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EVALUATION THE IMPACT OF HEAVY METALS ON WATER QUALITY IN GANGA RIVER AT VARANASI, INDIA

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ABSTRACT

Day after a day, the increase of heavy metals concentration in the riverine water have dramatically attired anthropogenic activities. Scientist and policy makers in India gave serious attention for the rising level of pollutants and changes in mid-stream water quality of Ganga River. The present investigation was attempted to study water quality of river Ganga and to record the quantitative change in heavy metals in water if any during the three consecutive months of sampling in 2013. A systematic study has been carried out to assess the impact of heavy metal concentration on water quality of river Ganga in Varanasi city. 36 water samples from four sampling stations i.e. By pass bridge upstream, Assi Ghat, Dashswamedh Ghat, and Raj Ghat bridge downstream, were collected and analyzed for Temperature, pH, concentrations of Cr, Ni, Cu, As, Cd, Pb in ($\mu g.L^{-1}$). The results from this study indicated significant accumulation of these heavy metals in the riverine water. The order of heavy metals accumulation in the riverine water was As > Pb > Cu >Ni > Cr > Cd. The analytical data indicates that all heavy metals studied are found to be in excess than the prescribed limit in some water samples of the study areas as compared to World Health Organization standards (WHOS) and toxicity reference value (TRV) for fresh water proposed by USEPA except Ni.

Natural history (general) QH540 – 549.5

Key words: Water pollution, Ganga river water, Heavy metals

1. INTRODUCTION

Currently, the pollution of river water by heavy metals become one of the major problems for rivers worldwide due to be the important source for providing safe water for drinking and agricultural purposes. The accumulation of heavy metals in high levels may be toxic to the human beings and affect the aquatic environment without any clear sign. Due to the increase the population worldwide, the anthropogenic activities increase and led to the accumulation of high quantity of hazardous materials especially heavy metals in water river worldwide (Islam et al., 2014) [1]. The sources of domestic and industrial activities if it is discharged to the riverine water without treatment led to the accumulation of heavy metals and affect the aquatic environment especially in the urban areas (Venugopal et al., 2009) [2]. The process for removal of heavy metals from riverine water cannot be done naturally due to decomposition so it is accumulate in riverine water and give a real alarm due to their toxicity. The heavy metals accumulate naturally by different processes like weathering and volcanic eruptions along with a variety of human activities. The distribution of heavy metals provide indication for the source of interring it to the aquatic environment, bioavailability and toxicity in water which is different from river to another (Pandey et al., 2014) [3]. Moreover, heavy metals accumulation in water may cause changing in physicochemical properties of water and make it unsuitable for human consumption. High concentration of heavy metals in water may accumulate in the human body and cause serious health problems like carcinogenesis (Schwartz, 1994) [4]. Pandy et al. (2012) found a strong relation between heavy metals concentrations in irrigation water and plants. Furthermore, heavy metals bio accumulate along the food chain and stick on the aquatic bodies. Accumulation of high quantity of heavy metals in the aquatic environment to the level that may be toxic for both humans and other organisms due to be part of the various food chains [5]. Sorensen (1976) found that traces of Cu , Zn are required for various biological processes [6]. While, Tort et al. (1987) found that adverse effect may happened in the biological systems due to increase the concentration of Pb, Cd [7]. The concentrations of Pb, Cr, Ni were high in fish tissues and sediments near the industrial areas (Thompson et al., 2000) [8]. The Ganga is a major river in India, flowing east through northern India into Bangladesh. Its basin covers 861,404 km^2, which is approximately 26 percent of the total land area of India. There are numerous settlements (cities, towns and villages) located in the basin, comprising 45 percent of the country's population, i.e., approximately half a billion people. This figure is expected to double by 2030 (Bennett and Birol, 2010) [9]. Defined as the 'river of India' by Nehru, Ganga has important economic, social, cultural and religious values. It accounts for about 31.6

percent of India's annual utilizable water resources, providing water for agriculture, aquaculture, hydropower generation, industry, and water supply for household consumption (Bureau of Applied Economics & Statistics, 2005) [10]. Untreated raw sewage discharged in the Ganga is estimated to be as much as one million M^3 per day (Murty et al., 2000) [11].

