Water Policy 6 (2004) 197–206

A nationwide assessment of wastewater use in Pakistan: an obscure activity or a vitally important one?

Jeroen H.J. Ensink[a], Tariq Mahmood[b], Wim van der Hoek[c], Liqa Raschid-Sally[c] and Felix P. Amerasinghe[c]

[a] *Corresponding author: International Water Management Institute (IWMI) Regional Office for South Asia, ICRISAT, Patancheru 502 324 andhra Pradesh, India. Fax: +91-40-2324-1239. E-mail: j.ensink@cgiar.org*

[b] *IWMI, Regional Office for Pakistan, Central Asia and the Middle East, 12 km Multan Road, howk Thokar Niaz Baig, 53700 Lahore, Pakistan. E-mail: t.mahmood@cgiar.org*

[c] *IWMI, PO Box 2075, Colombo, Sri Lanka. E-mail: w.van-der-hoek@cgiar.org, l.raschid@cgiar.org and f.amerasinghe@cgiar.org*

Received 19 September 2003; accepted in revised form 9 February 2004

Abstract

A nationwide assessment in Pakistan showed that the direct use of untreated wastewater for agriculture, particularly vegetable production, was common in most cities. The main reasons for this use were the absence of alternative water sources, the reliability of the wastewater supply, the nutrient value and the proximity to urban markets. It was estimated that 26% of the total domestic vegetable production of Pakistan was cultivated with wastewater. The importance of the wastewater was reflected in high water and land fees. Policy makers have to take the importance for local livelihoods and food security into account when making decisions regarding direct wastewater use.

Keywords: Agriculture; Irrigation; Nationwide assessment; Pakistan; Vegetables; Wastewater use

Introduction

Over 50% of Pakistan's population lives under arid to semi-arid conditions and agriculture in these areas would be impossible without irrigation. Pakistan is completely dependent on a single river system for all its irrigation water requirements. The Indus River and its tributaries supply, on a yearly basis, over 130 billion m^3 (1billion $= 10^9$) of water to the Indus Basin Irrigation System (IBIS), the largest contiguous irrigation system in the world. The population of Pakistan was 136 million in 1998 (Population Census Organization, 2001) and is expected to double by 2025. The increasing requirements of water for domestic, industrial and agricultural purposes will lead to severe water stress in the near future (Seckler *et al.*, 1998). Previous dry years have led to heated disputes between the two most populated and densely irrigated provinces, Sindh and Punjab over inter-provincial water distribution. As a response to this, extra storage reservoirs have been planned along the main Indus stem and its tributaries, but thus far none of the proposed sites has been approved and it might take several years before construction could be completed.

In Pakistan, as elsewhere in predominantly agricultural societies, irrigated agriculture is by far the largest consumer of fresh water and with increased competition for water by rapidly expanding urban populations and industry, the use of urban wastewater in agriculture is receiving renewed interest. The use of wastewater is a way to substitute and divert scarce fresh water resources away from agriculture towards other beneficial uses and can avoid pollution of fresh water bodies that are used for high value purposes. Use of wastewater for agriculture is common in all parts of the world, but different regions have different ways of using this resource. In many of the Middle Eastern countries the use of treated wastewater has become part of integrated water resource management. Israel is currently at the forefront and expects to meet 70% of its agricultural water demand in 2040 by treated wastewater (Haruvy, 1997). On the other hand, there are countries in Asia like China and Vietnam where untreated wastewater in concentrated or diluted form and night soil has been used for centuries in aquaculture and agriculture (Shuval *et al.*, 1986).

Planned and regulated use of wastewater can put this valuable resource to use whilst at the same time avoiding risks to human health, crop productivity and the environment (WHO, 1973; WHO, 1989; Pescod, 1992; USEPA, 1992). Some form of treatment is needed to meet the water quality standards that are set by international organizations and national governments. A wide range of wastewater treatment methodologies currently exist, of which some are able to remove all harmful pathogens and other pollutants to make it safe for agricultural and even domestic use. The full implementation of health, agronomic and environmental water quality standards is for many countries a long process and a step-wise implementation is therefore recommended in which target quality standards are gradually adjusted until the desired quality is obtained (Von Sperling & Fattal, 2001).

