Spatio-temporal microbial water quality assessment of selected natural streams of Islamabad, Pakistan

Waqar Azeem Jadoon[1], Masood Arshad[2], Imran Ullah[2]

[1]*Graduate school of Biosphere Science, Hiroshima University, 1-4-4 Kagamiyama, Higashi-Hiroshima, Hiroshima 739-8528, Japan.*
[2]*WWF - Pakistan, House No. 451, Street No. 2, Sector F-11/1, Islamabad, Pakistan*

Corresponding author: Waqar Azeem Jadoon (Email: waqar.jadoon@gmail.com)

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ABSTRACT

The study was conducted to examine the water quality of natural streams of Islamabad district in selected sites viz. urban, semi-urban and natural by using *Total coliforms* (TC), *Faecal coliforms* (FC) and *Escherichia coli* (*E. coli*) as indicator bacteria. During this study, a total of 44 samples were taken for three seasons (pre-monsoon, monsoon, and post-monsoon). The results revealed that almost all surveyed sites were contaminated if not all but at least in one season. Presence of FC in the stream of Margalla Hills National Park (MHNP) can be attributed to wildlife activities in the area. Urban and semi-urban areas showed higher faecal pollution in comparison to MHNP during all seasons. It was observed that 62.7 % urban, 61.1 % semi-urban and 14.2 % MHNP water samples have presence of *E. coli* for all seasons, TC and FC exceeded the 1600 MPN/100ml. The possible sources of faecal contamination include municipal waste, septic tanks in urban areas while runoff from agriculture and grazing lands, domestic animals and poultry waste in semi-urban areas are additional sources. High level of faecal pollution during monsoon season compared to pre-monsoon and post-monsoon seasons may be associated with increased run-off as a result of high density of rainfall during monsoon.

Introduction

The surface water quality is of great importance due to its effects on human health and aquatic ecosystems. Running water is highly vulnerable to pollution attributing to their role in carrying off the municipal and industrial wastewater and run-off from agriculture in its vast drainage basins. Anthropogenic influences, as well as natural processes, deteriorate surface water and impair their use for drinking, industrial, agricultural, recreation or other purposes. In Pakistan, due to lack of proper facilities of waste disposal only 1 % of wastewater is treated before being discharged directly into water bodies. It is general trend that concentration of different pollutants in urban areas is high as compared to suburb and natural environment (Lewis *et al*., 2007), which indirectly indicates anthropogenic activities. Although water bodies have their own system of keeping themselves clean but the untreated wastewater from cities is reaching above the threshold of these water sources to clean automatically (Wattoo *et al*., 2004).

There are many biological entities ranging from simple viruses, protozoan, and bacteria to complex organism deteriorating water quality (Miernik, 2004). Faecal *coliforms* and *Escherichia coli* (*E. coli*) are used as indicators of possible sewage contamination due to their presence in human and animal faeces (George *et al*., 2001; Hill *et al*., 2006; Lewis *et al*., 2007; Boyer, 2008). Other sources of faecal contamination are sewage plants, poultry farms, domestic and wild animal manure, and storm runoff (Lewis *et al*., 2007; Boyer, 2008). Although they are generally not harmful themselves, they indicate the possible presence of pathogenic bacteria, viruses, and protozoans that also live in human and animal digestive systems (Miernik, 2004). These pathogens cause serious health risk (Luther & Fujoika, 2004; Thurston-Enriquez *et al*., 2005; Hussain *et al*., 2007) and therefore contaminate water, which is no more suitable for potable supply unless suitably treated (Miernik, 2004). Since it is difficult, time consuming and expensive to test directly for the presence of a large variety of pathogens, water is usually tested for *coliforms*.

The objective of this study is to demonstrate the impact of intense anthropogenic interference on water quality in selected sites of Islamabad Capital Territory (ICT). The importance of such survey is documented through the fact that a majority of population living in Rawalpindi uses drinking water from Rawal Lake being fed by these natural streams. This highly polluted water may cause severe illnesses especially during summer months. In order to assess the water quality, a study was conducted to monitor the water quality of these streams in selected sites of Islamabad. The main objectives of this study are to (1) monitor microbial water quality by detecting the presence of total *Coliforms*, faecal *Coliforms* and *Escherichia coli* in surface water and (2) monitor spatial and temporal variation of faecal contamination in stream's water at selected sites of Islamabad.

Material and Methods

Study area

Islamabad the Federal Capital Territory of Pakistan is situated at the foothills of Himalayas at the edge of Pothohar Plateau in north of the country at an elevation of 558 m above mean sea level (Fig.1).

