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Short Research Article

Assessment of Heavy Metals in Surface and Ground Water Sources under Different Land Uses in Mid-hills of Himachal Pradesh

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Abstract

Investigations were carried out on analysis of water samples for heavy metals viz. Arsenic, Cadmium, Iron, lead, and zinc from surface and ground water from 12 sampling sites under agriculture, forest and urban land use during rainy, winter and summers seasons in areas was adjoining to Solan block of district Solan of Himachal Pradesh, India. The study carried during 2011−2012 in order to elucidate the fate of heavy metals in surface and ground water. The maximum As (0.05 ppb), Cd (0.14 ppb), Fe (1.68 ppb) and Pb (0.14 ppb) of surface water was recorded under urban land use system whereas Zn (0.46 ppb) was observed in forest land use. Maximum As (0.05 ppb), Fe (1.52 ppb), Pb (0.17 ppb) and Zn (0.59 ppb) of surface water was recorded during rainy seasons, whereas Cd (0.11 ppb) was recorded during summer seasons. In ground water, maximum As (0.03 ppb), Fe (2.83 ppb) and Zn (0.73 ppb) was noticed under forest land use system, whereas, Cd (0.18 ppb) in urban land use system and Pb (0.13 ppb) was recorded under agriculture land use system. Maximum As (0.04 ppb), Zn (0.98 ppb) and Pb (0.22 ppb) of ground water were recorded during rainy season, whereas, Cd (0.20 ppb) was recorded in summer season and Fe (2.74 ppb) in winter season. Hence, the study indicated that the common land uses in the mid-hills of Solan district did not influence the surface and ground water quality adversely.

1. Introduction

Future climate and land use changes will modify the current hydrological processes and consequently impact its surface and groundwater systems quantity and quality.While climate change will alter hydrological conditions due to changes in the major climate variables (air temperature, precipitation, and evapotranspiration), groundwater resources will be affected by climate change through their interaction with surface water bodies (e.g., lakes and rivers), but also indirectly through the recharge process (Jyrkama and Sykes, 2007). The land use within the watershed has great impact on the surface water quality. The quality of water may degrade due to change in land use and land cover patterns within the watershed as human activity increases (Huang et al., 2013). Land use impacts water quality through non point sources, which are major contributor of pollution to surface and ground water that are difficult to regulate (Salajegheh et al., 2011). According to Ademoroti (1996) metals with densities greater than 5 g cm^{-3} are referred to as heavy metals. Studies demonstrate that surface water quality has deteriorated noticeably in many countries in the past decades due to poor land use practices indicated by the strong relationships between declining water quality and increasing agricultural activities at the catchment area (Buck et al., 2004). Other findings note that urban land development greatly influences water quality as well (Osborne and Wiley, 1988). The pollution of water bodies with toxic metals are spreading throughout the world along with industrial progress. The existence of heavy metals in aquatic environments has led to serious concerns about their influence on plant and animal life. Rivers are dominant pathways for metals transport (Miller et al., 2003) and heavy metals become a significant pollutants of many small riverine systems (Dassenakis et al., 1998). Heavy metals are recognized to be powerful inhibitor of biodegradation activities (Deeb and Altalhi, 2009). The main source of metals in water are chemical weathering of minerals, soil leaching and the anthropogenic sources associated with industrial and domestic effluents, urban storm, water runoff, landfill, leachates, mining of coal and ore, atmospheric sources and inputs from rural areas. Unlike many other pollutants, heavy metals are difficult to remove from the environment (Ren et al., 2009). These metals cannot be degraded, and are ultimately indestructible. Environmental problems associated with heavy metals are difficult to settle because organic compounds are easily transformable by nature where as heavy metals are not. Most of the heavy metals have toxic effects on living organisms when exceeding a certain concentration. Likewise, some heavy metals are being subject to bioaccumulation when transferred to the food chain and which may pose threat to human health (USEPA, 1987).