From the above a serious concern most be considered because Ganges River water is used for both irrigation and drinking-water supply for a large population. Looking into the relevance of data on changing water quality of Ganga River, the present work was an attempt to assess the impact of monthly changes for heavy metals concentration in water of River Ganga at four selected sampling sites at Varanasi. The sites include Bypass Bridge Upstream, Assi Ghat, Dashwamedh Ghat, Raj Ghat Bridge downstream. The water of River Ganga at aforesaid sites was analyzed for temperature, pH, concentrations of Cr, Ni, Cu, As, Cd, Pb in ($\mu g.L^{-1}$).

2. MATERIALS AND METHODS

2.1. Study area and Sites

Varanasi (Lat: 25.3176,Long: 82.9739,N 25 19'4", E 82 58'26") also Benares, Banaras or Kashi, is a city on the banks of the Ganges in Uttar Pradesh, 320 kilometers southeast of the state capital, Lucknow. It is holiest of the seven sacred cities in Hinduism and Jainism. The city of Varanasi encompasses a total area of 1550.3 sq. km. It holds a population of 25.0811 lakhs with 10.5797 lakhs of urban and 14.5014 lakhs of rural population (as per 1991 census). **Figure 1** shows the sampling site of the ganga river in India. Varanasi has a humid subtropical climate with much variation in temperatures. Varanasi has at least 84 ghats (Steps in the ghats lead to the banks of River Ganga). As per scientists associated with the Ganga Action Plan, the river is changing course due to massive pollution and lack of proper cleaning of the banks of the river (Birol and Das, 2010) [12]. The following study was conducted at four selected sites of River Ganga at Varanasi during the period of January 2013 to March 2013. The selected sites were Bypass Bridge Upstream, Assi Ghat, Dashwamedh Ghat, Raj Ghat Bridge downstream.

