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Comparative Study of Various Metals in the Sewage Samples of Three Major Drains of the City-Patna, Bihar, India

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Abstract

Untreated sewage is a major water pollutant and widely used for irrigation in the agricultural fields of district Patna, Bihar, India. When sewage, containing heavy metals, irrigated into the agricultural fields, it enters into the human food chain by the process of bioaccumulation and biomagnification. In view of the above fact, the present study was conducted to determine the level of metals in the sewage samples of three major drains namely Mandiri, Rajapur and Pahari situated in the city Patna, Bihar, India, during March 2010 to February 2011. In comparison with other two drains, the metals were found in higher amount in the sewage of Pahari drain throughout the year.

Keywords: Sewage, Heavy metals, Chromium, Arsenic, Copper, Cadmium

1. Introduction

The pollution of metals/heavy metals/metalloids (or commonly heavy metals) in fresh water bodies, like streams, tributaries and rivers is not uncommon [1, 2]. Apart from geogenic causes of pollution, anthropogenic causes cost more [3, 4]. The anthropogenic causes mainly include the irrigation of metal rich ground water

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(geogenic) into agricultural fields [5], followed by runoffs, and, discharge of heavy metals loaded sewage into the aquifers [6, 7]. Increase of heavy metal contamination in the municipal wastes is mainly related to increase in urbanization and industrialization. The polluted sewages not only enter the river bodies, but also used to irrigate agricultural fields, mainly growing vegetables [8, 9]. An important reason behind the sewage water irrigation is the higher content of nitrogen, phosphorus and other organic matter, which prove beneficial for the growth of crops. However, unknowingly, the heavy metals also get spread along with, leading to their accumulation in crops [10]. Finally, humans get affected after consumption of these contaminated crops, causing serious ailments like cancer, classic skin lesions, cardiac and neurological disorders etc. [11, 12].

Heavy metals are named such because their densities exceed 5 g cm^{-3}[13].Some heavy metals, known to be present in sewage water, include Fe, Zn, Cu, Cr, Cd and As. Although As is a metalloid, it is considered as a heavy metal since its density is 5.73 g cm^{-3} [12]. Heavy metals exist as ions in the water.

This paper describes the monthly variation of heavy metals in sewage water of Mandiri, Rajapur and Pahari from March 2010 to February 2011. The estimated heavy metals included Fe, Zn, As, Cu, Cr and Cd. Other than heavy metals, some nutrient metals viz. K, Ca and Mg were also estimated along with.

2. Materials and Methods

2.1 Collection and preservation of samples

Sewage water samples were collected in corrosion-resistant plastic bottles (pre-rinsed with 10% sulphuric acid and distilled water), in triplicates from Mandiri, Rajapur and Pahari drains of Patna town at monthly basis from March 2010 to February 2011, between 7:00 a.m. and 8:00 am. Soon after the collection, the samples were preserved by adding concentrated nitric acid to attain final concentration of 2% (v/v). The samples, once preserved, were digested within seven days.

2.2 Digestion of samples and determination of heavy metals

The preserved samples were digested using the standard protocols mentioned in APHA (2005c). In brief, the samples (50 mL) were digested using concentrated HNO_3 till the achievement of pale yellow colored clear solution. The digested samples were filtered using Whattman No. 42 filter paper and stored in dilute acid rinsed sampling bottles at 4°C, till further analysis.

All the heavy/nutrient metals (viz. potassium, calcium, magnesium, zinc, copper, chromium, cadmium, iron) except arsenic were analyzed by Atomic Absorption Spectrophotometer (Perkin Elmer, USA) at the Central Instrumentation Laboratory, Department of Botany, Banaras Hindu University, Varanasi, India. Arsenic was analyzed using Hydride – Generation Atomic Absorption Spectrophotometer (HG-AAS) (Elico SL173, India) at the Department of Chemical Engineering, Institute of Technology, Banaras Hindu University, Varanasi, India.

