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High risk of hookworm infection among wastewater farmers in Pakistan

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Summary The health risks of wastewater use in agriculture were investigated in the city of Faisalabad, Pakistan, by means of a cross-sectional study. The study showed an increased risk of intestinal nematode infection and hookworm infection, in particular, in wastewater farmers (OR = 31.4, 95% CI 4.1—243) and their children (OR = 5.7, 95% CI 2.1—16) when compared with farming households using regular (non-wastewater) irrigation water. Textile labourers living in the same village as the wastewater farmers showed a lower risk of hookworm infection than wastewater farmers but an increased risk compared with farming households using regular irrigation water. Many urban and peri-urban farmers make a living by using untreated wastewater in the production of fresh produce for the urban market. Banning the use of untreated wastewater would deprive these farmers of their livelihood and affect food supply for the urban population. If treatment of wastewater is not a feasible option, the promotion of footwear and improved hygiene, the construction of toilets, in combination with regular anthelminthic treatment, would be suitable alternatives to safeguard the health of wastewater farmers and their children.

1. Introduction

The use of urban wastewater or sewage in agriculture has a long history and is receiving renewed attention in the light of increased global water scarcity (Scott et al., 2004). In a nationwide study

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in Pakistan, farmers mentioned the reliability of wastewater supply, its fertilizer value and the proximity of wastewater-irrigated fields to local urban markets as the main reasons for wastewater use (Ensink et al., 2004a). Past studies have shown an increased risk of typhoid fever and cholera as a result of exposure or consumption of wastewater-irrigated vegetables; however, it has been well established that the main health risk in relation to wastewater irrigation is infection with intestinal helminths (Blumenthal et al., 2000; Shuval et al., 1986; WHO, 1989). These health risks can be greatly reduced by treating the wastewater before its use. However, many of the existing wastewater treatment technologies are prohibitively expensive for low-income developing countries and the reality is that as much as two-thirds of the wastewater generated in the world receives no treatment at all (Mariño and Boland, 1999). The increasing importance of wastewater use in agriculture, especially in the absence of wastewater treatment facilities, makes it imperative to look for other ways to prevent or mitigate the negative health impacts. As part of a larger project on benefits and costs of untreated wastewater irrigation, we assessed the risk of intestinal helminth infections among farming families using wastewater compared with farming families not using wastewater and families not involved in farming at all in a peri-urban area of Faisalabad, Pakistan. A second aim was to present recommendations for safer use of wastewater within the financial constraints of the local community.

2. Materials and methods

2.1. Study area

Faisalabad is the third largest city in Pakistan with a population of just over 2 million (Population Census Organization, 2001). The city is water scarce due to highly saline groundwater, low rainfall and extreme temperatures ranging from −4 °C in January to 48 °C in May (Interconsultants and NESPAK, 1993). According to the local utility, approximately 550 000 m^3 of wastewater is disposed of daily, and of this volume, an estimated 176 000 m^3 (32%) is used without any form of treatment for the cultivation of vegetables, fodder, wheat, rice and cotton at the periphery of the city (Ensink et al., 2004b). A survey in and around the city revealed that at least nine different wastewater use sites, with a total area of over 2200 ha, could be identified. Most of the farmers were smallholders and cultivated approximately 1 ha per farming family. Faisalabad is one of the few cities in Pakistan with a wastewater treatment plant; however, one of the largest wastewater use sites in Faisalabad was situated right next to the wastewater treatment plant as farmers living nearby preferred the use of raw sewage because of the higher nutrient content and lower salinity levels compared with treated effluent (Ensink et al., 2004b).

The site around the wastewater treatment plant was selected for this study because of it size (>600 ha), the fact that all farmers used raw sewage and because all farmers were living 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 rest found employment in the textile industry in Faisalabad. The wastewater used for irrigation did not meet the WHO nematode guidelines for agricultural use, with hookworm concentrations found to be especially high throughout the year (Ensink et al., 2004b).

A control community located approximately 2.5 km away from the wastewater villages was 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 (International Water Management Institute, unpublished data).

All four communities selected for this study had their own functioning sewerage system, consisting of open drains and relied on the municipal water supply system and shallow seepage water from (non-wastewater) irrigation canals and fields for their drinking water.