The wastewater treatment method recommended for hot climates is a system of wastewater stabilization ponds (Mara, 2000). However, rapid urbanization and a lack of financial resources have resulted in a situation in which large parts of cities in the developing world lack sanitary collection and disposal systems and where only a limited percentage of all wastewater receives some form of treatment. In semi-arid and arid regions where water is scarce, this wastewater is, in many cases, used unregulated and untreated.

A year-long study by the International Water Management Institute (IWMI) in the southern Punjab showed that the use of untreated wastewater in Pakistan was common and that the impact of wastewater irrigation on farm households was substantial. The study showed that farmers had higher incomes and effectively jumped the poverty line through savings in fertilizer and higher yields as a result of wastewater use (van der Hoek *et al.*, 2002). There are reports that the use of (untreated) wastewater takes place on a large scale in India and other parts of the world (Shuval *et al.*, 1986; Strauss & Blumenthal, 1990; van der Hoek, 2004). However most of this data is anecdotal or based on single case studies and no systematic countrywide assessments have taken place.

The survey presented in this paper is an attempt to provide a nationwide assessment of the importance and characteristics of (untreated) wastewater use in Pakistan. Wastewater use in agriculture is often referred to as either direct use (in which wastewater is taken directly, without dilution, from the sewerage system) or indirect use (in which wastewater is first disposed of into a fresh water body before it is used by farmers). The latter case prevails in many of Pakistan's irrigation systems where the water quality does not conform to World Health Organization (WHO) guidelines (Ensink *et al*., 2002). Direct wastewater use poses a greater risk to agricultural sustainability and public health than indirect wastewater use, but has so far been studied very little and no comprehensive data is available for Pakistan. For this reason the survey opted to assess only direct wastewater use.

Material and methods

Study area

Pakistan is divided in four provinces: Baluchistan, North West Frontier Province (NWFP), Punjab and Sindh; two federal administered areas: Northern Areas, Azad Jammu and Kashmir; and one semi autonomous area: The Tribal Areas. Approximately 35% of Pakistan's population lives in cities (WHO, 2001) with Karachi, Lahore and Faisalabad as the main cities and industrial centers. Agriculture contributes about 24 % of the gross domestic product (GDP) and employs 47 % of the national employed labor force. The average number of people per household is 6.7 (National Institute of Population Studies, 1992). According to official figures, 96% and 94% of the urban population has access to improved water supply and sanitation, respectively (WHO, 2001). Pakistan has set out effluent disposal standards for industry in an environmental ordinance in 1993 but has not officially adopted either the USEPA or WHO health guidelines for agricultural use of wastewater.

Nationwide wastewater survey

A nationwide survey was conducted in the period from July 2002 until April 2003. All urban centers with a population over 10,000 in the four provinces (Baluchistan, NWFP, Punjab and Sindh) were selected with the help of the provincial census reports of 1998. It was decided not to include the disputed Northern Areas and Azad Jammu and Kashmir because of lack of access owing to political or physical constraints. The tribal areas bordering Afghanistan were not selected because of security reasons. This selection led to a total number of 388 cities, the largest of which was Karachi (Sindh, 9.3 million) and the smallest Daultala (Punjab, 10,051). These 388 cities were classified into four groups according to their population numbers (Table 1).

All cities in group I and II were selected, while from groups III and IV, 16 and 25 cities, respectively, were randomly selected. The decision to take a non-proportional selection was based on the assumption that smaller cities would contribute less to the total area irrigated by untreated wastewater than the larger cities. The number of cities to be surveyed was restricted to 60 because this was considered the maximum manageable with the resources available.

All of the selected cities, and in each city all identified direct wastewater-irrigated sites, were visited by one or two of the authors with a standard pre-tested questionnaire. This questionnaire

Table 1. Classification of Pakistani cities by size and province. The number of selected and visited cities per group is shown in brackets.

