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**WATER QUALITY ASSESSMENT OF RIVER RAVI
AROUND LAHORE CITY**

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ABSTRACT

The present study was conducted to assess the water quality of River Ravi at four sites, namely; Ravi Syphon, Shahdarah Bridge, Mohlanwal village and confluence point of Hudiara and Sattukatla drains during 2009-10. Twelve water samples were collected from four sites after an interval of 2 months and were analyzed for physical (color, odor and turbidity), chemical (pH, TDS, Cl, F, NO₃, Cu, Zn, Ni and Pb) and bacteriological (E. coli) parameters. The results were compared with WHO, US-EPA and Pak-EPA criteria of drinking water quality.

The study main findings of the study included:

- i) The color of water samples varied from yellowish to blackish, odor of these samples varied from odorless to objectionable (OB) and turbidity ranged from 19.7 to 122.7 NTU.
- ii) pH, TDS, Cl, F, NO₃, Cu, Zn, Ni and Pb ranged from 7.4 to 8.1, 178 to 985 ppm, 14.4 to 122.6 ppm, 0.23 to 0.73 ppm, 0.5 to 33.3 ppm, 0.04 to 0.18 ppm, 0.05 to 0.21 ppm, below detection level (BDL) to 0.12 ppm and BDL to 0.11 ppm, respectively
- iii) E. coli were found in all water samples.
- iv) pH, TDS, Cl, F, NO₃, Cu and Zn levels were found within the permissible limits of WHO, Pak-EPA and US-EPA for drinking water quality.
- v) Turbidity, Pb, Ni (except at Ravi Syphon) and E. coli levels exceeded the permissible limits for drinking water quality. The study also recommended measures and practices for sustainable management of surface water contamination.

Key Words: Drinking water quality, River Ravi, surface water, sustainable water management, water contamination

INTRODUCTION

Water covers three fourths of earth's surface and is one of essential ingredients of life [1]. The quality of water is as important as its quantity and the water should be free from pollution [2]. Globally, the discharge of effluents into

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water bodies and improper water management practices contributes significantly into the water pollution problems. The water quality is deteriorated in both industrialized as well as developing countries. More than half of the world's major rivers are contaminated which are polluting the surrounding ecosystems, deteriorating the groundwater quality and creating a risk for human health [3]. In Pakistan, untreated municipal and industrial wastewaters are indiscriminately discharged into the water bodies [4].

The Ravi River which has the smallest catchment of Pakistan's Rivers is 894 km long with a catchment area of 39,680 km² [5]. The municipal and industrial effluents are discharged in the River through Deg Nullah and Hudiara Drain. In addition, untreated municipal effluents of Lahore city and Shahdarah are disposed off into the River [6]. The discharge of untreated municipal and industrial effluents has converted the River into a sludge carrier [7]. The present investigation was carried out to assess the water quality of River Ravi for drinking purpose around Lahore City.

MATERIALS AND METHODS

The present study was conducted on River Ravi starting from Ravi Syphon and goes up to Mohlanwal village. In addition, confluence point of Hudiara and Sattukatla drains is also included in the study area (Figure 1).

