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Changing environmental conditions in the Nile delta: health and policy implications with special reference to schistosomiasis

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Throughout the twentieth century, the major rural health problems in Egypt have been water-related; yet environmental strategies such as water and sanitation have not been linked to health planning. A complex of interrelated environmental changes which have occurred in the Nile delta over the past 30 years, including an increase in population and domestic water use, and changing irrigation regimes, has affected patterns of transmission of water-related diseases. These changes are examined in general, as reflected in research and policy development. Current environmental health conditions are identified in two Nile delta villages in relation to the transmission of *Schistosoma mansoni*, which is now the predominant form of schistosomiasis in the delta; problems include canal water pollution, lack of drainage facilities for sullage and sewage and the disposal of latrine effluent. We argue that integrated schistosomiasis control strategies, which include sanitation and drainage interventions and health and hygiene education, should be given greater prominence in schistosomiasis control in Egypt, where current strategies focus on a curative approach, diagnosis and treatment, and to a lesser extent on vector control through molluscicide.

Keywords: schistosomiasis; *Schistosoma mansoni*; Egypt; environment.

Introduction

Environment and rural health in Egypt

Throughout the twentieth century the major rural health problems in Egypt have been water-related. Since the 1930s, researchers have attempted to assess the importance of the provision of potable water and latrines in the transmission of schistosomiasis and other helminthic diseases. However, planners have not linked water and sanitation related strategies to health planning, even though such interventions have been shown to have a health benefit (Esrey *et al.* 1991). For example, the focus of schistosomiasis control in Egypt has remained parasitological diagnosis and treatment, supplemented by control of snail vectors through molluscicide (Farley 1991).

Environmental issues as they relate to health in the Nile delta need to be seen in a holistic, dynamic context. In this region, where there is little rain, a dense network of canals and drains support intensive irrigated farming. Complex, interrelated changes which have gathered pace over the past 30 years require a reconsideration of the environmental aspects of disease control. These changes include: an increase in population, in settlement size, and in domestic water use; the extension of piped water systems and latrines coupled with an absence of systems for the safe removal of grey water and sewage; and rising canal and groundwater levels associated, in part, with the new irrigation regime following the construction of the Aswan High Dam.

This paper examines briefly the changing environmental conditions in the Nile delta,

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and looks at current conditions through a case study of schistosomiasis in two villages in Menoufia governorate. In conclusion, the paper explores briefly the implications of the current environmental conditions for the control of schistosomiasis, which is still one of the most important rural health problems in Egypt.

Materials and methods

An interdisciplinary, participatory study of two villages in Menoufia governorate, in the Nile delta 70 km north of Cairo, was carried out between 1991 and 1994. It looked at the broad context of schistosomiasis in the village setting, involving villagers and local government employees with an interest in schistosomiasis control in the two villages (El Katsha *et al.* 1994). To facilitate a comparative study of the relationship between water and sanitation facilities and schistosomiasis transmission, both villages selected had a piped water system, but only one had a sewerage system.

A census carried out in December 1991 and January 1992 provided complete individual and household baseline data on population, occupation, housing and household amenities, and reported water use patterns. A water contact study identified and characterized the main water contact activities; 37 sites were observed during 362 full day sessions in June–July 1992.

Anthropological studies are increasingly used in order to gain a greater understanding of behavior and attitudes which relate to health (Inhorn and Brown 1990). We used anthropological techniques such as key informant interviews, focus group discussions and participant observation, to obtain qualitative in-depth information on water-related behavior, knowledge and beliefs associated with schistosomiasis, and treatment through a local health unit. In both villages, focus group discussions on water use and exposure behavior were carried out with homogeneous groups of adolescent girls (2), young married women (6), young male farmers (6), primary school age boys (2) and girls (2), and teachers (2).

Participant observation and indepth interviews focused on the household, as a social unit sharing a common residence and usually eating together and sharing a common purse. One quarter of the positive households were matched with households with no cases. In this context, the study of women and socialization patterns provided a framework for a gender sensitive understanding of water use behavior and attitudes concerning schistosomiasis. A resident team of assistants worked in each village, supported by weekly visits from members of the research team.

