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Land Use Changes and Their Impact on Groundwater Quality in Mid Hills of Himachal Pradesh

Pratima Vaidya [1]* and Satish Kumar Bhardwaj [2]

[1] *Department of Environmental Science, Dr Y S Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh, India-173230*
Email: pratimaem@gmail.com

[2] *Professor and Head, Department of Environmental Science, Dr Y S Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh, India-173230*
Email: sbhardwajswm@rediffmail.com
* Corresponding author

ABSTRACT

Impact of dominant land use changes on groundwater quality was assessed in mid hills of Himachal Pradesh. Area under vegetable, orchard and urban settlements has increased, whereas traditional agriculture and forest has decreased in the region during last 30 years. To assess the impact of such changes on groundwater quality an experiment was designed by taking five dominant land uses viz., traditional agriculture, commercial vegetable farming, orchard, forest and urban under randomized block design with four replications in Kullu and Solan district. 60 ground water samples were collected and analyzed for various water quality parameters. Study revealed that the land use changes have exerted significant influence on ground water quality parameters like EC, BOD, COD, chloride, nitrate, sulphate, Ca, Mg, Fe, Pb, Cd and Cr. The BOD, COD Cl, NO_3, SO_4, Ca and Mg concentration in groundwater varied in the order of land use: urban > vegetable > orchard > traditional agriculture > forest. Vegetable and urban land uses have started to adversely influence groundwater quality by exceeding the values of heavy metals over permissible limits.

Key Words: BOD; COD; Forest; Heavy Metals; Intensive Farming; Orchard; Urban; Vegetable

INTRODUCTION

Human-induced disturbances such as land use changes, pollution of air, water, soil and losses of productive lands are increasingly threatening the ecosystem productivity and health at local, regional and global scales. Among these processes, land use/land cover changes have been recognized as one of the foremost factor in decline of the ecosystem integrity. Understanding the relationship between land use and water quality is helpful for identifying primary threats to water quality, and the relationships are meaningful for effective water quality management because they can be used to target critical land use areas and to institute relevant measures to minimize pollutant loadings (Abler et al. 2002). Rapid urbanization, industrialization and modern farming practices end up in increasing pollutant load in water resources. Agriculture and urbanization has both direct and indirect impact on consumption and quality of water (Jiang et al. 2015).

Globally area under traditional crops such as barley, millets, oats, pseudo cereals etc. is decreasing, though it is increasing under cereals, vegetables, fruit and oil crops. Urbanization is alarmingly increasing at the rate of 20,000 km^2 per year, consequently, influencing area under agriculture land use. Urban land use has been reported to intrude 80% of agricultural land and 10% each of forest and grassland (Holmgren 2006). In India during last 50 years, net sown area has increased from 41.8% to 46.1%, the forest areas have increased from

14.2% to 22.8% (Anonymous, 2013). The urban and rural settlements have increased from 3.3% to 8.5%. However, with rapid urbanization and its associated infrastructure development, the demand for land has been projected to increase. In such cases, the demands for additional lands will be resorted from agricultural or forests which would therefore influence the environmental quality in the times to come.

The pristine water resources are gradually being contaminated by addition of foreign material from surrounding point and non point sources. Agriculture land use systems has been reported to affect ground water quality through excessive nitrate, sulphate, calcium, magnesium, chloride and heavy metal accumulation underlying crops due to consistent use of fertilizers. In the recent past, urbanization rather than agricultural land use has emerged as a major factor in water quality degradation (Lu and Chen 2014, Weerasekara et al. 2015). The excessive use of nitrogenous fertilizers, sewage, animal waste and manure has also been identified as the cause of nitrate, sulphate and heavy metal pollution in the water sources of urban and rural areas.

