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Monitoring of Heavy Metals in Surface and Ground Water Sources Under Different Land Uses in Solan, Himachal Pradesh

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Abstract

Investigations were carried out on analysis of water samples for heavy metals viz. Arsenic, Cadmium, Lead, Iron and Zinc from surface and ground water from 39 sampling sites under different land uses (agriculture, forest and urban) during different seasons (rainy, winter and summer) in adjoining to Kandaghat town of Solan District of Himachal Pradesh, India. This study had been carried out from 2011-2012 in order to elucidate the fate of heavy metals in surface and ground water. The maximum As (0.39 ppb), Cd (0.07 ppb), Pb (0.66 ppb), Fe (0.03 ppb) and Zn (0.09 ppb) of surface water was recorded under urban land use. Maximum As (0.25 ppb), Cd (0.06 ppb), Pb (0.59 ppb) and Fe (0.03 ppb) of surface water was recorded during summer season whereas Zn (0.06 ppb) was recorded during rainy season. In ground water, maximum Cd (0.06 ppb), Pb (0.02 ppb) and Fe (0.03 ppb) was recorded under urban land use, whereas As (0.15 ppb), Pb (0.02 ppb) and Zn (0.15 ppb) were recorded under agriculture land use. Maximum Cd (0.06 ppb) and Fe (0.03 ppb) of ground water were recorded during summer season, whereas As (0.06 ppb), Pb (0.02 ppb) and Zn (0.15 ppb) were maximum during rainy season.

Highlights

- Five heavy metals were detected in water samples by ICAP-6300 DUO
- Heavy metals concentration varied seasonally under selected land uses
- In general, the results of the present study have shown that values of heavy metal are with in the maximum admissible limits of Bureau of Indian Standards.

***Keywords**: Surface water, Ground water, Heavy metal, Land use, Seasons.*

The land use within the watershed has great impact on the surface water quality. The water quality may degrade due to change in the land cover patterns within the watershed as human activity increase (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 5gcm^{-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 indicating by the strong relationships between declining water quality and increasing agricultural development at catchment scale (Buck *et al*., 2004). Other findings note that urban land development greatly influences water quality as well (Osborne and Wiley, 1988). The pollution of the water bodies with toxic metals is 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 a dominant pathway for metals transport (Miller *et al*., 2003) and heavy metals may become significant pollutants of many small riverine systems (Dassenakis *et al*., 1998). There is also evidence of prevailing heavy metal contamination of groundwater in many areas of India. Heavy metals are recognized to be powerful inhibitors of biodegradation activities (Deeb and Altalhi, 2009). The main natural sources of metals in waters are chemical weathering of minerals, soil leaching and the anthropogenic sources associated with industrial and domestic effluents, urban storm, water runoff, landfill leachate, 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 very 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 a threat to human health (USEPA, 1987).

Himachal Pradesh situated between North latitude: 30^{o} 22' 40" to 33^{o} 12' 40" and East longitude: 75^{o} 45' 55" to 79^{o} 04' 20" is wholly mountainous with altitude ranging from 350 to 6975 meter above mean sea level. The Kandaghat block is located between North latitude: 30^{o} 57' 99" and East longitude: 77^{o} 06' 47" at an elevation of 1458 meter above mean sea level. The Solan district of Himachal Pradesh has emerged as a hub for various types of industries, whereas intensive agricultural practices are also in progress which may further exaggerate heavy metal pollution of surface and underground water sources. Therefore in the present study, it 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 present study investigates 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 Factorial Randomized Block Design.

Materials and Methods

Micro level hydrological survey of Kandaghat was conducted to select water sources for sampling sites randomly. On the basis of survey the water sources under different land uses i.e. agriculture, forest and urban/sub urban were identified and inventorized for collection of water samples from different sources. Surface (streams and rivers) and ground water (hand pump, bore wells, tube wells) samples were collected in glass bottles by dipping it downwards (10-12 cm) below 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 samples were filtered by using Whatman filter paper No.1. The filtered samples were injected into Inductively Coupled Plasma Absorption Spectrometer-6300 DUO (ICAP-6300 Duo).

