Whereas the lowest ground water Fe of 0.36 mg l^{-1} was observed in Dharamshala. The data presented in Table 8 further stipulated that irrespective of the urban areas the seasons exerted significant influence on Fe in ground water. The water sources registered highest Fe of 0.85 mg l^{-1} in pre-monsoon season followed by post-monsoon (0.51 mg l^{-1}) and lowest of 0.43 mg l^{-1} in monsoon months. The urban areas and season interaction also induced significant variation in ground water Fe. The highest Fe of 0.97 mg l^{-1} was noticed in Kullu in pre-monsoon season and lowest was observed in Dharamshala (0.13 mg l^{-1}) in monsoon months.

Similarly, during second year ground water Fe in different urban areas was found to exhibit significant variations. The highest Fe of 0.98 mg l^{-1} was recorded in Kullu, followed by Mandi and Shimla with respective values of 0.54 and 0.50 mg l^{-1}. The lowest Fe was recorded in Dharamshala with value of 0.36 mg l^{-1}. The data presented in Table 8 further indicated that irrespective of locations, seasons exerted significant influence on ground water Fe. The highest Fe of 0.79 mg l^{-1} was discerned in pre-monsoon months followed by post-monsoon (0.53 mg l^{-1}) and lowest of 0.42 mg l^{-1} in monsoon season.

Table 8: Seasonal distribution of iron (mg l^{-1}) in ground water sources of urban areas

Urban areas \ Seasons	Pre-monsoon	Monsoon	Post-monsoon	Mean	Pre-monsoon	Monsoon	Post-monsoon	Mean	Pre-monsoon	Monsoon	Post-monsoon	Mean
	2018				**2019**				**Pooled**			
Shimla	0.78	0.25	0.43	0.49	0.79	0.23	0.50	0.50	0.78	0.24	0.47	0.50
Dharamshala	0.80	0.13	0.17	0.36	0.80	0.11	0.17	0.36	0.80	0.12	0.17	0.36
Mandi	0.86	0.46	0.52	0.62	0.61	0.49	0.53	0.54	0.74	0.47	0.53	0.58
Kullu	0.97	0.87	0.93	0.92	0.97	0.86	0.93	0.98	0.97	0.86	0.93	0.92
Mean	0.85	0.43	0.51		0.79	0.42	0.53		0.82	0.42	0.52	
$CD_{0.05}$												
Urban areas				0.09				0.09				0.07
Seasons				0.08				0.08				0.06
Seasons × Urban areas				0.16				0.17				0.11

The interaction of urban areas and seasons was also found to be significant with respect to the Fe of ground water sources. The highest Fe of 0.97 mg l^{-1} was noticed in Kullu in pre-monsoon season and lowest was observed in Dharamshala (0.11 mg l^{-1}) in monsoon months.

The pooled analysis of both the years also indicated the similar trend with respect to ground water Fe which followed the order: Kullu (0.92 mg l^{-1}) > Mandi (0.58 mg l^{-1}) > Shimla (0.50 mg l^{-1}) > Dharamshala (0.36 mg l^{-1}). Since, the level of Fe has not exceeded the permissible limits prescribed by the BIS and hence resulted no harmful effect on ground water sources and environmental ecosystem as a whole. Elevated concentration of Fe at Kullu town may be due to the presence of large number of automobiles repairing workshops which uses iron material for various operations. Similar, results are also reported by Puri (2011) [25] who also found an increase in the concentration of Fe in water sources which might be attributed to seepage of Fe containing waste water effluents to ground water sources. High concentration of Fe may also be attributed to the dissolution of iron bearing rocks or minerals from the soil strata in the study area.

