Impact of Urbanization on Water Resources of Pakistan: A review

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Abstract

This paper summarizes the various dimensions and impacts of urbanization on Pakistan's water resources in order to provide foundations for future water policy that will lead towards country's socio-economic development. Urbanization is considered as a major trend of the 21st century in many developing countries. Along with urbanization, an increase in population growth in recent years has put a pressure on the world's water resources in terms of water demand and pollution. Various issues related to water sector in urban areas of Pakistan have been identified including contamination of surface and ground water resources through industrial, agricultural and domestic discharge of waste and waste water, increasing floods, loss of wetlands and aquatic biodiversity, sea water intrusion and subsidence, physical reduction in water resources quantity and quality and operational and managerial incapacities. There are some other issues like unequal water distribution which together with population burden, rapid urbanization and growing industrialization are posing a huge challenge for Pakistan's water management in the 21st century. Taken together all the studies, this review suggests that to reduce vulnerability to water resources of Pakistan, there is a need for new systems of urban planning and governance institutions as the core of Pakistan's water crisis is water management.

Keywords:
Urbanization, industrialization, surface water resources, ground water resources, Pakistan

Introduction

There is a consensus that urbanization is one of the major trends of the 21st century in developing countries [1]. There are various direct as well as indirect links between environmental degradation and urbanization as increasing number of individuals depend on existing natural resources. The provision of water supply, sanitation and drainage are among some essentials of urbanization process and affect water resources severely and intensify the burden on urban hydrology [2].

Rapid urbanization caused deterioration of living environments within the cities, mainly within peri-urban areas. There are minor investments in water supply, sanitation, wastewater treatment and disposal facilities that are not in accordance with the pace of urbanization. As a result, waterways and reservoirs nearby the cities have been polluted and downstream communities are forced to utilize unsafe water [3].

Long-term change in the land use is referred to as urbanization which has tremendously increased in the last decades owing to the rapidly growing population. Although there is no international agreement as to what is an urban area, it is universally agreed upon that an area having a population of more than 20,000 is referred to as urban [4]. It is expected that world population will increase to more than 3 billion people in the era between 2010 and 2050. A major portion of this urbanization is caused by rural to urban migration; however, high fertility rates and reclassification of rural land into urban land are also major causes [5]. United Nations report that as for today 50% of the world population lives in cities and it is projected that this number will reach 67% by 2050. Developing countries are expected to have an even higher number that is 86% [6]. This will result in more than 200,000 people per day looking for new place to live in urban areas accompanied by growing urban water demands particularly in South America, East and West Africa and Asia [7].

Urbanization is a complex process and it is difficult to assess its impacts. Although only 2% of the overall land is covered by urban population, it has a large ecological footprint [8]. Urbanization has serious environmental effects in developing countries like bacteria, heavy metal, and viral contamination in urban water supplies, the release of air born pollutants, the spread of endemic disease due to overcrowded conditions as well as the spread of vectors like mosquitos, land subsidence and water shortages [9]. More than 78% of the greenhouse gases are emitted by global centers [10].

Water is ranked as the top global risk by the World Economic Forum and is considered the top risk faced by the world in next ten years [11]. High population growth in last years has put a pressure on the world's water resources in terms of water demand and pollution. Changes in land use patterns have serious implications for water resources at the global, regional and local levels. [12]. Stream ecosystem is threatened

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due to unplanned and rapid urbanization [13]. Threats to world's water resources include saltwater intrusion, groundwater depletion and quality deterioration [14, 15]. A number of people affected by devastating floods are expected to rise due to urbanization. Following problem are related to water in urban areas: 1) contamination of surface and ground water resources through industrial, agricultural and domestic discharge of waste and waste water 2) floods 3) loss of wetlands, sea water intrusion and subsidence 4) physical reduction in water resources 5) operational and managerial incapacities [16]. Competition for water resources poses a serious threat to the world's water resources which ultimately affects human health and survival.

