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Impact of Urbanization on Inflows and Water Quality of Rawal Lake

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Abstract. Two phenomena playing important role in affecting water resources all over the world are: urbanization and climate changes. Urban and peri-urban water bodies are very vulnerable to these phenomena in terms of quality and quantity protection. This study was aimed to perceive the impact of ever-increasing urbanization on water quality in the catchment area of Rawal Lake. Rawal Lake supplies water for domestic use to Rawalpindi city and Cantonment area. The water was found biologically unfit for human consumption due to total and faecal coliformus counts higher than WHO limits. Similarly, turbidity and calcium was more than WHO standards. There should be detailed study on climate change parallel to urbanization in the Rawal catchment to quantify its impacts on water quality and inflows.

Keywords: urbanization, inflows, water quality, Rawal Lake, Korang River

Introduction

Islamabad and Rawalpindi are two very important cities of Pakistan. Rawal Dam is constructed on Korang river along Pindi-Murree road near village Rawal at a distance of about nine miles from Rawalpindi town. Actually, Rawal Dam is the main source, providing raw water for drinking purpose for Rawalpindi city and Cantonment area. During the last few decades the process of urbanization covered the catchment area with a very high rate around the Rawal Lake, which has obviously affected the quantity as well as the quality of lake inflows. Urbanization is a pervasive and rapidly growing form of land use change. More than 75% of the U.S. population lives in urban areas, and it is expected that more than 60% of the world's population will live in urban areas by the year 2030, much of this growth occurring in developing nations (USCB, 2001; UNPD, 1997). Whereas the overall land area covered by urban growth remains small (2% of earth's land surface), its ecological footprint can be large (Folke *et al*., 1997). For example, it is estimated that urban centres produce more than 78% of global greenhouse gases (Grimm *et al*., 2000) and that some cities in the Baltic region claim ecosystem support areas 500 to 1000 times their size (Boland and Hanhammer, 1999).

The extensive and ever-increasing urbanization represents a threat to stream ecosystems. According to an estimate over 130,000 km of streams and rivers in the United States are impaired by urbanization (USEPA, 2000). Urbanization has had similarly devastating effects on stream quality in Europe (House *et al*., 1993). Despite the dramatic threat urbanization poses to stream ecosystems, there has not been a thorough synthesis of the ecological effects of urbanization on streams. There are reviews discussing the impacts of a few aspects of urbanization biology of pollution (Hynes, 1960), physical factors associated with drainage (Butler and Davies, 2000), urban stream management (Baer and Pringle, 2000) and a few general reviews aimed at engineers and invertebrate biologists (Suren, 2000; Ellis and Marsalek, 1996; House *et al*., 1993), but the ecological effects of urban growth on stream ecosystems have received less attention (Duda *et al*., 1982; Porcella and Sorenson, 1980). Tahir (1989) studied pollution problems in water supply systems of Rawalpindi and Islamabad city. Din *et al*. (1997) analyzed the quality of drinking water supplied to Islamabad. Khan (1999) collected and analyzed drinking water samples from restaurants and hospitals of Rawalpindi and Islamabad. In all 105 samples collected, a few samples were found unsafe with respect to TDS and turbidity. Malik (2007) examined biological oxygen demand of Rawal Lake. Iram *et al*. (2009) analyzed pesticides residue of Rawal and Simly Lakes and Aftab (2010) studied the spatial and temporal land use of Rawal Lake watershed. Ghumman (2011) assessed the water quality of Rawal Lake by long time

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monitoring. Urbanization in the catchment area is increasing with a very high percentage. The population in the last eleven years has increased up to 85% at a growth rate of 5.7% while, the built up urban land has increased up to 9%. On the other hand, forestland decreased up to 10%. Conclusions are focused on urbanization's enhancement; the impact it has on inflows considering too that there is no major transform noticed in rainfall. There is need to put a check on the urbanization in the catchment of Rawal Lake. A number of illegal housing projects and commercial construction activities are underway which is a major source of reduction in inflows and deteriorating the quality of water as well as producing more sediment inflow towards the reservoir. The main objective of this study was to analyze the water quality and inflow variations towards Rawal Lake due to urbanization.

