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ORIGINAL ARTICLE

Monitoring of heavy metal pollution and GIS derived land use changes in the major economic zone of Bangladesh

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Abstract Water pollution and land use changes are exceeding the limit in the most important economic zone, Dhaka Export Processing Zone (DEPZ) in Bangladesh and have become a great threat to the environment. To understand this threat, the dissolved metal concentration was measured from Turag and Bangshi River near DEPZ. The land use changes of DEPZ was measured and analyzed using Bangladesh Space Research and Remote Sensing Organization (SPARRSO) and Landsat TM images through Arc GIS 10.1, ERDAS Imagine 9.1. The dissolved Pb, Cd, Ni and Zn concentration were found to be higher in compare with those of water standards except Cu at every sampling point. Elevated concentration of Cd and its corresponding enrichment factor (EF%) indicated accumulation possibility of metals in the river bed sediments. The principal component analysis result also showed the dominance of Cd ions along with Ni ions in the river water. pH was found to be the controlling factor of every dissolved metal in the rivers sourced from DEPZ. Alongside, the study represents that the land use pattern has been changed remarkably. Large volume of water has been converted into unplanned settlement and urbanization. Land use changes may lead drastic changes in the land quality, such as decreases in biodiversity, instability of ecosystem, decreased soil quality, loss of nutrients, planned and unplanned urbanization, and bare land. Comprehensive synoptic researches are required to monitor the water pollution caused by DEPZ into these rivers and to determine the exact land uses for monitoring further changes.

Keywords Land use · GIS · Industrialization · Water pollution · Heavy metals

Introduction

Industrialization can play noteworthy role in socioeconomic development of a nation and guided to a nation towards desired economical steadiness. In the industrialization processes, a large number of areas including water bodies, forests, agricultural lands are converting to industrial zone or settlement area. On the other hand, unplanned urbanization is tolling up high environmental costs which in turn making a paradigm shift from blessing to burden. This urbanization is believed to be come from the industrial development (United Nations Population Fund 2007). As a consequence, the water qualities are deteriorating vigorously, water quantity decreasing, impeding ground water recharge and eventually wiping out from the ecological territory (Islam et al. 2016). The development of an industrial zone, e.g., national export processing zone may boost up this impact on environment.

Bangladesh is also undergoing rapid industrialization with the national goal of becoming a middle income

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656

Sustain. Water Resour. Manag. (2018) 4:655–666

country by 2021 (Islam et al. 2016). Several export processing zones have already been established throughout the country among which Dhaka Export Processing Zone (DEPZ) is the largest one leading and contributing significantly the nation's economy. DEPZ has started its operation in 1993 and at present, around 92 industrial units of both national and international origin are operating their production here (Islam et al. 2016; Akter et al. 2014). The DEPZ authority are permitting new industrial units in almost every year and thus acquiring new land from nearby territory. So, land is becoming a scarce resource here due to immense industrial and urbanization pressure (Sundara et al. 2012; Brammer 2002). Land use change is one of the most significant fields of human-induced environmental transformation from ancient times (Wolman and Fournier 1987; Tiwari et al. 2015; Udoyara and Robert 1994). Rapid industrialization leads to unsustainable land use change which contributes rapid resource depletion. Moreover, indefensible land use change may lead to ecological imbalance by disturbing natural components (Islam et al. 2010). On the other hand, the surrounding environment especially the water bodies are getting polluted due to the unwillingness of utilization of effluent treatment plant (ETP) to treat the wastewater by most of the industries (Hossain et al. 2012; Islam et al. 2017). As a result, most of these industries discharge untreated effluent into the surrounding environment resulting in adverse effects on ecosystem.

More attention is currently being directed towards monitoring changes in urban land use land cover (LULC) (Stow and Chen 2002). Specifically, geographic information system (GIS) and remote sensing has been widely used to classify and map LULC changes with different techniques and data sets, such as Landsat images that provide better classification of different landscape components at a large scale (Singh et al. 2014; Gajbhiye and Sharma 2013). Generally, the application of remotely sensed data for the assessment of changes in LULC requires less time, low cost and gives better accuracy at data analysis, update and retrieval. By understanding the driving forces of land use development in the past, the key features of modern GIS and remote-sensing tools to solve current problems, the outstanding real scale modeling of natural components, it is possible to sense environmental phenomena, uses of aquatic resources, natural calamities and especially, environmental pollution (Butt et al. 2015; Shammi et al. 2017). Similarly, the water pollution of both surface water and ground water can be also connected and sensed with the LULC changes by the help of GIS and remote-sensing tools. So, it is thus important to assess the current pollution scenario along with the land use change pattern using advance technologies. This study is an attempt to systematically examine the surface water quality and to determine

the change of land use pattern and the areal change of vegetation, settlement, water body and bare land of the DEPZ and the adjacent area. This research work will reveal the present metal pollution status and land use change pattern around DEPZ area which will be a basis of future research and monitoring activities for preventing pollution and land degradation.

Methods

Study area

DEPZ is situated at the confluence of Bangshi, Turag and Dhaleshwari River and 35 km southeast of Dhaka City. The area is locally named as Savar Upazila. DEPZ was established in 1993 where potential investors find a congenial investment climate free from cumbersome procedures (Mahbub et al. 2014). Geographically, this area is the southern part of Madhupur region. The study area extends from latitude 23°45′N to 24°00′N and longitude 90°00′E to 90°20′E. A limited extend of landscapes yet having distinct morphological features around DEPZ. Topography of this area comprises irregular elevated land blocks which is usually ideal for residential area. The surrounding low lying areas are mostly agricultural lands and water bodies. The land of the Upazila is composed of alluvium soil of the Pleistocene period having terrace-like topography locally named as Barind tract (partial) and Madhupur tract (Islam et al. 2016; Akter et al. 2014; Mahbub et al. 2014). Stratigraphic units exhibit an iron and manganese-rich deposit which lies generally as oxidized form. Paleomagnetic age dating unveils that these deposits ranged from lower Pleistocene to upper Pleistocene (GOB 1988). The Bangshi–Dhaleshwari and Turag comprises the drainage network of the study area (Khan et al. 2011; Krishna 1960). The geological succession established in the area is shown in Table 1.