Heavy metals are the elements with density greater than 6 g cm^{-3} and become toxic to living organisms only when they are exposed to excess levels. Commercial agriculture practices wherein indiscriminate use of fertilizers and pesticides is done, rapid increase in population and unplanned human settlements has resulted in direct and indirect release of domestic effluents and urban wastes into the environment which ultimately find their way into water bodies thereby making this important resource unfit for consumption (Shah and Singh 2016). Consumption of contaminated water may lead to chronic accumulation of toxic metals in human body resulting in disruption of various metabolic activities which may threaten the well being of human and animals.

Himalayan mid hills of the state Himachal Pradesh in India has undergone a tremendous transformation in land uses due to changes in agricultural cropping pattern, urbanization, industrialization and hydropower generation. In recent years, deterioration of water quality due to unsustainable human activities has therefore become a key environmental concern in the region. Land uses affect water quality through non point sources, which are major contributor of ground water pollution (Salajegheh et al. 2011). Therefore, understanding the relationship between land use and water quality is essential for identifying primary threat to water quality. The mid hills of Himachal Pradesh are emerging as the rapidly growing regions of North West Himalayas. In past three decades, the mid hills falling under Solan and Kullu districts of Himachal Pradesh have witnessed rapid urbanization, industrialization and changes in cropping pattern from paddy-wheat based to commercial vegetable and fruit production systems which might have exerted significant influence on the quality of groundwater. Therefore we assessed the dominant land use changes and their impact on groundwater quality of the mid hill region in Himachal Pradesh.

MATERIALS AND METHODS

Study Area

Groundwater samples were collected from various groundwater bodies in four blocks namely Kullu, Naggar, Solan and Kandaghat of Kullu and Solan districts of Himachal Pradesh falling in mid hill zone (650-1800m above mean sea level) (Figure 1). The study area has mild temperate climate with average annual rainfall of about 1200 mm. The mid hills area represents 16.4% of area under orchards, 20.8% of area under vegetables and 21% urban population of the state.

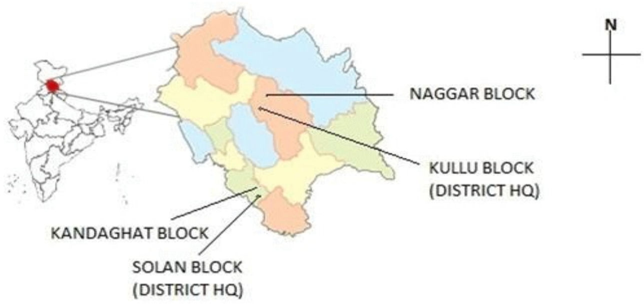

Figure 1. Map of the study area showing the selected sites in mid-hills of Himachal Pradesh.

Land Use Change

In order to assess the land use changes, the data on existing land use that of the past 30 years were collected from State Departments of Agriculture, Horticulture and Revenue. Data on forest area was extracted from State of Forest Reports of various years published by Forest Survey of India. The percent land use change was calculated by taking 1985 as the base year.

Experimental Details

Five dominant land uses namely (a) Traditional agriculture, (b) Commercial vegetable farming, (c) Commercial orchard, (d) Forest and (e) Urban were selected randomly in the mid hills falling in Kullu and Solan districts of Himachal Pradesh. The field study was conducted by taking five land uses as treatments which were arranged under randomized block design by taking four replications in the study area. Under each replication three subsamples were collected. The traditional agriculture land use consisted of wheat - maize cropping system which was low input based and by default an organic one and is being followed in the region for the last more than fifty years. Commercial vegetable farming system consisted of high input based system wherein commercial vegetable crops are being grown. Commercial orchards on the other hand comprised perennial temperate and stone fruit crops wherein injudicious use of fertilizers and pesticides is being practiced over the last thirty years. The forest was dominated by quercus, pine and deodar communities. Urban land use was composed of human settlements, hotels, public and private institutes and commercial centers etc. wherein urban solid waste and domestic effluents are disposed directly in the nearby area without any treatment.