Twice monthly rounds of snail collecting, and quarterly water quality tests were carried out in canals in the fields and in the villages, at sites where human activities were identified and studied. A 5% pilot epidemiological study was carried out in both villages to determine the sample size in each village which would yield around 100 positive cases of schistosomiasis, considered the minimum for epidemiological analysis. On the basis of this pilot study, a random sample of 15% houses in Kom el Akhdar and 6% in El Roda was identified. Fecal specimens were examined using the kato thick smear technique. Two slides were prepared and examined for each person, and quality control was carried out in the Primary Health Laboratory at the High Institute of Public Health, in Alexandria. As the pilot study found that in both villages the prevalence of *S. haematobium* was $< 1\%$, no urine samples were collected. All positive cases were treated with praziquantel. Follow-up testing identified incidence and re-infection rates. Prior to testing, health

unit staff were trained and their subsequent performance was monitored.

The historical context of research and disease control

Early environmental health studies

In the Nile delta in the 1930s the Rockefeller Foundation supported research projects to assess the importance of water and latrine provision in improving health conditions in rural areas (Farley 1991, chap. 6). In 1933, Headlee found evidence of widespread defecation in and around a small delta village in Qalubyia; there were few household latrines and a very low level of latrine use. People depended on well water, and sometimes canal water, for drinking. Schistosomiasis prevalence rates were high, but soil helminth levels relatively low (Headlee 1933). In the Qalubyia study villages, Scott and Barlow (1938) considered that the introduction of household latrines resulted in less defecation in the village space, but had a limited impact on the control of schistosomiasis, ascariasis and hookworm because contamination occurred mainly in the fields.

Rockefeller-supported projects in 1948–1952 in five villages in Qalubyia looked at the impact of water and sanitation-related interventions on human health. However, they were unable to implement a full range of environmental interventions, such as the planned communal laundry facilities. This project became embroiled in national and international politics in the years around the change of regime in 1952. The furor focused on the presentation and interpretation of findings concerning inadequate water and sanitation conditions in both the official project report and in the press in the US. Overall, in the study villages, 31% of the households had latrines, mostly insanitary pit latrines which the researchers considered were more of a health hazard than a benefit (Weir *et al.* 1952, Farley 1991, pp. 192–200). In the worst effected villages, ascariasis prevalence was 76%. Lower ascariasis rates in one village were attributed to the provision of adequate latrines (Chandler 1954, Kuntz and Lawless 1958).

The Egypt-49 project, supported by WHO, began in four villages in Beheira governorate, south of Alexandria in the early 1960s. Farooq claimed that conditions in the delta had changed little since Headlee wrote 30 years earlier (Farooq *et al.* 1966, Farley 1991, pp. 279–284). While 62% of the population lived in houses with a latrine, fewer than one quarter of mud-brick houses had latrines. Almost 90% of the population had access to a piped water supply, principally shared standpipes; access to such a supply was found to be related to lower schistosomiasis infection rates (Farooq *et al.* 1966).

Schistosomiasis control strategies

The life cycle of the schistosome was identified in Egypt by Leiper in 1915–1917, and in 1918 treatment with antimony tartrate (tartar emetic) was found to have some effect against the disease. Thus, the scene was set for a national level treatment program by the Ministry of Health, using mobile units and the special hospital annexes needed for the 30-day treatment schedule and for monitoring the extremely unpleasant and often dangerous side-effects.

In 1949, Khalil, the doyen of Egyptian parasitologists, stated that 14 of the 20 million Egyptians had schistosomiasis and that the disease seriously affected the health of army recruits and the productivity of agricultural workers. Treatment and molluscicide were the main features of the national control program under Khalil's leadership; no water or sanitation related activities were envisaged as part of the program. Khalil preferred

molluscicide to canal clearing; he disputed Barlow's findings, in a project financed by the Rockefeller Foundation, that canal clearing got rid of snails (Barlow 1937, Khalil 1949).