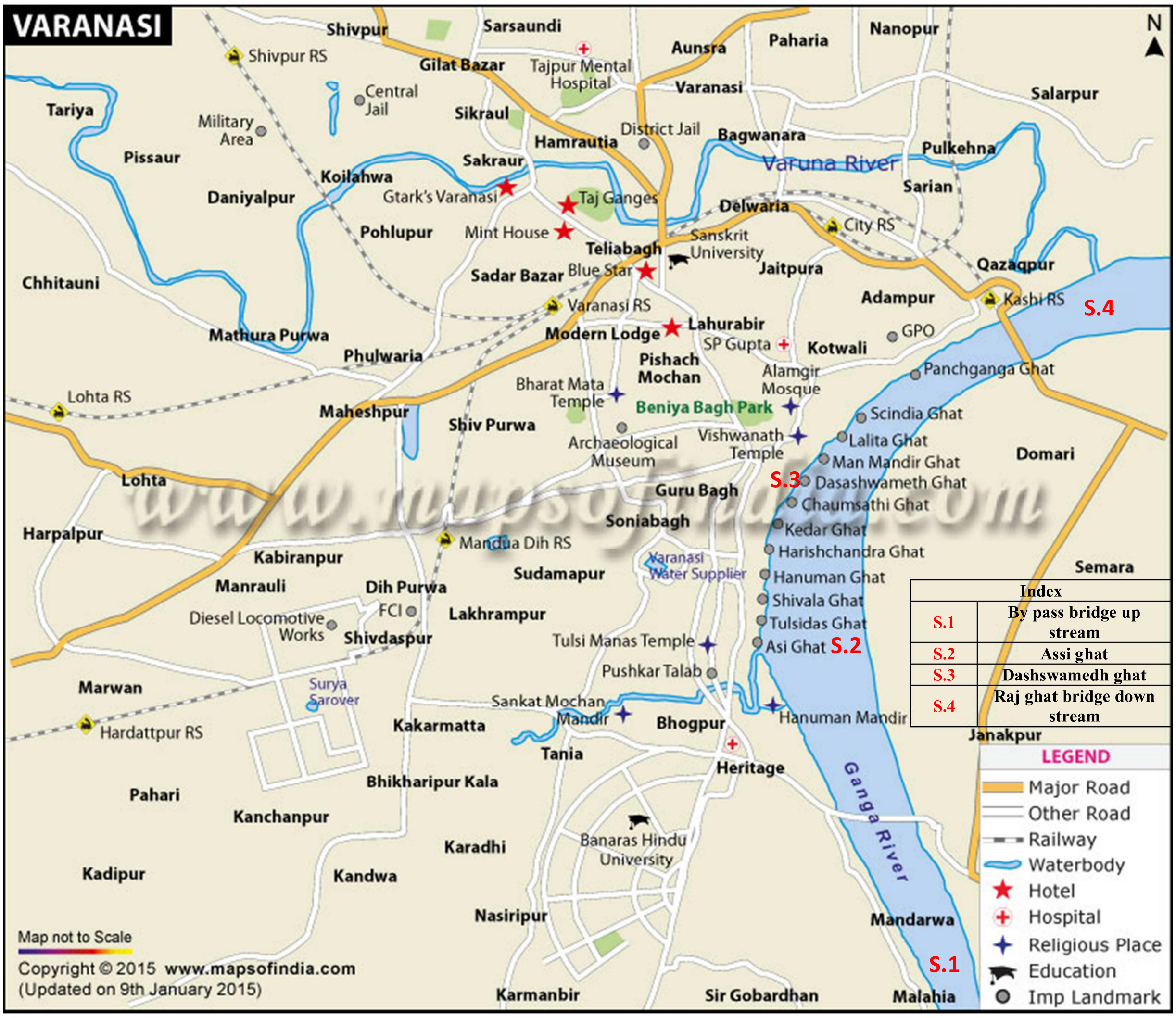


Fig.1 Sampling site (S.1 –S.4) at Varanasi on the Ganga river in India.

2.2. Sampling

A total of 36 water samples were collected from four different spots during a period of 3 months (January 2013 to March 2013). Water samples were collected at monthly interval for a period of 3 months i.e.January-March between 1.00 PM to 8.00 PM from four sampling sites i.e. By pass bridge upstream, Assi Ghat, Dashswamedh Ghat, and Raj Ghat bridge downstream. The samples were taken in plastic jerry canes and brought to the laboratory with necessary precautions. All samples were labeled properly. The temperature was recorded at the sites with the help of digital thermometer. Grab sampling was generally applied during the sampling.

2.3. Analysis

The water samples were brought to the laboratory and analyzed by standard methods (APHA,1998).The samples were analyzed for the following physicochemical parameters: Water Temperature (ºC), pH, concentrations of Cr, Ni, Cu, As, Cd, Pb ($\mu g.L^{-1}$). It is an established fact that the more harmful a given pollutant is, the smaller is its standard permissible value recommended for drinking water. Standard method for the examination of water and waste water was used (APHA,1998) for analysis [13]. The temperature of water was recorded directly in sampling sites using digital thermometer. The digital thermometer had a thermocouple was immersed in the water for the desired level. pH meter HACH EC10 was used and this method gave an accurate and quick measure of the pH. The essential feature of a pH meter is that it contains hydrogen sensitive electrode called indicator electrode and a calomel reference electrode. Most pH meters possess a temperature compensation system to avoid the difference arising due to the different temperatures. For the analysis of heavy metals, water samples (50 ml) were digested with concentrated HNO_3 (10 ml at 80 °C). The solution was filtered by using filter paper and diluted to 50 ml with double-distilled water.

Atomic absorption spectrophotometer (Perkins-Elmer Analyst 800), using a specific lamp of particular metal and the appropriate drift blank was used for the determination of heavy metals concentrations (Cr, Ni, Cu, As, Cd and Pb) in the filtrate. The detection limits ($\mu g/L^{-1}$) of heavy metals were 0.002 (Cr), 0.004 (Ni), 0.001 (Cu), 0.005 (As), 0.0005 (Cd) and 0.01 (Pb). The chemicals used were analytical grade.

3. RESULTS AND DISCUSSION

The results from this study indicated significant accumulation of these heavy metals in the riverine water. The order of heavy metals accumulation in the riverine water was As > Pb > Cu >Ni > Cr > Cd. Heavy metal concentrations in midstream river water increased consistently along the study gradient from Site 1 (By pass bridge upstream) to Site 4 (Raj ghat bridge downstream) (Tables 3-8). Monthly, recorded metal concentrations in the water were highest in March, followed by Fabruary, and lowest in January (Tables 3-8).