Total area covered by the city is 8,010 km^2 (33° 43′ 09.6″ N and 73 03′ 23.3″ E). Islamabad combines two ecological components: the Indo-Himalayan and Irano-Saharan ecosystem that together make it a unique location. The climate is sub-tropical semi-arid. Being present in monsoon rainfed area, it experiences two rainy seasons and receives sufficient rain. In winter, rain prevails from January to March and summer rain period extends from July to September. Fairly cold winters with sparse snowfall over the hills and sleet in the city are characteristic of area. Temperatures range from a minimum - 3.9°C in January to a maximum of 46.1°C in June. Average annual rainfall is 1000 mm (HWF, 2007). Rawal Lake along with two other manmade Simli and Khanpur Dams regulate the climate of Islamabad.

Data Collection

Selection of method and sampling sites

Discrete sampling technique was adopted to collect stream water samples (Thiagarajan *et al*., 2007; Kammerer *et al*., 2008). In order to examine the ecological consequences of microbial pollution, study area was divided into three parts: urban, semi-urban and MHNP. A total of 44 water samples were taken (19 in urban, 16 in semi-urban and 9 in MHNP) for pre-monsoon, monsoon and

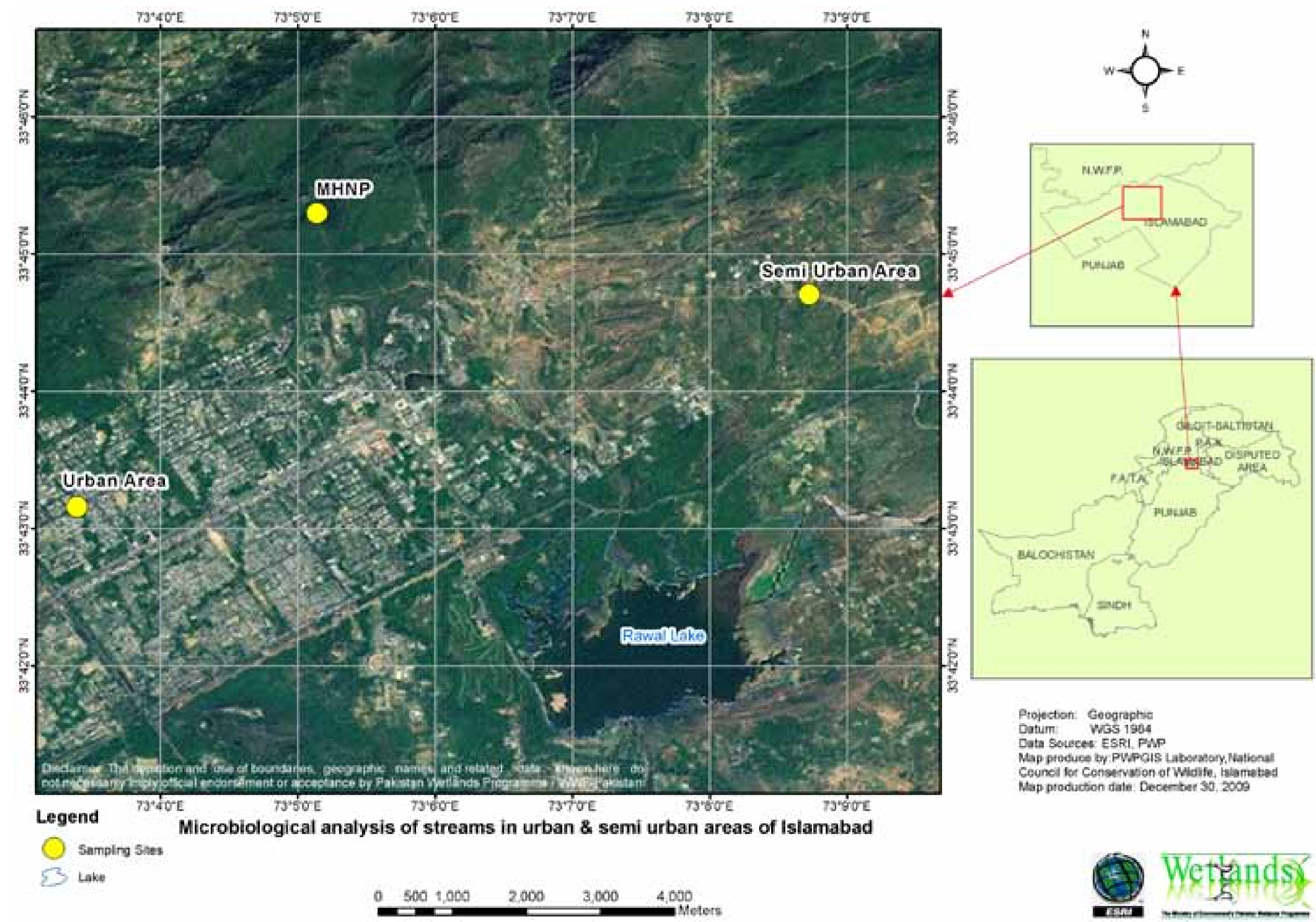

Figure 1: Study area showing the three sampling locations (Urban, Semi-urban and MHNP)