The question of schistosomiasis control continued to be a politically sensitive issue. Recent research has questioned the disinterestedness of Rockefeller Foundation activities in Mexico, and thus, by implication perhaps also in Egypt (Solorzano 1992). The Rockefeller activities, and those carried out by the Egypt-49 project in the early 1960s found it difficult to make sustained improvements in water and sanitation facilities. In any case, researchers could find only limited evidence that such interventions resulted in a decline in parasitic infections in the Nile delta. They were aware that human behavior, especially changing patterns of water and latrine use, should be studied but they lacked the opportunity to pursue this issue.

During the past decade, the availability of praziquantel, a single-dose drug with minimal side-effects, has resulted in a greater emphasis on chemotherapy as a control strategy (Warren 1993). Treatment lowers egg output and hence transmission and overall infection rates. However, high reinfection rates have been noted, especially among children (Chandiwana *et al.* 1991, Gryseels *et al.* 1991). This suggests that human behavior which results in contamination of, and exposure to, water sources, needs to be more thoroughly understood and findings incorporated into health education and environmental modification strategies.

The changing rural environment in the Nile delta

Rural water supply

Since 1952, Egyptian government policy has been to upgrade the standard of living of the rural population, especially through the provision of protected, piped water supplies. From an estimated 15% of the population reported supplied with potable water in 1952, the official figure rose to 72% in 1960. By 1980, Egypt stood out among countries of a similar economic level as having a remarkably high proportion of its population with access to potable water. By 1958 private household connections began to be provided, and consumption rose rapidly as the system expanded and the number of individual connections increased; these were designed to provide 60–100 l/capita daily, compared to 40–50 l from standpipes (White and White 1986).

Between 1980 and 1991, the USAID Local Development projects devoted 35% of their block grants for rural infrastructure to extend piped water supplies in rural areas; by 1992 this had involved a total expenditure of US$125 million. Less attention was paid to maintenance, and no provision was made for drainage in newly served settlements (Nicholson 1992). There is still a wide discrepancy between the level of service provision in the larger villages and in small, scattered hamlets.

Sanitation

The relative neglect of sanitation and drainage, compared to potable water supply, was not unique to Egypt, even during the United Nations Water Supply and Sanitation Decade, 1980–1990 (Cairncross 1989). In Egypt, USAID did not support a regular drainage program. Rather, it tested the suitability of various relatively sophisticated waste water treatment technologies for Egyptian conditions: primary treatment, stabilization ponds, modified stabilization ponds, acqualife processes, extended aeration and oxidation ditches (Gemmell 1989).

Drainage and water quality

Since the early 1980s in the Nile delta several detailed consultancy studies have documented the related problem of drainage due to lack of sanitation and the rising ground water levels, and the quality of surface water and of drinking water supplies (Binnie and Taylor 1980, Warner and Donaldson 1982). In 1991, in Menoufia, where conditions were relatively favorable compared to other areas in the delta, ground water was high in mineral content, mainly iron and manganese. Waterlogging and stagnant standing water in low-lying residential areas was recognized as a serious problem in some localities, especially in winter (K-Konsult 1991).

In the long term, issues of water quality, the rationalization of water use, and water conservation, are likely to be crucial as the amount of water available for Egypt is finite. From the Nile, 55.5 billion m^3 are available annually, fixed by international agreement between all Nile basin countries; a further 2.6 billion m^3 are available from sub-surface water, and 4.6 m^3 from recycled drainage water (Egyptian Environmental Affairs Agency 1992). A serious water shortage is likely by 2010, due to rapidly growing requirements for agriculture, industry and domestic consumption (*Egyptian Gazette* 1994, p. 8).

The irrigation system

Since the mid-nineteenth century, the Nile delta has gradually been transformed from an area of seasonal irrigation to one of the perennial, year-round irrigation through the construction of a series of Nile barrages and especially the Aswan Dam, in 1909, and the Aswan High Dam, completed in 1964. Until the construction of the High Dam, all canals were empty for 40–50 days in winter; today they are usually emptied for 2–3 weeks early in January or February for cleaning, so as not to interfere with watering winter crops.

