Impact of Urbanization on Inflows and Water Quality of Rawal Lake

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Abstract. Rawal Lake is a very beautiful lake located in Islamabad Park Area. A dam was built on this lake across Korang River in 1962 called Rawal Dam. It has a storage capacity of 47,500 acre feet and covers 3.5 square miles. Two canals are derived from the dam, Left Bank Canal and the Right Bank Canal. This study was carried out to perceive the impact of ever increasing urbanization in the catchment area on Rawal Lake water quality. Rawal Lake supplies water for domestic use to Rawalpindi city and Cantonment Area.

The results argue that the urbanization in the catchment area is increasing with a very high percentage especially the population in the last eleven years has increased up to 85% at a growth rate of 5.7%, while the built up land has increased 9%. On the other hand area under forest has decreased up to 10%. As a result of enhancement in urbanization inflows have decreased even though there is no major transform noticed in rainfall which is evident that urbanization has decreased the inflows. Urbanization also has an adverse effect on water quality which is found biologically unfit for human consumption.

Keywords: Urbanization, Inflows, Water Quality, Rawal Lake, Korang River.

Introduction

Water is indispensable for every living organism on earth for its survival. All body metabolisms require safe water; therefore safe drinking water is essential to good health. Islamabad and Rawalpindi are two very important big cities of Pakistan. Rawalpindi city is

one of the largest populated cities of province Punjab having population of about 1,409,768 people. Rawal dam is constructed on Korang River along Pindi-Murree road near village Rawal at a distance of about nine miles from Rawalpindi town. With the rapid population growth in the twin cities of Rawalpindi and Islamabad, the local authorities felt increasing need of domestic drinking water as the local well in the area were becoming short of water due to inadequate sub soil water resources. The government had to bend upon Rawal Dam to meet with the domestic needs of drinking water for the twin cities. Presently, Rawal Dam is the main source of providing raw water for drinking purpose for Rawalpindi City and Cantonment Area. For the last few decades the process of urbanization is covering the catchment area with a very high rate around the Rawal Lake which has obviously affected the quantity as well as the quality of inflows of lake. The impact of this urbanization on Rawal lake inflows and water quality needs a detailed research that why and how much deterioration in inflows, water quality and storage capacity has emerged since its construction and how it has affected its beneficiaries.

Clean and healthy drinking water in sufficient quantity is the basic need of human being but due to urbanization, pollution and other factors, this all is under threat. Rawal Dam reservoir is a major source to provide drinking water to Rawalpindi. But reservoir capacity is diminishing with the passage of time and water is getting polluted due to pollution and sedimentation generated by urbanization. The main objective of this study was to analyze the water quality and inflow variations towards Rawal Lake due to urbanization. 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 (UN Population Division 1997, US Census Bureau 2001).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 centers 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). This makes urbanization second only to agriculture as the major cause of stream impairment, even though the total area covered by urban land in the United States is minor in comparison to agricultural area. 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 (House et al., 1993; Ellis and Marsalek, 1996; Suren, 2000), but the ecological effects of urban growth on stream ecosystems have received less attention (Duda et al., 1982; Porcella and Sorenson, 1980).

Chemical effects of urbanization are far more variable than hydrologic or geomorphic effects and depend on the extent and type of urbanization (residential versus commercial/industrial), presence of wastewater treatment plant (WWTP) effluent and/or combined sewer overflows

(CSOs), and the extent of storm water drainage. Overall, there are more data on water and sediment chemistry in urban streams than any other aspect of their ecology. This is aided by several very large national datasets of stream chemistry that focus in whole or in part on urbanization [e.g., National Urban Runoff Program (United States), National Water Quality Assessment Program (USGS, 2001), Land-Ocean Interaction Study (UK) (Neal and Robson, 2000)]. One of the most significant water quality parameters affected by urbanization is water temperature. Temperature is a major regulator of living systems. Water temperature has been considered one of the most important factors determining the geographic distribution, growth rate and survival of fish and other aquatic organisms (Barthalow, 1989).

