ISSN(P): 2304-1455/ ISSN(E): 2224-4433

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To cite this article: Samina Khalil and Mehmood Khan Kakar (2011). Agricultural use of untreated urban wastewater in Pakistan. Asian Journal of Agriculture and Rural Development, 1(1), 21-26.

Asian Journal of Agriculture and Rural Development, 1(1)2011: 21-26

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Abstract

Untreated wastewater is used for irrigation in over 80% of all Pakistani communities with a population of over 10,000 inhabitants. The absence of a suitable alternative water source, wastewater's high nutrient value, reliability, and its proximity to urban markets are the main reasons for its use. Two case studies in Pakistan studied the impact of untreated wastewater use on health, environment, and income. The results showed a high increase in hookworm infections among wastewater users and a clear over-application of nutrients through wastewater. Heavy metal accumulation in soil over a period of 30 years was minimal in Haroonabad, a small town with no industry, but showed initial signs of excess levels in soil and plant material in Faisalabad, a city with large-scale industry. The impact of wastewater irrigation on household income was considerable as wastewater farmers earned approximately US$300/annum more than farmers using freshwater. Both case studies showed the importance of wastewater irrigation on local livelihoods. The lack of financial resources at municipal and provincial levels for wastewater treatment calls for other measures to reduce the negative impact of untreated wastewater use on health and environment, for example to manage groundwater, regular (canal) irrigation water, and wastewater conjunctively, and regular deworming treatment of those exposed to wastewater.

Keywords: Untreated wastewater, hookworm infections, metal accumulation, ground water

Introduction

Water is the most valuable and precious natural resource, as is essential for all forms of life and constitutes the principle part of all living beings. Water is used in different ways in human societies but the most frequent and regular use of water includes drinking, domestic use of water, and irrigation of agricultural crops. Whenever good quality water is scarce 'Marginal quality' water is used for the purpose of irrigation. Marginal quality water includes sewage water, industrial wastewater, and any water that is unfit for drinking purposes.

Water is becoming an increasingly scarce resource in many arid and semi-arid countries and planners have been forced to conceder any source of water, which might be used economically and effectively for the development purposes. At the same time population extended at a high rate, the need for food production is apparent. The potential for irrigation to raise both agricultural productivity and life standards of the rural poor has long been recognized.

Pakistan has a population of over 150 million and is one of the few countries that is almost completely dependent on a single river system for all its agricultural water demands.

The Indus River and its tributaries provide water to over 16 million hectares of land, situated in the mainly arid and semi-arid zones of the country. A rapidly growing population, saline groundwater, a poorly performing irrigation distribution system, and recurrent droughts have led to increased water shortages. Under these conditions, the use of

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ISSN(P): 2304-1455/ ISSN(E): 2224-4433
www.aessweb.com

untreated urban wastewater for agriculture has become a common and widespread practice.

Preliminary results from a country-wide survey in the four main provinces showed that untreated wastewater was used in 50 out of 60 visited cities. The three main reasons for the use of wastewater were the high salinity of groundwater, recent droughts that have led to a decline in groundwater tables, and the nutrient value of wastewater. Other important reasons were the proximity of urban markets and the reliability of wastewater, which unlike regular irrigation water is not subjected to a rotational schedule. In more than half of the visited cities some sort of fee was paid by farmers to either the municipality or the local wastewater utility for the use of wastewater. For example, in the city of Quetta, 212 farmers cultivating 800 ha collectively paid US$12,000/ annum for the right to use wastewater. This was 2.5 times more than the fee for regular irrigation water. Land rent in all cities reflected the importance of wastewater with the rent for land that had access to wastewater being at least double and in some cases up to six times that of land without access to wastewater. In the city of Quetta, the average annual rent for land with access to wastewater was US$940/ha, compared to US$170/ha for land irrigated by freshwater.

Description of area

Quetta valley in Pakistan is an arid mountainous region receiving an average rain fall of 200 mm, the estimated population of Quetta is 381,57 thousands and temperatures ranging from -15°C in January to 35°C in July. The area of the study is killi (village) Shahozai a small peri-urban settlement located in south west of Quetta city the province of Balochistan distance is approximately 11 km, the village is connected through two roads namely Sabzal and Brewry Road. The total area of the village is 2200 acre. The population of the village is estimated 2500 people and there are 175 houses some of which is mud “Kacha” (local name) and some are single story RCC houses.

