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Assessment of heavy metals in the surrounding soils and their bioconcentrations in few plants near Kathajodi river, Odisha, India

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Abstract: The present study was carried out mainly concentrate on assessment of heavy metal in the surrounding soils and their bioconcentration in the different plants near Kathajodi River. Soil and plant samples were collected along the Kathajodi river, Odisha, India. It was found that the dominance of heavy metals follows a decreasing order. The metal concentrations measured in soil at all location generally decreased in the order; Fe > Mn > Ni> Pb> Cu> Zn> Cd. Highest heavy metal concentration in river bank soil Cd (0.72±0.05 mgkg^{-1}); Ni (3.85±0.15 mgkg^{-1}); Cu (1.66±0.15 mgkg^{-1}); Zn (1.54±0.16 mgkg^{-1}); Pb (4.11±0.14 mgkg^{-1}); Fe (142.0±1.16 mgkg^{-1}); Mn (37.30±1.16 mgkg^{-1}) at different site . Among all the grass species *I. laxum* has the higher affinity for the accumulation of Cd (0.85±0.05) followed by Zn, Pb and Cu. This study indicates that bio concentration of heavy metals in the study area show preferential Cd uptake in the plants followed by Zn, Pb and it may lead to accumulates in the exposed plant part posing risk along the food chain. This calls for immediate action to be implemented to carry out necessary environment mitigation measures for the river as it can be attributed the discharge of untreated domestic waste and effluents in the river.

Keywords: Bioconcentration, Heavy metals, *I. laxum,* Kathajodi river, Soil

INTRODUCTION

Environment is a complex natural resource system that has originated from millenniums of evolutionary process during which all ecosystems and forms of life have developed. Twentieth century particularly has witnessed man's dominance over environment. In recent years, rapid economic and industrial growth intensified environmental pollution. One of the consequences of the escalating industrial activity is the growing accumulation of recalcitrant elements in natural ecosystems; particularly the accumulation of heavy metals in aquatic ecosystem. It has become a problem of great concern throughout the world as these metals are indestructible and have toxic effect on living organisms when they exceeds critical concentration limit (Macfarlane and Burchet, 2000). Increase in population, urbanization, industrialisation and agricultural practices have further aggravated the situation (Giguere *et al*., 2004).

Heavy metals are of particular concern due to their environmental persistence, biogeochemical recycling and ecological risk. Chemical leaching of bed rocks, water drainage basins and runoff from banks are the primary lithogenic source of heavy metals. Urban discharges and industrial waste water, combustion of fossil fuels, mining and smelting operations, processing and manufacturing industries, waste disposal including dumping etc, are the primary anthropogenic sources of metal pollution (Klavins *et. al*., 2000; Pardo *et. al*., 1990; Yu *et. al*., 2001; Upadhayay *et .al*., 2006; Barik, 2013). Heavy metals discharged into the aquatic bodies persist for long time and accumulate along the food chain. Metals present in the environment in minute quantities become part of various food chains through biomagnifications and their concentration increases to such a level that may prove to be toxic to both humans and other living organisms (Gopal *et. al*., 2002).

Study of surrounding soils plays an important role as they have a long residence time. Therefore, are important sources for the assessment of man-made contamination in rivers. Singh *et. al*., (2002) also reported that highly polluted are adversely affecting the ecological functioning of rivers due to heavy metal mobilization from urban areas in to biosphere. Pollution of the biosphere with toxic heavy metal has accelerated dramatically since the beginning of the industrial revolution. The use of plants has been a common practice for bio monitoring

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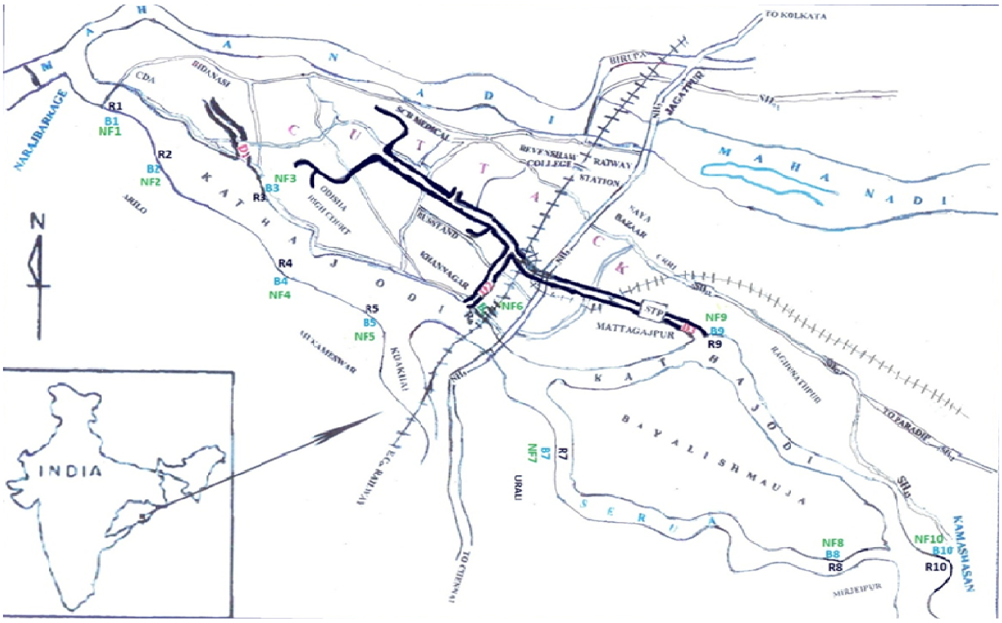

Fig.1. *Location of the study area.*

of metal contamination and its toxicity.

Cuttack, which is one of the oldest cities of India and was the capital city of Odisha for almost nine centuries was built as a military cantonment in 989 A.D. River Kathajodi in the Cuttack urban area is a significant distributaries of river Mahanadi. The exponential growth of Cuttack on the left side of Kathajodi river has led to severe water pollution in Kathojodi river. The quality of soil in the river bank is seriously affected by pollutants which enter the river through the disposal of untreated domestic and industrial effluents and sewage directly in to the river. During rainy season, when there is a flood in the upper catchment of the river, due to excess discharge of water from the Naraj Barrage, the Kathajodi river swells which enters the adjoining area of the southern bank of Kathajodi river and pollute the soil on the bank as well as the flood pan on the S-E side of the river through sediment deposits. Water coming from upper stream of river Mahanadi also carries sediments containing heavy metals due to its geogenic as well as anthropogenic origin and may contaminates the surrounding soils (De and Mitra, 2002).In order to accesses the heavy metal contamination status of Kathajodi river bank soil the present investigation was carried out to get more information on heavy metals pollution status in the river bank soil and its bioconcentration in plants.

MATERIALS AND METHODS

Study area: The city Cuttack lies on the east coast of India in the state of Odisha between Latitude: 20°30' N and Longitude: 85°49' 60" E. The river Mahanadi and Kathajodi surrounded the city forming a delta on which the city Cuttack is situated Figure.1. The basin displays dendritic to sub dendritic and rarely rectangular and trellises drainage patterns. At the downstream of Khannagar near Urali village, the river Kathajodi bifurcate and after few kilometre again joined, creating an island namely Bayalishmauja. The right side flow of the Kathajodi is called as Serua river in some area. After the joining of two flows, the river is named as river Devi .The width of Kathajodi river varies from a few hundred meters to two kilometers and is elongated to west to east direction. The river flows in Cuttack district and a few hundred meters in Jagatsinghpur district. The Kathajodi river receives discharge from river Mahanadi. The land surface slopes to the centro-axial zone both from the south and north and also has a low regional gradient to east**.** As the city is deltaic, being situated between the two rivers, low-lying areas are abundant and are frequently flooded by rain and flood water. The depth of the water table changes with the season, as during pre-monsoon it is 4 to 6m below ground level and 0 to 2m during post-monsoon (CGWB-1995). The Cuttack city is situated on the N-E side of this river Kathajodi, which receives the sewage and untreated domestic waste which are the causes of pollution.

The city of Cuttack enjoys a subtropical, monsoon climate with three distinct seasons, i.e. summer, winter and rainy. The winter season continues from November to February, the summer extends from March to June, and the rainy season from June to October. The average annual rainfall is 154 cm with 74 rainy days. The area receives about 85% of the annual rainfall from south-west monsoons and maximum precipitation occurs in July and August. Cyclonic weather has been a common phenomenon in the study area as it is situated on the east coast of India. The summer is hot and day time temperature reaches 45° C with a monthly mean of 39.2°C. Winter nights reach 8° C with a monthly mean temperature of 22.0°C. The estimated monthly mean combine evaporation and evapotranspiration of the study area is 17.7cm (Das *et*

Table 1. Description of the study area.