The increase of heavy metals in the surface waters depends on the anthropogenic activity and atmospheric deposition. Urban and agriculture runoff and sewage discharge point are the most important activities affecting the water quality and causing the accumulation of heavy metals. There were significant relation between-site differences in the concentrations of heavy metals in the present study. **Table 1 and Figure 2** shows the monthly variations in the temperature (°C) of river Ganga at Varanasi city. Temperature is the important factor which influences the chemical, biochemical and biological characteristic of the aquatic system. Temperature also alters the saturation values of solids and gases in water. The present investigation reveals that the temperature varied from a minimum 15.4°C in Jan (By Pass Bridge upstream) to maximum 23.6 (Raj Ghat downstream) in March. **Table 2 and Figure 3** shows the monthly variations in the pH of river Ganga at Varanasi city. Because most of the chemical and biochemical reaction are influenced by the pH it is of great practical importance. The adverse effect of most of the acids appear below 5 and of alkalis above the pH 9.5.The pH values were higher in January with the highest value 8.7 in Jan at Dashswamedh Ghat and lowest value 8.4 in March at By pass bridge upstream. **Table 3 and Figure 4** shows the monthly variations in the concentration of Cr in water of river Ganga at Varanasi city. The Cr concentrations were higher in March with the highest value 23 µg. L^{-1} at Dashswamedh Ghat and lowest value 5 µg. L^{-1} in Jan at Assi Ghat . **Table 4 and Figure 5** shows the monthly variations in the concentration of Ni in water of river Ganga at Varanasi city. The Ni concentrations were higher in March with the highest value 30 µg. L^{-1} at Dashswamedh Ghat and lowest value 12 µg. L^{-1} in Jan at Assi Ghat . **Table 5 and Figure 6** shows the Monthly variations in the concentration of Cu in water of river Ganga at Varanasi city. The Cu concentrations were higher in March with the highest value 30 µg. L^{-1} at Assi Ghat and lowest value 9 µg. L^{-1} in Jan at Assi Ghat. **Table 6 and Figure 7** shows the monthly variations in the concentration of As in water of river Ganga at Varanasi city. The As concentrations were higher in March with the highest value 80 µg. L^{-1} at Raj Ghat downstream and lowest value 10 µg. L^{-1} in Jan at By pass bridge upstream. **Table 7 and Figure 8** shows the Monthly variations in the concentration of Cd in water of river Ganga at Varanasi city. The Cd concentrations were higher in March with the highest value 21 µg. L^{-1} at Raj Ghat downstream and lowest value 0.9 µg. L^{-1} in Jan at By pass bridge upstream. **Table 8 and Figure 9** shows the Monthly variations in the concentration of Pb in water of river Ganga at Varanasi city. The Pb concentrations were higher in March with the highest value 53 µg. L^{-1} at Raj Ghat and lowest value 9 µg. L^{-1} in Jan at By pass bridge upstream.

Generally, the concentrations of heavy metals measured in different sites in the present study were comparable to previous studies like that was made on a Sabaki and Ramisi rivers in Kenya (Ochieng, Lalah, &Wandiga, 2009) [14].

The following study provide data and information's about the changes that happened for the concentrations of heavy metals in winter session (Jan. Fab. March). The major reasons for this changes in heavy metal concentrations can be assumed contributed to the different human activities like wastes from industries, domestics, irrigation, pathing, washing clothes, and disposal of dead bodies (Khan, 2011; Kar et al., 2008) [15,16]. In winter session, the level of water in the river is low compared with the level in the rainy session (July, August). The concentrations of heavy metals increase due to decreasing the level of water in Ganga river. The period chosen for the study is (January-March). A massive amount of water in river Ganga flowing and bring with it a huge amount of wastes from human activities and accumulate the heavy metals. The concentration of heavy metals may be high in the vicinity of point of discharge for the wastes due to reactions happened on the surface of sediments (Purushothaman and Chakrapani, 2007) [17]. In the present study, all studied sites were affected by the human activities. The suspended species and the speed of water in river is a major transporting agents for the traces concentrations of heavy metals in rivers and streams (Bibby and Webster-Brown, 2005) [18]. The atmospheric deposition is another source for the accumulation of heavy metals in the riverine water (Thornton and Dise, 1998) [19]. Ganga river also receives amount of heavy metals from air due to wind speed and direction (Pandey et al., 2010) [20]. A lot of vehicles working inside Varanasi city producing huge amount of particulates and bring with it huge amount of street dust to the atmosphere. The atmospheric particulates rich with metals Like Fe, Zn,… etc and deposit in water river (Gozzard et. al, 2011) [21]. Particulates that are coming from city wastes and farming along with that coming from atmospheric deposition will be added to the riverine water. Flow of water in the river restrict the surface mixing of nutrition particulates in the riverine water laterally and the atmospheric deposition may be the main factor for polluting the midstream of Ganga river with heavy metals.

