

Association between intestinal parasitic infections and type of sanitation system in rural El Salvador

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Summary

OBJECTIVE To identify demographic, behavioural and environmental determinants of intestinal parasitic infection, evaluate the impact of a variety of dry sanitation systems on intestinal parasitic infection, and evaluate the safety of using stored biosolids in agriculture in order to guide future sanitation interventions in rural areas of El Salvador.

METHODS Interviews were conducted with 109 households in eight communities where double-vaulted and solar urine-diverting desiccating latrines, pit latrines or no latrines were used. Faecal samples from 499 individuals were tested for enteric helminths and protozoa.

RESULTS Users of solar desiccating latrines had the lowest prevalence of enteric parasite infection. Double-vault, urine-diverting desiccating latrines effectively reduced the transmission of some pathogens, but may not achieve the conditions sufficient for the complete destruction of the more environmentally persistent pathogens, *Ascaris lumbricoides* and *Trichuris trichiura*. Contact with inadequately treated latrine biosolids was associated with an increased risk of *Ascaris* infection.

CONCLUSIONS Solar latrines were associated with the overall lowest prevalence of enteric parasitic infections. Members of households where latrine biosolids were used in agriculture had a higher prevalence of infection than those where biosolids were buried. We therefore recommend the promotion of solar latrines in rural areas of El Salvador over other dry sanitation systems, and recommend that stored biosolids not be used in agriculture.

keywords sanitation, ecological sanitation, latrines, geohelminths, *Ascaris*, biosolids

Introduction

Intestinal parasitic infections are among the most prevalent infections worldwide, with an estimated 3.5 billion people infected and 450 million ill (WHO 2001). While mortality from enteric helminths and protozoa is relatively low, morbidity and the indirect effects of apparently asymptomatic infections have a substantial impact on health and quality of life. The World Bank (1993) estimates the global burden of disease from geohelminth infections (*A. lumbricoides*, *T. trichiura* and hookworm) to be 2.4 million DALYs. In Latin America, the Pan American Health Organization (PAHO) (1997) estimates that helminth infections affect between 20% and 30% of the general population, with prevalences as high as 60–80% in endemic areas. Intestinal protozoan infections are even more prevalent.

Geohelminths and enteric protozoa are readily passed from person to person via the faecal-oral route, either directly, through contact with contaminated hands, or indirectly, via contamination of food, water, or the

environment. Sanitation reduces the dispersal of faeces in the environment and thus reduces the transmission of faecal-oral infections (Feachem *et al.* 1983). Reviews of the impact of sanitation on diarrhoeal disease estimate that sanitation interventions reduce diarrhoea morbidity in young children from 22% to 36% (Esrey *et al.* 1991; Fewtrell *et al.* 2005).

Currently, UNICEF & WHO (2004) estimate that 2.6 billion people worldwide lack access to adequate sanitation. Roughly 15% of the urban population and nearly 50% of the rural population of El Salvador do not have access to sanitation (Ministry of Health of El Salvador 1998). In many areas, pit latrines cannot be constructed due to rocky or hard soil, lack of space, or a high ground water table. Since the early 1990s, USAID, UNICEF and the Ministry of Health have promoted the construction of thousands of alternative, ecologically sustainable latrine models designed to contain human excreta while producing a soil conditioner that can be used in agriculture. Two models of 'eco-san' latrines found in El Salvador are the double-vault desiccating latrine [known in Latin America as

LASFs (*Letrina Abonera Seca Familiar*)] and the solar desiccating latrine. When the vault of these latrines is full, the biosolids (faeces plus soil, ash, lime or sawdust additives) are stored for weeks to months and then emptied. These systems rely on temperature, time, humidity, and pH to inactivate microbial pathogens in the faecal material.

While the theoretical impact of sanitation on reducing enteric parasitic infections is well accepted, latrines are often not used in a way that yields complete destruction of pathogens in human excreta. Little scientific research has been conducted to evaluate the impact of eco-san latrines on the prevalence of parasitic infections. Where latrine biosolids are used in agriculture, there is the possibility that these systems may increase exposure to enteric pathogens, particularly persistent soil-transmitted helminths that survive storage conditions of the latrines (Humphries *et al.* 1997; Hanoi Medical Team Report 1994, unpubl. obs.).

This study was designed to evaluate the impact of various latrine interventions on the prevalence of enteric parasitic infection in rural areas of El Salvador. Specific aims were (1) to obtain an estimate of the prevalence of intestinal helminth and protozoan infections in study communities with different types of sanitation; (2) to determine the demographic, behavioural and/or environmental factors, as well as attitudes and practices surrounding the excreta disposal that affect the risk of intestinal parasitic infection; (3) to determine which sanitation system designs most effectively control the transmission of enteric pathogens in rural El Salvador; and (4) to determine whether the practice of using stored biosolids from latrines in agriculture is safe or increases the risk of acquiring enteric parasitic infections.