Himachal Pradesh is situated between North latitude:30°22′40″ to 30°12´40´´ and East longitude: 75°45´55´´ to 79°04´20´´ is wholly mountainous with altitude ranging from 350 to 6975 meter above mean sea level. The Solan block is located between North latitude: 30°50´30´´ to 30°52´00´´ and East longitude 77°08´30´´ to 77°11´30´´ at an elevation of more than 1500 meter above mean sea level. The Solan district of Himachal Pradesh has emerged as a hub of various types of industries, whereas intensive agricultural practices are also in progress which may further exaggerate heavy metal pollution of surface and sub ground water sources. Therefore, the present study was aimed to evaluate the pollution level of heavy metal in surface and ground water via determining the accumulation of heavy metals in water samples. The study investigated the hypothesis that there is no significant difference in the occurrence of heavy metals with special reference to Arsenic, Cadmium, Iron, lead, and zinc and design used for the analysis was Randomized Block Design (Factorial).

2. Materials and Methods

The dominant land use systems namely agriculture, forest and sub urban were selected randomly representing complete Solan block of district Solan during the year 2011–2012. Under agriculture and forest land use system Barog, Solan, Deothi and Dharo ki Dhar areas were selected falling at an elevation range from (1818–1832 m). For Urban/Suburban land use Barog, Solan, Nauni-Oachghat and Salogara were selected with elevation range from (1508–1832m). The latitude and longitude of these area were also recorded (Table 1). In each land use system, water samples from surface and ground water sources were collected randomly during rainy, winter and summer seasons. In total there were nine treatments, which were replicated thrice under Randomized Block Design Factorial. Both surface (Streams and rivers) and ground water (hand pump, bore wells and tube wells) samples were collected in glass bottles by lowering the bottle at depth of about one foot below (10–12 cm) the water surface, opened and allowed to fill corked, while still under water (APHA, 2005) and preserved for quality analysis in refrigerator at 4 °C. The filtered samples were analyzed for heavy metals viz, As, Cd, Fe, Pb and Zn by using Inductively Coupled Plasma Absorption Spectrometer-6300 DUO (ICAP-6300 Duo). The heavy metals concentration in water samples were compared with the standards of Bureau of Indian Standards 10500.1991 (Table 2).

Table 1: Locations of study area

Land use systems	Study area	Latitude (N)	Longitude (E)	Elevation (m)
Agriculture	Barog	30°53´196´´ N	77°04´738´´ E	1832 m
	Solan	30°54´515´´ N	77°06´443´´ E	1559 m
	Deothi	30°56´432´´ N	77°02´298´´ E	1413 m
	Dharo Ki Dhar	30°52´837´´ N	77°10´814´´ E	1818 m
Forest	Barog	30°53´196´´ N	77°04´738″ E	1832 m
	Solan	30°54´581´´ N	77°06´130´´ E	1043 m
	Deothi	30°56´432´´ N	77°02´298´´ E	1413 m
	Dharo Ki Dhar	30°52´837´´ N	77°10´814´´ E	1818 m
Urban/ Suburban	Barog	30°53´196´´ N	77°04´738´´ E	1832 m
	Solan	30°54´515´´ N	77°06´443´´ E	1559 m
	Nauni-Oachghat	30°52´087´´ N	77°08´857´´ E	1275-1406 m
	Salogara	30°56´300´´ N	77°07´723´´ E	1508 m

Table 2: Indian standards of drinking water-specification (Bureau of Indian Standards 10500.1991)

Heavy Metals	Desirable Limit	Permissible Limit (In the absence of Alternate Source)
As (mgl^{-1})	0.05	No Relaxation
Cd (mgl^{-1})	0.01	No Relaxation
Pb (mgl^{-1})	0.05	No Relaxation
Fe (mgl^{-1})	0.3	No Relaxation
Zn (mgl^{-1})	5	No Relaxation

3. Results and Discussion

The surface water of the study area is used for irrigation purpose of agricultural lands and for domestic use. The water samples collected from surface water bodies show quite distinct composition of chemical indicators, as demonstrated in Table 3. The values of individual indicators determined for the surface water samples differed significantly. The mean values of the heavy metals contents arranged in As>Pb>Cd>Zn>Fe for surface water (Table 3) and Pb>As>Cd>Zn>Fe (Table 4)

Table 3: Summary statistics of the analytical results of heavy metals in surface water samples from Solan block of District Solan

