Low Risk for Helminth Infection in Wastewater-Fed Rice Cultivation in Vietnam

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Introduction

Vietnam is one of the developing countries where household wastewater and excreta have been used for decades and even centuries by farmers in urban and peri-urban areas in agriculture as well as aquaculture systems. Products from wastewater-fed systems contribute significantly to food production and food security in Vietnam (Raschid-Sally *et al.* 2004). However despite its widespread use, such practices are often informal and only to a limited degree recognized by the authorities and the public at large.

In Vietnam wastewater is used mostly untreated and this scenario is not likely to change in the near future without resources to provide adequate wastewater treatment facilities for the growing urban population. Irrigation with untreated wastewater can therefore pose risks for the health of irrigators, for communities in prolonged contact with the wastewater, to the consumers of produce irrigated with wastewater and through spread of pathogens in the environment. Epidemiological studies in different countries have established that the highest risk to human health of using wastewater in agriculture is posed by soil-transmitted intestinal helminth infections (Mara & Cairncross 1989; Blumenthal *et al.* 2000). However, little information is available about specific occupational risks for intestinal helminth infections associated with wastewater-irrigated rice culture. Infections with roundworm (*Ascaris*), whipworm (*Trichuris*), and hookworm are widespread in Vietnam (van der Hoek *et al.* 2003). But in addition to the use of wastewater, there are other environmental and human behavioral risk factors for infection with soil-transmitted helminths, of which poor sanitation is probably the most important one. The relative importance of the different risk factors in different wastewater use systems is unknown. This makes it difficult for policy makers and urban planners to make informed decisions about wastewater irrigation.

This study was done to assess the risk of helminth infection in association with wastewater-fed rice cultivation in an agricultural setting of Nam Dinh city, Vietnam.

Methods

In a cross sectional survey data were collected of 202 households in a commune where wastewater was used for irrigation and 201 households in a commune that used river water. Parasitological examination was conducted on single stool samples obtained from 1,088 individuals aged ≥15 years from the households. The irrigation water used in both communes was enumerated for helminth eggs and thermotolerant coliforms (bacterial fecal indicators.

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Results

Data from the irrigation water sampling showed that the microbiological quality of the river water was rather consistent during the sampling period, while that of wastewater varied between the four samplings. Nevertheless, as expected, wastewater contained higher concentrations of helminth eggs and thermotolerant coliforms. The quality of wastewater (40-200 eggs/L and 10^4 thermotolerant coliforms/100 ml) exceeded the WHO guidelines for wastewater application in agriculture and aquaculture, which stipulates less than 1 viable nematode egg per liter and less than 1,000 fecal coliforms per 100 ml (Mara & Cairncross 1989). The river water samples had a much lower level of thermotolerant coliforms, within the WHO permissible limit, and helminth eggs could not be found in 3 out of the 4 samples.

A total of 1,139 persons from the 403 households of My Tan (570 persons) and My Trung (569 persons) communes were included in the surveys. Their age ranged from 15 to 94 years old, with a mean age of 40.4 years in the wastewater exposed commune and 42.3 in the unexposed commune. There was no significant difference in the female/male ratio between the two communes. Compliance with stool examination was very high (95.5%) and out of the 1,088 samples that were available for analysis, 53.4% were positive for one or more of the three helminth parasites. Prevalence was 42.2% for *Ascaris* spp., 19.9% for *Trichuris* spp., and 10.5% for hookworm. There was no clear association between prevalence of helminth infection and age. However, it could be noted that for the age group of 60 years and above, the prevalence of infection with *Ascaris* spp. and *Trichuris* spp. decreased but the hookworm infection prevalence slightly increased.

The univariate analyses were performed with the data from the subjects that had provided a stool specimen. Surprisingly, people who were exposed to wastewater (all living in My Tan commune) had significant lower prevalence of *Ascaris* spp. and *Trichuris* spp. than people in My Trung commune and the people in My Tan commune who were not exposed to wastewater. For hookworm infection there was no significant difference between those exposed and not exposed to wastewater.

Not having a latrine was a strong risk factor for helminth infection (odds ratio [OR] for the three helminth parasites combined was 2.57, 95% CI 1.10-6.70). However, only 31 out of the 1,088 people had no latrine available. Therefore, in the further analyses we used the hygienic status of the latrine, with people not having a latrine regarded as a separate category, although its OR would not be used to interpret the results. People from households that did not apply any treatment on latrine waste after defecation (direct discharge) had an increased risk of infection with *Ascaris* spp. and *Trichuris* spp., such as those who used overhung fishpond latrines or disposed feces directly to open surface drains (OR for combined infection was 1.99, 95% CI 1.37-2.81).