2.3 Statistical analyses

Values of all the parameters in graphs are represented as means of respective three replicates along with respective standard errors (±SE). Two way Analysis of Variance (ANOVA) was calculated to determine the significance (at 0.05 level) of variation of the physico-chemical characteristics between the months and sites. SE and ANOVA were calculated using the package Microsoft Office Excel 2007 (Microsoft Corp. USA) and the same software was used to draw the graphs.

3. Results and Discussion

It is always expected for any sewage water to contain many non-toxic as well as toxic metals ions, as it accepts a wide spectrum of wastes, either domestic or industrial [3-6, 13]. Non-toxic metal ions like K, Na, Mg, Ca etc. are present in all sewages, whether domestic or industrial. This is mainly because these ions are the natives of underground as well as surface waters [14]. The toxic heavy metal ions like Fe, Zn, As, Cu, Cr, Cd, nickel, mercury etc. are generally area specific, since they fall under rare elements category [13]. The heavy metals are very toxic at biospheric level due to the phenomenon of biomagnifications [13]. They cause various diseases, from physiological disorders to cancer. Among the heavy metals, some are abundant in the industrial areas, like Zn, Cr, Cu, nickel, Cd etc. These ions reach the sewage water, when the untreated industrial effluents are released into it [15]. As and Fe emerge geogenically only in those areas, where underlying bed rocks are rich with these metal ores [16]. They get released into underground water, in turn reach the biosphere, and finally the sewage waters and indirectly affect the limnological characteristics of adjoining water bodies [17]. The present study was conducted to assess the monthly variation of various metal ions (both non-toxic nutrient ions and toxic heavy metal ions) like K, Ca, Mg, Fe, Zn, As, Cu, Cr and Cd in the sewage waters collected from Mandiri, Rajapur and Pahari drains.

K, Ca and Mg showed seasonal variation in its concentration at all study sites, with some minor variation (Figs. 1-3) The general trend indicated that the concentrations of K and Ca increased during summer, followed by a sudden decrease in rainy season. Mg, at the same instance, suffered an opposite variation. The increase in the concentration of these nutrient ions during summer season might be reasoned as in the summer months, the water level, irrespective of its origin, decreases due to evaporation. This decrease in water level results into enhancement of the nutrient concentration. Among the all three sites, Mandiri sewage showed maximum (nearly 3-fold) increase, depicting the difference in the evaporation rates based on the sites. Owing to the opposite trend of variation of Mg in all the sewage waters, 'the decrease in the value during summer season might be understood that the summer temperature seemed to be more favorable for the activities of microorganisms. Hence in the peak of its metabolic activities, they consumed Mg up to 3-fold, causing the decrement. During the winter season, the metabolic activities of microorganisms began to cease, leading to increase in concentration of Mg. Another reasoned fact for this phenomenon might also be the various discharge rates of Mg loaded wastes at different seasons. In case of K and Ca concentrations, the values faced a sudden decreased up to in August 2010 with respect to the previous month. For example, the decrease of K concentration (approximate values) in the three sites was: Mandiri = 31%; Rajapur = 33%; Pahari = 51%. Similarly the based on the three sites, Ca decrements (approximate values) in the sewages were recorded as: Mandiri = 21%; Rajapur and Pahari = 53%. This decrease of metal concentrations might be due to the increase in the water load of the drains due to rain, causing about 2-fold dilution of sewage water. As expected, the next month was recorded with an increase in the concentrations of K, Ca and Mg, when the rainfall depleted.

Heavy metals determined in the sewages of Mandiri, Rajapur and Pahari included Zn, Cu, Cr, Cd, Fe and As (Figs. 4-9). Zn, being an essential nutrient of biosphere, was found in quite low quantities. Among the three sites the trend of Zn variation based on the average concentration was Pahari > Rajapur > Mandiri drains (Fig. 4). As with the previously determined metals, Zn concentration did not decrease during rains. This may be due to the fact that although the dilution occurred in sewages during sewage waters, the discharge of Zn loaded wastes balanced the concentration of summer season. The trends of variation of Zn in the sewages at all three sites were highly significant as confirmed statistically by two-way ANOVA.