Tahir (1989) studied pollution problems in water supply systems of Rawalpindi and Islamabad city. The supply systems of both cities were found fit with respect to alkalinity, hardness, TDS, free CO_2, calcium, ferrous, lithium, manganese, sodium, zinc, nickel, chromium, potassium, sulfate, phosphates and chlorides. About 25% samples were found unsafe with respect to nitrates and 75% with respect to lead. Out of 53 samples (25 Islamabad, 28 Rawalpindi), 34% were found fit for drinking purpose. Source wise acceptable percentage was 34% of tap water, 0% for cistern, 60% for tubes well, 0% of well and 100% of tank water.

Din et al. (1997) analyzed the quality of drinking water supplied to Islamabad. They found that the chemical quality of most CDA tube-wells was satisfactory during the period of the study (September to December). However, some samples were found with 1.4 ppm strontium concentration. Khan (1999) collected and analyzed drinking water samples from restaurants and hospitals of Rawalpindi and Islamabad. In all 105 samples were collected, out of which 48 and 28 samples were collected from restaurants and hotels of Islamabad and Rawalpindi

and 14 and 15 samples were collected from hospitals of Islamabad and Rawalpindi respectively. A few samples were found unsafe with respect to TDS and Turbidity.

Materials and Methods

Data Collection. The inflows data was collected from Irrigation & Power Department, Govt. of Punjab and population data was collected from the Population and Census Organization Statistics Division, Government of Pakistan & Pakistan Environmental Protection Agency (Ministry of Environment) Islamabad, Pakistan. Land Use data was obtained from Revenue Department Government of Punjab & Capital Development Authority, Government of Pakistan, while the water quality data and sediment data was collected by field experiments.

Population Data. Data Regarding population in the catchment of Rawal Lake was collected from Population and Census Organization Statistics Division, Government of Pakistan & Pakistan Environmental Protection Agency (Ministry of Environment) Islamabad, Pakistan. As the census conducted by the government of Pakistan was in year 1998 so the data regarding population was also of 1998. To obtain the latest updated population data estimation was done using the following statistical technique;

$$P_t = P_o\,(1+r)^{n}$$

P_t = *Population at time 'T'*

P_o =*Population data available*

r = Growth Rate (5.75 %)

n = no. of years

Inflows Data. The 34 years data of inflows in to 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 1999-2009.

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, 532m)

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

Sample Collection and Preservation. Water samples for physio-chemical analysis were collected in polystyrene bottles of 0.5 and 1.5 liter 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 water and 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.

Results and Discussions

Inflows

Figure 1 shows the average monthly 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 has increased and that was due to heavy rains during monsoon season.