S. N.	Sampling station	Sampling station Description	Symbols for the sampling location River bank soil	Nonflooded soil
1	Naraj (85° 46’47”E 20°20’13”N)	Just after the barrage constructed on river Kathajodi	B1	NF1
2	Arilo (85°47’8.5”E 20°28’14.9”N)	A bushy wasteland	B2	NF2
3	CDA-Bidanasi (85 48’ 33”E 20°28’3.4”N)	City sewage disposal point	B3	NF3
4	Bidyadharpur (85°49’26.4”E 20°7’14.7”N)	A farming village with fly ash brick factory	B4	NF4
5	Brahmanigaon (85°52’7.3”E 20°26’56.3”N)	A fishing village	B5	NF5
6	Khannagar (85°54’3.5”E 20°44’30”N)	Under a bridge of railway track & Highway and after the raw city sewage disposal point	B6	NF6
7	Urali (85°54’14” E 20°42’29” N)	A farming village after the river bifurcated opposite side it receives city sewage	B7	NF7
8	Mirjeipur (85°58’12” E 20°36’46” N)	A farming village just before the bifurcated portion joined to its main river	B8	NF8
9	Raghunathpur (85°59’36” E 20°43’38” N)	A farming village with farming on river sand and also the sewage disposal in to river after treatment in a STP.	B9	NF9
10	Komashasan (86°02’43” E 20°36’35” N)	A village just after join of the river	B10	NF10

al., 2002).

Sampling: Ten different sampling stations were selected between Naraj barrage to Koma Shasana village of Jagatsinghpur district and were localized exactly by GPSMAP-6CSX (GRAMIN) locator (Fig.1 and Table 1). Soil samples from 0-15 cm soil depth from river bank (B1, B2, B3, B4, B5, B6, B7, B8, B9, B10) and non-flooded area control (NF1, NF2, NF3, NF4, NF5, NF6, NF7, NF8, NF9, NF10) were collected during post monsoon period in the month of November-December 2011. Soil samples were air-dried in the laboratory. Stones and plant fragments were removed from the river bed sediments by passing the dried samples through a 2mm sieve. The dried soil samples were grounded and sieved by using 2 mm sieve. All the samples were then stored in a polythene container and kept ready for analysis (Singh *et. al.*, 2002) and laboratory analysis of soil samples followed during January and February, 2012.

Plants samples: Plants sample are collected for the study are predominant grass and fodder species, samples (n=5) *C. dactylon* (Dub grass), *P. repens* (Regeda), *D. sanguinalis* (Kankadaghasa/Digitaria), *S. diander* and *I. laxum* (Panda suali), of the river bank and non flooded area were uprooted from the adjoining locations from where soil samples were collected, they were washed with 2 per cent detergent water to remove all adhered soil particles. Samples were cut into small pieces, air-dried for 2 days and finally dried at 80°C in the hot air oven till a constant weight is achieved and The dried plant sample were ground to fine powder with mortar and pestle. The crusted plant samples were passed through 100 mesh sieves and were preserved for analysis (Burton and Jhan, 1977; Barik, 2013).

Physico-chemical analysis of soil

Determination of pH and EC: pH of the soil is determined by a pH meter and EC (Electrical Conductivity) by conductivity bridge (APHA, 2011).

Determination of organic carbon content: Organic carbon was determined by Walkley and Black titration method (Black, 1965).

Determination of available N, P, K: Available N of the soil was determined by alkaline $KMnO_4$ method (Subbiah and Asija, 1956). Available P was estimated using Olsen’s extractant (Jackson, 1973) and available K was determined using ammonium acetate extractant (Jackson, 1973).

Determination of available heavy metals in soil: Available Fe, Cu, Zn Mn, Cd, Pb and Ni were determined by atomic absorption spectrophotometer (AAS), using diethylene triamien penta acetic acid (DTPA) as single extractant (Lindsay and Norvell, 1978). The instrument was set to zero by running the respective reagent blanks. Average values of three replicates were taken for each determination.

Determination of heavy metals in plants: Plant samples were weighed exactly 0.5g and kept in 5ml of Nitric Acid (HNO_3) overnight and followed by its digestion on heating mantle after addition of 5ml of diacid ($HClO_4$ + HCl) mixture on a hot plate under the hood till a clear solution is obtained. Digested sample solution was made to 50 ml volume with the double distilled water. Heavy metal analyses were carried out using flame atomic absorption spectrophotometer

(Spectra AA, Variant 55B AAS).The calibration curves were prepared separately for all the metals by running different concentrations of standard solutions (AOAC, 2000). The instrument was set to zero by running the respective reagent blanks.

Determination of bioconcentration factor (BCF): Bio Concentration Factor (BCF) is a common parameter for estimating the heavy metal concentration in plants and subsequently enters in to food chain, which is defined as the ratio between the concentration of heavy metals in the plant/flora and DTPA extractable heavy metal concentration in soil (Ghose and Singh, 2005).Data were analyzed for mean and standard deviation. The differences between DTPA-extractable metal contents in soils were statistically evaluated by applying t-test according to Snedecor and Cochran, (1967). Simple correlation and multiple regression analysis were also carried out to assess the relationships of DTPA-extractable metal with plant metal concentration, soil pH and organic carbon. The relations were tested at 5% level of significance.

RESULTS AND DISCUSSION

Physico-chemical characteristic of soil: The values of pH, EC, O.C. and available N, P, K, in the soil both river bank are presented in table 2 and 3. The pH of river bank soil in all sites was acidic. The highest pH value was at location B8 with value of 6.9±0.11 and lowest at B4 with value of 5.4±0.14. In non-flooded area the highest pH value at NF6 was 6.8 and lowest at NF3was 4.8. The organic carbon per cent was highest at B3 (0.85±0.05) and lowest at B10 (0.25± 0.05) on the river bank where as in non-flooded area highest organic carbon was observed at NF10 (0.25±0.05) and lowest at NF3 (0.12±0.0).The available nitrogen content of 213.4±1.14 kgha^{-1} was found highest at location B4, lowest at B8 (100.3±1.15 kgha^{-1}) on the river bank whereas on non-flooded soil highest available N (188.6±1.15 kgha^{-1}) at NF2 and lowest at NF 7 (87.8±1.12 kgha^{-1}) were observed. Similarly the available P content was found highest at location B_3 (51.7±1.13 kgha^{-1}), lowest at B5 (23.3±1.13 kgha^{-1}) on the river bank whereas on non-flooded soil highest available P (59.5±1.15 kgha^{-1}) at NF4 and lowest at NF 10 (87.8±1.12 kgha^{-1}) was observed. The available K content was found highest at location B9 (278.2±1.12 kgha^{-1}) lowest at B5 (100.6±1.14 kgha^{-1}) on the river bank whereas on non-flooded soil highest available K (567.6±1.14 kgha^{-1}) at NF5 and lowest at NF1 (155.6±1.14 kgha^{-1}) was recorded. The presence of higher nutrient level and organic carbon on the river bank site as compared to the non-flooded control site indicted that the former soil is more fertile (Fernandes, 1997). The flood water may carries lot of silts rich in nutrient and organic carbon and deposits on the river bank making it fertile soil. The presence of these parameters showed degree of mineralization due to high rate of loading and inclusion of organic pollutants (Prasad and Kumar, 2008).