Materials and methods

Subject selection

Subjects were selected from eight rural and semi-urban communities in the states of La Libertad and La Paz, El Salvador. Two communities had primarily LASF latrines, two had primarily solar latrines and four had pit latrines or no latrines. A list of all households was obtained from the health promoter of each community and households with the target latrine type were selected at random. Because of the small number of households with solar latrines, all households were included in the study. Additional households with LASF latrines where stored biosolids were used in agriculture, and where at least one household member worked in agriculture were specifically sought for inclusion in order to examine the impact of working in the fields on enteric parasitic infection prevalence.

Field methods

Informed consent was obtained from all adult participants and from parents or legal guardians of minors. Data collection procedures were approved by the Institutional Review Board of Emory University. Interviews were conducted with heads of 113 households where one of the four sanitation methods was used. Information was collected on demographics, health and behavioural factors related to sanitation. For families with latrines, we asked how latrine biosolids were used or discarded, how many people used the latrine, and about their general level of satisfaction with the latrine. For households that did not have a latrine, we asked about their defecation practices and preferences.

Each household member was provided with materials and detailed instructions for stool collection. Stool samples were collected on the following morning and taken to the Max Bloch Central Laboratory of the El Salvador Ministry of Health in San Salvador, where they were immediately fixed in formalin and later examined for enteric protozoa and helminths.

The field team returned to the study households after 2 weeks with the results of the laboratory tests and provided medication for persons who tested positive for helminths (Mebendazole, Albendazole, Pyrantel Pamoate, or Praziquantel as appropriate) or protozoa (Metronidazole). Medications were donated by the Healthy Schools program of the Ministry of Health of El Salvador, and were provided free of charge to all infected and at-risk individuals along with detailed instructions for their use. Where several household members tested positive for helminths, Mebendazole was distributed to all the individuals in the household (except children under 2 years of age and pregnant women) as prophylaxis whether or not the individual was enrolled in the study.

Laboratory methods

Stool samples were analysed for the presence of intestinal parasites by using the Evergreen Scientific Fecal Parasite Concentrator Kits[®] (Los Angeles, CA, USA), a modification of the Ritchie formalin-ether method that increases the sensitivity of helminth ova detection in stool. This technique uses formalin and ethyl acetate to remove lipids, and filtration and centrifugation to concentrate the ova or cysts in the sample. Processed samples were checked for the presence of intestinal parasite ova or cysts by light microscopy by using standardized methods. Diagnosis was made on the basis of morphology and size by experienced laboratory technicians.

Data management and analysis

Only persons above 3 years of age and for whom we had both stool sample results and a completed household questionnaire were included in the study analysis, for a total of 449 individuals. For the purposes of this study, samples were classified as either positive or negative, regardless of parasitic load. Socio-economic status (SES) was scored based on the house construction, having electricity, and ownership of home and household appliances and was dichotomized as high or low (above or below the 50th percentile).

Data from the questionnaires were double-entered into MICROSOFT EXCEL (Microsoft Corporation, Redmond, WA, USA) to ensure accuracy of the data. Data were later converted into SAS 8.0 (SAS Institute Inc, Cary, NC, USA) for further analysis. The level of statistical significance was set at $P = 0.05$. Confidence limits are reported at 95%. Univariate analysis was carried out for all variables by parasitic infection. Comparison between groups was performed by using the Cochran–Mantel–Haenszel test. ANOVA was used to measure trends in continuous variables as they related to parasitic infections. Multivariate logistic regression was employed to determine the association between potential risk factors and infection by each parasite, and the odds ratios and corresponding SEs for each variable. The Generalized Estimating Equation was

used to control for clustering of parasitic infections within households. Variables included in the logistic regression model for each parasite were selected based upon the significant associations with parasitic infection in stratified analysis, associations reported in other studies, or biological plausibility.

Results

A total of 107 households with 449 people were included in the final analyses. Thirty-one households used LASF latrines, 20 used solar latrines, 31 used pit latrines and 25 had no latrines. There was a range of demographic and environmental conditions, such as age structure, education, literacy, water source and house construction in the study communities (Table 1). Literacy ranged from 25% for women and 42% for males in El Almendral to 94% for women and 93% for males in Tecpan. Years of education ranged from 0 to 18, with a mean of 3.0 years for both females (median = 3.0, SD = 2.9) and males (median = 2.0, SD = 3.3). Our SES indicator showed little variation among the study households and communities. In La Joya and Nahualapa, water was provided primarily by piped systems; in Las Isletas, La Gloria and Tecpan, water was primarily provided by household wells; and in the remaining communities, community wells or springs were the principal water sources. The mean number of latrine

Table 1 Demographic characteristics of study population

Variable (<i>n</i>)	Category	<i>n</i> category	Per cent
Gender (449)	Male	221	49.2
	Female	228	50.8
Age (449)	4–12 years	145	32.3
	13–18 years	62	13.8
	19–40 years	141	31.4
	> 40 years	101	22.5
		261	58.7
Female head of household literate (445)		248	64.8
Male head of household literate (383)			
Latrine type (449)	Letrina Abonera	127	28.3
	Seca Familiar		
	Solar	79	17.6
	Pit	141	31.4
	None	102	22.7
Water source (445)	Piped	130	29.2
	Well	207	46.5
	Spring	108	24.3
Type of floor (449)	Dirt	270	60.1
	Cement/brick	179	39.9
Anti-helminthic medication in last 3 months (448)		93	20.8
Own pigs (384)		84	21.9

