Title: Wastewater Production, Treatment and Use in Pakistan

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Abstract:

Pakistan, once a water-surplus country, is now a water deficit country. The water availability has decreased from 1,299 m³ per capita in 1996-97 to 1,100 m³ per capita in 2006 and it is projected to less than 700 m³ per capita by 2025. Therefore, search for other non-conventional water resources for irrigation i.e. wastewater, has become important. In Pakistan, domestic and industrial wastewater is either discharged directly to a sewer system, a natural drain or water body, a nearby field or an internal septic tank. Mostly, this wastewater is not treated and none of the cities have any biological treatment process except Islamabad and Karachi, and even these cities treat only a small proportion (<8%) of their wastewater before disposal. The wastewater used for irrigation is valued by farmers, mainly because of its nutrient contents and reliability of supply and exert positive impacts on agriculture land values, households, monthly income and employment due to reuse of wastewater despite of the ill effects of wastewater irrigation on soil physical and chemical properties in addition to contamination of human food chain and related health risks. Limited information is available in this regard. There seems no national policy in effect on sustainable use of wastewater in this country. Problems of wastewater disposal tend to stem from distortions due to economy-wide policies, failure of targeted environmental policies and institutional failures. Thus laws and regulations have been formulated about treatment and disposal of wastewater but their implementation due to lack of resources and skilled manpower is the real issue. There is hardly any well organized study which focused on risk assessment in a systematic way. Some of the systematic work has been done by IWMI and Pak-EPA with financial aid from foreign donors. Therefore, a well-coordinated program is necessary to create awareness among different sections of the society including the general public, organizations, industrialists and farmers.

1. Water availability and use:

Pakistan has become a water deficit country due to depleting ground and surface water resources, loss in surface shortage, prevailing droughts and shift of fresh water from agriculture to more pressing domestic as well as industrial uses (Ensink *et al*., 2004). Therefore, search for other non-conventional water resources for irrigation i.e. wastewater has become important. The recent statistical data shows that the Indus System and its tributaries provide an average 142 MAF of water annually. Out of which nearly 96 MAF is utilized for irrigation, 36 MAF flows to sea and about 10 MAF is consumed by the system losses which include seepage, evaporation and spill during floods. Presently, 40.5 MAF groundwater is being pumped annually and about 36% of the groundwater is classified as highly saline and 60-80% as saline (Anonymous, 2011). Overall water availability has decreased from 1,299 cubic meters (m³) per capita in 1996-97 to 1,100 m³ per capita in 2006. It is projected that water availability will be less than 700 m³ per capita by 2025 against the international standard of 1500 m³ per capita (Pak-SCEA 2006).

The renewable water resources are estimated at 248 billion m3/year. Surface runoff is estimated at 243 billion m^3/year, while groundwater resources are about 55 billion m^3/year, most being the base flow of the river system. Of which 96.8% is withdrawn for agricultural purposes, 1.6% for domestic use and another 1.6% for industrial use. Pakistan would need more additional water in future to meet irrigation and other requirements of the people. This was not possible unless new storage dams were built.

2. Wastewater production and treatment:

2.1. Wastewater Production

Total discharge of wastewater for 14 major cities of Pakistan, computed on the basis of 1998 population census, is about 1.83×10^7 m^3 h^{-1} (FAO, 2002). Latest estimates reveal (PWSS, 2002 & Table 1) that total quantity of wastewater produced in Pakistan is 962,335 million gallons (4.369 x 10^9 m^3/yr) including 674,009 million gallons (3.060 x 10^9 m^3/yr; a figure of 5.54 x 10^9 m^3/yr for the year 2011) from municipal and 288,326 million gallons (1.309 x 10^9 m^3/yr) from industrial use. The total wastewater discharged to the major rivers is 392,511 million gallons (1.782 x 10^9 m^3/yr and 1/3rd of all wastewater), which includes 316,740 million gallons (1.438 x 10^9 m^3/yr) of municipal and 75,771 million gallons (0.344 x 10^9 m^3/yr) of industrial effluents. Petrochemicals, paper and pulp, food processing, tanneries, refineries, textile and sugar industries are major industrial contributors to wastewater pollution in Pakistan (UNIDO, 2000). It has also been estimated that around 2,000 million gallons of sewage is being discharged to local surface water bodies every day (Pak-SCEA 2006). The industrial sub-sectors of paper and board, sugar, textile, cement, polyester yarn, and fertilizer produce more than 80% of the total industrial effluents (WB-CWRAS Paper 3, 2005).