Urbanization in Pakistan

High growth of cities is a major problem in Pakistan. The rapid growth of cities is both due to population growth and migration from rural to urban areas. However, the natural increase in population is considered as a major contributing factor. In 1998, seven largest cities of the country (Karachi, Lahore, Faisalabad, Hyderabad, Rawalpindi, Multan and Gujranwala) had more than 1 million population. Total urban population increased from 40% in 1981 to 50% in 1998. Other than the above-mentioned cities, medium and small sized cities have grown at even higher rate. It is expected that about half of the total population of the country will live in cities by 2030. Urbanization results in replacement of natural land area with the manmade area that causes the formation of the urban dry island [17]. Landlessness of more than half of the rural households in Pakistan is a major reason for rural to urban migration. Population surge and industrial development and urbanization is a serious risk to water resources of Pakistan.

Table 1: Population, urbanization and industrialization in Pakistan, 1980-2025

Year	Population (million)	Population growth rate (%)	Urbanization (% of population)	Industrialization (share of manufacturing in real GDP in %)	Water demand for domestic use (MAF)
1980	84.9	3.0	24.1	13.8	-
1990	110.8	2.6	34.7	17.4	4.1
2000	140.5	2.1	47.5	23.0	5.2
2025*	228.8	2.4	-	-	9.7

Sources: Population Reference Bureau (2004); Ministry of Finanace & Economic Affairs (2004, 2001); Federal Bureau of Statistics (1991); Kahlown and Majeed (2002)

Note: * estimate

Projected demand for urban water will escalate by 95% till 2025 and growth in water demand for rural domestic purposes will be even higher [18]. 96 % of the available water is used for agriculture, 2% for industrial and 2% for domestic [19]. Major cities of Pakistan are already facing difficulties of groundwater withdrawal and dropping of water-table [20]. Increasing populations not only increase the call for industrial and domestic water but also increases the burden on infrastructure for wastewater treatment which is intensified by industrialization and migration into the cities. Solid waste collected from the cities is frequently dumped in landfills or sometimes thrown directly into the watercourses. Sources of water pollution include agricultural runoff, industrial waste and raw sewage which deteriorate the drinking water quality and ultimately human health [21].

Water Resources of Pakistan

Pakistan is an arid country with a single water supply source i.e. The Indus System consisting of six tributaries viz. Indus, Jhelum, Chenab, Sutlej, Ravi, Bias (Figure 1). Decades of disputes prevailed over water resources between India and Pakistan. Indus Water Treaty was signed in 1960 to end the water war between the two states. According to this treaty, the Indus River System was divided into two: Western rivers i.e. Indus, Jhelum and Chenab and the Eastern Rivers i.e. Ravi-Sutlej and Bias. Rainfall and melting of the HKH glaciers supply the rivers. Renewable water availability is 154 MAF out of which 45 MAF is groundwater. Water that is diverted in the Indus system fills theground water reservoir. Currently water withdrawals in Pakistan near about 142 MAF. 71 % from surface water and 29% from subsurface groundwater.

Groundwater is the main source of drinking water for Pakistan. The largest freshwater aquifer is found below the rim of the Himalaya. Most of the groundwater resources lie in Punjab. Farmers fulfill 40 % of their irrigation needs from ground water sources.

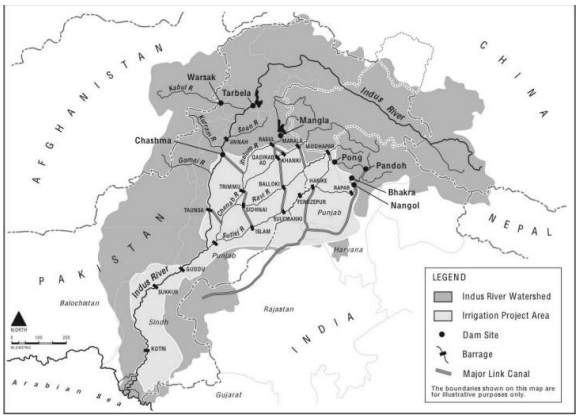

Figure 1: Indus River System

Pakistan is one of the sixth most populous countries of the world. It is expected that population will increase from 180 million in 2012 to 230 million in 2025. Population growth rate is very high i.e. a little more than 2.5%. The basic source of water demands is from cities. Per capita availability of water has declined from 5260 cubic metres in 1951 to 1040 in 2010 representing more than 400% decline [22]. It is expected that the country will become water scarce i.e. its per capita water availability will decline to less than five hundred metre cubes by 2035, some analysts even say it will reach this level by 2020 (Figure 2). Pakistan is 31st among the top 36 water-stressed countries of the world and has 4.31 baseline water stress score [23]. It is projected that in 2040 water stress level in Pakistan will be much more intense and will reach at the 23rd position among top 33 water-stressed countries [24]. Water stress is not only because of population pressure, urbanization, and industrialization but also comes from multiple disparities [25].

