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., 2003) [19]. 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 groundwater 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.

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.

| Seasons | Urban areas | 2018          | 2019          | Pooled       |
|---------|-------------|---------------|---------------|--------------|
|         | Pre-monsoon | Monsoon       | Post-monsoon  | Mean         | Pre-monsoon | Monsoon       | Post-monsoon  | Mean         | Pre-monsoon | Monsoon       | Post-monsoon  | Mean         |
| 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        | 0.005        | 0.006       | 0.005         | 0.005        | 0.005       |
| Kullu   | 0.005       | 0.002         | 0.003         | 0.003        | 0.005       | 0.003       | 0.003        | 0.003        | 0.005       | 0.002         | 0.003        | 0.003       |
| Mean    | 0.004       | 0.002         | 0.003         | 0.003        | 0.004       | 0.002       | 0.003        | 0.003        | 0.004       | 0.002         | 0.003        | 0.003       |
| CD₉₀,₀₅ |             |               |               |             |            |             |             |             |            |               |             |            |

| 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 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

| Urban areas | Pre-monsoon | Monsoon | Post-monsoon | Mean | Pre-monsoon | Monsoon | Post-monsoon | Mean | Pre-monsoon | Monsoon | Post-monsoon | Mean |
|-------------|-------------|---------|--------------|------|-------------|---------|--------------|------|-------------|---------|--------------|------|
| **2018** |
| 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 | 0.000 |
| Dharamshala |
| 0.001 | 0.000 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| Mandi |
| 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 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 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.000 | 0.000 |
| **2019** |
| 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 | 0.000 |
| Dharamshala |
| 0.001 | 0.000 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| Mandi |
| 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 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 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.000 | 0.000 |
| **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 | 0.000 |
| Dharamshala |
| 0.001 | 0.000 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| Mandi |
| 0.001 | 0.000 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| 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 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.000 | 0.000 |

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

| Urban areas | Pre-monsoon | Monsoon | Post-monsoon | Mean | Pre-monsoon | Monsoon | Post-monsoon | Mean | Pre-monsoon | Monsoon | Post-monsoon | Mean |
|-------------|-------------|---------|--------------|------|-------------|---------|--------------|------|-------------|---------|--------------|------|
| 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| 0.033       | 0.007   | 0.020        | 0.032| 0.032       | 0.006   | 0.018        |

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)\(^{[19]}\) 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 post-monsoon and monsoon (0.000 mg l\(^{-1}\)) months.

**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 Dharamshala followed by Shimla (0.004 mg l\(^{-1}\)). Whereas the lowest ground water Cr of 0.005 mg l\(^{-1}\) was observed in Mandi and Kullu. 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 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

| Urban areas | Pre-monsoon | Monsoon | Post-monsoon | Mean | Pre-monsoon | Monsoon | Post-monsoon | Mean | Pooled |
|-------------|-------------|---------|--------------|------|-------------|---------|--------------|------|--------|
| Shimla      | 0.009       | 0.004   | 0.005        | 0.006| 0.010       | 0.004   | 0.005        | 0.006| 0.009   |
| Dharamshala | 0.002       | 0.000   | 0.001        | 0.001| 0.002       | 0.000   | 0.001        | 0.001| 0.002   |
| Mandi       | 0.006       | 0.000   | 0.000        | 0.002| 0.004       | 0.000   | 0.000        | 0.001| 0.005   |
| Kullu       | 0.005       | 0.002   | 0.003        | 0.004| 0.005       | 0.003   | 0.004        | 0.004| 0.005   |
| Mean        | 0.005       | 0.002   | 0.002        | 0.002| 0.005       | 0.002   | 0.003        | 0.002| 0.005   |
| CD\(_{0.05}\) | 0.003       | 0.003   | 0.003        | 0.003| NS          | NS      | 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) \(^{[20]}\) 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

| Urban areas | Pre-monsoon | Monsoon | Post-monsoon | Mean | Pre-monsoon | Monsoon | Post-monsoon | Mean | Pooled |
|-------------|-------------|---------|--------------|------|-------------|---------|--------------|------|--------|
| Shimla      | 0.005       | 0.002   | 0.004        | 0.004| 0.005       | 0.002   | 0.004        | 0.004| 0.005   |
| Dharamshala | 0.004       | 0.002   | 0.007        | 0.005| 0.002       | 0.003   | 0.004        | 0.003| 0.003   |
| Mandi       | 0.009       | 0.002   | 0.007        | 0.006| 0.009       | 0.007   | 0.007        | 0.008| 0.009   |
| Kullu       | 0.006       | 0.005   | 0.005        | 0.005| 0.005       | 0.004   | 0.005        | 0.005| 0.005   |
| Mean        | 0.006       | 0.003   | 0.006        | 0.006| 0.005       | 0.004   | 0.005        | 0.005| 0.006   |
| CD\(_{0.05}\) | 0.002       | 0.002   | 0.002        | 0.002| NS          | NS      | 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) [9]; 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**

| Urban areas | Pre-monsoon | Monsoon | Post-monsoon | Mean | Pre-monsoon | Monsoon | Post-monsoon | Mean | Pooled |
|-------------|-------------|---------|--------------|------|-------------|---------|--------------|------|--------|
| Shimla      | 0.014       | 0.002   | 0.003        | 0.006| 0.014       | 0.002   | 0.003        | 0.006| 0.014  |
| Dharamshala | 0.012       | 0.009   | 0.010        | 0.010| 0.014       | 0.008   | 0.010        | 0.011| 0.013  |
| Mandi       | 0.006       | 0.004   | 0.004        | 0.005| 0.006       | 0.004   | 0.004        | 0.005| 0.006  |
| Kullu       | 0.003       | 0.001   | 0.001        | 0.002| 0.03        | 0.001   | 0.002        | 0.002| 0.003  |
| Mean        | 0.009       | 0.004   | 0.005        | 0.005| 0.009       | 0.004   | 0.005        | 0.005| 0.009  |

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 mg l⁻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 might 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 (Polkowski 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   | Pre-monsoon | Monsoon | Post-monsoon | Mean | Pre-monsoon | Monsoon | Post-monsoon | Mean | Pre-monsoon | Monsoon | Post-monsoon | Mean | Pooled |
|-----------|-------------|---------|--------------|------|-------------|---------|--------------|------|-------------|---------|--------------|------|--------|
| Urban areas |             |         |              |      |             |         |              |      |             |         |              |      |        |
| 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 | 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 | 0.58    |
| 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 | 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 | 0.16    |
| Mean      | 0.46        | 0.15    | 0.19         | 0.41 | 0.09        | 0.18    |              |      | 0.43        | 0.12    | 0.19         |      |         |
| CD₉₀₀₀     |             |         |              |      |             |         |              |      |             |         |              |      |         |
| 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 Ndedia 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.
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 high population, vehicular density and impaction of 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.

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

| Urban areas | Pre-monsoon | Monsoon | Post-monsoon | Mean | Pre-monsoon | Monsoon | Post-monsoon | Mean | Pre-monsoon | Monsoon | Post-monsoon | Mean | 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    | 0.31        | 0.79 | 0.79        | 0.42    | 0.53        | 0.82 | 0.82        | 0.42    | 0.52        |      |

\[ \text{Correlation:} \text{Urban areas} \times \text{Seasons} \quad 0.16 \quad 0.17 \quad 0.11 \]

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.

**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.

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