Table 1: Sector wise estimated wastewater production in Pakistan

Sr. No.	Source	Volume	
		10^6 m^3 y^{-1}	Percent %
1	Industry	395	6
2	Commercial	266	5
3	Urban residential	1,628	25
4	Rural residential	3,059	48
5	Agriculture	1,036	16
Total		6,414	100

Source: Pakistan's Wetlands Action Plan, 2000, prepared by NNCW and WWF

Table 2: Wastewater Produced Annually by Cities (WB-CWRAS Paper 3, 2005)

City	Urban population (1998 census)	Total wastewater produced (10^6 m^3/y)	% of Total	% of Treated	Receiving water Body
Lahore	5,143,495	287	12.5	0.01	River Ravi, irrigation canals, vegetable farms
Faisalabad	2,008,861	129	5.6	25.6	River Ravi, River Chenab and vegetable farms
Gujranwala	1,132,509	71	3.1	-	SCARP drains, vegetable farms
Rawalpindi	1,409768	40	1.8	-	River Soan and vegetable farms
Sheikhupura	870,110	15	0.7	-	SCARP drains
Multan	1,197,384	66	2.9	-	River Chenab, irrigation canals and farms
Sialkot	713,552	19	0.8	-	River Ravi, irrigation canals and farms
Karachi	9,339,023	604	26.3	15.9	Arabian Sea

Hyderabad	1,166,894	51	2.2	34.0	River Indus, irrigation canals and SCARP drains
Peshawar	982,816	52	2.3	36.2	Kabul River
Other	19,475,588	967	41.8	0.7	-
Total Urban	43,440,000	2,301	100.0	7.7	-

Source: Master Plan for *Urban Wastewater (Municipal and Industrial) Treatment Facilities in Pakistan*. Final Report, Lahore: Engineering, Planning and Management Consultants, 2002

2.2. Wastewater Treatment

In Pakistan, domestic waste containing household effluent and human waste is either discharged directly to a sewer system, a natural drain or water body, a nearby field or an internal septic tank. Normally, municipal wastewater is not subjected to any treatment and none of the cities have any biological treatment process except Islamabad and Karachi, and even these cities treat only a small proportion of their wastewater before disposal. Assuming that all the installed treatment plants are working at their full installed capacity, it is estimated that about 8% of urban wastewater is probably treated in municipal treatment plants (Table 2). Other estimates suggest that the figure is not greater than 1 per cent. The treated wastewater generally flows into open drains, and there are no provisions for reuse of the treated wastewater for agriculture or other municipal uses. Table above (2) shows ten large urban districts of the country, which produce more than 60% of the total urban wastewater including household, industrial and commercial wastewater (WB-CWRAS Paper 3, 2005). A negligible proportion i.e. 8% of wastewater in Pakistan is treated through sedimentation ponds to a primary level only but most of the treatment plants are not functional therefore the figure can be estimated around 1 per cent. There is no prevailing concept of treatment at secondary and tertiary level in this country. Although treatment facilities exist in about a dozen major cities, in some cases these have been built without the completion of associated sewerage networks, and the plants are often either under-loaded or abandoned (Pak-SCEA, 2006).