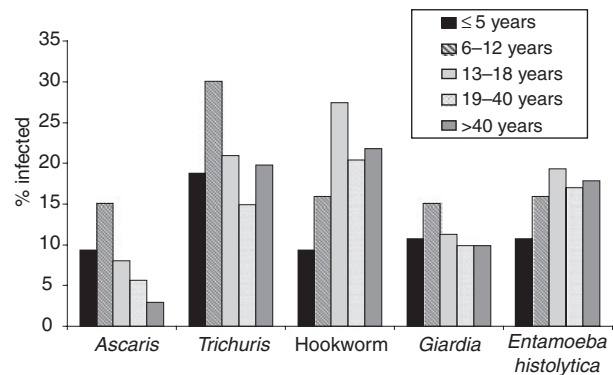
Table 2 Prevalence of parasitic infections in study population

Parasitic infection (<i>n</i> = 449)	Number infected	Per cent
<i>Ascaris lumbricoides</i>	36	8.0
<i>Trichuris trichiura</i>	94	20.9
Hookworm	100	22.3
<i>Hymenolepis nana</i>	17	3.8
<i>Strongyloides stercoralis</i>	9	2.0
<i>Giardia lamblia</i> (intestinales)	54	12.0
<i>Entamoeba histolytica</i>	78	17.4
Any helminthic infection	163	36.3
Any protozoan infection	113	25.2
Any intestinal parasite	239	53.2

users was 6.5 (SD = 4.0) per latrine. The number of latrine users generally reflected the number of household members excluding infants, except in Tepeagua, where latrines were often shared by up to 20 persons from three or four households.

Fifty-three per cent (*n* = 239) of the study population were infected with one or more intestinal parasites, with 42.7% harbouring multiple infections. Hookworm and *Trichuris* (22% and 21%, respectively) were the most common infections, and *Strongyloides* (2%) was the least common infection detected in the study population (Table 2).

Age was an important determinant for *Ascaris* infection. Children 6–12 years of age had an 11.5 times greater risk of *Ascaris* infection than individuals in the highest age category (CI = 2.3–57.9) when adjusted for household clustering and logistic regression model variables (see Table 3). While the association of other infections with age was not significant, *Trichuris* infection was highest among 6–12 year olds, hookworm was highest among adults, and *Giardia* was highest among children under 5 years of age. *Entamoeba histolytica* prevalence did not vary by age (Figure 1).

**Figure 1** Prevalence of parasitic infection by age.

As expected, several individual and household factors were significantly associated with prevalence of various helminth and protozoan infections. The prevalence of helminth infections was higher in households that owned pigs (*Ascaris*: OR = 1.9, CI = 0.7–5.0; hookworm: OR = 2.5, CI = 1.0–6.4). Having a dirt floor was significantly associated with higher prevalences of *Trichuris* (OR = 2.3, CI = 1.2–4.5), hookworm (OR = 2.8, CI = 1.3–6.2) and *Giardia* (OR = 2.8, CI = 1.1–7.0) infections. Having taken antihelminthic medication in the previous 3 months was protective for all helminths, and the association was significant for *Trichuris* (OR = 0.3, CI = 0.1–0.6) and hookworms (OR = 0.1, CI = 0.05–0.4). In the bivariate analysis, males had higher prevalences of infection than females (*Ascaris*: OR = 1.7, CI = 0.8–3.4; *Trichuris*: OR = 1.7, CI = 1.1–2.7; hookworm: OR = 2.1, CI = 1.3–3.3), and persons who worked in agriculture were more likely to have hookworm infection (OR = 1.9, CI = 1.2–3.1). Other variables examined but not found to be significantly associated with helminth or protozoan infection included: maternal and paternal

Table 3 Adjusted odds ratios for the association between latrine type and parasitic infection

	<i>Ascaris lumbricoides</i> * OR [95% CI]	<i>Trichuris trichiura</i> † OR [95% CI]	Hookworm‡ OR [95% CI]	<i>Giardia lamblia</i> § OR [95% CI]	<i>Entamoeba histolytica</i> ¶ OR [95% CI]
Letrina Abonera Seca Familiar (LASF) (<i>n</i> = 127)	15.5 [3.3–74.8]	7.1 [3.0–17.1]	0.5 [0.2–1.3]	0.4 [0.2–1.1]	0.5 [0.2–1.4]
Solar latrine (<i>n</i> = 79)	0.7 [0.1–8.2]	0.7 [0.2–1.9]	0.4 [0.1–1.3]	0.3 [0.1–1.1]	1.4 [0.5–4.2]
Pit latrine (<i>n</i> = 141)	0.9 [0.1–6.0]	0.6 [0.1–1.5]	1.4 [0.5–3.5]	0.5 [0.2–1.3]	0.8 [0.4–1.8]

Reference group = no latrine (*n* = 102). Analysis adjusted for household clustering. Model controlled for:

*Age, antihelminthic medication in the previous 3 months, having a dirt floor, and owning pigs.

†Age, antihelminthic medication in the previous 3 months, having a dirt floor, and type of water source.