DTPA-extractable heavy metal concentration in soil: The heavy metal concentration in soil of river bank and non-flooded area (control) was determined using standard procedures as in material methods. The values are presented in Table 4 and 5, there was wide variation in terms of heavy metal contents with reference to the sampling locations. The average DTPA-extractable Fe, Cu, Mn and Zn varied from 85.5 ±1.12 to 142.0±1.16 mgkg^{-1}, 0.46±0.04 to 1.64±0.15 mgkg^{-1}, 13.90 ±1.12 to 37.30±1.16 mgkg^{-1} and 0.67±0.03 to 1.54±0.16 mgkg^{-1}, respectively in the river bank soil. Whereas, in non-flooded soil it was varied from 12.2±1.14 to 102.5±1.16 mgkg^{-1}, 0.44±0.06 to 1.42±0.06 mgkg^{-1}, 8.05±1.13 to 18.95±1.15 mgkg^{-1}, and 0.41±0.09 to 1.13±0.07 mgkg^{-1}, respectively. The critical limits of deficiency of Fe, Cu, Mn and Zn are 4.5 mgkg^{-1}, 0.2 to 0.5 mgkg^{-1}, 2.0 mgkg^{-1} and 0.6 mgkg^{-1}, respectively. This may be due to the disposal of untreated domestic waste and sewage from the city. These are the major source of pollution in river (Mohan *et al*., 1996). Human and Industrial activities taking place along the river course be the reason for high contamination of all metals the sampling site. The critical limits of deficiency of Fe, Cu, Mn and Zn are 4.5 mgkg^{-1}, 0.2 to 0.5 mgkg^{-1}, 2.0 mgkg^{-1} and 0.6 mgkg^{-1}.The critical limit in soil for contamination as per permissible limit of Indian standard (Gupta *et al*., 2013) for Zn, Cd, Cu, Pb and Ni are 300-600 mgkg^{-1}, 3-6 mgkg^{-1}, 135-270 mgkg^{-1}, 250-500 mgkg^{-1} and 75-150 mgkg^{-1}. All these elements present in the soil of the study area are within the safe limit. The plant micronutrients such as Fe, Cu, Mn and Zn were present above the critical limit of deficiency indicating its higher fertility status with respect to these elements (Tables.4 and 5).

Cadmium: Highest Cd content was found at B10 and lowest was found at B3 among the river bank soil samples. Among non-flooded soil, highest Cd content was found at NF4 and lowest was found at NF5. Cd is a non essential elements that can causes kidney damage in human and negatively affect plant growth and development. This was above the probable effect level (Pascual-Barrera *et. al.*, 2004).

Nickel: Highest Ni content was found at B9 and lowest was found at B7 among the river bank soil, whereas highest Ni content was found at NF 10 and lowest was found at NF6 among non-flooded soil. Small amount Ni may be beneficial to plants and its plant toxicity varies in magnitude according to plant species. Ni poisoning in plants include dwarfing or repression of growth (Sharma, 2001).

Copper: Highest Cu content was found at B2 and lowest was found at B7 among the river bank soil, whereas highest Cu content was found at NF 10 and lowest was found at NF4 among non-flooded soil. The copper reaches the aquatic environment through dry and wet deposition which contaminate sediments and soil (Abound and Nandini, 2009).

Table 2. Some of the chemical parameter of the Kathajodi river bank soil.

S. N.	Location	pH (1:2)	EC (dSm^{-1})	O.C. (%)	Available N, P, K $kgha^{-1}$		
					N	P	K
1	B1	6.5±0.15	0.57±0.03	0.28±0.06	110.2±1.12	35.6±1.14	177.9±1.11
2	B2	6.4±0.11	0.26±0.04	0.32±0.02	100.5±1.15	39.5±1.15	222.3±1.13
3	B3	5.6±0.13	0.55±0.05	0.85±0.05	175.6±1.14	51.7±1.13	200.1±1.11
4	B4	5.4±0.14	0.46±0.04	0.57±0.03	213.4±1.14	26.2±1.12	255.7±1.13
5	B5	6.7±0.12	0.29±0.01	0.48±0.04	150.7±1.13	23.3±1.13	100.6±1.14
6	B6	6.7±0.13	0.35±0.05	0.75±0.05	125.4±1.14	33.4±1.14	200.1±1.11
7	B7	5.7±0.12	0.34±0.04	0.33±0.01	112.9±1.11	28.9±1.11	234.2±1.12
8	B8	6.9±0.11	0.38±0.02	0.67±0.03	100.3±1.13	29.4±1.16	256.0±1.15
9	B9	6.1±0.16	0.55±0.05	0.47±0.02	137.8±1.12	25.6±1.14	278.2±1.12
10	B10	6.8±0.13	0.49±0.01	0.25±0.05	137.3±1.13	41.7±1.13	207.9±1.11

Table 3. Chemical parameter of the non-flooded area soil (Control)

S. N.	Location	pH (1:2)	EC (dSm^{-1})	O.C. (%)	Available N, P, K $kgha^{-1}$		
					N	P	K
1	NF1	6.4±0.14	0.57±0.03	0.24±0.04	137.9±1.11	39.5±1.15	155.6±1.14
2	NF2	6.1±0.11	0.34±0.04	0.22±0.02	188.6±1.15	42.3±1.13	522.8±1.12
3	NF3	4.8±0.12	0.45±0.05	0.12±0.01	125.9±1.11	39.1±1.11	511.6±1.14
4	NF4	6.1±0.11	0.38±0.02	0.15±0.05	113.6±1.16	59.5±1.15	166.8±1.12
5	NF5	6.3±0.13	0.32±0.02	0.16±0.04	163.2±1.12	38.4±1.13	567.6±1.14
6	NF6	6.8±0.12	0.67±0.03	0.15±0.05	125.4±1.14	35.6±1.14	400.2±1.12
7	NF7	5.7±0.13	0.38±0.02	0.13±0.03	87.8±1.12	40.4±1.12	307.8±1.12
8	NF8	6.1±0.11	0.29±0.01	0.18±0.02	137.3±1.13	32.8±1.14	292.5±1.15
9	NF9	6.2±0.12	0.19±0.01	0.17±0.03	125.4±1.12	26.8±1.12	378.8±1.12
10	NF10	6.0±0.15	0.26±0.04	0.25±0.05	150.1±1.11	24.7±1.13	254.7±1.13

Table 4. DTPA extractable heavy metal content ($mgkg^{-1}$) in the soils of river bank.

S. N.	Location	Cd	Ni	Cu	Zn	Pb	Fe	Mn
1	B1	0.64±0.05	2.08±0.12	0.68±0.05	0.92±0.08	1.24±0.16	85.5±1.12	16.8±1.15
2	B2	0.47±0.09	2.24±0.14	0.46±0.04	0.85±0.05	1.12±0.13	109.5±1.16	17.2±1.14
3	B3	0.25±0.03	3.18±0.12	1.18±0.12	1.54±0.16	1.26±0.14	128.0±1.14	24.5±1.16
4	B4	0.46±0.04	3.56±0.15	1.26±0.14	0.79±0.01	3.09±0.11	120.5±1.16	25.6±1.13
5	B5	0.68±0.08	2.98±0.18	0.58±0.05	1.12±0.18	2.26±0.12	103.5±1.17	37.3±1.16
6	B6	0.66±0.06	3.76±0.11	1.19±0.13	1.23±0.17	4.11±0.14	136.5±1.13	28.2±1.14
7	B7	0.26±0.02	3.60±0.16	1.66±0.15	0.67±0.03	2.61±0.14	129.0±1.15	23.7±1.15
8	B8	0.72±0.05	3.45±0.13	0.85±0.05	0.75±0.05	1.35±0.15	101.8±1.12	13.9±1.12
9	B9	0.31±0.01	3.85±0.15	1.63±0.17	1.21±0.09	2.68±0.12	142.0±1.16	16.4±1.17
10	B10	0.67±0.07	2.98±0.15	0.82±0.08	0.89±0.01	1.98±0.12	122.5±1.18	17.4±1.13

Table 5. DTPA extractable heavy metal content ($mgkg^{-1}$) in the soils of non-flooded area.

S. N.	Location	Cd	Ni	Cu	Zn	Pb	Fe	Mn
1	NF1	0.31±0.02	2.12±0.02	1.42±0.06	0.64±0.06	1.07±0.08	17.6±1.12	18.5±1.15
2	NF2	0.46±0.05	2.06±0.06	0.66±0.02	0.44±0.06	1.19±0.01	17.3±1.15	08.2±1.16
3	NF3	0.24±0.03	3.02±0.05	0.96±0.04	1.03±0.17	1.08±0.02	102.5±1.16	08.1±1.13
4	NF4	0.52±0.07	3.01±0.07	0.44±0.06	0.47±0.03	1.22±0.03	12.2±1.14	13.2±1.12
5	NF5	0.14±0.06	2.07±0.03	1.15±0.05	1.13±0.07	1.28±0.06	13.6±1.12	12.3±1.17
6	NF6	0.42±0.01	1.52±0.08	1.13±0.07	0.41±0.09	1.37±0.04	59.8±1.16	15.9±1.14
7	NF7	0.34±0.08	2.04±0.05	0.80±0.05	0.80±0.05	1.01±0.01	43.3±1.17	15.9±1.16
8	NF8	0.51±0.04	3.02±0.04	1.32±0.12	0.76±0.04	1.34±0.09	44.9±1.14	12.5±1.15
9	NF9	0.21±0.08	2.43±0.06	1.15±0.15	0.52±0.08	1.23±0.03	65.4±1.12	15.6±1.11
10	NF10	0.31±0.05	3.34±0.01	0.46±0.14	0.95±0.05	1.12±0.05	48.2±1.15	11.2±1.12

Zinc: Highest Zn content was found at B3 and lowest was found at B7 among the river bank soil, whereas highest Ni content was found at NF 10 and lowest was found at NF6 among non-flooded soil. This may be due to effluent and urban sewage (Abbasi *et.al.*, 1998).