The construction of the High Dam, with higher year-round water levels and slower rates of flow, together with increasing levels of pollution from industrial and domestic waste and agricultural chemicals are thought to be responsible for the increase in *Biomphalaria* snail species (the vectors of *S. mansoni*) in the delta, at the expense of *Bulinus truncatus*, vector of *S. haematobium*. *Biomphalaria alexandrina* are generally more tolerant of low oxygen levels (O. El-Sebaie, personal communication), and favor more slowly flowing water than *Bulinus* species. The change in snail species is related to the growing predominance of *S. mansoni* in the delta (Abdel-Wahab *et al.* 1979, Abdel-Wahab 1982, Cline *et al.* 1979).

Population growth and changing living standards

Egypt's population has grown rapidly during the twentieth century, and is now approximately five times what it was 80 years ago: about 11 million in 1907 compared to approximately 55 million in 1989 (CAPMAS/UNICEF 1989, p. 17). While large cities, especially Cairo, have grown most rapidly, the population of many rural settlements has doubled in the last 30 years.

In the last 40 years living standards have increased, although this improvement has not been sustained during the last decade. New houses, two or three story buildings made of concrete and fired brick are replacing the single story mud-brick buildings. Modern houses have internal taps, latrines, showers and other modern amenities. However, few rural settlements have drainage or sewerage systems to remove the water so abundantly supplied and used. In the crowded center of these settlements, which may have 10000–

20000 residents, there is little space for septic tanks and the viability of such systems is threatened by the high water table.

Solid waste disposal

In earlier times, most waste was organic; food waste and agricultural by-products, then as now, were fed to livestock. Villagers now consume more goods which originate outside the village, and are packaged in paper or non-biodegradable plastics or tins. As few villages have solid waste collection systems, garbage is often thrown into the canals. When the canals are cleaned the debris is left on the canal bank. As the mud often contains a high proportion of garbage, especially plastic bags and rusty tin cans, it can no longer be used as a fertilizer.

Rural health

Since 1952, the densely populated delta and Nile valley has been provided with rural health units within 5 km of all residents. Over the past 40 years, health indictors have shown a marked improvement, especially for children (CAPMAS/UNICEF 1989). A Menoufia study recorded a dramatic decline in infant death rates between 1979/80 and 1990/91; the probability of dying by age five fell by 65%, and by age 1 by 55%. However, diarrhea is still the main cause of child death (Langsten and Hill 1994).

Child health gains are threatened by a deteriorating rural environment, and by falling living standards since the mid-1980s (UNICEF 1994). Trachoma is endemic in many rural communities (Miller and Lane 1988). A resurgence in lymphatic filariasis in the Nile delta and in Giza governorate, immediately south of Cairo, has been related to the increase in fecally polluted water sources which are breeding places for the vector, *Culex pipiens* (Harb *et al.* 1993, Gad *et al.* 1994, Mohamed *et al.* 1994). Fascioliasis, a liver fluke spread through contact with infected animal feces, is relatively common, but under-recorded, in the delta (Farag *et al.* 1979). In the delta, the change in the predominant schistosome species from *S. haematobium* to *S. mansoni* has serious public health implications (Cline *et al.* 1989, El Katsha and Watts 1995a).

Two villages in the Nile delta

The village setting

Like many Nile delta villages, Kom el Akhdar and El Roda are large and compact; they have populations of 7677 and 8181 respectively. In the last 30 years, the population of both villages has increased by 97%, as shown in Table 1, approximately in line with the overall Egyptian population increase. Other characteristics of the two villages, as recorded in the baseline census, are shown in Table 2.

The villages have expanded upwards and outward. The central areas remain very congested, reached by narrow, unpaved alleys which make vehicular access, such as that required for latrine emptying equipment, difficult. New style villas and apartment blocks are provided with most modern amenities. Mud-brick houses, which house one quarter of all households in Kom el Akhdar and 58% in El Roda, are often single story, with a central courtyard and adjacent animal shed.

