HEALTH RISKS OF IRRIGATION WITH UNTREATED URBAN WASTEWATER IN THE SOUTHERN PUNJAB, PAKISTAN

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

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SUMMARY

The use of wastewater for irrigation is a positive way to dispose of urban sewage water. This water contains a lot of nutrients and can serve as alternative water source in arid and semi-arid areas. However, wastewater contains a wide spectrum of pathogens and sometimes heavy metals and organic compounds that are hazardous to the environment and human health. Therefore, the World Health Organization advises treatment of wastewater before application to the fields, to protect farmers and crop consumers. In Pakistan and many other developing countries wastewater is used without any treatment, as treatment plants are expensive and farmers are willing to use this nutrient rich water without treatment. Knowledge about costs and benefits of treatment in developing countries is limited, as is knowledge about the actual environmental and health risks of irrigation with untreated urban wastewater. Therefore, the International Water Management Institute started a study on benefits and costs of irrigation with urban wastewater in Pakistan. The survey described in this report was part of this study and focussed on the health risks of irrigation with urban wastewater due to microbiological contamination.

To estimate the health risks of irrigation with urban wastewater, wastewater samples were analyzed and a cross sectional study was carried out in a farmer community that used untreated wastewater for irrigation near the town of Haroonabad in the Punjab Province. The health status of this community was compared with a farmer community in two peri-urban villages near the same town that used other water sources for irrigation.

The wastewater used around Haroonabad contained far more faecal coliform bacteria and helminth eggs than advised by the WHO. This poses a high health risk to farmers, their families and crop consumers. In the farmer community exposed to wastewater near Haroonabad, the prevalence of diarrheal diseases and hookworm infections was very high. The prevalence of these diseases was especially high among male farm workers. This group was highly exposed to wastewater, as they did a lot of the work in the fields manually and barefoot. In children of these farmers the prevalence of diarrheal diseases and hookworm was also higher than in the control population. For crop consumers the chance to acquire a hookworm infection seemed slightly increased.

Therefore, protective measures are required for farmers, their families and crop consumers. In the tropical climate of Pakistan treatment according to the bacteriological guidelines of the World Health Organization are difficult to realize. However, appropriate treatment of wastewater for helminth eggs and faecal coliform bacteria before application on the fields is highly recommended. If treatment is not feasible according to costs and benefits analysis, other protective measures should be taken. Low cost interventions could include, information on hygiene behavior for farmers, wearing of shoes and gloves while working in wastewater irrigated fields, regular treatment of farmers and their families with antihelmintic drugs and crop restrictions in wastewater irrigated fields.

1. INTRODUCTION

In many countries urban wastewater is used to irrigate agricultural land. The use of wastewater for irrigation is a way of disposing urban sewage water with several advantages. Wastewater contains a lot of nutrients, which make the crop yields increase without using fertilizer. Furthermore, sewage water is an alternative water source in arid and semi-arid areas where water is scarce. Besides these advantages, wastewater can contain heavy metals, organic compounds and a wide spectrum of enteric pathogens which have a negative impact on the environment and human health (Scott, Zarazua and Levine 2000). In 1989 WHO set guidelines for the maximum number of bacteria and helminth eggs in wastewater used for irrigation to protect farmers and consumers of crops (WHO 1989). Treatment methods were developed to reduce the hazardous elements in wastewater before its use on agricultural fields. However, in many developing countries wastewater is still used without any treatment. Treatment facilities are not available, people are not aware of the health and environmental hazards and the WHO guidelines are not feasible. Knowledge about the costs and benefits of treatment in developing countries is limited, as is knowledge about the actual environmental and health risks of irrigation with untreated urban wastewater.

Therefore, the International Water Management Institute started a study on benefits and costs of irrigation with urban wastewater in Pakistan. Many cities of Pakistan use wastewater from their sewerage systems for irrigation. This water is used without any treatment since the building of treatment plants is expensive, while farmers are willing to use the untreated wastewater. Farmers know that yields will increase by using this water. However, they are not aware of increased health risks and environmental concerns of using untreated wastewater. The survey described in this report was part of the study on benefits and costs of wastewater irrigation and focussed on the health risks to the community due to microbiological contamination. Since infectious diseases due to enteric pathogens are common in Pakistan (Ministry of Health, National HMIS Cell 1999), untreated wastewater is expected to contain a high concentration of excreted enteric pathogens. There is a potential health risk for all people who come in contact with this wastewater. To estimate the health risks of irrigation with urban wastewater in Pakistan wastewater samples were analyzed and a cross sectional study was carried out in a farmer community that used untreated wastewater for irrigation near the town of Haroonabad in the Punjab Province. The health status of this community was compared with a farmer community in two peri-urban villages near the same town that use other water sources for irrigation.