2.2. Study population

Following a general census and baseline household survey in the four selected communities, a cross-sectional study was carried out between August 2002 and July 2003. Based on the occupation of the male head of the household, three exposure groups could be identified from the census list: 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. Strict adherence to the *purdah* system of female seclusion in some households led to the decision to include only adult men. All children (male and female) between 2 and 12 years of age whose father was selected for the study were included. The sample size was calculated to detect an odds ratio (OR) of 2.0 for hookworm

infection with 95% confidence intervals (CI) and a power of 80%. To be able to control for a possible effect of living close to the wastewater-irrigated sites, more textile labourers than regular farming households were selected. Families were excluded from the survey when it turned out that they did not clearly belong to one of the three exposure groups, for example, textile labourers who were also involved in farming. A farmer in this study was defined as a person involved in all farm activities, which included land preparation, weeding, harvesting and irrigating. Dairy farmers who only infrequently visited (wastewater) irrigated fields to cut or purchase fodder were excluded from the study. Children were assigned to the same exposure group as their fathers. In this way, the final sample size consisted of 689 adults and 1104 children.

2.3. Data collection

Data was collected through questionnaire surveys, observations and a single stool sample analysis. Baseline household data was collected in the period February—July 2002 including 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 were type of water supply, ownership of a motor pump (reflecting good availability of water), presence or absence of a toilet and the use of footwear.

Stool samples were collected in standard 50 ml plastic containers labelled with individual ID-numbers. Stool containers were handed out in the late afternoon or early evening and collected in the early morning. The formalin-ether sedimentation method was used in Parasep® (DiaSys Europe Ltd, Wokingham, UK) faecal parasite concentrator tubes to determine intestinal nematode prevalence. Stool samples were analysed in a field laboratory operated by the International Water Management Institute (IWMI). The tubes were centrifuged at 1000 rpm for 10 min and then fat and formal water were drained off. Three slides of sediment were analysed in a saline solution under 10×10 magnification for intestinal nematode eggs and larvae.

During stool sample collection, the prevalence of self-medication was assessed using a brief individual questionnaire. Individuals were asked if they had visited a medical doctor or bought drugs at a shop, during the last month and asked to show old prescriptions and wrappers if available. At the end of the study, all shops selling medicines in a 5 km radius of the study area were visited to assess the general availability of antiparasitic medication.

2.4. Data analysis

Analysis was conducted at the level of the individual. Two age-groups were defined, adults (age >17 years) and children (2—12 years) as no difference was found between other age sub-groups. Statistical analysis was conducted using STATA 7.0 (Stata Corp., College Station, TX, USA). Univariate analysis was carried out for each outcome (*Ascaris*, *Trichuris*, hookworm) and for both age groups to explore the impact of wastewater irrigation and other potential risk factors. Only factors significantly ($P < 0.05$) associated with hookworm infection were fitted into a multivariate logistic regression model to be able to control for confounding by these variables.

2.5. Ethical considerations

Ethical clearance for the study was obtained in October 2001 from the Institute of Public Health, Lahore, Pakistan. Meetings were held in all four communities to explain the purpose of the planned study. Individual consent was obtained during the census and baseline household survey. All individuals with a positive stool sample for intestinal nematodes were informed on the following day and were provided with albendazole (Zentel, GHK). At the end of the study a general health camp was organized for all participating households to attend to other health problems.

3. Results

3.1. Characteristics of the study population

Stool samples were obtained from 1704 individuals, a compliancy of 95%. Compliancy was found to be similar in the three exposure groups. Illiteracy was high in all three groups with over 60% of the adults never having attended any formal schooling (Table 1). Textile labourers were on average younger than both groups of farmers but no significant difference in age was found between children of the three groups. Type of housing construction was considered a relevant indicator of socio-economic status and this showed that farmers using regular irrigation water were better off than textile labourers and wastewater farmers. Fewer