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 metal contents arranged in decreasing order were: Pb>As>Zn>Cd>Fe for surface water (Table 3) and Cd>As>Zn>Fe>Pb (Table 4) 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 0.12 to 0.17 ppb (Table 3) for collected surface water samples, whereas under forest land use the As range was slightly narrower

Table 1. Details of selected locations (AS- Agriculture surface, AG- Agriculture Underground, FS- Forest surface, FG- Forest Underground, US-Urban Surface, UG- Urban underground)

Code	Location	Latitude	Longitude	Elevation(m)
AS	Ashwani khad	N 30o57’88”	E 077o07’72”	1091
AS	Chail seasonal Khad	N 30o58’01”	E 077o11’27”	1848
AS	Kohari (Tap)	N 30o58’19”	E 077o06’84”	2930
AG	Kohari village (bawari)	N 30o58’25”	E 077o06’91”	1442
AG	Dolagh village (bawari)	N 30o57’46”	E 077o06’42”	1353
AG	Dolagh village	N30o57’46”	E077o06’42”	1349
AG	Mohag bagh (bawari)	N30o58’01”	E 077o11’27”	1839
AG	Mohag bagh (bore well)	N 30o58’03”	E 077o11’26”	1836
AG	Sadhupul bawari	N 30o59’39”	E 077o09’36”	1238
AG	Domehar spring water	N 31o00’73”	E 077o05’22”	1628
AG	Domehar hand pump	N 31o01’02”	E 077o03’51”	1439
AG	Domehar hand pump	N 31o01’29”	E 077o03’44”	1245
AG	Mamligh hand pump	N 31o02’70”	E 077o02’07”	1301
FS	Waknaghat	N 31o00’55”	E 077o05’40”	1666
FS	Halru ka nala	N 31o01’53”	E 077o04’44”	1236
FS	Gambher khad	N 31o02’70”	E 077o03’82”	1040
FS	Patta bravri Kamlayard	N 31o02’34”	E 077o00’87”	1240
FS	Dadh gharat	N 30o57’28”	E 077o06’78”	1443
FG	Kandaghat road (spring)	N 30o58’19”	E 077o06’98”	1390
FG	Forest ground hand pump	N 30o58’12”	E 077o06’88”	1411
FG	Bawari	N 30o58’22”	E 077o06’83”	1366
FG	Chail hand pump	N 30o58’05”	E 077o11’53”	2051
FG	Chail hand pump	N 30o58’05”	E 077o11’54”	2057
FG	Mohag forest bawari	N 30o58’05”	E 077o11’26”	1839
FG	Domeher	N 31o01’05”	E 077o04’91”	1518
FG	Ree spring	N 31o01’91”	E 077o03’98”	1212
FG	Mamligh	N 31o21’70”	E 077o02’06”	1306
FG	Mamligh	N 31o02’49”	E 077o00’88”	1252
FG	Mamligh spring	N 31o02’77”	E 077o02’48”	1179
US	Sadhupul ashwani khad	N 30o08’31”	E 077o15’12”	1225
US	Chail market Tap water	N 30o58’06”	E 077o11’53”	2055
US	Sakori H.P water	N 30o58’12”	E 077o11’12”	1242
US	Waknaghat tap water	N 31o00’55”	E 077o05’40”	1666
US	Mamligh	N 31o03’33”	E 077o01’51”	1336
UG	Srinagar hand pump	N 30o57’83”	E 077o06’06”	1458
UG	Srinagar ground water	N 30o57’87”	E 077o06’17”	1439
UG	Sadhupu hand pump	N 30o59’39”	E 077o09’37”	1242
UG	Mamligh	N 31o03’33”	E 077o01’51”	1336
UG	Kandaghat marker HP	N 30o57’99”	E 077o06’47”	1458

