WORLD WATER DAY
MARCH 2019

On the Theme of

"LEAVING NO ONE BEHIND"

Celebrated by

PAKISTAN ENGINEERING CONGRESS

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(4th Floor) Pakistan Engineering Congress Building,
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STUDY QUANTUM OF TRANSBOUNDARY GROUNDWATER FLOW FROM INDIA TO PAKISTAN

By

Engr. Dr. Muhammad Basharat[1], Engr. Muhammad Jawad[2], Engr. Dr. Muhammad Saeed[3] and Engr. Muhammad Shoaib[4]

ABSTRACT: The Government of Pakistan and the Government of India were equally desirous for attaining the most complete and satisfactory utilization of the water of the Indus River System. Therefore, in a spirit of goodwill and friendship, a treaty was pledged in 1960 between these two countries, called Indus Water Treaty (IWT), 1960. According to this treaty India was given exclusive rights on three eastern rivers Ravi, Beas and Sutlej. The whole IWT deals with surface water including rivers and surface drains entering from India to Pakistan. Groundwater recharge being function of surface water were not discussed or are not the part of the treaty.

The groundwater data was collected from Monitoring Organizations of both the countries and groundwater elevation contours were generated using GIS. Results revealed that the flow of groundwater has its gradient towards Pakistan in some areas and in some other areas the flow direction was found parallel to India-Pakistan Border following (NE to SW) in the direction of flow of surface water.

INTRODUCTION

With IWT of 1960 between Pakistan and India, Pakistan is bound to welcome any extra surface flows and drainage effluent being generated in India, as entering Pakistan due to natural surface drainage pattern. At the time of aforementioned treaty with India, the surface drainage water entering Pakistan was not creating any pollution issues. In contrary, nowadays the drains entering Pakistan, particularly Hudiara Drain is heavily laden with industrial, domestic and agro-chemical pollutants. Thus, with passage of time, urban, industrial and agricultural intensification ensuing to population multiplication across the boundary has now changed both the discharge and pollution patterns throughout the year. Also, throughout the Indian Punjab, excessive groundwater is being pumped, that too supported by electricity subsidy by the Indian government. That is why groundwater is being depleted at the highest possible rates across the borders in Indian Punjab. This has been established by international experts through GRACE studies (Rodell *et al.*, 2009), as well as Indian published research on groundwater in the area. With this developing story across the borders, the groundwater situation in Pakistani Punjab is also aggravating to various extents in different

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areas. However, the groundwater levels in Bari Doab are depleting excessively as compared to other Doabs in Punjab of Pakistan.

Consequently, the Pakistani water sector professionals are in a state of uncertainty that excessive groundwater level draw downs in India might also be enhancing indigenous groundwater depletion in Pakistani areas along the border, especially in Punjab. Thus, over the past half century period, both the surface water and groundwater issues between the two countries have got new dimensions, and therefore, need to be re-evaluated for any possible legal battle with the neighbor.

Indus Water Treaty (IWT, 1960)

It is a water-distribution treaty between India and Pakistan, brokered by the World Bank, signed in Karachi on September 19, 1960. According to this agreement, control over the water flowing in three "Eastern Rivers", Ravi, Beas and Sutlej with the mean flow of 33 Million Acre Feet (MAF) was given to India, while control over the water flowing in three "western" rivers, Indus, Jhelum Chenab with the mean flow of 125 MAF to Pakistan. The preamble of the treaty declares that the objectives of the treaty are recognizing rights & obligations of each country in settlement of water use from the Indus rivers system in a spirit of goodwill, friendship and cooperation contrary to the fears of Pakistan that India could potentially create droughts and floods in Pakistan, especially at times of war, since substantial water inflows of the Indus basin rivers are from India.

Thus, rivers are divided, not waters. It is very important to mention here that treaty includes only surface water transboundary distribution, but does not include any provision regarding groundwater distribution, which has become need of the hour. India can use the western river water for irrigation up to 701,000 acres with new water storage capacity not exceeding 1.25 MAF and use the rivers for run-off river hydro power plants with storage not exceeding 1.6 MAF and nominal flood storage capacity of 0.75 MAF. These water allocations made to the J&K state occupied by India are meagre to meet its irrigation water requirements whereas the treaty permitted enough water to irrigate 80% of the cultivated lands in the Indus river basin of Pakistan. It is also losing additional benefits by not permitting moderate water storages in upstream of J&K state whose water would be ultimately released to the Pakistan for its use and avoid few dams requirement in its territory. In 2003, J&K State Assembly passed a unanimous resolution for the abrogation of the treaty and again in June 2016, the Jammu and Kashmir assembly demanded for revision of the IWT. The legislators feel that the treaty trampled upon the rights of the people and treats the state of Jammu and Kashmir as a non-entity.

Indus Basin Irrigation System (IBIS) in Pakistan

Pakistan's economy is largely based on its agricultural production. Water is therefore a critical resource for its sustained economic development. In order to fully utilize the river water resources, the IBIS has emerged as the largest contiguous irrigation system in the world. The IBIS comprises of three large dams, eighty five small dams, nineteen barrages, twelve inter-river link canals, forty-five

canal commands and more than 1 million tube wells. In monetary terms, this network is the biggest infrastructure enterprise of Pakistan accounting for approximately US$ 300 billion of investment. The Figure 1 shows IBIS of Pakistan.

Water Availability of the IBIS

There are three main sources of water availability in the IBIS:

(A) River Water:

The average annual flow of Western Rivers of Indus Basin is approximately 142 MAF. About 104 MAF of this water is diverted for irrigation purposes and about 32 MAF outflows to the Arabian Sea, the rest is un-measured in the system.

(B).Rain Water:

Another source of water is the rainfall. Irrigated areas of Indus Basin receive on average 40 MAF water annually. Average rainfall in Pakistan is about 300mm which necessitates for irrigation.

(C). Groundwater:

The third source of water is groundwater, actually it is by-product of surface water. It provides approximately 40 percent of crop water requirements of the country, mostly in Punjab.

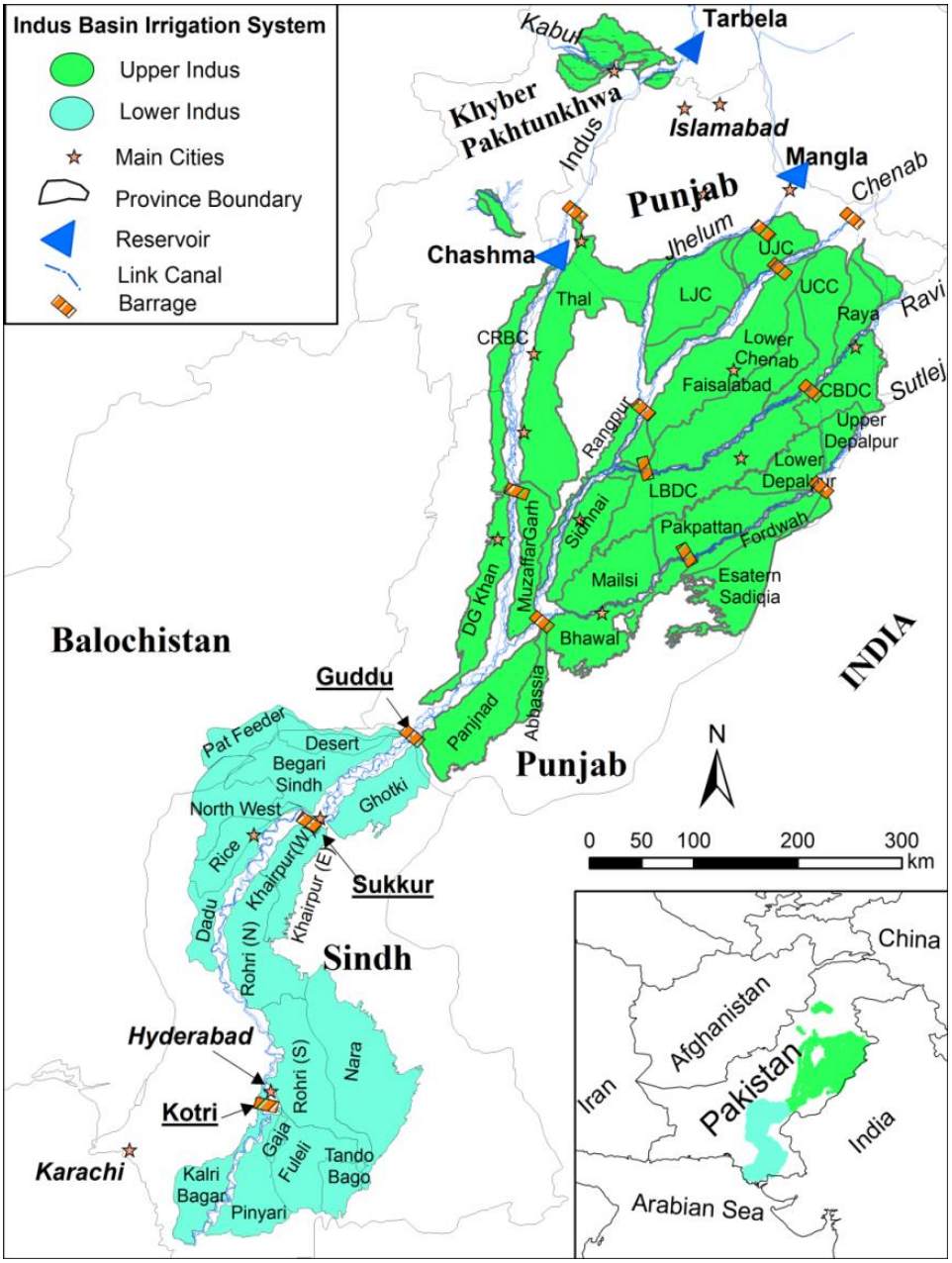


Figure 1 The IBIS System of Pakistan (Basharat,et al., 2015)

Challenges in IBIS

For any sustainable irrigation system that is dependent on river water supplies, it is necessary to have a system of Effluent disposal. However, when the British engineers designed and constructed the barrages and canals in Punjab and Sindh, they did not install an affluent disposal system. This lack of an effluent disposal

system gave rise to the twin problems of waterlogging and salinity. The problem is currently being addressed through construction of a network of disposal drains, many of which have been completed while others are under execution.

After the IWT the water of Eastern Rivers was stopped by India and the area of Bari Doab (area between Ravi and Sutlej rivers), in Pakistan suffered badly by the lack of water required for irrigation in the canal command areas fed by Eastern Rivers. So, the water is being drawn from Chenab, Indus and Jhelum to fulfill the needs of these areas through link canals and other structures. The diversion of surface water in India not only caused considerable reduction in surface water flow but also the groundwater recharge through seepage.

An Overview of Groundwater

In Pakistan when water requirement for agriculture is not fulfilled by limited surface water resources, groundwater is used in large amount in order to meet agriculture requirements and domestic (fully) in most of the cities. It is the groundwater that has contributed more than the surface water for the increased water requirements almost in every water use sector in the last 30-40 years. The groundwater is a unique resource, widely available, providing security against cyclic droughts, climate change and yet closely linked to surface water resources and the hydrological cycle. Its reliable supply, good quality and suitable temperature, relative turbidity and pollution free, minimal evaporation losses, and low cost of development are the attributes making groundwater more attractive.

Although, the increased productivity obtained so far from the agriculture sector can be attributed to many factors of production along with the efficient water management e.g. building of reservoirs, improvement in surface water distribution and application etc. However, among all these improvements and innovations (water and non-water), the major chunk of contribution is the part played by the groundwater component in the form of demand based water supply to the crops. This has been only possible due to renewable nature of the groundwater reservoir with continuous recharge from the surface.

The water stored in the aquifer can be compared to the money kept in a current account of bank. If you withdraw money at a faster rate then you have to recharge the account. Pumping water out of the aquifer faster than it is replenished over the long-term causes similar problems. The volume of groundwater in storage is decreasing in many areas of the country in response to pumping. For example, average annual groundwater depletion in various areas of the Lahore city ranges from 0.45 to 1.5 m/year, with an average of about 0.7 m/year. Excessive groundwater depletion is being observed in the Lower and Central parts of the Bari Doab. There are other areas as well. Some of the emerging negative effects of groundwater depletion in water stressed areas are:

- Drying up of wells;
- Deterioration of groundwater quality; and

- increasing pumping costs.

As the population is increasing, therefore domestic water use being on top priority is automatically increasing. This extra water usage in the domestic and industrial sectors had been compensated with the non-beneficial evaporation in the past (due to waterlogged conditions), and presently at the cost of negative groundwater balance in various areas. At the same time there are areas where waterlogging is still an alive issue. Thus, there is dire need to look into the existing water management in the country, at basin, regional and local scale (Basharat M. *et al.*, 2015).

Transboundary Water

The term "transboundary water" refers to sources of water that are shared among multiple user groups, with diverse values and different needs associated with water use. In this way, water crosses boundaries - be they those of economic sectors, legal jurisdictions, or political interests. From sets of individual irrigators and environmental advocates, to urban versus rural uses, to nations that straddle international waterways, essentially, all freshwater is transboundary water, and is important to society at local, national, regional, and international scales. Transboundary water share certain characteristics that make their management especially complicated.

Surface Drainage from India

There are four drains which are entering from India to Pakistan as following:

- Hudiara Drain;
- Kasur Nala;
- Fazilka Drain; and
- Salemshah Drain.

According to the Section IV point 4 of IWT, Pakistan shall maintain its proportions of the drains mentioned above with capacities not less than the capacities on the effective date (IWT, 1960). It is also mentioned in the treaty at Section IV point 10 that each partner declared its intention to prevent as far as practicable, undue pollution of the water of the Rivers.

Hudiara Drain

Hudiara Drain is one of the most polluted tributaries of River Ravi nowadays. The drain originates near Gurdaspur district of Indian Punjab and enters Pakistan at Lallo Village after carrying the industrial and domestic effluent of Amritsar district. The total length of Hudiara Drain is about 98 km (from its starting point up to its discharging point in Ravi). The length of the drain in Pakistan is 55 km. The drain is laden with a lot of heavy metals in India which are polluting not only the surface water of Pakistan but also Indian Punjab groundwater which ultimately comes to Pakistan through transboundary groundwater flow (Figure 2).

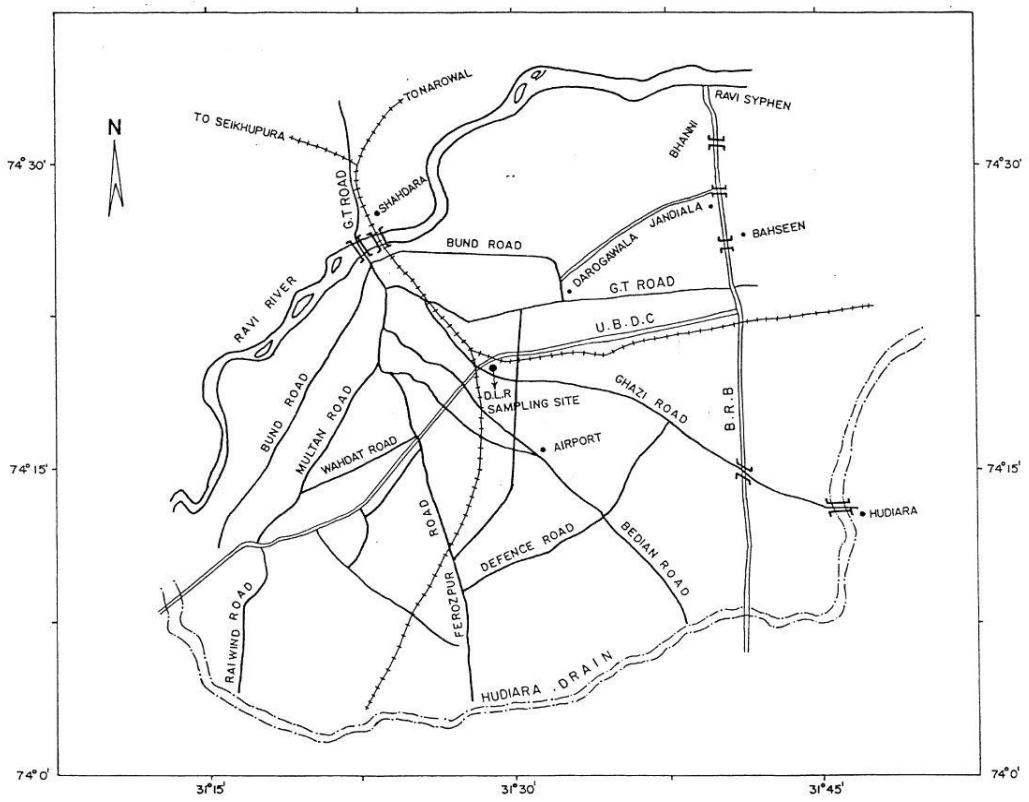


Figure 2 Layout of Hudiara Drain (Afzal S., et al., 2000).

Figures 3 and 4 show groundwater elevation on both sides of border, about 10 years back.

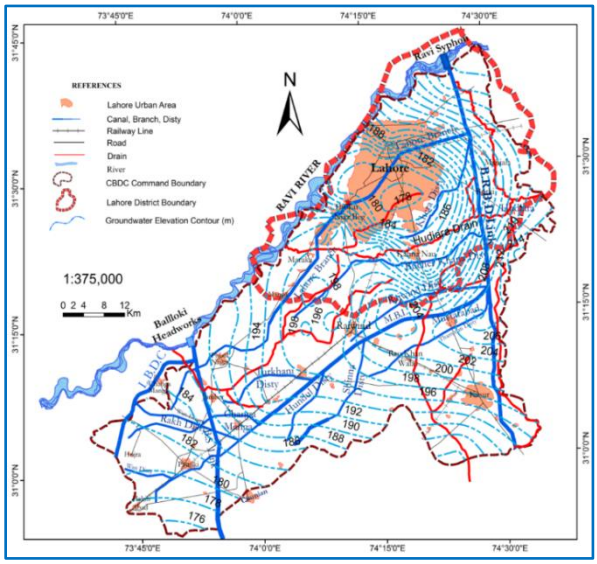


Figure 3: Groundwater Elevation Contours (m) on Pakistani Side of Bari Doab (Basarat and Rizvi, 2011)

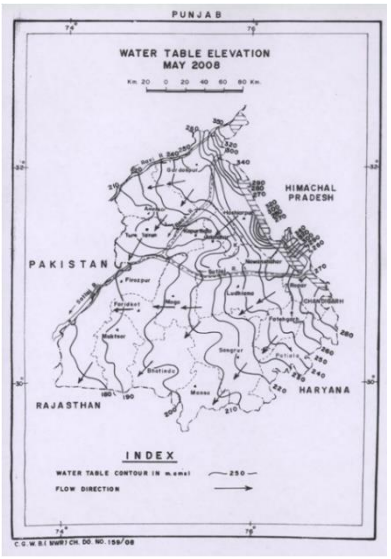


Figure 4:Groundwater Elevation Contours (m) on Indian Side of Bari Doab A (DK Chadha, 2016)

Hydrogeological Conditions of the Area

During nineteen sixties, US Geological Survey initiated hydrogeological investigations in the Punjab, Pakistan, in cooperation with WAPDA under the auspices of the US Agency for International Development (USAID). The investigations included the drilling of test bores, construction of test tubewells, Study of the lithological logs of 149 test holes (600´ to 1000´ depth) and 28 test tubewells (102´ to 356´ depth) indicates that Bari Doab consists of consolidated sand, silt and silty clay, with variable amounts of Kankers. The sands are principally grey or greyish-brown, fine to medium grained and subangular to sub rounded. Very fine sand is common, finer grained deposits generally include sandy silt, silt and silty clay with appreciable amounts of kanker and other concretionary materials (Greenman, 1967). In Bari doab area of Indian Punjab there are clay layers in aquifer. In Central Bari doab in Pakistani Punjab from Lahore to Okara clay layers are discontinuous and in lower Bari doab clay layers are absent

Aquifer System of India

Central Groundwater Board (CGWB) is mandated to carry out hydrogeological mapping aided with groundwater exploration, geophysical surveys, and evaluation of aquifer parameters, groundwater resource estimation and groundwater regime monitoring. Over the years, CGWB through its studies has created huge database in the form of water levels, water quality, sub-surface lithological & geophysical logs and aquifer parameters. Analysis of the data base has enabled the preparation of hydrogeological maps including the groundwater management plans where the aquifer wise area suitable for groundwater recharge, development

and conservation have been identified. Based on the hydrogeological characteristics, the entire country has been classified into 14 Principal Aquifer Systems and 42 major aquifers. Alluvium is the major aquifer system which covers maximum area of around 31% (CGWB, 2012).

Particularly, the lower and central parts of the Bari Doab are being excessively mined. The changes in groundwater levels over the last century in LBDC command (middle of Bari Doab), in response to irrigation system inception (without groundwater irrigation) and then from the 1960s onward, groundwater pumping by farmers to supplement short irrigation supplies, are shown in Figure 5. The average rate of groundwater rise was 23.5 cm/year for these six observation wells. The period from 1987 to 2008 indicates a depletion rate of 31.4 cm/year, i.e. an even faster depletion than its aforementioned rise. The lower half of the LBDC canal command is facing an acute groundwater mining problem. Also, in the upper part of the Bari Doab (CBDC irrigation system), there are no signs of extraordinary groundwater depletion and this can be attributed to relatively more rainfall in the area. Figures 5 and 6 show DTW in Bari Doab, Punjab, Pakistan in Post-Monsoon 2010 & 2014, respectively. The latest trends in groundwater levels at selected representative WASA tubewells for the years 2000 to 2014 is shown in Figure 6.

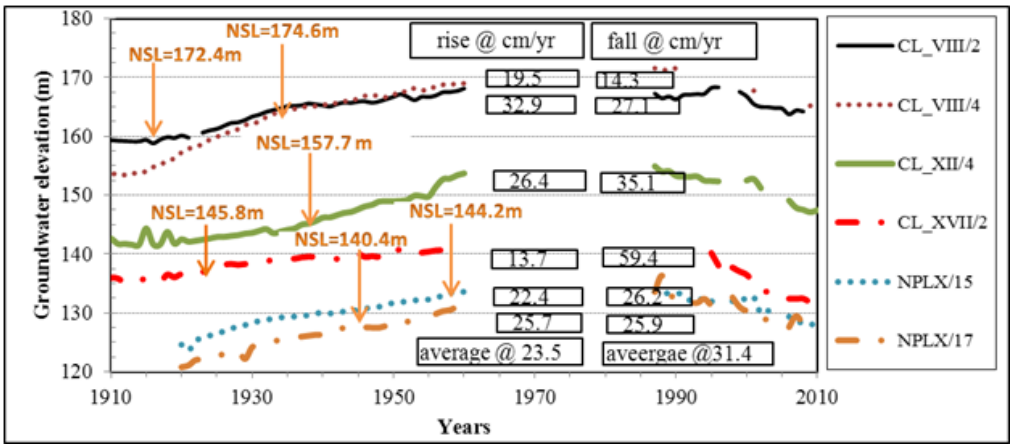


Figure 5 One Century Groundwater Levels, filling and depletion under LBDC Command (Basharat and Tariq, 2013).

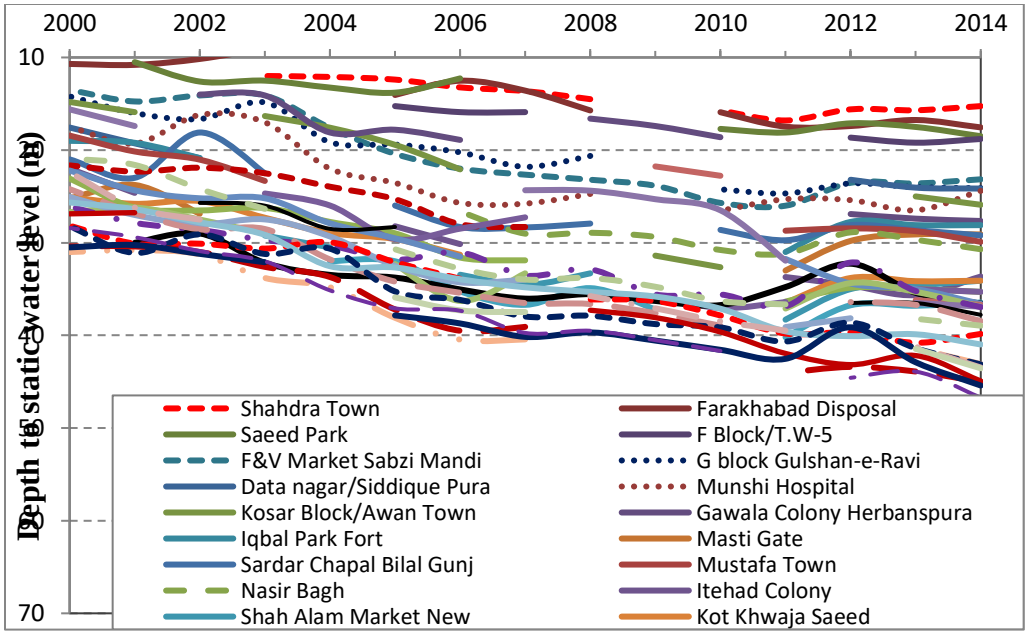


Figure 6 **Groundwater levels in Lahore City (2000 - 2014) (Basharat M., 2015)**

Accordingly, minimum annual depletion rate is along the Ravi River i.e. in Shahdra, Krishan Nagar, Farrukhabad (0.43m), then the areas of Data Nagar and Ravi road (0.45m), Sabzazar and Shadbagh 0.57m), Baghbanpura, Samanabad, Johar Town 0.83m), Ichra, Township, Green Town, Garden Town (1.0m) and Gulberg, Mozang, Mughalpura, Mustafabad (1.08m). Overall average annual groundwater depletion is 0.78m in WASA water supply area, whereas maximum depletion of 1.5 m/annum was found in the tubewells installed at Doungi Ground, Fazlia Colony of Mozang Sub-Division. Also, the maximum depth to groundwater was observed as 46.71m, in E-1 Block of Gulberg III. Thus, the areas of Gulberg and Shah Jamal, along the Lahore Branch Canal have maximum depth to groundwater, or in other words the centre of groundwater depression. In addition, over-exploitation of deeper groundwater is causing groundwater pollution due to leakage from shallow unconfined aquifers.

Transboundary Aquifer Types

Without considering the properties, especially land, groundwater management could not be complete. To account for these unique characteristics, transboundary groundwater management should utilize the three-dimensional approach, rather than the two-dimensional approach used for surface water. In the two-dimensional approach, scientists study the behavior of surface water on a single plane. With groundwater, water percolates into the soil, drawn by gravity. It moves along more than one plane. The three-dimensional approach takes into account this complexity of behavior.

It is hard to determine sovereignty for an aquifer with respect to the scale of both surface development and belowground structure. However, five different cases can be used to determine sovereignty (Barberis 1991, p. 168):

Case 1: A State-owned aquifer, which is the entire aquifer in a State.

Case 2: A confined aquifer divided by an international boundary.

Case 3: In aquifer that is entirely in the territory of a State linked hydrologically with an international river.

Case 4: An aquifer that is entirely in the territory of one State but is hydrologically linked with another aquifer in a neighboring State.

These best describe guidelines for classifying transboundary groundwater. Except for Case 1, these conditions address possible sharing of an aquifer between States. One modification of Case 2 should be noted: if there is a hydrological relationship where intra-State rivers/lakes are linked to an international aquifer, then it is important to be aware of this relationship because the intra-State rivers or lakes may have some influence on the aquifer. (Kyoko Matsumoto, 2002).

The aquifer system between India and Pakistan lies in case 2 out of the above given cases where the aquifers are shared and water of both side of boundary can move from one direction to the other depending upon the use and amount at one side of the aquifer.

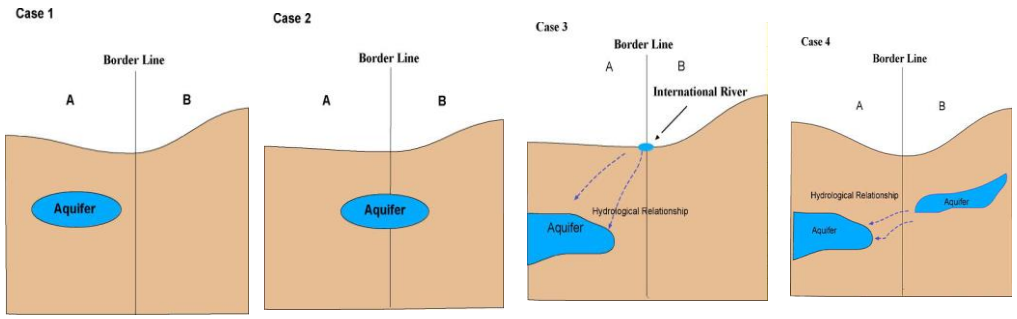


Figure 7 Schematic drawing of aquifer types.

These guidelines suggest possible conditions that determine the transboundary nature of aquifers, and provide a means by which States can proactively manage transboundary aquifers. In addition, these categories are important not only in defining the nature of the aquifer itself, but also in illustrating the scope of the hydrological relationships between aquifer-sharing States. Management with a transboundary element is extremely difficult because of the challenges of cooperation among neighboring countries. This can be an additional obstacle for transboundary aquifer management.

Evolution of International Groundwater Management in Environmental Law

The principles for transboundary groundwater management have not yet been visibly developed. The reasons for the absence of transboundary groundwater law

are, as Krishina and Salman (1999, p.163) point out, “the inadequacy of scientific data” and “complexity of the issues of groundwater.” In order to allow for uncertainty concerning the physical characteristics of groundwater, principles or laws on transboundary groundwater are left undefined or ambiguous. These ambiguities are discussed in real contexts in: the Helsinki Rules, Seoul Rules, Bellagio Draft Treaty, Agenda 21, The Law of the Non-Navigational Use of International Watercourses, and the Convention on the Protection and Use of Transboundary Watercourses and International Lakes.

Past Research work on water pollution of Hudiara

In Pakistan, annual per capita water availability was about 5260 m^3 in 1951, which had dropped to less than 1000 m^3 by the year 2015, a level commonly taken to indicate water scarcity. Whenever good quality water is scarce, water of marginal quality of drains has to be considered for use in agriculture (Asrar-ul-Haq *et al.*, 1997). Municipal wastewater also contained a variety of inorganic substances from domestic and industrial sources, including a number of potentially toxic elements such as cadmium, copper, lead, and zinc (Younas *et al.*, 1998) and nutrients (N and P) which are responsible for eutrophication of water bodies (Afzal *et al.*, 1998b). Even if major cations (Na, Ca, Mg), anions (CO_3, HCO_3, Cl, and SO_4), and toxic materials are not present in concentrations likely to affect humans, they might well be at phytotoxic levels, which would limit their agricultural use to affect humans, they might well be at phytotoxic levels, which would limit their agricultural use (Ayers and Wescot, 1989; Pescod, 1992); however, from the point of view of health, a very important consideration in agriculture use of wastewater, the contaminants of greatest concern are the pathogenic micro- and macro-organisms (to affect humans, they might well be at phytotoxic levels, which would limit their agricultural use (Ayers and Wescot, 1989; Pescod, 1992a).

Newspaper media (28th April, 1998: Dawn, the Frontier Post, The News) reported that the Hudiara Drain was turned into toxic waste from India due to the mortality of cattle reported in the area. The owners of the cattle bathed them in the drain water. The drain falls into the Ravi, it also destroys the aquatic life of the river and made it extremely dangerous for public health. The Ravi River already had a great concentration of industrial and chemical wastes from factories in and around Shahdra. The press demanded that the government should constantly monitor the water of the Hudiara Drain to determine the concentration of toxic elements, as well as carry out a campaign to warn the people of the area against the danger of using the drain water. It was told by the people living near the Hudiara Drain that before 1970, a large variety of fish existed there. At present there is no fish life in the Hudiara Drain due to high amount of pollutants present in it.

Transboundary Groundwater Drainage

For the determination of Transboundary groundwater flow the area of Bari Doab, Rechna Doab and Bahawalnagar area adjoining to Indian border were taken from Pakistani Side containing 138 observation wells. From Indian Side the districts of Indian Punjab, Amritsar, Ferozpur, Gurdaspur and Tarn Taran and Ganganagar

district from Rajasthan state were taken into consideration with total 243 observation wells data used for this study (as shown in Figure 8). The data of DTW from Indian side was taken from website of CGWB, India. The data used for both the countries is for the year 2017 post-monsoon. The total area of both sides is 57722.917 km^2 overall.

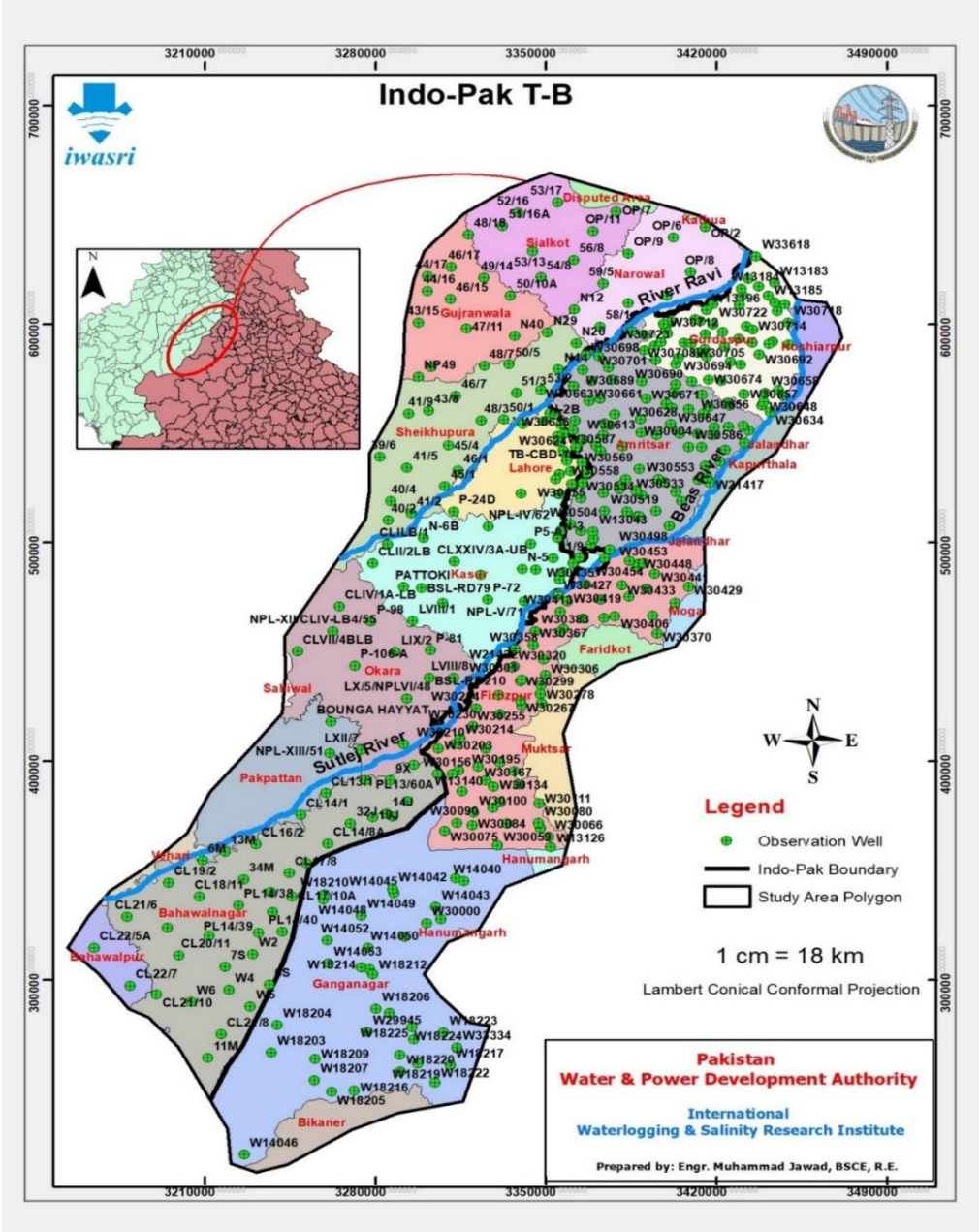


Figure 8 Observation points used for transboundary groundwater drainage

Hudiara Drain from India

Hudiara Drain is the main surface drainage carrying channel which enters Pakistan near Lallo village at Indian border after passing through the main Industrial Hub of Indian, Punjab. As far as Hudiara Drain is concerned, its discharge and pollution both parameters were to be checked at regular intervals. The whole Hudiara Drain was selected for the study purpose. Total five gaging stations were selected where discharge measurement was carried out. In addition to Hudiara Drain, Satukatla Drain was also took as a part of study area because it is the tributary of Hudiara Drain which throws the waste of Lahore area into Hudiara Drain.

Discharge Measurement of Hudiara Drain

The discharge measurement was carried out at five different gaging stations starting from the entrance of Hudiara Drain in the land of Pakistan near Lallo village upto end of the Drain at the point right after which the Drain discharges its water in Ravi River. The drain is an unlined channel, so the water also percolates into soil suspected to pollute groundwater underneath. The discharge measurement was carried out using the Velocity-Area method. The area was calculated by taking depth of water at different sections after regular intervals starting from a fixed reference

Velocity of flow was measured using current meter method at each interval as shown above. All the discharge measurement activities were carried out by ISRIP, WAPDA during different flow periods. The method for velocity measurement adopted was 0.6d method, where d is the depth of water from bed at the measuring section.

RESULTS AND DISCUSSIONS

The groundwater data was collected from both the countries, SCARPs Monitoring Organization (SMO) and Central Groundwater Board (CGWB), from Pakistan and India, respectively. The data was then processed on GIS for generation of elevation contours and profile development. The coordinate system used for the projection of layers was Lambert Conical Conformal Projection system with Datum taken as Kalyanpur India Zone-I. The discrete data points were interpolated using ordinary Kriging method, taking six points search radius set as an interpolation method. Semiveriogram model set for this project was spherical. The contour interval for the contours development was taken as 3m. All the elevations were taken from MSL. The reference to these elevations is Google Earth, for both sides of the border as the error involved in the values was found same everywhere in the study area.

Once the contours were generated, critical sections along the Indo-Pak border in the selected study area were searched out for steepest gradient. After marking the sections flow along these flow lines was calculated using Darcy's law of groundwater movement. The Figure 4.1 show study area with elevation contours.

Groundwater Drainage Quantum Computation

The groundwater flow was calculated using Darcy's law. Assumptions were made for Steady state condition of groundwater flow. Darcy's law states that: the velocity of flow of a liquid through a porous medium due to difference in pressure is proportional to the pressure gradient in the direction of flow.

The flow of water is described as:

$$Q = K.A. \left(\frac{hp - hQ}{L} \right)$$

The coefficient 'K' has dimensions of L/T, or velocity, and this is termed as the hydraulic conductivity.

The case above is described basically for flow of groundwater in confined aquifer. But the actual case of this study is unconfined aquifer everywhere in the study area along Indo-Pak border. For that there was considered no recharge of water from top, the flow takes place in the direction of fall of the hydraulic head, h, which is a function of the coordinate, x taken in the flow direction

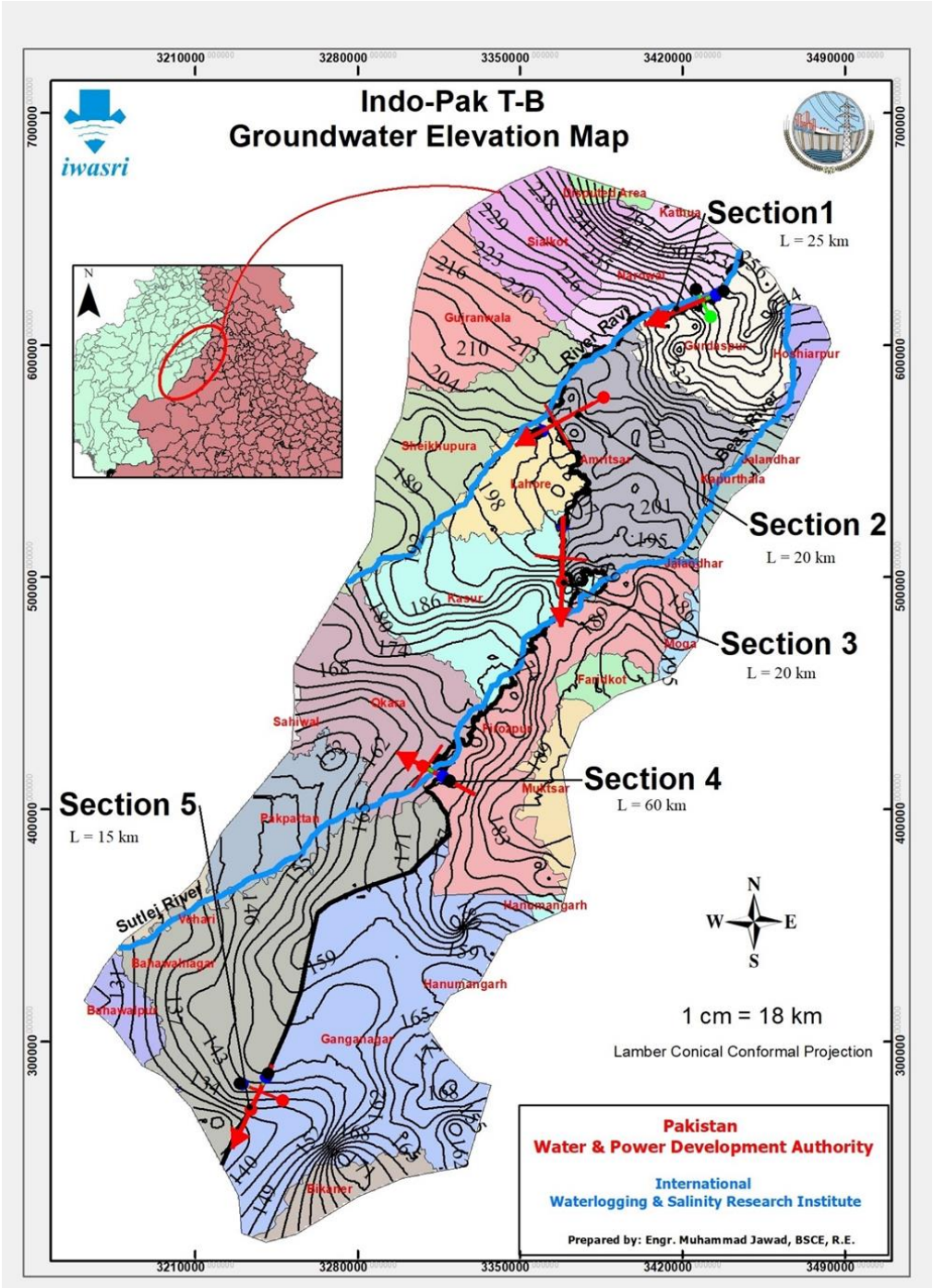


Figure 9: Indo-Pak Transboundary Groundwater Elevation Map across the border in Punjab.

The groundwater flow velocity, v, is governed by Darcy's law. Hence v is also a function of x and increases in the direction of flow. Since, v, according to Darcy's law is shown to be

$$V = K. \frac{dh}{dx} \qquad (1)$$

Dupuit Simplification

This problem to calculate groundwater flow was solved and elaborated by J. Dupuit, a French hydraulician, and published in 1863 and his assumptions for a flow in an unconfined aquifer is used to approximate the flow situation called Dupuit flow. The assumptions made by Dupuit are:

- The hydraulic gradient is equal to the slope of the watertable
- For small watertable gradients, the flow-lines are horizontal and the equipotential lines are vertical.

There is another assumption which was made during the flow computation for this paper particularly is that, there is no seepage from the top of the ground or the other way round the system was considered as an isolated. The flow was considered one dimensional solely.