Lead: Highest Pb content was found at B6 and lowest was found at B2 among the river bank soil, whereas highest Pb content was found at NF 6 and lowest was found at NF2 among non-flooded soil. Location B6 and NF6 are close to the highways and influenced by the automobile emission hence the Pb content is obviously higher in these location and also due to other activity near the river (Abbasi *et. al.*, 1998). Pb toxicity may cause amnesia and accelerating red blood cell destruction in human being (Anglin-Brown *et. al.*, 1995).

Iron: Highest Fe content was found at B9 and lowest was found at B1 among the river bank soil, whereas

Table 6. Heavy metal content (mgkg^{-1}) in the grasses of river bank (B)

S.N.	Location	Grass	Cd	Ni	Cu	Zn	Pb	Fe	Mn
1	B1								
		Cynodon	0.45±0.05	1.32±0.18	12.5±1.13	22.5±1.11	1.32±0.18	53.2±1.13	30.6±1.12
		Panicum	0.62±0.03	1.45±0.13	14.7±1.15	16.2±1.14	1.08±0.12	78.4±1.16	25.2±1.14
		Digitaria	0.12±0.06	1.32±0.16	10.2±1.14	14.9±1.13	1.12±0.13	59.5±1.15	68.7±1.13
		Sporobolus	0.35±0.03	1.05±0.11	11.5±1.18	17.3±1.17	1.25±0.15	72.8±1.12	42.5±1.12
		Iseilema	0.55±0.04	1.85±0.15	12.4±1.16	19.5±1.15	1.45±0.11	98.5±1.15	85.8±1.15
2	B2								
		Cynodon	0.23±0.03	1.48±0.12	15.7±1.13	16.3±1.17	1.25±0.13	63.2±1.14	13.5±1.11
		Panicum	0.39±0.02	1.15±0.15	15.6±1.15	38.6±1.14	1.05±0.15	99.2±1.12	15.9±1.13
		Digitaria	0.22±0.04	1.35±0.14	10.9±1.13	34.2±1.12	1.10±0.12	124.0±1.13	16.3±1.16
		Sporobolus	0.35±0.05	1.42±0.16	10.0±1.11	28.5±1.15	1.14±0.16	112.0±1.14	15.5±1.15
		Iseilema	0.26±0.08	1.25±0.11	12.5±1.14	22.5±1.13	1.35±0.11	127.5±1.15	17.5±1.12
3	B3								
		Cynodon	0.63±0.03	1.42±0.11	12.5±1.11	27.4±1.14	1.45±0.11	87.7±1.13	22.5±1.15
		Panicum	0.25±0.05	1.52±0.13	14.7±1.15	25.6±1.17	1.55±0.13	92.5±1.15	26.5±1.12
		Digitaria	0.72±0.03	1.25±0.16	16.1±1.13	37.2±1.13	1.25±0.12	145.2±1.13	23.2±1.11
		Sporobolus	0.31±0.06	2.34±0.13	10.5±1.16	30.6±1.14	1.35±0.15	122.4±1.12	39.5±1.13
		Iseilema	0.78±0.04	1.26±0.12	11.3±1.15	41.1±1.17	1.65±0.14	136.5±1.14	46.8±1.11
4	B4								
		Cynodon	0.38±0.02	1.15±0.11	16.5±1.15	32.5±1.17	1.35±0.14	129.5±1.15	52.2±1.16
		Panicum	0.16±0.06	1.08±0.12	15.1±1.11	37.3±1.14	1.45±0.12	152.2±1.12	33.5±1.11
		Digitaria	0.25±0.05	1.01±0.13	19.4±1.16	27.4±1.11	1.25±0.16	135.6±1.14	25.4±1.13
		Sporobolus	0.26±0.01	1.25±0.13	18.2±1.13	25.6±1.15	1.42±0.11	145.9±1.13	22.3±1.15
		Iseilema	0.22±0.03	1.48±0.12	13.3±1.15	25.5±1.13	1.65±0.15	138.5±1.11	26.7±1.12
5	B5								
		Cynodon	0.32±0.03	1.38±0.12	10.6±1.12	29.5±1.15	1.45±0.11	143.1±1.11	24.7±1.13
		Panicum	0.18±0.02	1.25±0.15	18.4±1.16	25.2±1.14	1.32±0.12	121.5±1.15	32.8±1.15
		Digitaria	0.14±0.07	1.18±0.16	10.8±1.15	28.3±1.17	1.62±0.13	157.7±1.17	24.8±1.14
		Sporobolus	0.24±0.05	1.22±0.13	16.6±1.17	15.8±1.12	1.30±0.15	124.6±1.14	30.2±1.12
		Iseilema	0.29±0.04	1.35±0.11	15.0±1.11	14.2±1.18	1.28±0.12	162.8±1.12	23.4±1.16
6	B6								
		Cynodon	0.84±0.02	1.45±0.15	19.6±1.14	42.5±1.15	1.32±0.12	173.0±1.15	77.0±1.13
		Panicum	0.46±0.03	1.28±0.11	18.3±1.13	47.7±1.13	1.42±0.15	174.2±1.12	36.4±1.12
		Digitaria	0.32±0.08	1.35±0.14	21.4±1.16	46.2±1.15	1.36±0.16	156.9±1.16	74.5±1.15
		Sporobolus	0.50±0.04	2.52±0.12	20.0±1.15	36.5±1.14	1.54±0.14	182.3±1.13	79.6±1.14
		Iseilema	0.85±0.05	3.55±0.13	20.1±1.12	52.9±1.11	1.57±0.12	141.6±1.14	49.6±1.16
7	B7								
		Cynodon	0.55±0.05	1.88±0.12	13.0±1.16	36.3±1.13	1.85±0.13	167.5±1.11	22.3±1.15
		Panicum	0.35±0.01	1.52±0.14	12.5±1.15	45.5±1.15	1.62±0.12	192.5±1.15	13.6±1.14
		Digitaria	0.58±0.04	1.45±0.15	18.4±1.13	26.8±1.14	1.65±0.15	172.6±1.14	25.2±1.12
		Sporobolus	0.63±0.02	1.62±0.13	14.2±1.14	36.1±1.11	1.74±0.14	163.9±1.16	15.6±1.12
		Iseilema	0.72±0.03	1.78±0.12	16.8±1.12	47.2±1.12	1.89±0.11	192.2±1.12	20.3±1.13

Contd.

Contd.

8	B8	Cynodon	0.45±0.01	1.65±0.11	15.5±1.15	25.7±1.13	1.62±0.14	125.0±1.11	29.2±1.14
		Panicum	0.42±0.02	1.45±0.15	15.4±1.16	28.2±1.14	1.35±0.13	162.5±1.13	12.3±1.11
		Digitaria	0.55±0.05	1.55±0.12	13.2±1.14	26.8±1.12	1.42±0.12	152.8±1.14	22.7±1.13
		Sporobolus	0.58±0.04	1.58±0.14	15.5±1.12	28.9±1.11	1.55±0.15	165.5±1.15	32.2±1.13
		Iseilema	0.67±0.03	1.35±0.13	12.7±1.13	28.5±1.15	1.52±0.12	135.2±1.12	22.8±1.12
9	B9	Cynodon	0.77±0.02	2.72±0.13	34.4±1.13	35.3±1.14	1.84±0.16	162.5±1.17	17.5±1.11
		Panicum	0.62±0.05	1.78±0.11	13.5±1.15	34.4±1.14	1.45±0.13	157.4±1.13	17.4±1.14
		Digitaria	0.69±0.04	1.88±0.12	12.2±1.12	35.5±1.14	1.62±0.14	159.2±1.12	23.5±1.15
		Sporobolus	0.75±0.03	1.65±0.15	11.2±1.14	36.2±1.14	1.75±0.15	160.5±1.15	72.0±1.13
		Iseilema	0.79±0.01	2.15±0.16	11.9±1.11	34.1±1.14	1.82±0.12	168.6±1.14	40.8±1.12
10	B10	Cynodon	0.56±0.01	1.75±0.11	25.6±1.16	34.4±1.14	1.65±0.16	144.2±1.16	21.1±1.15
		Panicum	0.45±0.05	1.65±0.14	11.3±1.13	19.2±1.14	1.45±0.13	103.9±1.12	14.6±1.16
		Digitaria	0.38±0.04	1.45±0.12	17.2±1.12	18.5±1.14	1.35±0.15	148.0±1.15	24.0±1.12
		Sporobolus	0.35±0.03	1.55±0.15	24.4±1.14	26.2±1.14	1.48±0.14	135.9±1.13	55.5±1.14
		Iseilema	0.48±0.02	1.85±0.13	16.5±1.15	21.7±1.14	1.52±0.12	126.9±1.11	29.1±1.19

highest Fe content was found at NF1 and lowest was found at NF3 among non-flooded soil.