Table 2. Indian standard drinking water - specification (Bureau of Indian Standards 10500.1991)

Heavy metals	Desirable limit	Permissible limit (in the absence of alternate source)
As(mg/l)	0.05	No relaxation
Cd(mg/l)	0.01	No relaxation
Pb(mg/l)	0.05	No relaxation
Fe(mg/l)	0.30	1.00
Zn(mg/l)	5.00	15.00

Table 3. Summary statistics of the analytical results of heavy metals in surface water samples from Kandaghat, Solan.

	Land uses				
Seasons	**Agriculture**	**Forest**	**Suburban**	**Mean**	**CD (p = 0.05)**
Arsenic (ppb)					
Rainy	0.12	0.04	0.01	0.06	L = 0.11
Winter	0.17	0.02	0.57	0.25	S = 0.11
Summer	0.12	0.02	0.60	0.25	L×S = 0.19
Mean	0.14	0.03	0.39	0.18	
Cadmium (ppb)					
Rainy	0.01	0.03	0.09	0.04	L = 0.02
Winter	0.04	0.02	0.01	0.02	S = 0.02
Summer	0.01	0.04	0.12	0.06	L×S = 0.03
Mean	0.02	0.03	0.07	0.04	
Lead (ppb)					
Rainy	0.05	0.01	0.65	0.24	L = 0.22
Winter	0.50	0.01	0.25	0.25	S = 0.22
Summer	0.67	0.01	1.10	0.59	L×S = 0.37
Mean	0.41	0.01	0.66	0.36	
Iron (ppb) Rainy	0.02	0.01	0.03	0.02	L = 0.01
Winter	0.02	0.02	0.01	0.02	S = 0.01
Summer	0.03	0.01	0.04	0.03	L×S = 0.01
Mean	0.02	0.01	0.03	0.02	
Zinc (ppb)					
Rainy	0.01	0.02	0.15	0.06	L = 0.03
Winter	0.00	0.02	0.10	0.04	S = 0.03
Summer				0.02	L×S = 0.05
Mean	0.01	0.02	0.09	0.04	

for all the seasons, namely 0.02 to 0.04 ppb. The highest value of As was recorded under suburban land use viz. 0.60 ppb during summer season. The range of As varied from 0.01 to 0.60 ppb for suburban land use during all three seasons. The cadmium content of the surface water samples varied, showing higher values in the suburban land use. Interestingly, the values of Cd increased in the winter season and then decreased in the summer season under agriculture land use whereas Cd concentration for forest and suburban land uses has shown decreasing trend for winter season and substantially increased again during summer 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 practice such as fertilization and use of fungicides tends to increase the concentration of heavy metals (Arsenic, Cadmium and zinc) in surface runoff in Tahtali basin, Turkey. The value of Pb varied under agriculture and suburban land use whereas no variation has been shown for forest land use for all three seasons. The values of Fe determined for the surface water samples did not differed significantly it varied from 0.01 to 0.04 ppb this may be due to lateritic nature of soil which contains iron and this results in washing of Fe contents into water (Acharya *et al*., 2010). The Zn ranged from 0.00 to 0.15 ppb. The sources of Zn are natural processes and human activities such as releasing of solid waste into water bodies (Qadir *et al*., 2013).

Table 4 Summary statistics of the analytical results of heavy metals in ground water samples from Kandaghat, Solan.