The variation of Cu in sewages of Mandiri, Rajapur and Pahari drains was statistically notable (Fig. 5; Table 1). Cu content was found in higher levels during summer at Mandiri and Rajapur sewages. This observation may be reasoned as the increased evaporation rate during the hotter months. As the rain arrived in August 2010, the Cu content suddenly decreased by nearly half in the sewages of both Mandiri and Pahari drains. The lowering of Cu concentration during winter was observed only in Mandiri and Rajapur sewages. Pahari sewage showed the opposite effect. This might be due to the presence of highly active of Cu utilizing microorganism in more numbers in sewage of Pahari, which consumed the heavy metal during lesser inflow of water in the sewages during winter. However, in Pahari sewage, Cu loaded waste discharge overruled the heavy metal consumption by microorganisms leading to increase in Cu concentration. However, in summer, the microorganisms were able to get optimum temperature for acting upon the Cu containing municipal waste, leading to winter-comparative decreased concentrations.

Similar to Cu variation, Cr (Fig. 6) was also present in higher concentrations during summer than winter, as well as a sharp decrease was observed during rainy season (August 2010). The reasons behind these variations were comparable to that of Cu variations in Mandiri and Pahari sewages. However, the variation was more significant for Cr than Cu, based on the sites. The gradation of Cr content based on sites were Pahari > Rajapur > Mandiri. Here, when the maximum recorded values was considered, Pahari was recorded with nearly 6.5 and 3 times more Cr content than Mandiri and Rajapur sewages, respectively. The reason/s might be due to the presence of higher amount of Cr loaded waste, or/and presence of lesser amount of Cr degrading microorganisms in Pahari than the other two study sites. The primary effects of Cr include toxicity mainly in the plant system [3,4].

The concentrations of Cd at all the three sites were significantly low, and were considered to be under safer limit. And even, the two-way ANOVA proved that the concentration did not vary significantly on the basis of months as well as sites (Table 1). But the rainy season had negative effect on the concentration of Cd at all the three sites, as the dilution of sewage water was high.

As per the above discussed heavy metals, the reason for their presence in the sewage water was primarily anthropogenic. But in case of Fe and As, the primary cause for their presence is geogenic, leading to the site specificity [5]. The human consumption and agricultural uses of Fe/As rich underground water are the main responsible factors for their entry into the biosphere [11]. Ultimately, these heavy metals laden wastes are disposed into the sewage water, leading to their accumulations. According to the recorded levels of Fe and As at all the three study sites, the former dominated in the Mandiri sewage, whereas, the latter dominated in the sewage water of Pahari drain. Considering both the heavy metals, higher concentrations were recorded in summer season, whereas, lower values were observed in the winter season. Furthermore, the rain water caused dilution in the sewage water and led to a sudden decrease in Fe and As concentrations at all the three sites. The contradictory effect of Fe on As was well observed at all the three sites. The results indicated that, the increase in Fe concentration in the ground water (which was ultimately discharged into the sewage) caused a lesser release of As at the geogenic level, and vice versa.

4. Conclusion

Concluding the above results, Pahari drain water was highly polluted with respect to Zn, Cu, Cr and As. Additionally, when the untreated sewage is used for irrigation, it gets accumulated into the vegetable crops, affecting the humans at a large. Not only the irrigation affects the human health, but when the heavy metal contaminated sewages are disposed into the riverine systems, the aquatic flora and fauna get harmed. Upon the consumption of heavy metals affected fishes, phenomenon of biomagnification takes place among the consumers like humans and animals, leading to serious health defects. The only cost – effective remedy to remove the heavy metals from sewage water is to use a constructed wetland. According to this procedure, the sewage water is allowed to pass through the constructed wetland, where the growing hyper accumulator plants take up all the heavy metals present, leading to the toxic metal free sewage. This sewage may further be treated as per the standard procedures before discharging into the larger aquatic bodies or used for irrigation purpose. The treated sewage, when discharged into the aquatic bodies, improves its limnological characteristics.