Group population size	Pakistan	Population	Baluchistan	NWFP	Punjab	Sindh
I > 1,000,000	7 (7)	21,490,000	–	–	5 (5)	2 (2)
II 250,001–1,000,000	12 (12)	5,150,000	1 (1)	1 (1)	8 (8)	2 (2)
III 100,001–250,000	32 (16)	4,795,000	–	4 (3)	21 (12)	7 (1)
IV 10,000–100,000	337 (25)	10,690,000	15 (1)	37 (3)	192 (13)	93 (8)
Total	388 (60)	42,125,000	16 (2)	42 (7)	226 (38)	104 (13)

dealt with issues related to water consumption, wastewater treatment, industrial activities and wastewater use and agronomic practices. During these visits, meetings were held with wastewater farmers (depending on the area irrigated 1–15 farmers were interviewed), disposal pump operators, Water and Sanitation Authority (WASA) staff and municipality officials. Where possible, simple discharge measurements were taken in wastewater drains and trunk sewers.

Average wastewater area and other parameters for the randomly selected cities in group III and IV were extrapolated to generate totals for groups III and IV that were added to the totals of groups I and II. The *t* test was used to test for differences between groups and provinces and a *p* value < 0.05 was considered to reflect a significant difference. Analyses were done with Microsoft Excel XP.

Results

Estimates of irrigated area and volumes of wastewater used

The total estimated area directly irrigated by wastewater was 32,500 hectares (Table 2), with 19,250 households depending on direct wastewater use for their livelihoods. The number of cities with wastewater treatment plants was very low, with only 4 of the 7 cities with over a million inhabitants having treatment facilities. In the entire country of Pakistan we estimated that only 2% of the 388 cities had wastewater treatment facilities. In those cities that did have wastewater treatment plants, the treatment capacity was limited: often less than 30% of the generated

Table 2. Characteristics of direct wastewater use by group of cities in Pakistan.

Group	Cities with DWW[a] use (%)	Total area irrigated (ha)	Range (ha/city)	Households involved	Average landholding (ha)
I	100	6,420	19–2139	3,819	1.6
II	83	3,234	0–798	1,645	2.0
III	91	8,146	0–919	3,277	2.5
IV	78	14,705	0–172	10,509	1.4
Pakistan	80	32,500		19,250	1.7

[a] DWW = Direct wastewater

wastewater received treatment. The estimated total amount of direct wastewater used daily in agriculture was 2, 400, 000 m^3, while an additional 400, 000 m^3/day of untreated wastewater was directly disposed of in irrigation canals. This represented 31% and 5%, respectively of the total amount of wastewater that was produced per day. The remaining 64% was either disposed of in rivers or in the Arabian Sea.

Cultivated crops and type of wastewater

In all cases the use of direct wastewater had started after the construction of a sewerage system. In some cities this was as far back as 1925, while for the large majority of the cities this happened in the mid-1970s and early 1980s. Vegetables were the most commonly grown crop and were cultivated all year round in all cities. The vegetables cultivated included cauliflower, spinach, tomato, pumpkin, ladyfinger, radish and potato. Other major wastewater crops were fodder (*Sorghum bicolor*), wheat, cotton, sugarcane and rice.

The wastewater used was predominantly of domestic origin except in the cities of over a million population size; the survey showed that only 8 (7 in group I and 1 in group II) of the total 60 cities surveyed had large-scale industry (tanneries, pharmaceutical or textile-related industry). Only one of these eight cities used the industrial wastewater for agriculture and this was because the farmers did not have access to any other water source. In the other cities, farmers considered wastewater of industrial origin to be damaging to the crops.