Season wise pooled analysis also revealed the similar trend in the order: pre-monsoon (0.82 mg l^{-1}) > post-monsoon (0.52 mg l^{-1}) > monsoon (0.42 mg l^{-1}). The highest Fe of 0.97 mg l^{-1} was noticed in Kullu in pre-monsoon season and lowest was observed in Dharamshala (0.12 mg l^{-1}) in monsoon months. The higher concentration of Fe during pre-monsoon months may be ascribed to less rains and relatively higher retention of the chemicals in soils as compared to post-monsoon season where dilution effect of high rains during monsoon might have reduced its concentration in the water sources. The pooled analysis of urban areas and seasons was also found to be significant with respect to the Fe of ground water sources. The highest Fe of 0.97 mg l^{-1} was noticed in Kullu in pre-monsoon season and lowest was observed in Dharamshala (0.12 mg l^{-1}) in monsoon months. The present trend of results is in line with findings of Sankar *et al*. (2010) [31] who have also noticed similar trend of Fe content under the influence of seasons.

Mercury

The analysis of water samples had been carried out for mercury (Hg) content of ground water sources in selected towns. But, the concentration of Hg was not detected in any of water samples collected from the ground water sources.

Conclusion

The study inferred that the major urban areas of Himachal Pradesh have started impacting the ground water quality however it was still within the permissible limits. The study inferred that the current activities in urban areas has started impacting the ground water quality which at present is in good to excellent category. Further, evinced by the fact that the urban areas having high population, vehicular density and rate of urbanization experienced elevated levels of toxic elements in ground water quality parameters. Therefore, in order to maintain the quality of the ground water sources within the safe limits, urbanization on ecological principles is recommended for sustainable development in the state.

References

1. Ahmed A, Ghosh PK, Hasan M, Rahman A. Surface and groundwater quality assessment and identification of hydrochemical characteristics of a south-western coastal area of Bangladesh. Environmental Monitoring and Assessment 2020;192(4):258. https://doi.org/10.1007/s10661-020-8227-0
2. Anonymous. Environmental Health Criteria 108. Nickel. WHO, Genewa 1991.
3. APHA. Standard methods for the examination of waste water. Washington DC 1998,161.
4. Ashraf MA, Maah MJ, Yusoff I. Heavy metals accumulation in plants growing in ex tin mining catchment. International Journal of Environmental Science and Technology 2011;8(2):401-416.
5. Bannat IM, Hussain ES, EL-Shahawi MS, Abu Hilal AH. Post-gulf war assessment of nutrients, heavy metal ions, hydrocarbons and bacterial pollution level in the United Arab Emirates coastal waters. Environment International 1998;24:109-116.
6. Bencko V. Nickel: A review of its occupational and environmental toxicology. Journal of Hygiene, Epidemiology, Microbiology and Immunology 1983;27:237.
7. Bennett BG. Exposure of man to environmental nickel-an exposure commitment assessment. Science of the Total Environment 1982;22(3):203.
8. Bu H, Tan X, Li S, Zhang Q. Temporal and spatial variations of water quality in the Jinshui River of the South Qinling Mts., China. Ecotox. Environ. Safe. 2010;73:907-913.
9. Cempel M, Nikel G. Nickel: A review of its sources and environmental toxicology. Polish Journal of Environmental Studies 2006;15(3):375-382.
10. Clarkson TW. Biological Monitoring of Toxic Metals; plenum press: New york 1998, 265-282.
11. Clayton GD, Clayton FE. Patty's Industrial Hygiene Toxicology, 4th ed.; A wiley-Interscience publication: New York 1994, 2157-2173.
12. CPCB. Status of ground water quality in India Part-II, Ground water quality series: GWQS/10/2007-2008. Central Pollution Control Board, Ministry of

