

# 10

## Raw wastewater use in agriculture; risk versus benefits

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### **10.1 WASTEWATER USE IN AGRICULTURE**

The use of urban wastewater or sewage in agriculture is seen by many as a vital component of integrated water management to overcome regional and global water scarcity (Scott *et al.* 2004). The use of treated wastewater is currently encouraged by the European Union, though its use in Europe is still limited, especially when compared to water-scarce countries such as Israel where treated wastewater is expected to meet 60% of the country's agriculture water demand (Haruvy *et al.* 1999). In water-scarce regions, the use of wastewater in agriculture will free up, and prevent the contamination of good quality water resources for the use in urban centres and industry. Although the use of treated wastewater in agriculture is encouraged and promoted, the unregulated use of untreated or partially treated wastewater in agriculture is estimated to be much

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more common (Scott *et al.* 2004). High construction, land and maintenance costs associated with most wastewater treatment technology, rapid and uncontrolled urban sprawl and farmers perceptions are all reasons why an estimated 3.5 to 20 million hectares of agricultural land are currently irrigated with partially or untreated wastewater (Ensink and van der Hoek 2007). Almost all of this is situated in developing countries.

Wastewater use, in the absence of wastewater treatment, tends to result in municipalities reacting in one of two ways:

- to ban wastewater irrigation and thus force farmers from their land; or
- to pretend that the use of untreated wastewater is not taking place.

Both are undesirable, as one deprives often poor farmers of their sole livelihood, while the other ignores a potential risk to public health. There is, therefore, a need to take a holistic, but most importantly, a realistic look at the use of untreated wastewater in agriculture, so that targeted health interventions can be provided until wastewater treatment can be implemented. This chapter, by using Pakistan as a case study, aims to identify the main health risks and benefits associated with the use of untreated sewage effluent in agriculture.

## 10.2 PAKISTAN

At the time of Pakistan's last census in 1998, its population stood at 132 million, a number which is expected to double by 2030. Pakistan is still a predominantly agricultural society and the agriculture relies heavily on the Indus Basin Irrigation System, which irrigates over 16 million hectares of agricultural land. As a result of the country's semi-arid to arid climate, agriculture without irrigation is virtually impossible. A nation-wide survey into the prevalence and characteristics of wastewater irrigation, revealed that in more than 80% of all cities and towns in Pakistan the use of wastewater in agriculture was practiced. The only prerequisite for the use of wastewater in agriculture was the presence of a centralized sewerage collection system. In all instances, wastewater was used in the peri-urban areas of the towns and cities around the disposal stations. Wastewater treatment plants were rare and found in only 2% of all cities (Ensink *et al.* 2004). In those cities where wastewater treatment plants were found, only a small proportion of generated wastewater was receiving treatment and, in these areas, farmers preferred the use of untreated wastewater, because of its higher nutrient status and lower salinity compared to treated wastewater. The most commonly grown crops with wastewater were vegetables (Plate 10.1) and fodder grasses.



Plate 10.1. Farmers growing spinach with untreated wastewater in Faisalabad, Pakistan (Photo: J. Ensink)

### 10.3 HEALTH IMPACT EVALUATION

The use of wastewater in agriculture poses both health risks and health opportunities to farmers, consumers and people living in close proximity to wastewater irrigated sites. The International Water Management Institute started a programme in 2000, which aimed to quantify both the risks and benefits of wastewater use in Pakistan. For this purpose the city of Faisalabad was selected for a five year study programme. This city was selected for the following reasons:

- over 2500 hectares over land were irrigated with domestic wastewater; and
- although a waste stabilization pond (WSP) was present, farmers preferred to use untreated wastewater (Plate 10.2).

At the start of the study, different costs (health risks) and benefits were identified for which separate studies were designed.