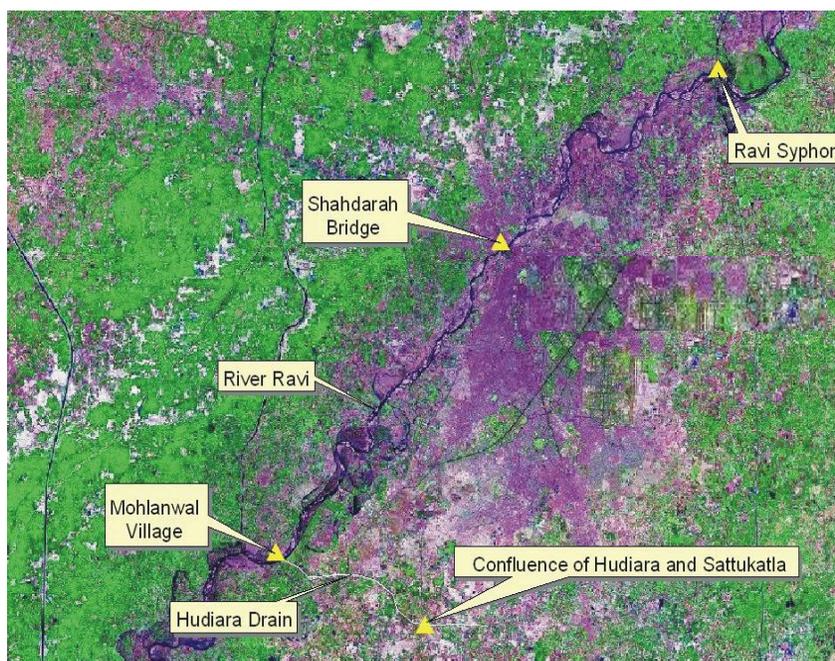


Figure 1. Schematic Map showing sampling sites

In the present study, twelve water samples were collected from River Ravi during November 2009 to March 2010 after every 2 month interval. The collection and preservation of samples were carried out according to standard methods prescribed by Greenberge *et. al*, 1992 [8]. The samples were analyzed for color, odor, turbidity, pH, TDS, Cl, F, NO₃, Cu, Zn, Ni, Pb and Escherichia coli. Color and odor

were measured by sensory tests or general observations, TDS were determined by multiplying the electrical conductivity (EC in dS/m) values with 640 and E. coli were measured by Bacti kit. The other parameters i.e. turbidity, pH, Cl, F, NO₃, Cu, Zn, Ni and Pb were analyzed according to standard methods prescribed by Greenberg *et. al*, 1992 [8]. The results were compared with WHO, US-EPA and Pak-EPA drinking water quality criteria (Table 1).

Table 1. Drinking Water Quality criteria

	TDS (ppm)	Cl (ppm)	Fl (ppm)	NO ₃ (ppm)	Cu (ppm)	Zn (ppm)	Ni (ppm)	Pb (ppm)	E. coli
WHO Criteria	<1000	250	1.5	50	2	3	0.02	0.01	0 in 100ml
Pak-EPA Criteria	<1000	< 250	≤1.5	≤ 50	2	5	≤0.02	≤0.05	0 in 100ml
US-EPA Criteria	1000	250	2	10	1	5	-	0.015	-

RESULTS AND DISCUSSION

Physical Parameters

Color and Odor: The color of water samples varied from yellowish to blackish and the odor of water samples varied from odorless to objectionable, OB (Table 2). The presence of color and odor in water samples indicates the disposal of domestic sewage and industrial effluents into the River Ravi and agricultural activities along the sampling sites.

Table 2. Color and odor analysis of water samples

Sr. #	Study Site	Color	Odor
1	Ravi Syphon	Yellowish	Odorless
2	Shahdarah Bridge	Blackish	OB
3	Mohlanwal Village	Blackish	OB
4	Confluence point of Hudiara and Sattukatla drain	Blackish	OB

Turbidity: The turbidity levels ranged from 19.7 to 122.7 NTU (Figure 2) with the minimum value at Ravi Syphon and maximum value at confluence point of drains.