Table 1 Monthly variation in water temperature, pH, Cr , Ni , Cu, As, Cd, Pb concentration (µg. L^{-1}) of River Ganga at Varanasi

Temperature °C

Site	Sub site	January	February	March
By pass bridge up stream	City side bank	15.2	19.0	23.5
	Mid-stream	15.3	18.8	23.1
	Off side bank	15.7	20.0	24.0
	Average	15.4	19.3	23.5
Assi ghat	City side bank	15.7	21.2	23.5
	Mid-stream	15.5	19.0	23.0
	Off side bank	16.0	21.5	23.7
	Average	15.7	20.6	23.4
Dashswamedh ghat	City side bank	15.1	19.1	23.3
	Mid-stream	15.5	18.7	22.9
	Off side bank	15.9	20.0	23.0
	Average	15.5	19.3	23.1
Raj ghat bridge down stream	City side bank	15.3	18.8	23.5
	Mid-stream	15.9	19.2	23.3
	Off side bank	16.0	20.0	24.0
	Average	15.7	19.0	23.6

pH

Site	Sub site	January	February	March
By pass bridge up stream	City side bank	8.26	8.20	8.00
	Mid-stream	8.68	8.65	8.65
	Off side bank	8.53	8.33	8.50
	Average	8.49	8.39	8.38
Assi ghat	City side bank	8.35	8.30	8.41
	Mid-stream	8.76	8.73	8.74
	Off side bank	8.64	8.60	8.61
	Average	8.58	8.54	8.59
Dashswamedh ghat	City side bank	8.65	8.48	8.53
	Mid-stream	8.63	8.60	8.67
	Off side bank	8.72	8.72	8.64
	Average	8.67	8.60	8.61
Raj ghat bridge down stream	City side bank	8.68	8.68	8.58
	Mid-stream	8.58	8.60	8.55
	Off side bank	8.62	8.60	8.50
	Average	8.63	8.63	8.54

Cr

Site	Sub site	January	February	March
By pass bridge up stream	City side bank	8.0	12.0	14.0
	Mid-stream	6.0	10.0	12.0
	Off side bank	7.0	11.0	13.0
	Average	7.0	11.0	13.0
Assi ghat	City side bank	7.0	15.0	17.0
	Mid-stream	4.0	12.0	14.0
	Off side bank	5.0	14.0	15.0
	Average	5.3	13.7	15.3
Dashswamedh ghat	City side bank	10.0	20.0	24.0
	Mid-stream	8.0	18.0	22.0
	Off side bank	9.0	19.0	23.0
	Average	9.0	19.0	23.0
Raj ghat bridge down stream	City side bank	12.0	21.0	23.0
	Mid-stream	10.0	19.0	20.0
	Off side bank	11.0	20.0	21.0
	Average	11.0	20.0	21.3
Average		8.1	15.9	18.2
WHOS (2004)	5			
TRV	11			

As

Site	Sub site	January	February	March
By pass bridge up stream	City side bank	10.0	16.0	20.0
	Mid-stream	8.0	12.0	15.0
	Off side bank	11.0	14.0	18.0
	Average	9.7	14.0	17. 7
Assi ghat	City side bank	17.0	20.0	24.0
	Mid-stream	14.0	17.0	20.0
	Off side bank	16.0	18.0	22.0
	Average	15.7	18.3	22.0
Dashswamedh ghat	City side bank	44.0	50.0	54.0
	Mid-stream	40.0	45.0	50.0
	Off side bank	41.0	46.0	51.0
	Average	41.7	47.0	51.7
Raj ghat bridge down stream	City side bank	65.0	70.0	83.0
	Mid-stream	60.0	72.0	78.0
	Off side bank	62.0	71.0	80.0
	Average	62.3	71.0	80.3
Average		32.3	37.6	42.9
WHOS (2004)	10			
TRV	150			