Materials and Methods

Case study. The Rawal Lake was selected as the study case in this research. This lake comprised of three tributaries named as main lake, Korang arm and Noorpur triple arm and is the main source of water supply to the Rawalpindi city. With the increase of population, water quality of Rawal Lake is deteriorating day by day.

Data collection. Below are the data typologies used:

Population data. Information regarding population in the catchment of Rawal Lake was collected from Population and Census Organization, Statistics Division, Government of Pakistan and Pakistan Environmental Protection Agency (Ministry of Environment) Islamabad, Pakistan. As the census conducted by the Government of Pakistan was in the year 1998 so the data regarding population was also of 1998. To obtain the latest updated population data estimation was done using the geometric projection:

$$P_t = P_o (1+r)^n$$

where:

P_t = population at time 'T'; P_o = population data available; r = growth rate, 5.75% (ave. annual growth rate in Islamabad from 1981-1998, Pakistan Bureau of Statistics); n = no. of years.

Inflows data. The 34 years data of inflows into the Rawal Lake, from 1975-2009 was collected from Irrigation & Power Department, Government of Punjab for analysis purpose.

Rainfall data. Data of rainfall was collected from Meterological Department. The data ranges from 1999 to 2009.

Water quality data. Water samples were collected from three main points having latitude, longitude and elevation with respect to mean sea level:

1- Main lake (33°41' 38" N, 73° 07' 25" E, 528 m)

2- Korang River (33° 43' 11" N, 73° 09' 45" E, 532 m)

3- Noorpur Shah Nullah (33° 43' 12" N, 73° 07' 20" E, 531m)

Sample collection and preservation. Water samples for physicochemical analysis were collected in polystyrene bottles of 0.5 and 1.5 L capacities. Following identifications were also marked on every sample of each site:

- **A** for bacterial analysis
- **B** for trace element analysis
- **C** for nitrate (N) analysis
- **D** for other water quality parameters

Before collecting the samples, the bottles were washed properly and rinsed thoroughly several times first with tap water then with distilled water. For bacterial analysis, samples were collected in sterilized containers (200 mL). Hydrochloric acid and boric acid were used as preservatives in the sampling bottles for trace elements and nitrate nitrogen, respectively before going to field. The first set of water samples was collected during the month of February. Water samples were collected from the centre by standing in the middle of the stream. Care was taken to keep the bottle well above the bed of the stream to avoid unwanted bed material going into the sample. It is difficult to obtain a truly representative sample when collecting surface water samples in case of lakes. Sampling point was selected carefully near to bank to avoid any kind of debris in the water. Considerable variations like seasonal stratification, rainfall, runoff and wind were also documented while collecting water samples especially from lake.

Methodological approach. To estimate the population up to the year 2009, geometrical progression technique was used. The inflows data was plotted up to the year 2009 to see the behaviour of inflows. Water quality samples were collected and analyzed in the laboratory and compared with previous studies.

Results and Discussion

Inflows. Figure 1 shows the average monthly rainfall and inflows during 1975-2009 which clearly indicates the fluctuating trend in inflows especially during the period considered for this study i.e., 1998-2009. It can be clearly visualized that trend of inflows has decreased in most of the years except during years 2001 and 2008 in which inflows had increased and that was due to heavy rains during monsoon season. Figure 2 represents the average annual inflows in the Rawal Lake, it shows that flows increased during the months of March-April and July-Sept. The reason is that during the months of Feb-March winter rains occur in the catchment area while during July-Sept. the monsoon occurs in the catchment due to which inflows increase during these months.

Population. The hydrological data of Rawal Lake was compared with the population (Fig. 3) in the catchment area of Rawal Lake to visualize the impact of population on inflows which indicates that population in the catchment area of Rawal Lake has increased from 60,733 in the year 1998 to 112,333 in the year 2009 which is almost 85% increase while on the other hand, the average of last ten years of flows from 1999-2009 has decreased as compared to average of inflows from 1988-1998. This decrease in inflows is approximately 44% which indicates that due to increase in population inflows have decreased significantly. The villages of Bhara Kahu, Malpur, Bani Gala and Noorpur Shahan are situated close to Rawal Lake. The estimated population of these villages is about 5000, other ten villages are situated in the catchment area of Rawal Lake under the administrative control of Murree Kahuta Development Authority (MKDA).