2. BACKGROUND

In areas where infectious diseases due to enteric pathogens are common, these pathogens are found in very high concentrations in the sewage water. When this water is used for irrigation without any treatment the pathogens are applied to the agricultural land. This is a potential health risk to people exposed to it, such as field workers and their families, consumers and handlers of wastewater-irrigated crops and people living in the neighborhood, passing the fields frequently.

However, the actual health risk, which is the risk of people falling ill, is lower than the potential health risk (WHO 1989). The potential health risk is only based on the number of pathogens in the wastewater, while the actual health risk depends on three more factors:

- The time pathogens survive in water or soil
- The dose in which pathogens are infective to a human host
- Host immunity for pathogens circulating in the environment.

The highest health risk is theoretically for helminth infections (table 1). Compared with other pathogens, helminths persist for long periods in the environment, host immunity is low to non-existent and the infective dose is small (Gaspard, Ambolet and Swartzbrod 1997). Epidemiological studies have shown that the actual risk of infection for people exposed to wastewater is the highest for the roundworm *Ascaris lumbricoidus*, the whipworm *Trichuris trichiura* and the hookworms *Ancylostoma duodenale* and *Necator americanus* (WHO 1989, Cifuentes 1993, 1994). The risk of acquiring a bacterial, protozoan or fungal infection due to exposure to wastewater is much lower. The survival time of these pathogens in the environment is lower and there is more host immunity. The lowest risk is for viral infections, mainly due to high host immunity for virus infections (WHO 1989, Swartzbrod 1995). However, an outbreak of cholera due to consumption of wastewater irrigated vegetables was reported in Israel (WHO 1989) and a significant higher prevalence of *Entamoeba histolytica* infections and diarrhea in children was observed in a wastewater-irrigated area in Mexico (Cifuentes 1993, 1994).

Although irrigation with wastewater has been practiced for centuries, the first health regulations were developed in the early 20th century. With the growing awareness and fear of transmission of communicable diseases, strict guidelines were set. However, these first health regulations lacked an epidemiological base and were too strict. In 1989 WHO set more realistic guidelines, based on epidemiological evidence (table 2) (Shuval 1991). However, recent evaluations show that these guidelines protect crop consumers, but not necessarily field workers and their families, especially children (Blumenthal et al. 1996). Therefore, new guidelines are in the development stage.

Table 1: Health risk from use of wastewater in agriculture

Type of pathogen / infection	Relative excess of frequency of infection or disease
Intestinal nematode infections (*Ascaris lumbricoidus, Trichuris trichiura,* hookworm)	High
Bacterial infections Bacterial diarrheas (e.g. cholera, typhoid)	Lower
Viruses Viral diarrheas Hepatitis A	Lowest

Source: World Health Organization 1989

Table 2: Recommended microbiological quality guidelines for wastewater used for crop irrigation[1]

Category	Reuse conditions	Exposed group	Intestinal nematodes[2] (arithmetic mean no. of eggs per liter[3])	Faecal coliforms (geometric mean no. per 100 ml[3])	Wastewater treatment expected to achieve the required microbiological quality
A	Irrigation of crops likely to be eaten uncooked, sports fields, public parks	Workers, consumers, public	≦ 1	≦ 1000[4]	A series of stabilization ponds designed to achieve the micro-biological quality indicated, or equivalent treatment
B	Irrigation of cereal crops, industrial crops, fodder crops, pasture and trees[5]	Workers	≦ 1	No standard recommended	Retention in stabilisation ponds for 8-10 days or equivalent helminth and faecal coliform removal
C	Localized irrigation[6] of crops in category B, if exposure of workers and the public does not occur	None	Not applicable	Not applicable	Pretreatment as required by the irrigation technology, but not less than primary sedimentation

Source: World Health Organization (1989)

Besides the microbiological contamination, chemical and organic pollutants, which are toxic for humans can also be present in wastewater. Of main public health concern are organic chemicals including pesticides and heavy metals such as lead and cadmium which can accumulate in crops, soil and groundwater (Hespanhol 1993). Although these chemical and organic pollutants can cause health problems, the emphasis of this study was on health hazards from microbiological contamination of wastewater. Chemical pollution of the wastewater was assessed as part of IWMI's study on benefits and costs of wastewater irrigation and will be reported elsewhere.