post-monsoon. Samples were collected from streams near bridge downstream in urban and semi-urban areas, while in MHNP no bridge was present hence no landmark was taken. The collected samples were analysed for *total coliforms, faecal coliforms and Escherichia coli* following Clesceri *et al*., (1998).

Water Sample Collection

Samples were collected in 2009 during base flow conditions (Lewis *et al*., 2007). All samples were collected in 100 ml sterilised plastic bottles and a space of at least 2.5 cm was left in the bottle to facilitate mixing by shaking (Hill *et al*., 2006).

Bacterial analysis

In order to ensure the quality, ten replicate tubes each containing 10 ml aliquot were used. Sample was poured in lactose broth and was incubated at 37°C for 48 hours. The production of gas in tubes showed positive results for the presence of bacteria. The Eosin Methylene Blue (EMB) endo agar plates were streak by using positive broth from presumptive test and were incubated for 24 hours at 37°C. Dark centres with green metallic shine on EMB and dark pink colour on endo agar plates are positive confirm phase. The presence was confirmed by using these positive and incubated on one lactose and one nutrient agar slant and these tubes were incubated for 24 hours at 37°C. Slides prepared from positive incubates were examined under microscope presence of gram-negative, short bacilli confirmed the presence of *E. coli*.

Data Analysis

Prior to performing the statistical analysis, the normality of the raw data was checked. Highly skewed raw data set was not normally distributed and required transformation. Due to high variation within data, it was not possible to transform the data through any test so non-parametric statistical tests were adopted for data analysis. Statistical analyses were performed using Minitab (ver. 11.12), Minitab Inc. Kruskal-Wallis test with alpha 0.05 was used to find out the difference between the groups (Rivero-Marcotegui *et al*., 1998; Rubel & Wisnivesky, 2005).

Results and discussion

Bacterial Density

The result of total *coliform*s, faecal *coliform*s and *E. coli* in surface water of study area for all three seasons are shown in (Table 1).

In urban area, the highest density of water samples with higher TC and FC count was observed during monsoon season. This high concentration may be attributed to high rainfall instances during monsoon as was proved by Hill *et al*., (2006) and WHO, (2003). As a result of these rains, the runoff from lawn, agricultural fields and over flowing of municipal waste increase phosphates and nitrates concentration in water bodies (Liu *et al*., 2000; Filoso *et al*., 2004; Williams *et al*., 2004 & 2005) which enhances bacterial growth (Mallin *et al*., 2000; Lewis *et al*., 2007). These nutrients also increased the water temperature, the critical parameter which is positively related with bacterial growth (Farooq *et al*., 2008).

Higher bacterial densities were present in semi-urban areas during all three seasons. *E. coli* were present at all, six and nine sampling sites during pre-monsoon, monsoon and post-monsoon respectively. In semi-urban areas, many gutter lines along with municipal waste directly open in streams. *Coliform*s abundances can be high possibly due to leaking or overflowing sanitary sewers (Duda *et al*., 1982; Rose, 2006). Run-off from agriculture and grazing land is another important source of faecal pollution to surface water (Thiagarajan *et al*., 2007) in semi-urban areas. In MHNP, faecal contamination was observed during monsoon season only two sites were characterised by the presence of *E. coli*. This faecal contamination in MHNP during monsoon may be attributed to surface runoff from adjoining lands (Lewis *et al*., 2007) and source of this contamination may be the wildlife.

Temporal Variation

The results of Kruskal Wallis Test ($H_{2,57}$ = 13.62, p<0.001) illustrated that there is variation in TC concentration for all three seasons in urban area which is further explored that this variation is due to pre-monsoon p<0.0015 and monsoon, post-monsoon were similar p<1. Results showed that higher accumulation has taken place during monsoon and post-monsoon seasons. Such high concentrations can be attributed to high density of storm drains that promote the rapid flushing of bacteria (Wallberg & Johnstone, 1995) from lawns, roads and other surfaces into streams (Frenzel & Couvillion, 2002). The FC accumulation in urban areas has high variation (Kruskal-Wallis Test, $H_{2,57}$ = 25.32, p<0.000) during three consecutive seasons. All three seasons were significantly different (pre-monsoon and monsoon p<0.000, pre-monsoon and post-monsoon p<0.0003, monsoon and post-monsoon p<0.003)

Table 1: Concentration of faecal bacteria (TC=Total *coliform*s, FC=Faecal *coliform*s expressed in MPN/100ml and *E. coli* as presence/absence) for U=urban, S=semi-urban and N=Natural sites during Pre-monsoon, Monsoon and Post-monsoon seasons in natural streams of Islamabad.