Bangshi River is an important river in central Bangladesh originates from the course of the old Brahmaputra and flows past the Madhupur tract. It flows through Tangail and meets the Tongi in Ghazipur and finally falls into the Dhaleshwari River. This river is 238 km long and 9 m depth but not navigable for most of the year except when swelled by the rains of the monsoon (Sikder et al. 2013). The Bangshi River is one of the most polluted rivers in Bangladesh. It received most of the effluent of DEPZ and becoming an unexpected waste dumping zone.

The Turag River another polluted river of the capital Dhaka also received effluent from DEPZ which eventually joins the Buriganga River near Dhaka. Buriganga River, on the other hand, originates from the Dhaleshwari River (Kamal et al. 1999). Most of the industries and factories in

Table 1 Geological succession of the study area (GSB report 1988)

Age	Formation	Lithological description	Thickness in meters
Holocene	Lowland	River bed deposit: grey sand and silty sand, medium to fine grained	0–8.53
		Natural levee and inter-stream deposit: sandy silt, silt and loam, grey and friable	1.21–4.27
		Back swamps and depression deposits: clay and silty clay, grey, bluish, grey to dark grey, peaty and sticky	0.61–15.24
	Highland	Highland alluvium: silt, sand and clay. These occur above the present flood level	0–3.048
Pleistocene	Madhupur clay	Local unconformity	30.48
		Red clay: light brown to brick red, massive oolitic and contains fossil woods, ferruginous and calcareous nodules and surficial deposit of slag.	
		Mottled clay: earthy grey with patches of orange, brown, massive, and contains calcareous and ferruginous nodules.	
Pliocene	Dupi Tila	Unconformity	
		Sandstone: yellow to yellowish, grey, massive cross bedded, fine to medium grained, coarse and contains gravels at depth, moderately consolidated.	

Dhaka are situated on the banks of these three rivers or very close to the river system. Thus, the pollution received by the confluence of these three rivers system mostly distributed its impact on the vast catchment area of Dhaka district. The industrial activities, natural weathering processes, population density are high in these three river system, whereas waste water purification level is considerably low.

Sample collection

Sample locations are determined by hand GPS (model no-GPS map 62 GARMIN). The locations of the sampling points are shown in Fig. 1. A total of 20 water samples were collected from different location of Turag River in 2014 during pre-monsoon period which were significantly enriched with industrial pollution. Earlier, 20 water samples were collected from Bangshi River in 2014 during monsoon. These two rivers are the main recipient and distributor of pollutants from the DEPZ and Dhaleshwari River, respectively. Samples are collected randomly by traverse method. Three samples have been collected from residential areas where the influence of industries is lower than the other locations. The water samples were collected in sterilized containers with caps as per APHA method (APHA-AWWA 1998). They were thoroughly cleaned by rinsing with 20% v/v HNO_3 and deionized water followed by repeated washing with sample water to avoid contamination in the bottle. The water samples were filtered using Millipore membrane filters (Omnipore TM, Ireland) with 0.45 mm pores and then stored in polystyrene bottles by acidification with concentrated nitric acid (AR grade; 60–61% with a density of 1.38 kg/L) to pH <2 for metal analysis. Sampling bottles were kept at 4 °C.

General water quality

The heavy metal contents of the samples were only checked throughout the study. Because, several other studies and also from our previous study, it is clear that heavy metals in water are the key pollutants which represent also the contents of other physiochemical parameters. The pH value plays a key role for metal pollution and retention in water bodies. Therefore, pH is also checked to correlate and confirm the presence of heavy metals. For the determination of pH, a glass electrode pH meter (Griffin pH meter, model no. 40) was used. The electrode was rinsed thoroughly using distilled water followed by dipping the electrode into the sample water and was kept until the stable reading was observed. For the dissolved metal analysis, river water samples were filtered using millipore membrane filters (Omnipore TM, Ireland) with 0.45 mm pores to remove the insoluble materials followed by acid digestion with grade conc. HNO_3 for 1.5 h. The precise concentration of HNO_3 was 60–61% with a density of 1.38 kg/L. The pH of the samples was measured to keep it <2. Flame atomic absorption spectrometer (FAAS) is a very common technique for detecting metals and metalloids in solid and aqueous samples. In this research, Varian AA240FS FAAS is used for the determination of concentrations of Ni, Cu, Zn, Pb and Cd.