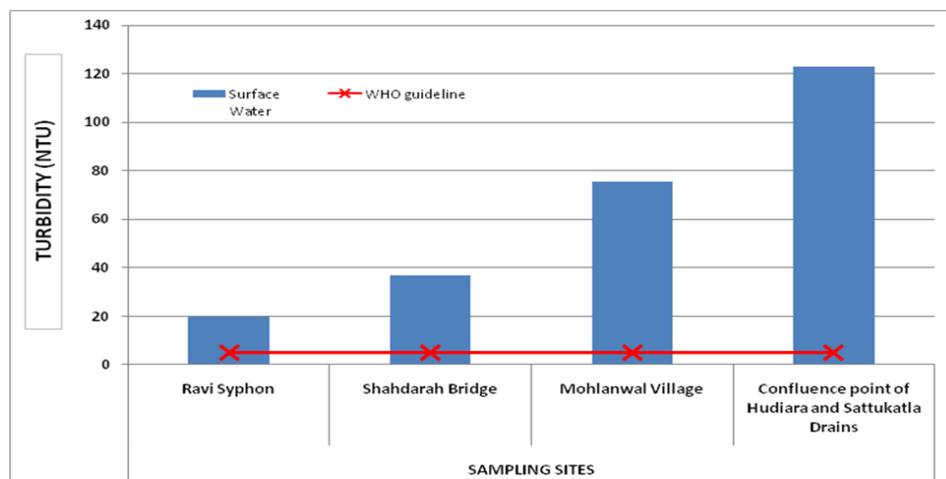


Figure 2. Turbidity levels of water samples

Turbidity of water samples showed an increase along the direction of flow of River up to Mohlanwal village and also at confluence point of drains. This is due to increase in pollution levels from industries and municipalities. The turbidity level at all the sampling sites was exceeding the WHO and Pak- EPA guideline values for drinking water (turbidity < 5 NTU).

Chemical Parameters

pH: The pH levels in the water samples ranged from 7.4 to 8.1 (Figure 3) with the minimum value at Shahdarah Bridge and maximum value at confluence point of drains. The pH level of the water samples showed a slight decreasing trend from Ravi Syphon to Shahdarah Bridge which then increased up to Mohlanwal village along the direction of flow and also at confluence point of drains. The high level of pH reflects the effect of pollution due to the discharge of municipal and industrial effluents and agricultural wastes. Past studies revealed that pH level at Ravi Syphon was 8.1 in the year 2007 [6] and it remained more or less stable till the present study (7.8). The pH level at Shahdarah Bridge remained more or less similar from the year 2000 till 2009 which was 8.3 [9,10,11 &12]. In the present study, pH level showed a slight decrease and reached at 7.4. In the present study, the pH at confluence point of drains reached at 8.1 which decrease from the year 2009 i.e. 9.0 [12] but is more or less similar from to the year 2000 and 2007 i.e. 8.2 [9 & 11]. The pH levels at all the sampling sites were within the permissible limits for drinking water (pH: 6.5 – 8.5).

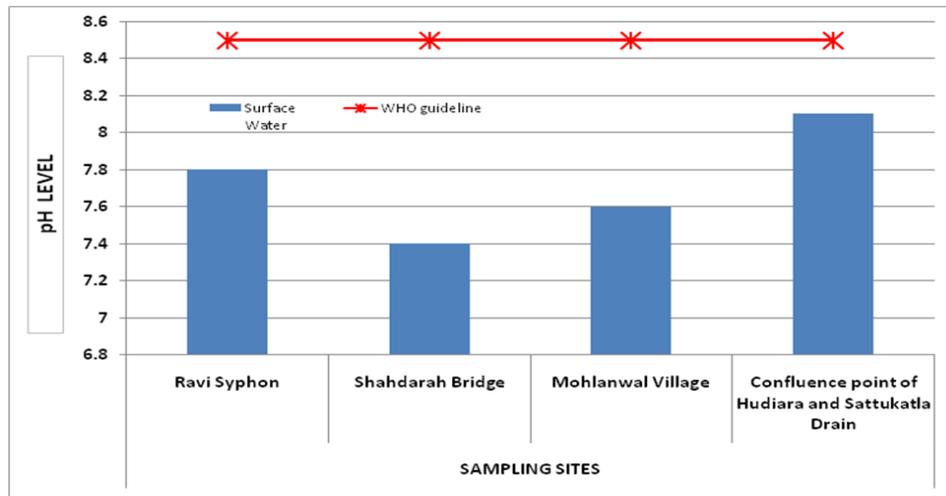


Figure 3. pH levels of water samples

Total Dissolved Solids (TDS): The TDS levels in the water samples ranged from 178 to 985 ppm (Figure 4) with the minimum value at Ravi Syphon and maximum value at confluence point of drains. TDS level in water samples showed an increase along the direction of flow of River up to Mohlanwal village and also at confluence point of drains due to discharge of municipal and industrial effluents from Lahore and nearby industrial areas. The TDS levels at Ravi Syphon in the present study was 178 ppm which showed a slight increase from the year 2007 i.e. 130 ppm [6]. The TDS level at Shahdarah Bridge was 186 ppm in the year 2007 [6] and in the present study, it was 307 ppm which indicated an increase in TDS levels. The present study showed that the TDS levels at the confluence points of drains were 985 ppm which indicated a slight decrease from the year 2000 i.e. 708 to 1256 ppm [13] and 2001 i.e. 1340 ppm [14]. In the present study, the value of TDS in all water samples was within the permissible limits for drinking water (Table 1).