Water charges and land rent

The importance of direct wastewater use was reflected in the average wastewater and land-rent charges. Wastewater fees were in some cases only charged to cover the electricity costs for running the disposal pumps, but in most cases there was a proper per hectare wastewater fee. In those cities where a wastewater fee was charged, this was on average 1070 Rupees/hectare/year (19.3 US$[1]), compared to 380 Rupees/hectare/year (6.8 US$) for regular irrigation water that was used to irrigate the same type of crops (Government of Pakistan, 2002). The total generated revenue for local municipalities and water and sanitation agencies by selling wastewater was substantial and was estimated at 14,700,000 Rupees/year (265,000 US$). Another important indicator regarding the importance of untreated wastewater was land rent, which was on average 19,500 Rupees/hectare/year (351 US$) for wastewater-irrigated land compared to 9,500 Rupees/hectare/year (171 US$) for non-wastewater-irrigated land.

Group and provincial differences

There were no significant differences in average area irrigated with wastewater between cities from groups I, II and III. Only the smaller (group IV) cities had significantly smaller wastewater-irrigated areas. This would indicate that there is no linear trend between the amount of wastewater produced and the wastewater-irrigated area in a city. No significant differences in land rent or wastewater charge per hectare could be found between the four different groups of cities. Provincial differences (Table 3) were found between Punjab and Sindh with respect to the number

[1]Conversion rate at 30 April 2003 (1 Pakistani Rupee = 0.018 US$).

Table 3. Characteristics of direct wastewater use by province in Pakistan.

Province	Cities with DWW[a] use (%)	Total area irrigated (ha)	% of DWW used	% of cities with wastewater-fee
Baluchistan[a]	100	1,008	78	–[b]
NWFP	98	1,210	30	0
Punjab	92	27,168	42	61
Sindh	42	3,114	9	23
Pakistan	80	32,500	31	44

[a] DWW = Direct wastewater
[b] Based on the results of two cities

of cities with direct use of wastewater ($p < 0.02$) and with respect to the area per city irrigated by direct wastewater ($p < 0.01$). None of the municipalities in NWFP charged a wastewater fee, but no other significant difference between the provinces in regard to wastewater charge or land rent could be found. Cities and towns situated in the brackish groundwater zones started using untreated wastewater on average 13 years earlier, compared to cities in fresh groundwater zones ($p < 0.03$).

Discussion

Livelihood and food security

The total area irrigated by direct wastewater of 32,500 hectares seems insignificant when compared to the more than 16 million hectares that are irrigated by the Indus Basin Irrigation System. However, the majority of the land irrigated by the IBIS in 2001–2002 was used for the cultivation of wheat (49%), rice (13%), cotton (19%) and sugarcane (6%), crops that do not require short irrigation intervals like vegetables (Government of Pakistan, 2002). The major advantage of wastewater is the fact that it allows farmers to irrigate whenever they deem it necessary and they do not need to wait for their turn within the irrigation schedule (van der Hoek *et al.*, 2002). The total area cultivated with vegetables (excluding garlic, onions, potatoes and melons) in Pakistan in 2002 was 125,000 hectares (FAOSTAT, 2003), which would mean that 26% of Pakistan's vegetables are cultivated with direct wastewater. This estimate, i.e. 26%, is most likely to be an underestimate, considering the fact that wastewater-irrigated land has higher cropping intensities, almost double that of non-wastewater-irrigated land. It would even be higher if we include areas of indirect wastewater use (which have not been surveyed here) assuming that vegetables are grown in these areas as well.

The Food and Agricultural Organization (FAO) and WHO recommend a daily consumption of at least 200 g of vegetables per person for a healthy diet (FAO and WHO, 1992). Based on 1.5 vegetable crops per year for wastewater-irrigated land and an estimated 10% higher yield as compared to regular irrigated land (FAOSTAT, 2003), direct wastewater use is currently producing enough vegetables to provide the daily recommended per capita vegetable intake for the entire population of Pakistan for 25 days in a year.