The unit discharge can be calculated as:

$$q = V.A \qquad (2)$$

Plugging V from equation (1)

$$q = V. A = (K. \frac{dh}{dx}) \text{ x } A \qquad (3)$$

A is the area containing saturated depth of water and thickness of layer. For a unit width A=h. Hence (3) becomes

$$q = (K. \frac{dh}{dx}) \text{ x } h \qquad (4$$

Multiplying (4) dx both sides

$$q.dx = K. h. dh \qquad (5)$$

Integrating both sides for taking the whole flow from position A to Position B

$$\int_0^L \mathbf{q}.\mathbf{dx} = K. \int_{hA}^{hB} \mathbf{h}.\mathbf{dx} \qquad (6)$$

Putting boundary values in (6) and simplifying

$$q . L = K [\frac{h_B^2}{2} - \frac{h_A^2}{2}] \qquad (7)$$

Rearranging (7) given final expression for Dupuit Equation for unit discharge calculation

$$q = - \frac{K}{L} [\frac{h_B^2}{2} - \frac{h_A^2}{2}] \qquad (8)$$

The negative sign indicates that flow is moving in the direction of falling head. Total discharge for width of section (W) can be calculated from (8) as:

$$Q = W \times q \qquad (9)$$

Table 1 Groundwater Flow Quantum Computations Table

Section No.	Section Length (km)	Profile Equation,w.r.t. MSL		Sq. (Head Difference)		Unit Discharge (cum/day)			Represen-tative Width (W) at Section (m)	Q for represent-tative width at designated Section Q = q x W (cum/day)	TB Flow Q (cum/day)	Remarks
		GW Elevation	Aquifer Depth Elevation	GE Elevation $h_B^2 - h_x^2$	Aquifer Bed Elevation $h_B^2 - h_x^2$	MSL to GW Elevation	MSL to Lowest Aquifer Bed Elevation	q(comm.) (cum/day)				
1	25	h = y = -0.0007x + 251.98	h = y = -0.0006x - 143.95	14076.3	225	7.31967	0.117	7.202676	10000	72026.76	0	Along Boundary (NE to SW)
2	20	h = y = 6E-09x^2 + 0.0002x + 114.54	h = y = 2E-08x^2 - 0.0001x - 182.98	3849.216	36	2.50199	0.0234	2.4785904	10000	24785.904	24785.904	Towards (Pakistan)
3	20	h = y = -2E-08x^2 - 6E-05x + 204.68	h = y = -0.0004x - 187.66	7281.616	64	4.73305	0.0416	4.6914504	10000	46914.504	0	Along Boundary (N to S)
4	60	h = y = -0.0002x + 169.78	h = y = 3E-08x^2 + 0.0006x - 221.24	1524.08	0	1.98130	0	1.981304	10000	19813.04	19813.04	Towards (Pakistan)
5	15	h = y = -9E-09x^2 - 0.0007x + 152.3	h = y = -0.0004x - 243.45	9906.962	36	8.58603	0.0312	8.5548337	10000	85548.3373	0	Along Boundary (NE to SW)

Chenab which join the Indus River on its left bank (eastern side) in Pakistan. According to this treaty, Ravi, Beas and Sutlej, which constitute the eastern rivers, are allocated for exclusive use by India before they enter Pakistan. However, a transition period of 10 years was permitted in which India was bound *to supply water to Pakistan from these rivers until Pakistan was able to build the canal system for utilisation of water of Jhelum, Chenab and the Indus itself,* allocated to cause.

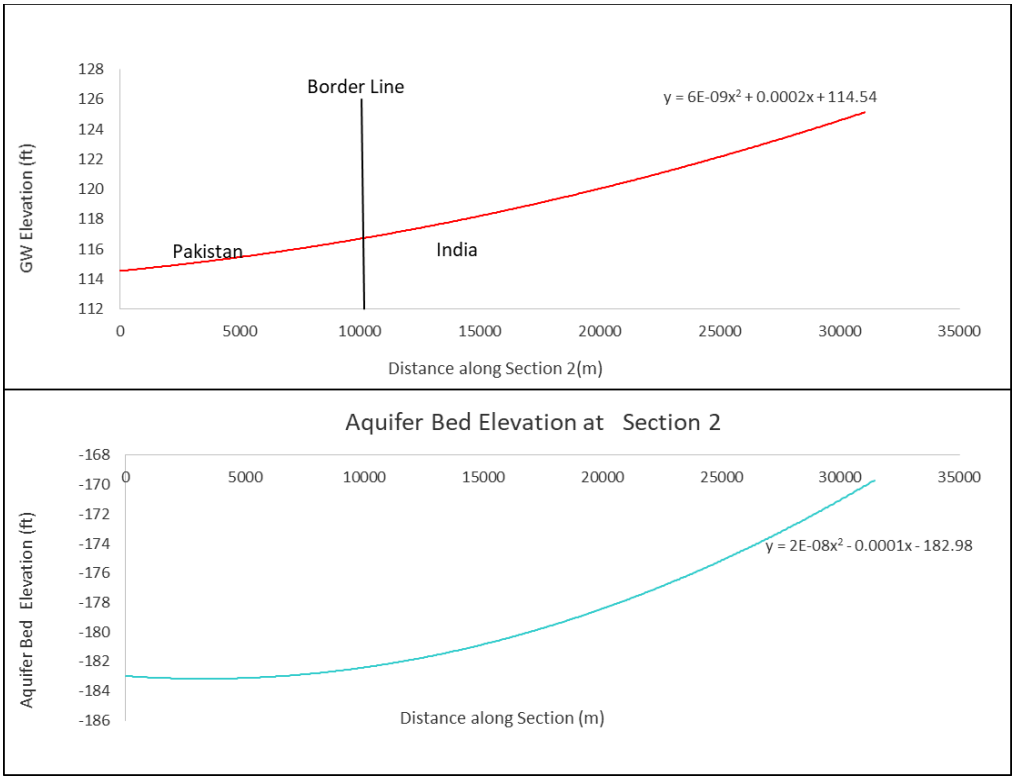


Figure 10 Groundwater elevation with Aquifer bed Elevation at Section 2

It under the treaty. Similarly, Pakistan has exclusive use of the Western Rivers Jhelum, Chenab and Indus but with some stipulations for development of projects on these rivers in India. Pakistan also received one-time financial compensation for the loss of water from the Eastern Rivers. Since March 31, 1970, after the 10-year moratorium, India has secured full rights for use of the water of the three rivers allocated to it. The treaty resulted in partitioning of the rivers rather than sharing of their water (Grag and Kumar, 2010). Once water below Madhupur being at below being at very low level and Ravi River is dried below Madhupur, the groundwater recharge in this affected area is significantly reduced causing an obvious elevation head difference across the border. This is the cause which renders the gradient direction towards Pakistan in area adjoining to Ravi River. Moreover, high pumping rate in Lahore is also a major

This was the equation used for calculation of groundwater flow calculation at the five sections of the study area as marked in Figure 6. For the purpose of flow computation profile sections were plotted of saturated depth elevation of groundwater along with aquifer bed elevation.

Using these groundwater elevation and aquifer bed profiles w.r.t. Mean Sea Level (MSL) and following Dupuit equation as derived above, flow table for all the sections as prepared. At every section the width of section was taken as 10km for

the representation of the whole area. The results show that at Section 1, 3 and 5 the flow of groundwater is along border line and across the border there is no flow theoretically either side of the border line. The results also indicate that in these areas the Transboundary groundwater is in equilibrium and is flowing NE to SW direction.

Section 2 and 4 indicate that gradient of groundwater flow is towards Pakistan. The location of Section 2 is just parallel to Ravi River. On the Ravi River, the earliest project built was the Madhopur Headworks, in 1902. It is a run-of-the river project (no storage envisaged) to divert flows through the Central Bari Doab Canal to provide irrigation in the command area of the then unified India.

Similarly, the case of Section 4 is very much similar to Section 2, where the River Sutlej facing the problem of low flow. In 1953 India constructed Harike Headworks on Sutlej River at the confluence of Beas and Sutlej River and stopped the water from entering Pakistan right after its construction. After IWT in 1960, very low water is being released below Ferozpur Headworks which is causing similar type of groundwater elevation gradient from India to Pakistan. Hence it can be inferred from the Figure 4.1 that in the area of Section 2 and Section 4 the GW elevation gradient is also a function of seepage quantum from the bed of Ravi and Sutlej Rivers, respectively. In total 0.0132 MAF groundwater is flowing towards Pakistan annually at section 2 and section 4 (cumulative).

Drainage Water Entering from India in Hudiara

As described in methodology that five gaging stations were installed at Hudiara at different RDs and discharge of flow was measured. One of these five gauges was installed at Satukatla Drain which is the main tributary of Hudiara Drain and carries the waste water of Pakistan (Lahore city) and outfalls in Hudiara Drain near Raiwind Road. Discharge in Hudiara and Satukatla Drain was monitored throughout the year to have a clear idea about the undulations in the drain during different months. Rating curve for each of the gaging station was prepared by taking discharge during different gage values in different flows. The rating curves are shown below.

After the development of these rating curves for all the gaging stations, discharge in Hudiara at these gaging stations was monitored during all seasons. Below are the statistical figures of discharge values at different gaging stations at different times.

During the course of 8 months observation of flow in Hudiara Drain at different gaging stations, it can be observed from the above given figures (Figure 4.16 to Figure 4.20) that the amount of flow in Hudiara is different in different months of a year. The amount of drainage water entering from India was found maximum during the month of October, i.e. right after the monsoon season (July to September) the water flows in Hudiara Drain is due to agricultural runoff and industrial plus domestic waste water.

Maximum discharge at gaging station 1 was observed as 347 cusecs in October and 101 cusecs being minimum during the month of May. The intermediate observations were between this range. Looking at the minimum value it can be conceived that in May flows are low due to the low rainfall intensity. All the flow in entering from India is waste water either of industries or agricultural or domestic. So during the low flow seasons the water of drain is more concentrated with polluted minerals and salts.

Similarly, considering Gaging Station 2 which was installed at the intersection BRBD Canal and Hudiara Drain at the d/s of BRBD Canal where Hudiara passes under the BRBD Canal. There was found no regular patron at this gaging station because here the gaging station does not present the true scenario due to the leakage in BRBD Canal carrying structure leakage waterfalls in Hudiara Drain and the dilution factor increases considerably.

Figure 11 shows the actual scenario of cross drainage structure at the intersection point of Hudiara and BRBD Canal, where canal in passing at the top of Hudiara Drain perpendicular to the direction of flow of Hudiara Drain.



Figure 11 Cross Drainage Structure at BRDB Canal

Between the reach of GS 2 and 3 some minor tributaries discharge water in Hudiara, especially at the time of post-monsoon season (October to December). Afterwards the flow at GS 3 is the usually the same as at GS 2, excluding seepage losses. The reach of this section of drain is 28 km and average drop of flow between these two sections during low flow seasons was observed as 167.39 cusecs. Between GS 2 and 3 there is approximately negligible pumping for agricultural use as this reach passes through developed area of Lahore city. As the bed of the drain is throughout earthen/unlined, so the continuous seepage from the bed of Hudiara contaminates the shallow groundwater resources in this area.

2.51 km downstream of GS 3, a major tributary of Hudiara, Satukatla Drain falls into it containing the major industrial and domestic effluent of Lahore city. At the point of confluence of Hudiara and Satukatla Drain the total discharge was observed as 659 cusecs as on October-2017. Longitudinal variations of flow at different gaging stations along the length of channel are shown in the Figure 4.22. The last Gaging Station (GS 5), was installed at Hudiara Drain 6.19 km downstream of confluence point of Hudiara and Satukatla Drain. Maximum discharge monitored at this GS was 519 cusecs in the month of May. After this GS the water of Hudiara merges with River Ravi and add to the pollution of water in Ravi.

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

Following are the conclusions drawn from this research:

- IWT 1960, involved only the surface water of Indian Sub-Continent and their distribution. However, the recharge of Groundwater is an important parameter which is the function of surface water flow and neglected in the treaty.
- It was found that, throughout the Indo-Pakistan border there is no such section where there was gradient of groundwater flow towards India. Rather, at two critical sections i.e. at section 2 and Section 4, the flow gradient is towards Pakistan. As a result, 0.0132 MAF/annum water is moving from India to Pakistan, where the groundwater elevation in India being at higher level than Pakistan.
- Moreover, increased pumping trends in Pakistan, mostly in Bari Doab area, also adding to it. In the other critical sections along Indo-Pak border the flow of groundwater is along the border following NE to SW direction at some places and N to S in other areas. Groundwater mining in Indian Punjab and Rajasthan areas is away from border, which is the effect of high rate of groundwater pumping in the populated areas for domestic and agricultural purposes.
- There are four eastern drains entering from Indian side, as mentioned in IWT. Out of all these drains Hudiara Drain carries more pollutants. A study was carried out on the pollution of Hudiara by Afzal S. *et al.* (2000). The results showed that COD, BOD and TSS were not in the permissible limit as defined by NEQS.
- In total the average annual volume of drainage effluent entering from Indian side to Pakistan in Hudiara Drain was calculated as 0.13 MAF/year containing 354 ppm Total Suspended Solids in drain water which becomes 57416Mg/year.

- After entering in Pakistan, a lot of small drains and one major drain Satukatla Drain outfalls in Hudiara Drain, unless Hudiara Drain discharges its water in Ravi River amounting to average volume of 0.36 MAF/year. The water of Hudiara mixes with Ravi River water which is then used for irrigation purpose through irrigation canals in area of Bari Doab.

RECOMMENDATIONS

Following are the recommendations of this paper regarding Transboundary groundwater drainage from India.

- Minimum water should be released in the eastern rivers i.e. in the Ravi, the Beas and the Sutlej, also called environmental flows round the year in order to recharge aquifer underneath to minimize the groundwater depletion in Bari Doab area which is not mentioned in IWT.
- National Water Policy of Pakistan, March-2018 recently approved by Government of Pakistan should be strictly implemented
- India must release its industrial and domestic effluent in Hudiara Drain and all other three drains after treatment, so that it may neither contaminate groundwater of Pakistan nor it disturb the Environment related parameters.

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A BILEVEL MULTIOBJECTIVE PROGRAM FOR OPTIMAL ALLOCATION OF WATER RESOURCES IN THE COMMAND AREA OF TAUNSA BARRAGE

By

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Abstract

Water is the basic requirement of all living thing. Water demands of various users have been increasing at an alarming rate due to the rapid population growth and industrialization which leads to conflicts among different water users. To overcome this issue optimal water allocation is required, so that each user is satisfied with allocation of the limited available water and maximum benefits can be obtained by the use of water. Therefore, in this study a bi-level multiobjective model based on linear programming for optimal allocation of limited available water among different users is formulated and applied at Taunsa barrage. The model allocates available water based on equity at upper level among different canals and on lower level based on satisfaction rate, net economic benefits among different crops. Benefits obtained by wheat, cotton, sugarcane, rice, onion, sunflower crops in optimized allocation are 2010, 704, 3214, 3899, 187 and 19 million rupees, respectively. The results indicate that the performance of model is satisfactory, and it optimally allocates the available water.

Keywords: Optimal water allocation, multiobjective programming, SICCON, Taunsa barrage, AW=Available Water, NEB=Net Economic Benefits, SR=Satisfaction Rate

Introduction

Water is basic need of all living things. With development of societies demand for fresh water is increasing and available resources are not able to meet demands Xu et al. (2013). Demand is continuously increasing due to which per capita availability of water is dropped below 1000m^3 IMF (2015). If available water (AW) is more than demand (D_n)it can be easily allocated but if AW is less than demand than it leads to conflict among different water user because each user wants to get maximum share of AW Babel et al. (2005). To avoid conflicts among various users different researchers worked on optimal allocation of water resources. First, single level multiobjective optimization model was developed for optimal allocation. Divakar et al. (2013) developed a multiobjective model by using SICCON technique for optimal allocation of AW among various user based on satisfaction rate (SR) and net economic benefits (NEB) of different users and applied the model in Chao Phraya basin, Thailand. The result showed that model successfully improved SR and NEB of different users. Li et al. (2016) conducted a study in

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Hongyashan irrigation area, northwest China and developed a linear fractional irrigation water allocation model to maximize NEB and minimize irrigation water used. The result showed that model successfully optimized AW among different crops. Noory et al. (2012); Davijani et al. (2016); Daghighi et al. (2017); Fanuel and Mushi (2018) all these researchers have developed multiobjective model for optimal allocation of AW.

Sometimes water allocation problem requires bilevel water allocation in which two different managers are involved for allocation of AW among different user, so it requires bilevel water allocation model. Zhang and Li (2014) developed bi-level water allocation model for optimal allocation of AW in Sanjiang Plain, China in which AW was allocated among different water users in different subareas of basin based on objectives of maximization of NEB and minimization of system failure risk and result showed that model successfully generated reasonable distribution plan. Zhang et al. (2012); Xu et al. (2013); Guo et al. (2014a); Hu et al. (2016) have developed bilevel water allocation model in different regions to optimally allocate limited AW resources. Yao et al. (2018) developed a bilevel water allocation model for optimal allocation of AW and applied it to a case study in Iran to check the model applicability. The result showed model successfully allocated AW among different water user based on objectives of minimizing the deviation and maximizing of NEB.

All these models were complex and difficult to apply in real world application; therefore, this study aims to develop and evaluate a simple and efficient bi-level multiobjective water allocation model.

Study area

Taunsa barrage is considered for optimization of available water resources. Taunsa barrage is situated in tehsil Kot Addu. The location of Taunsa barrage is shown in Fig. 1. Four canals are of taking from barrage which are D.G. Khan, Muzaffargarh, T. P. Link and Kachhi canals. All these canals are perennial canals. Flow at barrage site varies from 0 cumec to 22600 cumec and maximum discharge passes from barrage during months of June and July due to monsoon rainfall and snow melt in mountains.

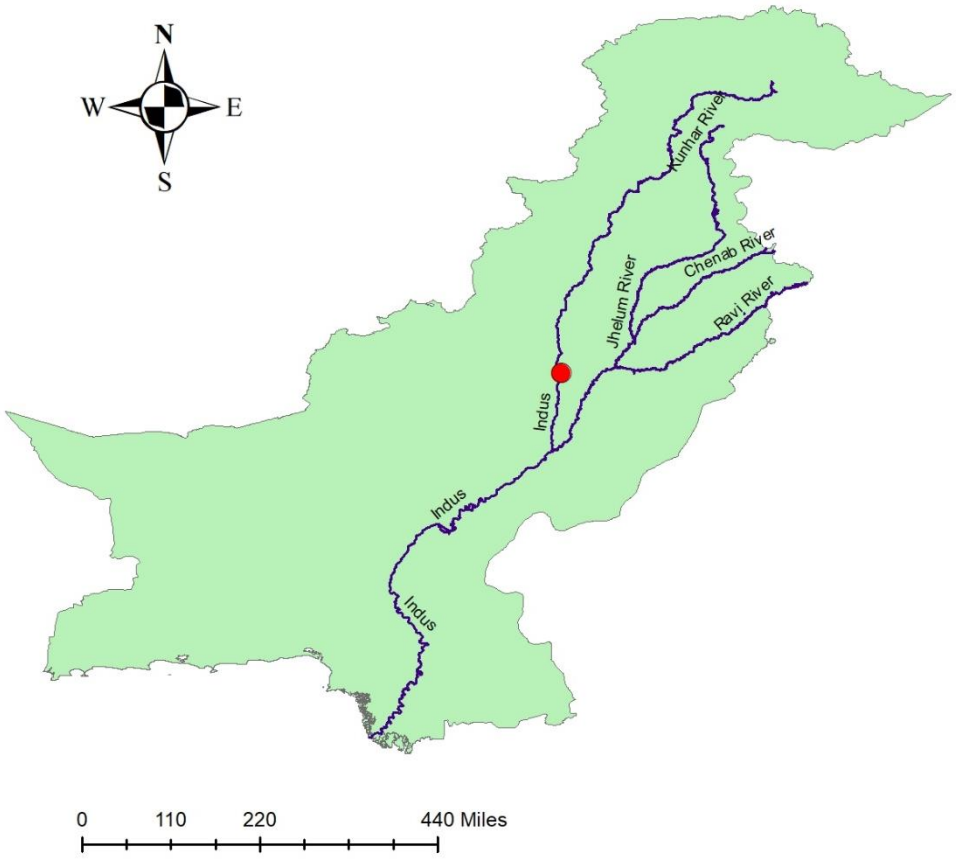


Fig. 1: Location map of Taunsa barrage.

Conceptual framework

Simultaneous compromise constraints (SICCON) technique

SICCON technique is used to convert single objective functions into single multi-objective function by making a compromise solution between the single objectives. A single objective problem with the weighted sum of the original objective functions, subjective to the compromise-constraint plus the original ones, is solved simultaneously.

In this technique deviational variables on left and right side of supposed to be zero value are incorporated into objective functions to find the optimal solution of the problem. Basic working of SICCON technique is shown in Fig. 2.

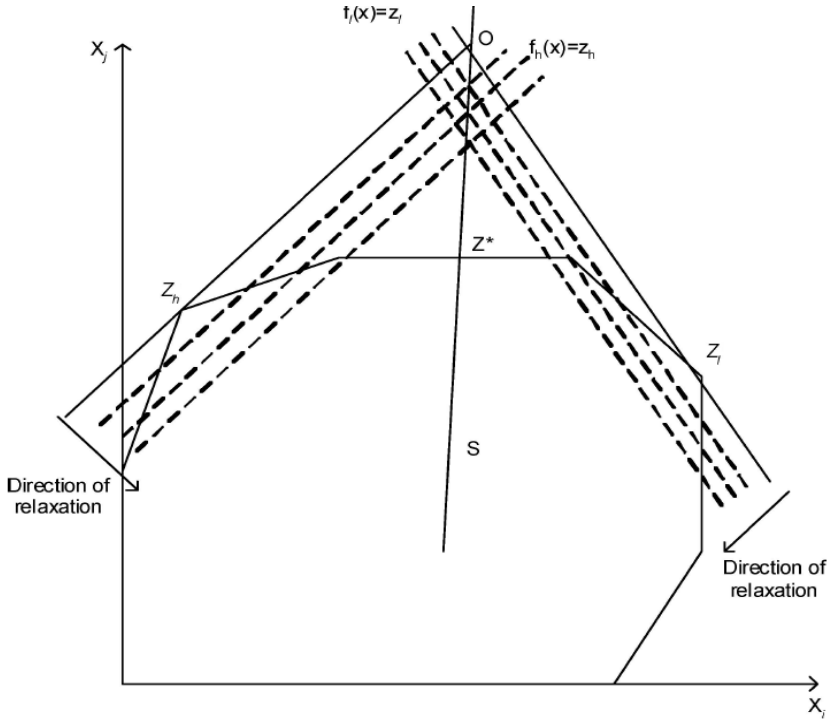


Fig. 2: Basic working of SICCON technique.

Here, $f_h(x)$ and $f_l(x)$ are objective functions whose individual maximum values are Z_h and Z_l respectively. Their point of interaction is O which lies outside of feasible region S. So, both objective functions must relax so that value lies on line Z^* which is feasible solution.

Objective functions

As the model is bilevel so water is allocated at two levels. The objective considered at these two levels are given here.

Upper level objective function

At upper level water is allocated based on equity among different canals which is calculated by using GINI coefficient. GINI coefficient is calculated by using the equation given.

$$Gini = \frac{1}{2n^2\bar{y}} \sum_{i=1}^{n} \sum_{j=1}^{n} \left| y_i - y_j \right| \quad (1)$$

Here, n is number of canals, $\bar{y}$ is average of water allocated to n canals, $y_i y_j$ is water allocated to canal i and j.

Minimum value of GINI represents that solution is more equitable. It varies from 0 to 1.

Lower level objective function

At lower level three objective functions are considered in this study for allocation of AW which are maximization of SR, maximization of NEB and maximization of both SR and NEB. These objectives are discussed here.

Maximization of satisfaction rate (OF1)

Satisfaction rate (SR) of different crops was calculated by using the formula given below,

$$OF_1 = \frac{1}{n}\sum_{c=1}^{n}\frac{S_c}{D_n} \quad \textbf{(2)}$$

Where, OF_1 is Objective function 1, S_c is water allocated to crop c, D_n is normal demand and n is number of crops. The value of OF_1 lies between 0 and 1.

Maximization of net economic benefits (OF2)

Net economic benefits of different crops are calculated by multiplying water allocated to a crop with economic value of water for that crop. The formula used for calculating OF_2 is given,

$$OF_2 = \frac{\sum_{c=1}^{n} S_c \times NEB_c}{AW_{(\text{total})} \times NEB_{\max}} \quad \textbf{(3)}$$

where, OF_2 is objective function 2, NEB_c is net economic benefits of crop c per unit volume of water. $AW_{(total)}$ is total available water and NEB_{max} is maximum net economic benefit among the crops considered. The value of OF_2 lies between 0 and 1.

Maximization of satisfaction rate and net economic benefits (OF12)

In this case both objective functions are maximized by using SICCON technique. SICCON technique is used to convert single objective functions into single multi objective function by assigning different weights to single objective function. Equation of SICCON technique is given below.

$$OF_{12} = w_1 \times [OF_1] + w_2 \times [OF_2] - (\sigma_{12}^{-} + \sigma_{12}^{+}) \quad \textbf{(4)}$$

Where, OF_{12} is objective function of maximization of both SR and NEB, w_1 is weight given to the first objective, w_2 is weight given to the second objective, , σ_{12}^{-} is negative deviation from the supposed to be zero value, and σ_{12}^{+} is positive deviations from the supposed to be zero value.

Methodology

Basic working of the model is shown in Fig. 3. First of all, water availably was calculated by using historical data. Flow data of 18 years was used for calculating AW that was collected from PMIU department. Then water demand of different

crops was calculated by using CROPWAT. For CROPWAT climatic data was required which was collected from PMD department. Water availability and demand was compared to check the difference between availability and demand, and it was found that water availability is very less as compare to demand. So, we need a model to optimally allocate AW among different crops. The model was developed in Excel spreadsheet for allocation of AW by using liner programming. In this model, at upper level AW is allocated based on equity among canals and at lower level SICCON technique is used for allocation of AW among different crops resources. Six different crops (wheat, cotton, sugarcane, rice, onion and sunflower) were considered for optimal allocation of AW in this study. Water was allocated on monthly basis by using three different allocation scenario which were OF_1, OF_2 and OF_{12}.

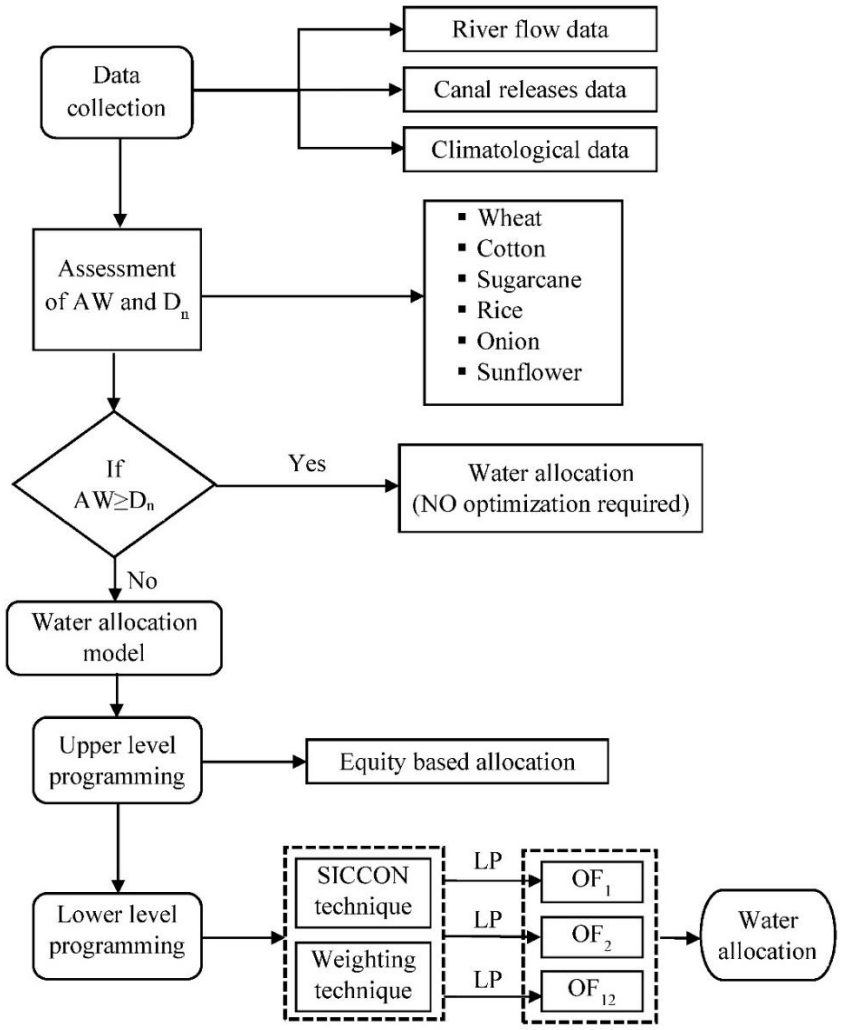


Fig. 3: Basic working of model.

Results and discussion

The developed model was applied at Taunsa barrage. Six crops were considered for optimal allocation of available water in D.G. Khan, Muzaffargarh canal area. First of all, mean annual AW was calculated by using historical flow data at barrage site. Water availability variation in different years is shown in Fig. 4. It is found that minimum water is available in year 2015, so, model was run only for year 2015. Water demand of different crops was calculated by using CROPWAT and compared with the water released in D.G. Khan, Muzaffargarh canal. Comparison of mean monthly demand and supply in D.G. Khan, Muzaffargarh canal area is shown in Fig. 5 and**Fig. 6** respectively.

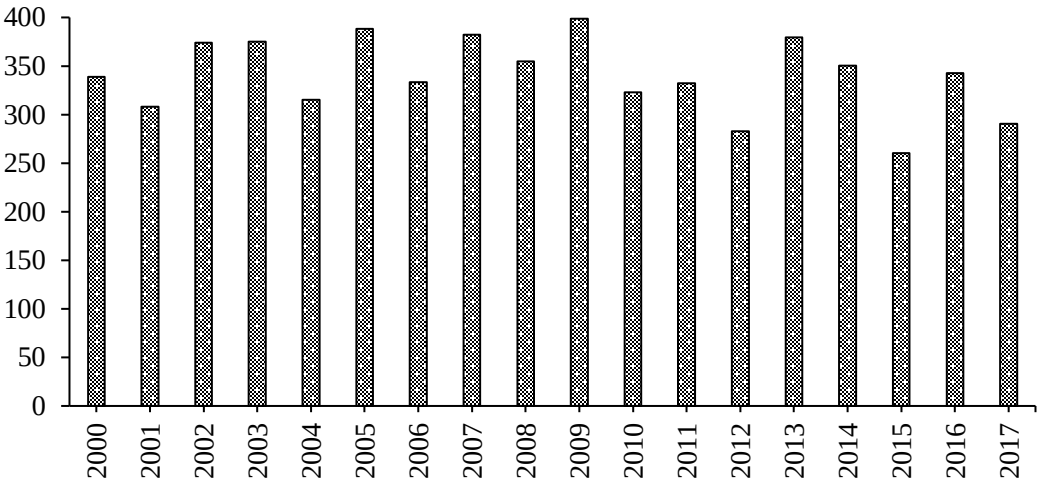


Fig. 4: Mean annual available water at barrage.

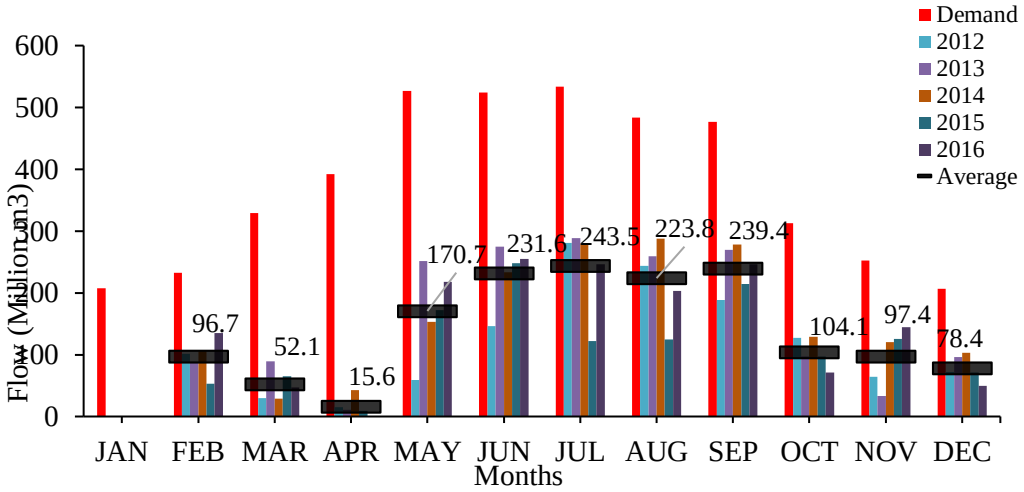


Fig. 5: Comparison of mean monthly demand and supply in D.G. Khan canal area.

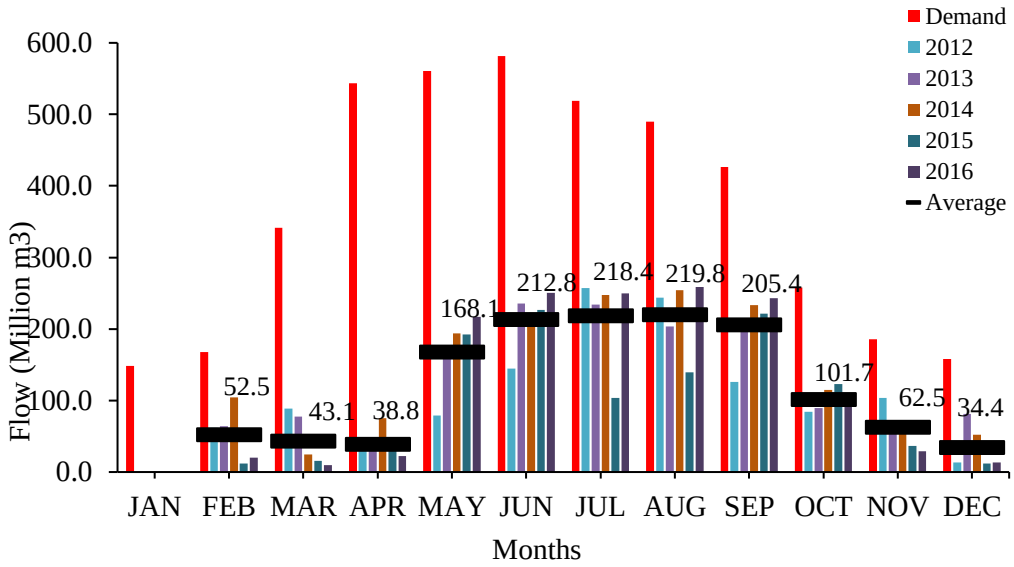


Fig. 6: Comparison of mean monthly demand and supply in Muzaffargarh canal area.

From the above figure it is clear that AW can fulfill only 40% demand of the crops, rest of crops demands are to be fulfilled from ground water.

The amount of water allocated to different crops in different objective functions is presented in table 1. From the table it can be seen that when first case of maximization of SR is considered the SR of each crop is maximized except wheat which has more SR in OF_2 because of highest economic value of water. In this case overall Satisfaction rate of 61% is achieved which is maximum possible SR. In second case when maximization of net economic benefits is considered maximum value of NEB (10770 Million rupees) is achieved.

In third case satisfaction rate of 52% is achieved which is less than first scenario but greater than second scenario and NEB of 10034 Million rupees is achieved which is greater than first scenario. Hence model performed as expected and result in multiobjective function is better than single objective function.

Table 1: Economic benefits and satisfaction rate of different crops in different objective functions.

Objective functions			OF_1			OF_2			OF_{12}		
		Demand	WAM	NEB	SR	WAM	NEB	SR	WAM	NEB	SR
		MCM	MCM	Million Rs.	(%)	MCM	Million Rs.	(%)	MCM	Million Rs.	(%)
D.G. Khan canal command area	Wheat	1484	327	1931	22	441	2599	30	289	1708	20
	Cotton	1424	211	488	15	212	491	15	218	505	15
	Sugarcane	539	469	1735	87	268	992	50	349	1290	65
	Rice	428	263	1186	61	370	1666	86	428	1928	100
	Onion	13	13	204	98	13	204	98	9	138	66
	Sunflower	22	20	16	92	0	0	0	10	8	46
		3911	1303	5560	62	1303	5952	46	1303	5577	52
Muzaffargarh canal command area	Wheat	1242	95	562	8	195	1153	16	51	302	4
	Cotton	1065	201	467	19	87	202	8	86	199	8
	Sugarcane	684	504	1865	74	395	1463	58	520	1924	76
	Rice	438	283	1271	65	429	1932	98	438	1971	100
	Onion	4	4	69	98	4	69	98	3	49	71
	Sunflower	24	24	19	100	0	0	0	13	11	55
		3457	1111	4253	60	1111	4818	46	1111	4456	52
	Total	7,368	2,415	9,813	61	2,415	10,770	46	2,415	10,034	52

Note: NEB= Net economic benefits, SR= Satisfaction rate, WAM= Water allocated by model

Conclusion

In this study a bi-level multiobjective optimization model is developed and applied to a case study at Taunsa barrage. From the historical data, it was found that water availability is very less compared to demand in that area. So, to allocate the limited AW, multiobjective model is used that maximize overall SR and NEB obtained by

using canal water. In case of OF_1 SR of 61% was achieved which is maximum possible SR by using the AW. In case of OF_2 NEB of 10770 million rupees is achieved which is maximum possible NEB. In case of OF_{12} NEB of 10034 million rupees was obtained against SR of 52%. In case of OF_{12} both NEB and SR obtained lies between individual objective functions, so, model performance is considered satisfactory. In case of optimized allocation, wheat, cotton, sugarcane, rice, onion, sunflower corps are allocated 341, 303, 869, 866, 12 and 24 MCM water, respectively and these crops obtained NEB of 2010, 704, 3214, 3899, 187 and 19 million rupees respectively.

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NATURAL BASED SOLUTIONS TO WATER CHALLEGES FOR PAKISTAN

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SUMMARY

The nature plays a vital role in water resources extent and quantity especially for agricultural economies and development as a whole in every walk of life. The 4th Assessment Report (AR4) by the three working groups of the Intergovernmental Panel on Climate Change (IPCC) has projected that average global surface temperature will increase by approximately over 4°C by the 21st century. The recent annual average temperatures for Northern and Southern Pakistan are about 19°C and 24°C respectively. The glaciers constitute about 2,700 km^3 of stored volume of ice (Roohi, 2005), equivalent to about 14 years of average Indus River System inflows. The thermal regime of Hindu Kush Himalayan (HKH) glaciating region has in general warmed up and the frequency of occurrence of moderate as well as severe heat waves have also increased significantly.

The climatic change in Pakistan has slowed down melting of glaciers and snow from mountains due to low temperatures in recent years in northern area, thus reducing flow of rivers resulting in severe water shortages during winter. However, temperature in the northern glaciating area is again rising since 2014-2015. Based on the studies available, it looks likely that the HKH glaciers are receding under the influence of global warming and their melting will increase with increase in summer temperatures. Recent simulation modeling conducted by Global Change Impact Studies Center (GCISC), Geneva, Switzerland, on Indus flows for a scenario where temperature will rise by 4°C and glaciers would shrink to half of their present size, indicates that overall annual river flows would reduce by about 15% and the monthly flow pattern would also change considerably, with more water coming in spring and early summer and less water in the later part of summer.

The extremes of nature are never feasible for water resource. Only a favorable climate is a source of balanced development. It is pertinent to explore that how we can use nature to overcome the water challenges of the 21st century. Environmental damage along with climate change, are driving the water-related crises we see around the world. Floods, drought and water pollution are all made worse by degraded vegetation, soil, rivers and lakes. When we neglect our ecosystems, we make it harder to provide everyone with the water we need to survive. Nature-based solutions have the potential to solve many of our water challenges. We need to do so much more with 'green' infrastructure and harmonize it with 'grey' infrastructure wherever possible. Planting new forests, reconnecting

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rivers to floodplains, and restoring wetlands will rebalance the water cycle and improve human health and livelihoods. Due to anticipated major climate change related concerns, it is projected that it will increase variability of monsoon rains to enhance the frequency and severity of high floods as during 2010 and recent past droughts. Incorporating realistic scenarios of water resources availability is a fundamental element of sustainable development. Water resources and climate change not only affects agriculture, but these also affect urban centers, industry and human health. Management of water resources requires a balanced and careful review of current knowledge under a comprehensive framework for the national development purposes of all sectors of life including environmental requirements.

1. INTRODUCTION

Water is at the core of sustainable development and is critical for socio-economic development, healthy ecosystems and for human survival itself. It is vital for reducing the global burden of disease and improving the health, welfare of society. It is central to the production and preservation of a host of benefits and services for people. Water is also at the heart of adaptation to climate change, serving as the crucial link between the climate system, human society and the environment. Water is a finite and irreplaceable resource that is fundamental to human well-being. It is only renewable if well managed. Today, more than 1.7 billion people live in river basins where depletion through use exceeds natural recharge, a trend that will see two-thirds of the world's population living in water-stressed countries by 2025. Water can pose a serious challenge to sustainable development but managed efficiently and equitably, water can play a key enabling role in strengthening the resilience of social, economic and environmental systems in the light of rapid and unpredictable changes. The extreme of nature are never feasible for water resource. Only a favorable climate is a source of balanced development. It is pertinent to explore that how we can use nature to overcome the water challenges of the 21st. century.

Environmental damage, together with climate change, is driving the water-related crises we see around the world. Floods, drought and water pollution are all made worse by degraded vegetation, soil, rivers and lakes. When we neglect our ecosystems, we make it harder to provide everyone with the water we need to survive and nourish. Nature-based solutions have the potential to solve many of our water challenges. We need to do so much more with 'green' infrastructure and harmonize it with 'grey' infrastructure wherever possible. Planting new forests, reconnecting rivers to floodplains, and restoring wetlands will rebalance the water cycle and improve human health and livelihoods. Agriculture plays a key role in providing (i) food availability (ii) an important source of income to purchase food; and (iii) foods with high nutritional status. Food security in Pakistan is dependent on agriculture and agriculture depends on availability of land and water. There has neither been any substantial horizontal expansion (new lands coming under cultivation) nor any significant vertical (per acre yield) growth despite having massive potential on each of the two areas. At the same time land and water

resources are becoming scarcer every day. The vertical growth has been more difficult and arduous part. Over the last 6 decades, our institutions and relevant agencies have not been able to educate farmers on crop management issues. The farming practices are still not at par with world standards and about 30% of horticulture crops are lost at post harvest level. Yields of all major cash and food crops are well below the world average. However, due to non-development of resource base, per capita water availability is falling and country is heading fast towards a water deficient country.

Along with other developing countries, Pakistan is facing the key issues of high demographic pressure and change in food consumption practices, rapid deterioration of natural resources, agricultural low productivity and water scarcity. The issues are becoming drastic in scale and impact. To meet the future food demand and water for competing sectors as well, improvement and modification of agricultural production system and water resources management are determining factors. To ensure food security we have to address not only the issue of water supply but also agriculture in an integrated manner. To achieve food security we need technology transfer and improve the efficient use of water. It is essential to create an enabling environment, which is built upon the principles of sustainable development, poverty reduction, knowledge-based institutions and a favorable investment program for land and water for judicious utilization of such resources.

Over 1.7 billion people are currently living in river basins where water use exceeds recharge, leading to the desiccation of rivers, depletion of groundwater and the degradation of ecosystems and the services they provide. As countries develop and populations grow global water demand (in terms of withdrawals) is projected to increase by 55% by 2050. . Already by 2025, two thirds of the world's population could be living in water-stressed countries if current consumption patterns continue. The economic loss from the inadequate delivery of water and sanitation was estimated to amount to 1.5 % of gross domestic product of the countries included in a WHO study on meeting the MDGs. According to some estimates, over 80% of wastewater is discharged without treatment. Water-related disasters are the most economically and socially destructive of all natural disasters. Since the original Rio Earth Summit in 1992 floods, droughts and storms have affected 4.2 billion people and caused USD 1.3 trillion of damage.