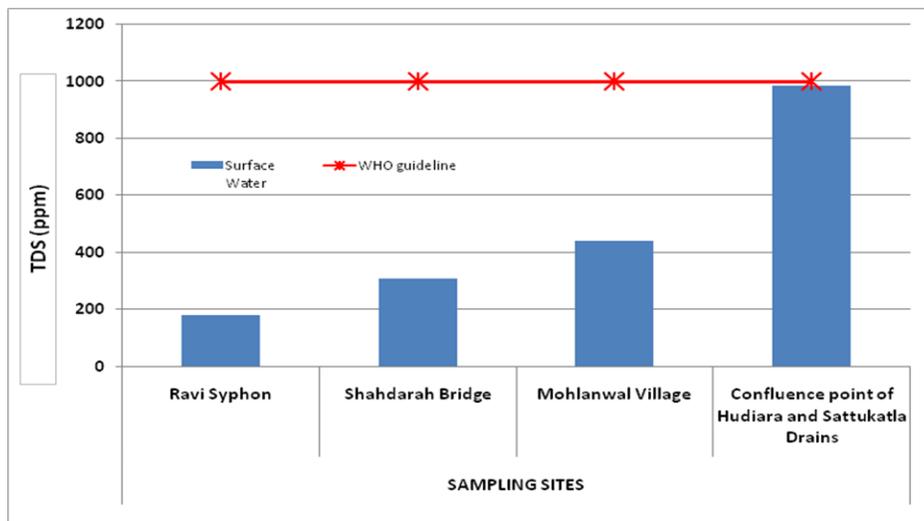


Figure 4. TDS values of water samples

Chloride (Cl): The chloride concentration ranged from 14.4 to 122.6 ppm (Figure 5) with the minimum value at Ravi Syphon and maximum value at confluence point of drains.

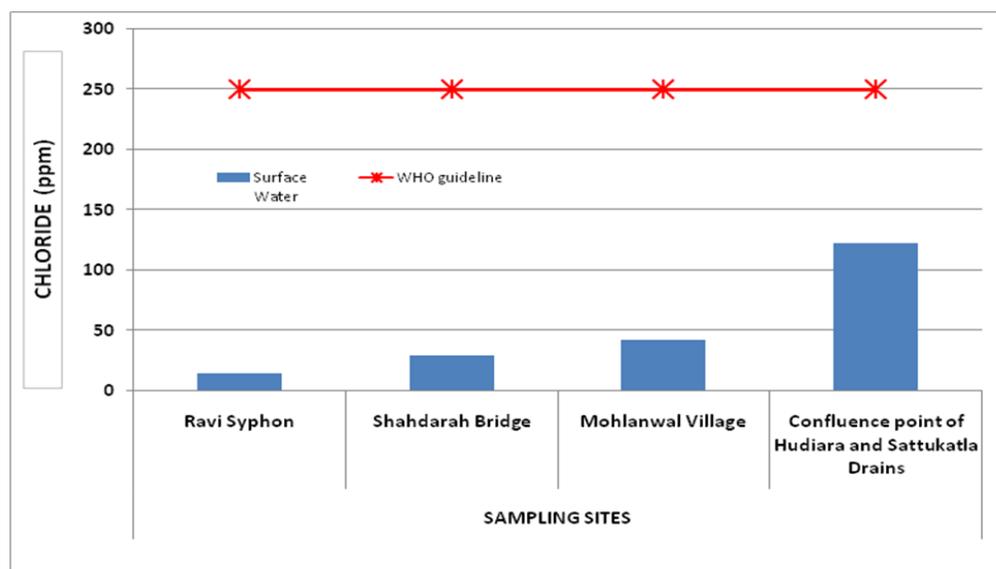


Figure 5. Chloride levels of water samples

The chloride level showed an increase along the direction of flow of River up to Mohlanwal village and also at confluence point of drains which reflects the effect of pollution due to discharge of municipal and industrial effluents, leachate from waste dumps and use of fertilizers. The past studies revealed that at Ravi Syphon, the chloride concentration showed an increase from the year 2007 i.e. 0.9 ppm [6] till the present study which showed 14.4 ppm. At Shahdarah Bridge, the chloride concentration was 1.0 ppm in the year 2007 [6] which increased to 29.3 ppm in the present study. The chloride concentration at Hudiara Drain was more or less similar from the year 2001 i.e. 200 ppm till the present study (122.6 ppm). The chloride levels at all sampling sites were within the permissible limits for drinking water (Table 1).