‡Age, antihelminthic medication in the previous 3 months, having a dirt floor, and type of water source.

§Having a dirt floor, socioeconomic status and type of water source.

¶Overt signs of malnutrition and type of water source.

Significant odds ratios (*P* < 0.05) are shown in bold.

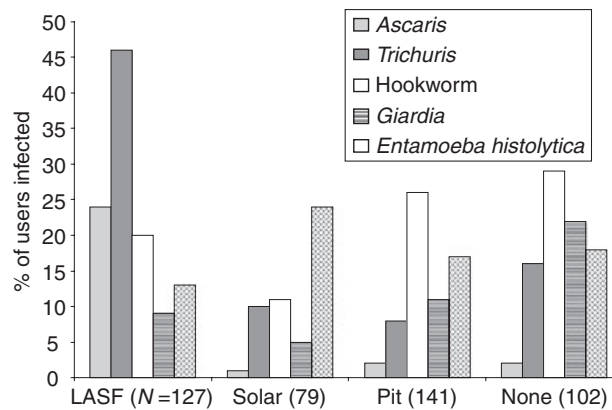


Figure 2 Prevalence of parasitic infection by latrine type.

literacy and education, SES, having had diarrhoea in the previous 2 weeks, overt signs of malnutrition, presence of dogs, cats or chickens, type of water supply and number of users per latrine.

The prevalence of helminth and protozoan infections varied by latrine type (Figure 2). Because of the multiple risk factors for these infections that were identified in the bivariate analyses, we used logistic regression to examine the association between sanitation system and parasitic infection after controlling for the effects of other potential risk factors and clustering of parasitic infection by household. LASFs appeared to be protective against hookworm, *Giardia* and *E. histolytica* when compared with having no latrine (not significant), but were associated with the highest prevalences of *Ascaris* and *Trichuris* when compared with all other sanitation systems (*Ascaris*: OR = 15.5, CI = 3.2–74.8; *Trichuris*: OR = 7.1, CI = 3.0–17.1). Solar latrine users had the lowest prevalences of *Ascaris*, hookworm and *Giardia* infection, but had the highest prevalence of *E. histolytica* infection. Pit latrines

appeared to be protective against *Trichuris* and *Giardia* infections, but had little effect on *Ascaris*, hookworm or *E. histolytica* (Table 3).

In the two LASF communities, the majority of parasitic infections was due to *Ascaris* and *Trichuris*; however, the overall prevalence was higher in Las Isletas than in La Joya (Figure 3). When each LASF community was analysed separately, the distribution of parasitic infections was similar, and the positive association between LASFs and *Ascaris* and *Trichuris* infections persisted (Las Isletas: *Ascaris*: OR = 18.2, CI = 3.9–84.9; *Trichuris*: OR = 9.5, CI = 3.8–23.6), (La Joya: *Ascaris*: OR = 7.2, CI = 0.2–220.3; *Trichuris*: OR = 2.7, CI = 0.7–10.8), although statistical power was reduced due to the small sample size. The study communities differed in several factors that can affect the prevalence of parasitic infection. Potential risk

Table 4 Comparison of *Ascaris* and *Trichuris* infection and differences in individual and household risk factors for two communities with Letrina Abonera Seca Familiar (LASF) latrines

Community variable	Las Isletas (n = 95), % (n)	La Joya (n = 32), % (n)
<i>Ascaris lumbricoides</i>	29 (28)	6 (2)
<i>Trichuris trichiura</i> *	58 (55)	13 (4)
<i>Protective factors received</i>		
Mebendazole	16 (15)	41 (13)
Piped water system	34 (32)	75 (24)
<i>Risk factors</i>		
Dirt floor	70 (67)	31 (10)
Own pigs	42 (40)	28 (9)
Lower SES	50 (48)	34 (11)
Age 6–12 years	27 (26)	12 (4)
Work in agriculture	24 (23)	6 (2)

*Differences in odds of parasitic infection between Las Isletas and La Joya were not significant for hookworm, *Giardia lamblia* or *Entamoeba histolytica*.

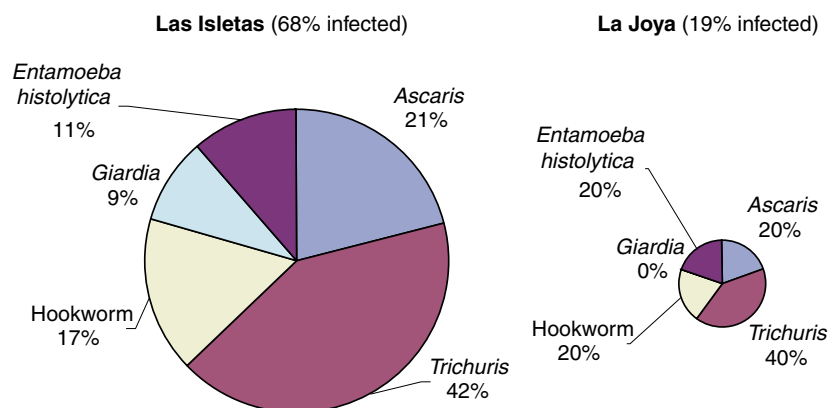


Figure 3 Distribution and prevalence of parasitic infection in two Letrina Abonera Seca Familiar communities.