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[1] In specific cases, local epidemiological, sociocultural and environmental factors should be taken into account, and the guidelines modified accordingly.

[2] *Ascaris lumbricoides*, *Trichuris trichiura* and hookworm species

[3] During the irrigation period

[4] A more stringent guidline (∗ 200 faecal coliforms per 100 ml) is appropriate for public lawns, with which the public may come in direct contact.

[5] In the case of fruit trees, irrigation should cease two weeks before fruit is picked, and no fruits should be picked from the ground. Sprinkler irrigation should not be used.

[6] Also called drip or trickle irrigation.

3. MATERIALS AND METHODS

3.1 Study Area

The study was carried out around the town of Haroonabad in the southern part of the Punjab Province in Pakistan. Haroonabad is a small town with about 80,000 inhabitants. Around this town there are agricultural areas, which are irrigated with untreated urban wastewater. The main crops grown are vegetables, which are sold to the markets in the city. On the main site, located north of the city, irrigation with wastewater is being practiced for about 30 years. In the middle of this main site there is a settlement, called Muslim Colony. Most farmers who work in the main wastewater irrigated site live in this settlement. (figure 1).

Near Haroonabad there are two peri-urban settlements, village 53/4R and 55/4R, where socio-economic and living conditions are comparable with the Muslim Colony (figure 1). The majority of houses are constructed with bricks and the roads are partly paved in all three settlements. Furthermore, all three settlements are connected with the municipal water supply scheme, which gives a relative reliable water supply. There is an organized system for disposal of sewage water in all three settlements. In the Muslim Colony there is an open sewerage system. In the two villages several houses have closed pipes connected to a wastewater pond, while others bring their wastewater from septic tanks to these ponds by an iron barrel on a cart. In one of the villages a person is hired to take care of disposal of wastewater from the houses not connected to the wastewater pond. Only at a few places wastewater drained in the street. Vegetables are one of the major crops grown around these two villages, just as around Muslim Colony. The only major difference between the two peri-urban villages and the Muslim Colony is that farmers in the villages are irrigating their land with canal or tubewell water. Wastewater is not used for irrigation around these villages.

Figure 1: Map of the study area (not to scale)

3.2 Study Population

To assess the health risks of irrigation with urban wastewater to farmers and their children a cross sectional survey was conducted. All households of Muslim Colony where at least one person was farming on wastewater fields during the 6 months before the start of the study were selected. From these households, all members who visited the fields at least once a week were selected. In addition, all children below the age of 12 of these households were included in the study population. Before the start of the study 43 households were identified according to the study criteria. After receiving information about the study through house visits and a community meeting, 39 households with a total of 204 members agreed to participate in the survey (table 3). All selected persons were given an identification number and demographic data was collected before the start of the study. Data was also obtained about water supply, availability of a water tank and sanitation of all selected households. Furthermore information was obtained on crops that the families were growing and eating.

In the villages 53/4R and 55/4R all households where at least one person was farming during the last half year were identified as control population. Water supplies to the house and sanitation facilities are two major factors influencing the prevalence of infections with enteric parasites (Feenstra, Hussain and van der Hoek 2000 (1,2)). Households in the two villages were matched with the selected households in Muslim Colony on the basis of these factors. Therefore, only families of village 53/4R and 55/4R with a connection to the water supply scheme and a toilet or water storage capacity were selected for the study (table 4). In the two villages, 65 households met these criteria. All these families agreed to participate in the study after information was given about the survey. From the selected households all members who visited the fields at least once a week were included in the study, while all children below the age of 12 in these households were also included (table 3). In total 339 individuals were selected in the control villages. Demographic data was collected in the two villages in the same way as in the Muslim Colony. In addition it was asked if the families used vegetables from the Haroonabad market, because these vegetables are mostly grown on wastewater irrigated fields.