Having only a limited storage capacity for drinking water (less than 2 m^3) was a risk factor for helminth infection. Presumably this reflects the amount of water that people had available for personal and household hygiene. Those individuals who practised hand washing after defecation experienced a lower risk of infections with *Ascaris* spp. and *Trichuris* spp.. In particular, hand washing with soap seemed to further reduce the risk of helminth infection. However, only the association between *Ascaris* spp. infection and no handwashing was found statistically significant. People using nightsoil, including fresh excreta on their agricultural fields, had a higher risk for helminth infection than those not using nightsoil, but the difference did not reach statistical significance (data not shown). Of the people involved in agricultural work (1,018 people), only 4.4% reported using personal protective measures while doing fieldwork, such as shoes, plastic boots or gloves. These people had a much lower risk of *Ascaris* and *Trichuris* infection than those not using any means of personal protection. Significant differences in the use of overhung fishpond latrines, non-treatment of latrine waste and the lack of protective measures were also observed, with conditions being worse in My Trung than in My Tan.

Socio-economic status (SES) was significantly associated with *Ascaris* spp. and *Trichuris* spp. infections but not with the combined infection of helminths. Households in My Trung were generally of lower SES than in My Tan ($p<0.05$). The risk for helminth infection was higher in people with lower levels of education (ranging from illiteracy to secondary school) compared to people of higher education (high school or university levels). No significant gender difference in risk of infection was found.

Specific agricultural practices, such as rice and vegetable farming or aquaculture, could not be associated with risk for helminth infection, except for flower planting that gave an increased risk (OR = 1.37, $p=0.078$, controlling for factor "commune"). However, this could not explain the difference in prevalence of helminth infections between the two communes because flower cultivation was more common among the households in My Tan commune than in My Trung commune. No significant differences between the two communes were found in the status of latrines, use of nightsoil or educational level.

Most risk factors pointed in the same direction for the three helminth parasites. Factors that were significantly associated with any of the helminth species were also significant for single infection with *Ascaris* spp. or *Trichuris* spp.. Unlike for *Ascaris* spp., *Trichuris* spp., and for the three parasites combined, few risk factors for hookworm could be identified. This could be due to the different way of transmission where hookworm depends on the penetration of human skin (usually the feet) by larvae, which develop from eggs passed in human stools into the environment. However, the much lower prevalence of hookworm compared with *Ascaris* could in itself explain why most risk factors did not reach statistical significance.

Because of a similar oral transmission pattern, the infections with *Ascaris* spp. and *Trichuris* spp. were combined as the outcome variable in the multivariate analysis (Table 1). Exposure to wastewater remained a significant protective factor, even when controlling for confounding by other variables. This indicates that other differences between the two communes than the ones considered in the study had impact on the prevalence of helminth infections. Poor standard of hygiene and sanitation, not using protective measures, and lack of access to large quantities of water, were independent risk factors in the multivariate analysis (Table 1). Because not every subject did participate in agricultural production, a separate logistic regression model was run, including only people doing farm work (N=1,018), to assess the effect of not using protective measures. However similar results were obtained with only slight changes in the odds ratios (data not shown). Variables that were significant in this model also stayed significantly in the other. Adding interaction terms of covariates did not improve the fit of the multivariate model (data not shown).

Table 1: Assessment of risk factors for helminth infections (Ascaris spp. and Trichuris spp. combined) using multivariate logistic regression (N=1,088)

Variables	*Ascaris* spp. and *Trichuris* spp.			
	OR*	P-value	OR**	P-value
Wastewater use	0.40 (9.32-0.52)	0.000	0.36 (0.28-0.47)	0.000
Hygienic status of latrine	1.49 (1.17-1.89)	0.001	1.31 (1.00-1.71)	0.051
Nightsoil use	1.27 (0.91-1.77)	0.166	1.17 (0.81-1.69)	0.410
Use of fresh excreta	1.31 (1.00-1.71)	0.046	n/a	
Treatment of latrine waste	1.97 (1.43-2.73)	0.000	n/a	
Hand washing	1.34 (1.04-1.73)	0.026	1.48 (1.33-3.04)	0.005
Use of protective measures[a]	1.78 (1.20-2.66)	0.004	2.01 (1.34-3.09)	0.001
Availability of drinking water	1.71 (1.20-2.43)	0.003	1.45 (0.98-2.14)	0.060
Level of education	1.49 (1.08-2.06)	0.016	1.35 (0.96-1.91)	0.084
Socioeconomic status	1.29 (1.02-1.64)	0.034	1.05 (0.81-1.36)	0.704

*, Crude OR; **, from the reduced model; n/a: the variable was dropped out during the stepwise multivariate analysis so there was no OR obtained in the reduced model; [a], people who did not do agricultural work were included in the group that used protective measures since it was assumed that they would probably do so when performing some fieldwork.

The helminth egg counts were low for all helminths . Except for a few infections with *Ascaris* spp. that would be classified as "moderate", all other infections would be classified as "light" according to WHO criteria (2002).