Irrigation in Quetta

Almost the only source of perennial water in the valley is ground water traditionally this was tapped using Karazes. These are near horizontal tunnels, which have one end intersecting the groundwater table, often near the valley sides where flows from the adjacent limestone formations .the tunnels then convey flow at a grade of less than the slope of the ground above, to a point where the tunnel intersects the surface and the and water flows into irrigation channels to use for agriculture. The shortage of the ground water for agriculture purposes, the farmers divert to use waste and pullulated water for cultivation.

Wastewater irrigated agriculture

The irrigation system of the village is also the traditional but due to the shortage of fresh water for irrigation purposes the farmer now widely use wastewater for cultivation the total area is 26712 Ha out of which 1500Ha could be irrigated with wastewater alone. At an average farm sizes less than one acre, this could provide livelihood support for about 150 farmers in the peri-urban areas of Quetta. Wastewater flows from drains into streams, which are usually used for irrigation.

Main cropping pattern

Along the main Quetta (Shahozai) wastewater nallas two distinct cropping systems are apparent: vegetable production; field crops with vegetables; the spatial variation of the cropping systems results from a combination of factors which include labour availability, farm size, and market access.

Open-space vegetable farming

A common picture in both urban and peri-urban areas of Pakistan is the cultivation of such cereals as maize in the rainy seasons and of irrigated vegetables in the dry seasons. More than 10 kinds of vegetables are cultivated, all of which are sold. The most perishable (often non-traditional) vegetables, such as cabage, coriander, cucumber and salad locally known as ghobi, dhanya and khira are usually grown in the urban and peri urban and harvested 1 times during the year (with only supplementary irrigation during the rainy season).

The use of polluted water for vegetable farming is more widespread in the more populated cities where safe water is scare and is used for domestic purposes. From a general survey among open-space farmers carried out in 2002, it was found that about 84% of nearly 100 farmers farming in and close to Quetta city and almost all 100 farmers in Quetta used polluted water for irrigation, at least during the dry seasons.

Typical urban farm sizes range from 0.1–0.2 ha and they increase in size along the urban–rural gradient. As production is market-oriented, farming is input- and output-intensive, particularly in terms of the use of water and such other farm inputs as poultry manure, pesticides and fertilisers. In Pakistan, most farmers use watering to irrigate, use water canal (nala) while only a few farmers with larger holdings in peri-urban areas use motor pumps.

Vegetable production

A distinct features of the intensive vegetable production systems is the continuous all year production of vegetables and the absence of a fallow. The proximity to the urban areas – i.e. the source of wastewater – ensures a reliable irrigation supply during the dry season (May - August). These production systems are predominantly found at Shahozai Quetta. The ease of access to local urban markets and high urban demand ensure a secure market for vegetable produce, particularly during the dry season when vegetable market prices increase three to five fold. The intensive vegetable production systems require considerably higher labour inputs than field crop. Household members normally meet these labour inputs but during peak periods additional farm labourers may be hired. Further examination of wastewater irrigation practices reveals a range of associated problems that threaten to outweigh the benefits. The improved crop yields are also offset by a problematic increase in the incidence of weeds and pests. A common picture in both urban and peri-urban areas of Quetta the cultivation of such cereals as maize in the rainy seasons and of irrigated vegetables in the dry seasons. More than 10 kinds of vegetables are cultivated, such as Spinach, salad leaves, Qulfa, mustard leaves, Maithee (local names), all of which are sold. The most perishable (often non-traditional) vegetables grown in the village and often harvested 11 times during the year (with only supplementary irrigation during the rainy season).