As Pakistan is water scarce country the shortfall of about 30 MAF of water by the year 2030 is to be met through creating storage facilities and diverting 21.5 MAF to canals which at present is flowing to sea after allowing 8.6 MAF for environmental flows. This additional diversion of 21.5 MAF at canal head would add about 15.6 MAF at farm gate. Exploiting, a potential of 6.4 MAF from groundwater and 3 MAF from rain water harvesting will add to this, making additional water availability at farm gate about 20 MAF. The program of water course improvement by 2030 will cover all the water courses of country enhancing water course efficiency significantly and will save wastage of water in the irrigation system and thus the total water availability at farm gate would be about 143 MAF.

The water requirements of 143 MAF by 2030 for all water using sectors would be safely met. Campaign on efficient use of water in domestic, industrial and agricultural sectors have been launched to disseminate knowledge and information to the water users especially farmers.

Rain water harvesting and use of treated water are also being adopted. Water is key factor for agro-socio-economic uplift through green revolution in the country. The additional water availability for irrigation and other relevant developments of efficient water use coupled with crop management as anticipated above, the country would not only be able to sustain food security but also would export more agricultural products. It can easily be seen that water plays a pivotal role in development of all sectors of life.

2. MILLENNIUM DEVELOPMENT GOALS (MDGS)

The Millennium Development Goals (MDGs), agreed in 2000, aim to have the proportion of people without sustainable access to safe drinking water and basic sanitation between 1990 and 2015. A total of 748 million people still do not have access to an improved drinking water source and existing indicators do not address the safety and reliability of water supplies. To reach the requirements of the right to access to safe drinking water requires real improvements for several billions of people. In July 2010, the General Assembly adopted a resolution, which “recognized the right to safe and clean drinking water and sanitation as a human right that is essential for the full enjoyment of life and all human rights”. The MDG target for sanitation is an even more pressing challenge, with 2.5 billion people currently lacking access to improved sanitation and over one billion still practicing open defecation. At current rates of progress, the sanitation target will be missed by over half a billion people. These global aggregates also mask large disparities between nations and regions, rich and poor, between rural and urban populations, as well as between disadvantaged groups and the general population. There is currently no global target to improve hygiene, despite this being one of the single most cost-effective public health interventions. As the time limit for the MDGs draws to a close in 2015, the global community is taking stock of how it can move towards a sustainable future. The MDG framework did not address the full water and development agenda, nor fully recognize its synergies with other areas and concerns.

3. SUSTAINABLE DEVELOPMENT GOALS (SDGS) ON WATER

The Rio+20 Conference (2012), was an opportunity to reflect on progress towards sustainable development over the previous 20 years. One of its main outcomes was an agreement to launch a process to develop a set of Sustainable Development Goals, which build on the Millennium Development Goals and converge with the post-2015 development agenda. The Zaragoza Conference focused on the tools for implementation stated in the outcome document of the United Nations Conference on Sustainable Development, held in Rio de Janeiro from 20 to 22 June 2012, entitled "The future we want", which includes finance, technology and capacity building, adding the institutional and policy dimensions.

Emphasis on 'Sustainability' was not included and human rights and inequalities were also largely ignored in the MDG framework. Subsequently, member states have agreed that human rights, equality and sustainability should form the core of the development agenda and be recognized as critical for true development. UN-Water's overarching goal is that "Securing Sustainable Water for All". The water goal and targets directly address the development aims of societies, promote human dignity and ensure achievements are sustainable over the long term leading development outcomes for the water utilizing sectors.

Sustainable development was explicitly popularized and contextualized by the Brundtland Commission in the document "Our Common Future" where it was defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (UN, 1987). The Brundtland Commission focused on three pillars of human well beings; economic, socio-political and ecological/environmental conditions. The basic concept endorses putting in place strong measures to spur economic and social development, particularly for people in developing countries, while ensuring that environmental integrity is sustained for future generations.

4. EFFECT OF GLOBAL WARMING ON WATER RESOURCES

Global weather changes and water resources are deeply inter-related. The largest source of freshwater is rain. Global climatic changes will have major effects on precipitation and runoff. In the relatively arid and semi-arid regions, modest changes in precipitation can have proportionately large impacts on water supplies. In mountainous watersheds, higher temperatures will increase the ratio of rain to snow, accelerate the rate of spring snowmelt, and shorten the overall snowfall season, leading to more rapid, earlier, and greater spring runoff because the temperature projections of climate models are less speculative than the projections of precipitation. Temperatures induced shifts in the relative amounts of rain and snow and in the timing of snowmelt in mountainous areas are considered likely. Climate induced changes in hydrology will affect the magnitude, frequency, and costs of extreme events. Flooding could become more frequent and extreme. Recent reports of the IPCC suggest that a greenhouse warming is likely to increase the number of intense precipitation days as well as flood frequencies in northern latitudes and snowmelt driven basins. These reports also suggest that the frequency and severity of droughts could increase in some areas, as a result of a decrease in total rainfall and more frequent dry spells.

The water resources in our region (Near East) are also affected by climate changes in the world at large. There is a significant change in climate of Asia, in general, and Near East, in particular, to warrant global climate change concerns, such as follows (IPCC, WG-II):

(a) **Lhasa, Tibet:** Warmest June1998 on record. Temperatures above 25°C (77°F) for 23 days.

(b) **Himalayas, India:** Glacial retreat at record pace. The Dokriani Barnak Glacier receded over 20 m in 1998, despite a severe winter. The Gangorti Glacier is retreating about 30 m per year. At this rate, scientists predict the loss of all central and eastern Himalayan glaciers by 2035.

(c) **Tien Shan Mountains, China:** Glacial ice reduced by one quarter in the past 40 years.

(d) **Middle East:** Severe drought has affected many parts, including Iran, Iraq and Jordan. Rainfall in parts of Iran decreased by 25% as compared to 1999. Eighteen out of the country's twenty-eight provinces are suffering in Iran.

(e) **In Iraq the flow of Tigris and Euphrates** rivers have reduced by around 20% of their average flow, with serious consequences for irrigated farming. Jordan's agricultural production has been severely affected in recent past due to drought. Most countries in Middle East are suffering the consequences of prolonged water-shortages.

The evidences listed above show that in the recent past dry years in Pakistan were not isolate events; as the whole Near East region suffered as well. A macro-scale hydrological model for river-flow suggests that the runoff of the Indus will decrease by 27% by the year 2050. This implies that the availability of fresh water in Pakistan is highly vulnerable to climate change. Availability of water from snow-fed rivers may increase in the short term, but decrease in the long-run. Runoff from rain-fed rivers may also change in the future. A reduction in snowmelt water will put the dry-season flow of these rivers under more stress than is the case now, especially in Pakistan where one major snow-fed river, the Indus, accounts for as much as 80 % of the normal water flow. Increased population and increasing demand for the agricultural, industrial and hydropower sectors will put additional stress on water resources. The 4th Assessment Report (AR4) by the three working groups of the Intergovernmental Panel on Climate Change (IPCC) has projected that average global surface temperature will increase by approximately over 4°C during the 21st century. The recent annual average temperatures for Northern and Southern Pakistan are about 19°C and 24°C respectively. The glaciers constitute about 2,700 km^3 of stored volume of ice (Roohi, 2005), equivalent to about 14 years of average Indus River System inflows. The thermal regime of Hindu Kush Himalayan (HKH) Glaciating region has in general warmed up and the frequency of occurrence of moderate as well as severe heat waves have also increased significantly.

The climatic change in Pakistan has slowed down melting of glaciers and snow from mountains due to low temperatures in recent years in northern area, thus reducing flow of rivers resulting in severe water shortages during winter. However, temperature in the northern glaciating area is again rising since 2014-2015. Based on the studies available, it looks likely that the HKH glaciers are receding under the influence of global warming and their melting will increase with increase in summer temperatures. Recent simulation modeling conducted by Global Change

Impact Studies Center (GCISC), Geneva, Switzerland, on Indus flows for a scenario where temperature will rise by 4°C and glaciers would shrink to half of their present size, indicates that overall annual river flows would reduce by about 15% and the monthly flow pattern would also change considerably, with more water coming in spring and early summer and less water in the later part of summer. Due to anticipated major climate change related concerns, it is projected that it will increase variability of monsoon rains to enhance the frequency and severity of high floods as during 2010 and recent past droughts. Incorporating realistic scenarios of water resources availability is a fundamental element of sustainable development.

Water resources and climate change not only affects agriculture, but these also affect urban centers, industry and human health. Management of water resources requires a balanced and careful review of current knowledge under a comprehensive framework for the national development purposes of all sectors of life including environmental requirements.

5. WATER REQUIREMENTS V/S AVAILABILITY

Population rise, urbanization and better socio-economic conditions have brought increasing pressure on water resources. Water availability in Pakistan is 900 m^3 per capita/year in 2017; this is already well below the 1,700 m^3 per capita/year threshold for water stressed conditions. Thus Pakistan is already fast moving into a condition of 'water scarcity'. This situation is likely to deteriorate in future as the gap between supply and demand widens. However, the gross additional water demand in 2017 for all sectors is about 21.0 MAF (15 MAF for agriculture and 6.0 MAF for municipal water supply, rural potable and sanitation, industry and the environment). The corresponding requirement at the canal head is nearly 30 MAF. Water available for future development is about 38 BCM (31 MAF) including 21.5 MAF of river flow, 6.4 MAF from groundwater and 3 MAF from rainfall harvesting. Future water requirements for all sectors are given in Table-1 and discussed in the proceeding paragraphs:

Table- 1: Future Water Needs at Farm Gate (MAF)

Sector	Year					
	2000*	**2010****	**2017****	**2020****	**2025***	**2030****
Agriculture	99.0	104.0	109.0	114.0	119.0	124.0
Water Supply & Sanitation	4.5	6.0	7.5	9.0	10.5	12.0
Industry	3.5	3.8	4.1	4.5	4.8	5.1
Environmental Protection	1.3	1.4	1.5	1.6	1.7	1.8
Total	**108.3**	**115.2**	**122.1**	**129.1**	**136.0**	**142.9**

*Source: *National Water Policy Vol.-II, January 2003-(2000 & 2025)*
*** Computed (2010, 2017, 2020 & 2030)*

a) **Agriculture:** The total area of the country is 79.61 Mha of which 29.4 Mha is designated as cultivated area. About 15.4 Mha cultivated land is served by canal water, while the remaining 5.2 Mha is rain fed while the remaining 8.8 Mha area is barren, needing additional water for irrigation. Almost 90 percent of water resources are being used to meet crop water demand. Increases in agricultural production to meet the needs of a rising population, will require additional water. Based on population growth projections, by 2030 an estimated additional 15 MAF will be needed for agriculture at the farm gate. The agriculture is by far the thirstiest consumer of water globally, accounting for 70% of water withdrawals worldwide, although this value varies considerably across countries. Rain fed agriculture provides production in the world, and its current productivity is, on average, little more than half the potential obtainable under optimal agricultural management. Pakistan's economy depends on agriculture which requires water as a prime input facto for raising crops. This sector provides subsistence and livelihood to over 70 % of population.

b) **Municipal Use***:* The current total water uses for domestic and municipal purposes in both urban and rural areas are estimated at 7.5 MAF. By 2030 requirements for water supply, rural potable water and sanitation are estimated to be 12.0 MAF with an increase of 4.5 MAF as compared to 2017. Worldwide, an estimated 748 million people remain without access to an improved source of water and 2.5 billion remain without access to improved sanitation. More than half the world already lives in urban areas and by 2050, it is expected that more than two-thirds of the global population of 9 billion will be living in cities. Furthermore, most of this growth will happen in developing countries, which have limited capacity to deal with this rapid change, and the growth will also lead to increase in the number of people living in slums, which often have very poor living conditions, including inadequate water and sanitation facilities. Therefore, the development of water resources for economic growth, social equity and environmental sustainability will be closely linked with the sustainable development of cities.

c) **Industry** - There are over half a million large and small industrial units in the country, of which nearly 120,000 are engaged in textile, chemical, fertilizer, tanneries and other manufacturing and processing activities. The water use by all industries and mines in year 2017 is estimated to be 4.1 MAF. This is expected to rise to 5.1 MAF by 2030, i.e. an additional requirement of 1.0 MAF. The Industry and energy together account for 20% of water demand. More-developed countries have a much larger proportion of freshwater withdrawals for industry than less-developed countries, where agriculture dominates. One of the biggest is globalization and how to spread the benefits of industrialization worldwide and without unsustainable impacts on water and other natural resources.

d) **Environment** - The environmental water requirement for 2017 is about 1.5 MAF. In order to ensure adequate water throughout Pakistan for wetlands, environmental protection and increased irrigated forestry, about 1.8 MAF water will be required by the year 2030.

e) **Ecosystems**: These are perhaps the most important challenge to sustainable development to have arisen in the last decades is the unfolding global ecological crisis that is becoming a barrier to further human development. From an ecological perspective, the sustainable development efforts have not been successful. Global environmental degradation has reached a critical level with major ecosystems approaching thresholds that could trigger massive collapse. The growing understanding of global planetary boundaries, which must be respected to protect Earth's life support systems, needs to be the basis of the future sustainable development framework.

6. WATER RESOURCES

Pakistan's water resources comprise of surface and ground water which are briefly described as follows:

6.1 Surface Water

The Indus River System is the major source of surface water which derives mostly from snow and glacial melting. Schematic Diagram of Rivers and Irrigation System and Land use of Pakistan are shown in **Figures 1 and 2**. Pakistan receives snowfall on the mountains during winter. Rainfall is in monsoon during July to September and it varies in magnitude, time of occurrence and aerial distribution. The mean annual precipitation ranges from less than 100 mm in parts of the Lower Indus Plain to over 750 mm near the foothills in the Upper Indus Plain. Pakistan is dependent on the four western rivers including Kabul, Indus, Jhelum and Chenab. Post-Tarbela (1976-2017) flows in Indus at Kalabagh, Jhelum at Mangla and Chenab at Marala and with eastern rivers small contribution on an average are 140 MAF. The three eastern tributaries of the Indus – Ravi, Sutlej and Beas – were allocated to India for its exclusive use. The Kabul River contributes 17 MAF on an average to the surface supplies of the country.

Consequent to Indus Water Treaty, Pakistan built Mangla and Tarbela Dams and link canals to transfer inter rivers (Indus Jhelum and Chenab) waters for irrigated agriculture in the commands of Ravi, Beas and Sutlej rivers whose waters were allocated to India. This opportunity of assured supplies through building additional storages and network of irrigation canals brought green revolution in 1970's. Further productivity was enhanced by adopting better varieties of crops like Maxi Pak wheat, Irri.8 rice and Baharia Maize along with genetic techniques and cultural practices. With high population growth and reduction in storage capacity due to sedimentation of the reservoirs, Pakistan which was affluent in water in seventies, became water scarce by end of 2000. No mega storage dam was built after completion of Tarbela Dam in 1976. Although Kalabagh Dam design was ready by

1987 but it could not be built due to non-consensus between the stake holders. Pakistan faces recurrent floods and droughts. During the last two decades three flood diversion canals, i.e. Greater Thal, Rainee and Kachhi Canals were completed to irrigate 0.21 Mha. A few small dams were built; i.e. Mirani, Sabakzai, Gomal Zam and Satpara which irrigate 0.11 Mha area. Diamer Basha Dam with live storage of 6.4 MAF is being started which would not only meet water shortages in the Indus Basin but would also supply water to some additional land to boost economy of Pakistan.

Pakistan is using mostly flood irrigation system. Water is diverted from rivers, by constructing dams/barrages, into canals, distributaries and water courses leading to the farm. Indus Basin Irrigation system one of the World's oldest and the largest contiguous irrigation system comprises of 19 barrages, 54 main canals having length over 60,000 kilometers and water courses length 1.6 million kilometers. Most of the canals built are unlined and about 40% of the diverted water at canal head is lost during conveyance to the farm gate. There has been significant improvement due to On Farm Water Management; lining of canals distributaries and watercourses, laser land leveling, low delta crops, salt tolerant varieties, furrow and bed, high efficiency drip and sprinkler irrigation techniques.

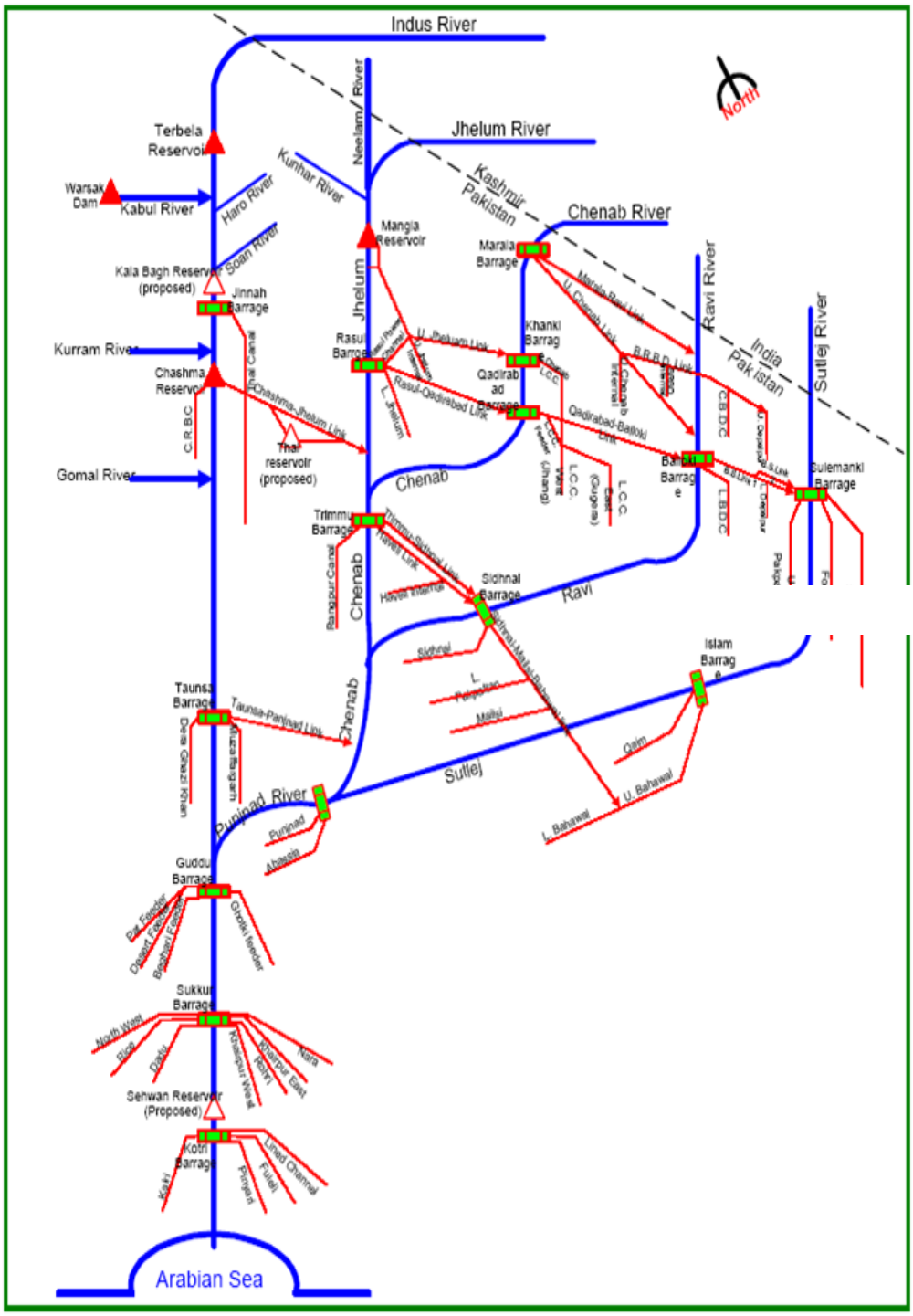


FIGURE 1: Schematic Diagram of Rivers and Irrigation System of Pakistan

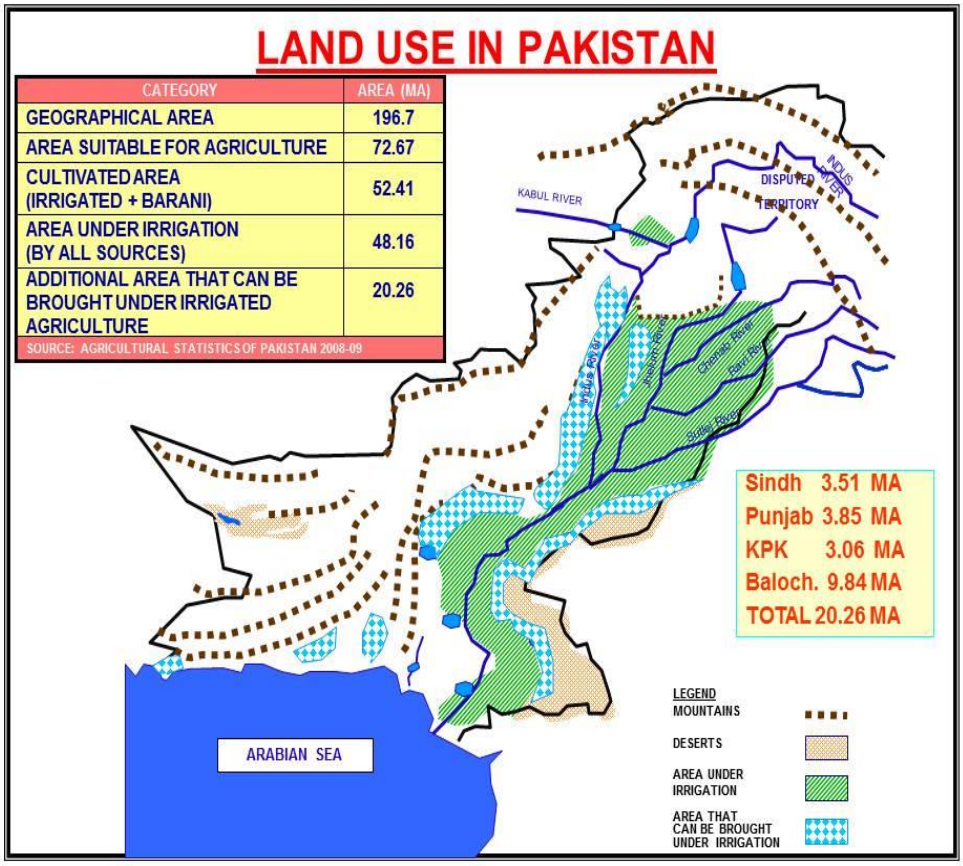


FIGURE 2: Land Use Map of Pakistan

6.2 Ground Water

Pakistan is extracting about 50 MAF from the aquifers and in fresh areas it has crossed the sustainable limit of safe yield. This over-mining and pollution of aquifers has resulted in secondary salinity and the presence of fluorides and arsenic in water, which in turn is degrading the quality of agricultural lands and creating health issues. The northern part of the Indus Basin has fresh water and most of the southern part has saline.

The Indus Waters Treaty led to the construction of multiple hydraulic structures. These enabled Pakistan to enhance water availability at canal head works to about 104 MAF. However, this has now decreased to 100 MAF because of the lack of further surface water development since construction of Tarbela dam and the significant loss of on-line storage capacity due to sedimentation. Out of the 100 MAF of annual canal diversion, only 58.3 MAF reaches the farm-gate and remaining 41.7 MAF is lost due to seepage and evaporation.

Pakistan is faced with increasing water scarcity and depending on assumptions of various future demand scenarios. Annual water requirements at canal head could

be in the range of 135-170 MAF in the coming years. Existing irrigation system is working on 40-45 percent efficiency. The National Water Strategy envisages raising irrigation efficiency to 50 percent from the current level of 40 percent. In order to improve the existing system, various steps such as On-Farm Water Management Program (OFWM) projects have been started in all provinces, including Gilgit-Baltistan, Azad Jammu & Kashmir and Islamabad Capital Territory areas. The projects undertaken are: - National Program for Improvement of Watercourses in Pakistan, Chaghai Water Management and Agriculture Development Project (IDB Assisted), National Project to stimulate the Adaptation of Permanent Raised Beds in Maize-Wheat and Cotton-Wheat Farming System in Pakistan. Efficient irrigation system is a pre-requisite for higher agricultural production as it helps in increasing the crop intensity. Despite the existence of a good irrigation canal network in Pakistan, it suffers from wastage of a large amount of water in the irrigation process. Water is the key input for agriculture, industry & urban development, as well as achieving Millennium Development Goals and targets and reducing poverty. The water sector gained major focus throughout the last decade in the development programs. Since water availability is persistently decreasing, the challenge is to formulate an effective and comprehensively efficient system of water resource management. The focus areas of investments in water sector are:

Augmentation of surface water resources by construction of small/medium and large dams is the need of the time. Conservation measures (lining of irrigation channels, modernization/ rehabilitation of irrigation system, lining of watercourses and efficiency enhancement etc.). Protection of infrastructure from onslaught of floods and water logging & salinity needed. Adoption of resource conservation technologies is fundamentally required. The Major Water Sector Projects under Implementation are given in Table-2. Although proposed Kalabagh Dam's design in ready since 1987 it could not be constructed due to lack of consensus between provinces, however, technically it is quite a viable project. In addition to the storage and irrigated projects, to upgrade irrigation for 291,000 Acres, a program has been started under "National Program for Water Conservation through High Efficiency Irrigation System (Drip & Sprinkler)" in Pakistan.

Table-2: WAPDA Major Water Sector on-going and recently Completed Projects

Projects	Location	Live Storage (MAF)	Area Under Irrigation (Acres)
Gomal Zam Dam	KPK	1.14	163,086
Greater Thal Canal (phase-I)	Punjab	-	355,000
Rainee Canal (phase-I)	Sindh	-	412,000
Kachhi Canal (phase-I)	Balochistan	-	102,000

Projects	Location	Live Storage (MAF)	Area Under Irrigation (Acres)
Raising of Mangla Dam	AJ & K	2.88	Indus Basin
Satpara Dam	Skardu	0.05	15,536
Diamir Basha Dam	GB/KPK	6.4	Indus Basin

7. WATER SECTOR ISSUES

There are many water sector issues faced by the country and major ones are as follows:

7.1 Water Shortage

Pakistan is one of the world's arid countries, with an average rainfall of under 240 mm per year. According to the benchmark water scarcity indicators (Faulken Mark), Pakistan`s per capita water availability is about 900 m^3 in 2017 and it places the country in the "high water stress" category (**Table**-**3**). The water shortage scenario in Pakistan is further aggravated with high variability of rainfall. The climate change and global warming is likely to severely affect the availability of water. After the loss of 3 major rivers, Ravi, Sutlej and Beas, to India under the Indus Waters Treaty 1960, India's construction of water storage infrastructure at Baghlihar and Kishanganga, is threatening the uninterrupted flow of water downstream into Pakistan. The per capita water availability v/s population is shown in **Figure**-**3**.

Table-3: Water Scarcity Indicators, FAO – 1992 (Faulken Mark)

>1700M^3/Capita	Water Scarcity Rare
<1700M^3/Capita	Country faces seasonal or regular water-stressed conditions
<1000M^3/Capita	Water shortages hamper the health and well-being of the human beings-Economic activities are affected
<500M^3/Capita	Shortages are severe constraints to human life

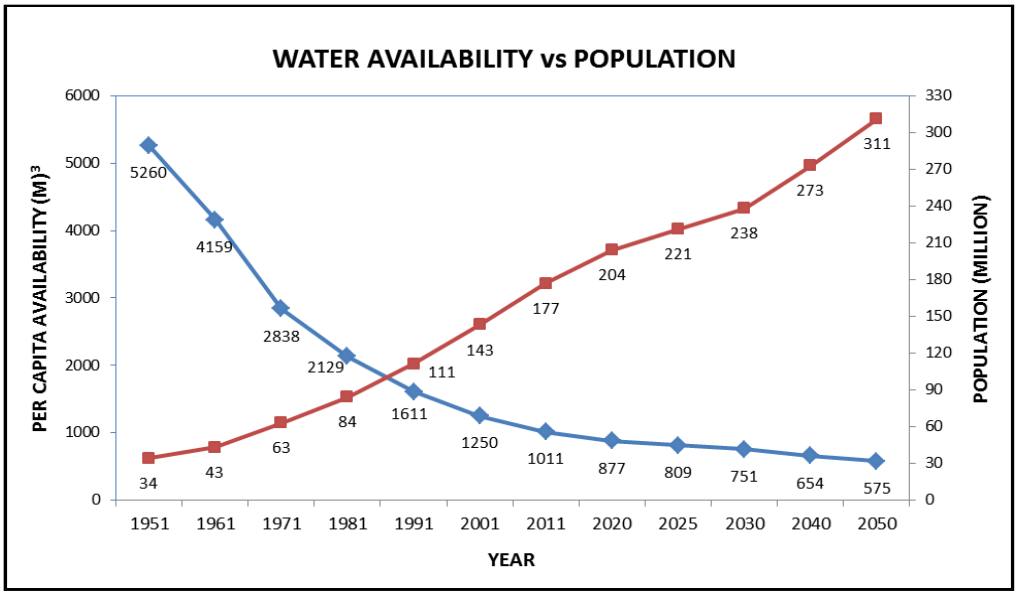


Figure 3: Water Availability v/s Population Growth

7.2 Low Water Productivity

Whatever water is available is utilized in an inefficient manner. A comparison of wheat yields in Pakistan Punjab, Indian Punjab and California (USA) shows that productivity of Pakistan as compared to India and California is about 3:6:10 per unit of land and about 5:8:10 per unit of water.

7.3 Aging and Outdated Infrastructure

Pakistan is blessed with one of the largest contiguous irrigation infrastructure. However, it was designed for water requirements of the 20th century and not for the 21st century. The design of system was for 60% cropping intensity and now the cropping intensity has crossed over 120%. Further the cropping pattern on which water demands and withdrawals were worked out was not supposed to cater for crops like sugarcane and rice which require high water use.

7.4 Low Water Charges

The water charges are very low and covers only 19% of O&M cost of irrigation network. The system maintenance requires a lot more attention due to deferred maintenance over the Past 100 years. The adequate water costing could offset O&M cost and could generate finances for new water sector projects. However, price control for crop production needs attention as farmers are mostly deprived from appropriate prices of production.

7.5 Innovative Knowledge Based Management

Challenges of the 21st century require the frontiers of knowledge and innovative approaches rather than historic practices. The institutions need redefining of their

roles and to develop their capacities according to new responsibilities for efficient water use.

7.6 Ownership, Reforms and Management

The irrigation infrastructures operation and on-farm practices need ownership of the stakeholders; such as farmers, professionals and revenue collectors. A joint management mode needs to be devised as Area Water Boards and Farmer's Organizations. Equity: Water provides prosperity and jobs, and acts as a "force multiplier" in the national economy. However, serious concerns exist with respect to spending common pool money to the benefit of selected groups in the absence of policy on equity. The disadvantaged groups are: a) Users at tail end of canal commands, b) Farmers outside Indus Basin.

7.7 Reservoir Sedimentation

Pakistan has three major reservoirs, which had as built storage capacity of 18.64 MAF. The storage capacity of Tarbela, Mangla and Chashma reservoirs has depleted by 4.99 MAF or 27% by the year 2017 due to sedimentation. It is estimated that the gross storage capacity would be reduced by 6.00 MAF or 32% by the year 2025 as shown in **Table-4**. Due to loss of storage, agriculture of Pakistan is facing water shortage during low flow seasons.

7.8 Un-captured Water

Despite acute water shortage in the system, data shows that a substantial amount of water escapes below Kotri to the Arabian Sea. Post-construction of Tarbela (1976-2010) average annual escapages below Kotri were 31.48 MAF, with a maximum of 91.83 MAF in 1994-95 and minimum of 0.79 MAF in 2000-01 (**Figure 4**). Most of the flow to the sea occurs during Kharif season and very little during Rabi season. For better water management, storage capacity should be equivalent to at least 40 percent of total water availability, but Pakistan's live storage capacity is about 7 percent of its overall river flows.

Table 4: Storage Loss Due to Sedimentation

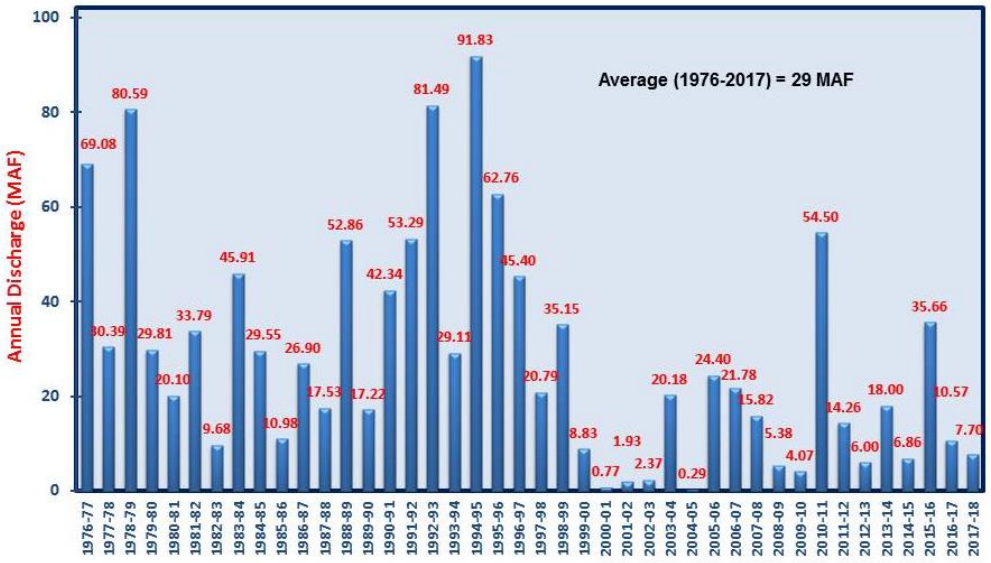
Reservoir (Commissioning Year)	Storage capacity			Storage loss	
	Original	Year 2017	Year 2025	Year 2017	Year 2025
	MAF	MAF (%)	MAF (%)	MAF (%)	MAF (%)
Tarbela (1976)	9.68	6.06 (63%)	5.37 (56%)	3.62 (37%)	4.3 (44%)
Mangla (1967)	5.34	4.35 (82%)	4.19 (79%)	0.99 (18%)	1.15 (21%)
Chashma (1971)	0.72	0.38 (53%)	0.27 (38%)	0.34 (47%)	0.45 (62%)
Sub-Total	15.74	10.79 (69%)	9.83 (63%)	4.95 (31%)	5.91 (37%)

Reservoir (Commissioning Year)	Storage capacity			Storage loss	
	Original	Year 2017	Year 2025	Year 2017	Year 2025
	MAF	MAF (%)	MAF (%)	MAF (%)	MAF (%)
Addition of Raising Mangla (2012)	2.90	2.86 (99%)	2.81 (97%)	0.04 (1%)	0.09 (3%)
Total	18.64	13.65 (73%)	12.64 (68%)	4.99 (27%)	6.00 (32%)

Source: WRM Directorate, WAPDA

7.9 Groundwater

Groundwater under the Indus Irrigation System has developed over centuries and due to infiltration of surface water as well as local rainfall. However, depending upon the quality, the useable groundwater is confined to an area of 10 million hectares. The development of this resource is through private tubewells and account for a gross abstraction of about 50 MAF per annum. The surface water and groundwater in all canal commands are being used conjunctively. In many canal commands, pumpage is greater than recharge, thus causing subsidence. There is no regular and proper monitoring of private tubewells capacity, their pumping hours and utilization. The private tubewells have increased over one million exploiting groundwater indiscriminately and over mining is occurring in certain areas. Due to this situation saline water intrusion is causing pollution of fresh water aquifers. Thus groundwater regulation is necessary to overcome such problems.



Source: WRMD WAPDA based on data supplied by Govt. of Sindh

Figure 4: Water Escapages below Kotri (MAF)

7.10 Rainwater Harvesting

Rainwater harvesting in Pothohar areas is a reasonable source of water for raising crops. With this technique about 5 to 6 % GDP earnings are generated. It is a good source of income and livelihood of uphill areas in the country and it is about 5.2 Mha are contributing towards uplift of the peoples of such areas. The rainwater harvesting provides about 3 MAF water.

8. FUTURE STRATEGIC AREAS FOR WATER MANAGEMENT

The core areas require immediate attention while formulating contingency action plan and management/policy plans to keep the country ever green are described in the proceeding paragraphs.

8.1 Water Demand Management

Water availability is diminishing with a growing population and increasing urbanization. The need for better water demand management is well established.

The following strategy represents some areas of immediate attention:

- Promoting efficient water use
- Rationalizing water price
- Optimizing cropping pattern to save water
- Integrated use and recycling of water
- Ground water regulation to avoid over mining
- Climate Change Impact on Water and Agriculture

Global weather changes and water resources are deeply inter-related. The largest source of freshwater is rain. Global climatic changes will have major effects on precipitation and runoff. In the relatively arid and semi-arid regions, modest changes in precipitation have large impacts on water supplies. In mountainous watersheds, higher temperatures will increase the ratio of rain to snow, accelerate the rate of spring snowmelt, and shorten the overall snowfall season, leading to more spring runoff. Because the temperature projections of climate models calculate less than the projections of precipitation, temperature-induced shifts in the relative amounts of rain and snow and in the timing of snowmelt in mountainous areas are considered likely. Climate-induced changes in hydrology will affect the magnitude, frequency, and costs of extreme events, which produce the greatest economic and social costs to humans beings. Flooding could become more frequent and extreme. Recent reports of the Intergovernmental Panel on Climate Change (IPCC) suggest that a greenhouse warming is likely to increase the number of intense precipitation days as well as flood-frequencies in northern latitudes and snowmelt-driven basins. These reports also suggest that the frequency and severity of droughts could increase in some areas, as a result of a decrease in total rainfall and more frequent dry spells.

A macro-scale hydrological model for river-flow suggests that the runoff of the Indus will decrease significantly by the year 2050 (IPCC, A4-WG-II). This implies

that the availability of fresh water in Pakistan is highly vulnerable to climate change. A reduction in average flow of snow-fed rivers, coupled with an increase in peak flows and sediment-yield would have major impacts on hydropower generation and agriculture. Availability of water from snow-fed rivers may increase in the short term, but decrease in the long-run. Runoff from rain-fed rivers may also change in the future. A reduction in snowmelt water will put the dry-season flow of these rivers under more stress than is the case now, especially in Pakistan where one major snow fed river, the Indus, accounts for as much as 80 % of the normal water flow. Increased population and increasing demand for the agricultural, industrial and hydropower sectors will put additional stress on water resources. In fact it is very true that water is really a naturally a source development of economies in the world.

8.2 Increasing the Productivity of Land and Water

Gaining more yield and value from less water can reduce future demand for water, limiting environmental degradation and easing competition for water. Adoption of best agriculture practices and resource conservation technologies can help to gain more yield per limit area.

9. CONCLUSIONS

The shortfall of about 30 MAF of water by the year 2030 is to be met through creating storage facilities and diverting 21.5 MAF to canals which at present is flowing to sea after allowing 8.6 MAF for environmental flows. This additional diversion of 21.5 MAF at canal head would add about 15.6 MAF at farm gate. The program of water course improvement by 2030 will cover all the water courses of country enhancing water course efficiency significantly and will save wastage of water in the irrigation system. It may be emphasized that water plays a pivotal role in development of all sectors of life. In fact it is very true that water is really a naturally a source development of economies in the world.

10. RECOMMENDATIONS

Campaign on efficient use of water in domestic, industrial and agricultural sectors have been launched to disseminate knowledge and information to the water users especially farmers. Rain water harvesting and use of treated water are also being adopted. Water is key factor for agro-socio-economic uplift in the country. The additional storage and other relevant developments of efficient water use in the country would not only be able to sustain food security but also would export more agricultural products to sustain the economy.

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WATER SAVING POTENTIAL IN RICE CROP USING BED PLANTATION TECHNIQUE

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Abstract

Rice is one of the major staple food crops in Pakistan. About 13 percent of cropped area of the country is used for rice production. Average yield of rice in Pakistan is 2.95 t/ha, while USA and China are receiving 7.40 and 6.19 t/ha respectively. On average, the world's rice fields use about 1.4 m^3 of water for producing 1 kg rice with a water use efficiency (WUE) of 0.71 kg/m^3, whereas in Pakistan it is less than 0.45 kg/m^3. The major reason for low WUE is a mindset to grow rice in stagnant water. Pakistan Council of Research in Water Resources (PCRWR) conducted series of experiments for growing rice crop using bed plantation technique at its R&D Centre near Sargodha (Punjab). Comparing the conventional sowing (flooded basins), 23 percent less amount of water applied under the bed plantation. WUE and average net income increased by 37 and 12 percent respectively in bed plantation technique as compared to conventional sowing. In Pakistan rice is grown on about 2.8 Mha area consuming about 40 billion cubic meters (BCM) water by conventional sowing. If the conventional sowing is converted to bed plantation, about 9 BCM of water can be saved with additional net income of 39 Billion Rupees. The study concluded and recommended the significant water saving potential in bed plantation of rice crop.

Key words: Bed plantation, Rice, Water saving.

1. INTRODUCTION

Rice is one of the major staple food crops in south Asia. About 240 million people in South Asia consume rice and/or wheat produced in rice-wheat system (Benites, 2001). Pakistan has agrarian rural based economy. Agriculture sector contributes about 21 % to GDP and absorbs 44% of the labour force whereas about 60% of the rural population derived their livelihood from agriculture (GoP, 2012).

Agriculture sector in Pakistan is continuously under stress due to the low yield of crops as compared to other developed countries (Ather et al., 2006). Increasing population has increased the water demand for industrial and domestic users. In this scenario, low water productivity in agriculture is a great concern. Increasing requirement of food can only be met by increasing in crop production per unit of water applied. This can be achieved through adoption of innovative irrigation technologies (Farooq et al., 2006).

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The shortage of canal water in many areas forced the farmers to rely on ground water (Taj et al., 2005). On average, the world's rice fields use around 1.4 m3 of water for producing 1 kg of rice with water use efficiency (WUE) of 0.71 kg/m3 whereas the WUE of rice in Pakistan is less than 0.45 kg/m3. In case of Basmati rice, the WUE is even as low as 0.08 kg/m3 found in the Lower Bari Doab Canal (LBDC) command (Ashraf et al., 2010).

The raised bed planting of crops is one of the improved techniques. It is being practiced for all crops in all over the world and is an effective and improved irrigation method with several advantages. Bed plantation increases the yield and reduces crops lodging risk (Hobbs and Gupta, 2003a). Studies in the USA have shown considerable water saving with irrigated rice on raised beds over conventional flooding (Vories et. al., 2002). Recent research activities in India and Pakistan showed many advantages of bed planting over conventional methods. It improved water distribution and water use efficiency, fertilizer use efficiency, reduced weed infestation and lodging (Gupta et al., 2000; Hobbs and Gupta, 2003b).

Pakistan Council of Research in Water Resources (PCRWR) conducted series of experiments for planting of rice on the beds during 2011-13 at its Research and Demonstration (R & D) Centre Sialmore, Sargodha (Punjab) to evaluate the potential of raised beds in terms of yield and WUE.

2. METHODOLOGY

2.1 Study Site

The Research and Demonstration Centre of PCRWR is located in village Hayatpur near Sialmore, District Sargodha, Major Crops of the area are; wheat, rice and sugarcane but farmers also produce some other crops and vegetables. The Centre falls in Chaj Doab the area between Chenab and Jhelum rivers). The soil of the Centre is non-saline, sandy loam, having average pH value of 7.9 and Electrical Conductivity (EC) of about 2.0 dSm^{-1}. Groundwater is the only source of irrigation. Being adjacent to Chenab River, the groundwater is good quality; EC of groundwater is 0.85 dSm-1, pH 7.5, Sodium Absorption Ratio (SAR) 3.20, and Residual Sodium Carbonate (RSC) of 3.0 meq/l. The study area is characterized by semi-arid climate; where more than 80% of the rainfall occurs during the monsoon season (June to September). Temperature rises upto 50 °C (122 °F) in the summer whereas in winter the minimum temperature recorded low as freezing point. Rainfall received at R & D Centre along with pan evaporation presented in figure 1.