Water supply and use

Both villages are supplied with piped water, but there is a lower coverage in El Roda than

Table 1. Population of Kom el Akhdar and El Roda

	Kom el Akhdar	*El Roda*
1991/1992 Baseline	7677	8181
1986 Census	7238	6774
1976 Census	5368	5598
1960 Census	3900	4027

Table 2. Characteristics of the study villages

	Kom el Akhdar	*El Roda*
Population	7677	8181
Mud-brick houses	25%	58%
HH with electricity	97%	90%
HH with water connection	78%	39%
HH with latrine	98%	94%
HH with sewerage system	33%	-
Solid waste collection	no	no
Health unit	no	yes
Village Council	no	no

1175 households in Kom el Akhdar, 1618 in El Roda.
Source: Complete baseline census, December 1991/January 1992.

in Kom el Akhdar, as shown in Table 2. There are no functioning standpipes in Kom el Akhdar. The three public standpipes in El Roda were closed down by the Village Council in 1991, apparently to conserve water; one was reopened in 1993 in response to pressure from local women. Where piped supplies are unavailable, shallow handpumps are used, which are more likely to be fecally contaminated, as shown in Table 7.

In the baseline census, reported behavior provided a useful preliminary guide to exposure patterns, although interviewees tend to present their behavior in a favorable light. Householders with access to water and sewerage connections reported somewhat less use of the canals for domestic activities, compared to those without access. Women living in mud-brick houses were significantly more likely to report using the canal for domestic tasks than were women living in red brick and concrete houses. Damp mud-brick houses are liable to collapse.

Participant observation and focus group discussions indicated that canal use persists even among women who knew about the dangers of schistosomiasis transmission from exposure to canal water. The women explained that for them, and especially for girls of marriageable age, meeting at the canal is an important part of daily sociability (see also El Katsha *et al.* 1989, chap. V).

Latrines and sewerage

Only a very few households in the two villages were without latrines, as shown in Table 2. Presence of latrines and reported latrine use is an unreliable guide to actual use (Fea-

chem *et al.* 1983). However, our in-depth studies found that excretion outside latrines is rare; there are no longer any concealed areas near the houses or by the canals. Occasionally excretion took place in concealed areas in the fields.

The baseline census showed that one third of all households in Kom el Akhdar had sewerage connections, and local records showed that two thirds were connected by the end of 1994. The drainage system helped to lower the water table in the village. However, the acqualife waste treatment system used in Kom el Akhdar was difficult to maintain and water quality tests in 1993 indicated that effluent quality was unsatisfactory.

According to the baseline census, 38 latrines in Kom el Akhdar and 61 in El Roda were reported to empty by pipe into the canal; in El Roda these pipes are often visible above the water line. One quarter of the latrines in Kom el Akhdar, and 65% of those in El Roda need to be emptied at some time or another. They are emptied by local contractors or by a local authority truck. However, in-depth discussions with those responsible for emptying latrines and disposing of the effluent indicated there is nowhere near the two villages to dispose safely and legally of such sewage effluent because of the intensive cultivation of village farmland, and the interlinked network of canals and drains.

Schistosomiasis

The random sample epidemiological survey showed an overall prevalence of *Schistosoma mansoni* of 8% in Kom el Akhdar, the village with the sewerage system, and 25% in El Roda. Prevalence rates are significantly higher among males than among females in both villages, as shown in Table 3. Among males, prevalence rates were notably higher among older cohorts in El Roda; the highest rates among females were found in the cohort aged 15–24 in both villages. These findings suggest differential patterns of exposure related to daily activities, especially farming for men and women, and domestic activities for women, which are supported by our in-depth study of water related behavior and its rationale; they will be discussed in a later paper.

More than three quarters of the infections, 72.5% in Kom el Akhdar and 68.7% in El Roda, were of low intensity, 100 eggs/g of feces or less, as shown in Table 4. Although higher intensity cases were rarer among females, there was no significant difference in intensity according to sex in either village.