Plate 10.2. Pipes taking untreated wastewater from a wastewater drain before it enters the WSP (Photo: J. Ensink)

### 10.3.1 Risks

The World Health Organization (WHO) guidelines on wastewater use in agriculture identified a wide range of potential health risks associated with the use of wastewater in agriculture (WHO 2006). These health risks mainly stem from the high concentrations of human and animal pathogens in wastewater but also from organic and inorganic substances.

The main health risks identified were:

- gastrointestinal infections, especially helminth infections, in farm workers as a result of direct exposure to wastewater;
- gastrointestinal infections in crop handlers and consumers as a result of the handling and consumption of wastewater irrigated produce;
- contamination of drinking-water groundwater sources with nitrates; and
- heavy metal build up in soil and concomitant uptake and accumulation in edible plants.

### 10.3.2 Benefits

World-wide, only 20% of the total area under agricultural production is irrigated. However, this area is responsible for over 40% of the global food production and irrigated agriculture is therefore seen as essential in feeding an ever expanding world population (Seckler *et al.* 1999). The benefits of wastewater compared to regular irrigation are:

- the increased availability and reliability of irrigation water;
- the presence of macro nutrients (nitrogen, phosphorus and potassium) which reduces the need for chemical fertilizer; and
- the availability of a water source in close proximity to urban markets, which reduces transportation costs and allows for the cultivation of perishable high value crops like vegetables.

## 10.4 COST-BENEFIT ANALYSIS

For the cost-benefit analysis, data was sourced from the study conducted in Faisalabad from 2000 to 2005. The different subcomponents of this research have been presented separately. In this chapter we present a cost-benefit analysis at four different levels: farmer, consumer, municipality and downstream water users.

### 10.4.1 Farmer

Untreated wastewater irrigation in Faisalabad has a long tradition. Local farmers report that untreated wastewater irrigation dates from at least the construction of the water-borne sewage system in 1972, although other farmers claimed that their families had used wastewater from one of the city's main outfall drains for over 80 years. Initial anecdotal evidence from some of the older farmers showed that farmers were very aware of the nutrient properties of the wastewater. Farmers claimed that the nutrient value of the wastewater used for irrigation had deteriorated since the municipality banned farmers from keeping cattle in the city, which meant that dung was no longer flushed into the central sewerage system.

A survey among 50 wastewater farmers and 50 regular farmers, revealed a strong preference for the use of wastewater. If given the choice, 86% of farmers currently using regular irrigation water would have opted to use wastewater, while only 4% of the farmers currently using untreated wastewater would have opted to use regular irrigation water (Ensink *et al.* 2008). An overwhelming

majority (92%) of all farmers identified the nutrient value, the reliability of wastewater, or both as the key incentives for the use of wastewater in agriculture. Farmers were found to be actively pursuing access and the right to use wastewater and were willing to pay a hefty fee. In Faisalabad, wastewater fees were between 6 and 12 times higher than fees for regular irrigation water. The irrigation water fee ranged from 620 rupees (US\$ 10) to 3700 rupees (US\$ 62) per hectare per year depending on the amount and the quality (nutrient content) of wastewater; with the highest fees paid for untreated wastewater (Ensink *et al.* 2007).

The research conducted in Faisalabad confirmed farmer views; farmers that used wastewater were able to apply more water and apply it in shorter intervals as compared to farmers who irrigated with regular irrigation water (Figure 10.1).