Sample Collection and Chemical Analysis

Sixty ground water samples were collected from the selected groundwater sources during October in 2015 and 2016 as per the standard procedure prescribed by APHA (2012). The water samples were collected in 1000 ml plastic bottles. Electrical conductivity and pH were determined by use of microprocessor based pH meter (EIA 510) and electrical conductivity meter (EIA 1601) respectively. pH, EC, Biological oxygen demand (BOD) and Chemical oxygen demand (COD) of the samples were analyzed immediately after collection by standard methods (APHA 2012). Samples were pretreated with the addition of 5 mL of 2 M concentrated HNO_3 in order to preserve the metals and also to avoid precipitation. These samples were then stored in a refrigerator at 4°C for further analysis. Nitrates, sulphate, phosphate, chlorides, Ca and Mg were determined following standards methods (APHA 2012). The concentrations of Fe, Cd, Cr, Pb, Zn and Hg in water were analyzed using Inductively Coupled Plasma Emission Spectrometer (ICP-6300 Duo).

Statistical Analysis

In order to study the long term impact of land uses on groundwater quality parameters, the data of 2015 and 2016 was pooled. The obtained data was subjected to statistical analysis to test the analysis of variance (ANOVA) and means were separated and compared through critical difference at 5% level of significance.

RESULTS AND DISCUSSION

Land Use Changes

The data presented in Table 1 indicate that the Kullu and Solan districts of Himachal Pradesh are experiencing marked changes in land use over the base year 1985. During the last 30 years, maximum increase was noticed in case of vegetable land use followed by orchards and urban land use, whereas, the area under traditional agriculture and forest land use has decreased by 11% and 12.3% respectively (Figures 2 and 5). Vegetable land use experienced a significant increase from 3,075 ha to 15,376 ha in 30 years (Figure 3). Area under orchards also increased from 4,799 ha to 10,223 ha (Figure 4). Urban land use exhibited a sharp rise from 1985 to 2015 (Figure 6). Rise in vegetable and orchards with time was probably due to high returns. The results are in line with the findings of Zang et al. (2007).

Table 1. The status of land use, area (ha) and change (%), in Kullu and Solan districts, Himachal Pradesh

Land uses	1985	2015	Change (%)
Traditional agriculture	109461	97380	-11.04
Vegetable	3075	15376	400.03
Orchard	4799	10223	113.02
Forest	286413	251270	-12.27
Urban	10307	21224	105.92

Impact of Land Use Changes on Groundwater Quality

The dominant land uses changes have significantly influenced the groundwater quality (Table 2). Interestingly, the pH and EC of groundwater remained within a

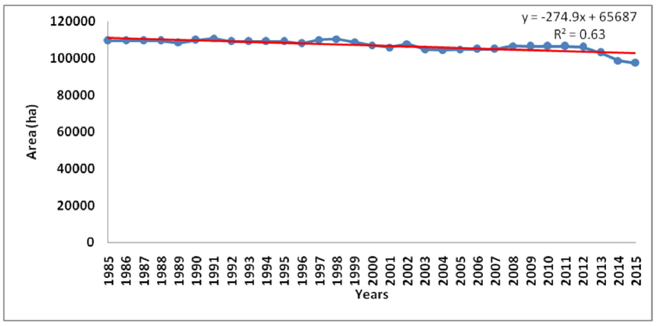

Figure 2. Trend of change in area under traditional agriculture of foodgrains in mid hills of Himachal Pradesh

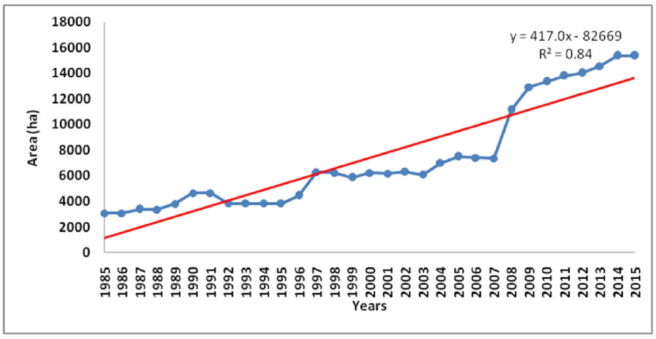

Figure 3. Trend of change in area under vegetables in mid hills of Himachal Pradesh