References

[1] S. Shardendu, D. Sayantan, D. Sharma and S. Irfan. "Luxury uptake and removal of phosphorus from water column by representative aquatic plants and its implication for wetland management", ISRN Soil Sci., vol. 2012, pp. 1-9, 2012. (http:// dx.doi.org/ 10.5402/ 2012/ 516947).

[2] K. V. Raju, R. K. Somashekhar and K. L. Prakash. "Spatio-temporal variation of heavy metals in Cauvery river basin", Proc. Int. Acad. Environ. Sci., vol. 3, pp. 59-75, 2013.

[3] D. Sayantan and Shardendu. "Amendment in phosphorus levels moderate the chromium toxicity in *Raphanussativus*L. as assayed by antioxidant enzymes activities", Ecotoxicol. Environ. Saf., vol 95, pp. 161-170, 2013.

[4] D. Sayantan and Shardendu. "Phosphorus amendment competitively prevents chromium uptake and mitigates its toxicity in *Spinaceaoleracea*L.", Indian J. Exp. Biol., vol. 53, pp. 395-405, 2015.

[5] D. Sayantan and Shardendu. "Phosphate amendments moderate the arsenate accumulation and its subsequent oxidative and physiological toxicities in *Amaranthusviridis*L.", Proc. Natl. Acad. Sci., India, Sect. B Biol. Sci., 2016. doi: 10.1007/s40011-016-0711-5.

[6] Shardendu, K. Tripti, D. N. Singh and D. Sayantan. "Evaluation of arsenic removal potential of arsenic resistant bacteria with the role of physiological and genomic factors", Indian J. Exp. Biol., vol. 55, pp. 251-261.

[7] K. Tripti, D. Sayantan, Shardendu, D. N. Singh and A. K..Tripathi. "Potential of uptake of arsenic (As V and As III) and reduction of As V to As III by *Bacillus licheniformis* (DAS1) under different stress", Korean J. Microbiol. Biotechnol., vol. 42, pp. 238-248, 2014.

[8] C. Su, L. Q. Jiang and W. J. Zhang, "A review on heavy metal contamination in the soil worldwide: situation, impacts and remediation techniques", Environ. Skept. Crit., vol. 3, pp. 24-38, 2014.

[9] R. G. Kakar, M. Yasinzai, A. U. Salarzai F. C. Oad and M. H. Siddiqui. "Irrigation with sewage water: assessment of water quality, nutrients and heavy metal distribution", Asian J. Plant Sci., vol. 5, pp. 438-440, 2006.

[10] M. A. Rahman, M. M. Rahman, K. Kadohashi and T. Maki et al. "Effect of external iron and arsenic species on chelant-enhanced iron bioavailability and arsenic uptake in rice (*Oryza sativa* L.)" Chemosphere, vol. 84, pp. 439-445, 2011.

[11] D. Chakraborty, S. C. Mukherjee, S. Pati, M. K. Sengupta, M. M. Rahman, U. K. Chowdhury, D. Lodh, C. R. Chanda and A. K. Chakraborty. "Arsenic groundwater contamination in middle Ganga plain, Bihar, India: a future danger?", Environ. Health Perspect., vol. 111, pp. 1194-1201, 2003.

[12] L. Järup. "Hazards of heavy metal contamination", British Med. Bull., vol. 68, pp. 167-182, 2003.

[13] J. S. Singh, S. P. Singh and S.R. Gupta. *Ecology Environment and Resource Conservation.* New Delhi, India: Anamaya Publishers, 2008.

[14] E. Singh. "Ecological Investigations of different municipal drains in Jaunpur", Ph. D Thesis. VBS Purvanchal University, Jaunpur. India, pp. 1-222, 2007.