Ni

Site	Sub site	January	February	March
By pass bridge up stream	City side bank	17.0	14.0	16.0
	Mid-stream	16.0	12.0	14.0
	Off side bank	15.0	13.0	15.0
	Average	16.0	13.0	15.0
Assi ghat	City side bank	13.0	20.0	24.0
	Mid-stream	11.0	18.0	20.0
	Off side bank	12.0	19.0	22.0
	Average	12.0	19.0	22.0
Dashswamedh ghat	City side bank	20.0	24.0	33.0
	Mid-stream	18.0	22.0	28.0
	Off side bank	19.0	23.0	29.0
	Average	19.0	23.0	30.0
Raj ghat bridge down stream	City side bank	23.0	27.0	28.0
	Mid-stream	20.0	24.0	25.0
	Off side bank	21.0	25.0	26.0
	Average	21.3	25.3	26.3
Average		17.1	20.1	23.3
WHOS (2004)	70			
TRV	52			

Cd

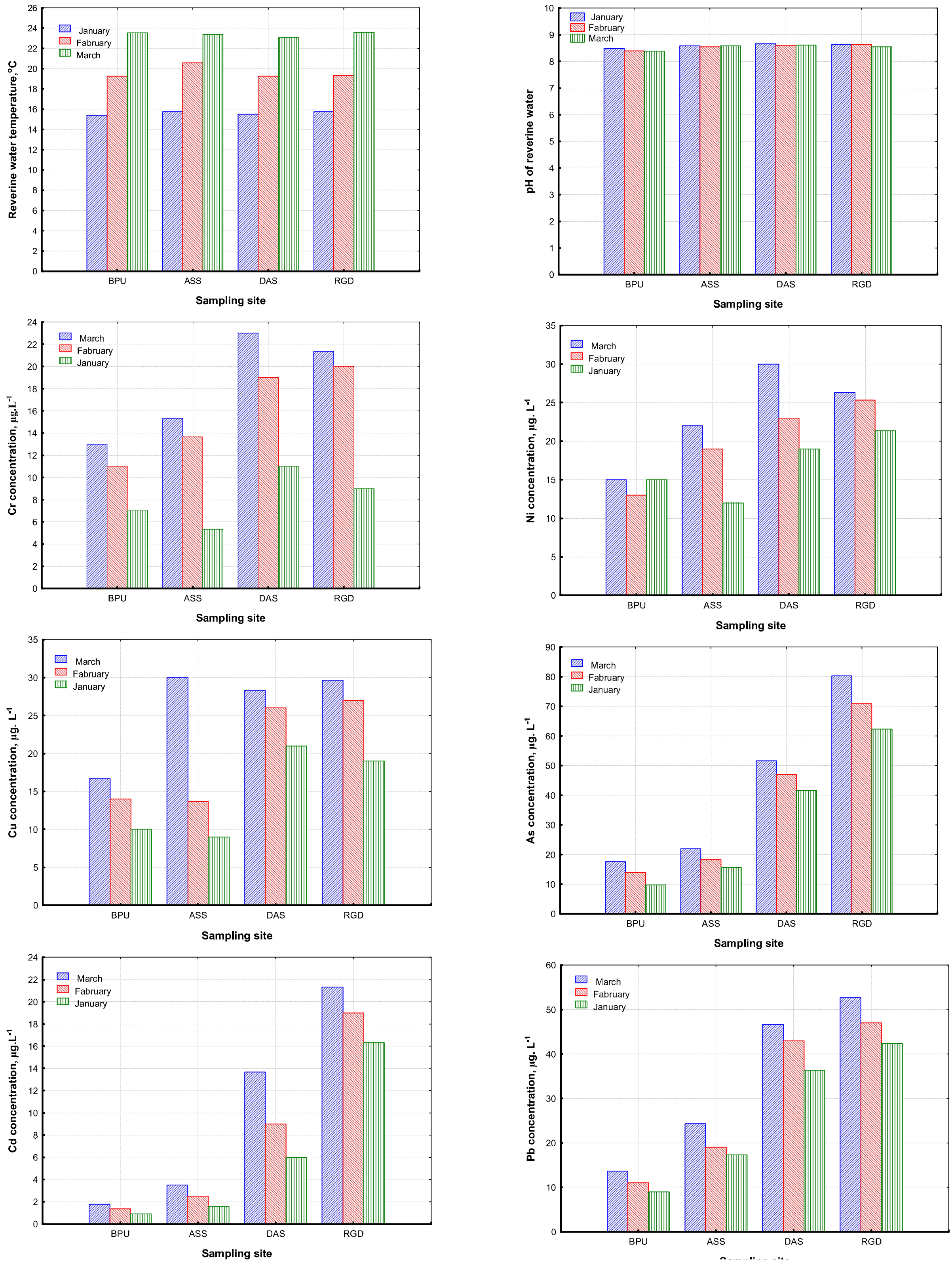
Site	Sub site	January	February	March
By pass bridge up stream	City side bank	1.0	1.5	2.0
	Mid-stream	0.8	1.2	1.5
	Off side bank	0.9	1.4	1.8
	Average	0.9	1.4	1.8
Assi ghat	City side bank	2.0	3.0	4.0
	Mid-stream	1.2	2.0	3.0
	Off side bank	1.5	2.5	3.5
	Average	1.6	2.5	3.5
Dashswamedh ghat	City side bank	7.0	10.0	15.0
	Mid-stream	5.0	8.0	12.0
	Off side bank	6.0	9.0	14.0
	Average	6.0	9.0	13.7
Raj ghat bridge down stream	City side bank	18.0	20.0	23.0
	Mid-stream	15.0	18.0	20.0
	Off side bank	16.0	19.0	21.0
	Average	16.3	19.0	21.3
Average		6.2	8.0	10.1
WHOS (2004)	3			
TRV	2			