Methodology

A farming systems survey was conducted in June 2004 using semi-structured interviews and participatory rural appraisal (PRA) techniques. The first phase consisted of an orientation and familiarisation survey of the farming systems located along the main Quetta wastewater nalla (open drains). This provided an opportunity to make initial contact with the farmers thereby introducing the research project and identifying some of their main concerns, issues and constraints, in addition, the geographical extent to which wastewater is used for irrigation was also gauged. The results of the preliminary survey was used to select the peri-urban village (Shahozai) that would be targeted during the survey; consideration was given to ensuring that a wide geographical area was covered in an attempt to identify spatial patterns and trends.

The second phase consisted of the main survey and incorporated semi-structured interviews; cropping calendars and on-farm transect walks. During the survey a total of 25 farmers and 25 non farmers were interviewed, consisting primarily of smallholders with plot sizes below one hectare (ha). In the peri-urban areas of Quetta land ownership and occupations are the principle criteria used by the villages to describe characteristics of the poor (Brook and Dávila, 2000). Indeed, many of the villagers themselves classify smallholders with plot sizes below two hectares as ‘poor’, while the landless – often employed as agricultural labourers – are classified as the ‘very poor’ (Hillyer *et al.*, 2002). The interviews were supported with cropping calendars and transect walks with the farmers through the areas that were irrigated with wastewater; most of the interviews took place in the farmers’ fields. And test for soil, plants, wastewater, the samples are collected from different areas of plots, field, and nalla respectively.

Socio-economic benefits of wastewater irrigation

Individual benefits

Preliminary cost/benefit analyses have been carried out for urban and peri-urban vegetable farmers in and around the open-space urban farmers can achieve annual income levels of US$400–600/ha. These levels are achieved due to the intensive nature of farming made possible partly by the free and reliable supply of water. However, being successful in this way requires careful observations of market demand in the lean season in order to properly plan for the required inputs, particularly seed (Danso and Drechsel, 2003). Also, dry season peri-urban vegetable farming is seen as a significant source for income generation, since during the wet season staple crops are also grown for household consumption.

On average, farm income from all vegetables amounts to about US$1,200/ha but a more conservative estimate considering actual crop mix could be US$500/ha (Cornish *et al.*, 2001). Most of the vegetable crops are grown in the dry months of November to February. The authors estimate the actual peri-urban area under informal irrigation within a 40-km radius of Quetta as 11,500 ha. This is less than the total area reported under formal irrigation in the area. The annual value of this production has been estimated as US$5.7 million. A significant part of this is produced with wastewater.
Wastewater contains so much of the stuff that posses the fertilizing qualities so it save the cost of fertilizer and wastewater is comparatively cheaper than the fresh water therefore it save quit good amount of the irrigated water for the farmers.

Aggregate benefit to the city

The value of wastewater irrigation should not only be seen from the perspective of livelihood support, employment, and income generation given that the actual (sometimes small) numbers of open-space farmers might not attract the attention of municipal authorities. The overall (aggregate) benefit to the city should also be highlighted. An example is the dependence of the city on irrigated urban vegetable production. Due to the lack of refrigerated transport and storage, the supply of perishable vegetables to urban dwellers depends significantly on this kind of agriculture (Nugent, 2000). In Senegal, for example, about 60% of the vegetables consumed in Dakar are produced within or close to the city (Niang *et al.*, 2002), mostly with wastewater.

Heavy metals results

Quetta

The results for Quetta indicate that because the pH of the soils analysed ranged from 7.72–8.30, the levels of copper (Cu), nickel (Ni), lead (Pb), and chromium (Cr) are within European Economic Community (EEC) maximum permissible (MP) levels (Table 8.3). No MP levels are established for cobalt (Co) and manganese (Mn). However, a significant accumulation of Pb and Cu can be observed within the top 0–15 cm of the 100% wastewater-irrigated soil profiles (Table 8.3). In contrast, Ni, Co, Cr and Mn remained relatively uniform irrespective of depth with mean (n=6) concentrations of Ni 30.2 (±0.4), Co 11.3 (±0.5), Cr 56.0 (±9.5) and Mn 256.9 (±18.4) mg/ kg (Table 8.3).