3.3 Data Collection

3.3.1 Potential health risks

The potential health risks of using untreated wastewater for irrigation around Haroonabad were assessed by analyzing water samples from the Hakra 4R and 6R canal, the main wastewater site and wash water of vegetables obtained from the wastewater irrigated fields. All samples were examined for helminth eggs, while the wastewater sample and several canal water samples from the 4R and 6R canal were tested for total coliform bacteria. The results were compared with the WHO guidelines.

The Parasep® Faecal Parasite concentrator (Intersep Company, UK) was used to examine samples for helminth eggs. The Parasep® Faecal

Table 3: Number of people and households selected for the study by exposure to wastewater

Wastewater exposure	*Selected households*	*Selected people*		*Male*	*Female*	*Total*
Exposed	39	204	*Adults*	70	4	74
			Children	65	65	130
Not exposed	65	339	*Adults*	126	52	178
			Children	85	76	161

Table 4: Water supply and toilet facilities in selected households by exposure to wastewater

Wastewater exposure	*Households connected to water supply scheme*		*Households with toilet facilities (flush or pour flush)*		*Households with a water tank*	
Exposed	37	95%	37	95%	22	56%
Not exposed	65	100%	54	83%	41	63%

Parasite concentrator employs the pincipal of the Ridley-Allan formol-ether sedimentation technique in an enclosed system. Water samples of 1 liter were poured in beakers and left to settle down. After 2 hours the supernatant was carefully removed with a syringe from each sample and 1/3 of the sediment was centrifuged in glass centrifuge tubes. After centrifugation the supernatant was carefully poured off and the sediment was transferred into Parasep® concentrator tubes. These tubes were also centrifuged and the full sediment in these tubes was examined under the microscope. The number of helminth eggs per liter was calculated.

Wastewater and canal water samples were examined for faecal coliform bacteria using a membrane filtration method. The water was filtered with 0.45µm Millipore filter under a vacuum pressure of 10cm Hg and incubated on a ColiBlue 24 (Hach Company, Colorado, USA) growth agar. The colonies of feacal coliform bacteria were counted and the number of these bacteria per 100ml sample was calculated.

3.3.2 Actual health risks

A cross sectional survey was carried out in the study population to assess the actual health risks for people involved with wastewater irrigation. Trained IWMI staff administered a health questionnaire to the selected people in April 2000, and collected and examined stool samples in May and June 2000. The health questionnaire included an open health question and questions about diarrhea, skin and nail diseases, typhoid, cholera and hepatitis. Stool samples were examined for intestinal parasites. IWMI staff distributed stool sample bottles with the identification number and name in Urdu script of the selected individuals. The family members were instructed on how to provide a sample. The bottles were collected the next morning. Fresh samples were examined in the IWMI laboratory in Haroonabad by trained laboratory technicians from the Haroonabad hospital and an IWMI staff member. A refresher course in examination of stool samples for intestinal parasites was given to them at the Institute of Public Health in Lahore before the start of the study. Stool samples were microscopically examined after concentration with the Parasep® Faecal Parasite concentrator (Intersep Company, UK). One fourth of the samples were also checked by direct smear method. All samples were preserved with 5ml of formaline solution per gram faeces (formalin 10%, glycerin 20% and distilled water 70%). These preserved samples were transported to the Institute of Public Health for examination by direct smear technique.

In this study three methods for examination of stool samples were used, since a survey carried out by IWMI in 1999 showed an unexpected low prevalence of soil transmitted helminths in a rural area near Haroonbad (Feenstra, Hussain and van der Hoek 2000 (1,2)). In that study only preserved samples were examined in the Institute of Public Health by direct smear method. It is possible that low intensity infections were missed, since no concentration method was used. Therefore, in this study we used a concentration technique. To compare the results of this study with the results of the study in the rural area near Haroonabad, the samples were also preserved and examined by direct smear method at the Institute of Public Health. To check the effect of preserving and the effect of concentrating, a direct smear examination was also done on part of the fresh samples.