The present number of inhabitants in these villages is not exactly known because the latest census data available is only for the year 1998, as per Government of Pakistan policy census is conducted after every ten years but unfortunately due to some unknown reasons it has not been conducted yet, therefore, the data of 1998 was utilized for estimation of approximate population in these villages by using statistical technique. The detail of population data of these villages is given in Table 1.

Land use. The land use data was compared with the inflows and is shown in Fig. 4. The graph reflects that from year 1998-2009 the urbanization has increased i.e., the built up area has increased and area under forests has decreased while there is also little change in agricultural activities as well as range land. On the other hand the trend of flows from 1998- 2009 has decreased.

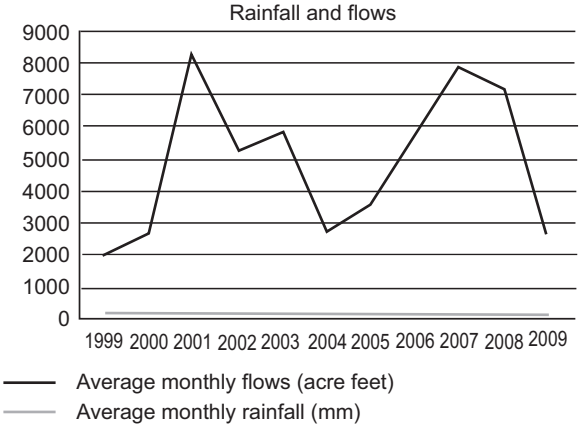

Fig. 1. Average monthly rainfall and inflows at Rawal Dam.

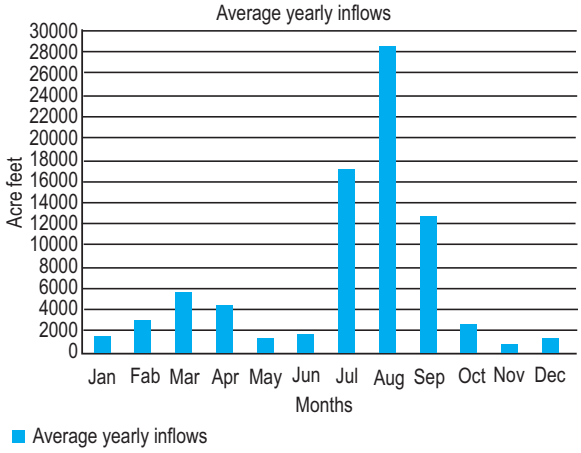

Fig. 2. Average yearly inflows at Rawal Dam.

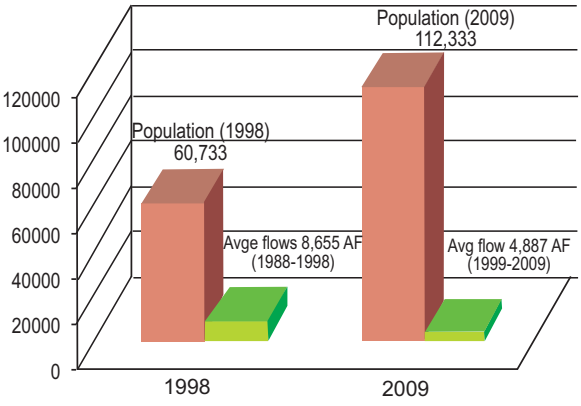

Fig. 3. Comparison of population and inflows.