Landuses / Seasons	Agriculture	Forest	Suburban	Mean	CD (p= 0.05)
Arsenic (ppb)					
Rainy	0.14	0.00	0.00	0.05	L= 0.06
Winter	0.00	0.01	0.01	0.01	S=0.06
Summer	0.02	0.01	0.07	0.03	L× S=0.1
Mean	0.05	0.00	0.03	0.03	
Lead (ppb)					
Rainy	0.41	0.09	0.00	0.17	L=0.16
Winter	0.00	0.05	0.01	0.02	S=0.16
Summer	0.01	0.02	0.00	0.01	L×S=0.27
Mean	0.14	0.05	0.00	0.06	
Cadmium (ppb)					
Rainy	0.01	0.00	0.04	0.02	L=0.08
Winter	0.03	0.00	0.03	0.02	S=0.08
Summer	0.00	0.00	0.34	0.11	L×S=0.14
Mean	0.01	0.00	0.13	0.05	
Zinc (ppb)					
Rainy	0.72	0.68	0.39	0.59	L=0.4
Winter	0.32	0.63	0.09	0.34	S=0.4
Summer	0.21	0.09	0.09	0.13	L×S=0.69
Mean	0.41	0.46	0.19	0.35	
Iron (ppb)					
Rainy	0.83	1.29	2.43	1.52	L=0.83
Winter	0.19	0.03	2.23	0.82	S=0.83
Summer	0.10	0.02	0.39	0.17	L×S=1.43
Mean	0.37	0.44	1.68	0.83	

Table 4: Summary statistics of the analytical results of heavy metals in ground water samples from Solan block of District Solan

Landuses / Seasons	Agriculture	Forest	Suburban	Mean	CD (p= 0.05)
Lead (ppb)					
Rainy	0.37	0.29	0.00	0.22	L= 0.21
Winter	0.02	0.01	0.01	0.01	S=0.21
Summer	0.02	0.01	0.00	0.01	L× S=0.36
Mean	0.13	0.10	0.00	0.08	
Arsenic (ppb)					
Rainy	0.03	0.09	0.00	0.04	L= 0.04
Winter	0.00	0.01	0.02	0.01	S=0.04
Summer	0.01	0.00	0.01	0.01	L× S=0.07
Mean	0.02	0.03	0.01	0.02	
Cadmium (ppb)					
Rainy	0.06	0.04	0.09	0.07	L= 0.13
Winter	0.12	0.01	0.20	0.11	S=0.13
Summer	0.33	0.01	0.26	0.20	L×S=0.22
Mean	0.17	0.02	0.18	0.12	
Zinc (ppb)					
Rainy	1.51	0.92	0.52	0.98	L= 0.42
Winter	0.06	1.10	0.60	0.59	S=0.42
Summer	0.15	0.17	0.21	0.17	L× S=0.73
Mean	0.57	0.73	0.44	0.58	
Iron (ppb)					
Rainy	2.09	3.32	2.72	2.71	L= 0.32
Winter	2.25	3.58	2.40	2.74	S=0.32
Summer	0.62	1.60	3.31	1.84	L× S=0.56
Mean	1.65	2.83	2.81	2.43	