Table 5 Prevalence of parasitic infection by discard method of biosolids from Letrina Abonera Seca Familiar and solar latrines, and among agricultural workers who use or do not use biosolids in the fields

Biosolids discard method	<i>Ascaris lumbricoides</i>	<i>Trichuris trichiura</i>	Hookworm	<i>Giardia lamblia</i>	<i>Entamoeba histolytica</i>
Fields (<i>n</i> = 60)					
OR [95% CI]	0.8 [0.3–2.4]	2.3 [1.1–5.1]	4.4 [1.6–12.0]	7.7 [0.9–64.3]	4.2 [1.3–13.6]
Frequency (%)	8 (13.3)	25 (41.7)	20 (33.3)	7 (11.7)	14 (23.3)
Household gardens or trees (<i>n</i> = 62)					
OR [95% CI]	1.1 [0.4–2.8]	2.0 [0.9–4.5]	0.8 [0.2–2.7]	6.2 [0.7–53.3]	2.6 [0.8–9.0]
Frequency (%)	10 (16.1)	24 (38.7)	5 (8.1)	6 (9.7)	10 (16.1)
Buried (in yard) (<i>n</i> = 59)					
OR [95% CI]	1.0 (ref.)	1.0 (ref.)	1.0 (ref.)	1.0 (ref.)	1.0 (ref.)
Frequency (%)	9 (15.3)	14 (23.7)	6 (10.2)	1 (1.7)	4 (6.8)
Agricultural workers from eco-san households where biosolids were used in fields, <i>vs.</i> agricultural workers from non-eco-san households					
From eco-san households (<i>n</i> = 20)					
OR [95% CI]	4.3 [0.3–72.1]	8.9 [3.0–26.2]	2.5 [0.9–6.7]	1.2 [0.3–4.6]	0.95 [0.2–3.7]
Frequency (%)	1 (5.0)	12 (60.0)	10 (50.0)	3 (15.0)	3 (15.0)
From non-eco-san households (<i>n</i> = 83)					
OR [95% CI]	1.0 (ref.)	1.0 (ref.)	1.0 (ref.)	1.0 (ref.)	1.0 (ref.)
Frequency (%)	1 (1.2)	12 (14.5)	24 (29.0)	11 (13.3)	13 (15.7)

factors such as having dirt floors, owning pigs, lower SES, age 6–12 years and working in agriculture were higher in Las Isletas, and protective factors, including Mebendazole distribution in schools and having a piped water system, were higher in La Joya (Table 4).

Eco-san latrines are designed to inactivate pathogens in stored biosolids and produce a safe end product for use in agriculture. In this population, where people who worked in agriculture were specifically sought out, only 29% of LASF and solar latrine users were from households that reported by using stored biosolids in agricultural fields. Thirty per cent dispersed the biosolids on household gardens or trees, and 29% buried the biosolids in their yard. The use of biosolids in agriculture was significantly associated with greater odds of infection with *Trichuris*, hookworm, *Giardia* and *E. histolytica* when compared with burying the biosolids. Dispersing biosolids in household gardens was associated with higher prevalences of *Trichuris*, *Giardia*, and *E. histolytica* (Table 5), but these increases were not significant.

When compared with members of households with pit latrines, where biosolids remain buried in pits, members of households where eco-san biosolids were buried in the yard after storage were 8.3 times more likely to be infected with *Ascaris* (CI = 2.1–31.8, $P < 0.001$), and 3.7 times more likely to be infected with *Trichuris* (CI = 1.6–8.7, $P = 0.002$). Prevalences of hookworm, *Giardia* and *E. histolytica*, however, were significantly lower for members of households who buried eco-san biosolids than for pit latrine users. This relationship was not observed for members of households where eco-san biosolids were used in agriculture or on household gardens.

Agricultural workers from households where biosolids were used in the fields (LASF or solar latrine communities) had significantly higher prevalence of *Trichuris* infection than agricultural workers from households without eco-san latrines (pit or no latrine communities) (OR = 8.9, CI = 3.0–26.2) (Table 5).

Discussion

The overall impact of sanitation on the reduction of enteric infections has been demonstrated by numerous studies (Henry 1981; Esrey *et al.* 1991; Asaolu & Ofozie 2003; Moraes & Cairncross 2004; Moraes *et al.* 2004; Traub *et al.* 2004; Fewtrell *et al.* 2005). As countries strive to meet the Millennium Development Goals to reduce by half the proportion of the global population that does not have adequate sanitation (UNICEF & WHO 2004), public and private implementing institutions and communities must make decisions about what type of sanitation systems are most suitable for the sociocultural context, economic resources and environment. The purpose of this study was to examine the impact of various dry sanitation systems on the prevalence of helminth and protozoa infections while accounting for other individual and household risk factors. More than half of the study subjects were infected with at least one type of intestinal parasite, indicating that these pathogens represent a significant health problem. The higher prevalence of *Ascaris* and *Trichuris* infections among LASF users when compared with persons with solar latrines, pit latrines or no sanitation suggests that LASFs may pose an increased risk for transmission of these helminths.