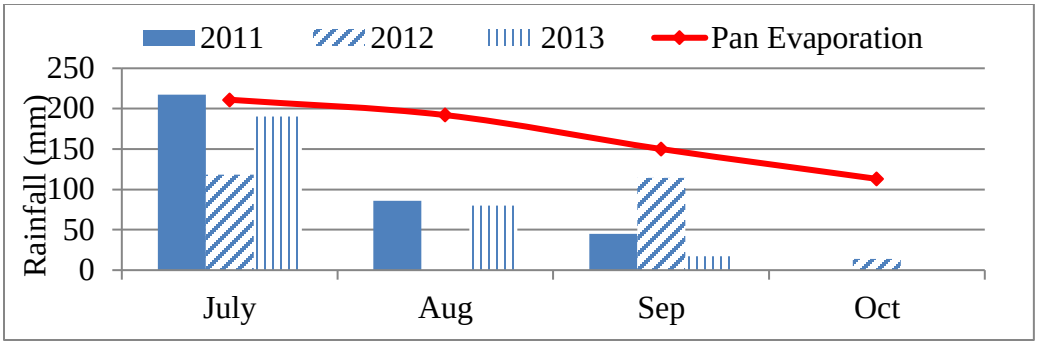


Figure-1: Rainfall and pan evaporation during the study period

2.2 Land Preparation

For conventional sowing, the land was prepared with two ploughings followed by LASER leveling. Finally, four ploughings and two planking were done before applying soaking dose (pre planting irrigation). After irrigation, puddling (two ploughings in standing water) was made before transplantation of rice nursery. For bed planting, in the conventionally prepared land, raised bed and furrows were made with the help of a bed shaper (Fig. 2a).



Figure-2a: Bed plantation of rice crop

The soil at the study site is sandy loam in texture with a field capacity of 14%, whereas the permanent wilting point is at 6%. The bulk density of the soil is 1.5 g/cm^3. Keeping in view the soil texture (sandy loam), top width of beds was adjusted at 30 cm each. The furrow to furrow distance was 60 cm, whereas the beds were kept 22 cm high at the time of preparation. The beds were prepared a day before the transplantation of the rice nursery. Irrigation water was applied in the furrows upto 2/3rd height of beds a day before transplantation as well to attaining optimum moisture level. About thirty days old rice nursery was carefully transplanted. Four rows were developed on each bed with a row-to-row distance of 12 cm and plant-to-plant distance of 22 cm (Fig. 2b).

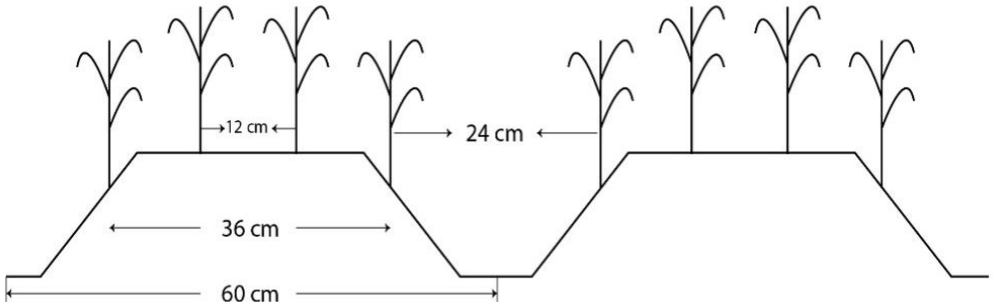


Figure-2b: Geometry of bed plantation for Rice crop

2.3 Fertilizer Applications

Fertilizer was applied with N, P, K, and Zn at the rates of 100, 100, 60 and 10 kg/ha, respectively. The sources of N, P, K, and Zn were Di-ammonium phosphate (DAP), Urea, Sulphate of Phosphate (SoP) and Zinc Sulphate ($ZnSO_4$) respectively. Fertilizer including DAP and SoP were applied at the time of final land preparation as basal dose with conventional broadcasting method. However, urea was applied in three splits after 15, 30 and 50 days of transplantation. Zinc sulfate was applied at the rate of 10 kg/ha about one month after planting to avoid zinc deficiency, which is common in this area. The calculated amount of fertilizers was applied by mixing with irrigation water ($ZnSO_4$) and by broadcast method (urea). Equal doses and type of fertilizers were applied in both the treatments (Conventional and Bed Plantation).

2.4 Pest and Weed Control

The rice was infested by stem borer at tillering and by rice bug at grain filling stages. Pesticide namely Nateevo containing taboconozole (50%) and tri-floxistrobin (25%) was applied at the rate of 62 gm/ha after 60 days of transplantation to control rice bug. To control weed growth during the initial stages of growth, weedicide (Sunstar/Ethapy chloran) was applied after stabilization of crop @ 62 gm/ha.

2.5 Irrigation Application

Irrigation scheduling was based on soil moisture deficit (SMD), estimated through the installation of tensiometers. Initially, irrigation applied daily in furrows till the establishment of crop (about two weeks). Then irrigation interval gradually increased and scheduling was conducted based on SMD in bed plantation plots. However, in conventional plots, standing water was maintained through crop period in accordance to the conventional practices. The tubewell discharge was measured by volumetric method and the amount of water applied in each irrigation was calculated accordingly. Irrigation on all plots was discontinued when the crop began to ripe.

2.6. Yield, Water Use Efficiency and Economic Analysis

The crop yield was determined on whole plot basis and the average yield of each treatment was calculated. Water use efficiency was estimated on the basis of yield obtained against the water used for the crop. Similarly, cost of production and income was compared for the economic analysis. The cost of production included the cost of water and non-water inputs from planting to harvesting of the crop. Similarly, the income includes income from the grain and biomass.

2.7 Soil Analysis

The soil samples were collected by using manual auger from each experiment plot at the depth of 00-15 cm and 16-30 cm pre-sowing (May) and post harvesting (November) of rice. The samples were analyzed in Distract Soil laboratory Sargodha of Agriculture Department, Government of Punjab. The soil samples were analyzed for Electrical Conductivity (EC_e), pH, Organic Matter (OM), Phosphorus (P) and Potassium (K).

2.8 Agronomic Parameters

Information on agronomic parameters like date of sowing and harvesting and plant growth parameters was recorded in each cropping season (Table 1).

Table-1: Agronomic parameters recorded in each season for rice crop

Year	2011		2012		2013	
	BP	Conv.	BP	Conv.	BP	Conv.
Variety	Basmati Pak	Basmati Pak	Basmati Pak	Basmati Pak	Basmati Pak	Basmati Pak
Date of sowing of nursery	09-Jun	06-Jun	11-Jun	11-Jun	09-Jun	09-Jun
Date of transplantation	25-Jul	27-Jul	01-Aug	02-Aug	21-Jul	22-Jul
Date of harvesting	09-Nov	09-Nov	12-Nov	12-Nov	18-Nov	18-Nov
Plant population (plants/ha)	*	*	230,000	150,000	200,000	130,000
Average tillers per plant	*	*	15	17	14	16

*Data not recorded.

Abbreviations used; BP = Bed PlantationConv. = Conventional Method

3. RESULTS AND DISCUSSION

3.1 Water Applied

Theoretically, the water requirement for land preparation is 150-200 mm but it can be as high as 650-900 mm when its duration is long (Bhuiyan *et al*., 1995). Field water input during growing season may vary from 500 to 800 mm. However, in Pakistan farmers are applying 2-3 times or even more water to rice crop than its actual requirements in a growing season (Ashraf et. al., 2010; 2014). During this study, on an average 144 cm of water was applied to the conventional sowing of rice and 112 cm to bed plantation. The amount of water applied under the bed plantation was, therefore, about 23% less as compared to conventional method (Table 2). The water applied to bed plantation in each irrigation was less as compared to conventional practice.

Bhuyan *et. al* (2012) conducted field experiments in Chuadanga district of Bangladesh on different agronomic aspects of bed planting rice; He reported that conventional method received higher amount of water with each irrigation with a total amount of 143 cm. However, in bed planting, the total amount applied was 101 cm thereby showing water saving of about 42%. Naresh et. al., (2017) also found through field experiments in India that depending up on soil type water saving in through bed planting ranges from 20 to 40%. According to Ashraf and Saeed – 2006, there is myth that rice needs standing water to grow; with this mindset, the farmers keep water standing in the fields, resulting into loss of huge amount of precious water, either as deep percolation or evaporation. This is not only the wastage of water but also the wastage of precious nutrients present in the soil. However, the water applied depends on the soil type, rice variety and the climatic conditions.

Table-2: Water applied to rice in bed plantation (BP) and conventional (Conv.) sowing methods

Year	Total water applied (cm)	
	BP	Conv.
2011	108[a]	141[b]
2012	124[a]	157[b]
2013	103[a]	135[b]
Average	***112***[a]	***144***[b]

Means with the same letters are not significantly different at P = 0.05

The results of the study were statistically analyzed by applying t-test to determine significance of difference between the two treatments (Table 2). The analysis reveals that the amount of water applied under the two treatments was significantly different at 95% confidence interval. Depth of water applied in conventional sowing is significantly high in comparison to bed plantation.

3.2 Crop Yield

The yield of rice grown with conventional method was 3340, 4784 and 3640 kg/ha during the years 2011, 2012 and 2013, respectively, whereas for bed plantation it was 3580, 4972 and 3917 kg/ha respectively. The yield in bed plantation was 6% higher than conventional flood basins (Table 3). This indicates that significant amount of water can be saved in bed plantation without compromising rice yield. The potential agronomic merits of beds also include improved soil structure due to reduced compaction through controlled trafficking. Moreover, waterlogging conditions are also reduced. These are responsible for improved rice production (Humphreys *et. al.* 2005). The statistical analysis of the study reveals that there is insignificant difference in yield for both methods of sowing (Table 3).

Table-3: Yield of rice in bed plantation (BP) and conventional (Conv.) sowing methods

Year	Yield (kg/ha)	
	BP	**Conv.**
2011	3580[a]	3340[a]
2012	4972[a]	4784[a]
2013	3917[a]	3640[a]
Average	***4156***[a]	***3921***[a]

Means with the same letters are not significantly different at P = 0.05

3.3 Water Use Efficiency (WUE)

Water-use efficiency is an estimate to measure how precisely irrigation water has been used for crop production. The WUE can be improved either by increasing crop yield or by reducing the amount of water needed without affecting the crop yield (Molden *et. al*., 2010). The WUE of rice grown on beds varied from 0.33 to 0.40 kg/m^3, whereas that for conventional sowing varied from 0.24 to 0.31 kg/m^3 (Table 4). On average, WUE of rice grown on beds was 37% higher than the conventional planting. The statistical analysis reveals that there is significant difference in water use efficiency for both methods of sowing. Water use efficiency in conventional sowing is significantly low in comparison to bed plantation (Table-4).

Naresh et. al., (2017) reported WUE of rice crop in India was 0.67 kg/m3 and 0.57 kg/m3 for bed plantation and conventional sowings, respectively. Which shows 18% higher WUE in bed plantation in comparison to conventional sowing. The better performance of raised beds over conventional methods was attributed to reduce waterlogging, improved soil physical properties and reduced lodging. Bed plantation method can, therefore, eliminate the need for puddling soils which is not only expensive but also accelerates the destruction of organic matter in soil. Despite puddling, a major portion of the water used in the production of rice in flooded basins percolates down through the soil profile. By reducing application of water and keeping the water content of the soil at or below the field capacity, most of the time, deep percolation of the water can be reduced.

Table-4: WUE of rice under bed plantation (BP) and conventional (Conv.) sowing

Year	Water use efficiency (kg/m3)	
	BP	Conv.
2011	0.33[a]	0.24[b]
2012	0.40[a]	0.31[b]
2013	0.38[a]	0.27[b]
Average	***0.37[a]***	***0.27[b]***

Means with the same letters are not significantly different at P = 0.05

Table-5: Economic analysis for rice crop

Year	Cost of production (PRK/ha)						Gross income (PKR/ha)		Net Income (PKR/ha)	
	Non water inputs		Water inputs		Total cost of inputs					
	BP	Conv.	BP	Conv.	BP	Conv.	BP	Conv.	BP	Conv.
2011	53501[a]	49734[a]	18900[a]	24675[b]	72401[a]	74409[a]	143200[a]	133600[a]	70799[a]	59191[a]
2012	54676[a]	51090[a]	21700[a]	27475[b]	76376[a]	78565[a]	228727[a]	220064[a]	152351[a]	141499[a]
2013	59379[a]	55412[a]	20600[a]	27000[b]	79979[a]	82412[a]	244813[a]	227500[a]	164834[a]	145089[a]
Average	***55852[a]***	***52079[a]***	***20400[a]***	***26383[b]***	***76252[a]***	***78462[a]***	***205580[a]***	***193721[a]***	***129328[a]***	***115260[a]***

Means with the same letters are not significantly different at P = 0.05

3.4 Economic Analysis

The economic analysis involves the total production cost, gross income and net return of the crop in both the irrigation methods (conventional and bed planting). On average, cost of production in bed planting was 3% less, gross income 6% higher and net income 12% higher as compared to conventional plantation. Though, statistical analysis reveals insignificant difference in gross income for both methods of sowing. However, significant difference was obvious in cost of water for both the irrigation methods (Table 5). Naresh et. al., (2017) reported that net profit for rice crop in India was IRs 37200 and IRs 23200 for bed plantation and conventional sowing respectively, revealed 60% higher net return for bed plantation as compared to conventional method. Mollah et al., (2009) reported highest (1.97) benefit-cost ratio in bed planting for 70 cm wide beds and the lowest (1.61) in conventional method for rice.

3.5 Soil Analysis

The soils were analyzed before (May) and after (November) each trial for determining any impact of treatment on its chemical properties and organic matter content. As rice is reclamative crop, therefore, the EC and pH of the soil decreased after each season (Fig. 3), whereas the organic matter and phosphorous improved particularly under bed plantations. Potassium contents, however, improved only under bed plantation, presumably due to less leaching because of less irrigation water applied (Fig. 4).

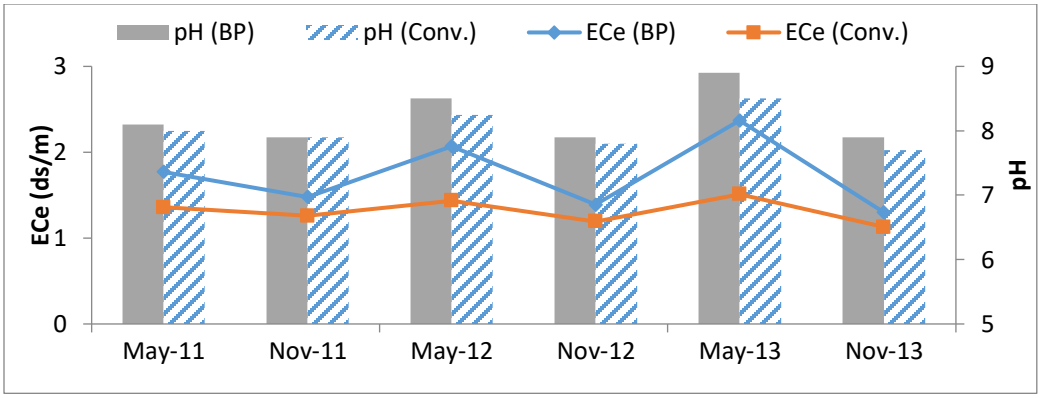


Figure-3: Electrical conductivity (ECe) and pH of soil during the study period (2011-13)

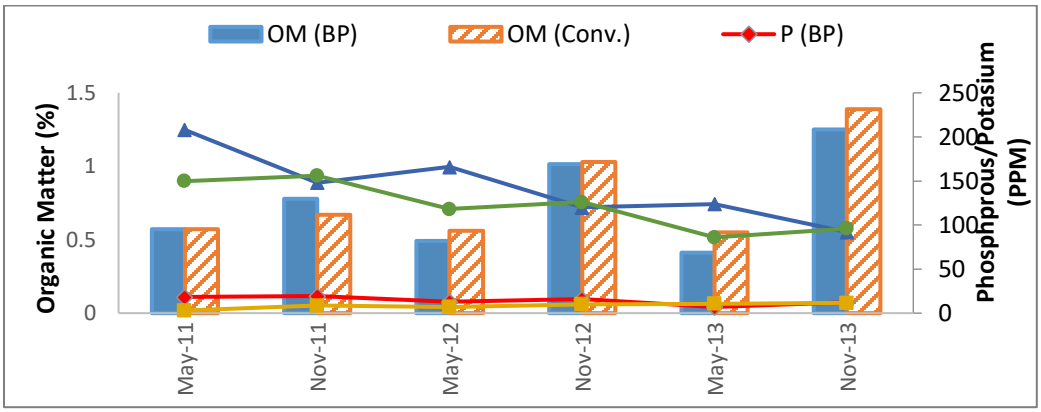


Figure-4: Organic matter, phosphorus (P) and potassium (K) of soil (2011-13)

4. CONCLUSIONS

Like any other crop, rice has it specific water requirement and does not essentially needs submerged conditions. Rice can be successfully grown on beds without compromising the yield with over 23% of water saving. In Pakistan rice is grown on about 2.8 Mha area consuming about 40 billion cubic meters (BCM) water by conventional sowing. If the conventional sowing is converted to bed plantation, about 9 BCM of water can be saved with additional net income of 39 Billion Rupees. Therefore, bed plantation is an inevitable option in water scared countries like Pakistan.

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SENSITIVITY ANALYSIS OF ALLIEVI CHART PARAMETERS FOR WATER HAMMER- A CASE STUDY

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Abstract

In order to avoid large increase of pressure due to instantaneous valve closure for hydro-electric power plants, sometimes a surge tank is installed to overcome excessive water hammer. The height of surge tank is designed by the highest possible water level during the operation. The present study attempts to find sensitivity of various depending parameters (closure time 't', pipe diameter 'D', roughness 'n', temperature of water 't' etc.) using a worksheet model of Allievi chart; a numerical method for estimating the surge oscillation in a simple surge tank in terms of non-dimensional parameters (pipe line constant 'K' and time constant 'N'). The operation regimes were chosen for critical scenarios such as sudden load rejections of the turbines.

In the present study hydraulic design of penstock for Naltar Hydropower Project, a potential site in Pakistan, was analyzed for computing maximum and minimum pressure in penstock. Sensitivity curves for penstock pressure were plotted for case study project by variation of parameters such as pipe diameter, roughness, closure time etc. The results enable designers/engineers to understand phenomena of surge in pressure shafts/ penstocks under sudden closure for maintaining safe conditions without endangering the machines or the structures.

Keywords: Surge, sensitivity, Allievi, hydroelectric, water hammer etc.

Introduction

Study the dynamic behavior of a hydropower plant (HPP) is a necessary prerequisite for ensuring safety and defining the transient phenomena such as increase of the rotational speed (runaway) of the units, increase of the pressure (head) in the hydraulic system (water hammer) and water level oscillation in the surge tank. Transient phenomena in HPP occurs during unit shutdown or startup, switching from one operation regime of HPP to another, load rejection, emergency shutdown, out of phase of synchronization etc. The accurate definition of the transient phenomena of the HPP and its units, taking into account various aspects of operation is an essential requirement for the design, performances and control of HPP. The numerical results of transient phenomena analyses are relied upon for very costly engineering decisions. Because of this, it is important that the researcher understands the effect unknown modeling parameters on the result of transient analysis. Usually, different researchers may choose alternate values for an unknown modeling parameter and this can have significant effects on the results.In the present study hydraulic design of penstock for Naltar Hydropower Project, a potential site in Pakistan, was analyzed for computing maximum and

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minimum pressure in penstock. Sensitivity curves for penstock pressure were plotted for case study project by variation of parameters such as pipe diameter, roughness, closure time etc.

Phenomena of Transient

Closure of a wicket gate/valve at the end of a conduit results in head rise on the upstream side of the gate/valve called water hammer. As a result, a pressure wave travels in the upstream direction and gets reflected from the free surface reservoir at the upstream end of the conduit and travels back towards the gate/valve resulting in development of a negative pressure in the conduit. This to and fro movement of the positive and negative pressure waves is gradually dissipated to zero by the friction of the conduit. The pressure wave velocity is calculated by the following equation:

$$a = \frac{1}{\sqrt{\rho\left(\frac{1}{K_w} + \frac{D\,C_1}{t\,E}\right)}}$$

Where

a = pressure wave velocity
ρ = density of water
K_w = volume modulus of water
D = diameter of conduit
C_1 = factor for anchorage and support of conduit
t = thickness of lining of tunnel or thickness of pipe/penstock
E = Young's modulus of elasticity of the lining or pipe material

The maximum head rise just on the upstream side of the gate/valve is calculated from the Allievi's chart as shown in Figure 1. To determine the maximum pressure rise from the Allievi's chart two constants given below are calculated:

Pipeline Constant $K = \frac{a\,V}{2\,g\,H_o}$

Time Constant $N = \frac{a\,T}{2\,L}$

Where

H_o = total head = reservoir level – elevation at centerline of wicket gate/valve
T = closure time of gate/valve
L = total length of the conduit up to gate/valve

For conduit with varying cross sections, varying anchorage & support and varying type of lining/pipe material, weighted average of pressure wave and flow velocities are calculated from the pressure wave and flow velocities of each section of the

conduit. The weighted average values are used to calculate the pipeline and time constants for determining maximum pressure rise from Allievi's Chart.

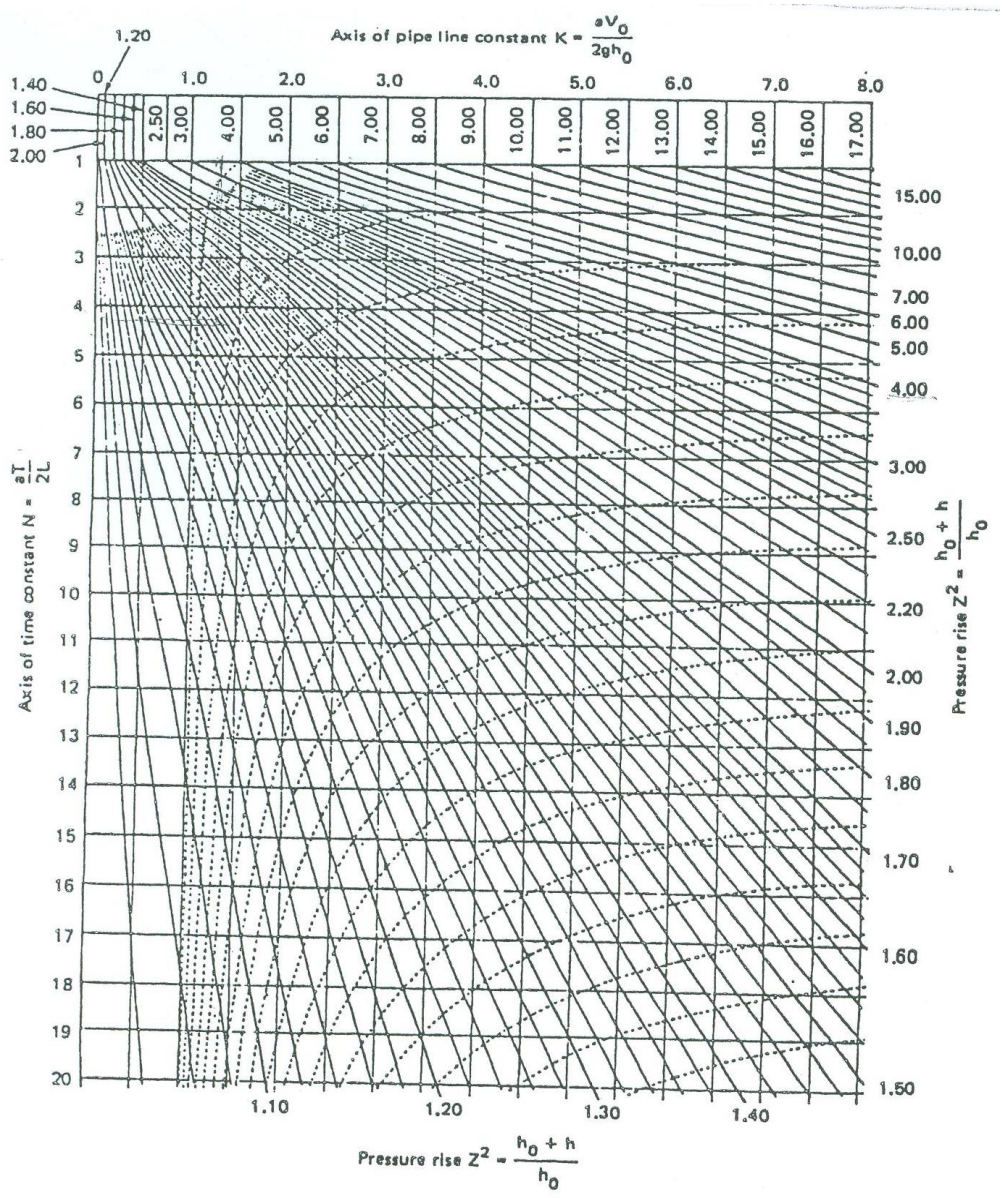


Figure-1: Allievi's Chart for Determination of Maximum Pressure Rise

Project Objectives

The present study covers following objectives

To find sensitivity of various depending parameters (closure time 'T', pipe diameter 'D', wave speed 'a', Length "L" and temperature of water 't' etc.) of Allievi chart for critical scenario such as sudden load rejections of the turbines

Development of sensitivity curves for transient for a case study project i.e. Naltar Hydropower Project

Case Study - Sensitivity Analysis for Penstock of Naltar-III

The powerhouse is open type and will house three numbers of Pelton wheel turbines. The power house will be connected to Normal Grid station through 66Kv transmission line. Salient features of the project are given in Table-1. Schematic diagram of the project over the Google Earth Imagery is shown as Figure-2.

Table-1: Salient Features of Naltar HPP

Item	Description	Parameters
Tyrolean Weir	Length Design Flood (1000 Years)	26 m 149.2 m^3/s
Connection Channel	Height Width Cross Section Length	2 m 2.3 m 4.6 m^2 430 m
Sand Trap	Width Depth Total Length	6 m 5 m 63 m
Headrace Channel	Height, internal Width , internal Cross Section Length	2.5 m 2.5 m 6.25 m^2 3200 m (approx.)
Forebay	Height Length Width	10 m 140 m 25 m
Penstock	Diameter Total Length	1.4 m 1224 m
Power House	Machine Hall Length Machine Hall Width Total Height	30.8 m 15.6 m 9.5 m
Tailrace	Height Length Width	2.0 m 50.0 m 3.0 m
Head	Gross Head Net Head	365.01m 356.10 m

Water hammer/Transient analysis has been carried out to determine the maximum pressures in the penstock, manifold and at turbine for the case when full load rejection of three turbines takes place. In this case the wicket gates/ valves of all the three turbines are assumed to close in a short period of time and the maximum combined pressures have been calculated for two and half, six and ten second wicket gate closure times separately.

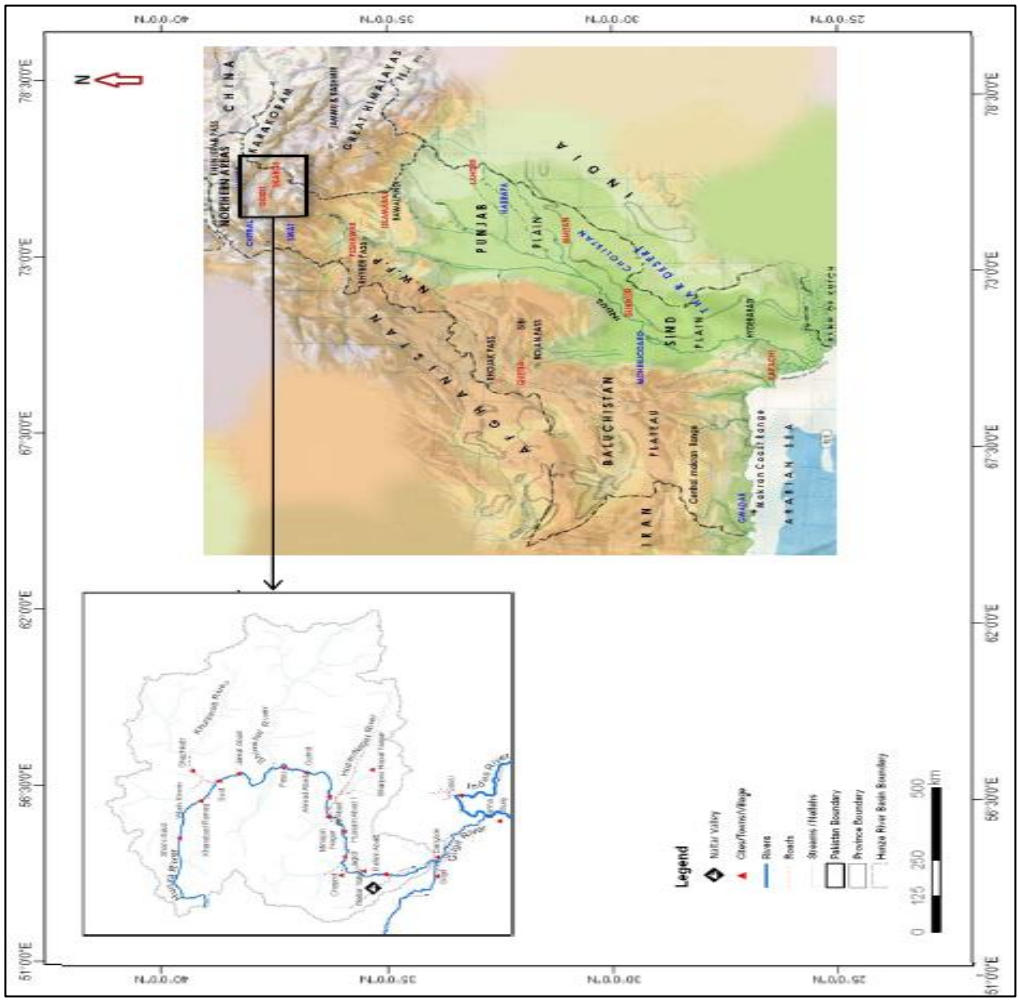


Figure-2: Location Map of the Project

As explained above Allievi's chart has been used to determine the maximum pressures. Weighted average of pressure wave velocity and flow velocity have been used for the determination of maximum pressure at the wicket gates from Allievi's chart. The pressure at other locations in the tunnel was determined by assuming linear decrease of the head rise up to the reservoir. Head losses in the penstock and manifold have been neglected for the determination of water hammer pressure. The layout configuration of turbines is shown in Figure 3 and Sectional view is shown in Figure 4. The turbine features are listed in Table 2.

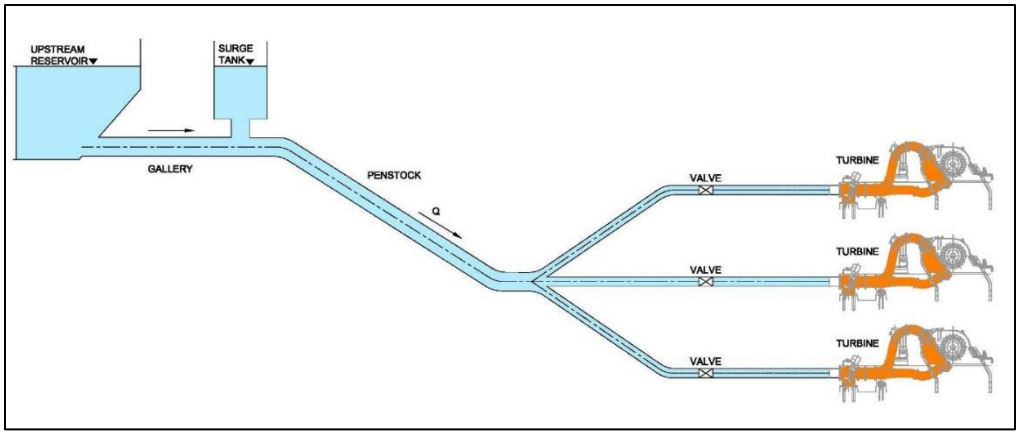


Figure-3: Layout of the hydropower plant with Pelton turbines

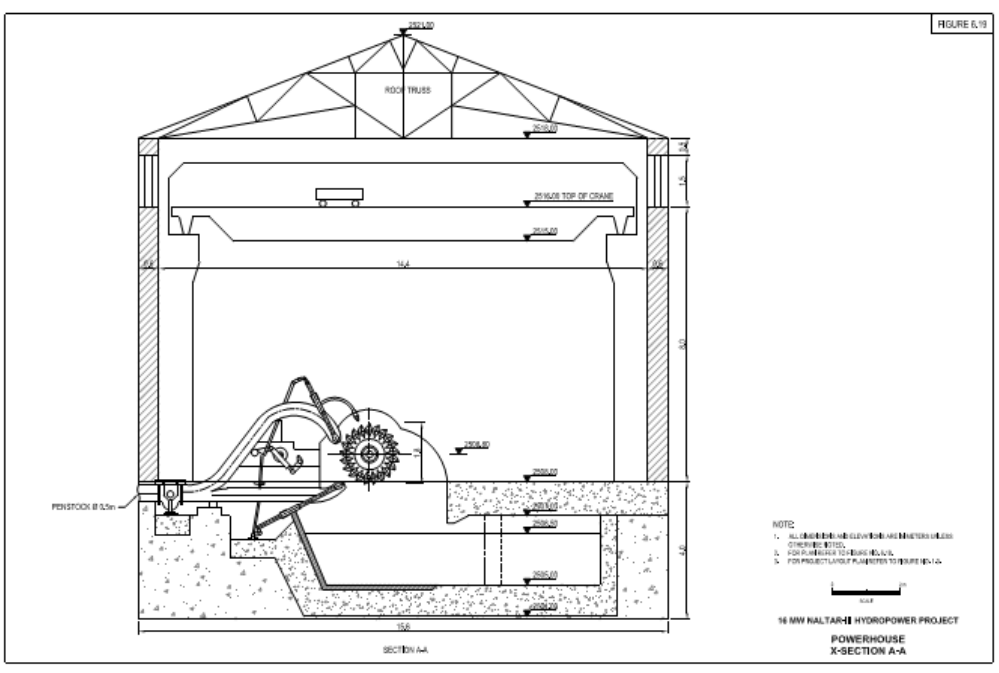


Figure-4: Sectional view of Power House of Naltar HPP

Table 2: Salient Features of Turbine of Naltar HPP

Type of Turbine	Pelton	
No. of Units	No.	3
Number of Jets	No.	2
Synchronous Speed	Rpm	600
Runaway Speed	rpm	1054
Shaft Configuration		Horizontal
Runner Pitch Diameter	m	1.278
Nozzle Diameter	cm	36
Rated Unit Discharge	m^3/s	1.733
Minimum Unit Discharge	m^3/s	0.43
Rated Net Head	m	356.10
Rated Turbine Output	MW	5.443
Rated Generator Output	MW	5.3
Efficiency	%	89.9

Sensitivity Scenarios for Transient Analysis

Maximum pressure rise has been computed under full load rejection against following scenarios:

- Effect of Closure Time on Pressure Rise
- Effect of Change of diameter of penstock on Pressure Rise
- Effect of Change of Wave speed on Pressure Rise
- Effect of Water Temperature on Pressure Rise
- Effect of Pipe length on Pressure Rise

- **Effect of Closure Time on Pressure Rise**

Impact of closure time on pressure rise has been studied keeping other parameters fixed. The results are graphically shown in Figure 5 below.

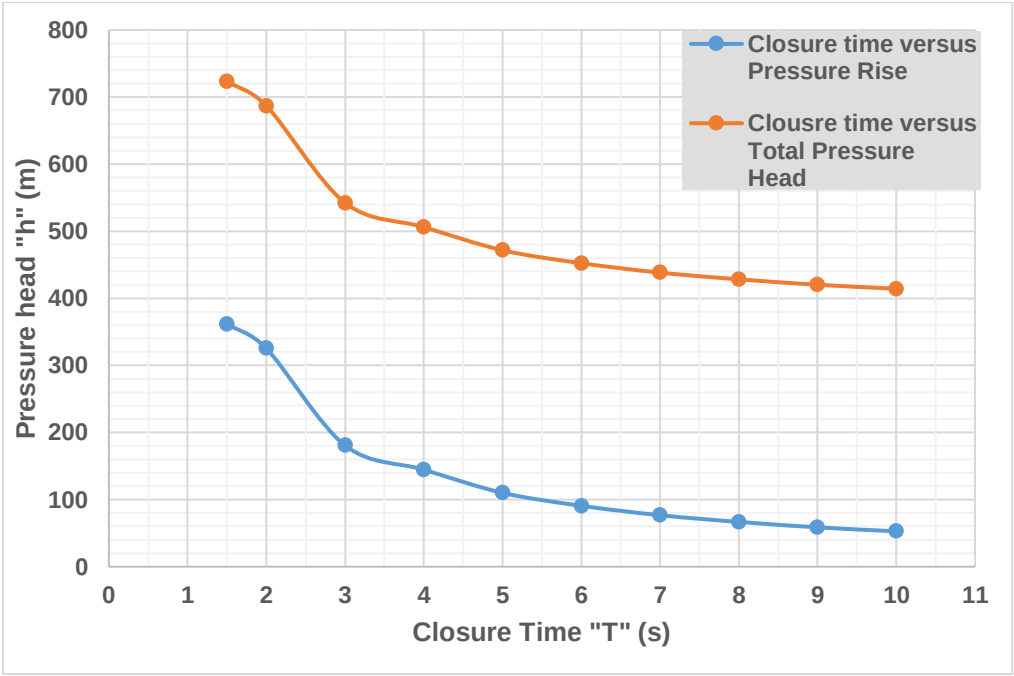


Figure-5: Effect of Closure Time on Pressure Rise

Following observations have been made:

With the decrease in closure time of turbine, pressure rise increases

For closure time from 10 sec - 6 sec, slope of line is 12.5

For closure time from 6 sec – 3 sec, slope of line is 26.66

For closure time from 3 sec – 1.5 sec, slope of line is 120

This shows that pressure rise increase from (a) to (b) two times and from (b) to (c) by 4.5 times. Rate of increase of pressure at closure time less than 3 sec is very steep

- **Effect of Change of diameter of penstock on Pressure Rise**

Impact of pipe diameter on pressure rise has been studied keeping other parameters fixed at closure time of 10sec. The results are graphically shown in Figure 6 below.

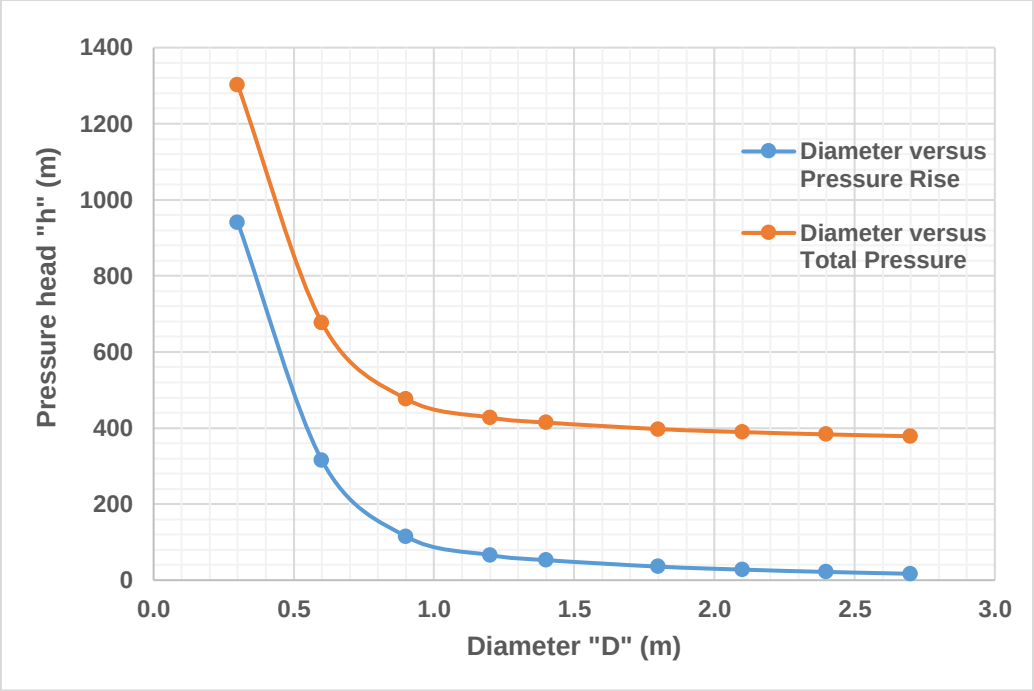


Figure-6: Effect of Pipe Diameter on Pressure Rise

Following observations have been made:

With the increase in penstock diameter, pressure rise decreases and vice versa

It is observed that for Naltar HPP against closure time of 10 sec, beyond 1m diameter, pressure rise is gradual, however, for pipe dia less than 1m pressure rise is exponential

- **Effect of Change of Wave speed on Pressure Rise**

Impact of pipe wave speed on pressure rise has been studied keeping other parameters fixed at closure time of 10sec. The results are graphically shown in Figure 7 below.

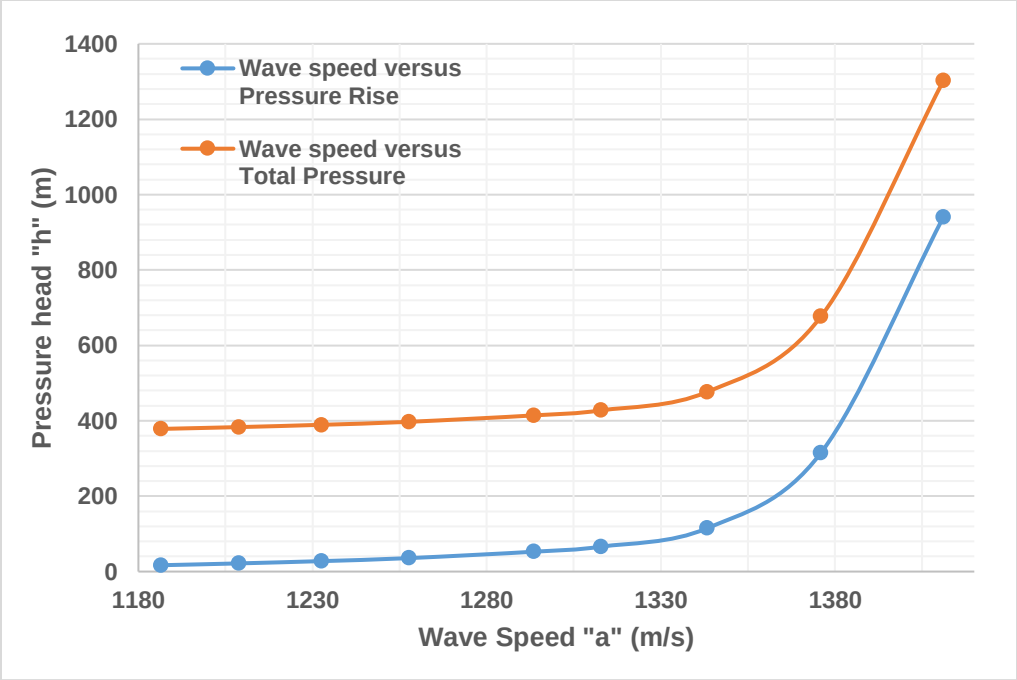


Figure-7: Effect of Pipe wave speed on Pressure Rise

Following observations have been made:

With the increase in wave speed, pressure rise increases and vice versa

It is observed that for Naltar HPP against closure time of 10 sec, upto wave speed of 1300 m/s pressure rise is gradual, however, beyond wave speed of 1300 m/s pressure rise is exponential

- **Effect of Water Temperature on Pressure Rise**

Impact of water temperature on pressure rise has been studied keeping other parameters fixed at closure time of 10sec. The results are graphically shown in Figure 8 below.