Reasons for use of direct wastewater

One of the main reasons for the use of wastewater appears to be the absence of an alternative water source. The provincial differences between Sindh on the one hand and Baluchistan, NWFP and Punjab on the other hand seem to confirm this. Sindh is the province most severely affected by groundwater salinity (Zuberi, 1999), but at the same time also has the highest per hectare water allocation within the IBIS (Khan, 1999), thereby having access to an alternative source of water. This might therefore explain why Sindh, in spite of saline groundwater conditions, has a relatively small area irrigated by direct wastewater. The assumption is further confirmed by the fact that the direct use of wastewater started earlier in cities in brackish groundwater zones.

Although Punjab has large areas affected by highly saline groundwater and low irrigation water allocations, large areas irrigated by direct wastewater were found within fresh groundwater zones and close to rivers. Explanations by farmers indicated that here, the reliability of supply, fertilizer value and proximity to urban markets were important reasons for its use. The fact that untreated wastewater is a profitable resource is reflected in a two-fold difference in land rent and an almost three-fold difference in water charges between wastewater and non-wastewater-irrigated land.

Impact on vegetable prices

A striking feature was the importance of wastewater for vegetable cultivation in Pakistan. In Faisalabad, the third largest city in the survey, weekly market prices of a number of vegetables were obtained from the local market committee. The data covered a one-year period, from March 2001 to February 2002. The average price of locally produced cauliflower[2] was Rupees 703 (standard deviation [SD] 364) against Rupees 1703 (SD 382) for cauliflower that was transported from other areas of the country. Locally produced potatoes[3] had an average price of Rupees 712 (SD 186) against 1262 (SD 255) for the potatoes that came from elsewhere. In both cases this difference was statistically significant (*t*-test, $p < 0.001$). The prices of vegetables are determined solely on the basis of supply and demand forces and it is clear that prices go down dramatically when sufficient local produce enters the market. Especially for the poor segments of the urban population the lower prices may be expected to have positive implications for their vegetable consumption pattern and subsequently their nutritional status. This potential positive health impact of wastewater irrigation should be further explored in future studies, together with potential negative health impacts and socio-economic and environmental impacts (Hussain *et al.*, 2001).

Guidelines, health risk and policy implications

Most of the municipal and water and sanitation agency officials expressed their concern about the health risks associated with the use of direct wastewater, but admitted that there was little they could do, as they had no means to enforce regulations. Wastewater inlets to farms if closed today, would be forced open within a couple of hours. The limited financial resources faced by all municipalities demand that priorities have to be set, with the highest priority for drinking water

[2]Price per 100 kg.

[3]Price per 100 kg.

supply, followed by the collection and disposal of wastewater, with little or no money available for the enforcement of water quality guidelines. Most municipalities have come to a welcome consensus in which local wastewater farmers pay the electricity cost of running the disposal pumps or a per hectare water fee. In some cities an annual auction of wastewater was organized and the money generated through the sale of wastewater was invested into the operation and maintenance of the drinking water or sewerage system.

Concerns for public health and consumer awareness have led to a number of court cases in several Pakistani cities. In Quetta, local wastewater farmers were ordered to have their produce tested for pathogens in a recognized national laboratory, after a group of local residents filed a complaint. Only after the produce showed no signs of pathogens were the farmers allowed to continue their practice. In Hyderabad, farmers and the local municipality have come to an agreement that the only crops that can be grown with wastewater are those that produce edible parts that grow above the ground. Potatoes, onions, carrots and garlic can therefore not be cultivated, though salad crops were allowed.

The absence of uniform guidelines regarding wastewater is a clear problem, as many officials complained about the lack of guidance on whether to allow or forbid the use of untreated wastewater. This lack of guidance is best shown through the large number of court cases that have occurred over the last ten years initiated by local utilities or water and sanitation agencies. The outcome of these court cases were either that farmers were forced to pay for wastewater or forced to abandon the use of wastewater. In the case of Faisalabad, a group of wastewater farmers successfully appealed against a court order forcing them to abandon the use of direct wastewater, after they proved that they had no access to another suitable water source.