3.3.3 Treatment of study population

The study population was treated for helminth and protozoal infections if the stool sample showed a positive result. Furthermore, a “Health Camp” was organized by IWMI for all participants of the study. A local doctor held a half-day clinic in the school in the Colony/village for all participants with a medical problem. Free treatment was provided.

3.4 Data Analysis

The data was analyzed using Microsoft Access and Excel and SPSS version 10 for Windows.

4. RESULTS

4.1 Population Covered by the Study

A representative part of the study population participated in all surveys. A very high coverage of 99.5 percent in the exposed and 97.1 percent in the unexposed population was reached for the health questionnaire. The number of people willing to provide a stool sample was lower (coverage 66.2 percent in the exposed and 55.5 percent in the unexposed population), though this group was still representative for the entire selected population.

However, some results had to be excluded from the analysis. In the selected group of adults exposed to wastewater only 4 (5%) females were present, while in the unexposed group 52 (29%) females were selected (table 2). To avoid bias due to this difference, all female adults were excluded for analysis. Furthermore, a number of the unexposed male adults were not farming, but only regular visitors to the fields for toilet purposes. These men were also excluded for analysis. The remaining group that was used for the analysis is presented in table 5.

4.2 Cropping Pattern

Vegetable was the main crop grown around Muslim Colony and the two control villages. All farmers living in Muslim Colony cultivated vegetables, while in village 53/4R and 55/4R this was 57 and 87 percent respectively. The main vegetables grown in the area were tomatoes, eggplant and cauliflower. All families consumed their own produce. However, in the control villages almost all households also obtained vegetables from the market in Haroonabad regularly. Most of the vegetables in this market were grown on wastewater irrigated fields.

4.3 Potential Health Hazards of the Wastewater around Haroonabad

Wastewater samples were analyzed to get an idea of potential heath risks. The results are compared with the WHO guidelines for wastewater and presented in table 6.

4.4 Prevalence of Diseases by Exposure to Wastewater

The prevalence of diseases, which could be spread by wastewater, was estimated from the results of the health questionnaire. The prevalence of different diseases by exposure to wastewater is presented in table 7. Skin and nail problems represent the situation at the moment of interview. For diarrhea, dysentery and the open health question a recall period of two weeks was used, while for typhoid, cholera and hepatitis a recall period of one month was used. The people

Table 5: Population used for analysis

Wastewater exposure	*Adult male farmers*	*Male children <12 years*	*Female children <12 years*	*Total*
Exposed	68	65	65	198
Unexposed	118	85	76	279

Table 6: Helminth eggs and faecal coliform bacteria in water samples compared with the WHO guidelines

Water source	*Helminth eggs (No. Per liter)* [7]	*Faecal coliforms (No. Per 100 ml)*
Wastewater	100	> 1,000,000
Canal water	Not detected (<5)	0-1,314
Vegetable wash water	Not detected (<5)	-
WHO guideline for wastewater [8]	**$\leq$ 1**	**$\leq$ 1,000**

[7] *Ascaris lumbricoides, Trichuris trichiura* and hookworm species.

[8] WHO guidelines category A (table 2): Guidelines for irrigation of crops likely to be eaten uncooked and for situations where farmers or the public are exposed directly to the wastewater. Both was the situation around Haroonabad.

interviewed did not mention cholera and hepatitis. Therefore these diseases do not appear in the table. The only problems frequently mentioned in the open health question were fever and colds, which appear as such in table 7.

Table 7 shows that diarrhea, diarrhea complicated with fever and nail problems were more frequently seen in the population exposed to wastewater. In figure 2 the prevalence of these diseases in the exposed and unexposed groups are compared for male farmers and children below the age of 12.

Nail problems seemed to be a problem of adult farmers. The most common nail problem in farmers in the exposed and in the unexposed group was koilonychia (spoon formed nails), which is associated with iron deficiency anaemia. In the exposed group also nail deformities associated with fungal infections were observed.