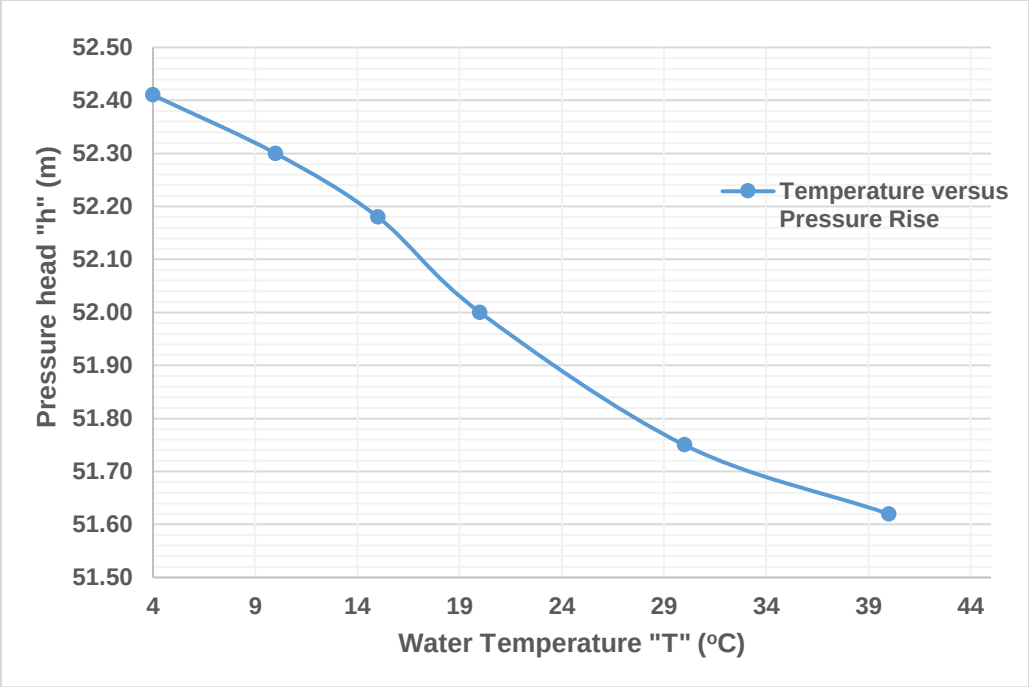


Figure-8: Effect of water temperature on Pressure Rise

Following observations have been made:

With the decrease in water temperature, pressure rise increases and vice versa

It is observed that for Naltar HPP against closure time of 10 sec, decrease of about 0.8 m pressure from increase of temperature from 4 °C to 40 °C. i.e. 0.02 m pressure rise increase with 1°C decrease in water temperature

- **Effect of Pipe length on Pressure Rise**

Impact of pipe length on pressure rise has been studied keeping other parameters fixed at closure time of 10sec. The results are graphically shown in Figure 9 below.

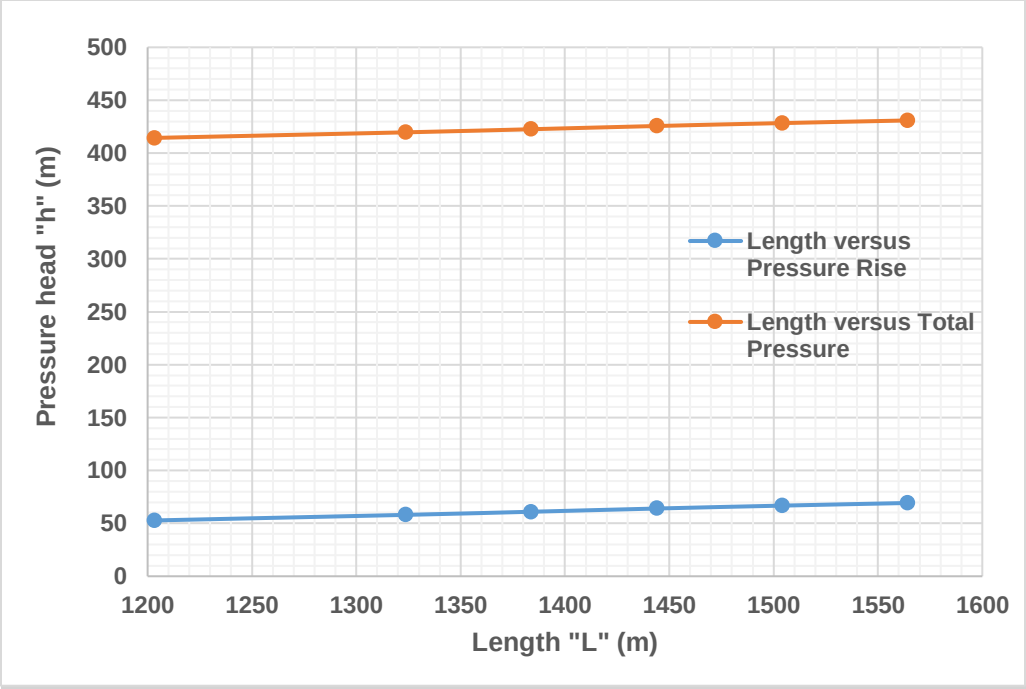


Figure-9: Effect of water temperature on Pressure Rise

Following observations have been made:

With the increase in pipe length, pressure rise increases and vice versa

It is observed that for Naltar HPP against closure time of 10 sec, pressure rise increases with length at a gradual rate i.e. 0.04 m pressure rise increase with 1 m increase in pipe length

Conclusions and Recommendations

Based on this study, parameters have been arranged in increasing order of their sensitivity to pressure rise:

Temp < Length < Pipe dia/Wave speed < Closure Time

It is further observed from case study project that, pressure rise at closure time less than 3 sec increases exponentially

The study will be useful to assess sensitivity of these parameters while fixation of penstock pipe parameters and design of surge tank

NUTRIENT REMOVAL EFFICIENCY OF CONSTRUCTED WETLAND FOR WASTEWATER TREATMENT AND REUSE

By

Kanza Naseer, Imran Hashmi[1]

Abstract

With declining trend in global water resources, wastewater reclamation and reuse have gained considerable importance. Beside conventional wastewater treatment technologies, Biological treatment system such as constructed wetland is one of established wastewater treatment technology used for suspended solid removal, BOD reduction, nutrient management and pathogen reduction. Current study was conducted at NUST H-12 campus Islamabad to monitor organic removal efficiency from constructed wetland, consisting of eight ponds. Each pond has specific hydrophytes such as (Typha latifola, Pistia stratiotes, Centella asiatica). Grab Samples were collected from sedimentation tank (inflow), ponds and collection tank (outflow) and further processed to measure organic removal efficiency. Physicochemical and microbial parameters were analysed according to standard methods (APHA) to determine organics removal rate through wetland system, that includes pH, Temperature, Turbidity, Electrical Conductivity (EC), Dissolved Oxygen (DO), Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), Total Suspended Solids (TSS), Total Dissolved Solids (TDS), Total Kjeldahl Nitrogen (TKN), Nitrate, Nitrite, Phosphate, Total coliforms and Helminthes quantification was also carried out by using Ballinger method. Significant spatial and temporal variations were observed with higher organics removal efficiency and final effluent proved to comply with the agriculture reuse standards. An excellent treatment efficiency was exhibited by the water quality parameters up to 74.2% for TSS, 74.2% COD, 95% Turbidity, 79% BOD, 68% Nitrite, 71% Nitrate, 69% TKN, 47.2% Phosphate, 83% Total Coliform and 99% Helminth eggs. Constructed wetland is proved to be efficient and reliable technique for removal of pollutants from domestic wastewater.

Key Words: Wastewater treatment, Constructed wetland, Agricultural Reuse

Introduction

Pakistan ranked 6th in context of world's most populous country with more than 190 million population which will exceed 240 million by 2030 (Hamid *et al.,* 2013) Consequently, the demand for food and water had already increased to feed its growing population. Similarly, increasing population, rapid urbanization, and an inefficient sewerage system are one of the most persistent issues that imparting immense pressure on the quality and quantity of existing water sources (Jaramillo and Restrepo 2017). Best solution to maintain quality and quantity of water is

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wastewater treatment systems. Wastewater treatment and reuse is considered an efficient tool for managing water resources that compensates water shortages and moderate surface water pollution.

Wastewater reclamation can be achieved through intensive conventional systems or natural, ecologically engineered treatment systems such as constructed wetlands. Although, constructed wetlands are very robust ecotechnology for domestic wastewater treatment and reuse in small dwellings because of their simple operation, great potential for nutrient removal and reuse, low cost and maintenance (Fountoulakis *et al*., 2017).

Constructed wetlands mimic the natural functions of wetland to treat contaminants. Various components of wetland including vegetation, substrate and microbes provide environment for physical, chemical and biological processes. They have been successfully used to mitigate environmental pollution by removing a wide variety of pollutants from wastewater such as organic compounds, suspended solids, pathogens, metals, and nutrients (Lavrnić & Mancini, 2016).

Study site

Present study was conducted on biological wastewater treatment plant (constructed wetland) located at NUST to evaluate the performance efficiency of the constructed wetland system and to check whether the treated water is fit for agricultural purposes.

Constructed wetland project was funded by United Nations Educational and Cultural Organization (UNESCO) and inaugurated by Minster of Science and Technology on 13th November 2014. The total volume of wastewater generated by NUST is about 200,000 US gallons per day and the flow into the treatment facility is maintained at 75000 US gallons per day at the inlet of CWs. Wetland system consists three steps first sedimentation tank, 8 ponds cultivated with different species of plants and FILTER technology that polish treated water from 8th pond and eventually stored in collection pond. Three macrophytes species that were cultivated in the system were *Pistia stratiotes* (Water lettuce), *Centella asiatica* (Pennywort)*, Typha latifolia* (Typha) and cad-Tail. Fig 1: show detailed picture of constructed wetland.

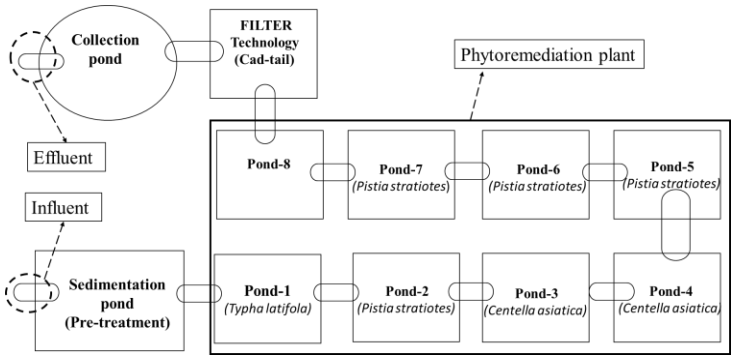


Figure-1: Schematic layout of constructed wetland

Methodology

Physicochemical and Biological parameters were used to analyze the efficiency of the wetlands during the four months period from October 2018 to January 2019. Sampling was carried out on weekly basis and all the physicochemical parameters were performed under the standard method for examination of water and wastewater (APHA, 2017).

Samples were collected twice a month (October 2018 to January 2019) from ten sites including sedimentation tank (inflow), ponds and collection tank (outflow) to measure nutrient removal efficiency at each site.

All methods for the collection, transport and storage of samples were carried out under the standard method for the examination of water and wastewater (APHA, 2017). Table-1 characterizes the equipment and methods used for various physicochemical parameters.

Biological parameters include total coliform and Helminthes egg quantification. Total coliform was performed according to APHA. 2017, using Membrane filtration technique and Helminthes egg quantification was also carried out by using Ballinger method (Jimenez *et al.,* 2016).

Parameters	**Units**	**Instrument and Methods**	**References**
pH	-	HACH 156 pH meter	**APHA, 2017**
Temperature	^{o}C	Laboratory Method-HACH	
Turbidity	NTU	Turbidity meter (HACH 2100N)	
Dissolved Oxygen	mg/L	Crison Oxi 45 DO meter	
Electric Conductance	µS/cm	Potentiometric Method-Conductivity Meter	
COD	mg/L	COD digester,	
BOD	mg/L	Incubation bottles	
TSS, TDS	mg/L	Gravimetric Dried Method	
Total Kjeldahl Nitrogen	mg/L	Kjeldahl Apparatus	
NO_3-N	mg/L	UV Spectrophotometric Screening Method	
NO_2-N	mg/L	Spectrophotometer, Colorimetric Method	
PO_4-P	mg/L	Spectrophotometer, Colorimetric Method	

Table-1: Methods and Equipment for Physicochemical Parameters

Results and Discussion

After a laboratory analysis of various samples and careful examination of the data, results are being reported for retrieving useful information. Results are outlined to quantify and evaluate the nutrient removal efficiency of constructed wetland. In National Environmental Quality Standard (NEQS) Pakistan, the permissible value of various parameters for wastewater Discharge and Agriculture reuse is as given in Table: 2

Parameter	Existing Standards for wastewater discharge	Revised Standards for wastewater discharge			Agricultural reuse standards
		Inland waters	Sewage	Sea	
Temperature	40°C	≥3°C	≥3°C	≥3°C	----
pH	6 – 10	6 – 9	6 – 9	6 - 9	6.5-8.5
BOD_5	80	80	250	80	<30 mg/L
COD	150	150	400	400	<150 mg/L
TSS	150	200	400	200	<100mg/L
EC	---	---	---	---	>2500 µS/m unacceptable
TDS	3500	3500	3500	3500	---
TC					<1000/100 CFU/mL
Helminthes egg	---	---	---	---	<1 egg/ L
Reference	NEQS, 1995	NEQS, 2000			EPA, 2006

Table-2: Standards for Waste water discharge & agricultural reuse

In fact, all observed pH values of final effluent ranges within NEQS for wastewater Discharge and agriculture reuse standards. pH of effluent decreases due to plant and microbial degradation of organic matter, leading to shift in pH to slight acidic (La Mora-Orozco *et al*., 2018)

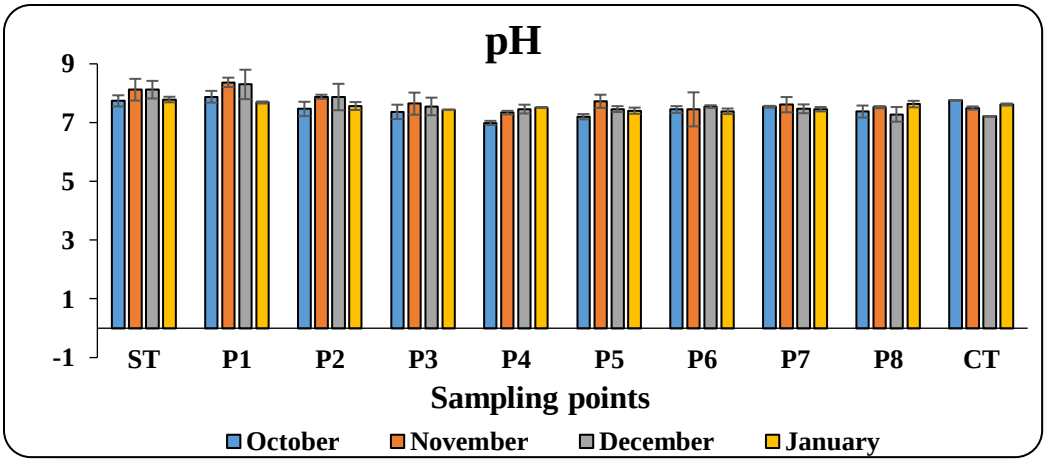


Figure-2: Monthly Variation of pH

Temperature decrease from October to January which also affect overall efficiency of treatment system. Low temperature limits plant growth microbial degradation of organic matter. Low plant growth decreases the nutrient uptake by plants.

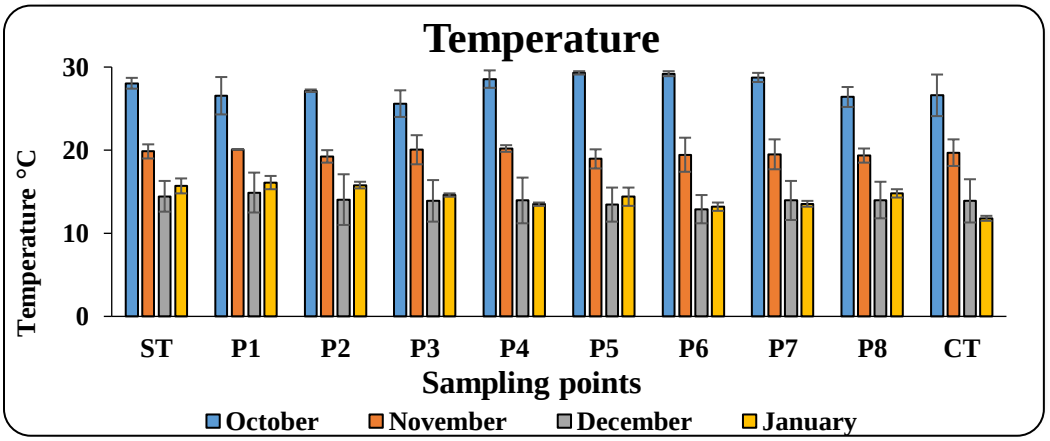


Figure-3: Monthly Variation of Temperature

Dissolved oxygen (DO) increases as water moves from Sedimentation tank to Collection tank. DO increased due to aerobic environment provided by plants and atmospheric diffusion (Liu. *etal*., 2016). Various parameters like Turbidity, TSS, TDS and BOD shows inverse relationship with DO (Joshi *etal*., 2009). Turbidity, TSS, TDS and BOD showed decreasing trend in whole treatment process.

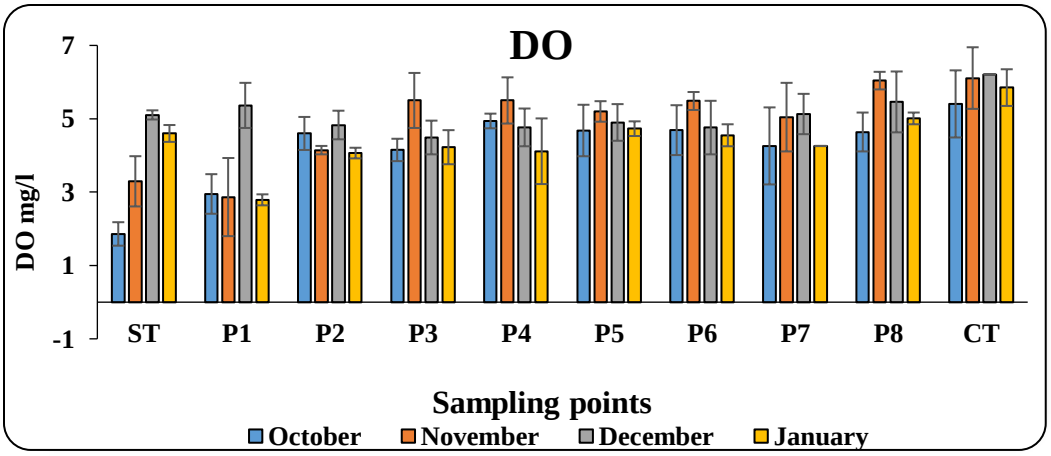


Figure-4: Monthly Variation of DO

Turbidity shows the physical status of water quality. Turbidity of water effected due to suspended particles (TSS), total dissolved solids (TDS), organic matter, as well as the microscopic organisms. Andleeb & Hashmi 2018 showed high removal of TSS and turbidity from effluent of horizontal subsurface flow constructed wetland.

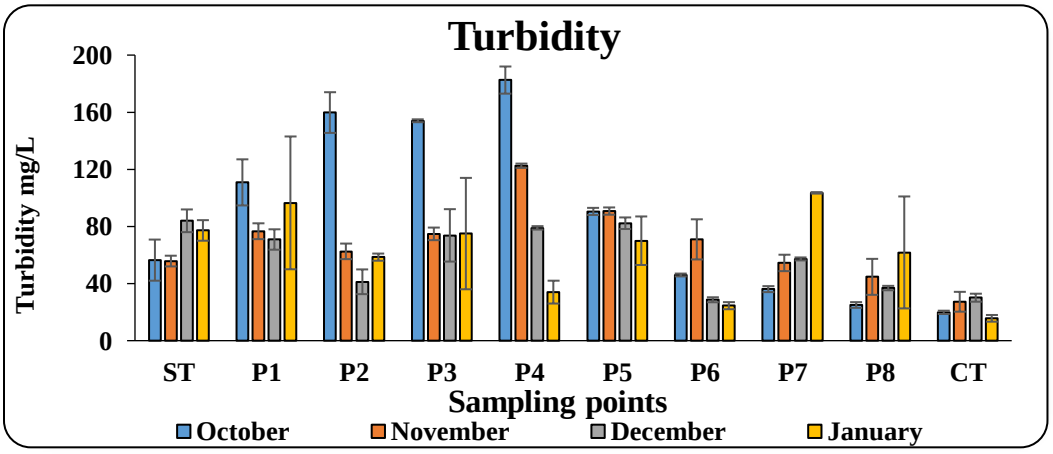


Figure-5: Monthly Variation of Turbidity

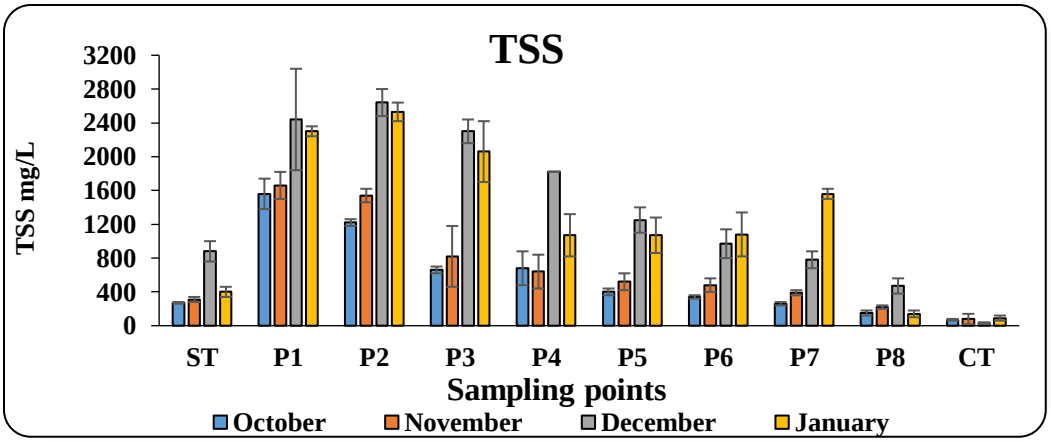


Figure-6: Monthly Variation of TSS

Total suspended solids showed varied results in different ponds, due to plant roots and biofilm. Main mechanism behind removal of suspended soils include sedimentation and filtration. Plant roots act as a barrier for suspended partials and increase removal efficiency.

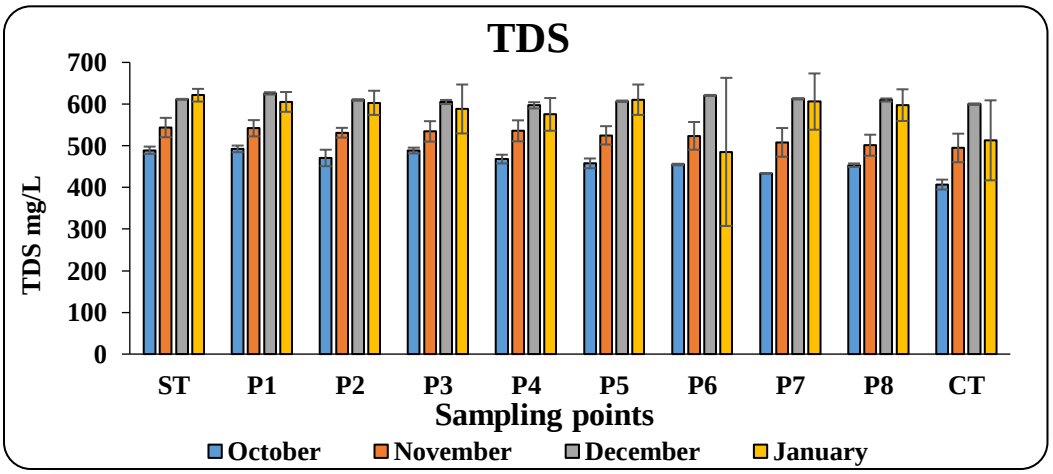


Figure-7: Monthly Variation of TDS

Total dissolved solids and electrical conductivity show similar trend. Its values increased with decreasing the temperature. Water consumption by society and plant uptake of nutrients decreased in winters. That cause low removal efficiency of dissolved solids.

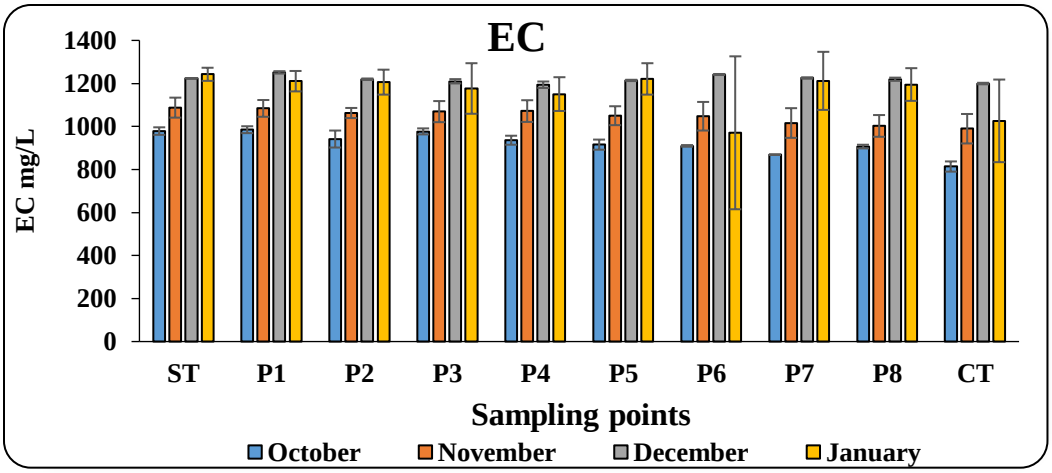


Figure-8: Monthly Variation of EC

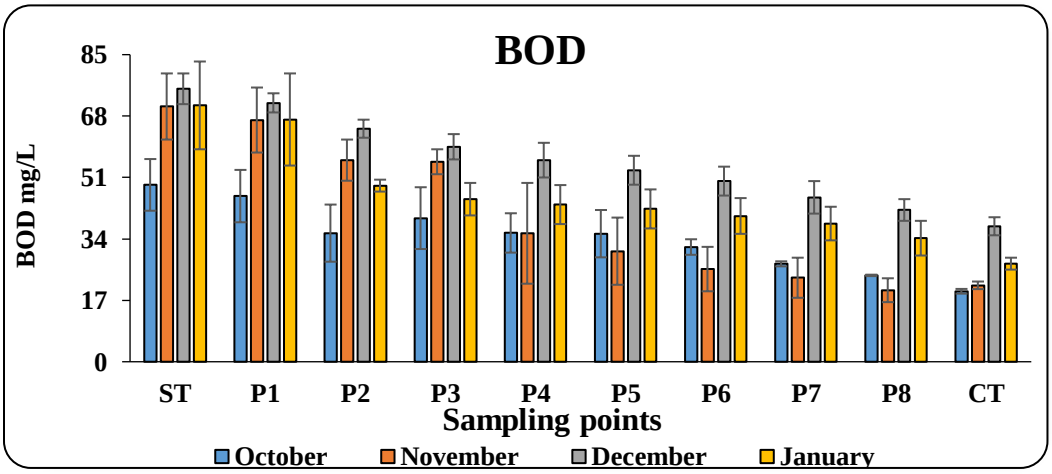


Figure-9: Monthly Variation of BOD

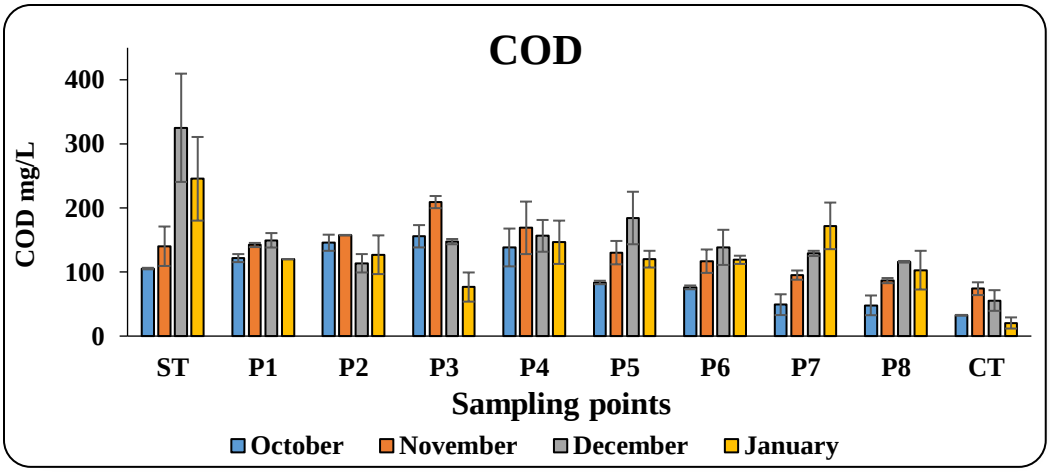


Figure-10: Monthly Variation of COD

COD shows decreasing trend as water pass through different ponds. Results have clearly demonstrated the strong removal efficiency of the system. COD of wastewater continuously increasing in winters. COD is because of the presence of organic matter so its major contributors are the dead plants. Low consumption of water also increases COD values.

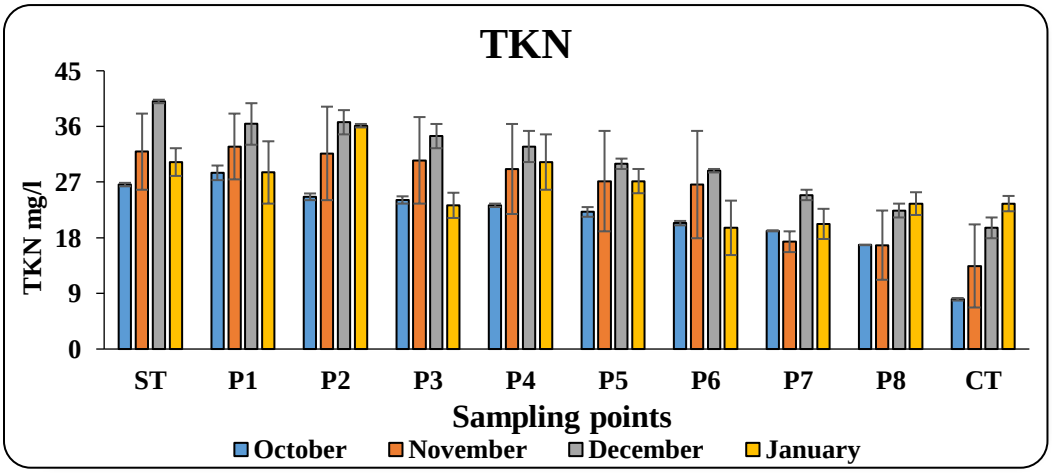


Figure-11: Monthly Variation of TKN

TKN, nitrate and nitrite removal efficiency decrease in winters because plant growth and microbial degradation minimize in winters. While in January high rainfall cause dilution of wastewater. Overall nitrogen removal is assisted by substrate, microbial pathways and uptake by plants as a result of nitrification–denitrification and assimilation (Qiao *et al*., 2018).

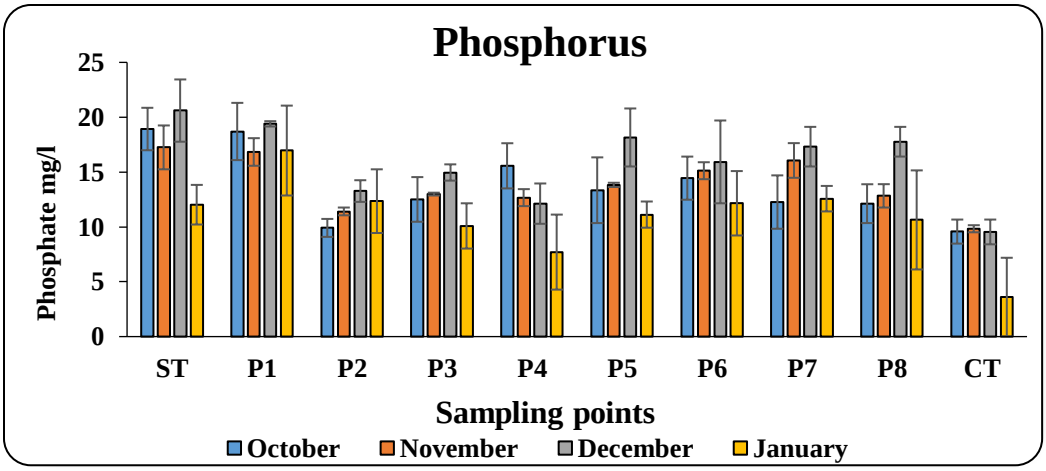


Figure-12: Monthly Variation of Phosphorus

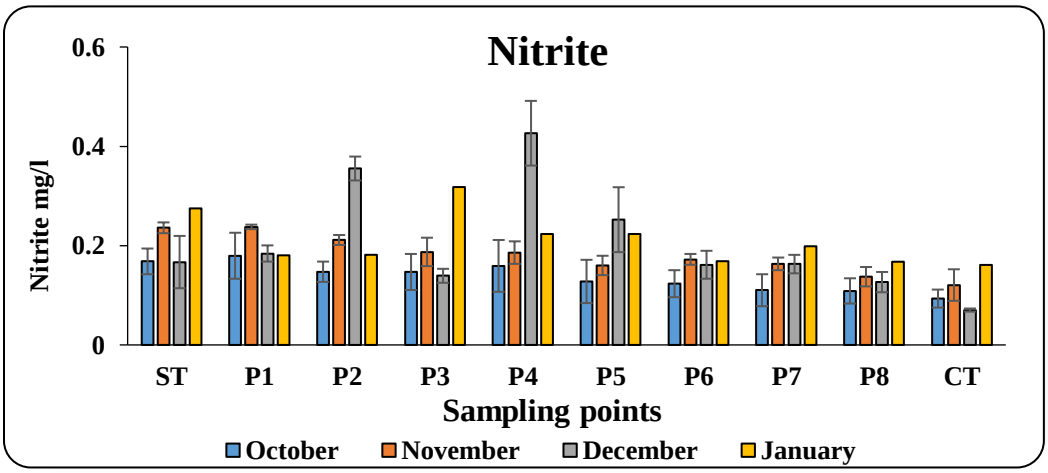


Figure-13: Monthly Variation of Nitrite

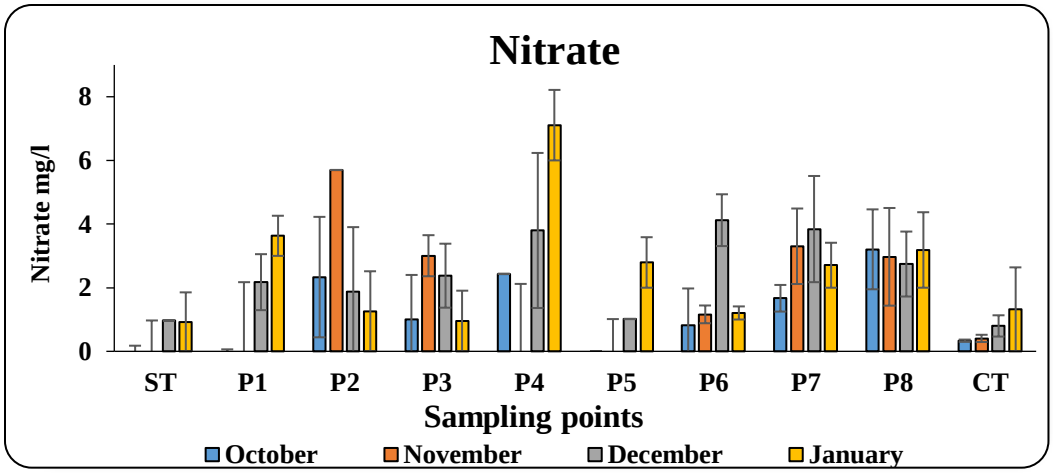


Figure-14: Monthly Variation of Nitrate

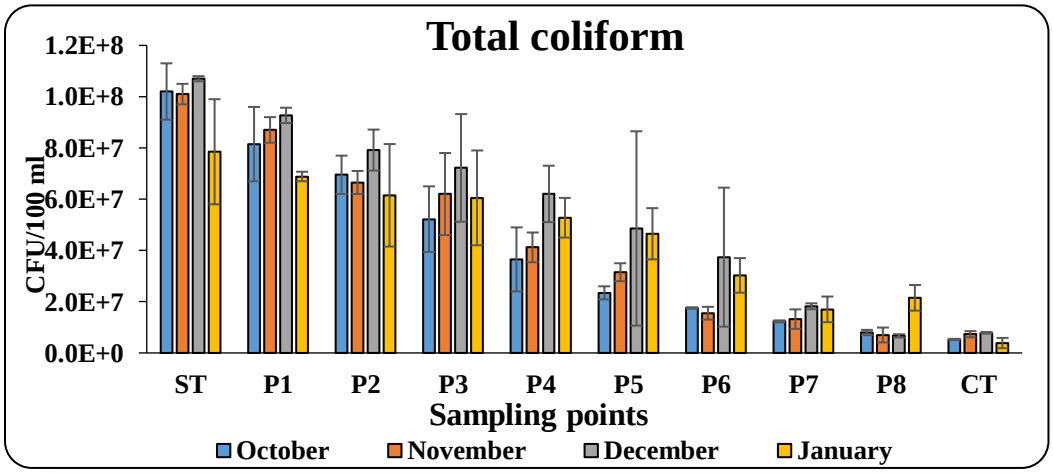


Figure-15: Monthly Variation of Total Coliform

Constructed wetland showed high removal rates of Total coliform and helminthes eggs. Coliform removal efficiency decreases in winters and exceeds agriculture reuse standards. Number of helminthes egg were high in October while decrease in the month of January. These results show temperature effect on Helminthes life cycle (Maya *et al*., 2012)

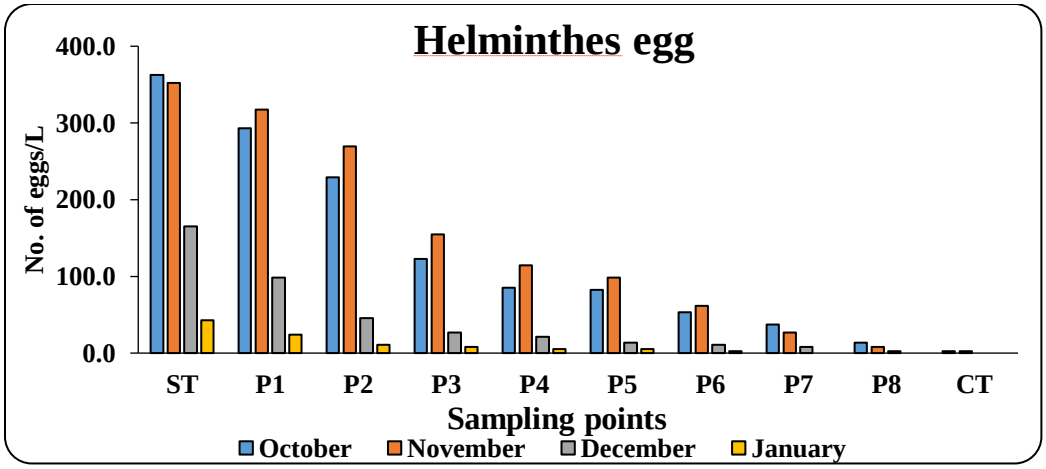


Figure-16: Monthly Variation of Helminthes Egg

Conclusions and Recommendations

Constructed wetlands are efficient and cost-effective wastewater treatment Technology. It will enhance sustainable use of water in agriculture and irrigation sector. Treated wastewater improve the yield of unproductive soils. There is dire need for implementation of constructed wetlands as wastewater treatment systems in Pakistan by improving policies, financial management and institutional dialogues, which would ultimately improve the agricultural production and can, boost up the economy of the nation. Involvement of Public and other stakeholders should be ensured for implementation at larger scale.

This research will be helpful to create awareness among the masses in the form of research papers, newspaper clippings, seminars, and short training programs, poster presentations at local and international levels. This technique if implemented will reduce water borne diseases as mixing of wastewater with the drinking water supplies will be highly reduced which is the major aspect highlighted in Sustainable development goals.

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LEACHATE POTENTIAL TO CONTAMINATE THE GROUNDWATER IN THE VICINITY OF LANDFILL SITES

By

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Abstract:

This review article talks about the different methods for the assessment of groundwater contamination used in different countries around the world. Different methods are highlighted on the basis of their suitability for the particular country to assess the quality of groundwater and the composition of leachate. A case study of Pakistan is also included that was conducted near a landfill site to observe a correlation between the leachate and the groundwater contamination in the vicinity of landfill site. This study indicated that TDS and turbidity values were exceeding the standard limit at every depth of water and the most variation was observed to be in shallow water. For shallow, moderate and deep level of water the highest values for turbidity was recorded as 10.1 NTU, 8.4 NTU and 4.5 NTU respectively. The coefficient of correlation was also observed between the leachate and the groundwater at moderate, deep and shallow depth.

Introduction

Overtime many techniques have been developed for the assessment of groundwater contamination. Two methods are commonly used that are, mathematical modelling and experimentation, focused on determination and estimation of impurities. From site to site the composition of leachate changes greatly or can changes in a specific site (Moo-Young H, 2004).

Groundwater is transparent, colourless, tasteless and odourless, liquid at normal temperature and chemically neutral in reaction and a universal solvent for many compounds. Just by assessing physical, chemical and biological characteristics of water we can conclude about its quality. Groundwater quality focuses on the various aspects of physico-chemical parameters of water that detect the status of pollution and suitability of a particular water body for various aquatic organisms. Ground water contamination is commonly defined as any physical, chemical or biological change in water quality which have an adverse impact on living organisms and the environment. (Sarker, 2013)

This research belongs to the study area Athens, Greece it was supported to observe the consequence of landfill leachate under the ground water resources present in that area. Physico-chemical parameters were observed for this purpose

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like heavy metals from the different sampling sites from up to 3 km of study region. The results found suggested that the quality of ground water was seriously deteriorated due to leachate contamination from the landfill. Two methods were adopted in this study the experimental determination of pollutant or mathematical modelling for their estimation. Experimental determination was preferred due to lack of presence of parameters required for the mathematical modelling. (M. Loizidou, 1993)

A research was conducted in China to determine the detrimental effects on ground water quality of leachate percolation. The main strategy of this study was to determine stable isotopic compositions of water and various physicochemical parameters in groundwater and surface water. The stable isotopic composition revealed that there were many activities of evaporation processes and elevation effects before the saturation zone was reached by the water and no significant heavy metal contamination was found in that area. A method called Principle component analysis was used to determine TDS, Cl^-, NH^{4+}, Mn and Fe concentrations were the main indicators of the contamination of groundwater caused when the landfill leachate percolated the ground water. Irrigation return flow is a major determinant of the quality of ground water shallow aquifer during the summers. A transport model was developed using MODFLOW and MT3DMS that gave us an adjective-dispersive two-dimensional model to extrapolate the extent of control in the contamination. The study showed that even after 13 years of operation the contamination plume was observed to be present in the upper aquifer as the results were obtained by transient flow models and chloride transport simulations with steady state. This difference between concentrations shows that the other factors might have had a possible contribution to increase the salinity of aquifer. The transient model shows that the certain factors like temporal water variations might greatly effects the movement of plume towards the aquifer. The results obtained showed that the ground water around this facility was not suitable to drink. (Dongmei Han) Similar study was performed for an open dumpsite in Telangana State, India where ground water samples were collected and analysed for groundwater contamination due to leachate. (Syeda Azeem Unnisa, 2017)

In this research Fe_3O_4 nanoparticles were used that were made highly active after modification with Ag and were then used to analyse photo catalytic degradation in landfill leachate and Surface enhanced Raman scattering (SERS). Signals generated from SERS was used to determine the composition of leachate and the common pollutants presents in it that were observed to be heavy metals, pesticides, phthalates, phenols. The thought that the homeland aquifers were facing landfill crisis was also confirmed by the SERS signals. The decomposition of leachate was also observed to be efficient by the use of Ag modifies Fe_3O_4 nanoparticles, the degradation was observed to be carried out at a constant rate of .003 per minute under the access of UV radiations. In the recent years SERS have caught much attention of the scientists due to their ability detect and distinguish between various types of analyte present in a medium. Its dependency on the vast Electromagnetic (EM) development carried through the noble metals

that have been modified and restructured makes it an extremely sensitive technique to carry out. This feature makes it an efficient tool to carryout analysis of certain single molecules in addition to their detection. When an analyte is situated in close proximity with the metal surface then the SERS efficiency is enhanced. Due to high surface to volume ratio Iron oxide nanoparticles had proved to be an efficient tool for the waste water treatment research. (Aarthi A., 2018)

SERS sign of landfill leachate determines the existence of communal pollutants in leachate. SERS signal is observed when an analyte gets closed to the surface of metal surface. Improvement of signal depends on a large area of analyte. (Arthi A., 2018)

A new type of SERS dynamic substrate of Ag modified iron oxide was created to exhibit both the photo catalytic degradation and SERS. The achieved SERS signals from the samples established the landfill catastrophe in home aquifers. Moreover, Silver modified Iron oxide NPs greatly decomposed leachate under UV irradiation with the rate of 0.003/min. The communal pollutants of heavy metals, pesticides, phthalate and phenols were identified by SERS substrate silver modified iron oxide from the groundwater and leachate. This method has been tried professionally with real samples, and its results suggest that because of doubtful design of the landfill the samples of groundwater were contaminated. Thus, silver modified Iron Oxide may play an important role of different applications, which includes the removal and identification of environmentally harmful substances to develop the human environment. (Arthi A., 2018)

The frequently used techniques for removal of solid wastes includes; dumping and landfills. But, landfilling can be seen as a potential source of land pollution. Therefore, even though landfilling is practiced, still the areas should be constantly monitored even after closure.