[15] B. Wei and L. Yang. "A review of heavy metal contaminations in urban soils, urban road dusts and agricultural soils from China", Microchem. J., vol. 94, pp. 99-107, 2010.

[16] Shardendu, N. Salhani, S. F. Boulyga and E. Stengel. "Phytoremediation of selenium by two helophyte species in sub-

surface flow constructed wetland", Chemosphere, vol. 50, pp. 967-973, 2003.
[17] S. S. Das and D. Sayantan. "Limnological studies on different ponds of Bihar, India: a review", Mapana J. Sci., 15, issue 4, pp. 49-53, 2016. doi: 10.12723/mjs.39.4

Appendix

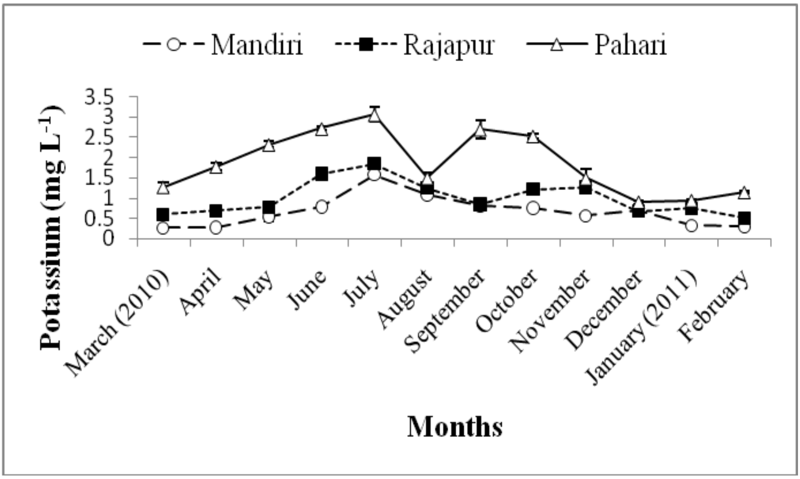

Figure 1 Monthly variation of K (mg L^{-1}) of sewage water at three sites viz. Mandiri, Rajapur and Pahari from March 2010 to February 2011. The values are means of respective three replicates with standard errors as vertical error bars.

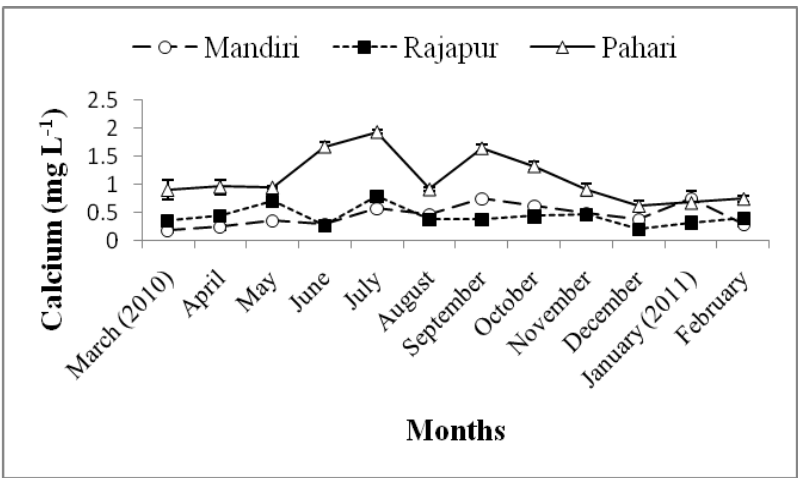

Figure 2 Monthly variation of Ca (mg L^{-1}) of sewage water at three sites viz. Mandiri, Rajapur and Pahari from March 2010 to February 2011. The values are means of the respective three replicates with standard errors as vertical error bars.