Satellite data collection and processing

To determine changes of land use pattern, the satellite image data has been used which were collected from SPARRSO, Bangladesh. All collected and gathered data have been processed manually and using the computer to operate the data accordance with the objectives and
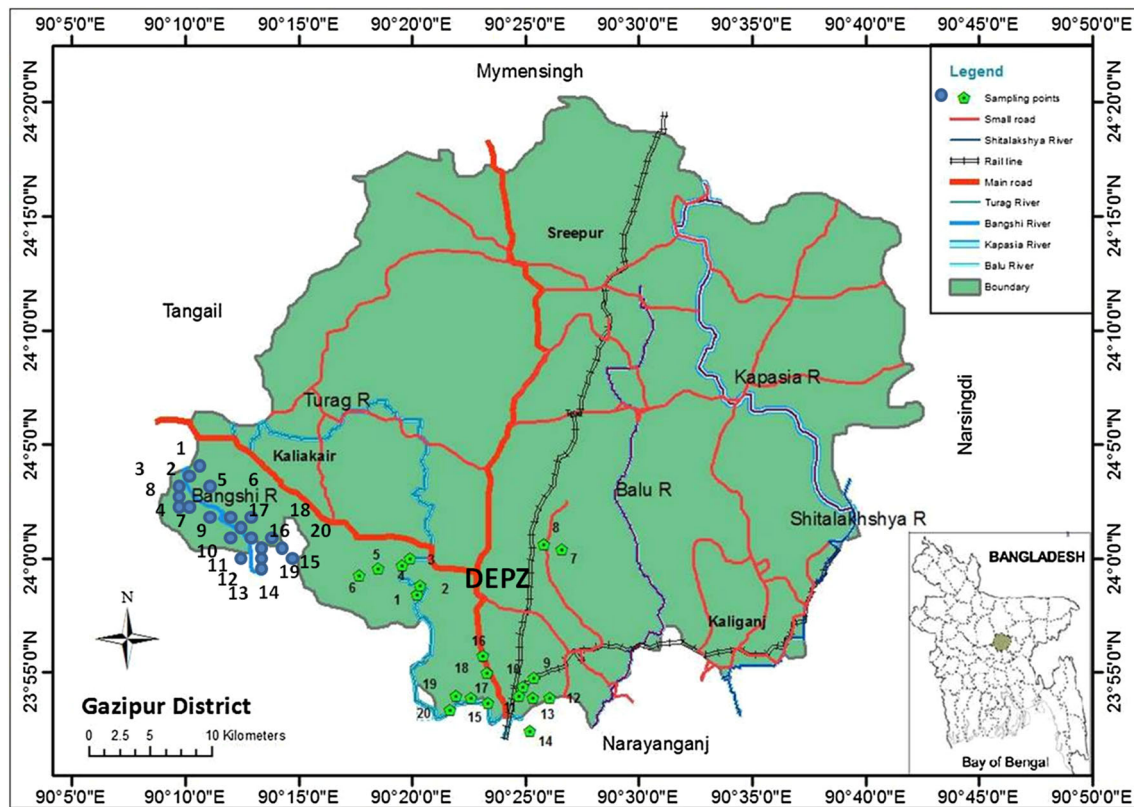
Fig. 1 Sampling points in Turag River (1–20) and Bangshi River (1–20) Dhaka, Bangladesh

guidelines of the research. For remote sensing analysis, three satellite images (Landsat TM image of 1992, Landsat TM image of 2003 and Landsat TM image of 2014) of the study area have been used. The image processing and analysis has been carried out using ERDAS IMAGINE 9.1 image processing software. Study area (DEPZ and the adjacent area) have been extracted using ERDAS IMA-GINE 9.1 software and presented in tabular and pictorial form by Microsoft excel software. The map output has been generated using Arc GIS 10.1. GIS Software (ERDAS Imagine 9.1, Arc GIS 10.1) was used for remote sensing data interpretation and classification, preparation maps, statistics generation, and analysis as well as visual pre-sentation. Study area have been subsisted from the big images and classified into four classes, e.g., water bodies, vegetation, build up area and bare land. White color in Figs. 4, 5 and 6 denotes for bare land, green for settlement area (build up area), red for vegetation and blue for water bodies. The features have been identified using Google Earth. Some features have been needed to recode for better classification using ERDAS Imagine 9.1. From satellite data interpretation, land use pattern were classified into two broad categories: first, settlement area which includes industries, planned and unplanned residential areas, roads, and second, undisturbed area which includes water bodies, vegetation, and bare land.

Statistical analysis

Enrichment factor (%) of heavy metal was calculated to understand the sources and accumulation trend using the following equation:

$$EF(\%) = \{(C - C_{min})/(C_{max} - C_{min})\} \times 100,$$

where C refers to the mean concentration of dissolved metals in the water sample (ppb), and C_{max} and C_{min} refer to the maximum and minimum concentrations (range) in (ppb), respectively, determined during the study. Pearson's correlation matrix was also calculated for different metals to understand the common sources of pollutants (Sikder et al. 2013). To interpret the variability of water quality parameters and to find their interrelations, multivariate principal components analysis (PCA) was conducted using XLSTAT statistical analysis software (Addinsoft, version-2016.1).

Results and discussion

General water qualities

The heavy metal contents of the sampling points of Bangshi River revealed a high level of water pollution

Table 2 Metal concentration in river water samples collected from both Turag and Bangshi River