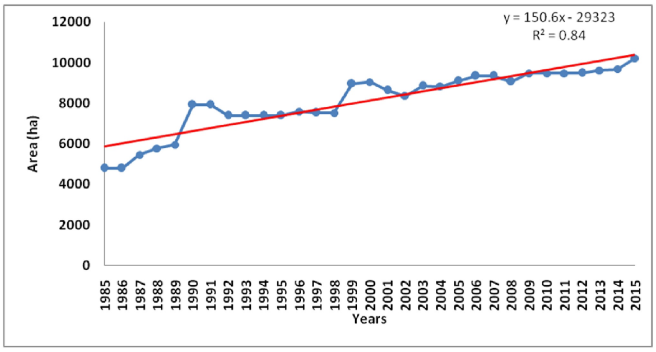

Figure 4. Trend of change in area under orchards in mid hills of Himachal Pradesh

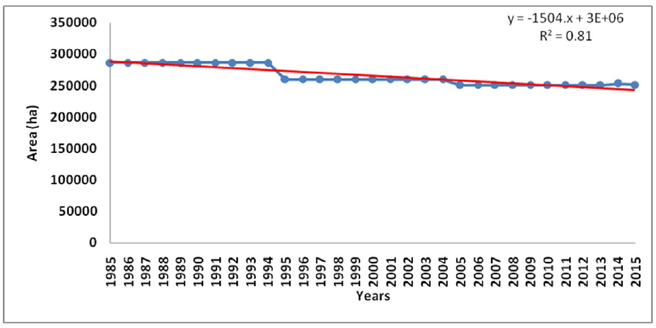

Figure 5. Trend of change in area under forests in mid hills of Himachal Pradesh

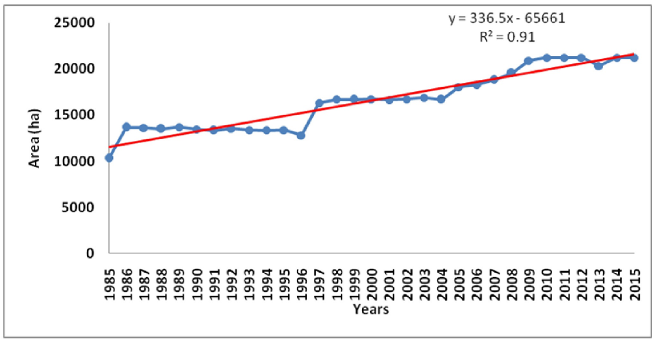

Figure 6. Trend of change in urban area in mid hills of Himachal Pradesh

normal ranges at 7.46 to 7.72 and 0.20 to 0.42 dS m^{-1} respectively, under dominant land uses of the region. No significant variation was noticed in pH under different land uses. Whereas, the groundwater EC varied significantly under land uses indicating thereby their influence on the salt concentration of groundwater. High EC was observed under urban land use (0.42 dS m^{-1}) followed by vegetables (0.35 dS m^{-1}), orchards (0.31 dS m^{-1}), traditional agriculture (0.26 dS m^{-1}) and forest (0.21dSm^{-1}). The EC of the study area was comparatively lower than that reported by Bali et al. (2015) who recorded high EC content in groundwater sources in Rajasthan, India. The results are similar to the findings of Abida and Harikrishna (2008) and Jiang et al. (2015) who observed high EC under urban land use as compared to agricultural land use.

Similarly, the dominant land uses also exerted significant influence on BOD of groundwater in the region that varied from 1.52 to 16.03 mg L^{-1}. Maximum BOD was observed under urban land use followed by vegetable, orchard and traditional agriculture. The forest land use resulted in the lowest BOD in groundwater of 1.52 mg L^{-1}. The BOD of groundwater under all land uses was above the permissible limits prescribed by CPCB (2009). This was probably due to high nutrient loading under agricultural based land uses as well as land disposal of domestic effluents and urban solid waste. The results are similar to those of Jiang et al. (2015).