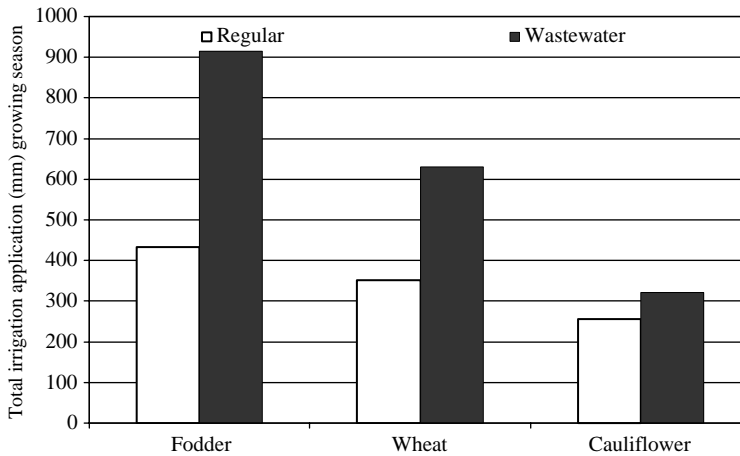


Figure 10.1. Wastewater and regular irrigation water applications (mm) for fodder, wheat and cauliflower in Faisalabad, Pakistan

By using wastewater, farmers were able to meet irrigation quantity requirements for fodder crops (558 mm) and wheat (590 mm), which would have been impossible with regular irrigation water. Regular irrigation water in Pakistan is subject to fixed rotations, where farmers get water once a week, with a fixed timing and quantity, irrespective of the crop grown or its growth stage. Wastewater allowed farmers to be more flexible in their crop choice and allowed farmers to grow vegetables, which have shallow rooting depths and need to be irrigated more frequently.

The nutrient value of untreated wastewater was high with total nitrogen concentrations sometimes exceeding 50 mg/l. Farmers mentioned that some crops could not be grown with wastewater, such as most root crops, while other crops such as wheat and rice sometimes exhibited excessive vegetative growth. However, wastewater was considered ideal for the cultivation of spinach and cauliflower. In Faisalabad, farmers were followed for a year and their fertilizer application was monitored on a weekly basis. The results showed that wastewater farmers predominantly applied fertilizers through the application of wastewater and the chemical fertilizer application was kept to an absolute minimum. When nutrient concentrations and irrigation application were multiplied and chemical fertilizer applications were added, wastewater farmers applied considerably more nutrients than regular farmers (Figure 10.2). Wastewater farmers on average applied 65 kg/ha of chemical fertilizer compared to 530 kg/ha by regular farmers. For the wastewater irrigated site around the WSP this constituted an annual saving of 300 tons of chemical fertilizer or approximately US\$ 51,000. If these figures are transposed for the whole of Pakistan, then an annual saving of over US\$ 2.5 million could be made.

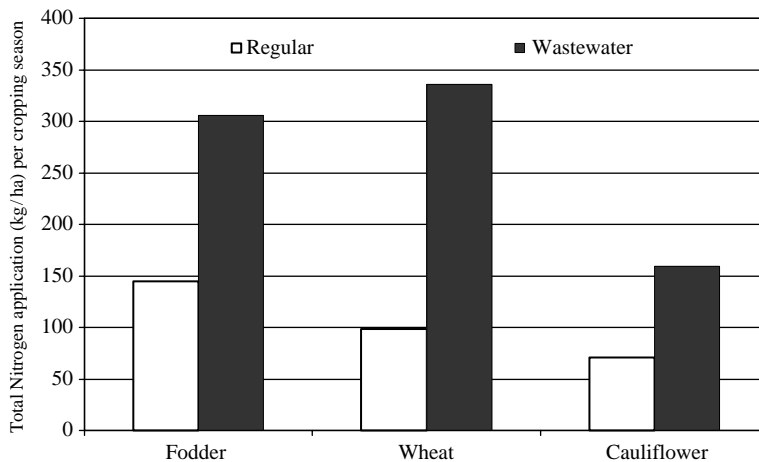


Figure 10.2. Nutrient applications (kg/ha) for fodder, wheat and cauliflower in Faisalabad, Pakistan

Savings in chemical fertilizers made up approximately 30% of total gross margin for wastewater farmers in Faisalabad, with higher cropping intensities and the cultivation of higher valued crops making up the remaining 70%. This

meant that wastewater farmers in Faisalabad earned, on average, approximately 35,000 RS (600 US\$) per year more than regular farmers.