Fluoride (F): The fluoride level in the water samples ranged from 0.23 to 0.73 ppm (Figure 6) with the minimum level at Ravi Syphon and maximum level at confluence point of drains. The fluoride level showed an increase along the direction of flow of River up to Mohlanwal village and also at confluence point of drains due to the pollution from nearby industries and agricultural activities. The fluoride levels at sampling sites were within the permissible limits for drinking water (Table 1).

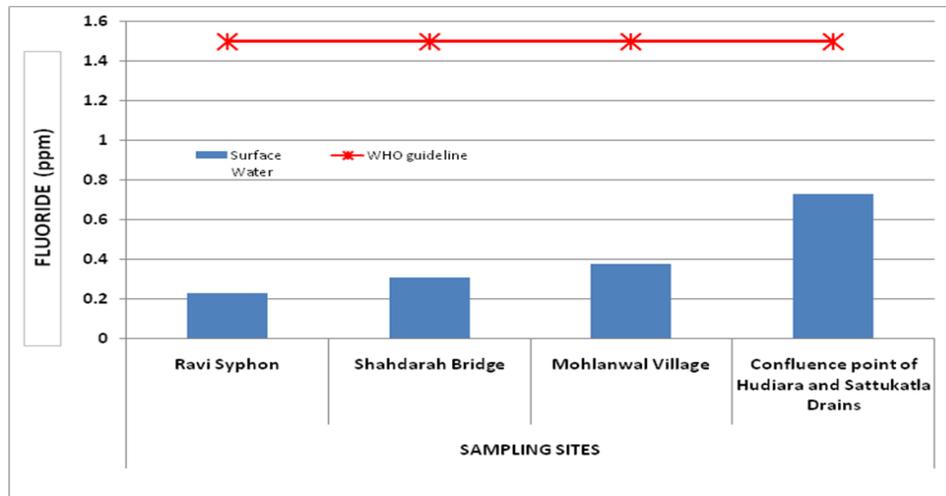


Figure 6. Fluoride levels of water samples

Nitrate (NO_3): The nitrate concentrations ranged from 0.5 to 33.3 ppm (Figure 7) with the minimum value at Ravi Syphon and maximum value at confluence point of drains. The nitrate levels of water samples showed an increase from Ravi Syphon to Shahdarah Bridge, and then decreased at Mohlanwal village along the direction of flow of River and increased at the confluence point of drains. The high nitrate level reflects the effect of pollution due to agricultural activities and discharge of municipal effluent. The past studies revealed that the nitrate concentration at Ravi Syphon in the year 2007 was 0.80 ppm [6] which decreased in the present study i.e. 0.5 ppm. At Shahdarah Bridge, the concentration of nitrate showed a slight increase from the year 2007 i.e. 3.20 ppm [6] till the present study (3.8 ppm). The nitrate levels at all sampling sites were within the permissible limits set by WHO, Pak-EPA and US-EPA (except for water at confluence point where it was high for standards set by US-EPA) for drinking water (Table 1).