The problem of industrial water pollution has remained uncontrolled because there have been little or no incentives for industry to treat their effluents (WWF, 2007). In Khyber Pakhtun Khawh province (formerly NWFP), 0.701 x 10^9 m^3/yr of industrial effluents containing a high level of pollutants are discharged into the River Kabul (SOE, 2005). In Sindh province, only two sugar mills (out of 34) have installed mechanisms for wastewater treatment mainly because of international pressure as these industries (distilleries) export their products (SOE, 2005). With an exception to fertilizer sector (UNIDO, 2000) which invested significantly in installing wastewater discharge treatment plants; throughout Pakistan the industrial approach towards environment is very discouraging. In Lahore, a major city of Punjab province, only 3 out of some 100 industries using hazardous chemicals treat their wastewater. The situation is even worst in Sindh province, for example, in Karachi, Industrial Trading Estate (SITE) and Korangi Industrial and Trading Estate (KITE), two of the biggest industrial estates in Pakistan, there is no effluent treatment plant. In Karachi for example, a city that accommodates 70% of Pakistan's industry, approximately 70% of wastewater, (i.e., > 0.242 x 10^9 m^3/yr) reaches the Arabian Sea without any form of treatment. Among the industries established in the industrial zone of Karachi, 16% come in the more polluting category while 59% can be classed in the somewhat polluting category. Only a portion of the generated industrial effluent (≈ 0.035 x 10^9 m^3/yr) from this zone goes to a Treatment Plant (TP1) and this treatment plant is only working at half of its capacity, because of the inadequate sewage piping system. Moreover, the NEQS prescribed by the Environmental Protection Agency of Pakistan are primarily concentration based. Unfortunately, limits on liquid industrial effluents are neither industry-specific nor do they have any relationship with the quantum of production. The NEQS prohibits dilution, but this can be easily circumvented (UNIDO, 2000).

As per a review of literature, out of 388 cities of Pakistan, only 8 have wastewater treatment facilities, that too up to primary level. According to the Pakistan Water Situational Analysis, there are three wastewater treatment plants in Islamabad, of which only one is functional. Karachi has two trickling filters, where effluents generally receive screening and sedimentation. Lahore has some screening and grit removal systems, but they are hardly functional. In Faisalabad, there is a wastewater treatment plant, in which wastewater receives primary treatment. In rural areas, wastewater treatment is nonexistent, leading to pollution of surface and groundwater.

3. Wastewater use/disposal:

Urban centres are the main cause of water pollution in this country. Typically, storm water drains and nullahs collect and carry untreated sewage which then flows into streams, rivers and irrigation canals. Although there are some sewerage collection systems, typically discharging to the nearest water body, collection levels are estimated to be no greater than 50% nationally (less than 20% in many rural areas). As per a careful estimation, the wastewater generated in Pakistan is directly used for irrigating an area of about 32,500 ha (Ensink *et al*., 2004). The estimated total amount of direct wastewater used in agriculture is 0.876×10^9 m^3/yr while that directly disposed of to water bodies, mainly irrigation canals, is around 0.146×10^9 m^3/yr (WB-CWRAS Paper 3, 2005).

Commonly grown crops include vegetables, fodder, cotton and to some extent rice. Vegetables receive wastewater irrigation almost twice a week, fodder once a week and cotton after 3 weeks. The crops grown in suburban areas while using wastewater include vegetables, and fodder as these fetch high prices in nearby urban markets. The quantity of N, P and K applied from sewage irrigations of 0.40 m in Faisalabad ranged from 116 to 195, 7 to 21 and 108 to 249 kg ha^{-1}, respectively. These quantities of N and K are quite sufficient for any crop while that of P is low and would need to be supplemented. Since P applied through sewage is 100% soluble, its availability is generally much higher than P applied through fertilizers. In another study conducted at Haroonabad (Pakistan), up to 2030, 1110 and 1580 kg ha^{-1} of N, P and K, respectively, per cropping season were added to the soils when crops were irrigated with sewage (Ensink *et al*., 2002). Efficiencies of nutrients (excess of nutrient above the recommended rate) applied through sewage irrigation ranged from 140 to 920 for N, 20 to 790 for P and 125 to 930% for K, depending upon the crop type and amount of sewage (Ensink *et al*., 2002). This estimated pollution indicates that sewage application to most of the crops may exceed N and P fertilizer needs over the growing season (Murtaza *et al*., 2010). When plant nutrient needs do not coincide with irrigation needs, the presence of nutrients in irrigation water may be problematic. For example, ill-timed and over-fertilization with N can cause excessive growth, encourage weed growth, increase chances of lodging and thus reduce crop yield (Asano and Pettygrove, 1987; Bouwer and Idelovitch, 1987). Moreover, presence of such nutrients in local water bodies can lead to eutrophication and thus deteriorating water quality and aquatic life. Yield and quality have been harmed by excess N in many crops, including tomatoes, potatoes, citrus, and grapes (Bouwer and Idelovitch, 1987).