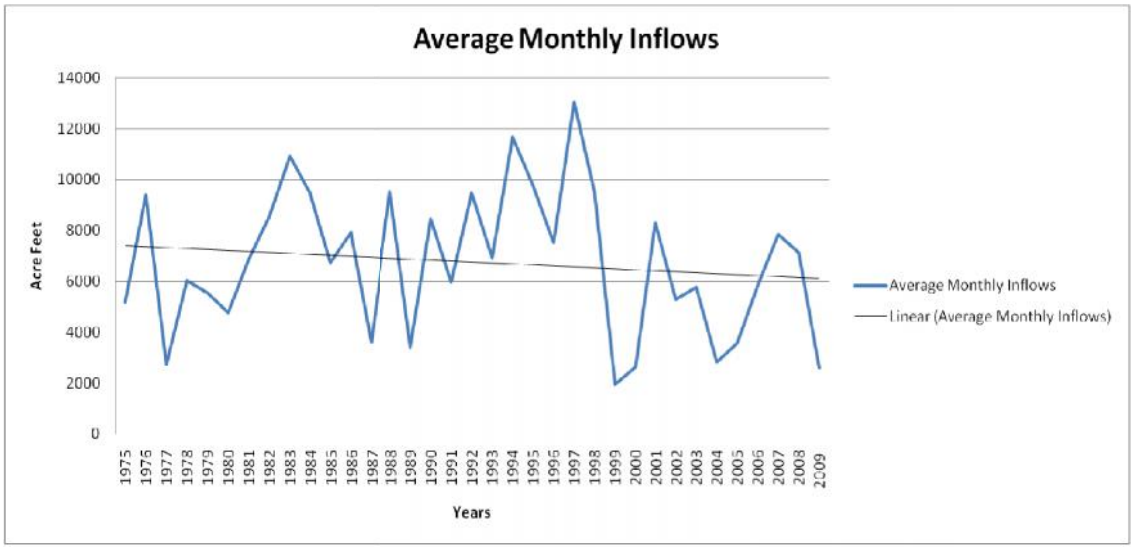

Fig. 1. Average monthly inflows at Rawal Dam

Figure 2 represents the average annual inflows in the Rawal Lake which shows that flows increased during the months of March-April and July-Sep. The reason is that during the months of Feb-March winter rains occur in the catchment area while during July-Sep the monsoon occurs in the catchment due to which inflows increase during these months.

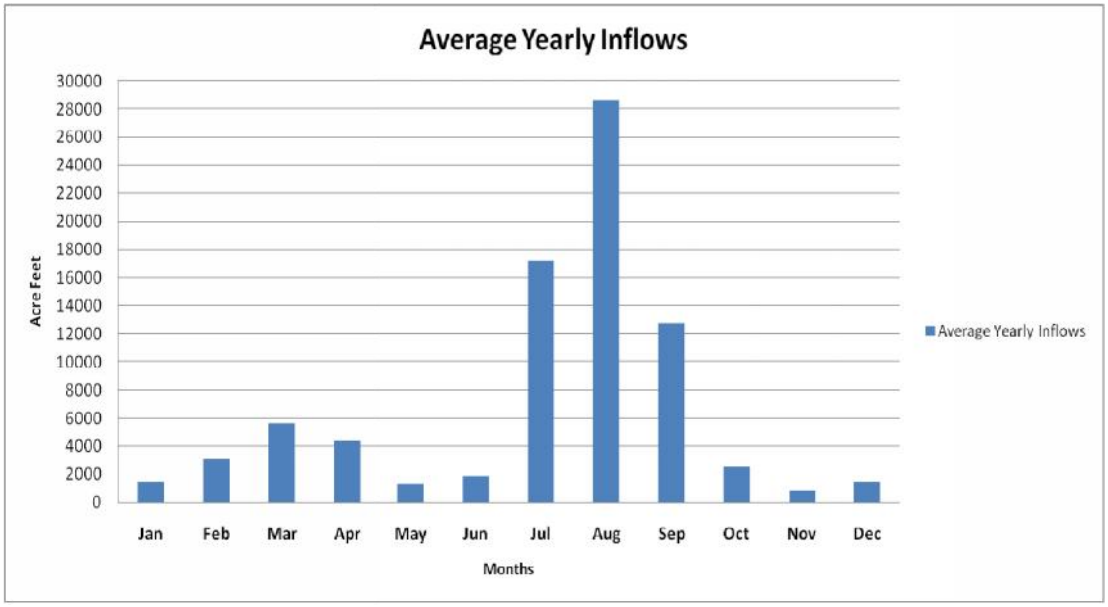

Fig. 2. Average yearly inflows at Rawal Dam

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 year 1998 to 112,333 in 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 5,000 (Mott Macdonald, 1995), other ten villages are situated in the catchment area of Rawal Lake under the administrative control of Murree Kahuta Development Authority.