As with the 100% wastewater-irrigated field, Pb and Cu levels were elevated at the soil surface (0–5 cm) of the conjunctively irrigated field (Table 8.3). However, the surface accumulation of Pb and Cu was restricted to 0–5 cm soil depth compared to 0–15 cm for the 100% wastewater-irrigated field. It is suggested that the elevated levels of Pb could be attributable to deposition from petrol fumes as the 100% irrigated wastewater site is located next to the central bus station. Other metal concentrations remain relatively uniform with depth with mean (n=6) concentrations of Ni 26.9 (±1.1), Co 12.3 (±0.9), Cr 46.5 (±4.6) and Mn 231.9 (±12.5) mg/kg.

Table 1: Total nitrogen (TN) application, nitrogen ratios and total amount of wastewater applied to vegetables Quetta, Pakistan

Quetta	TN/croping	Nitrogen ratio*	Total Water Applied (mm)
	450	445	312

Nitrogen ratio Total N applied / Recommended N×100

Table 2: Vertical distribution of heavy metal concentrations in soil (mg/kg) at varying soil depths in relation to type of irrigation water used at three sites in Quetta

Concentration (mg/kg) at various Soil depths*								
Type of	Pb	Pb	Cu	Cu	NI	Co	Mn	Cr

irrigation water								
100% wastewater	(0-15cm)* 19.7 (2.3)	(15-90cm) 8.2 (1.2)	(0-15cm) 82.9 (1.4)	(15-90cm) 70.1 (2.4)	(0-90cm) 32.2 (0.4)	(0-90cm) 11.3 (0.5)	(0-90cm) 256.9 (18.4)	(0-90cm) 56.0 (9.5)
Conjunctive use	(0-5cm) 12.4	(5-90cm) 6.4	(0-5cm) 77.3	(5-90cm) 58.4 (2.0)	(0-90cm) 26.9 (1.1)	(0-90cm) 12.3 (0.9)	(0-90cm) 231.9 (12.5)	(0-90cm) 46.5 (4.6)
Freshwater	(0-90cm) 7.9	(0-90cm)	(0-90cm) 21.9	(0-90cm)	(0-90cm) 22.5	(0-90cm) 11.2	(0-90cm) 185.7	(0-90cm) 64.2
EEC MP levels	50-300		50-140		30-75			100-150

[a] Sampling depth in parentheses.
[b] Standard deviation in parentheses and italicised.
[c] The range of European Economic Community (EEC) maximum permissible (MP) levels for Pb, Cu and Ni given in Table 8.3 correspond to soil pH.
The lower value given corresponds to a soil pH < 5.5 and the higher value a soil pH >7.0.

In contrast, both soil Pb and Cu in the Hectare (freshwater-irrigated) fields were significantly lower than in the wastewater-irrigated plots (Table 8.3). In addition, no surface accumulation of Pb or Cu was observed. In comparison to the wastewater-irrigated plots, levels of Ni, Co, Mn and Cr remained relatively uniform irrespective of soil depth.

Conclusion

Untreated wastewater irrigation poses serious health risks that cannot be ignored. While the risks to consumers may not be excessive, as most vegetables grown in land irrigated with wastewater are eaten cooked, the risks to farmers practicing flood irrigation cannot be ignored. The studies in Quetta show a 5-fold increase in the risk of hookworm infection among wastewater farmers. However many of these farmers have no other option or do not want to use other water. This was illustrated by some farmers in Quetta who had access to treated and untreated wastewater but opted for the untreated (black) wastewater as it was considered less saline and better for their crops.

In the present situation there seem to be clear gains for both farmers and municipalities. Farmers are willing to pay high water fees, which in turn are used by municipalities to finance the maintenance and operation costs of drinking water and sewerage services. However, the long-term sustainability is at risk as farmers are limited in their choice of crops and heavy metal uptake by wheat as measured in its grain is getting close to critical levels. Groundwater contamination due to extensive irrigation with wastewater has not been an issue for Quetta because the natural saline groundwater there means they have no alternative irrigation water source, but it would be an important issue in cities and towns in the fresh groundwater regions.

Although the use of wastewater is likely to become increasingly important for Pakistan as a combined strategy for water conservation and pollution prevention, management of this resource is in the hands of local farmers and municipalities. There seems to be little awareness of the risks involved in the use of untreated wastewater among local municipalities where the opinion of many is that ‘the farmer knows best’.

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