The wastewater used for irrigation is valued by farmers, mainly because of its nutrient contents and reliability of supply. Reuse of wastewater has many positive impacts on socio-economic aspects of the users. The data of Anwar *et al*. (2010) show that there is a major increase in price of agriculture land due to availability of wastewater and the average land value was Pak. Rs. 0.3

million per acre before the reuse of wastewater while after the availability of wastewater as alternative irrigation source it has increased up to Rs. 0.4- 0.6 million per acre. Similarly, monthly income of 87% households has increased and 77% respondents replied that employment opportunities have been generated. These are positive impacts on agriculture land values, households, monthly income and employment due to reuse of wastewater.

Land treatment of partially treated wastewater has been used as a low-cost method of wastewater disposal for a very long time. In Haroonabad (Pakistan), land irrigated with wastewater has a higher value than the canal irrigated land, and the land rents of wastewater irrigated farms were on average three and a half times higher than those of canal water irrigated lands (Hassan *et al*., 2001). Considering economics, impacts of wastewater irrigation can be grouped under (1) potential yield losses, (2) loss of soil productive capacity, (3) depreciation in market value of land, and (4) cost of additional nutrients and soil reclamation measures. After initial study by Ensink *et al*. (2004), several researchers of the country have focused on this area which was neglected in recent past. Further working on this aspect may only encourage growers about less use of chemical fertilizers unless they are equally educated about ill effects of wastewater irrigation on soil chemical and physical properties in addition to contamination of human food chain and related health risks.

4. Policies and institutional set-up for wastewater management:

4.1. Policy aspects and national strategy

There seems no national policy, in effect, on sustainable use of wastewater in this country. Moreover, economic incentives have not been introduced for industries to acquire environment-friendly technology. Problems of wastewater disposal tend to stem from distortions due to economy-wide policies, failure of targeted environmental policies, and institutional failures. Uneconomic water pricing exacerbates the problem in urban areas, where a flat rate is charged or water is provided free of charge, a policy that both encourages the wasteful use of water and eliminates incentives for suppliers of water services to upgrade their water supply, treatment, and disposal facilities. Laws and regulations have been formulated about treatment and disposal of wastewater in this country but their implementation due to lack of resources and skilled manpower is the real issue. The result is that, while an appropriate and necessary administrative capacity exists on paper, its effectiveness is seriously curtailed in practice due to these shortcomings. For example, the NEQS for industry and municipal discharges were originally formulated in 1993, but even voluntary compliance and reporting have yet to be instituted because of a lack of practical monitoring ability in the EPAs; the Environmental Impact Assessment (EIA) system is mandatory but seldom followed in the public sector; and environmental laboratories have been established in all provinces but function with skeletal staff and budgets inadequate even for their routine equipment and chemical needs. Similarly, environmental tribunals have been created but their capacity to deal with reported cases is extremely restricted, as minimal personnel have been deputed in only two provinces to collectively oversee the entire country (WB-CWRAS Paper 3, 2005).

The biggest challenge faced by policymakers at present, is how best to minimize the negative effects of wastewater use, while at the same time obtaining the maximum benefits from this resource. While most of the impacts of wastewater use, both negative as well as positive, are generally known, a comprehensive valuation of the benefits and costs of these impacts has not as yet been attempted. Conventional cost benefit analysis is not adequate to evaluate wastewater impacts due to the environmental and public good nature of the impacts (Hussain *et al*., 2001).