Table 1. Population status in Rawal Lake catchment

Village	Population 1998	Population 2009 (Estimated)
Kot Hathial (Bhara Kahu)	27,258	50,417
Malpur	3,743	6,923
Noorpur Shahan	8,075	14,936
Nambol	5,205	9,627
Sambi Tajal	3,876	7,169
Treet	2,137	3,953
Salgran	1,536	2,841
Manga	5,149	9,524
Karlot	717	1,326
Salkhitar	1,086	2,009
Kathar	995	1,840
Jumma	956	1,768
Total	60,733	112,333

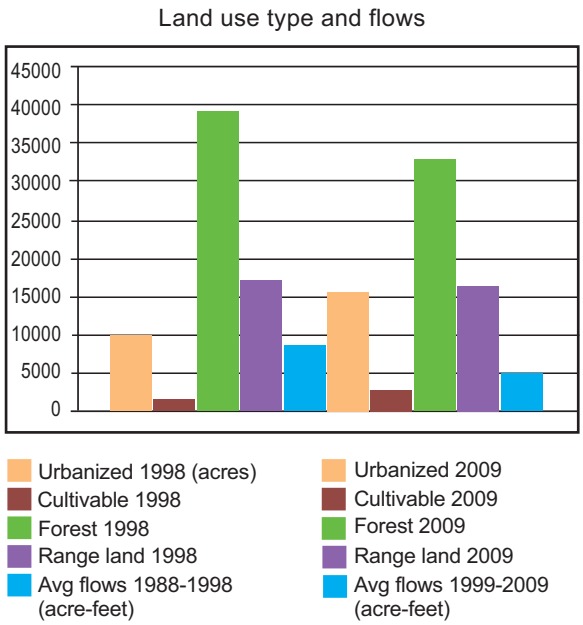

Fig. 4. Land use type in catchment of Rawal Lake and flows.

The water quality parameters i.e., physical and aesthetic, chemical, trace and ultra trace elements and microbiological parameters were analyzed according to WHO guidelines (WHO, 2004). Water quality parameters analyzed were compared with the previous analysis conducted by other agencies to have a comparison. The analyses reported in 2004 were conducted by Environmental Protection Agency (EPA), Ministry of Environment, Government of Pakistan in joint collaboration with Koich Kuwano, Japan International Cooperation Agency (JICA), whereas analysis reported in 2008 were conducted by National Institute of Health Islamabad (Nutrition Division).

Water quality parameters described in Table 2, shows the comparison of present and previous years studies available. The parameters discussed in year 2009 were obtained for this study purpose and analyzed at Pakistan Council of Research in Water Resources (PCRWR) water quality lab, Islamabad. The year 2008 represents the figures of Irrigation and Power Department, Government of Punjab and analysis were conducted by National Institute of Health (NIH) Islamabad, whereas the figures of 2004 are of Environmental Protection Agency, Government of Pakistan. The figures of 2008 and 2004 only shows the results of main Rawal Lake and Korang River, while for this study purpose Noorpur Shah tributary was also taken under consideration because it is one of the largest tributary which is contributing its share into the Rawal Lake. Moreover, in previous year figures many parameters were not analyzed, which are analyzed during this study, therefore, their values are left blank in table. All the values are compared with Pakistan Standards and Quality Control Authorities (PSQCA) guidelines. The Table shows that as far as physical and chemical parameters are concerned although the quality of water is deteriorating day by day but they are still under the permissible limits. Only the colour of Korang River water was found turbid during the year 2008 and the value of Ca^{++} for Noorpur Shahan tributary was found more than permissible limits. Whereas, the biological or bacteriological values such as total coliforms, faecal coliforms and *E. coli* of all samples were found more than permissible limits in all cases which is a matter of great concern because most of the water of Rawal Lake is used for drinking purpose and is bacteriologically unfit for human consumption. The values of these parameters are increasing year by year which is worsening the condition. The reason for all this is because the water of the lake for the last few decades is subjected to pollution due to increase in urbanization. This includes human settlements, poultry wastes (there are approximately 170 poultry farms having about 360 poultry sheds lying within the catchment area), recreational activities, agricultural activities (including pesticides & fertilizer), deforestation as mentioned earlier, the catchment area is subjected to deforestation due to increase in built up land, grazing of livestock

Table 2. Comparison of present and previous studies regarding water quality parameters of Rawal Lake