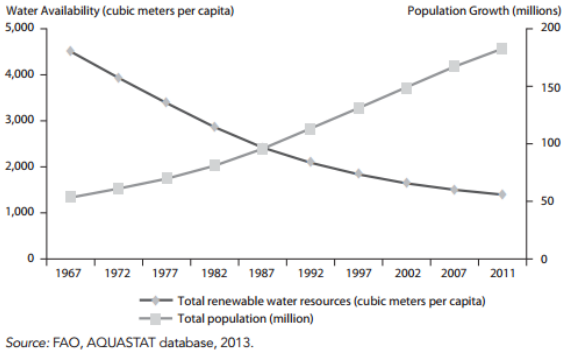

Figure 2: Water availability and population growth, 1967-2011

Impact of urbanization on water resources of major cities in Pakistan

Pakistan currently withdraws 83% of its renewable ground water. Daily protests are carried out against insufficient access to safe drinking water in cities. Increased dispossession of small and tenant farmers forces them to move to urban slums. It is expected by Human Development Index to spend 0.3% of GDP for water services but Pakistan spends less than 0.2% [26]. One of the Millennium Development Goals is to improve the source of water supply but Pakistan is not on track to achieve the goal primarily because of rising population in cities, little investment in water technologies and water losses [27].

Municipal sewage can be characterized as a main source of the surface as well as groundwater pollution in Pakistan. Approximately 13 MT (million tonnes) of wet excreta is generated annually, leading towards bacterial contamination. In urban sector approximately 2 MT of wet human excreta is produced every year and 50% of it goes into waterways causing severe water pollution [28]. Irrigation by raw sewage, disposal of industrial effluents, application of fertilizers and pesticides and intrusion of salt water due to over pumping are contaminating the ground water resources of the country [29]. There are few sewage treatments plants in the country that exist in Islamabad, Karachi, Peshawar, Faisalabad, and in some military cantonments [30]. Municipal sewage of Lahore is being drained into Ravi River that is used for drinking water supply and irrigation purposes. Municipal wastewater of Quetta is transported to a waterway for irrigation of vegetables [31].

Another cause of water pollution is solid waste. In Pakistan, solid waste generation rate is approximately 50,000 Mt tonnes per day and 60% of this waste is collected by municipalities. The collected solid waste from these cities is frequently dumped in landfills or sometimes thrown directly into the watercourses. Due to underfunding by the government and low revenue generation municipal infrastructure in Pakistan is not in a good shape [19].

The industrial centers of Lahore, Faisalabad, Karachi, and Sialkot contribute major pollution loads into their water bodies. Ground waters of Karachi, Faisalabad and Kasur are reported to have pesticide contamination [29]. In Pakistan, approximately 9,000 MG per day of wastewater is directly discharged into watercourses from various industries [32].

Impact of urbanization on water resources of Karachi

Karachi is one of the largest cities of Pakistan with a population of about 18 million and 5% population growth. It is a water-stressed city with total water supply to the city is 670 MGD while the minimum demand is 720 MGD and maximum around 972 MGD. Karachi uses surface water as a source of drinking water. Due to leakages and theft, distribution losses account for approximately 35% adding to the total shortage of around 285 MGe Supply of water to the city is just for a few hours per day. Population growth is one of the major reasons for water shortages in the city. There is a high rate of international and internal migration to the city. The population of the city was doubled due to migration following the partition in 1947. The population continues to grow due to inter-province conflicts and

Table 3: Karachi urban water supply facts

Karachi City- Urban water Supply Facts	**Million Gallons per day (MGD)**
Maximum water demand	972
Minimum Water Demand	720
Total Water supply	670
Water Loss Reduction (35%)	(234.50)
Total Available water Supply	435.50
Shortfall- Maximum Demand	*536.5*
Shortfall- Minimum Demand	*284.5*
Shortfall-Filtration Capacity	212