Environment and Forests, Government of India. Parivesh Bhawan, East Arjun Nagar Delhi – 110032. 2008, 334. www.cpcb.nic.in
13. CPCB. (Central Pollution Control Board). Guidelines for the measurements of Ambient Air Pollution, New Delhi. India 2011;(1);55.
14. Grandjean P. Human exposure to nickel. IARC Scientific Publications 1984;53:469.
15. Hanaa M, Eweida EA, Azza F. Heavy metals in drinking water and their environmental impact of human health 2000.
16. Kumar J, Puri A. A review of permissible limits of drinking water. Indian Journal of Occupational and Environmental Medicine 2012;16:40-44.
17. Kumar R, Singh RD, Sharma KD. Water resources of India. Current Science 2005;89(5):794-811.
18. Lashari KH, Korai AL, Sahato GA, Kazi TG. Limnological studies of Keenjhar Lake, District, Thatta, Sindh, Pakistan. Pakistan Journal of Analytical & Environmental Chemistry 2009;10: 39-47.
19. McDonald R, Green P, Balk D, Fekete BM, Revenga C, Todd M *et al*. Urban Growth, Climate Change, and Freshwater Availability. Proceedings of the National Academy of Sciences 2011;108(15):6312-6317.
20. Najafpour SH, Alkarkhi AFM, Kadir MOA, Najafpour GD. Evaluation of Spatial and Temporal Variation in River Water Quality. Int. J. Environ. Res. 2008;2:349-358.
21. Ndeda LA, Manohar S. Determination of heavy metals in Nairobi dam water, Kenya. Journal of Environmental Science, Toxicology and Food Technology 2014;8:68-73.
22. Park K. Preventive and Social Medicine. Jabalpur, India: M/S Banarsidas Bhanot Publishers 2009.
23. Pesce SF, Wunderlin DA. Use of water quality indices to verify the impact of Cordoba city (Argentina) on Suquia river. Water Research 2000;34:2915-2926.
24. Polkowska Z, Skarzynska K, Dubiella-Jackowska A, Staszek W, Namiesnik J. Evaluation of pollutant loading in the runoff water from a major urban highway (Gdansk Beltway, Poland). Global Nest Journal. 2007;9:269-275.
25. Puri R. Study Regarding Lake Water Pollution with Heavy Metals in Nagpur City (India). International Journal of Chemical, Environmental and Pharmaceutical Research 2011;2(1):34-39.
26. Rahman A, Imran A, Khan TA, Alam SD, Khan J. Recent trends of arsenic contamination in groundwater of Ballia district, Uttar Pradesh, India. Gazi University Journal of Science 2013;25:853-861.
27. Rahmanian N, Ali SHB, Homayoonfard M, Ali NJ, Rehan M, Sadef Y, *et al*. Analysis of physiochemical parameters to evaluate the drinking water quality in the state of perak, Malaysia. Journal of Chemistry 2015, 1-10. https://doi.org/10.1155/2015/716125
28. Rajmohan N, Elango L. Distribution of iron, manganese, zinc and atrazine in ground- water in parts of Palar and Cheyyar river basins, South India. *Journal of* Environmental Monitoring and Assessment 2005;107:115-131.
29. Ramadhan J. Impacts of agricultural activities to the water quality of the Mindu dam. MSc. Thesis, University of Dar es Salaam, Dar es Salaam, Tanzania 2007.
30. Ravichandran K, Jayaprakash M. Seasonal variation on physico-chemical parameters and trace metals in groundwater of an industrial area of north Chennai, India. Indian Journal of Science and Technology 2011;4:646-49.
31. Sankar R, Ramkumar L, Rajkoumar M, Sun J, Ananthan G. Seasonal variations in physico-chemical parameters and heavy metals in water and sediments of Uppanar estuary, Nagapattinam, India. Journal of Environmental Biology 2010;31:681-686.
32. Scott-Fordsmand JJ. Toxicity of nickel to soil organisms in Denmark. Reviews of Environmental Contamination and Toxicology 1997;148:1.
33. Shimba MJ, Jonah FE. Macroinvertebrates as bioindicators of water quality in the Mkondoa River, Tanzania, in an agricultural area. Afr. J. Aquat. Sci. 2016;41:1-9.
34. Spectrum. Chemical Fact sheet. Nickel 1998. website: http://www.speclab.com/elements/nickel. htm.
35. Von Burg R. Toxicology update. Journal of Applied Toxicology 1997;17:425