The groundwater exhibited significant variation in the chemical oxygen demand values (Table 2). The COD was highest (94.96 mg L^{-1}) under urban land use, followed by vegetable, orchard and traditional agriculture land use (74.58, 45.50 and 38.92 mg L^{-1}, respectively. The lowest COD (22.08 mg $L^{-1)}$ was observed under forest land use. The COD of groundwater under urban land use exceeded the permissible limits prescribed by CPCB (2009) and is likely to be due to disposal

Table 2. Status of groundwater quality parameters under dominant land uses in mid hills of Himachal Pradesh

Land uses	pH	EC (dS m^{-1})	BOD (mg L^{-1})	COD (mg L^{-1})	Cl^- (mg L^{-1})	Nitrate (mg L^{-1})	Phosphate (mg L^{-1})	Sulphate (mg L^{-1})	Ca (mg L^{-1})	Mg (mg L^{-1})
					Water Quality Parameters					
Traditional agriculture	7.68	0.26	3.10	38.92	13.92	1.55	0.08	48.71	23.77	8.58
Vegetable	7.46	0.35	10.55	74.58	22.16	2.26	0.18	66.00	32.56	11.00
Orchard	7.54	0.31	4.18	45.50	16.05	1.60	0.10	54.38	28.92	8.91
Forest	7.72	0.20	1.52	22.08	13.55	0.98	0.05	26.54	23.10	4.23
Urban	7.57	0.42	16.03	94.96	28.08	3.12	0.13	76.00	35.79	11.47
C.D.	NS	0.05	1.41	11.27	4.55	0.82	NS	21.40	5.27	2.78
CPCB	6.5-8.5	2.25	2	-	250	20	-	400	200	100
BIS	6.5-8.5	-	-	-	250	45	1	200	75	30
WHO	5.5-8.5	-	-	-	200	45	-	-	75	50

Table 3. Impact of dominated land uses on groundwater status of heavy metals in mid hills of Himachal Pradesh.

Land use	Heavy metal concentration (mg L^{-1})					
	Fe	Pb	Cd	Cr	Zn	Hg
Traditional agriculture	0.06	0.10	0.004	0.01	0.03	0.04
Vegetable	0.11	0.39	0.03	0.05	0.25	0.06
Orchard	0.09	0.20	0.02	0.03	0.06	0.05
Forest	0.02	0.04	0.001	0.001	0.01	0
Urban	0.47	0.38	0.04	0.09	0.28	0.02
Mean	0.15	0.21	0.03	0.04	0.13	0.03
C.D.	0.21	0.12	0.02	0.03	0.10	N/A
CPCB	0.3	0.1	-	-	15	-
BIS	0.3	0.10	0.01	0.05	5	0.001
WHO	0.1	0.05	0.005	0.05	3	0.006

of untreated sewage and industrial wastes, and chemical inputs under agricultural land uses such as the regular application of chemical fertilizers in vegetable fields. Lu and Chen (2014) also reported high BOD and COD values under urban land use followed by agri-culture and forest.

Chloride concentration in groundwater bodies under different land uses in mid hills of Himachal Pradesh ranged from 13.55 to 28.08 mg L^{-1} (Table 2). The concentration of chloride was significantly higher under urban land use (28.08 mg L^{-1}) followed by vegetable (22.16 mg L^{-1}), orchard (16.05 mg L^{-1}) and traditional agriculture (13.92 mg L^{-1}) and forest (13.55 mg L^{-1}). High chloride concentration in urban land use may be attributed to discharge from domestic sewage. Similar results were also obtained by Sharma et al. (2014) and Zhang et al. (2016).