Sample #	Pre-Monsoon			Monsoon			Post-Monsoon		
	TC	FC	E-Coli	TC	FC	E-Coli	TC	FC	E-Coli
U01	220	130	+ve	≥1600	≥1600	+ve	≥1600	350	+ve
U02	170	130	+ve	-	-	-	≥1600	≥1600	+ve
U03	130	27	+ve	≥1600	≥1600	-ve	≥1600	280	+ve
U04	8	8	+ve	≥1600	≥1600	-ve	≥1600	280	+ve
U05	Nil	Nil	-ve	≥1600	≥1600	+ve	≥1600	220	-ve
U06	Nil	Nil	-ve	≥1600	≥1600	-ve	≥1600	350	-ve
U07	≥1600	34	+ve	≥1600	≥1600	+ve	-	-	-
U08	≥1600	220	+ve	≥1600	≥1600	-ve	≥1600	280	+ve
U09	≥1600	33	+ve	≥1600	350	+ve	≥1600	220	+ve
U10	≥1600	17	+ve	≥1600	1600	+ve	≥1600	220	-ve
U11	≥1600	9	+ve	≥1600	34	-ve	≥1600	280	+ve
U12	50	9	+ve	≥1600	500	-ve	≥1600	280	+ve
U13	-	-	-	≥1600	34	-ve	≥1600	280	+ve
U14	34	27	+ve	≥1600	≥1600	-ve	≥1600	34	-ve
U15	280	34	+ve	≥1600	350	+ve	≥1600	33	+ve
U16	900	34	+ve	≥1600	1600	+ve	≥1600	34	-ve
U17	1600	34	+ve	≥1600	34	-ve	≥1600	350	-ve
U18	33	33	+ve	≥1600	500	-ve	≥1600	34	-ve
U19	350	350	+ve	≥1600	≥1600	-ve	1600	350	-ve
S20	≥1600	26	+tive	≥1600	220	-ve	≥1600	34	+ve
S21	≥1600	≥1600	+ve	≥1600	34	-ve	≥1600	170	+ve
S22	1600	34	+ve	-	-	-	1600	34	-ve
S23	≥1600	≥1600	+ve	≥1600	350	+ve	≥1600	33	-ve
S24	≥1600	≥1600	+ve	≥1600	280	+ve	≥1600	280	+ve
S25	110	70	+ve	≥1600	900	+ve	≥1600	220	-ve
S26	900	280	+ve	≥1600	350	+ve	≥1600	130	+ve
S27	1600	1600	+ve	≥1600	26	-ve	≥1600	350	-ve
S28	1600	1600	+ve	≥1600	22	-ve	500	33	-ve
S29	500	500	+ve	280	34	-ve	≥1600	280	+ve
S30	≥1600	≥1600	+ve	≥1600	33	-ve	≥1600	33	-ve
S31	240	240	+ve	1600	350	-ve	≥1600	350	+ve
S32	-	-	-	≥1600	34	-ve	300	130	+ve
S33	-	-	-	≥1600	33	+ve	≥1600	70	+ve
S34	-	-	-	80	27	-ve	500	34	+ve
S35	-	-	-	≥1600	≥1600	+ve	Nil	Nil	-ve
N36	26	Nil	-ve	600	35	-ve	80	22	-ve
N37	9	Nil	-ve	530	60	-ve	-	-	-
N38	14	Nil	-ve	170	13	-ve	900	Nil	-ve
N39	-	-	-	300	17	+ve	-	-	-
N40	-	-	-	100	23	-ve	-	-	-
N41	-	-	-	900	27	+ve	-	-	-
N42	-	-	-	350	30	-ve	-	-	-
N43	-	-	-	160	25	-ve	-	-	-
N44	-	-	-	500	220	-ve	-	-	-

for FC accumulation. Comparatively, low FC concentration during monsoon and post-monsoon may be the result of flooding in these streams, which has washed down the faecal contamination. In semi-urban areas, no significant difference (Kruskal-Wallis Test, $H_{2,44} = 0.23$, $p<0.892$) was observed for TC during all three seasons. On the other hand, FC accumulation varied significantly (Kruskal-Wallis Test, $H_{2,44} = 7.73$, $p<0.021$). The pair-wise comparison showed that pre-monsoon season representing the higher FC concentration is different from rest of two seasons (pre-monsoon and monsoon $p<0.0203$, pre-monsoon and post-monsoon $p<0.0114$, monsoon and post-monsoon $p<0.969$). In MHNP, maximum TC observed during monsoon and FC was present only in monsoon season.