Seasons	Land uses				
	Agriculture	**Forest**	**Suburban**	**Mean**	**CD (p = 0.05)**
Arsenic (ppb)					
Rainy	0.17	0.01	0.00	0.06	L = 0.01
Winter	0.16	0.01	0.13	0.10	S = 0.01
Summer	0.12	0.03	0.01	0.05	L×S = 0.02
Mean	0.15	0.02	0.05	0.07	
Cadmium (ppb)					
Rainy	0.02	0.01	0.02	0.02	L = 0.01
Winter	0.04	0.01	0.03	0.03	S = 0.01
Summer	0.01	0.03	0.14	0.06	L×S = 0.01
Mean	0.02	0.02	0.06	0.03	
Lead (ppb)					
Rainy	0.03	0.01	0.01	0.02	L = NS
Winter	0.01	0.02	0.03	0.02	S = NS
Summer	0.01	0.01	0.02	0.01	L×S = 0.01
Mean	0.02	0.01	0.02	0.01	
Iron (ppb)					
Rainy	0.02	0.01	0.02	0.01	L = 0.01
Winter	0.01	0.01	0.01	0.01	S = 0.01
Summer	0.01	0.02	0.06	0.03	L×S = 0.02
Mean	0.01	0.01	0.03	0.01	
Zinc (ppb)					
Rainy	0.40	0.01	0.04	0.15	L = 0.01
Winter	0.02	0.03	0.05	0.03	S = 0.01
Summer	0.02	0.01	0.04	0.02	L×S = 0.03
Mean	0.14	0.02	0.04	0.06	

Highest values of zinc were recorded under suburban land use for rainy as well as winter season, whereas for agriculture land use Zn concentration was highest during summer season 0.03 ppb. These findings are similar to the findings of Okweye and garner (2013) who studies the seasonal variation of heavy metals in Tennessee river basin and reported Zn (453 µg/l), Pb (123 µg/l), Cd, As and Fe in water samples.

The groundwater of the studied area is used for drinking and domestic purposes. The Arsenic (As) range detected for different seasons under agriculture land use varied from 0.12 to 0.17 ppb (Table 4) for collected ground water samples. The As content for forest land use are statistically at par to each other whereas for suburban land use As range varied from 0.00 to 0.13 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 values of Cd determined for the ground water samples are non significant to each other except under suburban land use during summer season, namely 0.14 ppb. The values of Pb ranged from 0.01 to 0.03 ppb for ground water samples which showed that all the values differed significantly.

Substantial change was observed in the Fe content during summer season under suburban land use. Presence of Fe in groundwater is identified which can lead to change of color of groundwater (Rowe *et al*., 1995). The range of Fe varied from 0.01 to 0.06 ppb under suburban land use for all three seasons. The Fe content for agriculture and forest land use ranged from 0.01 to 0.02 ppb. The Zn content of the ground water samples varied from 0.01 to 0.40 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 agriculture land use viz. 0.40 ppb during rainy season which then remained same for winter and summer seasons i.e. 0.02 ppb.

However, basing 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 the mean values higher concentrations of all metal indicators in surface water samples were recorded under suburban land use and similarly for As, Cd and Fe for ground water samples. Whereas the highest mean value of zinc was recorded under agriculture land use in ground water samples. These findings confirm the findings of Bichi and Bello (2013) who reported high concentration of Zn (11.4 mg/l) and lower concentration of Pb (1.3 mg/l) and Fe (1.5 mg/l) in ground water samples under agriculture land use in river Tatsawarki in the Kano, Nigeria.

Conclusion

The purpose of this study was to assess levels of (As, Cd, Fe, Pb and Zn) in both surface and ground water samples under different land uses in Kandaghat, Solan District of Himachal Pradesh. The results indicated that concentrations of heavy metals were low in water samples and found to be within the desirable limits of Indian standard drinking water - specification (Bureau of Indian Standards 10500:1991). Heavy metal concentrations were found to vary significantly during all the seasons and under different land uses. These variations may be linked to the land use practices. In future, these land use practices may result in increase of heavy metals in water sources and this could pose threat to aquatic as well as terrestrial life. Thus it is important to monitor surface and ground water sources on regular basis so that remedial measures could be taken to prevent harmful effects of heavy metal pollutants.

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