Table 1 Exposure group characteristics

	Regular farmers ($n = 476$)	Textile labourers ($n = 742$)	Wastewater farmers ($n = 486$)	Test statistic[a]	P
Average age (years)					
Adult	41.6 (16.0)	34.7 (12.6)	41.3 (15.4)	$F = 16.7$	<0.001
Child	7.1 (3.5)	6.9 (3.1)	6.9 (3.2)	$F = 0.67$	0.11
Average educational level (years)	2.2 (0.6)	3.0 (0.2)	2.1 (0.4)	$F = 3.18$	<0.001
House construction					
Poor	46%	86%	73%	$\chi^2 = 57$	<0.001
Good	54%	14%	27%		
Toilet					
No	5%	35%	54%	$\chi^2 = 70$	<0.001
Yes	95%	65%	46%		
Average landholding size (ha)	3.8 (4.1)	—	2.6 (3.9)	$F = 0.91$	0.30
Average number of buffaloes	2.0 (1.8)	0.3 (0.7)	2.5 (3.0)	$F = 64$	<0.001
Water supply					
Hand pump	24%	73%	68%	$\chi^2 = 92$	<0.001
Motor pump	76%	27%	32%		
Use of footwear					
In the village	93%	75%	79%	$\chi^2 = 59$	<0.001
In agriculture	5%	—	0%	$\chi^2 = 49$	<0.001

[a] Differences between the three exposure groups for each variable were tested with analysis of variance for continuous data and χ^2 tests for proportions.

than half of the wastewater farmers owned a toilet, against over 60% of the textile labourers and 95% of the regular farmers. Farmers and textile labourers without a toilet used agricultural fields for defecation. In the case of wastewater farmers and textile labourers these fields were wastewater-irrigated. There was a marked difference between the three groups in access to water for domestic purposes, with the majority of regular farmers owing a motor pump. The use of footwear was common but not during agricultural activities when only 5% of the farmers using regular irrigation water and none of the wastewater farmers used footwear in their fields.

3.2. Prevalence of intestinal nematode infection

Overall prevalence of intestinal nematode infection was 6.0% (66/1107) among the children and 7.7% (46/597) among the adults. Hookworm was found to be the most prevalent nematode infection with an overall prevalence of 4.6% (78/1704), followed by *Ascaris lumbricoides* (1.9% [32/1704]) and *Trichuris trichiura* (0.6% [10/1704]). Wastewater farmers and textile labourer households as well as their children showed a higher prevalence for all three intestinal nematode infections compared with regular farmer households (Table 2).

Table 2 Nematode prevalence by exposure and age group

	n	*Ascaris lumbricoides*	Hookworm	*Trichuris trichiura*
Adults				
Regular farmers	167	0.6%	0.0%	0.0%
Textile labourers	254	2.4%	3.5%	0.8%
Wastewater farmers	176	4.0% ($\chi^2 = 4.2$, $P = 0.12$)	13.6% ($\chi^2 = 33.8$, $P < 0.001$)	0.0% ($\chi^2 = 2.7$, $P = 0.26$)
Children				
Regular farmers	309	1.0%	0.6%	0.0%
Textile labourers	488	2.0%	4.9%	0.6%
Wastewater farmers	310	1.6% ($\chi^2 = 1.4$, $P = 0.50$)	6.1% ($\chi^2 = 13.6$, $P < 0.001$)	1.6% ($\chi^2 = 5.8$, $P = 0.06$)

Table 3 Risk of nematode and hookworm infection, among textile labourers, wastewater and regular farming households

	n	Odds ratio (95% CI)[a]	*P*
Adults			
Intestinal nematodes[b]			
Regular farmers	167	1.0	
Textile labourers	254	9.7 (1.2—78)	0.03
Wastewater farmers	176	31.4 (4.1—243)	0.001
Hookworm			
Regular farmers	167		
Textile labourers	254	1.0	
Wastewater farmers	176	4.0 (1.8—9.2)	<0.001
Children			
Intestinal nematodes			
Regular farmers	309	1.0	
Textile labourers	488	4.1 (1.5—11)	0.005
Wastewater farmers	310	5.7 (2.1—16)	0.001
Hookworm			
Regular farmers	309	1.0	
Textile labourers	488	6.9 (1.6—31)	0.01
Wastewater farmers	310	9.3 (2.0—43)	0.004

[a] Controlled for the presence of a toilet, house construction and type of water supply.
[b] *Ascaris*, *Trichuris* and hookworm combined.