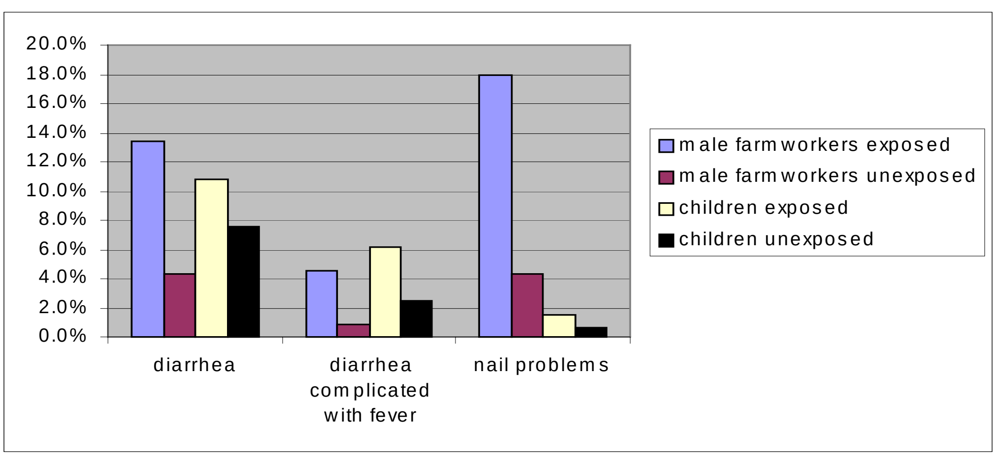
4.5 Prevalence of Intestinal Parasites by Exposure to Wastewater

To analyze the prevalences of intestinal parasites by exposure to wastewater, the results of the concentration method were used. A concentration method is more sensitive to find ova and cysts in low intense infections. In this study, concentration with the Parasep® Faecal Parasite concentrator gave more often a positive result for hookworm and *Entamoeba coli* infections than the direct smear method. For the other species no significant difference was seen. Compared to the results of the preserved samples, examined at the Institute of Public Health in Lahore, the concentration method gave the same trend in results for all different species. However, the number of positive samples was 3-5 times higher with the concentration method. In table 8, the number of positive samples of the different parasites is shown for 75 samples for which all three methods were used.

Table 7: Prevalence of diseases by exposure to wastewater with odds ratio and 95% confidence interval

Disease	*Exposed*	*Unexposed*	*OR*	*95% CI*
Diarrhea	11.7% (23)	6.2% (17)	2.00	1.04 – 3.85
Diarrhea complicated with fever	5.6% (11)	1.8% (5)	3.18	1.09 – 9.31
Dysentery	0.5% (1)	0	-	-
Skin problems	3.0% (6)	5.8% (16)	0.51	0.20 – 1.32
Nail problems	7.1% (14)	2.2% (6)	3.42	1.29 – 9.05
Typhoid	0	0.7% (2)	-	-
Fever / cold	11.7% (23)	11.7% (32)	1.00	0.57 – 1.77
Total number of health questionnaires	*197*	*274*		

Figure 2: Prevalence of diseases in male adult farm workers and children by exposure to wastewater



Since the concentration method was found the most sensitive, this method was used to analyze the difference in prevalence of intestinal parasites in the exposed and unexposed population. The results are presented in table 9.

Table 9 shows that the prevalence of hookworm and *Ascaris lumbricoides* infections were higher in the population exposed to wastewater. In figure 3, the prevalence of hookworm and *Ascaris lumbricoides* infections by exposure to wastewater is shown separate for male farmers and children below the age of 12. The prevalence of hookworm was especially high in exposed male farm workers. In children there was no significant difference between the exposed and unexposed group. However, *Ascaris lumbricoides* seems to be a problem in exposed children.

Besides direct exposure to wastewater, exposure to wastewater irrigated crops can also cause health problems. Most of the people of the two control villages bought crops regularly from the Haroonabad market. Since these vegetables are to a large extent grown on the wastewater irrigated fields around the city, people in the villages could be considered as consumers of wastewater irrigated crop. To evaluate the effect of crop consuming on the prevalence of intestinal parasites, the results of this study were compared with the results of a study carried out by IWMI in 1999 in a rural area about 50-100 kilometer from Haroonabad (Feenstra, Hussain and van der Hoek 2000 (1,2)). In the study in the rural area, only preserved samples from children below the age of 12 were examined. Therefore, the results of the preserved samples from children of the peri-urban villages without direct exposure to wastewater were used to compare with the results from the rural area. The results are presented in table 10.

The prevalence of hookworm was found slightly higher in the peri-urban villages, compared with the rural villages. The prevalences of the other intestinal parasites were comparable.