The breakdown of waste by microbes leads to formation of leachate which is enhanced by the rainwater that percolates through the solid waste. In landfills, without proper perimeters, the organic and inorganic matter migrates to unsaturated area, crowding it.

These days, for the geo-environmental persona of a site, non-invasive and non-crowding techniques can be used e.g. surface geophysics which supplies an outline of the area, supplying information for guidance.

Still, it is necessary to accentuate the results provided from the geophysical techniques are not convincing. Therefore, this data combination along with well monitoring are suggested for the confirmation of resistivity of groundwater which can alter due to porosity of rocks, contents of aqueous fluid and air, along with chemical changes in water. (Deiz Dias Lopes, 2012)

Over the whole life of HWL (hazardous waste landfill) Contamination of the groundwater due to leachate is the mostly destructive environmental impact. Considering the increasing HWL facilities and poor environmental risk

management, it is needed to develop a appropriate methods for environmental management.

A risk analysis method for hazardous waste landfill is effective and efficient. The basic structure was formed considering five important aspects i.e. Landfill management and risk acceptors, properties of leachate, media present underground and source term. From multimedia models it was discovered that planned system was quantitative and integrated and records for it can be composed and used for ERA in china.

Official data (MEP2011) give the 15.87 million tons calculated amount of hazardous waste in 2010 but it comes out to be 45.73 million tons in 2007. To deal with this huge quantity of waste, more landfill services needed for this and this increased due to industrial plants and abandoned hazardous chemicals. To fulfil this need, China planned many landfills for hazardous waste and their production plan accepted in 2004.Thirty one centres were included in management program and all complying with the relevant standards. In 2010, two hundred thirty seven medical waste and hazardous waste central disposal facilities and resulting HW settlement capacity 96.41*104 tons per year hence reached more than 4 times of previous one. (Ying Li, 2012)

To some extent, environmental crisis can be controlled at primary level but it's not that much easy and expensive as of HWLS in short time is. In china ERM is weak but recent environmental incidents raised alarming situation and this guidelines have been promulgated for its promotion i.e. due to defective risk analysis method. The new central hazardous waste dumping facilities were built in the deficient of standards and absence of experience. Thus requirement for development of environmental risk managing system arises.

By Many research studies it is proved that one main effect of landfill is groundwater contamination and considering it many assessments were carried out using different methodologies i.e.

1) transport characterization and degradation of leachate
2) observation of plumes of leachate near the landfill site
3) Laboratory experiment
4) Simulation by using mathematical models

These are applied in combined form in assessment and only last method give synthetic results and require detail data for modelling. These models are established from assumptions from real situation but they always results in uncertainty. Method 2 can also be used for actual contamination and mapping of the leachate movement but this is not reliable for long term pollution scenario. Method 1 is used for investigation of processes of waste decomposition outside HWL and method 3 results in deductions that are usually limited and distorted to the laboratory scope; a considerable result is usually achieved by repeated experiments.

This study tries to improve an efficient risk analysis method for more user-friendly but financial and human resource investments are the hurdles in developing simple and convenient risk analysis method and its results can be useful at macro level.

Indices system is always investigated from site choice, analysis of ground water, evaluation of leachate pollution, vulnerability of environment and decision making For the evaluation of leachate pollution, index of assessment are selected by the characteristic pollutant in leachate and contaminating the groundwater. Groundwater vulnerability is investigated by focusing on characteristics of underground environment. HRS and NCAPS are systems developed for assessing relative threat due to discharge of hazardous wastes and ranking the facilities. After those two environmental indicators that is groundwater EI and human exposure EI were established but are not adequate so, a synthetic analysis indices system is required for analysis of pollution of groundwater, management and operation of landfill and the guidelines required for landfill design,. (Ying Li, 2012)

The purpose of this method was to use the geophysics to determine water pollution, which is formed due to the percolation of leachate in landfilling. The aim of this study was to recognize the plume of leachate (leaching liquid) by the use of two techniques that is sampling of groundwater and geophysical technique for the sole purpose of determining the extent of contamination in groundwater. After using geophysical techniques, the leachate was final. The samples were tested for; heavy metals, TKN, alkalinity, chemical oxygen demand, conductivity, biological oxygen demand and pH. Through the electro-resistivity, morphology of the plume was finally determined. This was important for the water monitoring wells. These results indicated the correctness of geophysical study. The high values of electrical conductivity and alkalinity proved the water of those areas to be polluted by the plume. Even with the changes in seasons and environment, B BOD remained low comparing it to Brazilian environmental regulations. On the other hand, COD values are greater than 40x BOD. Moreover, the amount of copper (Cu), cadmium (Cd), zinc (Zn) and nickel (Ni) in water are lower than required standard amount as established in Brazil, but, Lead (Pb) concentration is higher than established by Brazilian legislation. (Deiz Dias Lopes, 2012)

Not having proper septic system and unlined landfill cause risk to surface water and groundwater resources. This study includes examination of plumes of leachate at landfill in sandy type aquifers, and the special effects of landfills on clay until settings. However, it's yet not properly understood. Furthermore, effective techniques are required to quantitatively connect groundwater soil impurity to the contamination of surface water.

This research was carried out in an ancient landfill that was unlined called Risby landfills. By the use of combination of mass balance method approach and historical investigation this study provides a method for the estimation of the contaminant mass discharge. The method seems to very well work at the level of screening level and it can be a part of risk analysis.

Pollutant mass discharge was determined for ammonium, dissolved organic carbon and chloride that are three common leachate indicators. For example, the chloride mass discharge was 9.4 tons per yr. from landfill whereas; to deep aquifer of limestone it was 1.4 tons per yr. Which as a result shows raise in amount of leachate indicators e.g. ammonium, dissolved organic carbon and chloride, in groundwater total discharge of chloride to small part of the landfill was about 31 kg per yr. By dissolving organic carbon, this method worked perfect for chloride, however, due to reduction process and spatial difference in composition the errors were raised for ammonium in the underlying clay till. (Nanna I. Thomsan, 2012)

The use of “sanitary landfills” in Mexico is mostly based upon open dumpsites or uncontrolled landfills. Interaction of aquifers - shallow and unconfined - with the contaminants from open dumps or landfills is a common phenomenon seen in the country. This research article might provide as an evidence for Mexican decision makers to make decisions and set their opinion regarding the contamination of shallow groundwater aquifers. For the identification of contaminants and their access to the shallow ground water aquifer mostly traditional methods were used like hydrological description, chemical analysis of water, (VES) vertical electrical sounding and (GPR) ground penetrating radar) used in geophysical studies. A model study site was taken that was in Mexicali – The Guadalupe Victoria landfill.

Geophysical studies of the area showed that the extent of the movement of leachate was recorded to be 20 meter from south-east edge and 40 meter from the north-west edge. The land that was influenced by the leachate was recorded to be 80 m extent from both sides of the leachate released from the landfill. The effects of leachate on the groundwater were calculated from the geochemical analysis. (Jaime A. Reyes-López, 2008)

A contract was made by the government of Alexandria with an international company to carry out the operation of collecting, transporting and discharging of solid waste to the landfill site. Duties of operation and construction were also included in this contract for the successful operation of the landfill. After the operation of landfill the groundwater and leachate quality was analysed to observe any harmful impacts of the landfill on the environment. A physico-chemical analysis was conducted that generated results suggesting a serious contamination of heavy metals and other harmful chemicals into the leachate. The ration between the BOD and the COD was observed to suggest the biodegradability and the instability of the leachate. Groundwater contamination was not observed in the surrounding area after calculation; certain parameters were observed but not harmful to exceed the EPA and WHO limits. The results obtained suggested that the anaerobic biodegradation was needed to be increased to stabilize leachate and continuous monitoring of groundwater and leachate was required for the successful operation of the landfill. (Magda M. Abd El-Salam, 2015)

A Case Study of Pakistan:

Leachate Analysis

The values obtained from the analysis of leachate samples are shown is Table 1. The pH of the samples ranged from 8.27 to 9.18. The samples exceeding the standard limits of pH were 30% given in NEQs that is 9. Electrical conductivity of leachate was recorded for only one month. The value obtained was 32030 µS/cm. The concentration of TDS in leachate exceeded the standard limits and had a mean value of 18889 mg/L. It was observed to be more than 5 times higher than the given limits in NEQs for TDS. TSS have its values ranging from 60 mg/L to a maximum of 920 mg/L. 33% of the samples exceeded their standard limits for the TSS that is 400 mg/L. BOD and COD for the leachate were observed to have a mean value of 1715 mg/L and 7433 mg/L respectively. COD was increased than the standard limits for all the samples but for BOD the samples exceeding their standard limits were 7%. Sulfate in the leachate was recorded to have a maximum value of 10400 mg/L that is nearly ten times higher than the given standard value. The concentration of chloride in the leachate had a mean value of 5504 mg/L, five times higher than the standard value.

Maximum value of cadmium was recorded to be 0.15 mg/L slightly higher than the standard value. The concentration of iron was recorded to higher than the standard value for 15% of the samples having a maximum value of 14.1 mg/L. Manganese and boron had their values well above the standard limits having maximum value of 11.8mg/L and 15.2 mg/L respectively. Half of the samples in case of zinc had slightly higher values than the standard limits and for Nickel higher value was recorded for only one sample. Total toxic metals were recorded to be seven time higher than the standard value. Samples that had a higher content of phenolic compounds than the standard value were 50%. The value was observed to be maximum of 0.418 mg/L. The concentration of total chlorine, cyanide, selenium, barium, silver, copper, mercury, arsenic, chromium was recorded to be within the standard limits.

Table-1: Analysis of leachate and groundwater quality

	Leachate Quality Analysis			Groundwater Quality Analysis		
S. No.	**Parameters**	**Unit**	**Mean Values**	**Parameters**	**Unit**	**Mean**
1	**PH**	PH Unit	8.82		PH Unit	7.5192308
2	**Electrical Conductivity**	µS/cm	32030	**pH**	TCU	10
3	**TDS**	mg/L	18889.846	**Color**	_	
4	**TSS**	mg/L	356.33333	**Taste**	_	
5	**Oil & Grease**	mg/L	22.166667	**Odor**	NTU	16.130769
7	**COD**	mg/L	7433.2308	**Turbidity**	mg/L	279.15385
8	**Phosphate, Total**	mg/L	50.05	**Total Hardness as CaCO3**	mg/L	461.30769
9	**NH3, Nitrogen**	mg/L	505.1	**TDS**	mg/L	0.0992308

S. No.	Leachate Quality Analysis Parameters	Unit	Mean Values	Groundwater Quality Analysis Parameters	Unit	Mean
10	**(BOD5) @ 20 °C**	mg/L	1715.3077	**Fluoride**	mg/L	3.2607692
12	**Sulfate**	mg/L	1190.4692	**Nitrate (NO3), Nitrogen**	mg/L	0.0725385
13	**Sulfides**		5.6458333	**Nitrite (NO2), Nitrogen**	mg/L	30.956154
14	**Chloride**	mg/L	5504.9954	**Chloride**	mg/L	0.0033333
15	**Fluoride**	mg/L	1.8783333	**Aluminum**	mg/L	0
16	**Ionic Detergents**	mg/L	3.0255	**Antimony**	mg/L	0.0342857
18	**Arsenic (As)**	mg/L	0.034375	**Barium**	mg/L	0.1054545
19	**Cadmium (Cd)**	mg/L	0.063	**Boron**	mg/L	0
20	**Chromium (Cr)**	mg/L	0.1153846	**Cadmium (Cd)**	mg/L	0.0047273
21	**Copper (Cu)**	mg/L	0.2061538	**Cyanide**	mg/L	0
22	**Iron (Fe)**	mg/L	4.9115385	**Mercury (Hg)**	mg/L	0.0035
23	**Lead (Pb)**	mg/L	0.0554615	**Nickel (Ni)**	mg/L	0
24	**Manganese (Mn)**	mg/L	1.5566154	**Selenium**	mg/L	0.0066667
25	**Nickel (Ni)**	mg/L	0.3708333	**Phenol**	mg/L	0.0661111
26	**Zinc (Zn)**	mg/L	3.7730769	**Zinc (Zn)**	mg/L	0.1134167
27	**Calcium**	mg/L	44	**Manganese (Mn)**	mg/L	0.0304167
28	**Sodium (Na)**	mg/L	2900	**Chromium**	mg/L	0.0458333
29	**Potassium (K)**	mg/L	4100	**Copper**	mg/L	0.0184167
30	**Mercury (Hg)**	mg/L	0	**Lead**	mg/L	0.0128571
31	**Silver**	mg/L	0.0198	**Arsenic**	mg/L	0.0338462
32	**Barium**	mg/L	0.1091667	**Total Chlorine**		
33	**Boron**	mg/L	3.6909091			
34	**Cyanide**	mg/L	0.1693333			
35	**Selenium**	mg/L	0			
36	**Phenolic compound**	mg/L	0.3295			
37	**Total Toxic Metals**	mg/L	2.2579167			
38	**Total Chlorine**	mg/L	0.0883333			

Groundwater Analysis:

The values for the groundwater quality analysis are given in Table 1. The results obtained were compared with the WHO standard values. The value of pH was recorded to be within the limits of standard values. A maximum of 8.04 pH was observed that shows a higher alkaline pH of water. Turbidity value was increased from the standard limits for 76% of the samples with a maximum of 18.9 NTU. Hardness in the samples ranged from 89 mg/L to 388 mg/L, nine out of thirteen samples had a hardness value of above 300mg/L but under the given standard limits. The maximum value of TDS observed was 716 mg/L, lower than the

standard value. Chloride content of the groundwater was recorded to range from 19.43 to 51 mg/L and was lower than the standard values given by WHO. Concentration of Boron was recorded to be a highest of 0.2 mg/L and in some samples it was below the detection limit. The value of boron was quite close to the standard value that is 0.3 mg/L. Phenol was one of the parameters exceeding its standard limits. It was observed to the highest of 0.02 mg/L and was ten times higher than the standard limits. The quantity of lead was maximum of 0.022mg/L higher than the standard limits. Nitrate, Nitrogen, Aluminium, antimony, barium, cadmium, cyanide, mercury, nickel, selenium, zinc, manganese, chromium, copper, arsenic, and total chlorine were recorded to be with in the standard limits.

Pearson Coefficient of Correlation between shallow water and leachate - 1

Sr. No.	Parameters	Shallow Depth	Leachate	Coefficient of Correlation
1	**pH**	7.53	8.82	0.982412656
2	**TDS**	413.3	18889.846	0.982700795
3	**Nitrate (NO3), Nitrogen**	1.6	26.23	0.999454928
4	**Chloride**	42	5504.9954	0.9999968
5	**Barium**	0	0.1091667	0.727706153
6	**Boron**	0.1	3.6909091	0.72243383
7	**Cadmium (Cd)**	0	0.063	0.537713395
8	**Cyanide**	0.003	0.1693333	0.526586493
9	**Mercury (Hg)**	0	0	0.517905041
10	**Nickel (Ni)**	0.003	0.3708333	0.497527816
11	**Selenium**	0	0	0.494510078
12	**Phenol**	0	0.3295	0.461806862
13	**Zinc (Zn)**	0.044	3.7730769	0.449395472
14	**Manganese (Mn)**	0.089	1.5566154	0.869570541
15	**Chromium**	0.03	0.1153846	0.989609247

Sr. No.	Parameters	Shallow Depth	Leachate	Coefficient of Correlation
16	**Copper**	0.056	0.2061538	0.990914584
17	**Lead**	0.013	0.0554615	0.890777869
18	**Arsenic**	0	0.034375	1
19	**Total Chlorine**	0.016	0.0883333	0.754275318

The statistical analysis for the Pearson's coefficient of correlation between shallow water and leachate indicate direct means of contamination among the two variables. Among physical parameters pH had a strong correlation of 0.98 between the two variables for sample 1 and 0.97 for sample 2. TDS showed a similar strong correlation with a value of 0.98 for sample 1 and 0.97 for sample 2. Among chemical parameters, Nitrate and Chloride concentrations showed the strongest correlation with a value of 0.99 for both samples except for nitrate in sample 2 which had a strong correlation value of 0.98. Arsenic had the highest correlation of 1for both samples. Chromium and copper had a strong correlation of 0.98 and 0.99 respectively for sample 1 and 0.92 and 0.99 respectively for sample 2.

Pearson Coefficient of Correlation between Shallow water and leachate - Sample 2

Sr. No	Parameters	Observation well water	Leachate	Coefficient of Correlation
1	**PH**	7.6	8.82	0.970143435
2	**TDS**	636	18889.846	0.970302351
3	**Nitrate (NO3), Nitrogen**	5.43	26.23	0.982371955
4	**Chloride**	28	5504.9954	0.999986417
5	**Barium**	0.055	0.1091667	0.623377225
6	**Boron**	0.1	3.6909091	0.658205702
7	**Cadmium (Cd)**	0	0.063	0.519600348
8	**Cyanide**	0.007	0.1693333	0.50872972

Sr. No	Parameters	Observation well water	Leachate	Coefficient of Correlation
9	**Mercury (Hg)**	0	0	0.500908613
10	**Nickel (Ni)**	0	0.3708333	0.482024679
11	**Selenium**	0	0	0.477828135
12	**Phenol**	0	0.3295	0.447215454
13	**Zinc (Zn)**	0.048	3.7730769	0.430503967
14	**Manganese (Mn)**	0.14	1.5566154	0.986162635
15	**Chromium**	0.02	0.1153846	0.90218876
16	**Copper**	0.041	0.2061538	0.923305879
17	**Lead**	0.013	0.0554615	0.993885962
18	**Arsenic**	0.006	0.034375	1
19	**Total Chlorine**	0.03	0.0883333	0.62517745

A total of 8 parameters were found to have significant or strong positive correlation between the two variables for moderate level depth and leachate. Arsenic had the strongest correlation of 1. Copper, Chloride, and Nitrate had the second strongest correlation of 0.999, 0.993, and 0.992 respectively.

Pearson Coefficient of Correlation between moderate level water and Leachate

Sr. No	Parameters	Moderate level water	Leachate	Coefficient of Correlation
1	**pH**	7.31	8.82	0.971059796
2	**TDS**	509	18889.846	0.971280444
3	**Nitrate (NO3), Nitrogen**	3.2	26.23	0.99215043
4	**Chloride**	24.4	5504.9954	0.999961506

Sr. No	Parameters	Moderate level water	Leachate	Coefficient of Correlation
5	**Barium**	0.024	0.1091667	0.425016791
6	**Boron**	0.08	3.6909091	0.418734726
7	**Cadmium (Cd)**	0.01	0.063	0.405045966
8	**Cyanide**	0.01	0.1693333	0.393128384
9	**Mercury (Hg)**	0	0	0.382158346
10	**Nickel (Ni)**	0.001	0.3708333	0.356621517
11	**Selenium**	0.001	0	0.348139542
12	**Phenol**	0.01	0.3295	0.306232112
13	**Zinc (Zn)**	0.07	3.7730769	0.280324951
14	**Manganese (Mn)**	0.18	1.5566154	0.745970902
15	**Chromium**	0.021	0.1153846	0.919157446
16	**Copper**	0.16	0.2061538	0.993672394
17	**Lead**	0.01	0.0554615	0.921776373
18	**Arsenic**	0.01	0.034375	1
19	**Total Chlorine**	0.05	0.0883333	0.752163480

Pearson's Coefficient of correlation between leachate and deep level water values for physical parameters such as pH and TDS have a strong correlation of 0.97 with leachate. Among the chemical parameters Lead, manganese and Chloride have the strong correlation of 0.99, 0.98, and 0.99 respectively.

Pearson Coefficient of Correlation between Deep level water and Leachate

Sr. No	Parameters	Deep level water	Leachate	Coefficient of Correlation
1	**pH**	7.52	8.82	0.973672358
2	**TDS**	366	18889.846	0.974058462

Sr. No	Parameters	Deep level water	Leachate	Coefficient of Correlation
3	**Nitrate (NO3), Nitrogen**	3.43	26.23	0.988663897
4	**Chloride**	22	5504.9954	0.999997233
5	**Barium**	0	0.1091667	0.807402853
6	**Boron**	0.06	3.6909091	0.805751966
7	**Cadmium (Cd)**	0	0.063	0.64206515
8	**Cyanide**	0.004	0.1693333	0.636832703
9	**Mercury (Hg)**	0	0	0.631664925
10	**Nickel (Ni)**	0.0016	0.3708333	0.619685553
11	**Selenium**	0	0	0.637060214
12	**Phenol**	0	0.3295	0.631581131
13	**Zinc (Zn)**	0.03	3.7730769	0.728867226
14	**Manganese (Mn)**	0.034	1.5566154	0.879620681
15	**Chromium**	0.019	0.1153846	0.759429093
16	**Copper**	0.02	0.2061538	0.763674022
17	**Lead**	0.013	0.0554615	0.999922783
18	**Arsenic**	0.0083	0.034375	1
19	**Total Chlorine**	0.02	0.0883333	0.635725434

Conclusion:

This review article shows the versatility of techniques that can be used for the assessment of groundwater contamination around landfills. It proves that over the years the techniques have evolved to give an efficient method to deal with the problem of groundwater contamination. Around the world several techniques were used to confirm the leachate contamination in groundwater. The right choice for techniques can vary with the provision of resources and the type of landfill. There is still room for the development of this technique. As the world is progressing more and more towards technologies like using nanoparticles for solving problems – this could also be one dimension towards which this assessment can be carried out.

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Need of Proper National-Action-Plan Under Appropriate Legislation/ Regulations/ Technologies/ Funding to Achieve Pakistan's Sustainable Development Goals[1] Specifically Goal 6 And Its Target 6.3[2]

Engr. Abdul Qayyum[3]

1 Abstract

The Human Right to Water and Sanitation was recognized by the United Nations (UN) General Assembly in 2010[4]. It has been recognized in international law through human rights treaties, declarations and other standards. It is derived from the human right to an adequate standard of living. Pakistan also has constitutionally promised to follow/ implement UN MDGs / SDGs. There are 17-UN SDGs, each has targets and indicators. Target 6.3[5] is regarding water and sanitation[6]. Astonishingly target 6.3 (although acknowledged human right) is not included in National SDGs[7].

In Pakistan due to nonconformity of MDGs (2000-2015)/ SDGs (2015-2030), high population growth, unplanned increasing urbanization, inefficient irrigation practices, lack of appropriate technologies, indefensible water uses and their fragmented management, especially unacceptable water supply/ sanitation system and absence of proper evaluation of floods/ floodplains/ regulations, the surface/ underground water has almost contaminated (Fig 1). These facts, triggered with climate change impacts, are more and more depleting and contaminating Pakistan's both water sources, i.e. surface as well as underground water, and the water almost is injurious both to human and aquatic life. Only passing of Climate Act-2017[8], issuing of National Climate change Policy[9] and/ or mere owning Sustainable Deployment Goals[10] is not sufficient.

Pakistan's Policy makers should clearly understand that economic prosperity, sustainable development and environmental stewardship present an intertwined challenge that must be addressed with coordinated and consistent policies both in and across departments, ministers and nations. Pakistan's owned/ adopted UN Sustainable Development Goals (2015-2030), which, if after revisiting, are implemented; provide a clear/ achievable path way to economic prosperity, sustainable development and environmental stewardship.

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[1] *http://www.un.org.pk/pakistans-challenges-sustainable-development-goals-2015-2030/*
[2] *http://indicators.report/targets/*
[3] *Team Leader, Contracts/ Procurement/Structural Specialist Techno-Consult International (Pvt.) Ltd*
[4] *http://www.onwa.ca/upload/documents/un-water-as-a-human-right.pdf*
[5] *http://indicators.report/targets/*
[6] http://www.sdg6monitoring.org/indicators/target-63/
[7] *https://www.pc.gov.pk/uploads/report/National_SDGs_Framework_-_NEC_2018.pdf*
[8] *http://www.mocc.gov.pk/frmDetails.aspx*
[9] *http://www.gcisc.org.pk/National_Climate_Change_Policy_2012.pdf*
[10] *https://www.pc.gov.pk/uploads/report/National_SDGs_Framework_-_NEC_2018.pdf*

Keeping in view the extreme vulnerable, to economic prosperity, sustainable development and environmental stewardship, condition of Pakistan, the author, via PEC, through this paper requests the policy makers of Pakistan, to fulfill their commitment to UN/ Pakistani nation, to implement all the 17 SDG", so that the requisite prosperity, sustainable development and environmental stewardship is achieved to Pakistan. The paper will give special emphasis to target 6.3[11].

2 Introduction

a. World leaders through, the United Nations Millennium Declaration, containing eight Millennium Development Goals (MDG)[12], signed in September 2000, committed to combat poverty, hunger, disease, illiteracy, environmental degradation, and discrimination against women up to 2015. Further to enhance the theme, seventeen Sustainable Development Goals (SDGs) were introduced in 2015. Indeed (SDGs)[13] are successors to the 'Millennium Development Goals MDGs – September 2000. The MDGs were adopted in 2000 by governments to make global progress on poverty, education, health, hunger and the environment. The MDGs expired at the end of 2015. During 25-27 September 2015, the member states of the United Nations met in New York for the United Nations (UN) Summit on Sustainable Development and adopted the new global goals for sustainable development. Being the UN determined theme, the world leaders guaranteed their commitment to the new, '2015-2030 Agenda for Sustainable Development', encompassing 17 universal and transformative SDGs. The SDGs are a universal set of goals, targets and indicators and all UN member states are expected to use these to frame their development agendas, socio-economic policies, and actions towards low carbon pathways for the next 15 years, in order to achieve a sustainable world where 'no one is left behind' without compromising sustainability of the planet. These new seventeen (17) global goals are much broader and comprehensive than the outgoing MDGs, as they attempt to address all three dimensions of sustainable development- economic, social and environmental. The UN urged all the nations to rigorously follow/ implement these goals through a measurable dynamic action plan. The 17-Sustainable Development Goals for the period 2015-2030 are:

i. End poverty in all its forms everywhere.
ii. End hunger, achieve food security and improved nutrition, and promote sustainable agriculture.
iii. Ensure healthy lives and promote well-being for all at all ages.
iv. Ensure inclusive and equitable quality education and promote life-long learning opportunities for all.
v. Achieve gender equality and empower all women and girls.
vi. Ensure availability and sustainable management of water and sanitation for all.

[11] http://www.sdg6monitoring.org/indicators/target-63/
[12] *https://en.wikipedia.org/wiki/Millennium_Development_Goals*
[13] *http://www.lead.org.pk/lead/attachments/SDGFlyer_english.pdf*

vii. Ensure access to affordable, reliable, sustainable, and modern energy for all.
viii. Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all.
ix. Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation.
x. Reduce inequality within and among countries.
xi. Make cities and human settlements inclusive, safe, resilient and sustainable.
xii. Ensure sustainable consumption and production patterns.
xiii. Take urgent action to combat climate change and its impacts (in line with the United Nations Framework Convention on Climate Change).
xiv. Conserve and sustainably use the oceans, seas and marine resources for sustainable development.
xv. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.
xvi. Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels.
xvii. Strengthen the means of implementation and revitalize the global partnership for sustainable development.

Note: Each of the above goals for the sake of managing the 'Monitoring-Imperative' has its targets and then each target has its distinctive indicators.[14]

b. Owner-Ship

Parliament of Pakistan adopted[15] UN's sustainable development goals (SDGs) as its own national development goals in February 2016. Ministry of Planning internalized SDGs in its development framework well before formally signing in September 2015 and it embedded SDGs in Pakistan Vision 2025. Accordingly Ministry of Planning, Development and Reform, Government of Pakistan, established a coordination mechanism with the federation units and formulated a document in March - 2018 under the title, "Summary for the National Economic Council (NEC) Sustainable Development Goals (SDGS) National Framework". Unfortunately this, inter alia, does not contain target 6.3.

c. The above mentioned document (foot note 15) is well worded, but, due to some constraints including lack of due commitment, legal/ technical provisions, missing of some important targets/ indicators (e.g. target 6.3 and its indicators) and the absence of a dynamic action plan, is not giving the anticipated results, and consequently the nation is deprived of the following probable, rather calculated benefits:

[14] *http://indicators.report/targets/*
[15] *https://www.pc.gov.pk/uploads/report/National_SDGs_Framework_-_NEC_2018.pdf*

- Adequate water supply/ sanitation (worldwide acknowledged basic human right).
- Less global warming and thereby less climate effects.
- Improved public health and thereby lot of saving on health budget.
- Inexhaustible energy.
- Jobs and other economic benefits, especially for Pakistan it can be a battery for economic growth.
- Stable/ reasonably affordable energy prices.
- Reliability and resilience to the system.
- Improvement in ecosystem of Pakistan.
- Availability of clean water/ improvement in recharging of aquifers with clean water.
- Resilience against contamination/ vulnerability to urban costal/ non-costal urban cities.

3 Relevant Definitions

i. The World Health Organization (WHO) defines the term "sanitation" as follows[16]:

"Sanitation generally refers to the provision of facilities and services for the safe disposal of human urine and feces. The word 'sanitation' also refers to the maintenance of hygienic conditions, through services such as garbage collection and wastewater disposal."

Sanitation includes all four of these engineering infrastructure items (even though often only the first one is strongly associated with the term "sanitation"): Excreta management systems, wastewater management systems (included here are wastewater treatment plants), solid waste management systems, drainage systems for rainwater, also called storm water drainage.

There are some variations on the use of the term "sanitation" between countries. For example, hygiene promotion is seen by some as an integral part of sanitation. For this reason, the Water Supply and Sanitation Collaborative Council defines sanitation as "The collection, transport, treatment and disposal or reuse of human excreta, domestic wastewater and solid waste, and associated hygiene promotion".

Despite the fact that sanitation includes wastewater treatment, the two terms are often used side by side as "sanitation and wastewater management", and according to UNFCCC Rule Book:

ii. **Vulnerability**: the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of

[16] *https://www.who.int/topics/sanitation/en/*

climate change and variation to which a system is exposed to its sensitivity, and its adaptive capacity.

iii. **Adaptation**, in the simplest terms, refers to the actions that countries will need to take to respond to the impacts of climate change that are already happening, while at the same time preparing for future impacts. It refers to changes in processes, practices and structures that can reduce our vulnerability to climate change impacts, such as sea level rise or food insecurity. It also includes making the most of any beneficial opportunities associated with climate change, such as increased crop yields or longer growing seasons in some regions.

Adaptation solutions take many shapes and forms, depending on the unique context of a community, business, organization, or region. There is no 'one-size-fits-all-solution'-adaptation can range from building flood defenses, setting up early warning systems for cyclones and switching to drought-resistant crops, to redesigning communication systems, business operations and government policies. Many nations and communities are already taking steps to build resilient societies and economies, but far greater action and ambition will be needed to cost effectively manage the risks, both now and in the future.

iv. **Resilience:** the ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organization, and the capacity to adapt to stress and change.

v. **Climate Finance Fund[17]:** In accordance with the principle of "common but differentiated responsibility and respective capabilities" set out in the UNFCCC, developed country Parties are to provide financial resources to assist developing country Parties in implementing the objectives of the UNFCCC. The Paris Agreement reaffirms the obligations of developed countries, while for the first time also encouraging voluntary contributions by other Parties. Developed country Parties should also continue to take the lead in mobilizing climate finance from a wide variety of sources, instruments and channels, noting the significant role of public funds, through a variety of actions, including supporting country-driven strategies, and taking into account the needs and priorities of developing country Parties. Such mobilization of climate finance should represent a progression beyond previous efforts.

vi. **UN Agenda 2030:** The High-level Political Forum on Sustainable Development is the central UN platform for the follow-up and review of the 2030 Agenda for Sustainable Development adopted at the United Nations Sustainable Development Summit on 25 September 2015. Preamble. This Agenda is a plan of action for people, planet and prosperity.

[17] *https://unfccc.int/topics/climate-finance/the-big-picture/climate-finance-in-the-negotiations*

vii. UN Joint Fund for Agenda 2030[18]: The Joint Fund for 2030 Agenda is an institutional design feature that will enable a UN Development System at country level becoming more coherent, collaborative and efficient in supporting countries in achieving the purposes of 2030 Agenda. The overall strategic focus of the Joint Fund is to support national SDG policy and investments to accelerate and scale up SDG-progress at the national level, and to do so through joint policy and programme contributions of the UNCT's, under the leadership of the RC, and in line with UN Development System reforms.

4 SDG-6 is:

Ensure availability and sustainable management of water and sanitation for all, i.e. it emphasizes that the sustainable water resources are essential to human health, environmental sustainability and economic prosperity. This vital resource is under threat (especially in Pakistan[19]), making it crucial to address the challenges related to water, sanitation and hygiene for populations and water-related ecosystems. Currently, more than 2 billion people are affected by water stress, which will only increase with population growth and the effects of climate change. Achieving universal access to drinking water, sanitation, hygiene and ensuring that services are safely managed remain major challenges and meeting them are crucial to further progress in health, education and poverty eradication. All UN member countries, including Pakistan, have guaranteed/ promised through their constitutions/ legal framework that they will provide these facilities/ requirements to all their people by 2030.

Target 6.3 is read as, "By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, having the proportion of untreated wastewater and substantially increase recycling and safe reuse for all".

5 Present Threats to Pakistan & Practicalities in Pakistan

a. Threats

Although Pakistan owned UN SDGs, as its own SDGs and promised, section 2 (b) above, its systematical implementation, through progress measuring action plan, but on ground situation is worsening more and more. Presently Pakistan is indexed as:

i. The 7th most vulnerable country[20] to the impacts (droughts/ floods/ extreme vulnerability of costal areas etc.) of climate change.

ii. Pakistan is the seventh worst country in terms of access to basic sanitation[21] (target 6.3.2).

[18] *https://www.un.org/sustainabledevelopment/financing-for-development/*
[19] *https://www.dawn.com/news/1372293*
[20] *https://germanwatch.org/en/cri*
[21] *https://www.dawn.com/news/1372293*

iii. Pakistan is the 10th country with the lowest[22] access to clean water(target 6.3.1), and;

iv. According to a recent report by the International Monetary Fund (IMF), Pakistan ranks third in the world among countries facing acute water shortage[23]. Reports by the United Nations Development Programme (UNDP) and the Pakistan Council of Research in Water Resources (PCRWR) also warn the authorities that the South Asian country will reach absolute water scarcity by 2025.

v. Researchers predict that Pakistan is on its way to becoming the most water-stressed country in the region by the year 2040[24].

b. Practicalities in Pakistan

Pakistan's high population growth, unplanned increasing urbanization, inefficient irrigation practices, lack of appropriate technologies, indefensible water uses and their fragmented management, especially unacceptable water supply/ sanitation system and absence of proper evaluation of floods/ floodplains/ regulations has already made the surface/ underground water contaminated. Untreated waste water, both domestic and industry, when enters in adjacent nullahs, streams, canals and/ or rivers, heavily pollutes all type of recipients (Fig 1, 2 B), i.e. in Pakistan, Fig 2(B), no recycling, clear violation of indicator 6.3.1 is being exercised. Consequently, Pakistan's both water sources, surface as well as underground, are not only depleting but also getting more and more contaminated and the water almost is injurious both to human and aquatic life. The dual problems of clean water shortage (Indicator 6.3.2) and untreated waste water (target 6.3.1) overflow triggered with anticipated effects of climate change (long droughts & subsequent floods) are serious, present and future, threats to Pakistan and this problem is hurting the public wellbeing/ economics/ environment even more by the passage of time. There is thus an urgent need for a focused overview of the water quality/supply and wastewater treatment sector in Pakistan, i.e. Pakistan's efforts and commitment for SDG and specifically to improve water/ sanitation, being the acknowledged basic human right, need to be conceived / planned / implemented through a doable/ measurable action plan, having ambitions, desired by UN target 6.3.

6 Acceptable, based on good Engineering/ Management in the world.

During MDGs period (2000-2015), almost all countries carried out[25] "Vision 2030 Studies - the Resilience of Water Supply and Sanitation in the Face of Climate Change and implemented the studies accordingly and during SDGs period (2015-2030), the countries are still studying new feasibilities and/

[22] *https://www.thenews.com.pk/print/418698-pakistan-third-amongst-countries-facing-water-shortages*
[23] *https://www.thenews.com.pk/print/418698-pakistan-third-amongst-countries-facing-water-shortages*
[24] *https://www.dw.com/en/water-crisis-why-is-pakistan-running-dry/a-44110280*
[25] *https://www.who.int/water_sanitation_health/vision_2030_9789241598422.pdf?ua*

implementing the findings of the then studies, including those required via SDG. It is concluded that the range of challenges related to climate change, triggered with water supply and wastewater treatment sector is very great. Its depending on geography, economics, administrative/ financial capacity, and demography of different cities, varies to some extent. Many of the challenges are general, and some are more specific to particular countries/ cities. SDGs provide clear/ achievable path way to economic prosperity, sustainable development and environmental stewardship.

Typical acceptable water-use cycle (UN target 6.3/ indicator 6.3.1-minimizing release of hazardous chemicals and materials etc. by recycling and safe reuse globally) for cities[26] and other developed supplies is shown in Fig. 2 (A). It depicts a ladder regarding storage, supply, distribution, and wastewater treatment and disposal systems that provide organized water services to established urban areas and in line with indicator 6.3.1. Contrary to this, the practice in Pakistan is shown in Fig 2(B), no recycling and thereby injurious both to human and aquatic life.

Typical components of urban/ coastal urban water sector as impacted by climate change[27] are shown in Fig. 3. It guides the policy makers regarding the steps/ precautions, to be considered, while formulating their planning SDG, against climate change. It is prudent to mention that, otherwise, almost 1000 KM long costal belt, of Pakistan, is under threat regarding ingress of sea water and thereby the quality of water and vulnerability of delta delta levees.

Pakistan's rivers/ streams, requiring suitable legislation for floodplains/ flood management/ regulations, under appropriate return periods to accommodate anticipated floods and then recharging the aquifers with clean water, are shown in Fig. 4. Special emphasis is requested for the three eastern three rivers.

7 Impacts on Pakistan

Sections 5/6 in view and acknowledging that Pakistan has both costal-urban and non-costal-urban cities triggered with no provision of sanitation, the following are the impacts:

i. Glacier melt in the Himalayas, due to expected rise in temperature, is projected to increase flooding, which in turn will affect already under stressed water resources. This will be followed by decreased river flows over time as glaciers recede.
ii. Freshwater availability is also projected to decrease further which will lead to biodiversity loss and reduce availability of freshwater for the population.

[26] http://uccrn.org/files/2014/02/ARC3-Chapter-5.pdf
[27] *https://www.researchgate.net/publication/317316333_Managing_consequences_of_climate-driven_species_redistribution_requires_integration_of_ecology_conservation_and_social_science*

iii. Coastal areas bordering the Arabian[28] Sea in the south of Pakistan will be at greatest risk due to increased flooding from the sea and in some cases, the rivers.

iv. Being a predominantly agriculture economy, climate change is estimated to decrease crop yields in Pakistan which in turn will affect livelihoods and food production. Combining the decreased yields with the current rapid population growth and poor urbanization in the country, the risk of hunger and food security will raise high.

v. Widespread morbidity and mortality due to diseases primarily associated with floods and droughts are expected to rise. Increases in coastal water temperatures would intensify the abundance of cholera.

vi. The impact of climate change will also aggravate the existing social inequalities of resource use and intensify social factors leading to instability, conflicts, displacement of people and changes in migration patterns.

vii. Unattended floodplains of all rivers in Pakistan, especially the three western rivers can cause huge disasters.

viii. According to Global Climate Risk Index (CRI-2018)[29], Pakistan ranks at 7th position (period 1997-2016) among the most adversely affected countries by Climate Change. Inter alia, only financial loss, leaving the residual losses, was of the tune of US$ 3816.82 Million.

ix. Whole nation is extremely vulnerable to water borne deceases[30] causing the health budget to many folds.

8 Managing the 'Monitoring Imperative' in the Context of SDG Target 6.3 on proportion of good ambient water quality (indicator 6.3.2) and proportion of Wastewater, safely treated (indicator 6.3.1)

i. General

The UN 2030 Agenda has 17 SDGs underpinned by 169 targets that are described by >230 indicators with associated methods. Pakistan has owned/ adopted[31] all SDG/ targets and indicators as its own national SDG. There seems some inconsistency between the national targets/ indicators and UN SDG 2030. National SDGs does not contain, inter alia, target 6.3/ its indicators (6.3.1 & 6.3.2), although included in UN SDGs/ UN Agenda 2030. However, this overall system (targets/ indicators) is aspirational and most of the targets do not have numerical values for the globe. The 2030 Agenda states that it is the responsibility of countries to contextualize the Goals and Targets for their own purpose and that it is implementation at a country level that will be the key to success of the SDGs. Targets are defined as aspirational and global, with

[28] *https://www.researchgate.net/profile/Asif_Inam/publication/266838504_THE_IMPACT_OF_SEA_LEVEL_RISE_ON_PAKISTAN'S_COASTAL_ZONES-_IN_A_CLIMATE_CHANGE_SCENARIO/links/543cecad0cf2c432f7422e21.pdf*

[29] *https://germanwatch.org/en/cri*

[30] *https://www.pureitwater.com/PK/waterborne-diseases*

[31] *https://www.pc.gov.pk/uploads/report/National_SDGs_Framework_-_NEC_2018.pdf*

each government setting its own national Targets guided by the global level of ambition but taking into account national circumstances. The Sustainable Development Goals (SDGs) pose many challenges to the nations that adopted them in 2015. For all SDGs, a fundamental challenge is how to assess the progress being made with respect to both the current and desired situations. Thus the definition of targets and indicators is an integral part of the development of the SDGs and their implementation will be accompanied by extensive monitoring campaigns. The SDGs and their accompanying targets are seen as "a management tool to help countries develop implementation strategies and allocate resources accordingly, as well as a report card to measure progress towards sustainable development and help ensure the accountability of all stakeholders for achieving the SDGs".

ii. Monitoring in the Context of Target 6.3[32]

Target 6.3 has the aim to improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and increasing recycling and safe reuse by 2030 for all. Progress toward this target will be assessed on the basis of two indicators: 6.3.1, the proportion of wastewater safely treated, and 6.3.2, the proportion of water bodies with good ambient water quality.

Indeed target 6.3 is an extension of the Millennium Development Goal (MDG) target 10 (Halve, by 2015, the proportion of people without sustainable access to safe drinking water and basic sanitation), which was defined under Goal 7, Ensure environmental sustainability. This extension recognizes that access to basic sanitation (i.e., a toilet) is only one step in a chain that includes containment, emptying, transport, treatment and reuse/ disposal. Nonetheless, the experience with monitoring for this MDG target and the capacity for data management that has been developed[33] provides a basis for acquiring and handling monitoring data for indicator 6.3.1, proportion of waste water safely treated, as well as for indicator 6.3.2, proportion of bodies of water with good ambient water quality.

iii. Monitoring of indicator 6.3.1:

Proportion of wastewater generated by households and by economic activities which are safely treated based on treatment ladders as defined by the SEEA. Managing point and diffusing sources of pollutants (target 6.3.1-sanitation) presents quite different needs and challenges with regard to water quality monitoring (target 6.3.2 water quality availability). For example, the identification of waste water treatment plant (WWTPs) for upgrading could be made on the basis of population density, dilution in receiving waters and

[32] *https://www.mdpi.com/2071-1050/9/9/1572/htm*
[33] *https://www.wssinfo.org/*

proximity to drinking water intakes and the success of implementing measures can be assessed by reduction in the toxicity of WWTP effluent[34].