3.3. Risk factors

The absence of a toilet and thus subsequently the regular use of agricultural fields or publicly recognized defecation sites was associated with an increased risk of hookworm infection (OR = 1.9, 95% CI 1.2—2.8). The ownership of a motor pump, reflecting good availability of domestic water as well as high socio-economic status was associated with a decreased risk of hookworm infection (OR = 0.5, 95% CI 0.3—0.9). Poor house construction (brick wall, mud plaster and tiled or thatched roofs) compared with good house construction (fully concrete) resulted in a significant increased risk of hookworm infection (OR = 2.3, 95% CI 1.3—4.4). Further exploration of the data showed interaction between the variables type of water supply and type of toilet, and between type of toilet and house construction. These interaction terms were included in the multivariate models but only slightly changed the regression coefficients of interest.

The risk of nematode infections in adults remained strongly associated with the use of wastewater or living close to wastewater-irrigated sites after controlling for confounding by these variables (Table 3). Similarly, children of wastewater farmers had an increased risk of nematode infections when compared with children of textile labourers and children of regular farmers. Infection with hookworm was clearly the main risk associated with wastewater irrigation, with *Ascaris* and *Trichuris* not showing a significant increased risk between any of the exposure and age groups. Not a single hookworm infection was detected among regular farmers.

3.4. Self-medication and availability of anthelminthic drugs

Only 0.4% of the sampled population reported having visited a doctor or taken medication from a shop in the past month and only one person could show the documentation that was provided with his anthelminthic medication. The anthelminthic medication survey found 13 shops, six lady health workers, three basic health units (BHU) and three medical doctors within a 5 km radius of the selected villages. A total of 12 different brands and five different active ingredients were found (Table 4). Prices per full treatment regime ranged from free of cost in BHUs and from lady health workers to a maximum of US$0.5 for a mebendazole suspension in a private shop.

4. Discussion

This study showed an increased risk of nematode, and in particular hookworm, infections in

Table 4 Type, availability and price of anthelminthic medication from basic health units, medical doctors, lady health workers and medical shops in a radius of 5 km of the study villages

	Basic health unit ($n = 2$)	Doctor ($n = 3$)	Lady health worker ($n = 6$)	Medical shop ($n = 13$)	Total ($n = 24$)
Number of brands	2	2	1	10	12
Active ingredients	Mebendazole Pyrantel	Levamisole Mebendazole	Piperazine	Albendazole Levamisole Mebendazole Piperazine Pyrantel	Albendazole Levamisole Mebendazole Piperazine Pyrantel
Available in (%) of visited health units	50	33	67	92	75
Average stock (full treatment regime)	157	3.7	24	27	34
Total stock	314	11	145	343	813
Average price/dose (US$)	Free	Free	Free	0.19	0.08

Rate: US$1 = 60 Pakistan rupees.

farming families using untreated wastewater for irrigation. The risk was found to be highest in adults but was also significantly increased in the children of wastewater farmers. Textile labourers and their children showed a prevalence and risk of hookworm infection in between that of wastewater and regular farming families.

4.1. Health risks as result of exposure to wastewater

The high risk of hookworm infection among adult wastewater farmers and their children in Faisalabad confirms the results of past studies on the subcontinent. In another town in the Punjab, Pakistan, a hookworm prevalence of 75% was reported among adult wastewater farmers and 20% among their children (Ensink et al., 2004c; Feenstra et al., 2000b). In India, over 60% of adult wastewater farmers were infected with hookworm (Krishnamoorthi et al., 1973). In studies in Mexico and Morocco, *Ascaris* was found to be the main risk associated with wastewater use (Blumenthal et al., 2001; Habbari et al., 1999; Peasey, 2000). In contrast, prevalence of *Ascaris* infection in the present study was found to be very low, even though the *Ascaris* egg concentrations in wastewater used for irrigation were higher than those found in the studies in Mexico (Ensink et al., 2004b).

During the course of the study, children were regularly seen playing in wastewater-irrigated fields or assisting their parents in agricultural activities like weeding and harvesting. This could explain the increased risk for hookworm infection among children of wastewater farmers. After controlling for level of sanitary facilities, the results still showed an increased risk of hookworm infection among those children that were not occupationally exposed to wastewater. The 'wastewater' villages were completely surrounded by wastewater-irrigated fields and as a result children playing and adults interacting in and around the villages could be expected to be in daily contact with wastewater contaminated soil.