There were clear differences in nutritional status between the two communes. The mean Z-score of weight-for-age for children in My Tan was significantly ($p<0.01$) higher than that of children in My Trung. The percentage of children underweight (<-2SD from the median of the NCHS reference) was 20.7% in My Tan and 27.8% in My Trung (Chi squared test = 5.45, P = 0.02). Children living in the non-wastewater site had an increased risk of being underweight (OR=1.47, 95% CI 1.05-2.06).

Discussion

Contrary to what was expected, people who were exposed to wastewater had a lower prevalence of helminth infection than those who were not exposed. The study could therefore not find evidence that rice cultivation with urban wastewater posed a risk for intestinal helminth infection in agricultural workers. Despite taking account of differences in socio-economic status and sanitary practices, the variables included in the study could not fully explain the difference in infection prevalence between the exposed and non-exposed. The most probable explanation for the lower prevalence of helminth infection in My Tan commune would still be the overall higher welfare level as compared with My Trung. This was reflected in the better child nutritional status in the exposed commune. Nutritional status is a well-known compound indicator representing effects of access to food, standards of living, womens' educational level, access to water supply and sanitation, and burden of infectious diseases. These aspects might have been insufficiently captured in the variables that we used. This also bears on possible flaws in the design of the study. The study was designed as a cross-sectional study with analysis at the individual level. However, one could criticize the approach as being a comparison between an exposed and an unexposed community. Such a "one to one comparison" is a major methodological problem in many studies on environmental sanitation, as pointed out by Blum & Feachem (1983). Our interest was not the difference between the two communities but the relative importance of different risk factors throughout the entire study population. We felt that the chosen design was justifiable because the communities were located very close to each other and were similar in many aspects. Another limitation of the study is that some of the variables pertained to individuals while other variables pertained to all members in a household. It is well known that helminth infections tend to aggregate in certain individuals within households, in certain households, and in certain communities. We did not account for this aggregation. Especially aggregation of heavy infections is extremely relevant for targeting control measures but we feel that this phenomenon of aggregation did not affect the validity of the individual-level risk assessments.

Our analyses showed that most of the people infected with *Ascaris* spp. and *Trichuris* spp. came from lower socioeconomic groups and households with inadequate sanitary conditions and poor hygiene practices. This is in line with findings from previous studies such as by Al-Shammari *et al.* (2001), Cifuentes (1998), and Kightlinger *et al.* (1995).

Another possible explanation of the counterintuitive findings of the present study is that the concentration of helminth eggs in the irrigation water might have been too low to cause an increase in human helminth infection prevalence. Although worm counts in wastewater samples exceeded the WHO guideline level, the samples were collected just before the wastewater entered the pumping station, from where the wastewater was distributed to local irrigation canals and then to the paddy fields. After the pumping station, the helminth eggs in wastewater would have been diluted because of natural sedimentation processes along the wastewater flow, together with the die-off of eggs because they do not have optimal conditions for their survival and development, which is a moist, warm and shady environment (Paniker 2002). This could have resulted in a low concentration of helminth eggs in the water in the fields, to which the farmers were actually exposed. The quality of the wastewater in My Tan commune was to some extent similar to or better than that studied elsewhere, such as in the Mezquital Valley (Mexico) with concentrations of 10^8 thermotolerant coliforms/100 ml and 90-150 helminth eggs/L (Cifuentes 1998) or in Calcutta with 200-2130 helminth eggs/L (Ayres *et al.* 1992). Furthermore, it could be questioned whether farmers using wastewater in wet rice cultivation would be exposed to any particular risk for *Ascaris* spp. and *Trichuris* spp. infections, since such farmers must have an oral intake of the eggs present in the wastewater to acquire the infection. This is different from wastewater irrigated crops, including crops consumed raw, where an oral intake of eggs will mainly occur through consumption of contaminated produce.

Our findings of lower prevalence of helminth infections in a wastewater dependent area are inconsistent with other studies of the effect of wastewater on enteric infections. In a study in Mexico, Blumenthal *et al.* (2001) reported that the risk of infection with *A. lumbricoides* in those aged >5 years when directly exposed to untreated wastewater (6×10^7 thermotolerant coliforms/100 ml and 90-135 helminth eggs/L) was 13.5 times higher than for those who were not exposed. However, the prevalence of *Ascaris* spp. infection in adults above 15 years of age in the exposed group (4.3%) was much lower than what was found in the present study in Vietnam. Living in a wastewater using area was also found to be associated with ascariasis, but not with trichuriasis, in children in Morocco (Habbari *et al.* 2000). That study also found low intensities of the helminth infections in wastewater as well as non-wastewater areas.

Conclusion and Perspectives

In conclusion, this study showed no evidence that rice cultivation with wastewater poses a risk for helminth infection. More detailed studies are needed on the reduction of fecal indicators and helminth eggs in peri-urban wastewater-irrigated rice culture systems and on the relative importance of wastewater irrigation compared to other risk factors for human helminth infection such as poor sanitation and poverty.

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