In contrast, the inputs of diffuse sources can (by definition) only be tracked by assessing the quality of receiving waters. Source attribution, however, requires detailed attention to the pathways by which pollutants travel from the source area(s) to the receiving water as well as other variables (e.g., application rates, rainfall) that may be highly variable in space and time. Intensive monitoring campaigns have demonstrated substantial temporal variability (i.e., peak concentrations) especially for streams and small rivers that are unlikely to be captured in conventional water quality monitoring programs. In addition, such conventional programs address known target analyses and are insufficient to track novel or emerging contaminants. The precautionary principle provides justification for ancillary, exploratory monitoring.

iv. Monitoring the Indicator 6.3.2[35]

The indicator (6.3.2) is defined as the proportion of water bodies in the country that have good ambient water quality. Ambient water quality refers to natural, untreated water in rivers, lakes and ground waters and represents a combination of natural influences together with the impacts of all anthropogenic activities. The document of foot note (32) provides the Monitoring of the Indicator 6.3.2. It summaries background information and context for the implementation of indicator 6.3.2. It outlines the requirements and steps for Level-1 reporting of the methodology with guidance on each step, and also for Level-2 monitoring for countries with a greater water quality monitoring capacity.

v. Concerns/ Obstacles/ Constraints to National SDGs

a. Efforts to achieve SDGs could be hindered by number of internal and external obstacles like ever increasing population and consequent pressures on resources affecting economic growth of the country. War on terror and socio-political disturbances have also extracted their toll on human development. Cooperation from global community has largely been inadequate and impacts of global economic recession have also slowed down the pace of progress on SDGs.

b. While SDGs are widely regarded as the best vehicle to address poverty alleviation in Pakistan, the country has a long way to go on the path of sustainable development (foot note 29). A major challenge in monitoring actual performance is availability of data to monitor progress. It was noted that of the 230 indicators, reliable data was not available on at least one fourth. Data on 45 percent indicators was available in scattered form but was not being analyzed or computed.

[34] *https://www.ncbi.nlm.nih.gov/pubmed/24915506*
[35] *http://www.unwater.org/publications/step-step-methodology-monitoring-water-quality-6-3-2/*

c. Another problem at the grass root level is the absence of administrative and financial powers of the district governments, despite devolution from federal government to provincial governments. A significant challenge is how to create awareness and knowledge about SDGs, how critical the SDG goals are to uplifting the lives of the people and how to make the process sustainable.

d. In formulating these prioritized SDGs resources and institutional constraints have been kept in view. That is why, some of the nationally adopted Goals and Targets are lower than the Global Goals and Targets (e.g. targets/ indicators) of SDG 6. Even these lower goals will be realized only with strong political, policy and institutional support. The specific policy support required for each goal has been indicated in the Annex (of foot note 37). It will also require effective collaboration with non-government sector and partnerships with community organizations and private sector to achieve these targets. An enabling environment has to be developed by all tiers of government.

e. The national SDGs need revisit due to inappropriate prioritization, missing of some important/ urgent targets/ indicators.

f. Development and implementation of goals/ targets/ indicators, in national SDGs, is not ensured on the requisite integrated manner which would guarantee across the 3-dimensions of sustainability, across all sectors of the economy and society, and from the local to global level.

9 Conclusion

Our national SDGs frame work requires revisit. UN Agenda 2030[36] for Sustainable Development provides a global blueprint for dignity, peace and prosperity for people and the planet, now and in the future. The nations spent a few years into the Agenda, are experiencing a pleasant change in civil society, private sector, and governments are translating this shared vision into national development plans and strategies. Total goals are 17, each has its targets/ indicators to implement/ monitor the progress. Every Goal/ target/ indicator matters. Goal 6 is to ensure access to safe water sources and sanitation for all (worldwide, including Pakistan, acknowledged basic human right). The cost, if we do not correct the problem, is high both for the people and for the economy. Pakistan needs an action plan on priority bases so that the anticipated, rather calculated, benefits (section 2 c- above) are reached to the nation at the earliest.

10 Recommendations

United Nation's 17 Sustainable Development Goals[37] are a call for action by all countries – poor, rich and middle-income – to promote prosperity while

[36] *https://www.un.org/sustainabledevelopment/sustainable-development-goals/*
[37] *https://www.un.org/sustainabledevelopment/*

protecting the planet. They recognize that ending poverty must go hand-in-hand with strategies that build economic growth and address a range of social needs including education, health, social protection, and job opportunities, while tackling climate change and environmental protection. Pakistan's policy makers (Federation including Federation-Units, technical/ legal experts, law and peace enforcing agencies) may be circulated the UN Agenda-2030 and the corresponding National Sustainable Development Goals framework[38], and then comprehensive discussions regarding:

i. Relative Priority of SDGs for Pakistan and then adequate selection of targets/indicators.

ii. Discussion on each goal / target / indicator (of both SDGs) and inclusion in National SDGs, if some target/ indicator is missing in National SDGs.

iii. Threats, to Pakistan, mentioned in sections-6 are more significant than terrorism, faced by Pakistan during the last few decades, therefore, let us consider the constitution of a National- Action- Plan (2019-2030) to combat the threats of section 6, including the promotion of prosperity, eradication of poverty, addressing a range of social needs including education, health, social protection and job opportunities, while tracking climate change and environmental protection, through the implementation of integrated program of implementing SDGs, in Pakistan.

11 Important note[39] [40]

As actions / activities, required to implement SDGs come under the definition of "Adaptation" defined by UNFCCC/ UN Agenda 2030, therefore, as permissible, financing, for development under SDGs, if the feasibilities to implement SDGs are worked out in a systematic, competent. Efficient, transparent and integrated manner, can easily be prayed from the UNFCCC/ UNSDG relevant funds.

[38] *https://www.pc.gov.pk/uploads/report/National_SDGs_Framework_-_NEC_2018.pdf*
[39] *https://unfccc.int/topics/climate-finance/the-big-picture/climate-finance-in-the-negotiations*
[40] *https://www.un.org/sustainabledevelopment/financing-for-development/*

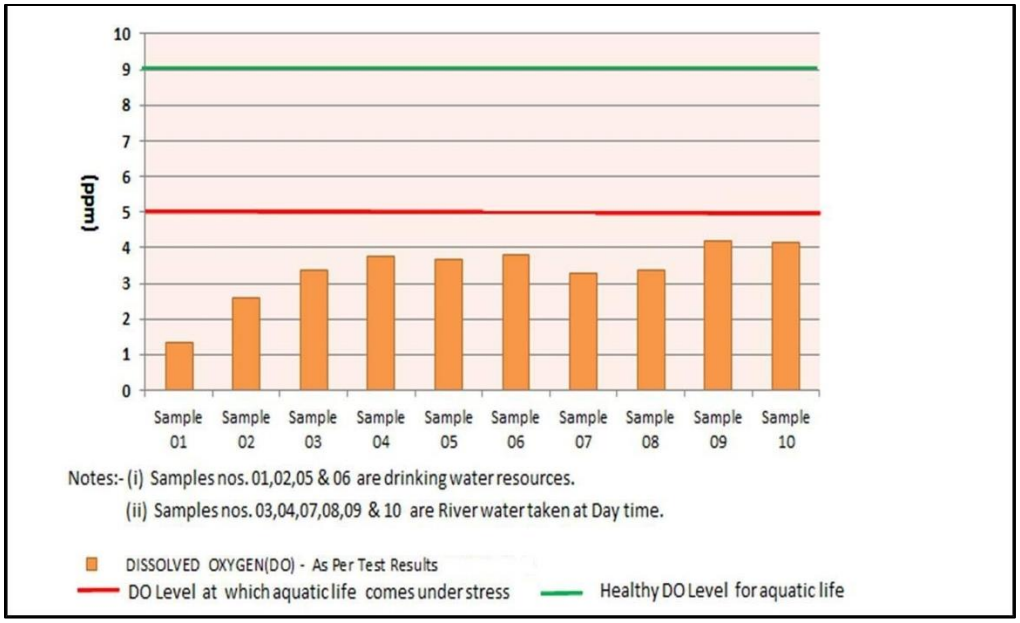


Figure – 1: Dissolved Oxygen (DO) of water sample dated April 30-2018, River Punch District Kotli, AJK (General status of water quality in Pakistan, when rivers pass through cities)

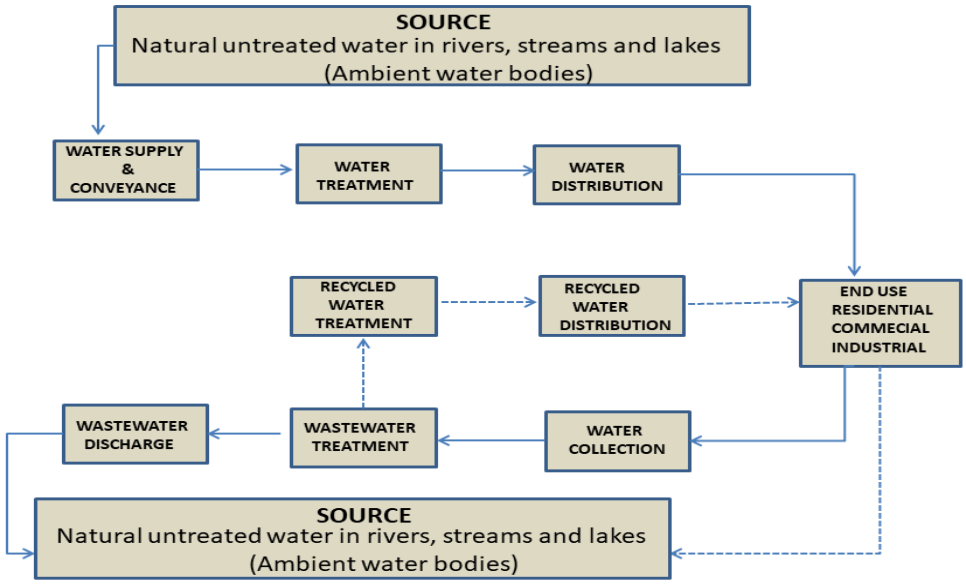


Figure – 2 (A): Typical water-use cycle for cities and other developed supplies; dashed arrows indicate pathways that sometimes occur

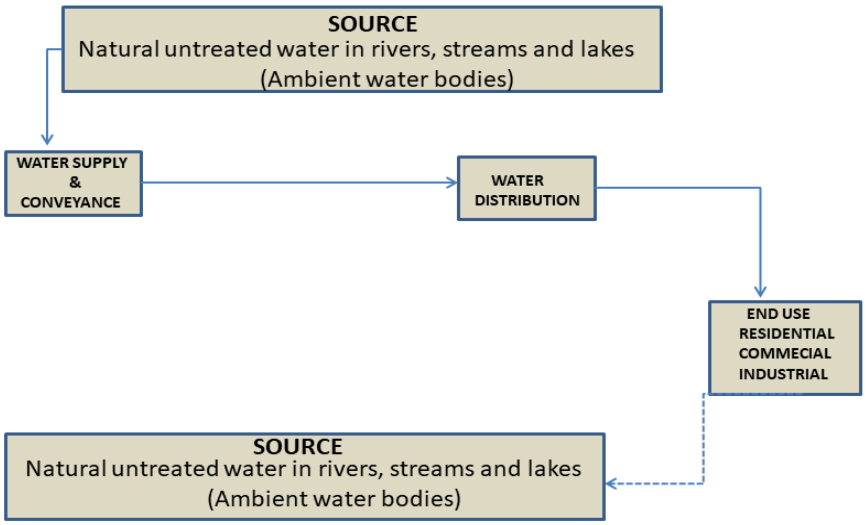


Figure – 2 (B): Typical water-use cycle for cities and other developed supplies; in Pakistan.

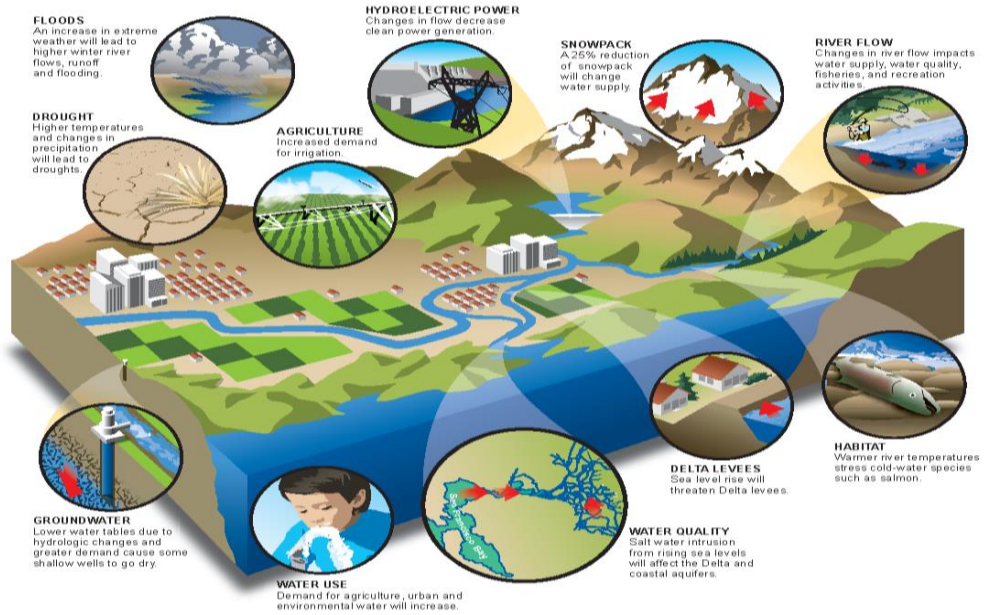


Figure – 3: Diagram showing the typical components of non-coastal urban/ coastal urban water sector as impacted by climate change

Figure 4 : Diagram showing natural untreated water bodies (Rivers,streams and lakes) , which require special attention of policy makers of Pakistan to manage appropriate floodplain under appropriate legislation –Indicated in 6.3.2



S.No.	River	Sources of water	Details
1	Indus River	Sênggê Zangbo	At Tibetan Plateau The Tibetan Plateau lies between the Himalayan range to the south and the Taklamakan Desert to the north.
2	Jhelum River	Verinag Spring	At Pir Panjal Range is a group of mountains in the Inner Himalayan region, running from east-southeast to west-northwest across the Indian
3	Sutlej River	Mount Kailash	Himalayas
4	Chenab River	Bara-lacha la	Himalayas
5	Ravi River	Chamba district	Chamba district of Himachal Pradesh, India
6	Kabul River	Sanglakh Range	Sanglakh Range is an offshoot of the Hindukush just west of Kabul
7	Gomal River	Katawaz Region	is a town in and administrative seat of Zarghun Shar District, Paktika Province, in eastern Afghanistan.
8	Neelum River	Vishansar Lake	Jammu and Kashmir, India.
9	Swat River	Hindu Kush Mountains	central Afghanistan to northern Pakistan
10	Zhob River	hseen Valley(Tsai Mehtarzai	Balochistan
11	Soan River	Bun Village	foothills of Patriata and Murree.
12	Gilgit River	Shandur lake	Gilgit-Baltistan
13	Panjnad River	Chenab River, Sutlej, Jhelum	Punjab
14	Kunar River	Hindu Kush Mountains	central Afghanistan to northern Pakistan
15	Hunza River	Kilik and Khunjerab nalat(fed by glaciers)	Gilgit-Baltistan
16	Dasht River	Mirani Dam	south of the Central Makran Range in Kech District in Balochistan
17	Shyok River	Rimo Glacier	One of the tongues of Siachen Glacier
18	Hub River	Pab Range	south eastern Balochistan
19	Kurram River	0 km southeast of Gardez, Pak	Afghanistan
20	Kunhar River	Lulusar Lake	Kaghan Valley.
21	Panjkora River	Hindu Kush Mountains	central Afghanistan to northern Pakistan
22	Gambila River	ies in the hills six miles south	eastern Afghanistan
23	aggar-Hatia R	hivalik Hills, Himachal Prade	foothills of the Himalayas
24	Rupal River	Rupal Glacier	northern Pakistan
25	Lyari River	Drainage basin	North east of karachi
26	Tawi River	Kali Kundi glacier	Bhaderwah in Doda district of jammu and kashmir
27	Suru River	Panzella glacier	Kargil district of Jammu and Kashmi
28	Poonch River	facing foothills of Pir Panjal	south of Jammu and Kashmir
29	Shigar River	khoro Glacier and Biafo Glac	Gilgit-Baltistan
30	Neelum River	Vishansar Lake	Ganderbal, Kashmir valley
31	Dori River	s tributary of the Helmand Ri	Kandahar Province in Afghanistan
32	Korang River	Murree Hills	Murree
33	Rakshan River	doki pass, south west of Shire	District Washuk, Balochistan, Pakistan.
34	Braldu River	Baltoro Glacier, Biafo Glacier	Gilgit-Baltistan
35	Haro River	Murree Hills	Murree
36	Bara river	Tirah Valley	Bara Tehsil, Khyber Agency.
37	Hispar River	Hispar Glacier	In the Karakoram mountains of Gilgit-Baltistan
38	River Jindi	hills of Malakand Agency	district of Charsadda, in Khyber-Pakhtunkhwa
39	Kundar River	Sulaiman Mountains	Balochistan

Figure – 4

Annex - 1

Floods in Pakistan

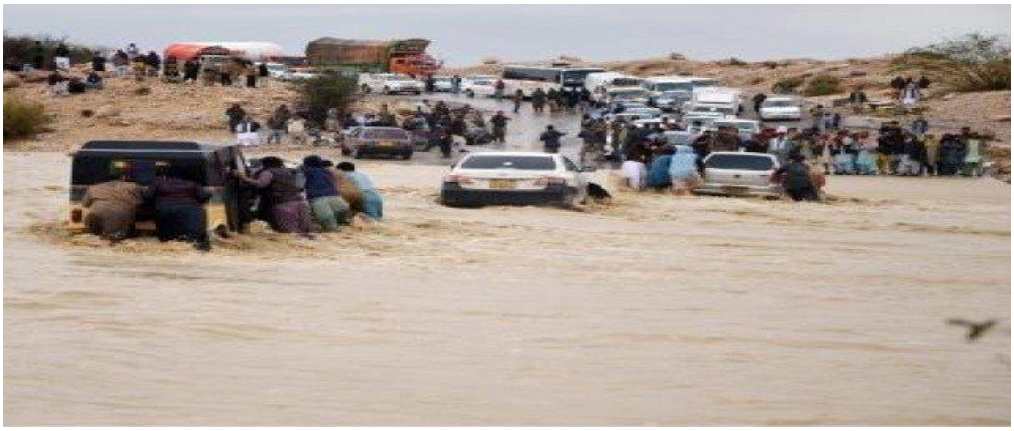












WATER QUALITY ASSESSMENT OF RAWAL DAM WITH SPECIAL CONSIDERATION TO CHATTAR, MURREE STREAM

By

Hamza Bin Riaz, Imran Hashmi[1]

Abstract

Rawal Dam being the only water reservoir of Rawalpindi and Islamabad, serves the water needs of millions of people for their domestic and drinking usage. There is a serious need for appropriate water quality monitoring for future planning and management of water resource. Rawal Dam depends on number of streams and river for its replenishing, one being the Chattar Stream, located near the Murree hill station, it falls into the Korang river, which flows directly into the Rawal Dam, thus making a huge portion of the water reserved in it, thus water quality assessment of the Chattar-stream is necessary. The water quality parameters of the stream were assessed, for which nine grab samples were collected from each of its two sub divisions; the small and the large one. The physico-chemical parameters were assessed using standard protocols, these include pH, Temperature, Turbidity, Electrical Conductivity (EC), Total Dissolved Solid (TDS), Dissolved Oxygen (DO), Hardness, Alkalinity, Chemical Oxygen Demand (COD), Nitrate, Nitrite, Total Kjeldahl Nitrogen (TKN) and Phosphate, whereas microbiological parameter assessed was *Escherichia coli* by (MPN) most probable number technique. The study reveals that all the parameters were within the WHO permissible limits. The presence of organic matter, waste water intrusion was also obvious as reflected by COD, Nitrate, Nitrite and Total Kjeldahl Nitrogen. Presence of *Escherichia coli* in almost all the samples implies the deteriorating quality of water in the stream.

1. Introduction

Water, essential for existence and survival of life, is highly susceptible to organic, inorganic and biological contamination. Lakes are an essential source of freshwater for human populations among freshwater entities, Physicochemical and microbiological characteristics of surface water of lakes are generally determined by the climatic, geo-morphological, and geochemical conditions. Unpredictability in water quality depends on surrounding vegetation, and land-use activities in the catchment basin (Hanh *et al*., 2010). Deterioration of lake watersheds has adverse effects on aquatic ecosystems and ecological structure and functioning of lakes is highly dependent on the spatial and temporal heterogeneity of limnological characteristics. Water-level variability changes ecosystem development, affecting nutrient flows, metabolism, and decomposition and interactions between biological

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organisms (Qadir & Malik, 2009; Sánchez-Carrillo & Álvarez-Cobelas, 2001). Deterioration of water quality is one of the challenges for restoration and management of lake systems (Sharpley *et al*., 1994), and due to its impacts on social, economic, health, and other aspects, has been recognized as a problem of serious concern at local, regional, and global level (Malik & Zeb, 2009).

In Pakistan, most of the people do not have access to clean drinking water. Human related activities and natural processes have strong influence on ecological integrity of ecosystem as well as on quality of fresh water (Qadir *et al*. 2008). 56 percent of total population of Pakistan enjoys safe drinking water as reported by Bureau of statistics. The water bodies are contaminated due to the discharge of domestic and industrial wastewater (approx. 4 Million Acre Feet (MAF) per year. Faulty drainage system accompanied by poor supply lines result in the supply of unsafe drinking water to households (Mohsin *et al*. 2013).

In Pakistan due to rapid industrialization, lakes and reservoirs are facing severe deterioration of surface water quality which ultimately affects human health. Most of non-biodegradable contaminants are directly released in to the streams without any prior treatment. For the past few decades, the magnitude of surface water pollution continues to increase day by day, and lake eco-system are facing many problems such as impairment of water quality and over fishing. Rawal Lake Reservoir is known for its ecological significance, situated in the Margalla Hills National Park (Malik & Zeb, 2009). Rawalpindi, being used also for outdoor recreation
activities such as water sports, boating, and fishing. It has 2,300 m3/s discharge capacity, covers an area of 8.8 km2 with maximum depth of 31 m. The lake reservoir is facing deterioration of its water quality due to surface runoff, agricultural and human settlements in Bara-Kahu, and Noorpur Shahan Villages and the Diplomatic Enclave, Islamabad, poultry waste, recreational use of motorboats, car-wash activities along its banks, untreated effluent discharged into its feeding streams .i.e. Rumli, Shahdra, Korung, and University Streams, and shoreline banks which fall into the reservoir. There is no treatment plant, and raw sewage and municipal waste are discharged directly into the natural streams which feed Rawal Lake Reservoir. There are reports on decline in fish yield and high level of heavy-metal contaminants in recent years. The aims of the present study is to monitor the water of Rawal dam with special consideration to Murree, Chattar Stream which ultimately becomes a part of Korang River.

2. Materials and Methods

2.1 Study area

Sampling of water is the most important part of the water quality analysis. The results obtained, using the most accurate analysis technique, will be misleading, if the samples were not true representative of the water to be tested.

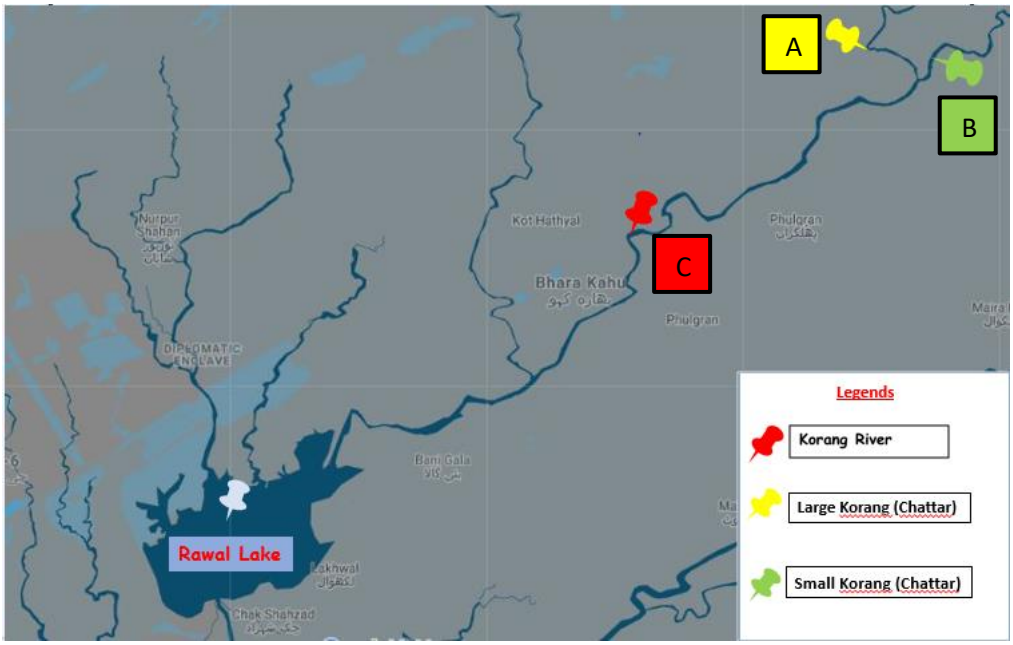


Figure 2.1 Sampling points (Chattar Stream)

An intensive program was set up to collect water samples at certain critical locations along the Murree, Chattar Stream and its tributaries categorize as small korang and large korang as given in Table 1. The map showing the location of sampling points is given by Fig.2.1. The water samples were collected in white glass bottles having well-fitted stoppers.

Sr no.	Points	Location	Coordinates
A	Large Korang, Chattar, Murree Stream	Up - Stream	33.782413, 73.2435
		Mid - Stream	33.77866, 73.23714
		Down - Stream	33.77181, 73.23907
B	Small Korang, Chattar, Murree Stream	Up - Stream	33.78986, 73.27947
		Mid - Stream	33.78636, 73.27213
		Down - Stream	33.76906, 73.24491
C	Korang River	Main River	33.71999, 73.16293

Table-1: Location of sampling points

2.2 Analysis

Sampling:

To study the water quality, auto-claved sampling bottle of 500ml was filled completely from each sampling site mentioned above for the determination of water quality.

Physico-chemical and Microbiological Analysis:

All the physico-chemical and biological parameters of water were determined as suggested by American Public Health Association (APHA, 2017). Table: 2 characterizes the equipment and methods used for various physicochemical parameters.

Parameters	Units	Instruments used	Method of analysis	Methodology
pH	-	pH meter (HACH 156)	Potentiometric method	**APHA, 2017**
Temperature	˚C	HACH session 1	Laboratory method	
Conductivity	(µS/cm)	Conductivity meter (Ino Lab 720)	Potentiometric method	
Total dissolved solids	(mg/L)	Conductivity meter (Ino Lab 720)	Potentiometric method	
Turbidity	(NTU)	Turbidity meter (HACH 2100 P)	Laboratory method	
DO	(mg/L)	DOmeter (HACH 156)	Potentiometric method	
Hardness	(mg/L)	Titration Method	Laboratory method	
Alkalinity	(mg/L)	Titration Method	Laboratory method	
NO_3-N	(mg/L)	Spectrophotometer	Laboratory method	
NO_2-N	(mg/L)	Spectrophotometer	Laboratory method	
Total Kjeldahl Nitrogen	(mg/L)	Kjeldahl Assembly	Laboratory method	
Phosphate	(mg/L)	Spectrophotometer	Laboratory method	
Chemical oxygen demand	(mg/L)	Through titration	Closed reflux method	

Table-2 Physico-chemical Parameters

3. Results and Discussion

The aim and objective of this study is to evaluate the intensity of contaminants by identifying different sources of pollution. Mean values of all physico-chemical parameters were shown in **Table-3**

Parameter	Units	Mean Value (Min-Max)	WHO limits
pH	----	8 (7.9 - 8.4)	6.5-8.5
Temperature	°C	17.9 (18.86 - 19.3.3)	Ambient
Electrical Conductivity	µS/cm	863 (857 - 864)	750
Turbidity	NTU	24.43 (19.5 - 24)	<5
TDS	mg/l	431(427 - 445)	<1000

Parameter	Units	Mean Value (Min-Max)	WHO limits
Dissolved Oxygen	mg/l	5.1 (2.8 – 5.9)	--
Alkalinity	mg/l	317.66 (300 -340)	<500
Hardness	mg/l	349 (328 -376)	<100
Nitrate	mg/l	9.1 (3.1- 9.3)	10
Nitrite	mg/l	0.7 (0.2 -0.9)	3
Phosphate	mg/l	7.9 (3 - 9.2)	0.3
Chemical Oxygen Demand	mg/l	118.2 (15 - 120)	--
Total Kjeldahl Nitrogen	mg/l	10.1 (2 – 10.9)	0.5

Table-3: Mean Values Physico-chemical parameters

The average temperature of selected sampling sites was shown in Figure 3.1. On the average, almost all sampling sites temperature remains constant.

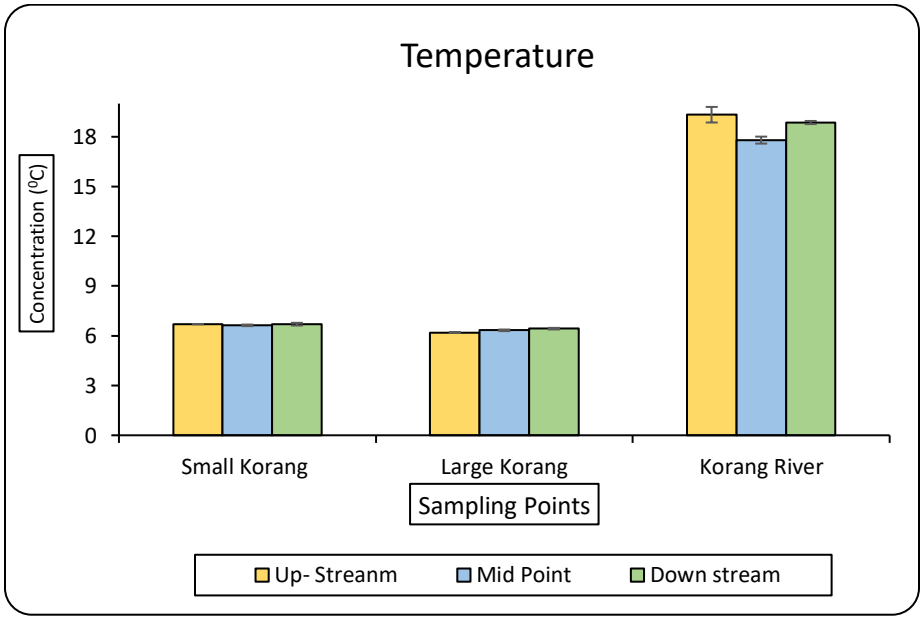


Figure-3.1: Average temperature at selected sites

The pH value measured at selected sites during field analysis are shown in Figure 3.2. The acceptable pH range for drinking water according to WHO guidelines is 6.5-8.5 and all the water samples were within this range.

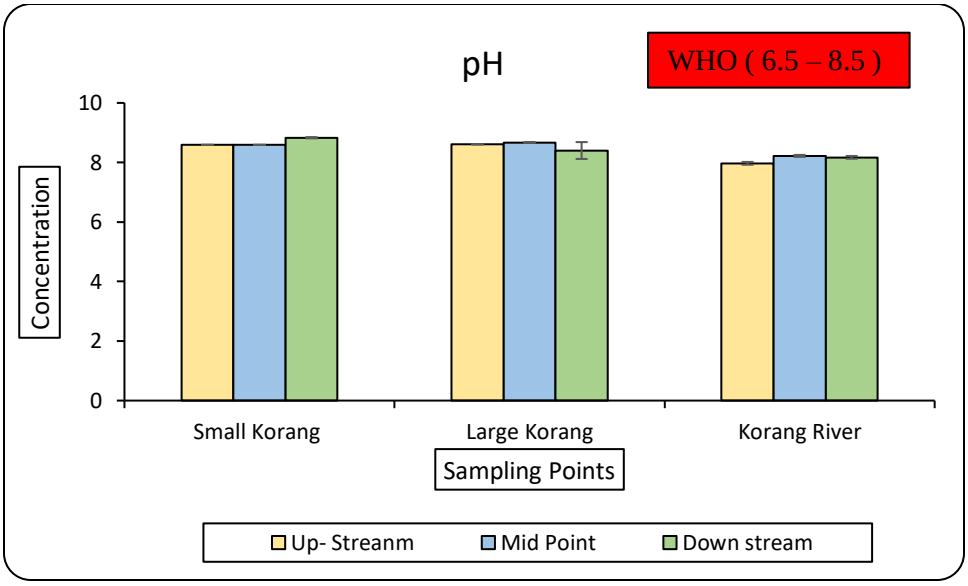


Figure-3.2: Average pH at selected sites

The Electrical Conductivity of all selected sampling sites were within WHO permissible limits except Korang river which is due to direct discharge of industrial waste in to the river as shown in Figure 3.3.

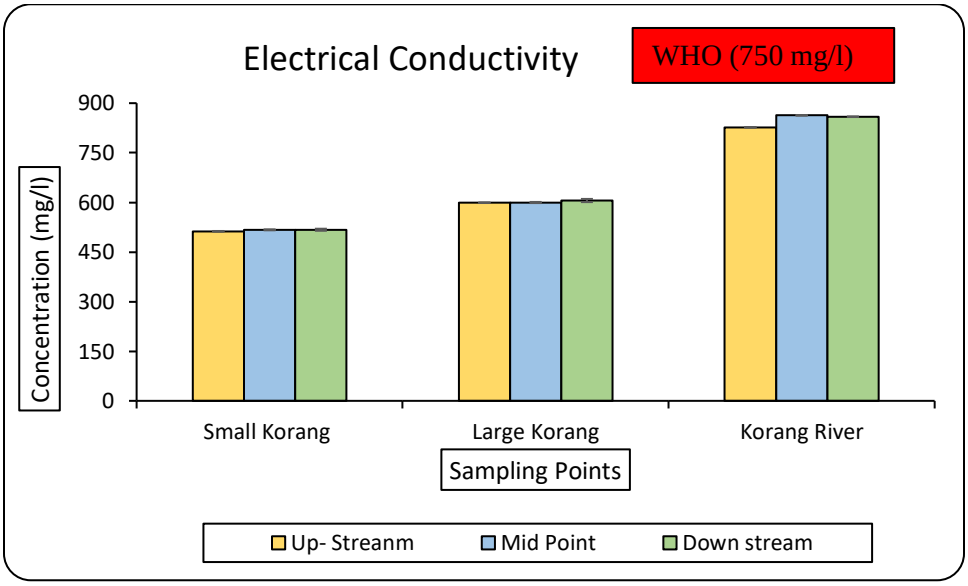


Figure-3.3: Average Electrical Conductivity at selected sites

TDS values are the measure of soluble salts in the water and have a linear relationship with electrical conductivity. All the recorded values of TDS were well within WHO permissible limits as shown in Figure 3.4.

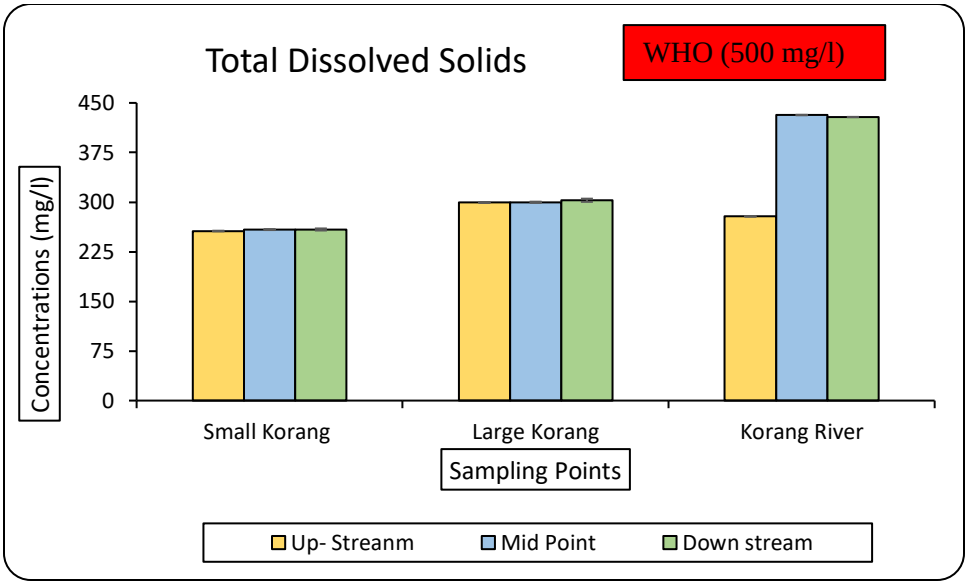


Figure-3.4: Average TDS at selected sites

Hardness is the total amount of polyvalent cations especially calcium and magnesium in the water and is measured in mg/l as $CaCO_3$. Almost all the samples cross WHO permissible limits which is due to intrusion of domestic waste water and human waste into the stream as shown in Figure 3.5.

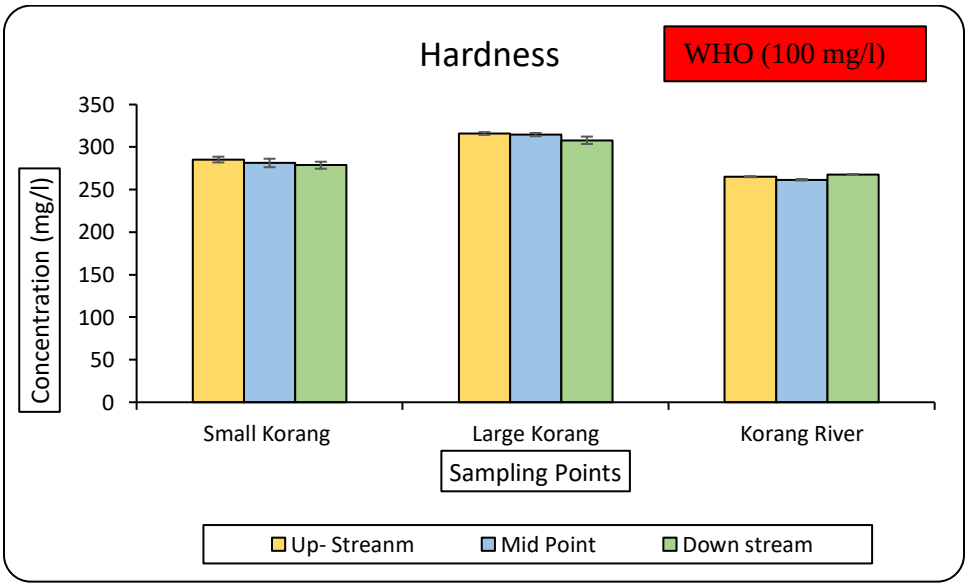


Figure-3.5: Average Hardness at selected sites

Dissolved oxygen in almost all streams ranges from 2.9 – 5.5 mg/L with an average of 5.1 mg/L during the reported period as shown in Figure 3.6. As the temperature

of water goes up, the concentration of dissolved oxygen lowered down as depicted in Korang river.

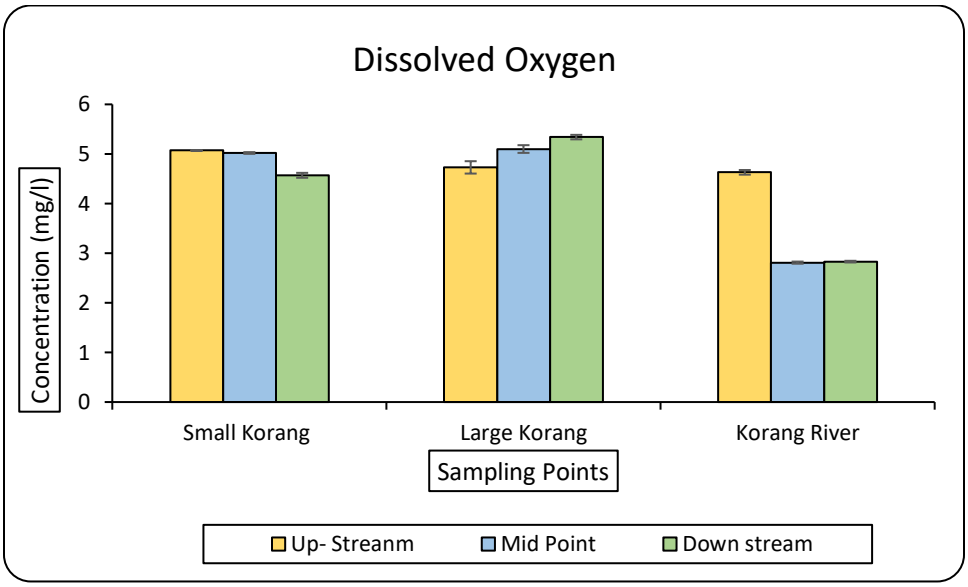


Figure-3.6: Average DO at selected sites

Measuring Alkalinity is important in determining a stream's ability to neutralize acidic pollution from rainfall and wastewater. Almost all the samples were with in WHO permissible limits as shown in Figure 3.7.

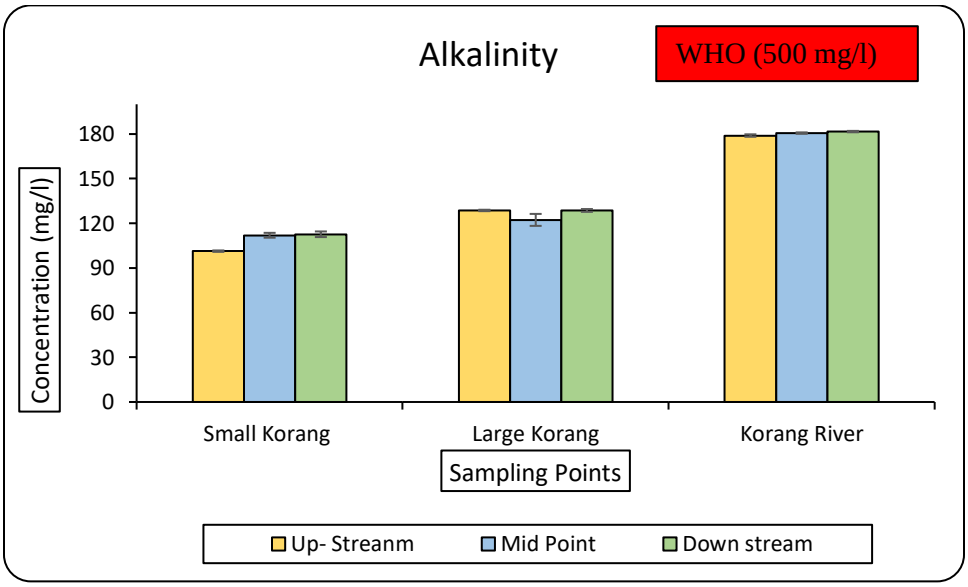


Figure-3.7: Average Alkalinity at selected sites

Overall data recorded from selected sampling sites revealed that turbidity values were within WHO permissible limits except Korang river as shown in Figure 3.8. The possible causes included but not limited to untreated domestic and animal waste, runoff carrying various salts, forestry and poultry disposals. It was an alarming if drinking water with possibility of abnormal condition may contain pathogenic bacteria.