Prime importance should be given to the treatment of industrial effluent before it is allowed to pour in Drain. The environmental laws and their implementation need be dealt more seriously and responsibly. The practice of usage of untreated wastewater for irrigation of fields should be immediately stopped as it is harmful for the consumers of those vegetables and crops. Pumping of groundwater near wastewater drains for drinking purposes must be avoided. In some cases, sewage is auctioned by the municipalities to the highest bidder, often a group of rich farmers, who then rent out their fields to poor landless farmers. Under these conditions, the use of sewage is considered a win- a -win situation by both the authorities those are responsible for sewage disposal and the farmers who get its reliable supply with high nutrient content (Ensink *et al*., 2004). In relation to wastewater irrigation, economic analyses should also have to conduct with precise perspectives keeping in mind for example municipality optimizing treatment costs, or farmers or a regional entity maximizing income, or evaluating environmental impacts.

4.2. Organizational set-up and Responsibilities

The data provided by the following organizations is highly acknowledged.

4.2.1. National organization(s)

Organisation name: Pakistan Council of Research in Water Resources
Organisation type: Public Sector Research Organization
Roles and responsibilities:

- To monitor the water quality and to establish a permanent water quality-monitoring network
- To provide financial and technical support to universities and research institutes for collaborative research
- Environmental impacts of sewage water irrigation on ground water quality
- Simulation of contaminant transport to mitigate environmental effects of wastewater in rivers

Organisation name: Pakistan Council of Scientific & Industrial Research
Organisation type: Public Sector Research Organization
Roles and responsibilities:

- To conduct R&D work on problems faced by the industrial sector and maintain linkages through seminars, workshops, publications, and provision of assistance to academic institutions.
- To undertake cooperative research with local and foreign R&D organizations and commerce-industrial outfits on projects of national interest
- Human resource development through organized training courses and diffusive on – job grooming of manpower for industry and research centres to broaden the science & technology
- To provide infrastructure/analytical facilities for analysis of industrial effluents like toxic metals, cyanides, chlorides, nitrate, biological oxygen demand, and chemical oxygen demand.

Organisation name: Pakistan Environmental Protection Agency (plus provincial Chapters)
Organisation type: Government Organization for National Policy Drafting
Roles and responsibilities:
Strictly enforce national environmental quality standards and self monitoring and reporting system

- Introduce discharge licensing system for industry
- Make installations of wastewater treatment plants an integral part of all sewage schemes Devise and implement the national sanitation policy
- Devise and implement master plans for treatment of municipal and industrial wastewater in urban and rural areas

- Establish cleaner production centres and promote cleaner production techniques and practices Encourage reduction, recycling, and reuse of industrial and municipal wastewater
- To develop and enforce national standards for land, water and air quality parameters with reference to pollution

4.2.2. Regional (local) organisation(s):

Organisation name: Institute of Soil and Environmental Sciences, University of Agriculture Faisalabad, Pakistan
Organisation type: University/Research Institute
Roles and responsibilities:

- Monitoring effect of wastewater application in agricultural lands where mostly vegetables are grown Risk assessment of metal-contaminated soils
- Prediction of long term impacts of wastewater irrigation on soil chemical properties
- Review of past work done in the field of wastewater application on irrigated lands in Pakistan Role of organic and inorganic amendments in immobilization of heavy metals in wastewater irrigated soils
- Predict the bio-availability of trace and toxic metals in soil and transfer to the human food chain.

Organisation name: Centre of Excellence in Analytical Chemistry, University of Sindh, Jamshoro, Pakistan
Organisation type: University/Research Centre
Roles and responsibilities:

- Determining effect of sewage sludge application in agricultural lands where mostly vegetables are grown Risk assessment of metal-contaminated soils
- Predict the bio-availability of trace and toxic metals in soil and transfer to the human food chain. The feasibility of using an industrial sewage sludge produce in Pakistan as agricultural fertilizer used for cultivation of *Sorghum bicolor* L and other fodder crops
- Heavy metal accumulation in different varieties of wheat grown in soil amended with domestic sewage sludge