Sample No.	Turag River						Bangshi River					
	pH	Pb (ppb)	Cu (ppb)	Cd (ppb)	Ni (ppb)	Zn (ppb)	pH	Pb (ppb)	Cu (ppb)	Cd (ppb)	Ni (ppb)	Zn (ppb)
S-1	6.94	285.8	18.8	7.6	54.0	2321.8	8.1	19.2	3.8	3.5	7.3	26.8
S-2	7.15	331.2	29.2	7.5	1012.0	3374.4	8.0	21.5	2.8	2.8	6.2	17.0
S-3	6.50	393.6	63.9	9.9	29.2	3106.4	7.8	24.6	2.3	2.6	5.6	33.1
S-4	7.50	399.2	78.7	9.5	181.7	3125.8	7.9	16.7	2.6	3.9	6.9	15.6
S-5	7.33	484.3	71.7	9.0	34.4	2283.3	7.7	21.4	3.8	4.8	6.4	19.6
S-6	6.01	524.0	35.3	13.3	347.2	3239.4	7.9	18.6	3.8	2.2	6.6	21.5
S-7	6.72	563.7	58.7	11.2	64.4	4001.5	7.9	23.5	3.4	4.6	16.3	81.8
S-8	6.16	830.2	57.0	1.9	40.9	3091.2	7.8	32.8	9.1	2.9	21.8	14.6
S-9	7.45	490.0	86.5	1.7	86.5	3190.3	7.1	33.7	9.2	3.0	5.1	14.6
S-10	6.78	540.0	70.9	17.4	179.1	3180.3	7.7	16.5	1.5	2.9	6.3	18.9
S-11	6.94	40.0	83.0	12.8	39.6	3180.7	7.8	20.0	5.6	4.9	11.2	35.6
S-12	5.90	25.0	52.6	14.7	50.1	3180.7	7.4	17.5	2.9	3.8	16.5	35.9
S-13	6.23	81.7	58.7	13.6	50.1	3211.3	7.7	23.4	6.9	3.6	17.3	25.9
S-14	6.76	81.7	58.7	14.2	112.6	3102.8	7.6	25.9	2.7	3.7	8.9	27.9
S-15	7.55	47.6	142.9	16.2	52.7	3104.4	8.1	21.3	3.8	4.1	9.3	19.6
S-16	6.83	98.7	50.9	11.9	52.7	3172.9	7.9	23.7	2.7	3.1	6.4	31.8
S-17	7.85	36.3	102.1	13.3	61.8	3238.9	7.6	18.6	2.9	4.2	26.3	27.9
S-18	5.88	87.3	64.8	13.6	254.7	3145.3	7.4	22.0	3.9	3.5	5.4	24.3
S-19	6.89	51.4	43.9	15.6	67.4	3094.2	7.1	27.3	7.1	4.0	6.5	26.8
S-20	7.56	166.7	87.2	13.9	324.0	3202.5	7.8	20.8	8.5	2.3	11.3	18.9
WHO	6.5–8.5	10.0	2000.0	3.0	10.0	3000.0	6.5–8.5	10.0	2000.0	3.0	10.0	3000.00

when compared with the values recommended by World Health Organization (WHO) (WHO 2011). Five potent toxic metals were measured in this study, e.g., Ni, Cu, Zn, Pb and Cd (Table 2). The concentrations (µg/L) of these metals in Bangshi River showed a wide variation in different sampling sites. Among the investigated five metals, Ni, Pb and Cd exceeded the standard levels provided by WHO where Pb was in extreme level. Most of the industries of DEPZ are textile, fabrics and dying industries where leaded dyes are using extensively (Islam et al. 2016). The untreated effluents released by these industries are the main reason of this elevated level of Pb in Bangshi River. In contrast, 50 times elevated level of Pb were recorded during pre-monsoon season at Turag River. In all sampling points at Turag River, the Pb concentration exceeded the standard level recommended by WHO. Cadmium is considered one of the toxic heavy metals due to its harmful effects on fauna, flora, and human beings (Sikder et al. 2015). Pb has been well recognized as a potent enzyme inhibitor, carcinogen, and teratogen to cause renal disturbances, lung insufficiency, bone lesions, cancer, and hypertension in humans (Sikder et al. 2015)]. Concentrations of Cd were found as maximum levels depicting the overall metal pollution in Bangshi River during monsoon. On the other hand, 18 out of 20 samples have elevated level

of Cd (1.7–17.4 ppb) during pre-monsoon. There are six plastic industries, four leather processing industries and four electronic and metal processing industries in DEPZ (WHO 2011). Cd may be appeared in the river water at this elevated level due to the effluent released from these industries (Zhiyuan et al. 2014). In case of Ni, this study reported high concentration of it in the Turag River during pre-monsoon, whereas 7 out of 20 samples contain elevated level of Ni in the Bangshi River. Ni is well known for its carcinogenic and toxic effects in high doses which generally released into the river water from power plants, metal factories and waste incinerators of DEPZ (Zhu et al. 2014). Cu was in the permissible limit in Bangshi River and Turag River during monsoon and pre-monsoon, respectively. This result was also supported by our earlier studies (Sikder et al. 2012, 2013). In contrast, Zn exceeded the threshold limit in all sampling points in Turag River, whereas there was no such a case reported for Bangshi River. This is may be due to the fact of seasonal variability as because every tributaries of Bangshi River inundated with rain water during monsoon. Surprisingly, we found elevated level of Pb in the Turag River and Bangshi River during pre-monsoon and monsoon, respectively. Though, there are no industries using Pb compounds or released Pb containing effluents. The presence of this high content of Pb into these

rivers may be from the small entrepreneurs/ locally based river bank industries that used to discharge their effluents directly in the rivers.

pH and enrichment factors

It is generally agreed that higher pH keeps low concentration of dissolved metals. When the pH in water drops, metal solubility increases and the metal particles become more mobile. That is why metals are more toxic in soft waters. On the other hand, metals can become 'locked up' in bottom sediments at higher pH, where they remain for many years (Perrin et al. 2014). It was observed from this study that the water body comprises high pH during monsoon and thus the metal concentration in water expectedly low. Surprisingly, slightly acidic to neutral pH was recorded for almost all water samples of Turag River during pre-monsoon. This result coincides with the elevated metal concentration of Turag River (Sikder et al. 2013; Shammi et al. 2014). An awful aspect of this result is the tendency of heavy metals accumulation into the bottom sediments which usually supported by the EF (%) analysis (Fig. 2). Fortunately, only Cd was found with high EF (%) in all sampling rivers, whereas the other metals were far below the threshold limit (Sikder et al. 2012). These results suggested great accumulation of dissolved Cd ions in river

bed sediments which may severely deteriorate the water quality and surrounding environment (Perrin et al. 2014). To support the above results, the correlation matrix was calculated. Table 3 shows significant correlation between Cd and Pb in the Turag River, and between Pb and Cu in the Bangshi River. Expectedly, pH was found logically correlated with every metal.