Conclusions

The direct use of untreated wastewater in Pakistan is common and provides important benefits to farmers through its high reliability and nutrient content. With approximately 26% of Pakistan's vegetables grown on untreated wastewater, the practice is certainly not an obscure activity but of great importance to livelihoods and food security. The practice of direct wastewater irrigation therefore deserves more attention especially considering Pakistan's rapidly growing population and its already stretched water resources, which are likely to lead to an increase in the use of untreated wastewater in the near future. Assessments of this kind have not been carried out previously, with the result that figures quoted at national, regional and global scales are more in the nature of "guesstimates" than scientifically validated figures. We believe that the methodology used in this study has wide applicability elsewhere and would contribute not only to determining the real extents of wastewater use but also the crop production and socio-economic aspects of its use.

Wastewater irrigation, and especially the use of untreated wastewater, is often considered a serious health hazard. In the case of Pakistan, in (many of) the cities studied, the irrigation allocation for regular irrigation water does not allow for the cultivation of vegetables, hence farmers turn to the use of untreated wastewater to grow these high value crops which have a ready market in the cities. Wastewater is therefore essential for the supply of vegetables to these cities and many urban residents would be deprived of daily fresh vegetables if wastewater irrigation were banned.

Despite these benefits, the health, environmental and agronomic risks cannot be ignored and a clear government policy with respect to wastewater use is required. The full treatment of all wastewater currently used for irrigation is an unobtainable goal in the short or medium term. A complete ban on the use of untreated wastewater, as advocated by municipal officers, seems impossible to enforce. Strict enforcement of crop restrictions is also not feasible, as the cultivation of vegetables is not only the most profitable type of agriculture for farmers but also the crop that is under the strictest water quality regulations.

A step-wise implementation of water quality guidelines is recommended for Pakistan, though during this step-wise implementation, interventions aimed to minimize and control health and environmental risks should be promoted. Human exposure control methods, like the use of footwear and gloves, could considerably reduce the health risks of untreated wastewater to farmers and could be promoted through farmer and water-users associations. Different irrigation techniques, conjunctive use of different water sources and the availability of clean water for washing of produce before it is sent to local markets would improve food safety and promote environmental sustainability, while regular treatment of those exposed to wastewater with anti-parasitic medication would prevent long term health effects.

In the case of Pakistan, to make any of these control measures work, it seems vital that policy makers realize that untreated wastewater irrigation is not just a health and environmental hazard but is important for livelihoods and food security. The adoption and implementation of the WHO and FAO guidelines on wastewater use is desirable, but currently unfeasible and therefore a flexible and creative approach to risk reduction is needed to guarantee that farmers can maintain their livelihoods, while at the same time health risks can be reduced and agricultural sustainability guaranteed.

Acknowledgement

IWMI gratefully acknowledges financial support from the German Federal Ministry for Economic Cooperation and Development (BMZ) for its research on the use of wastewater in Pakistan. This research contributes to the Comprehensive Assessment of Water Management in Agriculture (*www.iwmi.org/assessment*) and this national survey was supported by a grant from the Government of The Netherlands to the Comprehensive Assessment.

References

Ensink, J. H. J., Aslam, M. R., Konradsen, F., Jensen, P. K. & van der Hoek, W. (2002). *Linkages between Irrigation and Drinking Water in Pakistan*. Working Paper 46. International Water Management Institute, Colombo, Sri Lanka.

FAOSTAT (Food and Agriculture Organization of the United Nations) (2003). http://faostat.fao.org/faostat/form?collection=production.Crops.Derived&Domain=production&servlet=1&hasbulk=0&version=ext&lang=EN

Food and Agricultural Organization (FAO) & World Health Organization (WHO) (1992). Major issues for nutrition strategies: Incorporating nutrition objectives into development policies and programs. *International Conference on Nutrition*. Theme Paper No. 8. FAO, Rome, Italy.

Government of Pakistan (2002). *Pakistan Economic Survey 2001–02*. Finance Division, Economic Adviser's Wing, Islamabad, Pakistan.