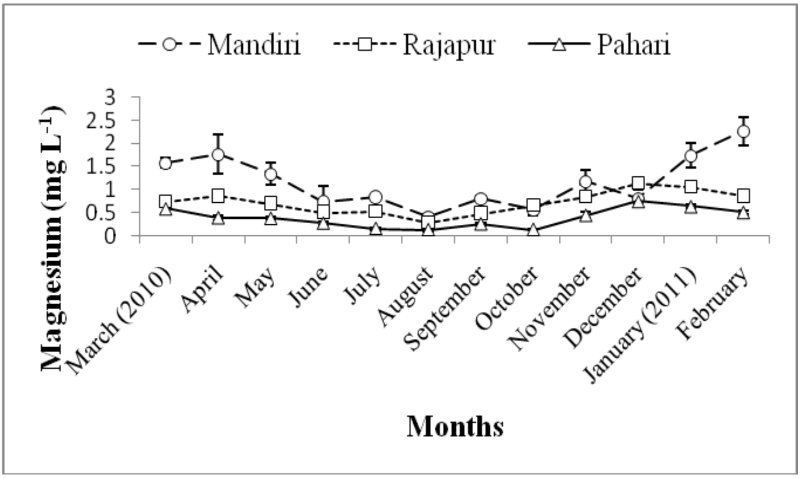

Figure 3 Monthly variation of Mg (mg L^{-1}) of sewage water at three sites viz. Mandiri, Rajapur and Pahari from March 2010 to February 2011. The values are means of respective three replicates with standard errors as vertical error bars.

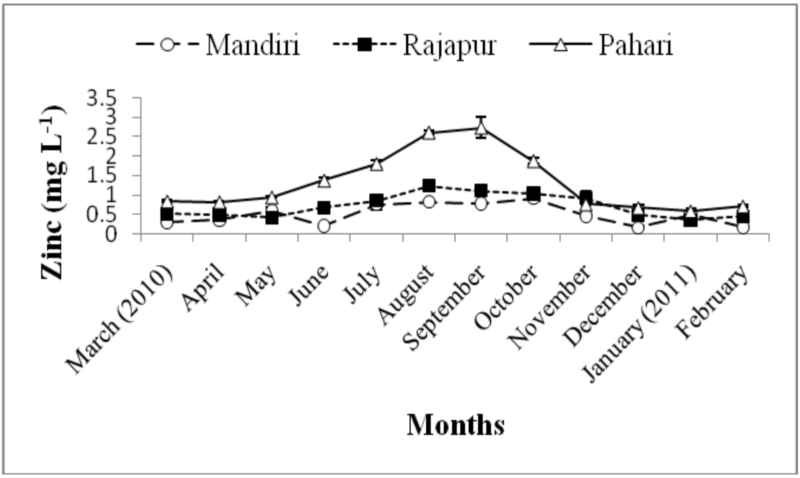

Figure 4 Monthly variation of Zn (mg L^{-1}) of sewage water at three sites viz. Mandiri, Rajapur and Pahari from March 2010 to February 2011. The values are means of respective three replicates with standard errors as vertical error bars.