Source: [33]

migrations. It is predicted by the Karachi Strategic Development Plan 2020 that water demand will increase to 1368 MGD. From 1991 to 2000 urbanization in Karachi increased from 486-729.2 km2 while from 2000 to 2013 the urbanization was almost double i.e. 1582.5 km2 [34] (Figure 3)

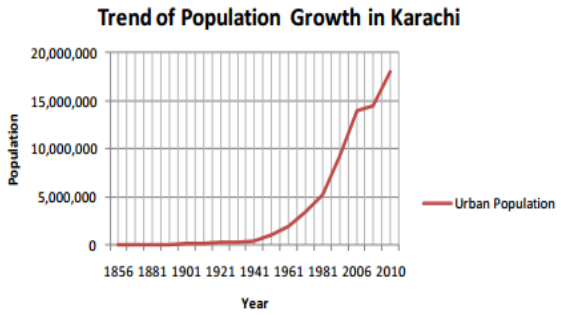

Figure 3: Population growth in Karachi

Source: [33]

The metropolitan city of Karachi has faced many violent conflicts in terms of water supply, particularly in its slum areas like Layari. Lack of access to safe drinking water increases the discontent among the residents of Layari. It is expected that the settlement receives five million gallons of water per day but in fact it receives only 30 thousand per day [35]. The gap between supply and demand in urban cities like Karachi make people rely on Private Water Vendors for their water supply. 60% of the piped water consumers in Karachi also depend on informal vendors due to interrupted supply of water [36].

Impact of urbanization on water resources of Lahore

Lahore is the second largest city of Pakistan with a total population of 10 million [37]. Following independence in 1947, a huge number of people migrated to Lahore. As per 1998 census, the total population of Lahore was 5143495 which increased to 8462000 in 2009 as a result of which the study has grown in all directions since 1947 [38]. Water is supplied to Lahore through Bambawala-Ravi-Badian-Deplapur that feeds the Upper and Lower Bari Doab on the Pak-Indian border. The water supply comes from groundwater which is estimated around 3.79, 0.92, 0.77 MCM/day. Groundwater is extracted from a single, unconfined aquifer from a depth of around 120-200 m. Groundwater is pumped for domestic, industrial and commercial purposes. More than 10,000 tube wells have been installed to cater the water needs of the agricultural sector. Lahore receives average annual rainfall around 715 mm. However, the water availability is low as the groundwater discharge is much more as compared to recharge due to urbanization.

Drinking water is supplied to 6.0 million users by Water and Sanitation Authority (WASA) through 484 tube wells. Extraction from these tube wells is around 2.2 MCM/ day while the tube wells run 14-18 hours per day. Water demand has increased tremendously in last decades from around 180 litres per capita per day in 1967 to 274 litres per capita per day in 2013. In the absence of any act, private authorities pump water indiscriminately (0.37 MCM/day).

River Ravi is polluting due to high amounts of industrial and sewage effluents in the river. These effluents are resulting in increased metal contamination in the water. Seven major stations are discharging sewage from municipal sources in the river. Hudiara drain carries effluents from 212 industries while Deg Nullah carries effluents from 149 industries in the river Ravi. Due to these reasons, river Ravi acts as a waste water carrier [39].

Impact of urbanization on water resources of Quetta

Quetta is located in Quetta Valley of Baluchistan province. In 1975, the population of the city was 260,000. The city started expanding soon afterwards due to migrations related to water from Afghanistan. The population doubled by 1985 and by 1998, reached around 560,000. Recently, drought conditions in surrounding areas resulted in migration to Quetta. Currently, the population of Quetta is crossing 1.2 million causing water shortage problems [9].

To observe the effect of land use changes, Khan et al., 2013 collected LANDSAT images from 1975 to 2009. Temporal changes were observed in the Spin Karaz, a water reservoir in the north-west of Quetta that is used to supply water to Quetta city. LANDSAT image revealed that total water covered area in 1975 by this reservoir was 1.04 km2. By 1989, the area reduced to 0.69 km2 ; totally dried up in 2001 and regained a little water by 2009 (0.47 km2). In 1989, Water and Power Development Authority (WAPDA) observed a decline of 0.25 metre per year in the ground water of Quetta [40].