Principal component analysis (PCA)

The original set of every metals including pH was transformed into a smaller set of linear combinations to get the principal components which showed correlations among the water quality variables. Accordingly, 40 sampling points were plotted in the PCA graph (Fig. 3). In the PCA matrix, distant variables along with the neighbor one corresponds positive correlation. If they are orthogonal, they are not correlated and the rest of the variables on opposite side of the center are significantly negatively correlated (Sikder et al. 2013). Therefore, Cd and Ni were found the dominant parameters followed by Pb. Zn were also found at elevated level in the sampling point from 2 to 20. Expectedly, maximum sampling points and their corresponding variables of Bangshi River (21–40) were in the other side from Turag River. This result clearly indicated the variability of pollution with variability of season. We found identical results of Turag River in case of Bangshi River during pre-monsoon in our previous study (Sikder et al. 2013).

Other than this pollution, these rivers are also filling up every day with residential, industrial and commercial garbage. Due to over spilling of pollutants from DEPZ and due to lack of cultivable fertile lands in this area, human settlement are going far away and the newly vacant agricultural land and residential area are encroaching by the DEPZ for the establishment of new industries.
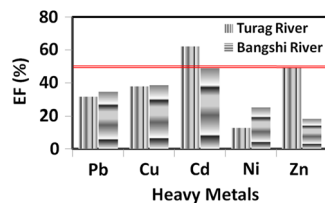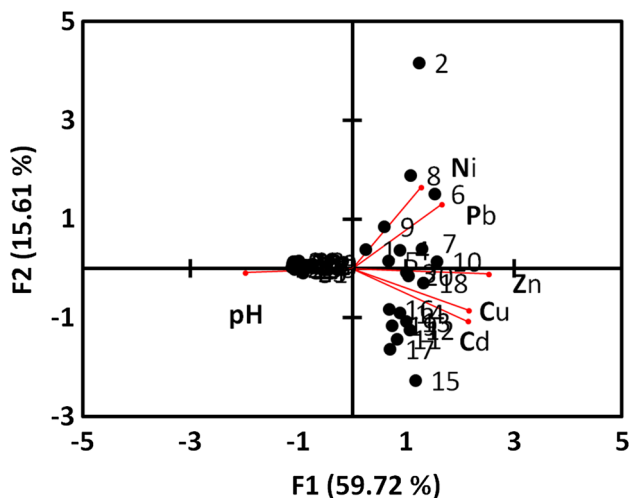

Fig. 2 Metal enrichment factors (%) in all sampling locations

Table 3 Correlation analysis of metals at all sampling points in Turag River and Bangshi River

	pH	Pb (ppb)	Cu (ppb)	Cd (ppb)	Ni (ppb)	Zn (ppb)
Turag River						
pH	1.00					
Pb (ppb)	−0.11	1.00				
Cu (ppb)	**0.54**	−0.22	1.00			
Cd (ppb)	−0.09	**−0.62**	0.22	1.00		
Ni (ppb)	0.06	0.09	−0.31	−0.09	1.00	
Zn (ppb)	−0.13	0.03	0.11	0.17	0.22	1.00
Bangshi River						
pH	1.00					
Pb (ppb)	−0.44	1.00				
Cu (ppb)	−0.38	**0.67**	1.00			
Cd (ppb)	−0.07	−0.18	−0.18	1.00		
Ni (ppb)	−0.01	0.03	0.20	0.22	1.00	
Zn (ppb)	0.07	−0.06	−0.25	0.43	0.26	1.00

Fig. 3 Principal component analysis (PCA) to project metals in both Turag and Bangshi River. All observations were calculated for two principal factors, F1 (*X* axis) and F2 (*Y* axis), and the vector sign shows the loading of the original variable on the computed factor

Land use land cover (LULC) map in 1992, 2003 and 2014

Land use land cover (LULC) can be understood as two separate terms that are often used interchangeably. From the analysis it has been observed that LULC has been changed drastically. Large volume of area is converted to industrial area or settlement area. Visual representation of the gradual change of land cover is represented in Figs. 4, 5 and 6.

From the land cover map of 1992, it is clear that major land use pattern was vegetation which includes agriculture, forestland, grass plain. Agriculture was the main mean of income. Second category of land use was settlement such as housing, building structure and market area. Following the settlement area, water bodies occupy a large volume of area involving river, canal, ponds, beel, low lying areas, etc. Fourth category of land cover pattern was bare land which may fallow land or exposed area.
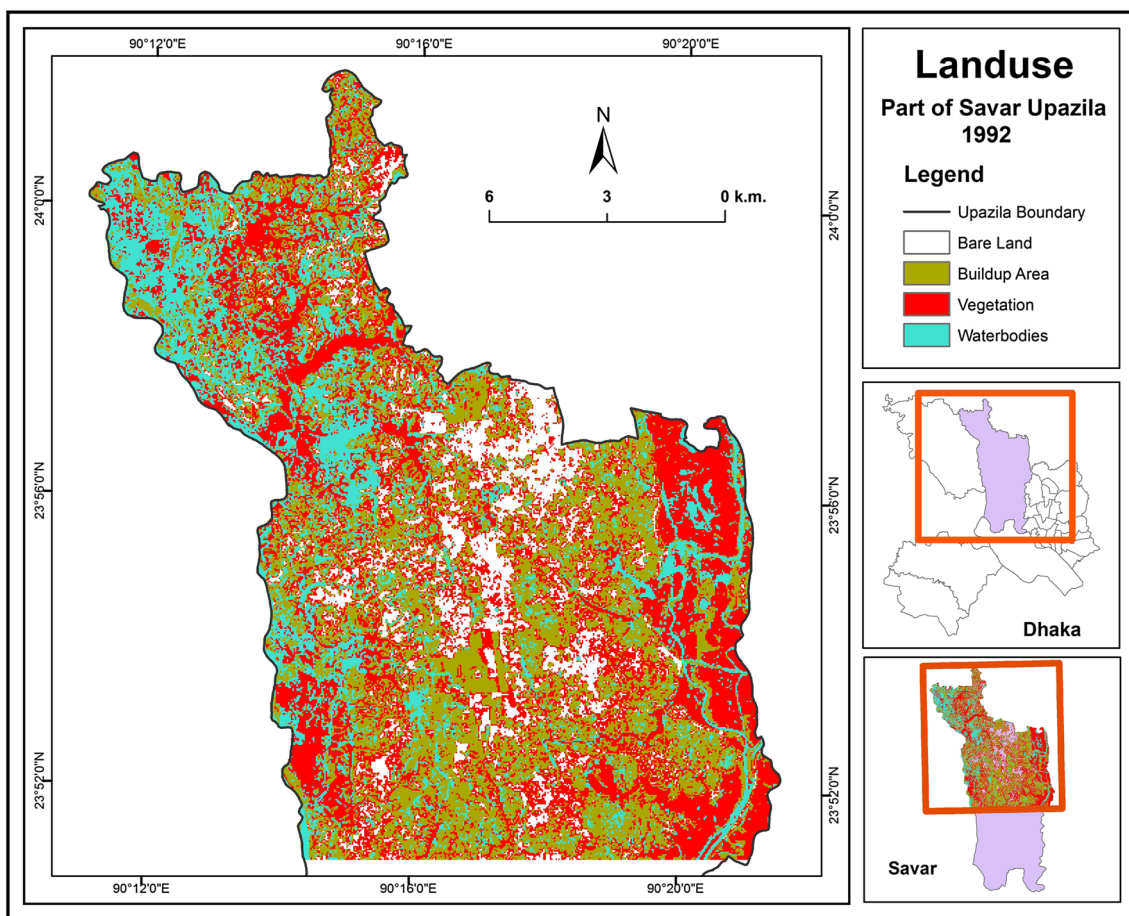