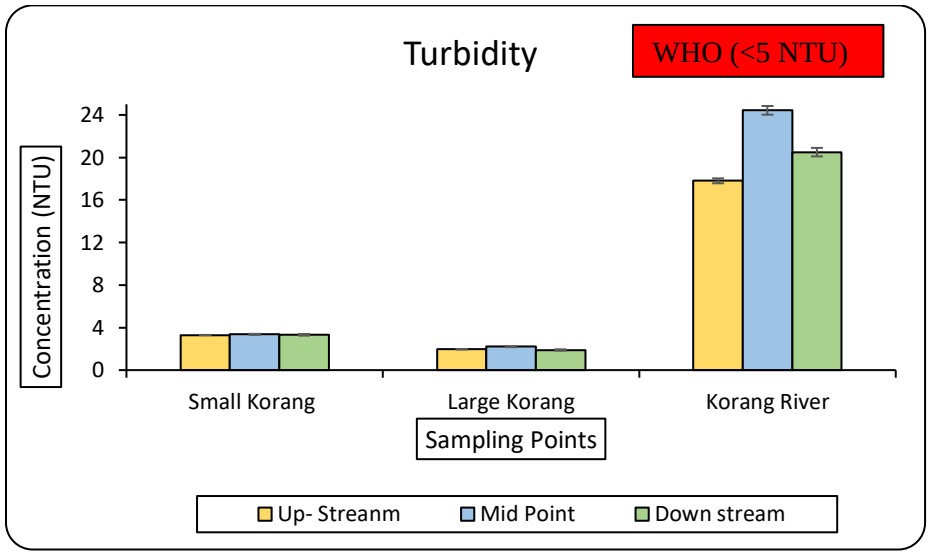


Figure-3.8: Average Turbidity at selected sites

Presence of phosphate could be the discharge of human and animal waste, detergents, forest leaves, fertilizers, synthetic material and poultry waste. Almost all the samples were within WHO permissible limits as shown in Figure 3.9.

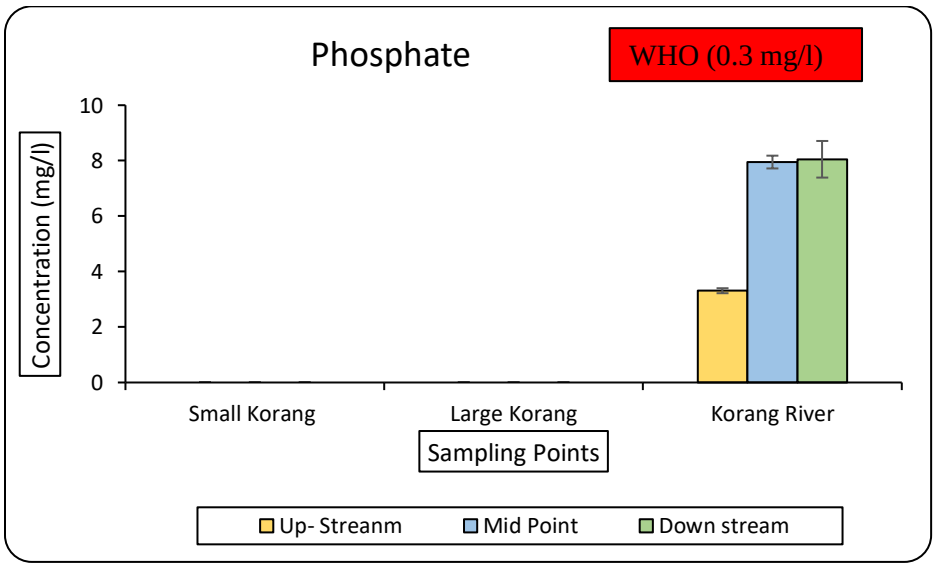


Figure-3.9: Average Phosphate at selected sites

Presence of organic matter, waste water intrusion was also obvious as reflected by COD, Nitrate, Nitrite and Total Kjeldahl Nitrogen as shown in Figure 3.10 - 3.13.

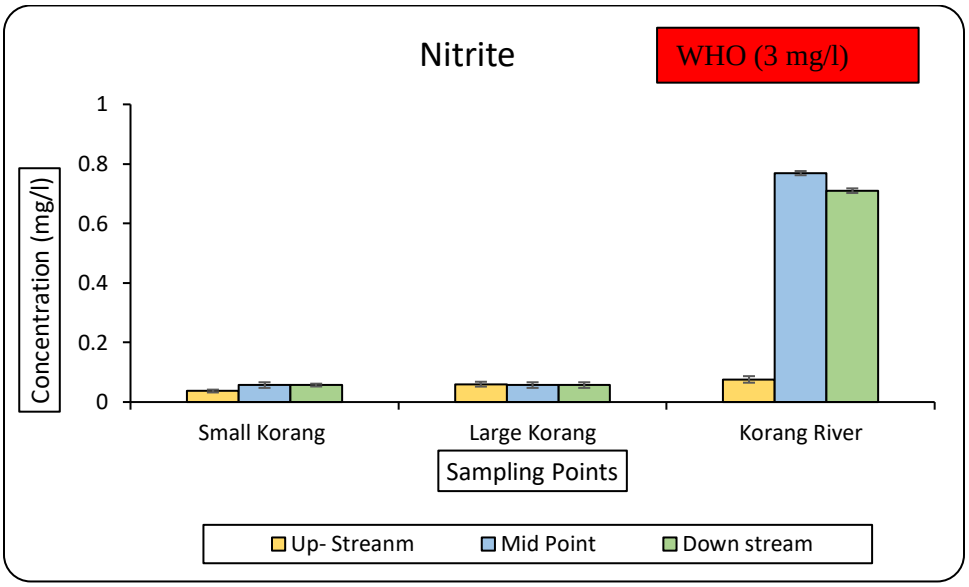


Figure-3.10: Average Nitrite at selected sites

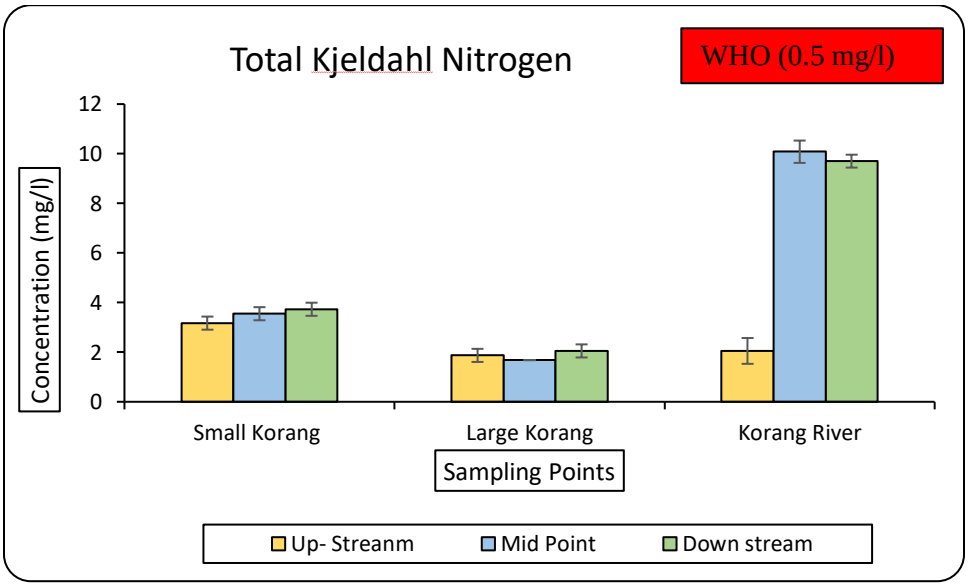


Figure-3.11: Average TKN at selected sites

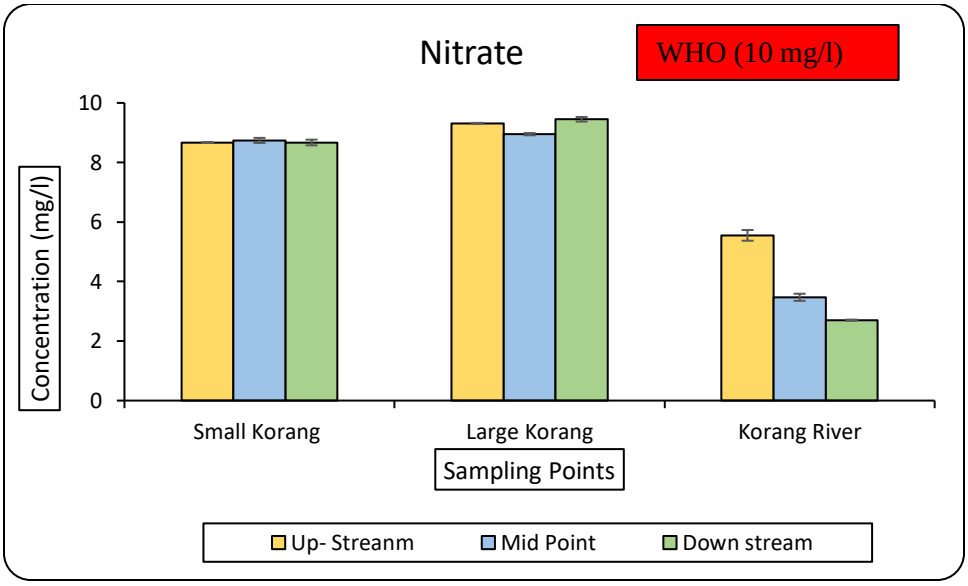


Figure-3.12: Average Nitrate at selected sites

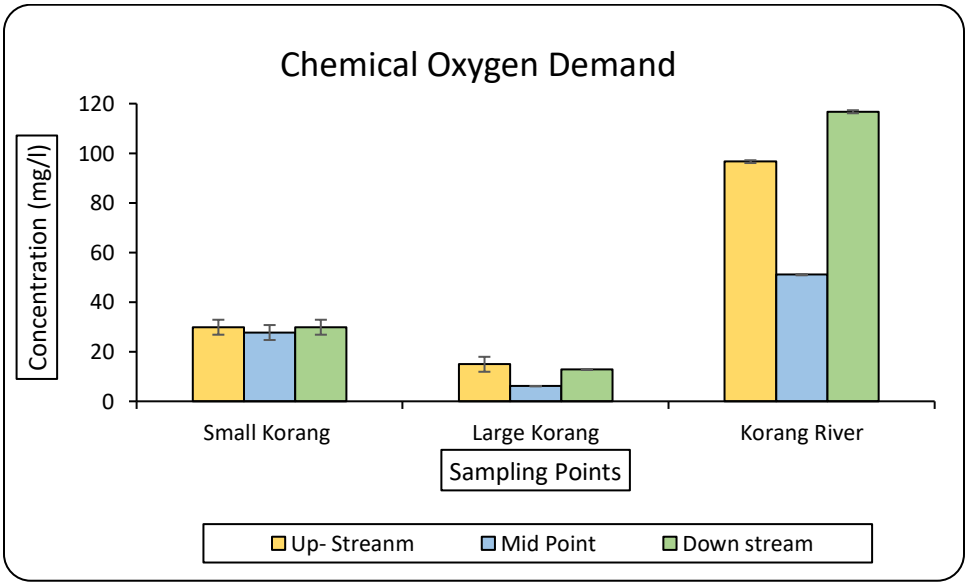


Figure-3.13: Average COD at selected sites

Another important parameter regarding performance evaluation of drinking water utilization is the microbial quality of water. According to WHO guidelines *E. coli* and fecal coliform bacteria must not be detectable in any 100ml sample of water intended for drinking purpose. All the samples were heavily contaminated as shown in Figure 3.14.

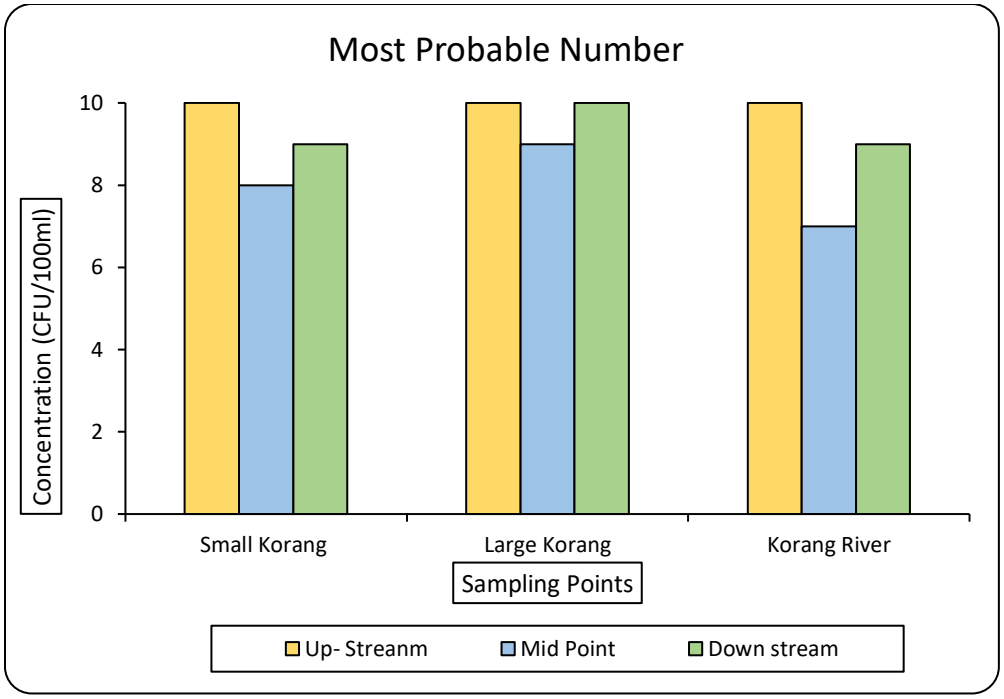


Figure-3.14: Average MPN values at selected sites

4. Conclusion and Recommendations

Study reveals that all the parameters were within the WHO permissible limits. Presence of organic matter, waste water intrusion was also obvious as reflected by COD, Nitrate, Nitrite and Total Kjeldahl Nitrogen. Also, there is a presence of *Escherichia coli* in almost all the samples implies the deteriorating quality of water in the stream

- Above studies have provided baseline infrastructure for research efforts and create awareness regarding Water Quality Assessment.
- Based on results, recommendations were proposed to government, EPAs, Ministry of Climate Change, RDA, CDA and WASA.
- Drafting guidelines and regular monitoring for water disinfection and for existing water testing laboratories to ensure safe water to the consumers.
- Consequently, strengthening existing water quality scenario to some extent prevailing in the country and thereby reducing overall budget disbursed on health infrastructure.
- In addition, best management practices and training was imparted for the provision of adequate water and sanitation services in Pakistan.

Acknowledgements

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WATER CONTAMINATION AS A MAIN SOURCE OF WATER SCARCITY IN PAKISTAN

M. Iftikhar, B. K. Bakht[1], Dr. Eng. A. Yasar[1], Dr. A.B Tabinda[1], M. N. Anwar[1]

Abstract

In Pakistan the ground water is one of the major sources of water consumption and it is also a valuable resource, but due to landfill leachate, uncontrolled hazardous waste sites, freeway disposal of wastewater from industries and agriculture causes the pollution of natural water resource. The research shows that Arsenic and Fluorine are two major pollutants in groundwater of Pakistan and more than 50% of groundwater wells have their increase concentrations even it exceeds from the permissible WHO limits results in water shortage and various health related problems like anemia, gastrointestinal irritation, lung infections, hepatitis, intestinal infections and diarrhea, dysentery, cholera, respiratory paralysis, typhoid fever, jaundice and skin diseases in children as well as in older and younger adults. This review sums up the outcomes of various research studies conducted for groundwater quality status and water shortage in Pakistan. The scarcity of safe and healthy water sources causes 20% of the population to use clean water, but the rest of 80% population has no access to safe water. The study shows that there is an immediate need of taking measures to control groundwater contamination and water scarcity such as management of waste, use water wisely, reduce, reuse, recycle, use fewer chemicals, plant more trees and spread awareness about water contamination and water scarcity.

INTRODUCTION

The most important element of the life is the water it is the essential element of the human body and comprises of almost 60% of the human body. Almost 71% of the Earth's surface is covered with the water of which almost 3% is covered with the fresh water. Furthermore, of all the total fresh water present on the earth surface only a very small portion about 0.01% of the total fresh water is available for the human use (Hinrichsen and Tacio, 2002). This small fresh water available for the human use would have been enough for all the requirements of the human and their future generations if this water would have been consumed on the principle of sustainability. But unfortunately, unplanned and unsustainable consumption along with the contamination of the fresh water with the pollutants and rapid population growth has resulted in the immense stress of fresh water. It has been recently reported by UNO (United Nation Organization) that the population of the world is increasing rapidly while on the other hand availability of the fresh water is decreasing exponentially. It is studied that once the water is contaminated it is known as "not available water for consumption"

According to the report many countries of the world including Middle East, Africa and South Asia would have serious threats of water shortage in the upcoming two

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decades of the world. In the developing countries this problem is further stressed seriously by the poor management and lack of the professional and financial support (PCRWR, 2005).

Pakistan is among the developing countries and like other developing countries. Pakistan is also facing very serious threat related to the upcoming episode of the water scarcity and water pollution (PCRWR, 2005). Pakistan has almost consumed all its available water sources unsustainably and is considered as the water stressed and is expected to be water scarce country in the upcoming few years (Hashmi et al., 2009a; WWF, 2007). One of the reasons for the exponential continuous decrease in the water quantity from the rivers, lakes, and ground water as well is the precipitation rate. This precipitation rate in Pakistan is very lower than the evaporation rate in the Pakistan. This water is further enhanced by the financial and professional constrains like lack of the new water reservoirs and some natural factors like long droughts etc. (PCRWR, 2005; Ullah et al., 2009). In Pakistan decrease in the quantity of the water along with the increase in the demand of the water and unsustainable use of the water has resulted in the severe water shortage in almost all sectors of the country. It is estimated that water availability per capita is decreased from 5000 in 1951 to 1100 m^3 per annum in Pakistan (WB-SCEA, 2006). It is also proposed that the exponential increase in the population of the Pakistan along with the no development in the reservoirs of water storage may cause decrease in the water availability per capita of less than 1000 m^3 from the year 2010 and onwards3 (PAK-EPA, 2005b). This situation could get more worst in the areas located outside the Indus Basin where the per capita per annum water availability is already very low almost below 1000m^3.The water availability situation in certain areas is more worst where people do not get clean fresh water even for the purpose of drinking and are forced to drink brackish polluted water (Ullah et al., 2009). The behind the scenes are worst in the Baluchistan Province where the underground aquifers and the water reservoirs are decreasing by a rate of 3.5 m annually and these are expected to be exhausted in the upcoming 15 years (Sajjad et al., 1998). The increasing demand of water in the multiple sectors along with the decrease in the quantity of the water has resulted into the severe problems and issues related to the water. This has also affected the quality of the water and has resulted into different types of the water pollution. Due to this water pollution a large amount of the water available in different reservoirs like rivers, aquifers and lakes is not considered safe for the use of human. Thus, this water is also considered as no water.

STATUS OF WATER QUALITY IN PAKISTAN

A detailed study on the water quality of the Pakistan in different cities of the four provinces was conducted by Pakistan Council of Research in Water Resource (PCRWR) from 2002 TO 2006. This study was conducted in major 23 cities in all the four provinces. The conclusion of this study is presented in the table below. The study has revealed that almost 84-89% of the water available in the country was below the drinking standards recommended for the human consumption by WHO (World Health Organization) (PCRWR, 2008a). It was also surveyed that due

to the poor quality of the fresh water available in the reservoirs people were compelled to use mineral water provided by the different companies in plastic bottles. Furthermore, this water available in the packed plastic bottles is also of not good quality because of no proper processing and monitoring systems (Rosemann, 2005).

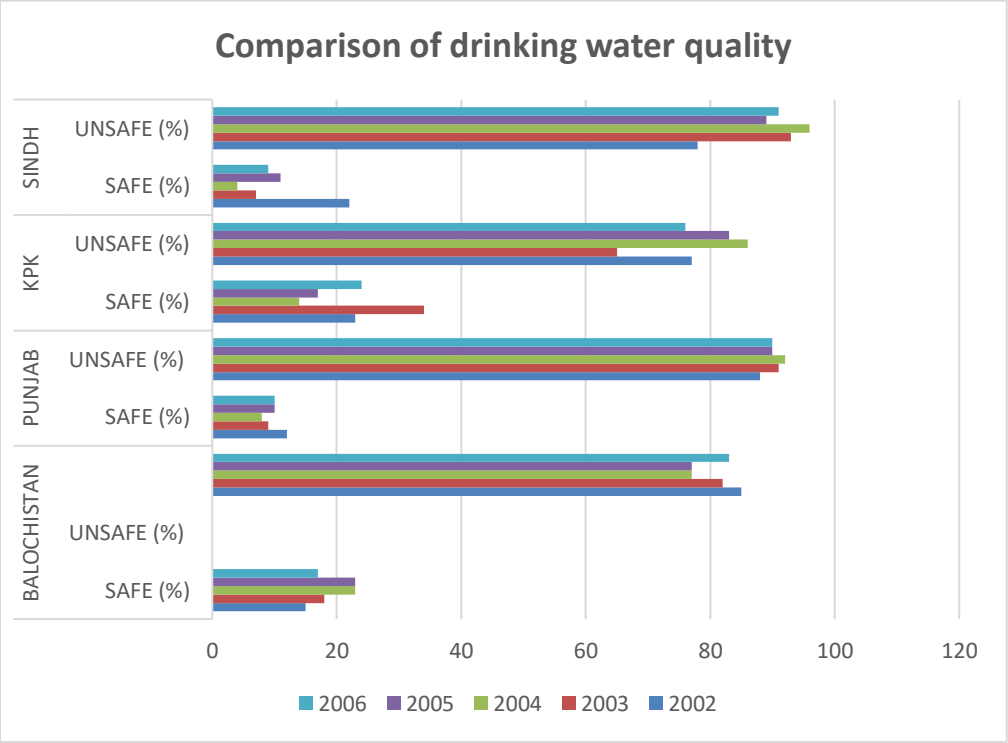


Table 1: Five years comparison of drinking water quality in provinces of Pakistan. Percentage of safe and unsafe drinking water samples (PCRWR, 2008a).

MAJOR POLLUTANTS OF WATER

There are many matters and substances which are considered as the major and active water pollutants which are further classified into different groups. Some important and most common are listed below:

- Pathogens
- Inorganic Pollutants
- Anions and Cations
- Water-Soluble Radioactive Substances
- Organic Pollutants
- Heavy Metals

All the pollutants mentioned above if cross their threshold limits in the water are harmful and can cause severe health problems in humans as well as in other living organisms in the ecosystem. In some areas heavy metals and pathogens are

providing serious threat to the water quality and providing high level of water pollution.

PATHOGENIC (BACTERIAL) CONTAMINATION

Most common bacteria found in the water are the coliforms and the microbial analysis of the water especially of the drinking water is done for the purpose of the detection of the bacteria, protozoa and other pathogens. Califorms bacteria are commonly present in the environment and their presence in the environment is not harmful for the humans but their presence in the water is the indicator that the water is contaminated by the pathogens (Farooq et al., 2008). According to the WHO standards no E.coli or Califorms bacteria should be present in the water supposed to be consumed for the drinking purpose (WHO, 1993). (Fig 1)

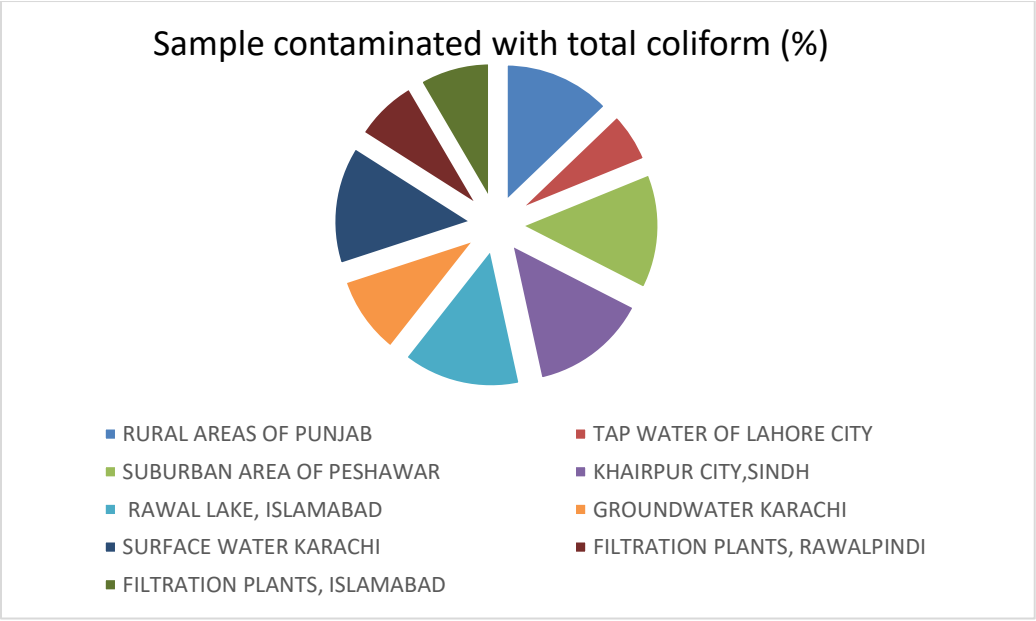


Figure 2: Bacterial contamination of the drinking water from different sources (A. Azizullah et al).

HEAVY METAL CONTAMINATION

Natural water also contains impurities in the form of toxic elements or heavy metals as these elements dissolve in water and consumption of this water may lead to serious threats (Ilyas and Sarwar, 2003). These metals contaminate water at both surface and groundwater levels. This contamination is mostly through most of the human activities for example improper disposal of industrial, agricultural and municipal waste. Some of these metals are important for the human health but because of the extreme pollution the amount of these metals has increased in water which possess serious threats to the human health (Midrar-Ul-Haq et al., 2005). In Pakistan toxic metal concentrations has increased the maximum

admissible limits both at the ground and surface water levels, water situation of different locations of Pakistan are discussed below in table.

ROUND WATER					
LOCATION	**Zn(µg/l)**	**Cu(µg/l)**	**Fe(µg/l)**	**Mn(µg/l)**	**Cd(µg/l)**
KARACHI	4.02	0.09	-	-	0.04
HASANABDAL	0.009	0.02	0.07	0.02	0.001
PALSOI	0.34	0.34	0.3	0.21	0.04
MULTAN	-	-	2.7	1	-
MUZAFFARGARH	-	-	1.65	0.69	-
RISALPUR	0.13	0.21	0.16	1.22	0.04
FAISALABAD	1.84	1.3	3.7	1.06	-
GADOON	0.066	0.893	0.037	0.164	0.025
HATTAR	0.05	0.03	0.08	0.12	0.03
HAYATABAD	0.1	O.36	0.08	0.12	0.03
KALALANWALA	-	-	-	-	-
KASUR	0.14	-	2.57	0.04	0.007
SIALKOT	0.16	0.06	0.3	0.03	
MANCHAR LAKE	-	-	-	-	-

SURFACCE WATER					
LOCATION	**Zn(µg/l)**	**Cu(µg/l)**	**Fe(µg/l)**	**Mn(µg/l)**	**Cd(µg/l)**
TARBELA RESERVIOR	0.028	0.04	0.012	0.018	0.004
CHASHMA RESERVIOR	0.029	0.004	0.004	0.004	0.003
LLOYD RESERVIOR	0.028	0.004	0.012	0.018	0.002
RIVER RAVI	0.034	0.006	0.127	0.0097	0.0014
PALOSI DRAIN	0.239	0	0.75	0.242	0.004
MALIR RIVER	0.16	0.31	0.78	0.33	-
RIVER CHENAB	-	-	0.18	0.28	-
BARARIVER	0.06	1.2	1.75	0.85	0.2
KALAR KAHAR LAKE	2.82	1.2	5.46	-	0.05
HUDAIRA DRAIN	1.7	0.45	7	0.85	0.18
MANCHAR LAKE JAMSHORO	-	-	-	-	-

Table2: Heavy metal contamination of the water was done from the different locations of the Pakistan (A. Azizullah et al).

FLOURINE AND ARSENIC

There are two types of sources of fluorine the natural and the anthropogenic activities. Volcanic gases and F-bearing minerals like igneous and metamorphic

rocks are natural sources of fluorine. Mining activities of phosphate and industrial waste water disposal are anthropogenic sources that contribute in excess amount of fluorine in groundwater. Fluorine excess amount causes negative effects in humans such as alteration of DNA-structure, the destruction of immune systems and damage to nervous system. The study shows that fluoride concentration in the Tharparkar region of Pakistan is very high 1.27-43.11 mg/L. (Zia. 2018)

In Southeast and South Asia the groundwater is highly contaminated by the carcinogenic element known as Arsenic (As) (Singh and Ghosh 2012; Sing et al). The WHO standard of this hazardous compound is 10 microgram per litre but in Pakistan the local standard is adopted of less than 50 micro gram per litre. The research shows that in Lahore 89.71 %(Fig 2) of groundwater wells are composed of Arsenic contamination (Environmental Protection Department 2010) .This element is highly hazardous as it causes serious disease like cancer, anemia and cardiovascular disease. (Muhammad and Sohail, 2017)

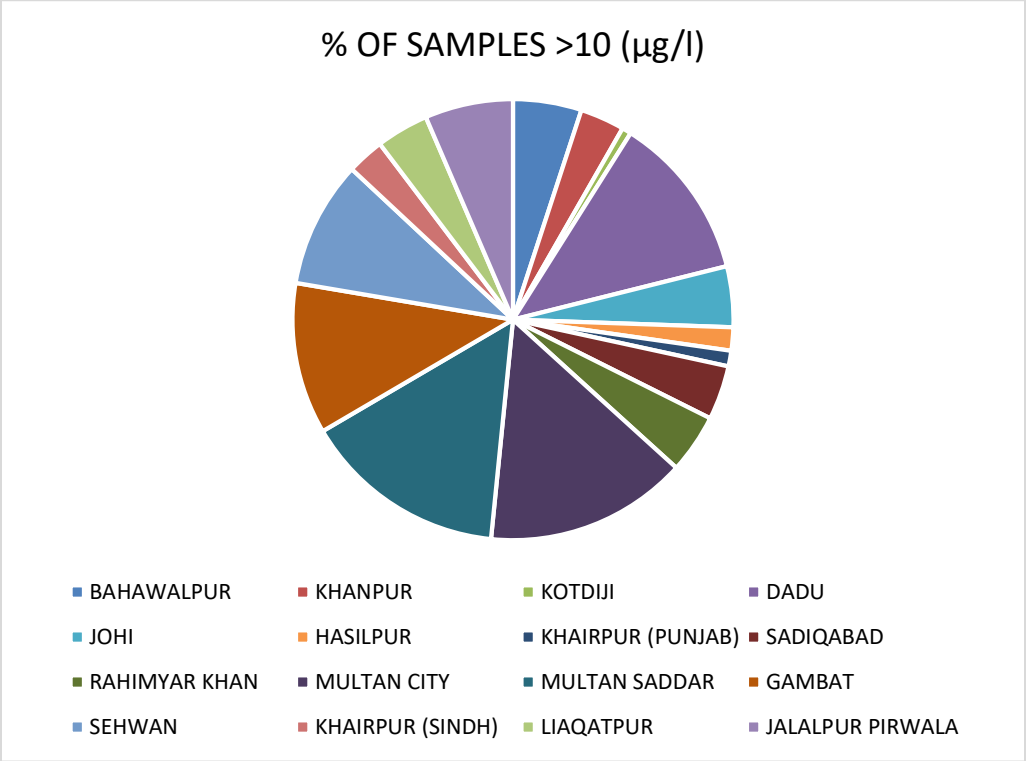


Figure 3: Arsenic contamination in various districts of the Pakistan PCRWR (2008b,c)

PESTICIDES CONTAMINATION

Pesticides are present in surface as well as in groundwater sources of the world. In most parts of the world this resource is used as source of drinking water and for agriculture use. The use of pesticides from past few decades induce its presence

in the whole environment. It is present everywhere including air, soil, water and biotic environment. (Julia Plattner, 2018) The pesticides mainly through rainfall move into groundwater. Pesticides causes water contamination at larger extent that many governmental and non-governmental organizations are forced to regulate the pesticides concentration in drinking water. (Chbib Chaza, 2018)

Table 3: Pesticide concentration in ground and surface water samples of Pakistan (Tariq et al., 2007).

Sampling Location	**Water Type**	**Concentration (micro gram per litre)**	**Pesticide Detected**	**References**
Samundri, Faisalabad, Kala Shah Kaku and Lahore	Shallow groundwater	0.1-0.2	Endrin	Jabber et al. (1993)
Swabi, Chota Lahore, Takhbai Mardan	Groundwater	0.0-0.03	Chlorpyrifos	Ahad et al (2000)
Multan	Groundwater	0.0-0.13	Endosulfan	Ahad et al (2001)
Different Districts of Punjab	Surface and groundwater	0-0.935	DDT (Dichlorodiphenyl trichloroethane)	Asi et al. (2008)
Rawal Lake, Pakistan	Water from surface	0.06-13.28 (3.3)	Azinophos-methyle	Ahad et al. (2006)

WATER QUALITY STANDARDS

The toxicity of water is related to the High TDS level. The groundwater with high TDS causes indigestion diseases in humans. Turbidity of the water accounts for cloudiness of the water. This becomes the cause of microbial growth result in water borne disease.

Parameter	**National Drinking Water Quality Standards**	**WHO (World Health Organization)**
Conductivity (μS/cm)	1000	_
Total Dissolved Soild (mg/L)	1000	1000
pH	6.5-9	6.5-8.5
Total Suspended Solid (mg/L)	25	_
Turbidity (mg/L)	_	5
Arsenic (mg/L)	0.01	0.01
Zinc (mg/L)	3	None
Iron (mg/L)	0.3	0.3
Copper (mg/L)	1	2

Parameter	National Drinking Water Quality Standards	WHO (World Health Organization)
Magnesium (mg/L)	150	None
Cadmium (mg/L)	0.003	0.003
Chromium (mg/L)	0.05	0.05
Tin (mg/L)	_	_
Mercuty (mg/L)	0.001	0.006

The safe limits to determine drinking water quality (N. Rahmanian, 2015)

The presence of sulfate and carbonates of calcium and magnesium contributed in the hardness of water. The pH maintenance for the drinking water is also very important. The increase pH above 11 or below 4 causes many kinds of problems in humans like eye and mucous membrane irritation and skin diseases

WATER POLLUTION SOURCES:

Water pollution is mainly caused by human activities such as municipal, domestic and industrial wastes in water bodies. (Hammer, 1986) (Kahlown and Majeed, 2003) .Everyday approximately 2 million tons of sewage is discharged into world's water and in developing country like Pakistan the 90% of untreated sewage is added into the water sources. There are very few collecting systems in the country which collect 50% of the urban cities pollution and only 10% is treated (WWF, 2007). There are few countries which has lion's share in the waste water:

- Hyderabad
- Sialkot
- Lahore
- Karachi
- Rawalpindi
- Faisalabad

As Pakistan is the agriculture country this also poses its negative effect because excessive use of agrochemicals in agriculture. In developed countries like China and USA there is a huge contamination of agriculture chemicals (Li and Zhang, 1999). In Pakistan the natural groundwater is highly effected by the use of fertilizers and pesticides results in the alarming situation of waste water.

The agriculture water leaches into the nearby water bodies and causes threat to marine life as well as human life. The nitrates, ammonia, sulphates, phosphates and nitrites causes eutrophication in the water and become the indirect harm to the environment. Many algae are harmful to animals as well as humans like cyanobacterium microcystis produces hepatotoxic microcystin.

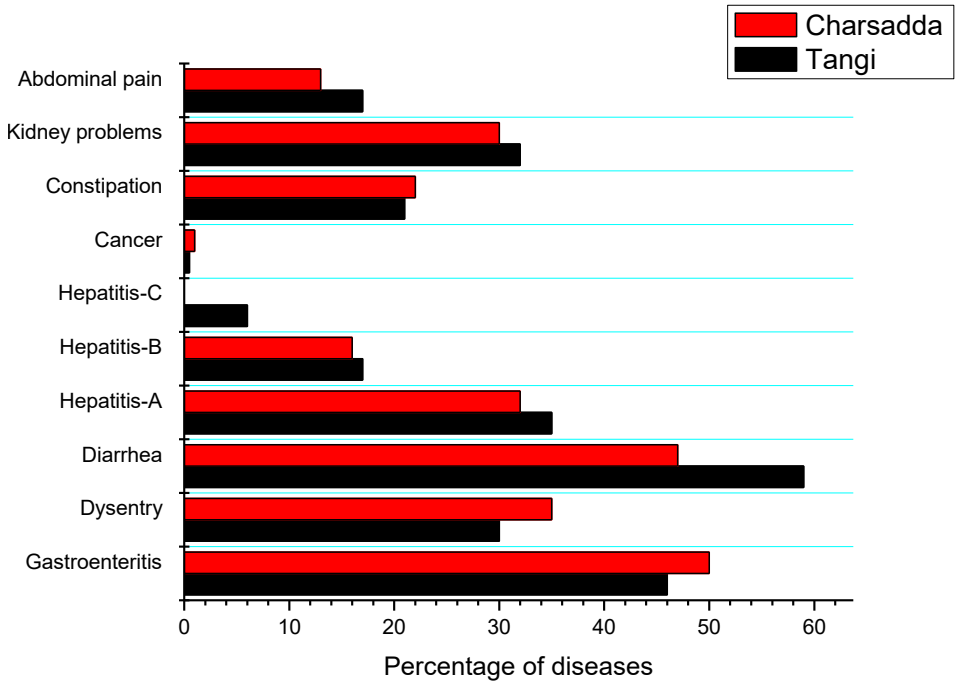
Many fertilizers are direct threat to the groundwater. Fertilizers produce by product which are harmful compounds for nature of soil as well as water. When they accumulated in the soil they give rise to compounds that are dangerous for

humans. In this way the contamination by agrochemicals are more than industrial and domestic wastage. (MOE-PAK 2005a)

HUMAN HEALTH

Water contamination is a big threat to health of human beings. The large part of human body is composed of water. If this is in large quantity then its poor quality directly effects the health of human. The WHO and UNISEF reported that in developing countries more than 2.2 million people are at verge of death due to poor water quality . Water related infections and parasitic diseases are causes more than 60% mortality in the whole world.

“An estimated 1.1 billion people lack access to safe drinking water, 2.5 billion people have no access to proper sanitation, and more than 5 million people die each year from water-related diseases — 10 times the number killed in wars, on average, each year. All too often water is treated as an infinite free good. Yet even where supplies are sufficient or plentiful, they are increasingly at risk from pollution and rising demand. By 2025, two thirds of the world's population is likely to live in countries with moderate or severe water shortages” (UNO Secretary General on world water day 2002).



Sardar Khan, 2013

A study is conducted in which number of households are selected in order to measure the rate of diseases caused by consumption of contaminated water. There are two districts selected Tangi and Charsadda .The number of households

of Tangi is 1620 and of Charsadda is 1554. The number of males are 3000 (Tangi) and 3500 (Charsadda) and the number of females are 3200 (Tangi) and 3157 (Charsadda). The chart above represents the percentage of different diseases prevailed in two different areas by the consumption of contaminated water. (Sardar Khan, 2013)

CONCLUSION AND RECOMMENDATIONS

In Pakistan the drinking water is not safe for human consumption because the pollutant contents are in increase concentration even they exceed from permissible quality standards. The heavy metals concentration is also increasing from standards and limits set by WHO (World Health Organization). The most common heavy metals are Chromium, Iron, Cadmium, Nickel and Arsenic. Fluoride and Nitrates are also a threat in some parts as fluoride in some areas is very low whereas in some parts it is very high. The main source of water pollution is uncontrolled municipal waste and untreated industrial wastes. In rural areas the monitoring of water quality is totally absent (Aziz; 2005). The water disinfection practices like chlorination is either unsatisfactory or nonexistent. This causes serious human related problems.

Waterborne disease is the main issue cause by the chemical and bacteriological pollution of public drinking water. The is an insufficient record of water related diseases and the lack of diagnostic technology contributed to the blur picture of water linked diseases result in poor handling of these diseases.

There are various recommendations to the problem of deteriorating water quality:

1) The proper monitory procedures should be introduced in every part of the country.
2) Purification of water should be made mandatory by local authorities.
3) The continuous water supply should be compulsory in order to avoid intermittent contamination and to fulfill the water needs.
4) The sewage pipelines should be away from water supply.
5) It should made compulsory for industries to install waste water treatment plants. The industrial water should be monitor regularly.
6) The pesticides should be treated safely. The farmers should provide regular education and awareness about the use and disposal of pesticides.
7) There should be guidance for storage of water inside the houses.
8) There is a strong need of implementation of strict laws.
9) The old rusty water supply lines should be treated regularly.
10) There is a need for proper sewage handling in urban areas of Pakistan. (Azizullah ;2011)

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Listing of Papers Presented at Various World Water Day(s), Commemorated by

Pakistan Engineering Congress

Sr. No.	Title of Paper	Name of Author
	2005 – Water of Life:	
1.	Constructing New Dams for Pakistan's Survival	Engr. Dr. Izhar-ul-Haq,
2.	Implementation of Indus Waters Treaty-1960	Engr. Syed Jamaat Ali Shah
3.	Pakistan's Water Resources Development and Global Perspective	Engr. M. Mushtaq Ch., Dr. Allah Bakhsh Sufi
4.	Reducing the Impact of Unplanned Urbanization of a Riparian Eco-System: A case study on designing a Plan for Sustainable Utilization of Flood Plains on River Ravi	Dr. Amin U. Khan
5.	Ground Water use in Pakistan : Opportunities and Limitations	Dr. Muhammad Nawaz Bhutta
6.	Development of Sub-Surface Drainage Data Base System for Use in Waterlogging and salinity Management Issues	Dr. Aftab H. Azhar, M. M.Alam, M. Rafiq
	2006 – Water Scarcity:	
7	World Water Day, March 22, 2006	Engr. Muhammad Mushtaq Chaudhry
8	Water as Instrument of Peace the Vision of Indus Waters Treaty-1960	Engr. Syed Jamaat Ali Shah
9	Water Resources Development in Pakistan	Engr. Dr. Izhar-ul-Haq, S. Tanveer Abbas
10	Risk Perception towards flooding and environment in low income urban communities	Dr. S. M. Saeed Shah, M. Kaleem Sarwar
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12	Introducing Modern Environment Friendly Technology for Water Management in Customary environment of Pakistan	Abdul Hakeem Khan, Sarfraz Munir, Dr. Hugh Turral
13	Assessing the Behaviour of Groundwater Recharge using Water Table Fluctuation Method	Jehanzeb Masud, Asaf Sarwar
14	Hydro Energy and Water Vision in Pakistan	Abdul Qayyum

2007 – Coping with Water Scarcity:

15	Water Scarcity & Wapda Vision 2025	M. Mushtaq Chaudhry, Dr. Allah Bakhsh Sufi
16	Combating Water Scarcity	Dr. Izhar-ul-Haq, S. Tanveer Abbas
17	Role of Groundwater in Coping with Scarcity of Water	Dr. Muhammad Nawaz Bhutta
18	Coping with Water Scarcity & Indus Waters Treaty Vision	Engr. Usman-e-Ghani
19	Growing Scarcity of the Water Resource	Shafqat Masood
20	Waste Water Re-use Crop Production: An Option for Sustainable Agriculture Under Water Scarce Environments	Sarfraz Munir, Abdul Hakeem Khan, Waqas Ahmad, Aamir Nazeer
21	Efficient Irrigation Techniques to Cope with Water Scarcity	Engr. Muhammad Yasin
22	Groundwater Sustainability to Cope with Water Scarcity	Jehanzeb Masud, M. Arshad

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26	Hospital Hazardous Waste Management	Ali Sher A. Baloch, Asma Iftikhar
27	Appropriate Technologies of Sewage Treatment For Urban Centers & Large Villages of Punjab	Engr. Shabbir Ahmad Qureshi
28	Adverse Effects of Poor Waste Water Management Practices On Ground Water Quality in Rawalpindi And Mitigation Strategies	Lt. Col Islam-ul-Haq TI (M) (Retd), W. A. Cheema
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131	Seasonal Variations in the Efficiency of Oxidation and Stabilization Ponds for the Treatment of Sewage in Faisalabad City	Dr. Abdullah Yasar, Ms. Noreen Ashraf, Dr. A. B. Tabinda, M. Naveed Anwar, Mr. Mujtaba Baqir, Mr. Ahmad Iqbal, Mr. Anam Waheed
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