L. F. Corrales *et al.* **Sanitation design and enteric parasitosis**

Ecological sanitation aims to contain human excreta until enteric pathogens are inactivated, and then promotes recycling of nutrients in the human excreta to improve agriculture. Although the majority of excreted nitrogen and potassium are contained in urine, urine collection is not customary in this population. Biosolids contain phosphorus but primarily serve as a soil conditioner. To date, there has been insufficient research on microbial inactivation in eco-san biosolids and on the subsequent health effects associated with their use in agriculture. Our field studies in El Salvador indicate that microbial die-off in eco-san latrines depends primarily on high pH and high temperature (Moe & Izurieta 2003). Some of these latrines may not consistently achieve the conditions necessary for complete destruction of enteric pathogens and may promote pathogen persistence if they provide favourable conditions. The persistence of geohelminth ova in biosolids has been observed in other studies (Feachem *et al.* 1983, Schönning & Stenström 2004). Eco-san latrine maintenance requires periodic contact with the biosolids by the user when emptying the latrine vaults. Thus, if the enteric pathogens in the biosolids are not inactivated, eco-san latrines may pose a risk of exposure to enteric pathogens.

Survival of pathogens in latrines

In order to determine whether the eco-san latrines produced a safe end product, we previously examined ova recovery and viability in stored biosolid samples collected from LASF and solar latrines in the study communities. Viable *Ascaris* and *Trichuris* ova were detected in LASF samples that had been stored for up to 2 years, while no viable ova were recovered from solar latrines. Solar latrines generally achieved higher internal temperatures than LASFs, the key determinant of *Ascaris* destruction, and produced a safer end product than the LASFs (Moe *et al.* 2001).

The results of this study indicate that LASF and solar latrines were protective for hookworm and *Giardia*, suggesting effective containment and destruction of these less environmentally persistent pathogens. Because hookworm ova have a fine membrane that is highly sensitive to changes in temperature, humidity and pH, even slight changes in the physical environment are probably sufficient to inactivate them (Mabaso *et al.* 2003; Hotez *et al.* 2004). *Entamoeba histolytica* was not associated with any individual or household variable, suggesting that, because of its ubiquity and multiple routes of transmission, risk lies in community-level factors that were not measured in this study.

Association between the fate of stored latrine biosolids and risk of infection

In the communities where eco-san latrines were installed in El Salvador, few people worked in agriculture. Therefore, the disposal of the latrine biosolids when it was time to empty the vault presented a problem in this setting. Some households where at least one member worked in agriculture reported using biosolids in the fields. Other households discarded the biosolids around the house either in household gardens, around fruit trees, or in the river, lake or street. Others buried the biosolids in their yard. The greater prevalence of helminth infections observed among agricultural workers who had contact with biosolids in the fields compared with agricultural workers who were not exposed to biosolids points to greater contact with infectious agents where biosolids were used in the fields. This is consistent with studies from Vietnam where the use of fresh human faeces as fertilizer was associated with increased helminth infections (Humphries *et al.* 1997; Hanoi Medical Team Report 1994, unpubl. obs.).

The higher prevalence of *Trichuris* and protozoan infections among members of households who used the biosolids on household plants and trees, when compared with members of households where biosolids were buried, indicates a risk associated with the dispersal of biosolids around the home. If the biosolids are buried, human exposure and the potential for parasitic transmission are reduced. However, the act of transferring contents from the latrine vault to a pit introduces an additional opportunity for parasitic transmission if the biosolids still contain infective pathogens. This may explain the higher prevalence of the more persistent helminths (*Ascaris* and *Trichuris*) among users of eco-san latrines who buried biosolids when compared with pit latrine users. Although most *Ascaris* and *Trichuris* infection was observed among children under 12 years, the prevalence of infection for subjects from households where biosolids were buried was much higher among adults than among children (57% in adults >31 years, *vs.* 14% in children <12 years). This finding lends further support to the hypothesis that transmission is more likely to occur during emptying of the latrine (a task performed by adults), than from contact with the biosolids after they have been buried.

The results of this epidemiological study confirm the findings of our previous microbiological studies that the biosolids from some eco-san latrines still have viable helminth ova and contact may be associated with increased risk of infection.

Individual and household factors

The presence and type of dry sanitation system can influence an individual's risk of exposure and infection, but these effects are moderated by other demographic, behavioural and environmental factors.

The higher prevalence observed for *Ascaris* and *Trichuris* among children is consistent with the age distribution observed in other studies (Anderson *et al.* 1993; Smith *et al.* 2001; Traub *et al.* 2004) and most likely reflects transmission from frequent contact with peers. Children are more likely than adults to defecate in the open environment and to play in areas where excreta are dispersed, either by open defecation or by discarding latrine contents. Consistent with typical distribution patterns, hookworm prevalence was highest among young adults, although the reasons for this pattern remain unclear (Anderson *et al.* 1993; Hotez *et al.* 2004). When the age distribution of helminth infection was analysed by latrine type, the age patterns differed only for users of solar latrines, where *Ascaris*, *Trichuris* and hookworm prevalences peaked among children < 5 years of age. The higher prevalence of helminth infections among the youngest children, who generally do not use the latrines, may reflect interruption of transmission by solar latrines among those who do use the latrines.