Fig. 4 Land use pattern in the study area in 1992

662

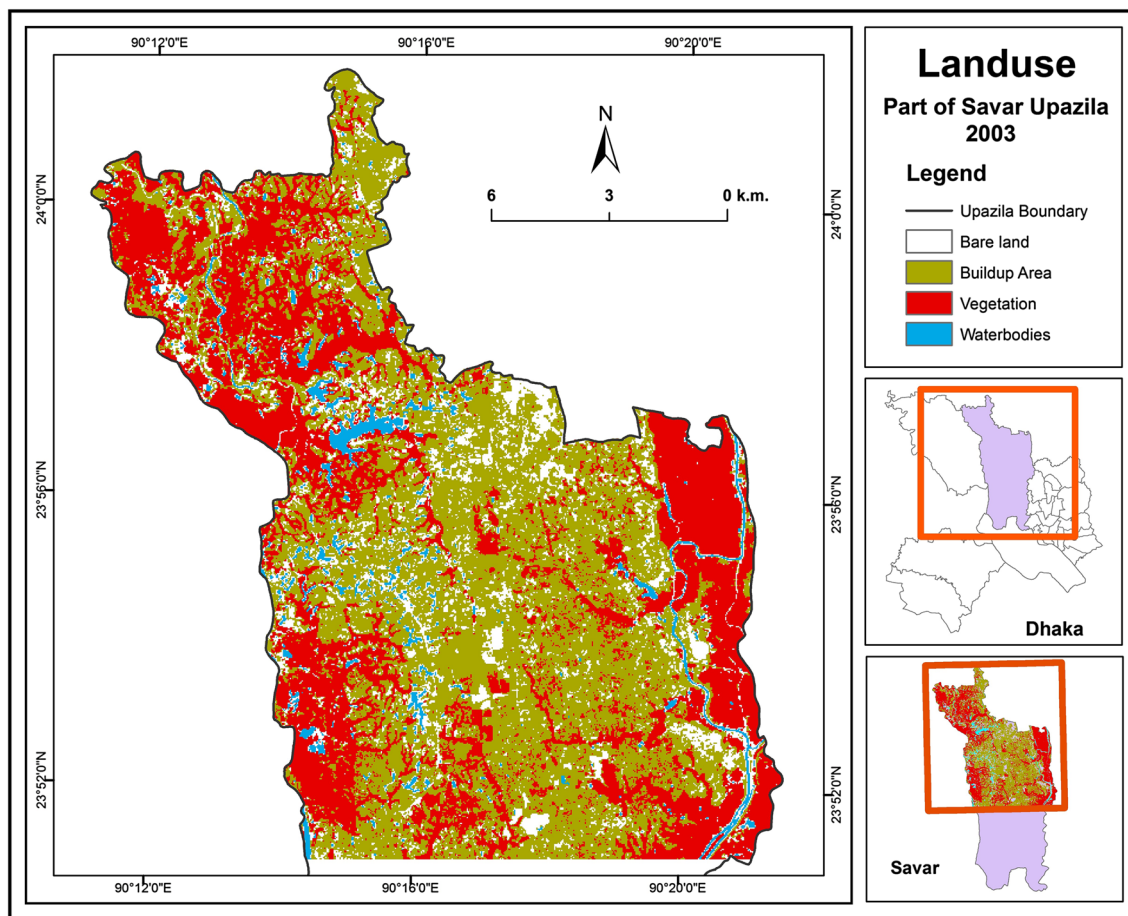Sustain. Water Resour. Manag. (2018) 4:655–666

Fig. 5 Land use pattern in the study area in 2003

The analysis of land cover map of 2003 revealed that major land use pattern has been changed from year 1992. Major land use category was settlement whereas vegetation was major land use category in 1992. Second category of land use was vegetation followed by bare land and water bodies. But volume of water bodies reduced significantly, where agricultural practice was increased occupying the low lying areas which were water bodies.