Schistosomiasis cases were found throughout the space of the village, regardless of access to village canals. However, they were clustered in households, with 195 cases in 125 households; 149 households had no cases. This clustering can be related to common patterns of exposure behavior and knowledge in the household setting.

In both villages, villagers' levels of knowledge, and perceptions of schistosomiasis was similar. Schistosomiasis infection levels were higher in the village with a rural health unit. The rural health units have a pivotal role in schistosomiasis control in Egypt, providing free diagnosis and treatment (El Katsha and Watts 1995b).

Other infections

During pilot school testing for *S. mansoni*, other parasitic infections were identified in stool specimens. Of a total of 258 primary school children tested in November–December 1993 and in March 1994 in both villages, 33 specimens had ascaris eggs (13%), and 31 (12%) had pinworm, oxyuriasis, eggs; stool samples alone are likely to identify only about 5% of infected individuals with oxyuriasis. Technicians testing stool specimens in

Table 3. Prevalence of *S. mansoni* by age and sex, 1992

	Males			*Females*		
	No. tested	*Positive*	*%*	*No. tested*	*Positive*	*%*
Kom el Akhdar						
< 5	75	–	–	58	–	–
5–14	156	7	4.5%	140	8	5.7%
15–24	74	12	16.2	94	9	9.6
25–34	36	8	22.2	82	5	6.0
35–44	57	11	19.3	59	3	5.0
45–54	41	5	12.2	29	1	3.4
55–64	20	6	30	24	1	4.2
> 65	25	3	12	22	1	4.5
Total	484	52	10.7%	508	28	5.5%
El Roda						
< 5	42	2	4.8%	29	–	–
5–14	60	12	19.7%	85	10	11.8
15–24	30	11	36.6	32	12	37.5
25–34	31	14	45.2	37	14	37.8
35–44	27	11	40.7	24	6	25.0
45–54	8	4	50.0	13	3	23.0
55–64	12	7	58.3	12	1	8.3
> 65	5	3	60.0	6	2	33.3
Total	216	64	30.0%	238	48	20.2

Table 4. Intensity and prevalence rates, 1992

Intensity	*Males*	*Females*
Kom el Akhdar		
Low	35	23
Medium	11	4
High	6	1
Total	52	28
El Roda		
Low	45	32
Medium	11	9
High	8	7
Total	64	48

*Low < 100 eggs per gram of feces; medium 100–199; high 200 and over.

Kom el Akhdar village identified 70 cases of oxyuriasis, 51 cases of ascaris, 9 cases of fascioliasis, 14 cases of *Hymenolepis nana*, and 6 cases of amoebiasis. These data indicate the presence of fecally-transmitted infections which flourish in conditions of poor sanitation (Feachem 1984). Canal water quality tests in both villages identified the presence of *Entamoeba histolytica, Entamoeba coli* and *Giardia* cysts, indicating pollution by domestic waste water.

The impact of water and sanitation on infection

Schistosomiasis infection levels were lower in Kom el Akhdar, which has a sewerage system and a higher proportion of household water connections than El Roda. However, a study of the relationship between water and sanitation provisions and infection at the household level indicates a rather different picture. In El Roda with a lower overall proportion of household connections, there was a significant relationship between prevalence and the absence of household water; this relationship did not hold for Kom el Akhdar, as shown in Table 5. Similarly, in 1993, incidence figures, compared to those not infected in 1992 and 1993, were correlated to absence of water connections in el Roda, but not in Kom el Akhdar, as shown in Table 6.

In Kom el Akhdar there was no statistically significant relationship between the absence of household sewerage connections and prevalence; indeed the rate for cases in households without connections (25 of 382, 6.5%) was somewhat lower than for those with connections (55 of 610, 9%). These findings were similar to those for the incidence rates in 1993 compared with those who were not infected in 1992; 3.6% of incidence cases occurred in households without sewerage, and 4% in those with sewerage.