When asked about the risks of wastewater use in agriculture, 20% of all wastewater farmers mentioned that it could contribute to poor health, although surprisingly none of the farmers could recall a disease episode associated with its usage, often claiming that they had used wastewater for so long that they were immune to it.

The wastewater irrigated site around the WSP was selected for a cross-sectional epidemiological study, investigating the direct health impact of untreated wastewater use in agriculture. The wastewater irrigated site around the WSP comprised approximately 600 hectares and all farmers lived in three communities located in the middle of the wastewater irrigated fields. These three communities together had a population of 4837, of which roughly half lived in households that were involved in wastewater irrigation while the majority of the other half found employment in the textile industry in Faisalabad. A control community located approximately 2.5 kilometres away from the wastewater villages was also selected. This village had a population of 7508 and almost all households were involved in agriculture using regular irrigation water that had previously been found to be free of nematode eggs.

Following a general census and baseline household survey three exposure groups were identified:

- wastewater farmers;
- textile labourers; and
- farmers using regular irrigation water.

Textile labourers were included because they were not involved in agriculture but were living close to wastewater irrigated fields. Data were collected through questionnaire surveys, observations and a single stool sample analysis. Baseline household data included agricultural data (type of activities, time spent in fields and cultivated crops) and information on potential confounding variables. Socio-economic variables included literacy, type of house construction, land holding and ownership of cattle. Sanitation and hygiene related characteristics included the type of water supply, ownership of a motor pump (reflecting good availability of water), presence or absence of a latrine and the use of footwear. The epidemiological cross sectional study conducted in Faisalabad found a low prevalence of helminth infections (Table 10.1) and, in particular, low prevalence of intestinal nematode (hookworm, *Ascaris lumbricoides* and *Trichuris trichiura*) infections (6.5%); the main risks associated with wastewater irrigation. This was surprising, especially given the

the high (> 700 eggs/l) concentration of intestinal helminth eggs found in the untreated wastewater. When different confounding variables were controlled for, wastewater farmers showed an increased risk only for hookworm infection (Odds ratio: 23; 95% confidence interval: 5.5 - 96) and *Giardia intestinalis* infection (Odds ratio: 3.3; 95% confidence interval: 2.5 – 4.4). Textile labourers were found in general to have a helminth prevalence in between that of wastewater farmers and regular farmers. Textile labourers were found to have an increased risk of hookworm and *Giardia* infection, though this risk was lower than found for wastewater farmers (Ensink *et al.* 2005; Ensink *et al.* 2006).

Table 10.1. Prevalence of helminth and protozoal infections in wastewater farming, textile labourer and regular farming households

	Wastewater farm households	Textile labourer household	Regular farm households
Helminth			
<i>Ascaris lumbricoides</i>	2.5%	2.2%	0.8%
Hookworm	8.8%	4.4%	0.4%
<i>Trichuris Trichiuria</i>	1.0%	0.7%	0.0%
<i>Hymenolepis nana</i>	13.0%	8.4%	2.5%
<i>Taenia saginata</i>	0.4%	0.1%	0.4%
Other			
<i>Giardia intestinalis</i>	77.4%	72.1%	49.2%
Diarrhoea	5.2%	4.0%	1.9%
<i>Giardia</i> + diarrhoea	4.1%	2.8%	1.3%

Although the epidemiological study found an increased risk of both hookworm and *Giardia* infection in textile labourers and wastewater farmers, it is important to add that both wastewater farmers and textile labourers were of lower socio-economic status and had poorer access to water supply and sanitation than the regular farm households. This was reflected in poorer housing, a lower availability of water and more people practising open defecation. In addition, although all villages had sewage disposal infrastructure, often consisting of a system of open drains, wastewater was often found ponding in the ‘wastewater village’ (Plate 10.3), while the ‘regular’ farmer village was found to be free from wastewater year round. Finally, the prevalence of helminth infection found in Faisalabad was low and in line with national figures, while the large majority of the *Giardia* infections was found to be asymptomatic.