Organisation name: Centre of Excellence in Water Resources Engineering, University of Engineering and Technology Lahore
Organisation type: University/Research Institute
Roles and responsibilities:

- Evaluating environmental impacts of the untreated wastewater irrigation
- Quantify the extent of groundwater contamination using wastewater irrigation and to evaluate their effects on human health of the local community

Organisation name: Institute of Environmental Studies, University of Karachi
Organisation type: University/Research Institute
Roles and responsibilities:

- Determining effect of treated wastewater and equivalent basal fertilizer on growth parameters, chlorophyll and nutrient contents of grain crops and vegetables

Organisation name: Department of Soil and Environmental Science, University of Peshawar, Peshawar
Organisation type: University/Research Institute

Roles and responsibilities:

- Evaluating concentration of metals in sewage and canal water used for irrigation
- Use of constructed wetland for the removal of heavy metals from industrial wastewater

Organisation name: Institute of Soil Chemistry, Ayyub Agriculture Research Institute Faisalabad
Organisation type: Research Institute
Roles and responsibilities:

- Evaluating hazardous effects of sewage water on the environment: Focus on heavy metals and chemical composition of soil and vegetables
- Nutrient value of sewage water for crops and potential hazards to humans due to wastewater contaminants
- Long-term disposal of city sewage effluent on agricultural lands

Organisation name: Department of Soil Science, University of Arid Agriculture Rawalpindi
Organisation type: University/Research Institute
Roles and responsibilities:

- Assessing quality of sewage for irrigation
- Heavy metals, soil salinity/sodicity and soil fertility status of soils and plants of some sewage-irrigated farms
- Heavy metal contents of vegetables irrigated by sewage/tube well water

Organisation name: Urban Resource Centre Karachi
Organisation type: Local Government Body
Roles and responsibilities:

- Sanitation program supported by the Orangi Pilot Project's Research and Training Institute (OPP–RTI) in informal settlements in Karachi
- Support for the inhabitants of Karachi Metropolitan to plan, implement and finance the "internal components" – sanitary latrines in the houses, underground sewers in the lanes and neighborhood collector sewers – and support for local governments to finance the larger "external" trunk sewers into which the neighborhood sewers feed and also treatment plants

Organisation name: Water And Sanitation Agency (WASA)
Organisation type: Local Government Body
Roles and responsibilities:

- Provision and maintenance of neat and clean drinking water and drainage facilities.
- Desilting of open and closed drains and manholes.

4.2.3. Other organisation(s)
Organisation name: IWMI
Organisation type: International Institute/Research Centre
Roles and responsibilities:

- Health risks of irrigation with untreated urban wastewater Urban wastewater: a valuable resource for agriculture
- Use of untreated wastewater in peri-urban agriculture: Risks and opportunities
- Hookworm and intestinal nematodes infections among wastewater farmers and their families Wastewater irrigated vegetables: market handling versus irrigation water quality Assessment of the use of wastewater for irrigation
- The use of untreated wastewater in agriculture: Strategies for Health Risk Management

Organisation name: IUCN Pakistan

Organisation type: International Organization Country Chapter

Roles and responsibilities:

- Formulation of Environmental Law in Pakistan which would serve as a reference resource for law students and teachers, practicing lawyers, lawmakers, judges, administrators, corporate officers, etc
- Integration of environment and development
- Facilitation for the creation of a supportive policy and legal framework

Organisation name: Water Aid Pakistan

Organisation type: International Charity Pakistan Chapter

Roles and responsibilities:

- To helping people escape from poverty and disease caused by living without safe water and sanitation
- To help establish sustainable water supplies and latrines and to influence government policy to serve the interests of vulnerable people

Organisation name: WWF Pakistan

Organisation type: International Conversation Organization

Roles and responsibilities:

- To meet and counter the growing conservation and environment issues
- To learn and implement new and better ways to conserve and serve the environment
- To help conserve freshwater and marine biodiversity through reducing human water footprint

5. Research/practice on different aspects of wastewater:

Up-till now, there is no centre for research on wastewater that deals exclusively with this issue. Instead, various departments of educational and research bodies randomly do some research work on this aspect. Most of the studies are published in local journals due to poor quality of the project work. There is dire need to fortify such scattered efforts so that a collective future action plan could be devised well in time. For example, up- till now, there is no short term or long term study available that explains ill effects of wastewater, if any, on soil physical properties, in this country. In Pakistan where safe effluent disposal facilities and its treatment are non-existent or limited, raw sewage is used to irrigate fodders, ornamental and food crops including vegetables (Murtaza *et al*., 2010).