Cu

Site	Sub site	January	February	March
By pass bridge up stream	City side bank	11.0	15.0	18.0
	Mid-stream	9.0	13.0	15.0
	Off side bank	10.0	14.0	17.0
	Average	10.0	14.0	16.7
Assi ghat	City side bank	10.0	15.0	33.0
	Mid-stream	8.0	12.0	28.0
	Off side bank	9.0	14.0	29.0
	Average	9.0	13.7	30.0
Dashswamedh ghat	City side bank	22.0	27.0	30.0
	Mid-stream	20.0	25.0	27.0
	Off side bank	21.0	26.0	28.0
	Average	21.0	26.0	28.3
Raj ghat bridge down stream	City side bank	20.0	28.0	31.0
	Mid-stream	19.0	26.0	28.0
	Off side bank	18.0	27.0	30.0
	Average	19.0	27.0	29.7
Average		17.4	20.2	23.5
WHOS (2004)	2000			
TRV	9			

Pb

Site	Sub site	January	February	March
By pass bridge up stream	City side bank	10.0	12.0	15.0
	Mid-stream	8.0	10.0	12.0
	Off side bank	9.0	11.0	14.0
	Average	9.0	11.0	13. 7
Assi ghat	City side bank	19.0	20.0	26.0
	Mid-stream	16.0	18.0	23.0
	Off side bank	17.0	19.0	24.0
	Average	17.3	19.0	24.3
Dashswamedh ghat	City side bank	39.0	45.0	48.0
	Mid-stream	33.0	40.0	45.0
	Off side bank	37.0	44.0	47.0
	Average	36.3	43.0	46. 7
Raj ghat bridge down stream	City side bank	45.0	48.0	55.0
	Mid-stream	40.0	46.0	49.0
	Off side bank	42.0	47.0	54.0
	Average	42.3	47.0	52. 7
Average		26.3	30.0	34.3
WHOS (2004)	10			
TRV	3			



Monthly variation in water temperature, pH, Cr , Ni , Cu, As, Cd, Pb concentration (µg. L^{-1}) of River Ganga at Varanasi