Plate 10.3. Wastewater ponding in the streets of one of the 'wastewater' study villages (Photo: J. Ensink)

#### *10.4.1.1 Conclusion*

Farmers claimed that wastewater irrigation posed no risk to their health as they claimed to have become immune to the wastewater. The results of the epidemiological survey did not confirm their views, but the direct health impact of wastewater irrigation on farmer health was not dramatic. There was a small difference in the prevalence between regular and wastewater farmers which is unlikely to cause major health problems. Pakistan operates a system of free Basic Health Units where anthelmintic medication<sup>1</sup> is readily available in sufficient quantities. Biannual anthelmintic treatment programmes, combined with medical health camps, would probably eliminate the health problems associated with the direct exposure to untreated wastewater.

It is clear that, for farmers, the benefits of wastewater irrigation far outweigh the risks. Wastewater was found to be more reliable and more flexible allowing

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<sup>1</sup> Drugs that act against helminth infections.

farmers to grow more profitable crops, and have a higher cropping intensity, while the nutrient value of wastewater led to large savings in chemical fertilizer cost. The advantage of growing vegetables means that farmers can harvest more than two times per year, and can even play the market and thereby maximize their income. An added advantage of vegetable cultivation is that some produce will be retained for household use, which will contribute to a healthier diet and consequently better health.

### 10.4.2 Consumers

The nationwide survey in Pakistan showed the importance of wastewater for the cultivation of vegetables. It was estimated that 26% of all vegetables grown in Pakistan were grown using wastewater (Ensink *et al.* 2004). In Faisalabad, weekly market prices of cauliflowers were obtained from the local market committee. The average price of locally produced wastewater-grown cauliflowers was Rupees 703 (SD = 364) against Rupees 1703 (SD 382) for cauliflowers that were transported from other areas of the country. The prices of vegetables were 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. For the poor segments of the urban population, especially, the lower prices may have positive implications for their vegetable consumption pattern and subsequently their nutritional status. In addition, short transportation and shelf life will have a positive effect on the nutritional quality of fresh produce.

In Faisalabad, the wastewater used for irrigation was of predominantly domestic origin with low levels of organic and inorganic pollutants (Ensink *et al.* 2008). The wastewater irrigated sites in and around Faisalabad exhibited elevated levels of heavy metals as a result of wastewater irrigation, though levels were within permissible limits and no significant uptake by plants was found to have taken place (Ensink *et al.* 2008). The main risk for consumers therefore stemmed from the high *E. coli* ( $1.8 \times 10^7$  cfu/100 ml) and helminth egg (968 eggs/l) concentrations found in untreated wastewater.

To assess the impact of poor quality water use on produce quality, vegetable samples were collected from two farms from April 2004 to March 2005, on a fortnightly basis. At these two farms, vegetables ready for harvest were collected and analysed for *E. coli* and helminth eggs. Vegetables were always sold to the same market salesman; and this market salesman was visited the next morning at his market stall. Here, the vegetables from the same harvest batch as sampled the previous day were purchased and analysed for *E. coli* and helminth eggs. Produce samples were collected from the market between 8 and 10 am to allow

sufficient market handling of the produce. Vegetables irrigated by river water were not found to be cultivated in close proximity to Faisalabad.

Although high pathogen concentrations were found in untreated wastewater, these concentrations did not translate into high concentrations on locally grown vegetables. This was probably due to the bed and furrow irrigation technique, which prevents direct contact between wastewater and produce and the local climatic conditions, with high temperatures and low humidity, which promoted rapid die-off of pathogens.