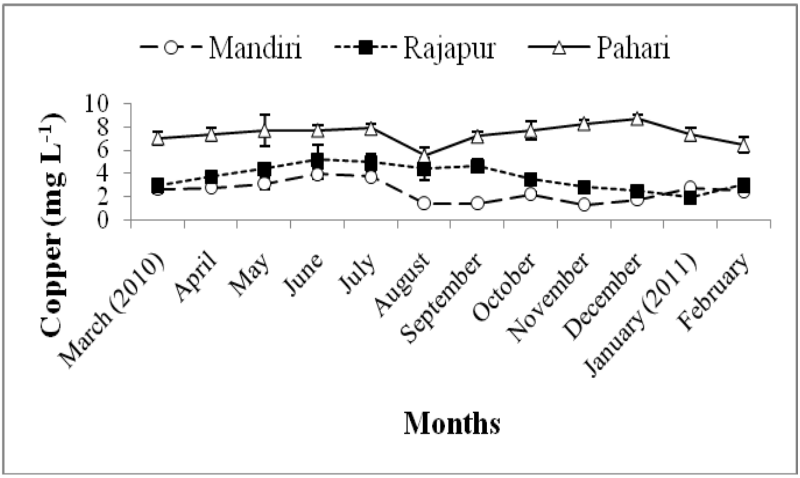

Figure 5 Monthly variation of Cu (mg L^{-1}) of sewage water at three sites viz. Mandiri, Rajapur and Pahari from March 2010 to February 2011. The values are means of respective three replicates with standard errors as vertical error bars.

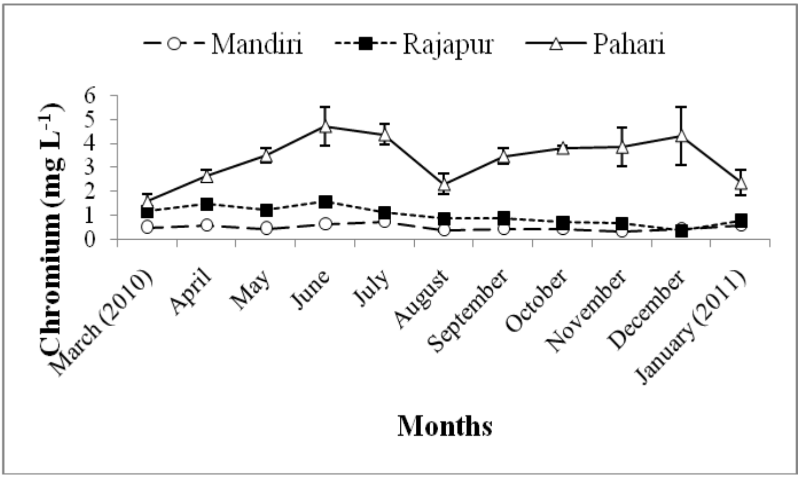

Figure 6 Monthly variation of Cr (mg L^{-1}) of sewage water at three sites viz. Mandiri, Rajapur and Pahari from March 2010 to February 2011. The values are means of respective three replicates with standard errors as vertical error bars.

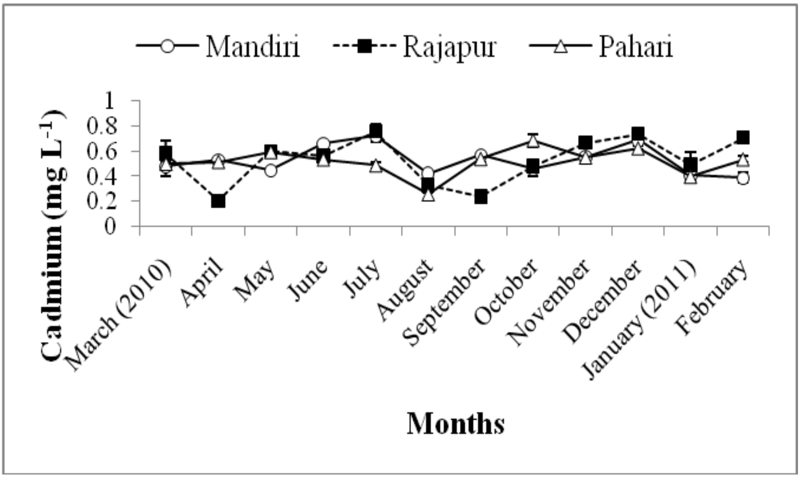

Figure 7 Monthly variation of Cd (mg L^{-1}) of sewage water at three sites viz. Mandiri, Rajapur and Pahari from March 2010 to February 2011. The values are means of respective three replicates with standard errors as vertical error bars.