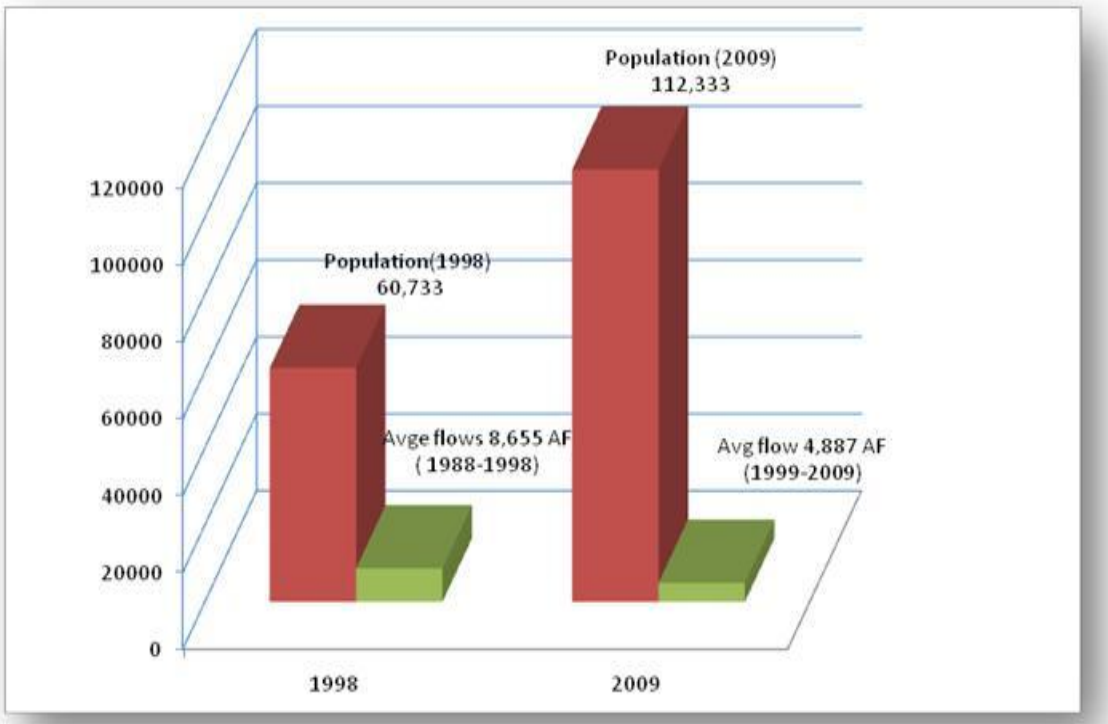

Fig. 3. Comparison of population and inflows.

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.

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
Noor Pur 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**

Results and Discussions

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, JICA Senior Volunteer, and 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 year's 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, where as the Figures of 2004 are of Environmental Protection Agency, Government of Pakistan. The Figures of 2008 & 2004 only shows the results of Main Rawal Lake and Korang River while for this study purpose Noor Pur Shah tributary was also taken under consideration because it is one of the largest tributary which is contributing its share in to the Rawal Lake. Moreover in previous year figures many parameters were not analyzed, which are analyzed during this study so 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 year 2008 and the value of Ca^{++} for Noor Pur Shah tributary was found more than permissible limit. Whereas the biological or bacteriological values such as Total Coliforms, Fecal Coliforms and E.Coli of all samples were found more than permissible limit 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 bacteriologicaly 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 lie 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 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.

Table 2. Comparison of Water Quality Parameters of Rawal Lake.

Organization	Source	Colour	Odor and Taste	Ec uS/cm	pH	Turbidity NTU	Alkalinity ppm	HCO_3 ppm	Ca ppm	CO_3 ppm	Cl ppm	Hardness Mg/L
PSQCA		colorless	Unobjectionable	*NGVS*	*6.5- 8.5*	*5*	*NGVS*	*NGVS*	*75*	*NGVS*	*250*	*500*
2009 PCRWR	Main Lake	colorless	Unobjectionable	416	8.23	6.56	172	162	51	10	10	192
	Korang River	colorless	Unobjectionable	516	8.29	15.20	202	182	61	20	13	232
	Noorpur Nullah	colorless	Unobjectionable	629	8.53	0.77	272	242	91	30	21	312
2008 NIH	Main Lake	colorless	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 ppm	K ppm	Na ppm	SO_4 ppm	NO_3 ppm	PO_4 ppm	TDS ppm	As ppb	F ppm	Fe ppm	T. Coliforms MPN/100ml	F. Coliforms MPN/100ml	E.Coli ±
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

Conclusions

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 shows 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% to 23.12% while area under forest has decreased from 58% to 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 Shah Stream and Korang River. The water is biologically unfit for human consumption. The total and fecal coli form 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

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 are a major source of reduction in inflows and are deteriorating the quality of water as well as producing more sediment inflow towards the reservoir. 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. The water of Rawal Lake is bacteriologicaly unfit for human consumption so proper treatment should be done.

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