As originally intended, the sewerage system benefitted all villagers by lowering ground water levels, which helped to dry out damp houses, and contaminated stagnant ponds and muddy areas in the village. Although the sewerage system removed sewage from the immediate vicinity of the village, the treatment plant was not working satisfactorily. During the project period, a range of 3–45% removal of the biochemical oxygen demand (BOD) in the effluent shows that the plant is not efficient in treating raw sewage. The

Table 5. Prevalence of *S. mansoni* and household water connections

	With connection			*Without connection*		
	No. tested	*Positive*	*%*	*No. tested*	*Positive*	*%*
Kom el Akhdar	772	61	8.4	220	19	8.6
El Roda*	195	31	15.9	259	81	31.3

*Pearson Chi-square, $p = 0.00017$.

Table 6. Water connections and incidence, 1993

	Not infected 1992 & 1993	*Incidence 1993*	
Kom el Akhdar			
With	658	23	3.4%
Without	188	10	5.0%
El Roda*			
With	139	8	5.4%
Without	145	20	12.1%

*Pearson Chi-square, $p = 0.039$.

bacteriological quality of the effluent was similar to raw sewage, or even higher. Thus, the quality of the treated waste water discharged into a drain ½ km from the settled area was not within the limits of Law 48 of 1982 for the protection of the River Nile.

The sewerage system was originally planned to lower the water table in the village, rather than as a health-related intervention. Thus, no health education or community participation was associated with this intervention.

Water quality

Water quality tests were conducted seasonally at 10 sites in canals in Kom el Akhdar and 12 in El Roda. All samples indicated high BOD and COD throughout the year, showing high levels of sewage and other organic pollutants; at one site of domestic activity in Kom el Akhdar, fecal coliform counts ranged between 10^5 and 10^7 throughout 1993. At the most polluted sites, fecal pollution and pollution from detergents inhibited the survival of vector snails and/or *S. mansoni* cercariae. There is some evidence that agricultural chemicals sprayed on cotton during the summer find their way to canals and contribute to low snail population in summer.

The chemical analysis of the canal water for dissolved solids and hardness is lower than the level found for drinking water and private handpumps, as shown in Table 7. The level of hardness in El Roda is slightly higher than that in Kom el Akhdar, which may result in a somewhat greater use of canal water for domestic tasks in El Roda. Overall, levels of hardness are lower than in many other villages in Menoufia governorate (K-Konsult 1991, pp. 24–33). In both study villages, the quality of the piped water and that from handpumps tested is within the legal limits for drinking water.

Snail vectors of schistosomiasis

Snail numbers varied seasonally, with fewer in winter, especially after the annual canal clearing in January, and in high summer when water temperatures are high. These findings are similar to those for *Biomphalaria* elsewhere in the delta (Yousif *et al.* 1993a, b). Water hyacinth, which provides shelter for snail breeding, and food, is widespread in village canals. Any increase in the level of pollution and contamination decreases the possibility of finding live snails; snails which are found are dead.

The contrast in snail populations is likely to be related to the pollution levels and contrasting canal regimes in the two villages, this may be the most important explanation

Table 7. Average water quality of different types of water in the two villages

Village	*Kom el Akhdar*			*El Roda*		
	Canal water	*Main tank water*	*Hand pump water*	*Canal water*	*Main tank water*	*Hand pump water*
Dissolved solids (mg/l)	200–260	580	510–770	200–430	760	790–910
Hardness (mg/l)	210–280	450	360–420	230–300	380	430–520
Fecal coliform CFU/100 ml	10^2–10^5	0	0–36	10^2–10^9	0	0–91
Plate count CFU/me	10^2–10^9	300	65–3200	10^2–10^6	11×10^4	620–105

for the differences in infection rates in the two villages. In Kom el Akhdar, a lower population count is obtained as the canals, especially the largest canal in the village, the Kafr Tanbidi canal, have a higher overall rate of water flow and water level; during the irrigation cycle canals dry out for a number of days and few snails survive. In contrast, in El Roda, when canals are full and relatively slow flowing larger numbers of snails are found; the canals rarely dry out because they are all interconnected and fill rapidly. In El Roda, high pollution levels may favor the survival of *Biomphalaria* snails compared to the less tolerant *Bulinus* species. Few infected *Biomphalaria* snails were found; more were found in El Roda than in Kom el Akhdar. This was not unusual; a single infected snail can release millions of infective cercariae into the water.