Manganese: Highest Mn content was found at B5 and lowest was found at B8 among the river bank soil, whereas highest Mn content was found at NF1 and lowest was found at NF3 among non-flooded soil. The metal concentrations measured in soil at both the sites i.e. river bank and non flooded generally decreased in the order; Fe > Mn > Ni> Pb>Cu>Zn>Cd. although this pattern varied moderately between Ni and Pb, there was no statistical difference in DTPA extractable heavy metal content *viz.* Cu, Zn, Pb, Ni and Cd in the soils of river bank and non flooded. However soil of river bank showed higher available Fe and Mn content. The soils on the river bank situated in the low lying area subjected to flooding by the river water and remained water logging for a considerable period of time, under reducing environment the reduced species of Fe and Mn are always higher than the soil remained dry and aerated. Additionally flood water might have carried out Fe and Mn bearing materials from the upper catchment of Mahanadi and deposited on the river bank. The pattern of variation of Fe and Mn concentration in the soils of river bank as well as in non flooded soil was similar from Naraj to Komashasana along the river stream. Moreover the Mn concentration was reduced at B8, B9 and B10 located on the river bank towards downstream indicating that sewage effluents may not be a source of Fe and Mn deposit on the river bank (Barik, 2013).

Heavy metal concentration in plants: Five grasses namely *C. dactylon* (Dub grass), *P. repens* (Regeda), *D. sanguinalis* (Kankadaghasa/Crab grass), *S. diander* (Jhari grass) and *I. laxum* (Panda Suali grass) naturally grown on both the river bank soil as in non flooded soil and mostly used for cattle feeding in the locality were collected as representative vegetation samples and the heavy metal content was determined by using standard procedures as laid down in materials and methods. The values are presented in table 6 and 7. It was found that most of the heavy metal concentration in different grass species grown on the river bank were statistical at par with those grown on non-flooded area. There was wide variation in terms of heavy metal contents with reference to the location of the samples. Lokeshwari and Chandrappa, (2006) has reported more heavy metal accumulation in plants grown in the sewage irrigated soil near the Bellandur lake, Bangalore city, Karnataka are agreement with this. Among the species there was a wide variation in the heavy metal accumulation. *P. repens* has the highest quantity of Fe content, *S. diander* has highest quantity of Cu and *I. laxum* has highest quantities of Mn (85±1.15) $mgkg^{-1}$, Zn (94.1±1.14) $mgkg^{-1}$,Cd (0.85±0.05) $mgkg^{-1}$, Ni (3.55±0.13) $mgkg^{-1}$ and Pb (1.89±0.11) $mgkg^{-1}$. This indicates *I. laxum* is a good accumulator of heavy metals as reported by Lokeshwari and Chandrapa (2006). The accumulation of particular metals is compared with the presence of

Table 7. Heavy metal content (mgkg^{-1}) in the grasses of non-flooded areas .

S. N.	Location	Grass	Cd	Ni	Cu	Zn	Pb	Fe	Mn
1	NF1								
		Cynodon	0.42±0.02	1.25±0.11	11.6±1.16	20.2±1.14	1.12±0.14	51.8±1.15	17.5±1.11
		Panicum	0.75±0.05	1.24±0.12	11.8±1.11	17.5±1.15	1.18±0.13	71.2±1.12	15.0±1.13
		Digitaria	0.56±0.01	1.35±0.13	11.2±1.15	14.9±1.11	1.24±0.12	79.5±1.13	23.9±1.14
		Sporobolus	0.38±0.04	1.95±0.11	10.1±1.12	16.4±1.13	1.15±0.15	78.2±1.14	15.8±1.12
		Iseilema	0.52±0.03	1.45±0.15	11.5±1.13	18.8±1.12	1.45±0.11	92.5±1.12	18.9±1.15
2	NF2								
		Cynodon	0.30±0.05	1.38±0.16	18.9±1.14	26.3±1.13	1.18±0.13	53.7±1.15	25.8±1.13
		Panicum	0.38±0.03	1.05±0.15	14.7±1.16	29.6±1.16	1.02±0.15	89.2±1.12	27.7±1.15
		Digitaria	0.25±0.05	1.24±0.11	10.2±1.13	32.5±1.14	1.08±0.12	132.0±1.14	23.8±1.12
		Sporobolus	0.34±0.04	1.35±0.14	11.5±1.12	26.2±1.12	1.11±0.11	104.0±1.12	22.5±1.13
		Iseilema	0.22±0.06	1.22±0.12	14.5±1.56	25.5±1.15	1.24±0.14	107.5±1.15	32.8±1.14
3	NF3								
		Cynodon	0.18±0.03	1.41±0.11	10.5±1.11	26.4±1.12	1.38±0.15	82.5±1.13	18.6±1.14
		Panicum	0.15±0.05	1.32±0.14	12.5±1.12	23.5±1.14	1.21±0.14	81.2±1.12	28.5±1.11
		Digitaria	0.12±0.04	1.22±0.12	15.1±1.15	34.8±1.13	1.18±0.11	105.8±1.14	17.5±1.15
		Sporobolus	0.18±0.02	1.32±0.15	20.2±1.13	30.2±1.11	1.27±0.13	102.5±1.13	29.7±1.12
		Iseilema	0.16±0.06	1.23±0.13	16.3±1.14	20.6±1.16	1.56±0.12	132.6±1.16	28.3±1.13
4	NF4								
		Cynodon	0.32±0.05	1.11±0.11	14.4±1.12	20.7±1.13	1.34±0.11	121.4±1.13	16.2±1.12
		Panicum	0.11±0.01	1.02±0.14	14.6±1.14	27.8±1.12	1.12±0.12	146.5±1.14	19.2±1.11
		Digitaria	0.22±0.04	1.01±0.11	17.3±1.13	25.2±1.11	1.24±0.13	125.2±1.12	25.6±1.13
		Sporobolus	0.25±0.05	1.22±0.12	16.1±1.11	22.5±1.15	1.41±0.11	123.5±1.15	30.2±1.12
		Iseilema	0.20±0.02	1.47±0.15	12.2±1.14	22.4±1.14	1.26±0.14	124.2±1.11	25.4±1.14
5	NF5								
		Cynodon	0.25±0.05	1.22±0.13	22.2±1.13	38.5±1.15	1.42±0.15	133.1±1.15	25.8±1.12
		Panicum	0.16±0.06	1.12±0.15	15.2±1.11	14.2±1.13	1.28±0.11	111.5±1.11	17.2±1.15
		Digitaria	0.12±0.02	1.12±0.12	18.4±1.12	11.8±1.11	1.24±0.14	137.7±1.15	42.2±1.13
		Sporobolus	0.21±0.01	1.01±0.14	14.6±1.16	24.2±1.14	1.27±0.12	114.6±1.14	21.3±1.11
		Iseilema	0.22±0.03	1.32±0.12	11.2±1.14	26.4±1.12	1.24±0.13	172.8±1.12	35.0±1.14
6	NF6								
		Cynodon	0.41±0.01	1.45±0.15	13.4±1.14	28.2±1.14	1.26±0.14	163.0±1.15	37.5±1.11
		Panicum	0.42±0.06	1.24±0.11	18.3±1.15	16.7±1.13	1.24±0.13	152.4±1.13	24.8±1.14
		Digitaria	0.29±0.05	1.32±0.13	11.6±1.13	22.2±1.12	1.28±0.14	145.9±1.11	28.5±1.13
		Sporobolus	0.32±0.02	1.53±0.12	10.2±1.11	32.5±1.13	1.21±0.11	171.3±1.12	39.2±1.12
		Iseilema	0.52±0.02	1.52±0.14	10.2±1.12	21.9±1.11	1.52±0.12	132.6±1.14	29.5±1.15
7	NF7								
		Cynodon	0.45±0.05	1.36±0.11	11.2±1.12	12.3±1.11	1.18±0.12	152.5±1.15	16.8±1.13
		Panicum	0.32±0.01	1.58±0.14	11.5±1.13	12.4±1.12	1.08±0.14	167.4±1.13	22.6±1.14
		Digitaria	0.53±0.02	1.35±0.15	16.4±1.14	13.6±1.14	1.35±0.11	170.8±1.12	18.7±1.12
		Sporobolus	0.58±0.06	1.64±0.14	13.1±1.11	21.3±1.13	1.05±0.15	158.6±1.14	25.6±1.14
		Iseilema	0.64±0.03	1.72±0.12	14.8±1.12	27.5±1.15	1.32±0.12	145.4±1.12	24.5±1.15

Contd.