Haruvy, N. (1997). Agricultural reuse of wastewater: nation-wide cost-benefit analysis. *Agriculture, Ecosystems & Environment*, *66* (2), 113–119.

Hussain, I., Raschid, L., Hanjra, M. A., Marikar, F. & van der Hoek, W. (2001). *A Framework for Analyzing Socioeconomic, Health and Environmental Impacts of Wastewater Use in Agriculture in Developing Countries*. Working Paper 26. International Water Management Institute, Colombo, Sri Lanka.

Khan, A.R. (1999). *An Analysis of the Surface Water Resources and Water Delivery Systems in the Indus Basin*. Report 93. International Water Management Institute, Lahore, Pakistan.

Mara, D. D. (2000). The production of microbiologically safe effluents for wastewater reuse in the Middle East and North Africa. *Water, Air and Soil Pollution*, *123*, 595–603

National Institute of Population Studies. (1992). *Pakistan Demographic and Health Survey 1990/1991*. National Institute of Population Studies, Islamabad, Pakistan & IRD/Macro International Inc. Columbia, Maryland, USA.

Pescod, M. D. (1992). Wastewater treatment and use in agriculture. *Irrigation and Drainage*, Paper 47. Food and Agricultural Organization (FAO), Rome, Italy.

Population Census Organization (2001). *1998 Provincial Census Report of Punjab*. Statistics Division, Population Census Organization, Islamabad, Pakistan.

Seckler, D., Amarasinghe, U., Molden, D., de Silva, R. & Barker, R. (1998). *World Water Demand and Supply, 1990 to 2025: scenarios and issues*. Research Report 19, International Water Management Institute, Colombo, Sri Lanka.

Shuval, H. I., Adin, A., Fattal, B., Rawitz, E. & Yekutiel, P. (1986). *Wastewater Irrigation in Developing Countries: Health effects and technical solutions*. Technical Paper No. 51. The World Bank, Washington, USA.

Strauss, M. & Blumenthal, U. J. (1990). *Human Waste Use in Agriculture and Aquaculture: Utilization Practices and Health Perspectives*. International Reference Centre for Waste Disposal, Duebendorf, Switzerland.

United States Environmental Protection Agency (USEPA) (1992). *Guidelines for Water Reuse*. USEPA, Washington, USA.

Van der Hoek, W., ul Hassan, M., Ensink, J. H. J., Feenstra, S., Raschid-Sally, L., Munir, S., Aslam, R. M., Ali, N., Hussain, R. & Matsuno, Y. (2002). *Urban Wastewater: a valuable resource for agriculture. A case study from Haroonabad, Pakistan*. Research Report 63. International Water Management Institute, Colombo, Sri Lanka.

Van der Hoek, W. (2004). Framework for a global assessment of the extent of wastewater irrigation: The need for a common wastewater typology. In: *Wastewater Use in Irrigated Agriculture: Confronting the Livelihood and Environmental Realities*. CABI Publishing and IDRC India.

Von Sperling, M. & Fattal, B. (2001). Implementation of guidelines: some practical aspects. In: *Water Quality: Guidelines, Standards and Health. Assessment of risk and risk management for water-related infectious disease*. (Fewtrell, L. & Bartram, J. (Eds.)). IWA Publishing, London, United Kingdom.

World Health Organization (WHO) (1973). *Reuse of Effluents: methods of wastewater treatment and health safeguards*. Technical Report Series 518. WHO, Geneva, Switzerland.

World Health Organization (WHO) (1989). *Health Guidelines for the Use of Wastewater in Agriculture and Aquaculture*. Technical Report Series 778. WHO, Geneva, Switzerland.

World Health Organization (WHO) (2001). *Global Water Supply and Sanitation Assessment Report 2000*. WHO, Geneva, Switzerland.

Zuberi, F.A. (1999). *Integrated Surface and Groundwater Management Programme for Pakistan: Groundwater resource study*. Internal Report No. 99/7. International Waterlogging and Salinity Research Institute and Pakistan Water and Power Development Authority, Lahore, Pakistan.