Impact of urbanization on water resources of Rawalpindi/Islamabad

With high population growth in twin cities, Rawalpindi is one the highest populated cities in Punjab with a population of about 1,409,768 people. It

uses surface water as a water source. Rawal Dam is the source of water supply to twin cities. Since the last few years, rapid urbanization around the catchment area of Rawal Lake has affected the quality and quantity of inflows to lake (including two tributaries Korang River and Noorpur Shah Stream). In the catchment area, the population increased by 85 % from 60, 733 in 1998 to 112,333 in 2009. However, inflows decreased by 44% from 1999 to 2009.

It is observed that physical and chemical properties are found within limits; although the quality is rapidly deteriorating. They reported that the values of total coliforms, fecal coliforms and E. coli were found more than the limits permissible and the values are increasing with each passing year. This poses a serious threat to human health as water for Rawal Lake is used for domestic purposes. The lake is surrounded by human settlements and is subjected to land use change from 1998 to 2009 from various activities like agricultural activities (pesticides etc), recreational activities. Lake receives a high amount of poultry waste because the catchment area has approximately 170 poultry farms with 360 poultry sheds. High rates of deforestation (decline in forest cover from 58% to 48%) are observed in the catchment area due to a high population which leads to livestock grazing, cutting of trees for firewood and increase in built-up land from 14.7% to 23.12%.

Impact of urbanization on water resources of Peshawar

Peshawar is the provincial Capital and the largest city of Khyber Pakhtunkhwa. Peshawar has an increasing trend of urbanization. The Urban population of the city was 982, 816 in 1998 which increased to 1,694,937 in 2013. High population growth demands extraction of ground water as a result of which groundwater is declining in the city. Peshawar region relies on river Kabul for domestic, agricultural and industrial activities. Discharge of untreated wastewater, domestic sewage and agricultural run-off into the river results in pollution in the upstream and downstream areas of the river making it unfit for human consumption and for the aquatic biota [41]

Impact of urbanization on water resources of Faisalabad

Faisalabad is the third largest city of Pakistan with a total population of around 2,191,200. The population will rise to 5.2 million by the end of 2030. It is known as the Manchester of Pakistan with a large number of industrial units. It is a densely populated city and the demand for water is increasing every year due to high population growth. The city will need 8.3 million cubic metres per day by the end of 2020 and 11.2 million cubic metres by the end of 2030 [19]. A Large number of industrial units has created problems for the discharge of industrial wastes as only a few industries have treatment plants and untreated wastewater is disposed of in water bodies [42]. Approximately 250 industries discharge their effluents into open drains and municipal sewers that eventually join the river Ravi. The effluents contain toxins (chemical and biological) that affect human beings and ecosystems. These issues make ground water in Faisalabad unfit for human consumption. 83% of the population in Faisalabad relies on groundwater as the main source of water for consumption. Cadmium and chromium concentration in ground waters of Faisalabad are higher than the critical levels set by World Health Organization [43].

Other than these Hyderabad, Multan and Gujranwala are also facing issues related to water. Hyderabad is the sixth most populous city of Pakistan and uses surface water as a source of drinking water. Water supplies are heavily contaminated with E. coli [44]. Due to unavailability of sufficient data, these cities are not discussed in the review. Industrial and municipal discharges of Sialkot city ultimately reach the river Chenab and effluents from Kasur tanneries are drained into Pandoki drain that finally joins Sutlej River [25].

Conclusion

Issues like poor quality and inequitable access are major obstacles to water resource management of the country. Population surge, industrial growth and urbanization are a serious threat to water resources of Pakistan. Poor water quality issues and industrial effluents discharged into waterways pose serious health hazards like water-borne diseases (dysentery, diarrhoea, malaria, hepatitis) and also threaten the livelihood sources of fishing communities. In addition to poor water quality, unequal distribution of irrigation waters, water logging, salinity, seepage, soil erosion, salt accumulation, silting of water reservoirs, increased variability in water flows, groundwater resource exhaustion, decreasing surface storage capacities and droughts are leading towards a reduction in agriculture production and hence triggering food security. This review proposes that core issue of the water crisis in Pakistan is water management, instead of water availability, and unequal water distribution, together with increasing population burden, rapid urbanization, and increasing industrialization, poses a serious challenge to water management in Pakistan.

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