Ensink *et al*. (2004) estimated that the average gross margin for a sewage user farmer in Pakistan was US$173 ha^{-1}, which was substantially higher than the farmer using canal water, about US$43 ha^{-1}, mainly because of higher cropping intensities and the ability to cultivate crops with higher market values. In a study from Faisalabad District, Punjab, Pakistan (Baig *et al*., 2011), net benefit from crop production per Pakistan rupee invested for wastewater irrigation returned Pak. Rs. 5.56 on an average as compared to Pak. Rs. 2.20 for fresh water irrigation. But average days of illness in wastewater area were 11.44 days per person per annum as compared to 8.04 days in fresh water area. Ashfaq *et al*. (2010) in a study reported that in case of wastewater use areas, per person health expenditures were Pak Rs. 4178 as compared to fresh water used areas where it was Pak Rs. 3537, due to higher number of days of illness in case of wastewater use areas around Faisalabad. Reuse of wastewater has many positive impacts on socio-economic aspects of the users. The data of Anwar *et al*. (2010) show that there is a major increase in price of agriculture land due to availability of wastewater and the average land value was Pak. Rs. 0.3 million per acre before the reuse of wastewater while after the availability of wastewater as alternative irrigation source it has increased up to Rs. 0.4- 0.6 million per acre. Similarly, monthly income of 87% households has increased and 77% respondents replied that employment opportunities have been generated. These are positive impacts on agriculture land values, households, monthly income and employment due to reuse of wastewater.

In developing countries including Pakistan, little work is being conducted on this very important research area. Limited information is available on the physical treatment of effluents and soils, bioremediation of effluents and soils, advanced chemical oxidation treatments, thermal remediation strategies, waste landfills and amendments to decrease bioavailability. The restriction in research seems to be related solely to the high cost of implementation on such research. Under these circumstances, at least crop restriction can be used to protect the health of consumers when water of sufficient quality is not available for unrestricted irrigation. For example, water of poorer quality can be used to irrigate non-vegetable crops as cotton, lawns, ornamental or crops that are cooked well before consumption. There is also lack of information regarding both the short and long term effect of wastewater on soil physical properties which needs to be addressed. Moreover, if polluted water treatment at the source is not economically feasible at this time then there should be screening of crop genotypes which are hyper-accumulators of heavy metals in their eatable portions, especially vegetables. Laws should be framed, to encourage farmers to grow only those genotypes which accumulate relatively very low amounts of metals in their eatable portions, especially around major cities of Pakistan. While genotypic/cultivar differences in plant uptake of metals are well documented but absolutely no work has been conducted in this regard in Pakistan. There is hardly any well organized study conducted in this country which focused on risk assessment in a systematic way. Moreover, there are no studies which concern heavy metals bioavailability employing animal trials. Some of the systematic work has been done by IWMI and Pakistan Environmental Protection Agency with financial aid from foreign donors.

Followings are the few best reports that encompass several aspects of this subject in a comprehensive manner:

United Nations Industrial Development Organization (UNIDO). 2000. Industrial Policy and the Environment in Pakistan. UNIDO, Vienna, Austria.

Ensink, J. H. J., van der Hoek, W., Matsuno, Y., Munir, S. and Aslam, M. R. 2002. Use of Untreated Waste Water in Peri-urban Agriculture in Pakistan: Risks and Opportunities. IWMI Research Report No. 64. International Water Management Institute (IWMI), Colombo, Sri Lanka.