Contd.

8	NF8	Cynodon	0.45±0.05	1.65±0.15	15.5±1.15	25.7±1.15	1.02±0.11	118.0±1.11	17.9±1.11
		Panicum	0.42±0.03	1.45±0.11	15.4±1.14	18.2±1.12	1.05±0.15	149.5±1.15	18.0±1.15
		Digitaria	0.55±0.05	1.55±0.14	13.2±1.11	16.8±1.14	1.12±0.13	146.4±1.14	12.7±1.12
		Sporobolus	0.58±0.04	1.58±0.12	15.5±1.13	28.9±1.11	1.25±0.14	132.2±1.13	15.7±1.13
		Iseilema	0.67±0.02	1.35±0.13	12.7±1.12	38.5±1.12	1.22±0.12	128.5±1.12	28.5±1.15
9	NF9	Cynodon	0.68±0.05	2.32±0.14	28.5±1.15	35.5±1.12	1.22±0.12	158.5±1.15	34.9±1.15
		Panicum	0.58±0.01	1.62±0.13	21.4±1.13	14.2±1.13	1.03±0.15	148.4±1.11	18.8±1.12
		Digitaria	0.62±0.04	1.75±0.15	20.1±1.11	35.4±1.14	1.28±0.12	154.2±1.12	25.6±1.14
		Sporobolus	0.72±0.02	1.49±0.11	29.2±1.12	26.3±1.12	1.04±0.14	162.5±1.13	15.6±1.13
		Iseilema	0.65±0.05	2.18±0.12	18.6±1.14	34.1±1.11	1.27±0.13	165.6±1.14	17.8±1.12
10	NF10	Cynodon	0.47±0.03	1.72±0.15	22.1±1.11	32.4±1.14	1.03±0.13	143.2±1.13	25.9±1.11
		Panicum	0.39±0.01	1.64±0.14	10.3±1.13	19.2±1.12	1.12±0.16	101.9±1.15	29.1±1.12
		Digitaria	0.32±0.02	1.42±0.12	16.4±1.14	17.3±1.13	1.05±0.15	135.0±1.11	26.7±1.15
		Sporobolus	0.35±0.05	1.54±0.13	18.5±1.15	22.5±1.15	1.42±0.14	131.9±1.14	38.7±1.12
		Iseilema	0.42±0.04	1.82±0.12	15.2±1.12	21.6±1.14	1.18±0.12	125.9±1.12	28.8±1.13

that metal in soil.

Cadmium: The Cd content in *C. dactylon*, *P. repens*, *D. sanguinalis*, *S. diander* and *I. laxum* in the river bank were varied between 0.23 to 0.84 $mgkg^{-1}$, 0.16±0.06 to 0.62±0.05 $mgkg^{-1}$, 0.12±0.02 to 0.72±0.02 $mgkg^{-1}$, 0.24±0.05 to 0.75±0.03 $mgkg^{-1}$ and 0.22±0.03 to 0.85 $mgkg^{-1}$ respectively. Whereas non-flooded soil, the Cd content varied between 0.18±0.02 to 0.68±0.05 $mgkg^{-1}$, 0.11±0.01 to 0.75±0.05 $mgkg^{-1}$, 0.12±0.02 to 0.62±0.04 $mgkg^{-1}$, 0.18±0.02 to 0.72±0.02 $mgkg^{-1}$ and 0.16±0.06 to 0.67±0.02 $mgkg^{-1}$, respectively. Grass species studied, highest concentration of Cd was found in *I. laxum* at both river bank non -flooded soil. This may be due to in plants Cd accumulates in several tissue and complexes with amino acids, organic acids and other major parts of plant metabolism (Benavides *et. al.*, 2005).

Nickel: The Ni content in *C. dactylon*, *P. repens*, *D. sanguinalis*, *S. diander* and *I. laxum* in the river bank are varied between 1.15±0.11 to 2.72±0.13 $mgkg^{-1}$, 1.08±0.12 to 1.78±0.11 $mgkg^{-1}$, 1.01±0.13 to 1.88±0.12 $mgkg^{-1}$, 1.05±0.11 to 2.52±0.12 $mgkg^{-1}$ and 1.25±0.11 to 3.55±0.13 $mgkg^{-1}$ respectively. Whereas in non-flooded soil, the Ni content varied between 1.11±0.11 to 2.32±0.14 $mgkg^{-1}$, 1.02±0.14 to 1.64±0.14$mgkg^{-1}$, 1.01±0.11 to 1.75±0.15 $mgkg^{-1}$, 1.01±0.14 to 1.95±0.11 $mgkg^{-1}$ and 1.22±0.12 $mgkg^{-1}$ to 2.18±0.12 $mgkg^{-1}$, respectively. Grass species studied, highest concentration of Ni was found in *I. laxum* at river bank soil and *C. dactylon* in non flooded soil. This may causes plant toxicity by dwarfing or repressing of growth (Sharma, 2001).

Copper: The Cu content in *C. dactylon*, *P. repens*, *D. sanguinalis*, *S. diander* and *I. laxum*in the river bank are varied between 12.5±1.13 to 34.4±1.13 $mgkg^{-1}$, 11.3±1.13 to 18.4±1.16 $mgkg^{-1}$, 10.2±1.14 to 21.4±1.16 $mgkg^{-1}$, 10.0±1.11 to 24.4±1.14 $mgkg^{-1}$ and 11.3±1.15 to 20.1±1.12 $mgkg^{-1}$ respectively. Whereas in non-flooded soil, the Cu content varied between 10.5±1.11 to 28.5±1.15 $mgkg^{-1}$, 10.3±1.13 to 21.4±1.13 $mgkg^{-1}$,10.2±1.13 to 20.1±1.11 $mgkg^{-1}$, 10.1±0.12 to 29.2±1.12 $mgkg^{-1}$ and 10.2±1.12 $mgkg^{-1}$ to 18.6±1.14 $mgkg^{-1}$. The grass species studied, highest concentration of Cu was found in *C. dactylon* at the river bank and non flooded soil. Similar findings are also reported by Abbassi *et al*. (1998).

Zinc: The Zn content in *C. dactylon*, *P. repens*, *D. sanguinalis*, *S. diander* and *I. laxum*in the river bank are varied between 16.3±1.17 to 42.5±1.15 $mgkg^{-1}$, 16.2±1.14 to 47.7±1.13 $mgkg^{-1}$, 14.9±1.13 to 46.2±1.15 $mgkg^{-1}$, 15.8±1.12 to 36.5±1.14 $mgkg^{-1}$ and 14.2±1.18 to 52.9±1.11 $mgkg^{-1}$ respectively. Whereas non-flooded soil, the Cu content varied between 12.3±1.11 to 38.5±1.15 $mgkg^{-1}$, 12.4±1.12 to 29.6±1.16 $mgkg^{-1}$, 11.8±1.11 to 35.4±1.14 $mgkg^{-1}$, $mgkg^{-1}$, 16.4±1.13 to 32.5±1.13 $mgkg^{-1}$ and 18.8±1.12 to 38.5±1.15 $mgkg^{-1}$, respectively. Grass species studied, highest concentration of Zn was found in *I. laxum* at the river bank.

Table 8 . Correlation matrix among soil properties and metal content in the grass species.