4.2. *Ascaris* and hookworm prevalence in Pakistan

Information on the prevalence of intestinal nematode infections in the general population of Pakistan is scanty. A literature search, with keywords *Ascaris*, hookworm, and Pakistan, in the on-line search engines PubMed (http://www.ncbi.nlm.nih.gov/PubMed/), Pakmedinet (http://www.pakmedinet.com/) and the library at the Institute of Public Health in Lahore resulted in only 11 publications (excluding hospital-based or experimental studies) on intestinal nematode infections in Pakistan. These papers and reports covered a period from 1982 till 2003 in all four provinces and the Northern Areas (NA) of Pakistan (Table 5). The majority of these studies had not differentiated between adults and children and had failed to report either one or more of the following design characteristics: age group under investigation, stool sample analysis method, selection criteria and whether the study was conducted in urban or rural areas. Only two studies (Feenstra et al., 2000b; Nishiura et al., 2002) used the formal-ether concentration method, while the other studies that had specified a method used the direct smear method. This method has shown to result in a consistently lower prevalence of infection, especially in the case of light infections, as compared

Table 5 Prevalence of *Ascaris* and hookworm infections in the four major provinces of Pakistan as reported by other studies

	Total annual rainfall (mm)[#]	Temperature (°C)[#]		Prevalence (%) for all age groups			
				Ascaris lumbricoides		Hookworm	
		Max	Min	Mean	Range	Mean	Range
NWFP and NA[a,b,c,f,i,j,k]	364	40.2	3.9	38.0	7.4–91	0.4	0–1.7
Punjab[b,d,e,g,h]	530	40.7	5.1	9.3	0–35	7.6	1.1–27
Sindh[b]	188	32.5	14.2	2.9	1.9–3.9	0	
Baluchistan[b]	243	38.1	1.6	2.3	1.0–3.6	0	
Pakistan				21	0–91	3.7	0–27

NWFP: North West Frontier Province; NA: Northern Areas.
[a] Bano and Begum, 1981.
[b] National Institute of Health, 1988.
[c] Khan et al., 1987.
[d] Ahmed, 1993.
[e] Malik et al., 1993.
[f] Hussain et al., 1997.
[g] Feenstra et al., 2000a.
[h] Feenstra et al., 2000b.
[i] Nishiura et al., 2002.
[j] Ahmed et al., 2003.
[k] Waqar et al., 2003.
[#] Source: Quetta (Balochistan), Peshawar (NWFP and NA), Lahore (Punjab) and Karachi (Sindh) http://www.worldclimate.com/.

with the formal-ether concentration (Ridley and Hawgood, 1956) and the reported prevalences in these papers could therefore be underestimates. The design flaws of some previous studies in combination with the inconsistency in methods make it difficult to place the results of this study in a wider national perspective.

The *Ascaris* prevalence in all three exposure groups in Faisalabad was found to be similar to that of other studies conducted in Pakistan, with the exception of the North West Frontier Province (NWFP) and NA where the *Ascaris* prevalence was found to be much higher (Table 4). Hookworm prevalence throughout Pakistan, in individuals that were not occupationally exposed to (untreated) wastewater, was found to be very low (ranging from 0 to 5.4%) with the exception of only one study which reported a 26.5% hookworm prevalence in peri-urban farming families in Southern Punjab (Feenstra et al., 2000b). Hookworm prevalence in regular farming and textile labourer households fell within the national range. Hookworm prevalence in textile labourer households was found to be higher in children than in adults, which does not correspond to normal age intensity curves, as the highest hookworm prevalence is normally attained in adults (Crompton, 2000). The highest hookworm prevalence was found in adult wastewater farmers and their children and this prevalence was much higher than the national average.

4.3. WHO wastewater use guidelines

In 1989, an intestinal nematode water quality standard ($\leq$1 egg/litre) was included in the WHO guidelines for wastewater use in agriculture (WHO, 1989). A review in the year 2000, based on new epidemiological evidence, resulted in a proposal for revision of the 1989 guidelines (Blumenthal et al., 2000) and the need to adopt a stricter nematode guideline value of less than 0.1 eggs per litre. However, others have suggested the guideline value could be increased to 10 eggs per litre (Ayres et al., 1992). This study is unable to provide any new evidence to support either a stricter or a more lenient guideline value but does raise a question about the validity of the current guideline value.