The groundwater sources under dominant land uses in mid hills found to vary in nitrate content (Table 2). Under different land uses the nitrate concentration were found to range from 0.98 to 3.12 mg L^{-1}. The maximum nitrate value of 3.12 mg L^{-1} was noticed under urban land use which was followed by vegetable, orchard and traditional agriculture land use with respective values of 2.26, 1.60 and 1.55 mg L^{-1}. Whereas the significantly lowest nitrate value of 0.98 mg L^{-1} was observed under forest land use. No significant difference was observed in phosphate concentration in groundwater bodies under different land uses of mid hills of Himachal Pradesh. The values of nitrate and phosphate were within the permissible limits prescribed by BIS (2005) and WHO (2011) for drinking water. The results are in consonance with the findings of Zhang et al. (2007), who has also observed high nitrate and phosphorus loadings in urban and agriculture land use.

Sulphate content in groundwater ranged from 26.54 to 76.00 mg L^{-1} (Table 2) and was significantly higher under urban land use (76.0 mg L^{-1}) followed by vegetable land use (66.0 mg L^{-1}). Lowest sulphate concentration was observed in ground water under forest land use. The results indicated that urban and vegetable land uses tend to increase the sulphates in groundwater, although the values were within the permissible limits (CPCB 2009 and BIS 2005) for drinking water. The results are similar to those of Sharma et al. (2014).

Among different land uses of mid hills of Himachal Pradesh calcium concentration in groundwater sources ranged from 23.10 to 35.79 mg L^{-1}. Calcium concentration in groundwater sources under different land uses of mid hills was significantly highest under urban land use (35.79 mg L^{-1}) followed by vegetable land use (32.56 mg L^{-1}). Significantly lowest calcium concentration was observed under forest land use (23.10 mg L^{-1}). Magnesium concentration among different land uses in mid hills ranged between 4.23 to 11.47 mg L^{-1} and followed the trend: urban (11.47 mg L^{-1}) > vegetable (11.00 mg L^{-1}) > orchard (8.91 mg L^{-1}) > traditional agriculture (8.58 mg L^{-1}). However, significantly lowest Mg concentration of 4.23 mg L^{-1} was observed under forest land use. The results are in line with the findings of Sim et al. (2016).

The Fe concentration in groundwater ranged from 0.02 to 0.47 mg L^{-1} (Table 3). Significantly highest Fe concentration of 0.47 mg L^{-1} was observed under urban land use followed by vegetable, orchard, traditional agriculture and forest land use with respective values of 0.11, 0.09, 0.06, 0.02 mg L^{-1}. The Fe concentration under all land uses was lower than permissible values of CPCB (2009) and BIS (2005) in all groundwater sources except for vegetable and urban land uses. Relatively higher Fe concentrations in groundwater were also observed by Rana et al. (2016) in mid hill region.

Pb concentration in ground water sources under all land uses and varied from 0.04 to 0.39 mg L^{-1}. Highest Pb concentration of 0.39 mg L^{-1} in ground water resources was observed under vegetable land use followed by urban (0.38 mg L^{-1}), orchard (0.20 mg L^{-1}) and traditional agriculture (0.10 mg L^{-1}). Lowest Pb concentration was observed under forest land use (0.04 mg L^{-1}). Results are in conformity with the findings of Ndungu and Bhardwaj (2016) for mid hill region. The Pb content of groundwater under all land uses were found to be beyond permissible limits prescribed by CPCB (2009) except for forest land use which suggests high Pb pollution risk in the region. High Pb content under urban land use might be from plumbing in buildings, paints, pipes, building material etc. Excessive use of agro-chemicals such as fertilizers and pesticide sprays may contribute to elevated Pb concentration in water bodies under vegetable and fruit orchard based land uses.

The Cd content in ground water sources varied from 0.001- 0.04 mg L^{-1}. The concentration of Cd in water bodies was also above the prescribed WHO (2011) and BIS (2005) levels except for traditional agriculture and forest land uses. Highest Cd concentration in groundwater sources was observed in urban land use (0.04 mg L^{-1}) followed by vegetable, orchard and traditional agriculture land use with respective values of 0.03, 0.02 and 0.004 mg L^{-1}. Significantly lowest Cd concentration of 0.001 mg L^{-1} was observed under forest land use. Relatively high Cd concentration in vegetable and orchard land uses may possibly be ascribed to chemical based farming in the region. The results are in compliance with the findings of Zhang et al. (2007), Ndungu and Bhardwaj (2016), Rana et al. (2016) and Wijayawardhana et al. (2016).