Males may be at increased risk of hookworm infection if they work in fields where contaminated biosolids are used as fertilizer. They are also more likely to have increased contact with other pathogens through contact with contaminated biosolids when the latrine vaults are emptied, a job typically done by males.

Anthelmintic medication (Mebendazole) was distributed through most schools; however, community members estimated that fewer than 70% of school-aged children attended the school. Subjects who had taken anthelmintic medication in the previous 3 months had a lower prevalence of infection with any helminth, but protection was only significant for hookworm. Recall bias may have affected the reporting of having taken medication or the type of medication taken. Additionally, several studies have demonstrated the development of resistance to anthelmintic medications (Bennett *et al.* 2000; Geertz & Gryseels 2000; Albonico *et al.* 2005; Bethony *et al.* 2006). The low association observed between helminth infection and having taken Mebendazole in the previous 3 months may point to the development of such resistance. This underscores the importance of environmental approaches that focus on preventing exposure to parasites in addition to those that treat infection.

Dirt floors were associated with two- to threefold greater prevalences of hookworm, *Trichuris* and *Giardia* infections. Because juvenile hookworms usually infect their hosts s.c. through bare feet, having a dirt floor poses an increased risk of hookworm infection. As dirt is not a direct route of transmission for *Trichuris* or *Giardia*, the associations observed are more likely to reflect SES, where households in the lowest category usually had dirt floors, rather than brick or cement.

Pigs consume faeces and may disperse contaminated faeces on their hooves or snouts around the home and surrounding property. In the univariate analysis, there was a strong association between helminth infections and having pigs; but in the logistic regression models, the association was only significant for hookworm, suggesting that pigs are closely correlated with other factors, such as SES, working in agriculture, or the presence of small children who defecate in areas accessed by pigs. Other investigators have also observed an association between pig ownership and specific helminth infections and suggested that pigs may serve to disseminate infectious stages of human parasites and may also serve as hosts for human-derived *Ascaris* (Olsen *et al.* 2001; Traub *et al.* 2004).

Community factors

While the association between LASFs and infection with *Ascaris* and *Trichuris* existed in both LASF communities, the strength of the association was greater for subjects in Las Isletas than La Joya. Inter-community differences (Table 4) largely explain the vast differences in prevalence, and it is likely that community-specific factors other than sanitation systems contributed to the higher prevalence of infection observed in Las Isletas, or modified the impact of the intervention. Las Isletas, a peri-urban community situated on the road to the capital, was visibly more crowded and contaminated than La Joya. In contrast, La Joya is situated in a more remote and pristine environment on the banks of a lake that community members use for bathing, washing and cooking. Increased water availability may result in better hygiene, and reduce faecal-oral transmission of enteric pathogens that occur through contaminated hands and food.

Our assessment of the impact of these individual, household and community factors on the prevalence of parasite infection confirms the conclusions of other investigators: The transmission of these infections is due not only to environmental sanitation conditions, but also to the interaction of various socioeconomic and cultural factors. Parasite transmission has both a domestic component (around the household) and a public domain component

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(outside the household) (Moraes & Cairncross 2004; Moraes *et al.* 2004).

Limitations of this study

In order to reduce the confounding by factors not related to sanitation system, subjects with the same latrine type were sampled from at least two different communities, and communities were matched as closely as possible on SES and geographic features. However, the communities where eco-san latrines were installed were generally more accessible than those with pit latrines or no latrines, which tended to be more remote and had poorer living conditions. Because latrine interventions were carried out as community-wide programs, it was not possible to compare households with different latrine types in the same community, and with eight communities, adjusting the analysis for clustering at the community level was not possible.

Our ability to conduct stratified analyses was limited for certain variables by small sample sizes. Small sample size in some communities may also have accounted for large confidence intervals and inadequate power to test certain associations.

Conclusions and recommendations

Given the predicted growth of populations living in water-scarce regions and the ubiquity of helminth and protozoa infections, it is essential that a range of safe and effective dry sanitation system options are available for public health interventions in rural and urban settings in various sociocultural, environmental and climatic conditions. Previous studies that have examined the association between geohelminth infections and sanitation only assessed the impact of pit latrines, flush toilets or open defecation (Asaolu & Ofoezie 2003; Gupta *et al.* 2003; Moraes *et al.* 2004). This study is the first to compare the health impact of three different dry sanitation systems and examine both geohelminth and protozoan infections. The results of this study indicate the following:

- The use of LASF and solar latrines was associated with a lower prevalence of the less environmentally persistent pathogens, hookworm, *Giardia lamblia* and *E. histolytica*, suggesting that eco-san latrines are an effective intervention to reduce transmission of these pathogens.
- The use of LASF latrines was associated with a higher prevalence of the more environmentally persistent pathogens, *A. lumbricoides* and *T. trichiura*. Based on the patterns of infection observed here and our previous ova viability data, it is likely that these

latrines do not consistently achieve the conditions necessary for complete destruction of these organisms in the biosolids.