Table 8: Number of positive samples for intestinal parasites in 75 samples examined with three different methods

Parasite	Concentration Method	Direct Smear Fresh Sample	Direct Smear Preserved Sample
Giardia lamblia	27 (36.0%)	36 (48.0%)	15 (20.0%)
Entamoeba coli	38 (50.7%)	24 (32.0%)	12 (16.0%)
Entamoeba histolytica	12 (16.0%)	9 (12.0%)	1 (1.3%)
Ascaris lumbricoides	1 (1.3%)	0 (0.0%)	0 (0.0%)
Trichuris trichiura	0 (0.0%)	0 (0.0%)	0 (0.0%)
Hookworm	31 (41.3%)	15 (20.0%)	8 (10.7%)
Taenia saginata	1 (1.3%)	2 (2.7%)	0 (0.0%)
Hymenolepis nana	10 (13.3%)	9 (12.0%)	6 (8.0%)
Total no. of samples	*75*	*75*	*75*

Table 9: Prevalence of intestinal parasitic infections by exposure to wastewater with odds ratio and 95% confidence interval (concentration method)

Disease	*Exposed*	*Unexposed*	*OR*	*95% CI*
Giardia lamblia	36.4% (48)	33.8% (51)	1.12	0.69 – 1.83
Entamoeba coli	37.9% (50)	43.7% (66)	0.79	0.49 – 1.27
Entamoeba histolytica	15.2% (20)	10.6% (16)	1.51	0.75 – 3.05
Ascaris lumbricoides	5.3% (7)	0	-	-
Trichuris trichiura	0.8% (1)	0	-	-
Hookworm	38.6% (51)	26.5% (40)	1.75	1.06 – 2.89
Taenia saginata	0.8% (1)	0	-	-
Hymenolepis nana	9.1% (12)	15.2% (23)	0.56	0.27 – 1.17
Total number of stool samples	*132*	*151*		

Figure 3: Prevalence of intestinal parasites in male adult farm workers and children by exposure to Wastewater (concentration method)

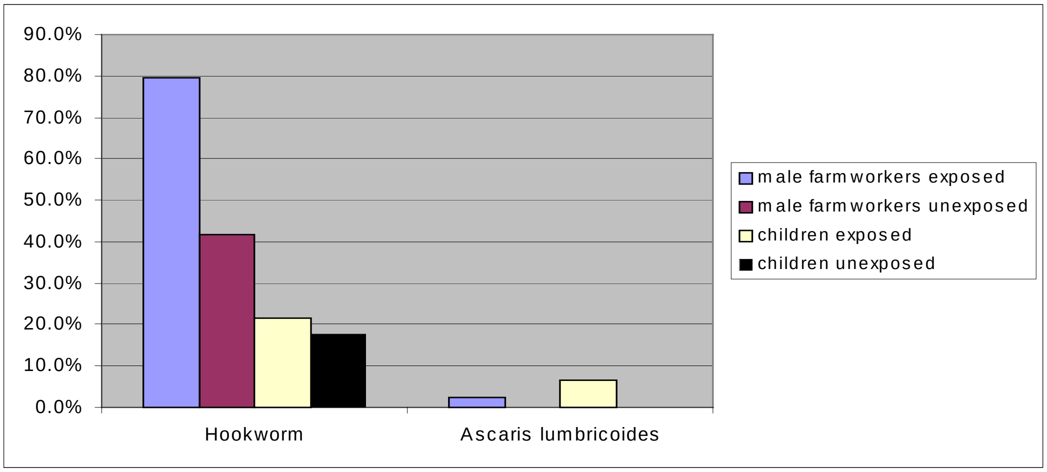


Table 10: Prevalence of intestinal parasites in children below the age of 12 in peri-urban and rural villages around Haroonabad (preserved samples, direct smear)

Parasite	Peri-urban	Rural[9]
Giardia lamblia	31.9% (30)	39.2% (104)
Entamoeba coli	13.8% (13)	12.5% (33)
Entamoeba histolytica	1.1% (1)	3.8% (10)
Ascaris lumbricoides	0% (0)	1.9% (5)
Trichuris trichiura	0% (0)	0.8% (2)
Hookworm	4.3% (4)	2.3% (6)
Taenia saginata	0% (0)	0% (0)
Hymenolepis nana	10.6% (10)	7.5% (20)
Number of samples	94	265