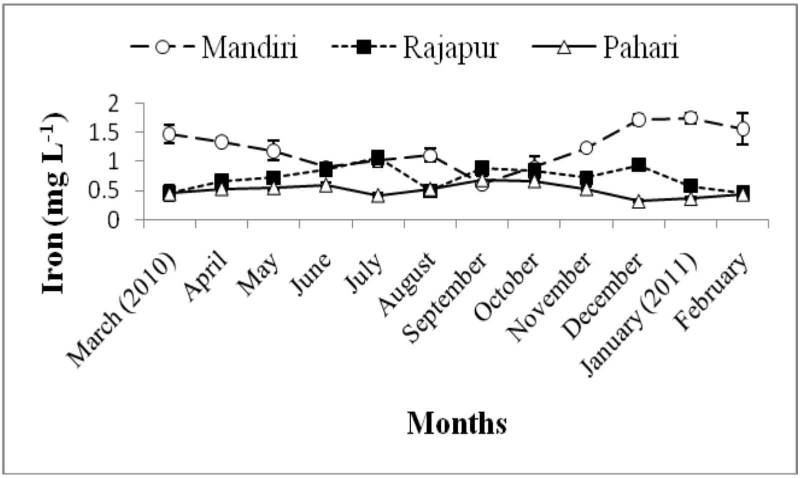

Figure 8 Monthly variation of Fe (mg L^{-1}) of sewage water at three sites viz. Mandiri, Rajapur and Pahari from March 2010 to February 2011. The values are means of respective three replicates with standard errors as vertical error bars.

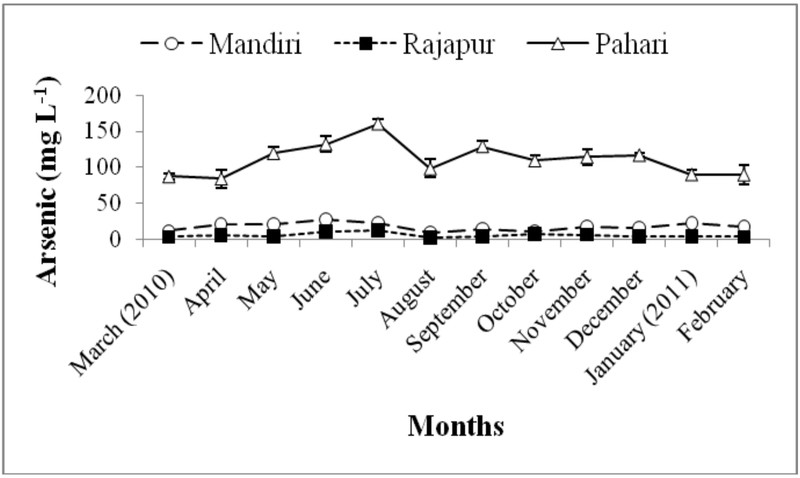

Figure 9 Monthly variation of As (mg L^{-1}) of sewage water at three sites viz. Mandiri, Rajapur and Pahari from March 2010 to February 2011. The values are means of respective three replicates with standard errors as vertical error bars.

S. No.	Parameters	Sources of Variation					
		Sites			Months		
		F-value	*p*<	d.f.	F-value	*p*<	d.f.
1	K	36.12	0.001	2	5.27	0.001	11
2	Ca	27.55	0.001	2	1.89	n.s.	11
3	Mg	23.66	0.001	2	3.47	0.01	11
4	Zn	19.84	0.001	2	4.87	0.001	11
5	Cu	78.29	0.001	2	1.42	n.s.	11
6	Cr	67.89	0.001	2	1.04	n.s.	11
7	Cd	0.03	n.s.	2	2.1	n.s.	11
8	Fe	21.01	0.001	2	0.2	n.s.	11
9	As	269.52	0.001	2	1.72	n.s.	11

Table 1 Two-way ANOVA for determining the significance of variation of physiochemical parameters with respect to sites and months. Significance is represented at 0.01 and 0.001 levels. The non significant variation are represented as n.s. Additionally, the F statistics and degrees of freedom (d.f.) is also depicted.