Organization	Source	Colour	Odour and taste	EC (uS/cm)	pH	Turbidity (NTU)	Alkalinity	HCO_3	Ca	CO_3	Cl	Hardness (Mg/L)
							(ppm)					
2008 PSQCA	-	Colourless	Unobjectionable	NGVS	6.5-8.5	5	NGVS	NGVS	75	NGVS	250	500
2009 PCRWR	Main lake	Colourless	Unobjectionable	416	8.23	6.56	172	162	51	10	10	192
	Korang River	Colourless	Unobjectionable	516	8.29	15.20	202	182	61	20	13	232
	Noorpur Nullah	Colourless	Unobjectionable	629	8.53	0.77	272	242	91	30	21	312
2008 NIH	Main lake	Colourless	Unobjectionable	407	7.9	32	-	-	46	-	20	200
	Korang River	Turbid	Unobjectionable	412	7.8	86	-	-	46	-	17	190
2004 EPA	Main lake	-	-	-	8.2	-	-	-	-	-	15.8	-
	Korang River	-	-	-	8.1	-	-	-	-	-	13	-

Organization	Source	Mg	K	Na	SO_4	NO_3	PO_4	TDS	As	F	Fe	*T. coliforms*	*F. Coliforms*	*E. Coli* ±
		(ppm)										(MPN/100 mL)		
2008 PSQCA		150	12	200	250	10	NGVS	1000	10	1.5	0.3	NIL	NIL	-Ve
2009 PCRWR	Main lake	16	3.6	13	30	0.9	0.10	233	0.85	0.28	BDL	10	10	-ve
	Korang River	19	4.9	20	46	2	BDL	289	0.71	0.24	0.03	≥1600	350	+ve
	Noorpur Nullah	21	4.5	21	41	3	1.06	377	0.59	0.34	0.03	≥1600	350	+ve
2008 NIH	Main Lake	20	3	22	50	1	-	305	-	-	-	240	-	+ve
	Korang River	18	3	23	54	1	-	309	-	-	-	240	-	+ve
2004 EPA	Main Lake	10.9	3.1	13.8	19.7	1.78	0.03	-	-	-	BDL	-	-	-
	Korang River	9.8	2.99	13.7	22.1	2.14	0.04	-	-	-	BDL	-	-	-

*BDL = below detection limit; **NGVS = no guideline value set.

and cutting of wood for fuel by villagers. These all are the factors which are deteriorating the water of Rawal Lake day by day and there should be a check on all these activities.

Conclusion

The population in the catchment area of Rawal Lake has grown enormously specially during the last 11 years i.e., 1998-2009. The estimated population results show an increase of 84% as compared to that of 1998 at a growth rate of 5.75% per annum. The land use pattern has changed in the catchment of Rawal Lake; during the period 1998-2009 the area under the category of built up land has increased from 14.7-23.12%, while area under forest has decreased from 58-48%. The average inflows from (1998-2009) has decreased as compared to the average of previous years inflows, the increase in urbanization in the catchment area is a factor of this decrease in inflows. There is no major change in the rainfall in the catchment area but inflows have decreased which proves that urbanization is decreasing inflows. The increase in urbanization has decreased the quality of water of Rawal Lake and its two major tributaries i.e. Noorpur Shahan stream and Korang River. The water is biologically unfit for human consumption. The total and fecal coliform bacteria are more in count than the WHO standards. The *E. coli* bacteria is also found +ve in Noorpur Shah stream and Korang River. The main lake and Korang River water was also found more turbid than the WHO standards. The amount of calcium was observed more than WHO standards in case of Noorpur Shah stream.

Recommendations and perspectives

There is need to put a check on the urbanization in the catchment area of Rawal Lake. A number of illegal housing projects and commercial construction activities are underway which is a major source of reduction in inflows and deteriorating the quality of water as well as producing more sediment inflow towards the reservoir. Climate change is another factor for decreasing inflows of the lake. Area under forest must be increased which is decreasing day by day and is not only creating environmental problems but also reducing the flows and increasing sediment input rate. As most of the water of the Rawal Lake is used for domestic purposes so proper monitoring strategy should be adopted to check the quality status.

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