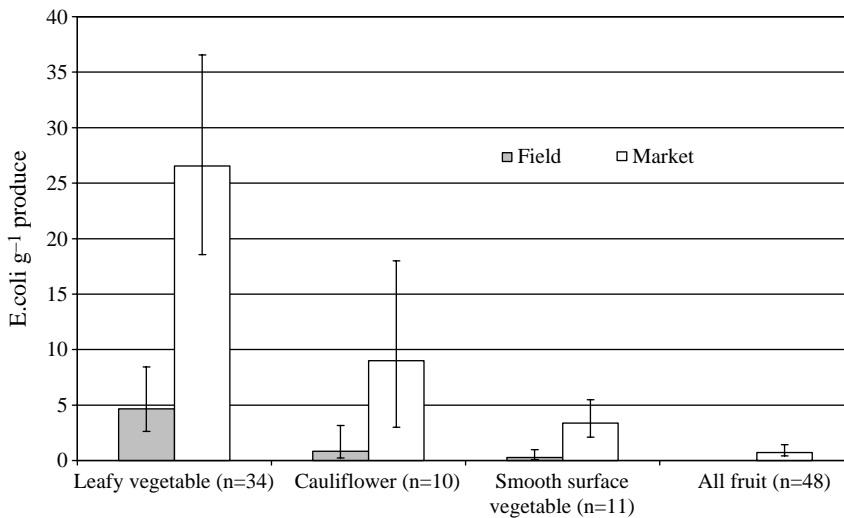


Figure 10.3. *E. coli* concentrations of vegetables and fruit samples collected from wastewater irrigated fields and the local market

During the survey, a total of 110 vegetable samples were collected; 55 at the wastewater irrigated fields and 55 at the market. A total of 8 different vegetables were collected and subjected to microbial analysis. The survey found relatively low concentrations of *E. coli* (geometric mean 1.9 *E. coli/g*) at the farm. Of the different sub-groups of vegetables, the low growing leafy vegetables were found to have the highest concentrations of *E. coli* (Figure 10.3). Vegetables collected from the market were found to have statistically significantly higher concentrations of *E. coli* (geometric mean 14.3 *E. coli/g*) compared to those analysed directly from the field. The difference between field and market was highly significant for each of the vegetable subtypes (Figure 10.3). Helminth eggs on the field vegetables were found at a geometric mean concentration of 0.7

eggs/g, with leafy vegetables showing the highest concentrations (1.1 eggs/g), while cauliflowers had low levels (0.1 eggs/g) and smooth surfaced vegetables were found to be free of helminth eggs. The vegetable samples collected from the market contained, on average, three times more helminth eggs (2.1 eggs/g) compared to the vegetables collected from the field.

The survey also found *E. coli* on fruit samples irrigated with normal irrigation water. The results of the survey suggest that unhygienic post-harvest handling was the major source of produce contamination. This implies that interventions at the market, such as the provision of clean water to wash produce, are better and more cost-effective ways to protect public health than wastewater treatment.

#### *10.4.2.1 Conclusion*

Most consumers in Faisalabad and probably all other cities in Pakistan, are unaware of the type of irrigation water used to produce their vegetables. This poses a potential health risk. The unhygienic handling of produce at the local market, however, results in even higher pathogen concentrations on vegetables and fruit than the use of untreated wastewater for irrigation. The overall benefit for consumers therefore consists of a reduced price and increased availability of fresh vegetables.

### **10.4.3 Municipality**

The use of wastewater has posed a dilemma to the local water and sanitation agency (WASA) in Faisalabad. Farmers over the last 10 years have gone to court to gain access to wastewater. The last court case granted farmers the right to use wastewater as farmers had no access to another water source and wastewater was thus their sole livelihood. WASA further acknowledged that there was basically no possible way that the use of wastewater could be stopped as farm inlets, once closed, would be reopened in matter of hours.

The municipality currently operates the WSP at an annual cost of US\$ 100,000. The WSP was built with foreign assistance with the objective to provide agriculture with a safe source of water. However, with farmers unwilling to use treated effluent, the WSP runs at a loss. Agreements have been reached with local farmers over wastewater fees and the WASA is renting out land around the WSP to farmers, as a way to generate money. WASA-Faisalabad, like most water supply and sanitation utilities in developing countries, is cash strapped, the high land and water fees that farmers are willing to pay for untreated wastewater offers WASA a way to recuperate money and invest this in improvements in its water supply and sanitation network.