Worldwide Fund for Nature (WWF). 2007. Pakistan's waters at risk: Water & health related issues in Pakistan & key recommendations, Available at http://www.wwfpak.org /pdf/water-report.pdf

Murtaza, G., A. Ghafoor, M. Qadir, G. Owens, M.A. Aziz, M.H. Zia, and Saifullah. 2010. Disposal and Use of Sewage on Agricultural Lands in Pakistan: A Review. Pedosphere 20: 23-34.

Pakistan Water Sector Strategy (PWSS). 2002. National water sector profile, volume 5, October 2002, Ministry of Water and Power, Office of the Chief Engineering Advisor. Available at http://waterinfo.net.pk/cms/pdf/vol5.pdf

Moreover, International Water Management Institute has published several reports about various aspects of wastewater in past that can be accessed at www.iwmi.org

6. Status and need for the knowledge and skills on the safe use of wastewater:

While a comprehensive national policy and institutional framework for environmental management is in place, there are significant weaknesses in the current administrative and implementation capacity, typical of a developing country setting like Pakistan. Principal among these are a ubiquitous shortage of trained manpower and insufficient budgetary allocations, a lack of clear definition of roles, work plans and targets, specific capacity gaps on the safe use of wastewater in irrigation by individuals or institutions dealing with wastewater management, and ineffective coordination and communication between federal, provincial and local administrative entities. Most urgently needed is the availability of skilled human resources for implementing national or international guidelines for the safe use of wastewater in agriculture or other purposes. There are no regulations in existence that guide what to be grown with wastewater. Farmers should be made aware of and encouraged to grow resistant and non food plants (i.e. fiber crops, lawns, parks and ornamental plants) with wastewater irrigation. A clear and practical strategy needs to be defined to implement existing policies. There is dire need to minimize weaknesses in coordination among different sections of the society including the general public, organizations, industrialists and farmers. Moreover, there is also need to prioritize the knowledge and skills and develop capacities within various institutions to deal with different aspects of safe use of wastewater in agriculture.

7. Conclusions

Pakistan's water-resources have been diminishing at an alarming rate, as can be concluded from the above-stated facts. It is now a water deficit country. The water availability has decreased from 1,299 m^3 per capita in 1996-97 to 1,100 m^3 per capita in 2006 and that of projected less than 700 m^3 per capita by 2025. Therefore, search for other non-conventional water resources for irrigation i.e. wastewater has become important. In Pakistan, it is estimated that around 2,000 million gallons daily and 962,335 million gallons annually wastewater is being produced and discharged to surface water bodies. This domestic and industrial wastewater is either discharged directly to a sewer system, a natural drain or water body, a nearby field or an internal septic tank. This wastewater is normally not treated and none of the cities have any biological treatment process except Islamabad and Karachi, and even these cities treat only a small proportion (<8%) of their wastewater before disposal. The wastewater used for irrigation is valued by farmers, mainly because of its nutrient contents and reliability of supply and exert positive impacts on agriculture land values, households, monthly income and employment due to reuse of wastewater despite of the ill effects of wastewater irrigation on soil physical and chemical properties in addition to contamination of human food chain and related health risks. Limited information is available in this regard and needs capacity development. There seems no national policy in effect on sustainable use of wastewater in this country. While a comprehensive national policy and institutional framework for environmental management is in place, there are significant weaknesses in the current administrative and implementation capacity. A clear and practical strategy needs to be defined to implement these policies. Moreover, economic incentives have not been introduced for industries to acquire environment-friendly technology. Problems of wastewater disposal tend to stem from distortions due to economy-wide policies, failure of targeted environmental policies, and institutional failures. Thus laws and regulations have been formulated about treatment and disposal of wastewater but their implementation due to lack of resources and skilled manpower is the real issue. There is hardly any well organized study conducted which focused on risk assessment in a systematic way. Some of the systematic work has been done by IWMI and Pak-EPA with financial aid from foreign donors. Therefore a well-coordinated program is necessary to create awareness among different sections of the society including the general public, organizations, industrialists and farmers and to remediate polluted wastewater by using modern techniques.

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