Under dominant land uses of the study area the Cr content of groundwater ranged from 0.001 to 0.09 mg L^{-1} which was above the prescribed standard 0.05 mg L^{-1} of BIS (2005) and WHO (2011) except forest land use. Land use wise distribution of Cr in groundwater was highest under urban followed by vegetable, orchard and traditional agriculture land use with the respective value of 0.09, 0.05, 0.03 and 0.01 mg L^{-1}. Lowest Cr concentration was observed under forest land use (0.001 mg L^{-1}). Discharge of untreated sewage, paints, textile, poultry and small scale industrial waste might have contributed to high Cr concentration in water resources under urban land use.

Zn concentration in groundwater bodies ranged from 0.01 to 0.28 mg L^{-1}, with the maximum concentration being under urban land use followed by the vegetables (0.25 mg L^{-1}). The lowest Zn concentration was observed under forest land use (0.01mg L^{-1}) which was at par with that under orchards and traditional agriculture. However, the Zn levels in groundwater were well below the limits prescribed by CPCB (2009), BIS (2005) and WHO (2011). Sources of Zn under urban land uses can be natural and anthropogenic such as dumping of solid waste (Quadir et al. 2013).

Concentration of Hg in groundwater sources ranged from 0.00 to 0.06 mg L^{-1} respectively and did not vary significantly among different land uses. Highest Hg concentration of 0.06 mg L^{-1} was observed in groundwater sources under vegetable land use followed by orchards (0.05 mg L^{-1}), traditional agriculture (0.04 mg L^{-1}) and urban (0.02 mg L^{-1}) which were slightly higher than the permissible limits by BIS (2005) and WHO (2011). However, no trace of Hg was observed in groundwater sources of forest land use. The buildup of Hg in groundwater bodies under agriculture based and urban land uses might be due to use of chemical fertilizers and pesticides and dumping of solid waste. The results are in line with the findings of Wijayawardhana et al. (2016).

The elevated concentration of Fe, Pb, Cd, Cr, Zn and Hg above permissible limits under urban, vegetable and orchard land use were observed as compared to forest and traditional agriculture. The results are in line with the findings of Aloueimine et al. (2006). Urban wastes contain high heavy metals concentrations such as Pb, Cd in old batteries, Cr, Cd, Pb in paints, pigments and electroplating and Cd and Ni in plastics. The unscientific dumping of urban waste material might have contributed to toxic heavy metal accumulation in ground water bodies of the region. Significant levels of Cd, Hg, Pb and Cr were reported in phosphate fertilizers (Wijayawardhana et al. 2016). Equally, anthropogenic activities associated to the urban development generate wastes and pollutants on the catchment surfaces that may be washed out to water bodies during storm events.

CONCLUSION

The study revealed that during the last thirty years the mid hill region of Himachal Pradesh has witnessed an increase in vegetable, urban and orchard and a decrease in traditional agriculture and forest land use. These changes in dominant land uses have started influencing water quality parameters of groundwater sources. BOD, Pb, Cd, Cr, and Hg concentrations in groundwater sources of the region were observed beyond the permissible limits. Indiscriminate use of agrochemicals under commercial vegetable and orchards and unscientific dumping of solid waste in urban areas lead to accumulation of heavy metals beyond the permissible limits as compare to traditional agriculture and forest. Therefore, it is strongly recommended that in vegetable and fruit growing areas pesticides, fertilizers and other agro-chemicals should be used judiciously in order to avoid the contamination of valuable water resources. Moreover the scientific waste management, urban runoff management and treatment of municipal sewage before releasing it into water bodies should be done to avoid the toxic element contamination of ground water bodies.

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