In the present study it is clear that the accumulation of heavy metals due to the atmospheric deposition is a major source and this is the same conclusion was found in another study that explain the increase of concentrations of (Cd, Cr, Zn) and another heavy metals due to the atmospheric deposition (Anand and Pandey, 2014) [22]. Samples were collected along the river ganga for four sites and for each site, samples were taken for city side bank, midstream, and off side bank and the result showed that the concentration of heavy metals were high in the city side bank for all the sites and reduce in the off side bank (rural) and this is due to the highly effect of human activity. In the midstream there is a reduction in the concentration of heavy metals because of the flow speed. In general, the concentration of heavy metals increases in the direction of flow in the river from By Pass Bridge upstream until Raj ghat bridge downstream where the heavy metals concentrate there. In the present study, the human activity in the city and rural sites are a major sources of accumulation the heavy metals in the city and off side banks. While, the samples are taken in the midstream explain the effect of atmospheric deposition. The concentrations of heavy metals measured in the present study are higher than that accepted for the drinking water as in the standard for environmental quality (WHO, 2004). The concentrations of (Cr, As, Cd, Pb) are higher than limits accepted internationally as in the world health organization (WHO, 2004), while, the concentrations of (Ni, Cu) are in the limits accepted internationally. Temperature of riverine water also effect on the heavy metals concentrations. Where the concentrations increases from January to march. Generally, heavy metals precipitate in alkali media in the form of undissolved oxide and carbonate. It is proved that the toxicity of heavy metals increase with decreasing the concentration dissolved oxygen in water. While, increase of temperature decrease the quantity of dissolved oxygen in water (DO). Then, increase of temperature will increase the toxicity level due to depleting the dissolved oxygen. Increasing the energy demand for microorganism will increase the rate of inspiration for the organism and led to the accumulation of wastes in high rate (Bonga and Lock, 2003) [23].

4. CONCLUSION

Day after a day, heavy metals accumulation increased in the Ganges river in Varanasi due to the increase of anthropogenic activities which comes with huge amount of untreated wastes discharged into the river. The present data indicates a strong effect of the variety of industrial and domestic activities inside Varanasi region. The bioaccumulation of heavy metals is cause of concern if the concentration of heavy metals may not harm the aquatic organisms. The sources of heavy metals have to monitored to control the concentration level of heavy metals in the riverine water. The concentrations of heavy metals measured in the present study are higher than that accepted for the drinking water as in the standard for environmental quality (WHO, 2004) [24]. The concentrations of (Cr, As, Cd, Pb) are higher than limits accepted internationally as in the world health organization (WHO, 2004), while, the concentrations of (Ni, Cu) are in the limits accepted internationally. Temperature of riverine water also effect on the heavy metals concentrations.

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تقييم اثر المعادن الثقيلة على نوعية المياه في نهر الكنج في مدينة بنارس الهندية

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الخلاصة

يوما بعد يوم يزداد تركيز المعادن الثقيلة في مياه الانهار مما يؤثر سلبا وبصورة دراماتيكية على الفعاليات الحيوية المختلفة. العلماء وصانعي القرار في الهند ركزوا اهتمامهم على ارتفاع مستوى الملوثات والتغيرات الكبيرة في نوعية المياه في مجرى نهر الكنج لاهميته الكبيرة. الدراسة الحالية هي محاولة لتقييم نوعية المياه في نهر الكنج من خلال قياس التغيرات النوعية للمياه ومستوى التغيرات في تراكيز المعادن الثقيلة التي حدثت خلال ثلاثة اشهر (كانون الثاني، شباط، اذار) لسنة (2013). تم اجراء دراسة منتظمة على مياه نهر الكنج في مدينة بنارس الهندية واخذ (36) نموذج من اربع محطات مختلفة على طول مجرى النهر في المدينة المذكورة اعلاه. وجد ان ترتيب تراكم المعادن الثقيلة في مياه النهر كانت (As > Pb > Cu >Ni > Cr > Cd). تم تحليل النماذج لمعرفة الحامضية ودرجة الحرارة وتراكيز العناصر الثقيلة المختلفة. تبين من خلال الدراسة ان تراكيز العناصر الثقيلة المدروسة المأخوذة من بعض المحطات كانت اكثر من الحدود المسموح بها في مواصفات منظمة الصحة العالمية والقيمة المرجعية المسموح بها عالميا .

الكلمات المفتاحية: تلوث الماء ، مياه نهر الكنج، المعادن الثقيلة.