The contamination of groundwater as a result of wastewater irrigation would have been a major concern for the municipal council. The study findings showed high concentrations of *E. coli*, nitrate and nitrites in groundwater. However, in Faisalabad and many other areas of Pakistan, groundwater is unfit for domestic purposes as a result of naturally occurring high salinity.

#### **10.4.4 Downstream water users**

As a result of naturally occurring salinity, approximately 50 million people in Pakistan rely on irrigation canals for their domestic water supply, including drinking (van der Hoek *et al.* 2001). In the absence of wastewater treatment, wastewater is disposed of untreated into irrigation canals and rivers, thereby exposing downstream water users to unknown health risks.

### **10.5 CONCLUSIONS**

The Faisalabad case study shows that wastewater use for crop production is a practice with many benefits. It sustains livelihoods of poor peri-urban farming families, contributes to urban food security, helps in solving the urban sanitation problem by preventing pollution of surface water and makes optimal use of the resources (water and nutrients). The health risks associated with wastewater use in agriculture to farmers and consumers of produce can be reduced by proper irrigation water management and implementation of existing public health measures, even when wastewater treatment is not feasible.

### **10.6 RECOMMENDATIONS FOR SAFE USE**

The research in Faisalabad showed a negative impact of untreated wastewater use on the health of wastewater farming families. However, in the absence of wastewater treatment the only alternative to wastewater use in Pakistan is the disposal of untreated wastewater into rivers and irrigation canals. This could potentially pose a much greater health risks as river and irrigation water serve as the only source of domestic drinking water for millions of people in the rural areas of Pakistan, especially in those areas with high natural groundwater salinity. This presents a situation whereby either a small group of wastewater farmers is exposed to a known and relatively easy to contain health risk or a potentially much larger group of downstream water users is exposed to an unknown health risk if wastewater is discharged directly into surface water bodies. To ban wastewater use in Pakistan would be counterproductive and

unenforceable, as is acknowledged by local authorities throughout Pakistan. However the current situation where wastewater irrigation is either not recognised or where authorities turn a blind eye, is not sustainable either. Wastewater irrigation makes important contributions to urban food security and farmer livelihoods in Pakistan, however its risks should not be ignored. We propose that the risks that are associated with the use of untreated (domestic) wastewater could be contained through a set of practical and enforceable measures. The first step would be to formalize, on a national level, two local regulations which were found to have been agreed between farmers and local authorities throughout Pakistan. These are:

- only produce that will be consumed after cooking can be grown with untreated wastewater; and
- root crops, or other crops grown underground, like potatoes, onions and carrots can not be grown with untreated wastewater.

To minimize the direct health impact of untreated wastewater use on farming families we propose:

- biannual mass treatment of farmers and their children with anthelmintic drugs; and
- general improvements in water supply and sanitation in wastewater villages and local produce markets.

Anthelmintic medication is manufactured in Pakistan and is, thus, readily available and cheap. Rural health workers and Basic Health Units, which provide free medical care, were found to have large stocks of anthelmintic medication available. The availability of a health care infrastructure close to, or in, wastewater irrigated villages in combination with well established wastewater farmer associations offers an excellent opportunity to distribute anthelmintic medication. Children could successfully be targeted through school based (anthelmintic) programmes. Most wastewater farmers belonged to weaker socio-economic groups and the study found lower levels of water supply and sanitation coverage in wastewater villages compared to regular farming villages. Investments in the improvement of local water supply and sanitation might provide greater public health benefits, and could be more cost effective than wastewater treatment. Improvements in local water supply will have the added benefit that more (clean) water will be available at local markets, which will improve post harvest practices and, thus, the quality of the produce. The use of footwear in irrigated fields, often suggested as a suitable preventive measure

against hookworm infection, was considered uncomfortable and impractical by farmers and is unlikely to be an acceptable intervention in Pakistan.

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