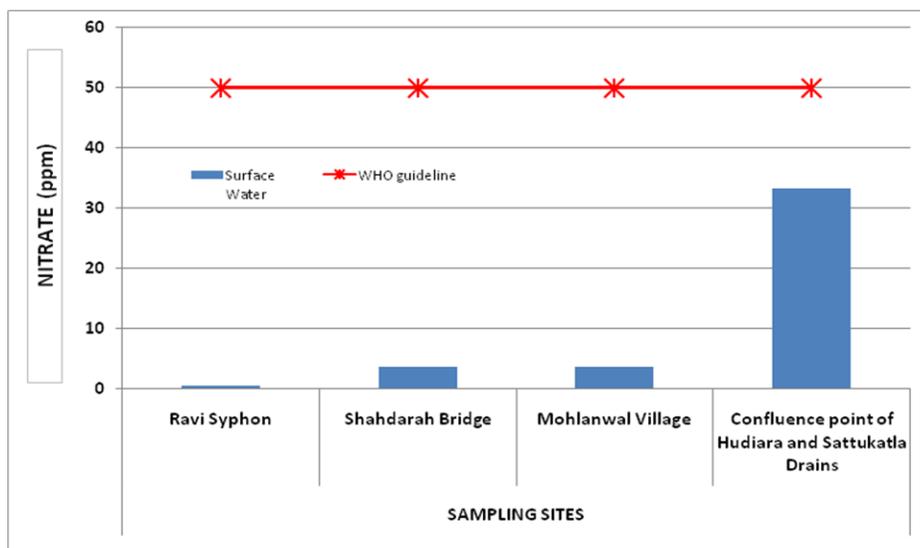


Figure 7. Nitrate levels of water samples

Copper (Cu): The copper level in the water samples ranged from 0.04 to 0.18 ppm (Figure 8) with the minimum level at Ravi Syphon and the maximum level at confluence point of drains.



Figure 8. Copper concentrations of water samples

The copper levels in water samples showed an increase along the direction of flow of River up to Mohlanwal village and also at confluence point of drains. The textile industries, dyeing units and electroplating workshops at Lahore and nearby industrial areas are the main sources of copper in the effluents. Past studies revealed that the copper levels at Ravi Syphon showed a slight decrease from the year 2007 i.e. 0.06 ppm [6] till the present study where it reached at 0.04 ppm. The copper levels at Shahdarah Bridge remained more or less similar from the year 2007 i.e. 0.11 to 0.28 ppm [11] to 2009 i.e. 0.22 ppm [12] till the present study (0.13 ppm). The copper level at Hudiara drain is highly variant from the year 2000 i.e. 0.062 to 0.163 ppm [13], 2001 i.e. 0.27 ppm [14], 2007 and 2009 i.e. 0.68 ppm [11 & 12] till the present study where it decreased at confluence point of drains and reached 0.18 ppm and it may be due to the timing of effluent discharged into the drain. However, a systematic and comprehensive program is required to monitor and validate the copper concentrations at Hudiara Drain. The copper levels at all sampling sites were within the permissible limits for drinking water (Table 1).

Zinc (Zn): The zinc concentrations ranged from 0.05 to 0.21 ppm (Figure 9) with the minimum value at Ravi Syphon and maximum value at confluence point of drains. The zinc levels showed an increase along the direction of flow of River up to Mohlanwal village and also at confluence point of drains. The agriculture waste, fish excreta and chemical industries are the main source of zinc in surface water. In the present study, the zinc concentration at Shahdarah Bridge decreased from the year 2000 i.e. 0.50 ppm [9], 2001 i.e. 0.52 ppm [10] and 2007 i.e. 0.61 ppm [11] and reached at 0.11 ppm. The zinc concentrations at Hudiara drain are highly variant from the year 2000 i.e. 0.92 to 1.57 ppm [9], 2001 i.e. 1.64 ppm [10], 2007 i.e. 0.86 ppm [11] and 2009 i.e. 0.82 ppm till the present study i.e. 0.21 ppm. Therefore, zinc

concentration needs to be carefully studied through systematic and comprehensive program. The zinc levels at all sampling sites were within the permissible limits for drinking water (Table 1).