Particulars	pH	EC	OC	N	P	K
C. dactylon						
Cd	0.21	0.11	0.49*	-0.07	-0.25	-0.33
Ni	0.06	-0.11	0.05	-0.17	-0.49*	0.03
Cu	0.27	-0.44*	-0.12	0.20	-0.16	0.27
Zn	0.11	-0.13	0.30	0.39	-0.45*	0.17
Pb	0.04	0.23	0.37	-0.09	-0.13	-0.13
Fe	0.15	-0.18	0.10	-0.13	-0.42	-0.04
Mn	0.20	0.01	0.48*	0.24	-0.30	-0.04
P. repens						
Cd	0.43	0.25	-0.03	-0.28	-0.27	-0.22
Ni	-0.01	0.05	0.09	-0.30	-0.36	-0.18
Cu	0.37	-0.23	0.20	0.03	-0.21	0.07
Zn	-0.08	-0.12	0.57*	0.08	-0.13	-0.26
Pb	-0.06	0.33	0.65*	0.24	-0.15	-0.26
Fe	0.08	-0.20	0.19	-0.27	-0.32	-0.10
Mn	-0.23	0.01	0.30	0.45*	-0.15	0.00
D. sanguinalis						
Cd	-0.05	0.09	0.30	-0.12	-0.09	-0.21
Ni	0.22	-0.08	0.02	-0.36	-0.47*	-0.03
Cu	-0.27	-0.31	0.15	0.10	0.00	0.07
Zn	-0.14	-0.13	0.56*	0.10	-0.04	-0.03
Pb	0.15	0.08	0.34	-0.17	-0.36	-0.31
Fe	0.04	-0.36	0.24	-0.02	-0.27	0.06
Mn	0.35	0.14	0.26	-0.06	-0.06	-0.13
S. diander						
Cd	0.13	-0.19	0.10	-0.40	-0.41	-0.10
Ni	0.06	0.17	0.59*	-0.05	0.10	-0.32
Cu	0.14	-0.60*	0.20	0.14	-0.40	-0.18
Zn	-0.14	0.07	0.32	-0.06	-0.09	0.24
Pb	0.03	0.15	0.49*	0.01	-0.25	-0.31
Fe	0.14	-0.15	0.29	-0.17	-0.37	0.00
Mn	0.29	0.37	0.45	-0.04	-0.06	-0.22
I.laxum						
Cd	0.22	0.17	0.44	-0.31	-0.22	-0.32
Ni	0.26	-0.07	0.29	-0.20	-0.27	-0.23
Cu	-0.09	-0.50*	0.06	-0.13	-0.30	-0.02
Zn	-0.11	-0.17	0.46*	-0.04	-0.08	-0.03
Pb	-0.21	0.53*	0.49*	0.01	-0.15	-0.19
Fe	-0.14	-0.35	0.13	-0.04	-0.41	0.15
MN	0.07	0.22	0.10	0.04	0.03	-0.08

* Significant at $p < 0.05$

Similar findings are also reported by Pascal-Burresa *et al*., (2004).

Lead: The Pb content in *C. dactylon*, *P. repens*, *D. sanguinalis*, *S. diander* and *I. laxum* at river bank were varied between 1.25±0.13 to 1.85±0.13 mgkg^{-1}, 1.05±0.15 to 1.62±0.12 mgkg^{-1}, 1.14±0.16 mgkg^{-1}, 1.14±0.16 to 1.75±0.15 mgkg^{-1} and 1.28±0.12 to 1.89±0.11 mgkg^{-1} respectively. Grass species studied, highest concentration of Zn was found in *I. laxum* at the river bank as well as non-flooded soil. It was in agreement with critical range of Pb as described by Nirmal *et al*. (2006).

Iron: The Fe content in *C. dactylon*, *P. repens*, *D. sanguinalis*, *S. diander* and *I. laxum* are varied between 53.2±1.13 mgkg^{-1} to 173.0±1.15 mgkg^{-1}, 78.4±1.16 to 192.1±1.15 mgkg^{-1}, 59.5±1.15 mgkg^{-1} to 172.6±1.14 mgkg^{-1}, 72.8±1.12 to 182.3±1.13 mgkg^{-1} and 98.5±1.15 to 192.2±1.12 mgkg^{-1} respectively. Grass species studied, highest concentration of Fe was found in *I. laxum* at river bank as well as non-flooded soil. The river bank and non-flooded soil had higher Fe concentration. This may be due to the heavy metal accumulation in the river bank by the flood during rainy season (Bhargava *et. al*., 2009).

Manganese: The Mn content in *C. dactylon*, *P. repens, D. sanguinalis, S. diander and I. laxum* are varied between 13.5±1.11 to 77.0±1.13 mgkg^{-1}, 12.3±1.11 to 36.4±1.12 mgkg^{-1}, 16.3±1.16 to 74.5±1.15 mgkg^{-1},

Table 9. Bio Concentration Factors ($mg/kg_{dwt.plant}/mg/kg_{dwt.soil}$) of heavy metals of river bank .

S. N.	Location	Grass	Cd	Ni	Cu	Zn	Pb	Fe	Mn
1	B1								
		Cynodon	0.70	0.63	18.3	24.4	1.06	0.62	1.81
		Panicum	0.96	0.69	21.6	17.6	0.87	0.91	1.50
		Digitaria	0.35	0.63	15.0	16.1	0.90	0.69	4.10
		Sporobolus	0.54	0.50	16.9	18.8	1.01	0.85	2.50
		Iseilema	0.85	0.88	18.2	21.2	1.16	1.15	5.10
2	B2								
		Cynodon	0.48	0.66	34.1	19.1	1.10	0.57	0.78
		Panicum	0.82	0.51	33.9	45.5	0.93	0.90	0.92
		Digitaria	0.46	0.60	23.6	40.2	0.98	1.13	0.94
		Sporobolus	0.74	0.63	21.7	33.5	1.01	1.02	0.90
		Iseilema	0.55	0.55	27.1	26.4	1.20	1.16	1.01
3	B3								
		Cynodon	2.50	0.44	10.6	17.8	1.15	0.68	0.91
		Panicum	1.00	0.70	12.4	16.6	1.23	0.72	1.20
		Digitaria	0.48	0.39	13.6	24.1	0.99	1.13	0.94
		Sporobolus	0.84	0.73	8.9	19.8	1.07	0.95	1.61
		Iseilema	0.91	0.39	9.6	26.6	1.30	1.06	1.91
4	B4								
		Cynodon	0.82	0.32	13.1	41.1	4.40	1.07	2.03
		Panicum	0.34	0.30	11.9	47.2	0.50	1.26	1.31
		Digitaria	0.54	0.28	15.4	34.6	0.40	1.12	0.99
		Sporobolus	0.56	0.35	14.4	32.4	0.40	1.21	0.87
		Iseilema	0.47	0.41	10.5	32.3	0.50	1.14	1.04
5	B5								
		Cynodon	0.47	0.46	18.3	26.3	0.64	1.38	0.66
		Panicum	0.26	0.41	31.7	22.5	0.58	1.17	0.87
		Digitaria	0.20	0.39	18.6	25.3	0.71	1.52	0.66
		Sporobolus	0.35	0.40	28.6	14.1	0.57	1.20	0.80
		Iseilema	0.42	0.45	25.8	12.6	0.56	1.57	0.62
6	B6								
		Cynodon	1.27	0.38	16.5	34.5	0.32	1.26	2.73
		Panicum	0.69	0.34	15.4	38.7	0.34	1.27	1.29
		Digitaria	0.48	0.35	18.0	37.5	0.33	1.14	2.64
		Sporobolus	0.75	0.67	16.8	29.6	0.37	1.33	2.82
		Iseilema	1.28	0.94	25.2	43.0	0.38	1.03	1.75
7	B7								
		Cynodon	2.11	0.52	7.8	54.1	1.04	1.29	0.94
		Panicum	1.34	0.42	7.5	67.9	1.10	1.49	0.57
		Digitaria	2.23	0.40	11.1	40.0	1.15	1.33	1.06
		Sporobolus	2.42	0.45	8.5	53.9	1.07	1.27	0.65
		Iseilema	2.70	0.49	10.1	70.4	1.35	1.48	0.85
8	B8								
		Cynodon	0.62	0.47	18.2	34.2	0.99	1.22	2.10
		Panicum	0.58	0.42	18.1	37.6	0.85	1.59	0.88
		Digitaria	0.76	0.44	15.5	35.7	0.90	1.50	1.63
		Sporobolus	0.80	0.45	18.2	38.5	0.93	1.62	2.31
		Iseilema	1.05	0.39	14.9	38.0	1.04	1.32	1.64
9	B9								
		Cynodon	2.5	0.70	8.8	29.1	1.27	1.14	1.06
		Panicum	2.0	0.46	8.3	28.4	1.12	1.10	1.06
		Digitaria	2.2	0.48	7.5	29.3	1.09	1.12	1.43
		Sporobolus	2.4	0.42	6.9	29.9	1.17	1.13	4.39
		Iseilema	2.5	0.56	7.3	28.2	1.44	1.18	2.48
10	B10								
		Cynodon	0.83	0.58	31.2	38.6		1.17	1.20
		Panicum	0.67	0.55	13.7	21.5	0.75	0.84	0.83
		Digitaria	0.56	0.48	21.0	20.8	0.68	1.20	1.37
		Sporobolus	0.52	0.52	17.5	29.4	0.74	1.10	3.17
		Iseilema	0.71	0.62	20.1	24.3	0.76	1.03	1.67