Spatial Variation

Kruskal Wallis Test performed on TC for all sites and all seasons showed significant variation ($H_{2,115} = 16.38$ $p<0.000$) and pair-wise comparison showed variation as MHNP while the other two sites are same (urban and semi-urban $p< 0.729$, urban and MHNP $p<0.0004$, semi-urban and MHNP $p<0.0000$). High concentration of TC in urban and semi-urban areas compared to MHNP may be due to land cover. Similar results showing high concentration of faecal bacteria in urban than rural sites have been found in earlier studies (Lewis *et al*., 2007; Frenzel & Couvillion, 2002). Mallin *et al*., (2000) found that faecal *coliform*s abundance correlated positively with human population density, percentage of developed land, and percentage of impervious surface. Faecal *coliforms* density observed in three sites varied significantly (Kruskal-Wallis Test, $H_{2,111} = 8.36$ $p< 0.015$) representing that MHNP is different from rest of two sites (urban and semi-urban p< 0.834, urban and MHNP p<0.011, semi-urban and MHNP 0.0025). The highest FC accumulation taken place in semi-urban areas may not be only due to human waste; the phenomena may be attributed to domestic and wild animals (Mallin *et al*., 2000; WHO, 2003; Rose, 2006). The poultry related activities in catchment areas of Korang River, cattle rearing, and grazing sites may be important sources of faecal bacteria to streams of this area (Fernandez-Alvarez *et al.,* 1991).

Presence absence of *E. coli*

The presence absence data of *E. coli* in all three sites with seasonal variation is shown in Figure 2. It shows that highest number (62.7%) of *E. coli* presence was observed in semi-urban area followed by urban area (61.1%) and least was in MHNP (14.2%). These results are not in accordance with the standards and indicate the presence of faecal pollution in water system.

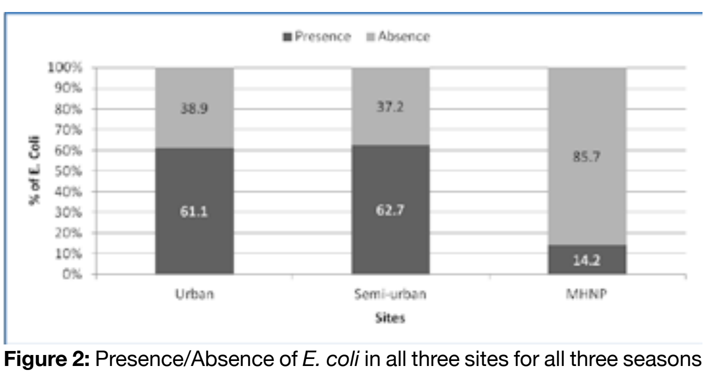

Figure 2: Presence/Absence of *E. coli* in all three sites for all three seasons

Water Quality and Health

Water quality of these natural streams is very important as these streams feed Rawal Dam, the water of which after purification is supplied to residents of Rawalpindi for drinking. However, some previous studies have detected faecal *coliforms* and other bacteria in drinking water of Rawalpindi and Islamabad (Tahir, 1989; Din *et al*., 1997; Farooq *et al*., 2008). Such situations are disappointing because the presence of faecal and other pathogenic bacteria in drinking water are causing many diseases (Agboatwallah, 2002) in the habitants of twin cities. Faecal contamination of water results in enteric infection, which may be viral, bacterial, or parasitic. The water consumed by resident of Islamabad and Rawalpindi may potentially cause such diseases. A study conducted by UNICEF (Pak-SECA, 2006) found that 20-40% of the hospital beds in Pakistan are occupied by patients suffering from water related diseases.

Conclusion

The study demonstrated that faecal pollution in natural streams of Islamabad has intensified due to lack of proper municipal waste facilities particularly in semi-urban areas. It is concluded that in semi-urban areas that faecal contamination is very high and demands dare need for remediation. The surface run-off, increased concentration of nutrients and municipal waste in urban areas are major contributing sources for higher bacterial densities. It has become clear that there are two main sources of faecal contamination i.e. natural and anthropogenic. High level of faecal pollution renders water unfit for human use prior to proper treatment. There may be the chance of presence of pathogens along with these indicator bacteria in the drinking water, which poses many diseases.

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