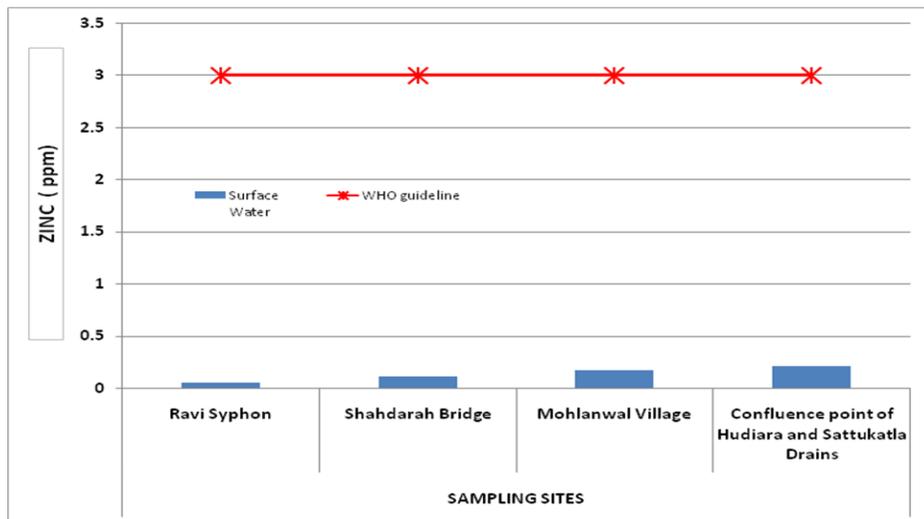


Figure 9. Zinc concentrations of water samples

Nickel (Ni): The nickel level ranged from BDL to 0.12 ppm (Figure 10) with the minimum level at Ravi Syphon and maximum at confluence point of drains. The nickel levels at Ravi Syphon were below the detection limit which then increased up to Mohlanwal village along the direction of flow and also at confluence point of drains. The high level of nickel reflects the effect of pollution due to discharge of industrial effluents (from oil and ghee industries, dyeing units and electroplating workshops at Lahore and nearby industrial areas). The nickel levels at Shahdarah Bridge for the year 2009 i.e. 0.02 ppm [12] and at Hudiara drain for the year 2007 [11] and 2009 [12] i.e. 0.27 are close to the present study. The nickel levels at all sampling sites except at Ravi Syphon and Shahdarah Bridge were exceeding the permissible limits for drinking water (Table 1).

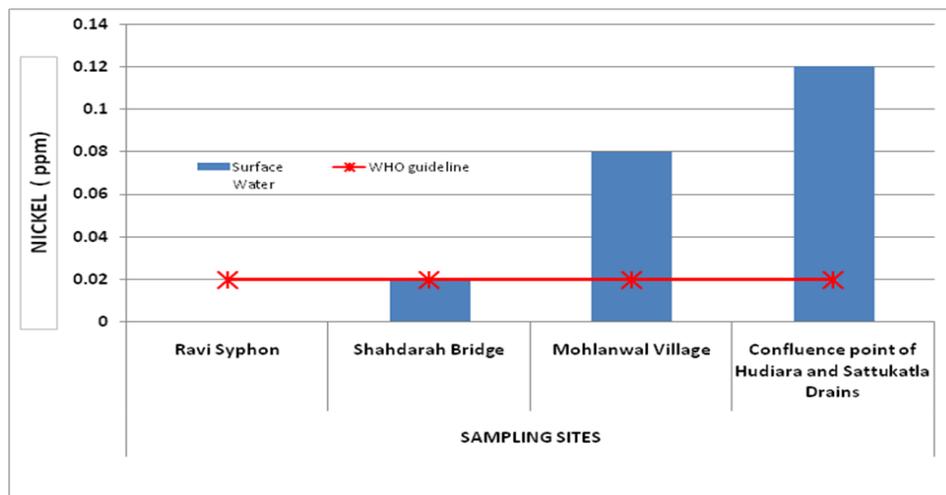


Figure 10. Nickel levels of water samples

Lead (Pb): The lead level in the water samples ranged from BDL to 0.11 ppm (Figure 11) with the minimum level at Ravi Syphon and maximum at Mohlanwal village.