Analyzing land use pattern of 2014, it can be concluded that major land use class was settlement, whereas water bodies was main land cover in that area. Water bodies were encroached rapidly just after the establishment of export processing zone. Rest of the areas is occupied by vegetation, bare land and water bodies, respectively.

Satellite image interpretation of the study area in 1992, 2003 and 2014 has shown that the land use pattern has been remarkably changed in their nature. It is evident that the water bodies of the study area were shown 19.53, 3.37 and 3.45% of the total area at 1992, 2003 and 2014, respectively (Table 4). From this scenario, it is clear that the water bodies of the study area are decreasing day by day but it is remarkably decreased in between 1992 and 2003.

Surface water bodies are very much important for recharging groundwater and also important for maintaining aquatic ecological balance.

In case of vegetation, image interpretation map of the study area shown that the vegetative area has been decreased moderately from 1992 to 2014. From the image interpretation map, in the year 1992, 2003, 2014, the vegetative area was 36.29, 36.49 and 25.87%, respectively (Table 4). It may happen due to the replacement of vegetation cover area with industries along with planned or unplanned residential area (Yin et al. 2011; Jun 2011). Vegetation cover in any area is very much important for maintaining natural balance. However, this study indicates that the vegetative cover is decreasing day by day posing threat to the environment.

Settlement area is increasing continuously. From the image interpretation map, it has been computed that the settlement areas were 33.51, 47.78 and 55.93%, respectively, at 1992, 2003 and 2014 (Table 4). Unplanned residential area has been emerged as a dominant land use category which is also shown by a previous study (Sangwan et al. 2014). Rapid settlement growth indicates high
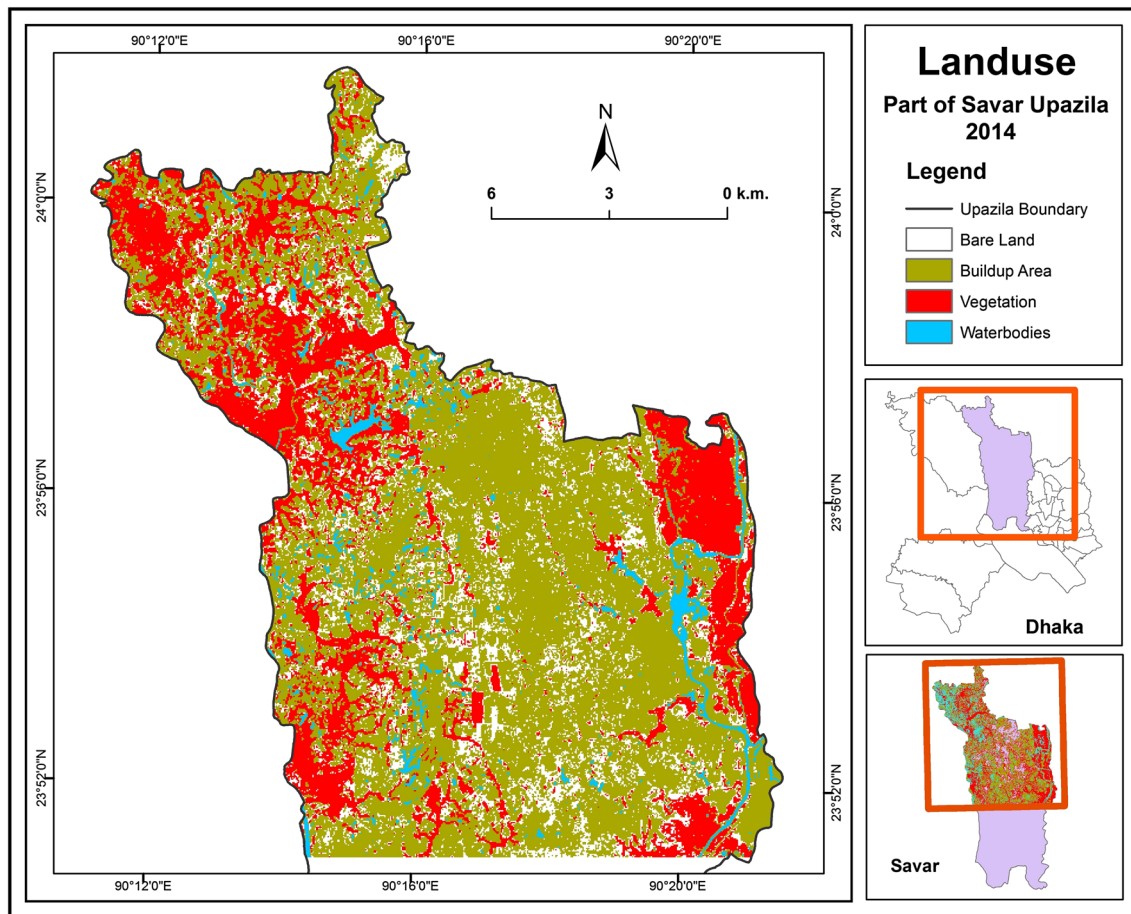
Fig. 6 Land use pattern in the study area in 2014

Table 4 Areal extent of land use features around DEPZ area and its percentage

Land use types	Land use area (hector) and its percentage					
	1992		2003		2014	
	Land use area (hector)	Total area (%)	Land use area (hector)	Total area (%)	Land use area (hector)	Total area (%)
Water bodies	3585.32	19.53	618.93	3.37	632.7	3.45
Vegetation	6662.37	36.29	6697.71	36.49	4748.85	25.87
Settlement area	6152.2	33.51	8771.13	47.78	10,267.65	55.93
Bare land	1956.78	10.66	2268.90	12.35	2707.47	14.75
Total	18,356.67	100	18,356.67	100	18356.67	100

economic development of the area which in turn pose threat to the adjacent environment. If the settlement increases in such extent then this will become a burden to the nature and will disturb the ecological balance.