for ground water. The observed trends in the changes were rather different in both the water sources viz. surface as well as ground water (Table 3 and 4). The Arsenic (As) range detected for different seasons under agriculture land has shown a substantial change: it varied from 0.02 to 0.14 ppb (Table 3) for collected surface water samples, whereas under forest land use the As range was slightly narrower for all the seasons, namely 0.00 to 0.02 ppb. The highest value of As was recorded under agriculture land use viz. 0.14 during rainy season. The concentration of As varied from 0.01 to 0.07 ppb for sub urban land use during three seasons. Since, the level of As has not exceeded the permissible limits prescribed by the BIS and hence resulted no harmful effect on soil and environmental ecosystem as a whole. The value of Pb varied under agriculture and forest land use whereas no variation shown for sub urban land use for all the three seasons. The Cd content of the surface water samples varied, showing higher values (0.04 to 0.34 ppb) in the sub urban land use. Interestingly, the values of Cd increased in the in the summer season under sub urban land use (0.14 ppb), whereas Cd concentration for forest and agriculture has shown decreasing trends for winter season followed by rainy season. The presence of the mobile form of cadmium (Wojtkowska, 2013) indicates the possible release of Cd into the water environment. Boyacioglu and Boyacioglu (2011) reported that agricultural practices such as fertilization and use of fungicides tends to increase the concentration of heavy metals (Arsenic, Cadmium and Zinc) in surface water runoff in Tahtali basin, Turkey. The maximum concentration of Cd in surface water during summer season is in agreement with the findings of (Sankar et al., 2010) who have also recorded maximum concentration of cadmium during summer season. Zn ranged from 0.09 to 0.72 ppb in surface water. The sources of Zn are natural processes and human activities such as releasing of solid waste into water bodies (Qadir et al., 2013). The highest values of zinc were recorded under agriculture land use for rainy season (0.72 ppb) as well as winter season (0.32 ppb), whereas for forest land use Zn concentration was highest during rainy season 0.68 ppb. Similar results are reported by Okweye and Garner (2013) who studied the seasonal variation of heavy metals in Tennessee river basin and reported Zn (453 μgl^{-1}), Pb (123 μgl^{-1}) Cd, As and Fe in water samples. The Fe content of surface water samples differed significantly it varied from 0.02 to 2.43 ppb. The highest concentration of Fe (2.43 ppb) in surface water was recorded under urban/suburban land use. This can be due to the presence of large number of automobile repairing workshops which uses iron material for various operations. Similar, results are also reported by Puri (2011) who also found increase content of Fe in surface water sources, and this may be attributed to seepage of Fe containing waste water effluents to surface water sources.

The ground water of the studied area is used for drinking and domestic purposes. The values of Pb ranged from 0.00 to 0.37 ppb for ground water samples which showed that all the values differed significantly. The As range detected for different seasons under agriculture land use varied from 0.02 to 0.14 ppb (Table 4) for collected ground water samples. The As content for agriculture land use and urban/suburban land use are statistically at par to each other whereas for forest land use As range varied from 0.00 to 0.09 ppb. According to (Singh et al., 2010) the ground water of nine districts of India and fifty districts of Bangladesh has been reported highly contaminated with arsenic which may be due to natural cause such as weathering reactions and anthropogenic cause viz. leaching of pesticides from agriculture fields and leaching from dumped domestic waste into ground water. The value of Cd for ground water was influenced by land use system, however, it was within the permissible limits prescribed by BIS (Table 2) . The ground water under urban/suburban land use system was found to have highest mean cadmium content 0.18 ppb, whereas the lowest content 0.02 ppb (Table 4) was noticed under forest land use system. The seasons of the year showed a non-significant effect with respect to the Cd content of ground water sources of Solan block. The Zn content of the ground water samples varied from 0.15 to 1.51 ppb which has shown a substantial change of Zn in water samples with respect to seasons as well as land uses. The highest value of Zn was recorded under forest land uses viz. 1.10 ppb during rainy season which then remained for winter and summer season i.e. 0.54 ppb. Substantial change was observed in the Fe content during winter season under forest land use system. Presence of Fe in groundwater is identified which can lead to change in color of ground water (Rowe et al., 1995). The range of Fe varied from 1.60 to 3.58 ppb under forest land use for all three seasons. The Fe content of urban/sub urban land use ranged from 2.40 to 3.31 ppb and found highest in summer season 3.31 ppb. The results corroborate with the findings of (Acharya et al., 2011) who have reported maximum content of iron during summer under urban land use.

However, based on this study clear differences were found between metal concentrations in the surface and ground water samples during different seasons and land uses. According to mean values higher concentrations of As, Cd and Fe in surface water samples were recorded under urban land use, whereas for ground water mean values higher concentrations of As, Fe and Zn were observed under forest land use. Whereas the highest mean value of Fe was recorded under forest land use in winter season which was statistically at par with rainy season in same land use system and urban land use in summer season. These findings confirm the findings of Acharya and Chatterjee (2010) who have reported maximum content of iron during summer season.

4. Conclusion

Different land uses and seasons in mid-hills region of Solan district of H.P has exerted varied responses with respect to heavy metals like As, Cd, Fe, Pb and Zn built up in surface and ground water sources of water. However, all the heavy metals were within the permissible limits prescribed by BIS, except Fe which exceeded permissible limit under forest land use system. Therefore, regular monitoring of land use is required to conserve the environment of mid-hills of Himachal Pradesh on sustainable basis.

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