[9] The results from Survey I (Feenstra, Hussain, van der Hoek, 2000 (2))

5. DISCUSSION AND CONCLUSIONS

5.1 Health Risks of Irrigation with Wastewater around Haroonabad

The untreated wastewater of the main site in Haroonabad, which was used for irrigation, contained a concentration of helminth eggs and faecal coliform bacteria that exceeded far the WHO guidelines (table 6). This poses a high potential health risk to both farmers and crop consumers in the area. Farmers are at high risk, because they have intensive contact with wastewater, as they do most of the fieldwork manually and barefoot. Crop consumers are at high risk, because in the wastewater irrigated fields vegetables are grown that are eaten uncooked. Tomatoes, a major crop on the wastewater irrigated fields, are widely used in salads. However, it is questionable whether bacteriological guidelines from the WHO are applicable for the warm climate in Pakistan, which facilitates bacterial growth. Canal water in the same area also contained often more faecal coliform bacteria than recommended by the WHO for treated wastewater.

Besides a potential health risk due to a high concentration of bacteria and helminth eggs in the Haroonabad wastewater, an actual increased health risk was observed in farmers and their families. Farmers who were irrigating their land with wastewater had a significantly higher prevalence of diarrheal diseases than farmers who were irrigating their land with canal or tubewell water. The prevalence of diarrheal diseases was also higher in children of farmers working with wastewater. Beside diarrheal diseases, nail problems were more common in farmers exposed to wastewater. The most common nail problem was koilonychia (spoon shaped nails), associated with iron deficiency anaemia. The high prevalence of this problem can be explained by the very high prevalence of 80 percent hookworm infections observed in farm workers exposed to wastewater. Hookworm infections can cause aneamia by blood loss due to damage of the intestinal wall. It is not surprising to find a high prevalence of hookworm infections, since larvae can easily penetrate through the skin of farmers, as they are mostly working barefoot in the wastewater irrigated fields. The prevalence of hookworm infections was not significantly different between children of exposed and unexposed farmers. However, in children of farmers exposed to wastewater, infections with *Ascaris lumbricoides* were more common.

Although no helminth eggs were found in wash water from vegetables grown on the wastewater irrigated fields in this study, contamination of vegetables is described in other studies (WHO 1989, Blumethal 1996). Several vegetables that are grown on the wastewater irrigated fields around Haroonabad are eaten raw. This poses health risks to crop consumers. However, only a slightly higher prevalence of hookworm was found in children of the peri-urban villages, compared with rural villages. The prevalences of the other intestinal parasites were found in the same range (table 10). In the peri-urban villages crops from the market in Haroonabad are used, which are grown on the wastewater irrigated fields. Villagers in the rural areas further away from Haroonabad obtain their vegetables from other sources, which are not contaminated by wastewater. Therefore, this slightly increased prevalence of hookworm in children in the peri-urban villages could be an indication that consumers of vegetables grown on the wastewater irrigated fields have an increased risk to acquire hookworm infections.

5.2 Conclusions and Recommendations

Although the disposal of wastewater on agricultural fields has a lot of benefits, the use of this water without any treatment poses serious health risks to farmers and their children. The prevalence of diarrheal diseases and hookworm infections was very high in farmers working on wastewater irrigated fields, while in children of these farmers the prevalence of these diseases was also high. Besides farmers and there families, there is an indication that crop consumers might have a higher chance to acquire an infection with hookworm.

Therefore, protective measures are required for farmers, their families and crop consumers. The health guidelines for faecal coliform bacteria in wastewater from the WHO seem difficult to realize in the tropical climate of the Punjab Province, since canal water also exceeds the guidelines regularly. However, an appropriate form of treatment of wastewater for helminth eggs and faecal coliform bacteria before application to the fields is highly recommended. If treatment is not possible because of the high costs, other protective measures should be taken. Low cost interventions could include, information on hygiene behavior for farmers, wearing of shoes and gloves while working in wastewater irrigated fields, regular treatment of farmers and their families with antihelmintic drugs and crop restrictions in wastewater irrigated fields.

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