It has been determined from the map that the bare areas in the study places were 10.66, 12.35 and 14.75%, respectively, at 1992, 2003 and 2014 (Table 4). The productive agricultural land is converted to the unproductive bare land while pollution load is worsening the water flow resulted the adjacent rivers dried up.

From Table 5, it is evident that the land use pattern has been changed intensively in the study area. In 1992, the major land cover was water bodies which are very important natural component in any area for fulfilling the demand of fresh water and maintaining food chain. But in 2014, it has been observed that the major land use pattern is

664

Sustain. Water Resour. Manag. (2018) 4:655–666

Table 5 Change in land use pattern of the study area from 1992 to 2014

Land use types	Area (hector) and its percentage		Change in areal extent		Remarks
	1992	2014	From 1992 to 2014		
	Land use area (hector)	Land use are (hector)	Area (hector) increase/decrease	Land use changes increase/decrease (%)	
Water bodies	3585.32	632.7	2952.62	16.09	Decreased
Vegetation	6662.37	4748.85	1913.52	10.42	Decreased
Settlement	6152.2	10,267.65	4115.45	22.41	Increased
Exposed area	1956.78	2707.47	750.69	4.09	Increased

converted into unplanned settlement which usually destructed the natural aquatic environment. From 1992 to 2014, the water bodies and vegetation cover decreased almost 16.09 and 10.42%, respectively. Vegetation cover is usually reduced because of the human encroachment. It has been shown that the settlement increased (22.41%) dramatically in the study area from 1992 to 2014. On the other hand, exposed area from 1992 to 2014 increased slightly which may have happened due to the collection of satellite images in the fallow period or the land unproductively for the effluent from the industries. From 1992 to 2014, the exposed area increased 4.09% in the context of total area.

Connection between pollution and LULC

Urban development has been linked to many environmental problems, including air pollution, water pollution, and loss of wildlife habitat (Marland et al. 2003). Unplanned urbanization makes a haphazard situation where different environmental problems generally arise. Urban runoff often contains nutrients, sediment and toxic contaminants, and can cause not only water pollution but also large variation in stream flow and temperatures (Czech et al. 2000; Wu 2008). LULC patterns largely depend on anthropogenic practices to achieve natural and socioeconomic development. LULC also affects the watershed which in turn affects water quality, leading to increased surface runoff, reduced groundwater discharge, and transfer of pollutants (Butt et al. 2015). The land use changes were mostly done for establishing an industrial belt called DEPZ. This establishment of DEPZ has given cancer-like effects to the adjacent area. To support the DEPZ, lots of small and medium enterprises were developed closest to DEPZ, rapid urbanization taken place to supply human resources to DEPZ, intensive infrastructure, roads, amusement parks, etc, were developed nearby DEPZ. So, the overall land cover has been substantially changed into a new format, and therefore the environment has changed significantly in compare to the earlier one. Among all changes, watershed changes were the most vital one. Because a watershed is not only a hydrological unit but also plays an important part in socio-ecological perspective by providing economical, food, and social security as well as provision of life support services to local residents (Singh et al. 2014). The careless disposal of untreated wastewater and solid waste to the main confluence of Bangshi, Turag and Dhaleshwari River near DEPZ significantly contributes to the poor quality of the water. The industries discharged heavy metals containing effluent in the confluence and thus the water quality deteriorates tremendously around the watersheds which in turn affect the whole catchment environment and biodiversity. In addition, the household wastes also bestowed into the watersheds around DEPZ, therefore, the combined impact of both industrial and household wastes worsen the overall environmental condition. Furthermore, the shrinking of the total watersheds around DEPZ is evident due to LULC changes and thus the effluent receiving water bodies is lessened. Polluted water becomes a threat to public health, livestock, wildlife, fish and other biodiversity. These pollutants have potential to retard the growth and aquatic flora and fauna (Gajbhiye and Sharma 2013). LULC changes in the watershed area have negative impacts on water quality, fragmentation of aquatic animals, soil erosion, and river pollution due to deforestation and discharge of municipal garbage and industrial waste (Hua 2015). Territory destruction, fragmentation, and modification associated with urban expansion have been identified as the leading causes of biodiversity decline and species extinctions (Haque et al. 2013). Urban expansion and intensive unplanned agriculture is also a major threat to the health, productivity, and biodiversity throughout the world.

Conclusion

Since long time, the effluents of DEPZ are being discharged into the Turag River and Bangshi River without any prior treatment. The water qualities of these rivers are deteriorating due to the presence of high level of toxic heavy metals, e.g., Pb, Cd, Zn and Ni. These dissolved metals are controlled by pH and correlated with each other. Pearson correlation

matrix, enrichment factor (%) analysis and principal component analysis results indicated the severity of water pollution in this area due to the effluent of DEPZ. On the other hand, land use pattern has been changed remarkably; large volume of water body has been converted to industrial settlement, planned and unplanned urbanization, bare land, etc. Water body's area has been reduced violently and the settlement in the study area increased very rapidly after industrialization. Land use and land management practices have a major impact on natural resources including water, soil, air, nutrients, plants, and animals. Rigorous deforestation may cause soil erosion, desertification, and other soil degradations. Deforestation leads to the greenhouse effect, destroys natural habitats and biodiversity, affects the hydrological cycle and increases soil erosion, runoff, flooding and landslides. Built-up development causes air pollution, water pollution, and urban runoff and flooding. Habitat destruction, fragmentation, and alteration associated with urban development are a leading cause of biodiversity decline and species extinctions. So, proper effluent treatment through physical, chemical and biological process along with the synoptic monitoring of land use changes is of utmost necessity to combat the ongoing challenges.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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666

Sustain. Water Resour. Manag. (2018) 4:655–666

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