Table 10. Bio Concentration Factors ($mg/kg_{dwt.plant}/mg/kg_{dwt.soil}$) of heavy metals of non-flooded area

S. N.	Location	Grass	Cd	Ni	Cu	Zn	Pb	Fe	Mn
1	NF1								
		Cynodon	1.35	0.58	8.16	31.5	1.04	2.94	0.94
		Panicum	2.41	0.58	8.35	27.3	1.10	4.04	0.81
		Digitaria	1.80	0.63	7.90	23.3	1.15	4.5	1.20
		Sporobolus	1.20	0.91	7.11	25.6	1.07	4.4	0.85
		Iseilema	1.67	0.68	8.10	29.3	1.35	5.2	1.02
2	NF2								
		Cynodon	0.65	0.66	28.6	59.7	0.99	3.1	3.14
		Panicum	0.82	0.49	22.3	67.2	0.85	5.1	3.37
		Digitaria	0.54	0.60	15.4	73.8	0.90	7.6	2.90
		Sporobolus	0.73	0.65	17.4	59.5	0.93	6.01	2.74
		Iseilema	0.47	0.59	21.9	57.9	1.04	6.2	4.00
3	NF3								
		Cynodon	0.75	0.46	10.9	25.6	1.27	0.8	2.2
		Panicum	0.62	0.43	13.0	22.8	1.12	0.79	3.5
		Digitaria	0.50	0.40	15.7	31.5	1.09	1.03	2.1
		Sporobolus	0.75	0.43	21.0	29.3	1.17	1	3.6
		Iseilema	0.66	0.40	17.0	20.0	1.44	1.29	3.4
4	NF4								
		Cynodon	0.61	0.36	32.7	44.0	1.09	9.9	1.2
		Panicum	0.21	0.33	33.1	59.1	0.91	12.0	1.4
		Digitaria	0.42	0.33	39.3	53.6	1.01	10.2	1.9
		Sporobolus	0.48	0.40	36.5	47.8	1.15	10.1	2.28
		Iseilema	0.38	0.48	27.7	47.6	1.03	10.2	1.9
5	NF5								
		Cynodon	1.78	0.58	19.3	34.0	1.10	9.7	2.09
		Panicum	1.14	0.54	13.2	12.5	1.00	8.9	1.4
		Digitaria	0.85	0.54	16.0	10.4	0.96	10.12	3.4
		Sporobolus	1.50	0.48	12.7	21.4	0.99	8.4	1.7
		Iseilema	1.57	0.63	9.7	23.3	0.96	12.7	2.8
6	NF6								
		Cynodon	0.97	0.95	11.8	68.7	0.91	2.72	2.3
		Panicum	1.00	0.81	16.2	40.7	0.90	2.54	1.55
		Digitaria	0.69	0.86	10.2	54.1	0.93	2.4	1.8
		Sporobolus	0.76	1.0	9.0	79.2	0.88	2.8	2.4
		Iseilema	1.23	1.0	9.0	54.1	1.10	2.2	1.8
7	NF7								
		Cynodon	1.32	0.66	14	15.3	1.16	3.5	1.05
		Panicum	0.94	0.77	14.3	15.5	1.06	3.8	1.4
		Digitaria	1.55	0.66	20.5	17.0	1.33	3.9	1.17
		Sporobolus	1.70	0.80	16.3	26.6	1.03	3.6	1.6
		Iseilema	1.88	0.84	18.5	34.4	1.30	3.35	1.5
8	NF8								
		Cynodon	0.88	0.54	11.7	33.8	0.76	2.6	1.4
		Panicum	0.82	0.48	11.6	23.9	0.78	3.3	1.44
		Digitaria	1.07	0.51	10.0	22.1	0.83	3.2	1.01
		Sporobolus	1.13	0.52	11.7	38.0	0.93	2.9	1.2
		Iseilema	1.31	0.44	9.6	50.6	0.91	2.8	1.48
9	NF9								
		Cynodon	3.23	0.95	24.7	68.2	0.99	2.42	2.23
		Panicum	2.76	0.66	18.6	27.3	0.83	2.26	1.20
		Digitaria	2.95	0.72	17.4	68.1	1.04	2.35	1.64
		Sporobolus	3.42	0.61	16.7	50.5	0.84	2.48	1.00
		Iseilema	2.01	0.89	16.1	65.5	1.03	2.53	1.14
10	NF10								
		Cynodon	1.51	0.51	48.0	34.1	0.91	3.0	2.31
		Panicum	1.25	0.49	22.4	20.2	1.00	2.1	2.5
		Digitaria	1.03	0.42	35.6	18.2	0.93	2.8	2.3
		Sporobolus	1.12	0.46	40.2	23.6	1.26	2.7	3.4
		Iseilema	1.35	0.54	33.0	22.7	1.05	2.6	2.57

15.5±1.15 to 79.6±1.14 $mgkg^{-1}$ and 17.5±1.12 to 49.6±1.16 $mgkg^{-1}$. Grass species studied, highest concentration of Mn was found in *S. diander* in the river bank soil and *D. sanguinalis* in non flooded soil. The grasses on river bank had higher Mn concentration in all the locations. This may be due to the heavy metal accumulation in the river bank by the flood during rainy season (Bhargava *et al*., 2009).

Correlation study: Metal uptake by grass plant was affected by several factors including metal concentrations in soils, soil pH, organic matter content, types of plant etc. The correlation matrix of metal contents in grass species and some of the soil properties are given in the table.8. It is generally accepted that the metal concentration in soil is the dominant factor. Relationships between total metal contents in plants and surface soils, metals in plants were highly comparable with those of soil counterparts, although the gradient can differ between plant species. The result indicates that the pollution of the river had effect on the quality of river bank soil during the study period (Nouri *et al.,* 2006).

Bio concentration factor: The generic BCF expressed in $mg/kg_{dwt.plant}$ / $mg/kg_{dwt.soil}$ have been used as indicator for the affinity for the accumulation of metals in plants. The mean BCF value varies widely with the type of metal and species of the grasses (Table 9). Irrespective of the grass species the BCF values of the metal in river bank follows the order Zn>Cu>Mn>Fe>Pb>Cd>Ni. In the non-flooded soil the order remained same except that the BCF value of Fe was greater than Mn. There was wide variation in the BCF values for Fe and Mn among the grass species and location i.e. river bank soil and non flooded soil. The BCF value of Cd was found to be highest in *I. laxum*. This indicated that among all the grass species *I. laxum* had high affinity for the accumulation of Cadmium followed by Zn, Pb and Cu (Table 9 and 10). All grasses had equal affinity for Ni. The higher the BCF values the higher the risk posed to the organism along the food chain (Mellem *et al.,* 2009).

Conclusion

It was concluded from the study that the dominance of heavy metals follows a decreasing order of Fe > Mn > Ni> Pb>Cu>Zn>Cd. The values of Pb, Cd, Cu, Zn progressively increased in river bank soil from Naraj to Komashasan indicating their enrichment by effluent discharge of the city towards lower stream of Cuttack city . Soil of river bank is more fertile with higher available Fe and Mn content. Among the grass species there was a wide variation in the heavy metal accumulation. Grass species *I. laxum* has the higher affinity for the accumulation of Cd (0.85±0.05) followed by Zn, Pb and Cu. Kathajodi river stretch around the Cuttack city is greatly influenced by direct discharge of urban waste and effluent in the river and necessitates adequate strategies or management |planning to control the intrusion of pollutants in the river system and which can prevent contamination of fertile soil of river bank.

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