- The use of solar latrines was associated with lower prevalence of *A. lumbricoides*, *T. trichiura*, *G. lamblia*, and hookworm when compared with LASFs, and lower prevalence of *A. lumbricoides* and hookworm when compared with pit latrines. Based on this data, and our observations of the lack of viable helminth ova in the biosolids from the solar latrines, we recommend the promotion of solar latrines over LASFs in rural areas of El Salvador.
- Opportunities for pathogen transmission occur when an eco-san latrine vault is emptied and the biosolids are discarded or used in agriculture. In this study, burying biosolids from eco-san latrines was associated with the lowest infection prevalences. Until there are improved eco-san latrine designs that consistently destroy enteric pathogens, eco-san users should be advised to bury biosolids, and refrain from using biosolids in agriculture.
- Community characteristics, such as general contamination, water supply and soil type, may modify the effect of individual and household risk factors on the prevalence of parasitic infections. Environmental, demographic and behavioural factors will impact the effectiveness of environmental sanitation to control the spread of enteric pathogens and must be considered when planning and implementing sanitation interventions.

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L. F. Corrales *et al.* **Sanitation design and enteric parasitosis****Association entre les infections parasitaires intestinales et le type de système d'hygiène utilisé en milieu rural au Salvador**

OBJECTIF Identifier les déterminants démographiques comportementaux et environnementaux pour les infections parasitaires intestinales, évaluer les impacts d'une variété de systèmes d'hygiène d'assèchement sur les infections parasitaires intestinales et évaluer la sûreté de l'utilisation du stockage de biosolides dans l'agriculture dans le but de guider les futures interventions d'hygiène dans les zones rurales au Salvador

MÉTHODES Des interviews ont été menées dans 109 familles dans 8 communautés différentes dans lesquelles sont utilisées des latrines bi-compartmentales avec séparation de l'urine et dessiccation solaire, des latrines simples ou pas de latrines du tout. Des échantillons de selles de 499 individus ont été testés pour la détection d'helminthes et de protozoaires.

RÉSULTATS Les utilisateurs de latrines à dessiccation solaire avaient la plus faible prévalence d'infections à parasites entériques. Les latrines bi-compartmentales avec séparation de l'urine et dessiccation solaire réduisaient efficacement la transmission de certains pathogènes mais n'atteindraient pas des conditions suffisantes pour la destruction des pathogènes les plus persistants dans l'environnement tels que *A. lumbricoides* et *T. trichiura*. Le contact avec des biosolides de latrines inadéquatement traitées était associé à un risque élevé d'infection aux *Ascaris*.

CONCLUSION Les latrines solaires étaient associées avec la prévalence totale la plus basse pour les infections parasitaires entériques. Les membres des familles dans lesquelles les biosolides des latrines étaient utilisés en agriculture avaient une prévalence plus élevée d'infections par rapport à ceux des familles pour lesquels les biosolides étaient enterrés. Nous recommandons alors la promotion des latrines solaires dans les zones rurales du Salvador par rapport à tout autre système d'hygiène par assèchement et recommandons que les biosolides stockés ne soient pas utilisés en agriculture.

mots clés hygiène, hygiène écologique, latrines, géohelminthes, *Ascaris*, biosolides

Asociación entre las infecciones parasitarias intestinales y el tipo de sistema sanitario en El Salvador rural

OBJETIVO Identificar los determinantes demográficos, conductuales y ambientales de las infecciones parasitarias intestinales, evaluar el impacto de una variedad de sistemas sanitarios sobre las infecciones parasitarias intestinales y evaluar la seguridad de utilizar biosólidos almacenados en agricultura, con el fin de servir como guía para futuras intervenciones sanitarias en un área rural del El Salvador.

MÉTODOS Se llevaron a cabo encuestas en 109 hogares de 8 comunidades en donde se utilizaban o no latrinas de los siguientes tipos: letrina abonera, letrina abonera de secado solar y letrina de hoyo seco. Las muestras fecales de 499 individuos fueron examinadas en busca de helmintos y protozoos entéricos.

RESULTADOS Los usuarios de letrinas aboneras de secado solar tenían la menor prevalencia de infección entérica parasitaria. El uso de letrinas aboneras de doble cámara reducía de forma efectiva la transmisión de algunos patógenos pero podría no tener las condiciones adecuadas para la completa destrucción de aquellos patógenos ambientalmente más persistentes: *A. lumbricoides* y *T. trichiura*. El contacto con biosólidos de letrina inadecuadamente tratados estaba asociado con un mayor riesgo de infección por *Ascaris*.

CONCLUSIONES Las letrinas solares estaban asociadas con la menor prevalencia de infecciones parasitarias entéricas. Los miembros de hogares en los que se utilizaban biosólidos de letrina para la agricultura tenían una mayor prevalencia de infección que aquellos en donde los biosólidos eran enterrados. Por lo tanto, recomendamos promover el uso de letrinas solares en áreas rurales de El Salvador por encima de otros sistemas sanitarios secos, y así como el que no se utilicen los biosólidos en agricultura.

palabras clave sistemas sanitarios, sistemas sanitarios ecológicos, letrinas, geohelminths, *Ascaris*, biosólidos