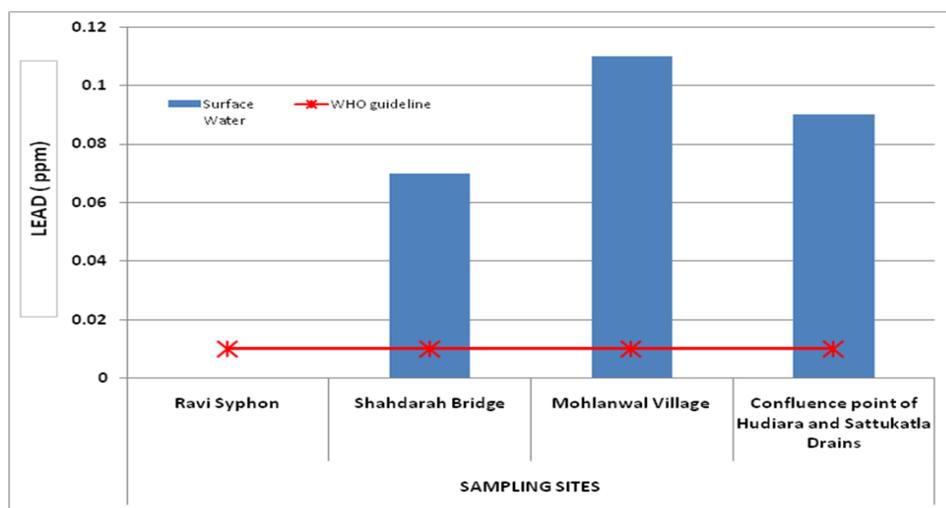


Figure 11. Lead levels of water samples

The lead levels at Ravi Syphon were below the detection limit which then increased up to Mohlanwal village along the direction of flow of River and then decreased at confluence point of drains. The main sources of lead include paint and coating industries and lead batteries manufacturing units at Lahore and nearby industrial areas. Past studies showed that the lead value at Shahdarah Bridge for the year 2001 i.e. 0.25 ppm [10] was close to the present study. While the lead concentration in the previous studies at Ravi Syphon for the year 2007 i.e. 1.0 ppm [6], Shahdarah Bridge for 2007 i.e. 0.0003 ppm [11] and negligible in 2009 [10], at Hudiara Drain for the year 2000 i.e. 0.062 ppm [13], 2001 i.e. 0.76 ppm [10], 2007 and 2009 i.e. 0.66 ppm [11 &12] and 2009 are highly variant. In order to have a better understanding, a systematic and comprehensive monitoring program is required. The lead levels at all sampling sites except at Ravi Syphon exceeded the permissible limits for drinking water (Table 1).

Bacteriological Parameters

E. coli: *E. coli* were found in all water samples. The presence of *E. coli* indicated the contamination of water body with agricultural, domestic and animal wastes. The past studies revealed the contamination of Ravi Syphon and Hudiara drain with faecal coliforms in the year 2000 [13 &15]. The *E. coli* levels at all sites were exceeding the permissible limits for drinking water (Table 1).

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

- The color of water samples varied from yellowish to blackish, odor varied from odorless to objectionable (OB) and turbidity ranged from 19.7 to 122.7 NTU.

- pH, TDS, Cl, F, NO₃, Cu, Zn, Ni and Pb ranged from 7.4 to 8.1, 178 to 985 ppm, 14.4 to 122.6 ppm, 0.23 to 0.73 ppm, 0.5 to 33.3 ppm, 0.04 to 0.18 ppm, 0.05 to 0.21 ppm, BDL to 0.12 ppm and BDL to 0.11 ppm, respectively.
- E. coli were present in all water samples.
- The pH, TDS, Cl, F, NO₃, Cu and Zn levels of water samples were within the permissible limits of WHO, Pak-EPA and US-EPA for drinking water quality. Turbidity, Pb, Ni (except at Ravi Syphon) and E. coli levels were exceeding the permissible limits for drinking water quality.
- The surface water pollution is caused by the disposal of untreated municipal and industrial effluents into the River Ravi.
- The pollution levels are increasing along the direction of flow of River Ravi relative to Ravi Syphon site and are maximum at the confluence point of Hudiara and Sattukatla drain. This is happening due to high level of pollution inputs from municipal and industrial wastes coming from Lahore and nearby industrial areas as the River flows through the city.

Recommendations

- Regular monitoring of surface water quality is required with the emphasis on pollution control strategies.
- Water quality laws and regulations need to be enforced effectively.
- The installation of wastewater treatment plants in the industries needs to be made mandatory for installation permits / licenses.
- A proper solid waste management system needs to be put in place to prevent the dumping of solid waste into and along the banks of the River Ravi.
- A comprehensive spatial and temporal database needs to be developed and managed through regular assessment and monitoring of quantity and quality of industrial effluents being disposed off into the River Ravi. This would help in development and implementation of effective measures and strategies for control and mitigation of surface water contamination. .

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