Nematode egg concentrations in the wastewater used for irrigation were found to be very high with an average hookworm concentration of 558 eggs per litre and on average 142 *Ascaris* eggs per litre (Ensink et al., 2004b). Based on the findings of previous studies in Mexico, India and Pakistan, the intestinal nematode prevalence in Faisalabad, and especially the *Ascaris* prevalence, could have been expected to be much higher. The relatively low *Ascaris* and hookworm prevalence in this study as compared with other 'wastewater studies' could well be attributed to the wide availability of free and cheap anthelminthic medication but could also

indicate a rapid die-off of eggs and larvae in agricultural fields.

This last hypothesis could be supported by the extreme climate in Faisalabad where temperatures soar up to 48 °C in summer and rainfall is limited. Egg and larvae desiccation is promoted by high temperatures and hookworm eggs will generally not hatch above 35 °C (Udonsi and Atata, 1987). Maximum temperature above 35 °C was recorded in Faisalabad for 7 months during the period September 2001—August 2002 (Faisalabad Agricultural University, unpublished data, 2002) and this would have promoted a rapid die-off of hookworm larvae and possibly *Ascaris* eggs. This suggests that, rather than a single global water quality guideline, there is a need for multiple regional water quality guidelines in which local climatic conditions, soil type, agricultural practises and dietary habits are taken into consideration.

4.4. Self-medication

Self-medication is common in Pakistan (Donnelly et al., 1997) and the easy and wide availability of anthelminthic medication close to the study area would support the hypothesis that prevalence of helminth infections is kept low by regular use of anthelminthic drugs. Although this study has tried to assess self-medication, no clear pattern emerged. Single tablets without label or packing were sold without a prescription making it nearly impossible to trace what kind of medication had been taken. Recall for self-medication and visits to doctors or shops selling medicines were set at 1 month, which might have been too long for effective recall, but too short to assess the possible impact of anthelminthic medication on prevalence levels in the population as it generally takes a minimum of one to three years before pretreatment *Ascaris* and hookworm prevalence have been attained (Bradley et al., 1993; Elkins et al., 1986; Hall et al., 1992; Quinnell et al., 2001).

Over-consumption of drugs is arguably one of the most important public health problems in Pakistan (Siddiqi et al., 2002). In the case of antibiotics, this has the serious effect of causing resistance amongst pathogenic bacteria. Currently, resistance of helminths against anthelminthic drugs is not considered a major problem and the drugs are generally safe (Horton, 2000). However, high treatment frequency and under-dosing are factors that potentially can cause resistance to anthelminthic drugs in the future (Geerts and Gryseels, 2001). While the long-term solution to the global burden of soil-transmitted helminth infections is improved living conditions, especially improved sanitation and hygiene behaviour, the most promising short-term approach is the mass treatment of children with anthelminthic drugs. Repeated treatment with safe, single-dose, affordable anthelminthic drugs should also be considered as a control measure for hookworm and other soil-transmitted helminth infections in high-risk child and adult populations exposed to wastewater. Obviously, it is better to prevent soil-transmitted worm infections by adequate sanitation and treatment of domestic wastewater. However, this remains an idealized state in the future whereas regular treatment could provide immediate benefits.

5. Conclusion

Although this study has confirmed that untreated wastewater irrigation poses serious health risks it must not be ignored that it also offers a livelihood to many of the urban poor and is a source of cheap and fresh produce. An outright ban on untreated wastewater use would therefore be undesirable and unenforceable, while crop restrictions would take away the profitability for farmers. Implementation of water quality guidelines should reflect national conditions, priorities and capacities to provide wastewater treatment. Setting targets that are too high can be counterproductive: they may be ignored if they are not attainable. The introduction of guidelines should take a step-wise approach (Von Sperling and Fattal, 2001) that should be implemented in combination with human exposure control interventions. In the case of the Faisalabad villages, promotion of regular anthelminthic treatment through agricultural extension workers, lady health workers or water users' associations seems a potential viable option, while the use of basic footwear when visiting fields and promotion of toilet use and improved hygiene are other potential mitigation measures.

Conflicts of interest

The authors have no conflicts of interest concerning the work reported in this paper.

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