Sources of fecal contamination

Canal water is contaminated in most of the sites in the village where domestic activities are carried out, at sites close to pipes which discharge sewage into the canals, and where garbage is dumped. Some sites where there is no obvious source of contamination were identified in Kom el Akhdar: this contamination may result from dumping of sewage in nearby villages.

In both villages, sources of chemical pollution and fecal contamination of canals, are, approximately in order of importance; dumping of evacuated sewage in canals and drains: sewage discharge through pipes from houses direct to canals: disposal of sullage (domestic waste water) directly into canals: disposal of solid wastes on the banks of the canal or in the water: and activities of women at the canal.

Villagers' perceptions of environmental problems

Over 90% of 226 adults surveyed in both villages considered that their villages had serious environmental problems. The villagers characterize environmental problems as associated with the disposal of septic tank effluent, solid waste, and waste water.

Older villagers claimed that the canals were used more frequently in the past, and for a very wide range of activities; people were able to use the canals because they were clean and unpolluted with garbage. As one woman said: When I was a child I drank canal water, it was sweet as milk. Villagers did, however, point out that as there was no other source of water, they took care to keep the canal clean. Some villagers also said that in the past they did not know about the health dangers of using canal water, whereas today the health dangers of using the canal, and of dumping garbage and sewage in the canal are almost universally recognized. While perceptions of conditions in the past may be idealized, the general impression is of a shared awareness of the deterioration in the village environment.

Conclusions

Environmental health problems in the Nile delta are complex and change over time. The research project was designed to explore the relationship between water supply and excreta disposal facilities and schistosomiasis transmission and prevalence. We found no clearly demonstrable link between water and sanitation connections at the household level and schistosomiasis infection. Exposure behavior such as activities at canals, contamination behavior, and health knowledge are similar in both villages, and do not appear to be modified to any great extent by water and sanitation provision at the house-

hold level. However, inadequate sanitation and drainage facilities have a village-wide impact, especially as they affect canal ecology, and thus the survival levels of host snails and cercariae. Such conditions, which we believe are widespread in the Nile delta, suggest the need for a two-fold environmental strategy combining a wide range of technologies for environmental improvement with a greater concern for the capabilities, concerns and knowledge of the end users.

A reliable and regular source of protected water is needed to provide full health benefits for settlements which have no provisions, or a low level of provision (such as El Roda with only one third of households with water connections and few standpipes). Given current conditions in the delta, sewerage/drainage systems are crucial in lowering the groundwater table and minimizing canal pollution. Egyptian engineers are currently working to identify affordable and sustainable drainage and/or sewage disposal systems, such as small bore systems linked to existing septic tanks. Cleaning canals, removing garbage, and vegetation and organic matter which provides food for snails and sheltered breeding sites, could have a marked impact on snail populations, as could the manipulation of canal regimes to maintain water flow and/or dry out canals periodically.

Villagers share a common concern about drainage and water pollution problems, and the inadequate system of disposal of latrine effluent, and know of the danger of schistosomiasis from exposure to canal water. Thus, community participation in activities related to schistosomiasis control, such as canal clearing, is feasible. The effective utilization of water and sanitation related innovations, and modifying or changing unhealthful behavior, requires health education in the community setting. It is unreasonable to expect water related behavior to change if no environmental changes are introduced, as local people can provide good reasons why they persist in canal contact activities, and find it difficult to safely dispose of latrine effluent.

The recommended approach to schistosomiasis control is preventive, rather than curative, and encourages sustainability and community participation to improve the health status of all rural people. It accords with the integrated strategies now recommended by the World Health Organization. Here, the relative importance of the various elements in the strategy – diagnosis, treatment, health education, community participation and environmental interventions – is seen to vary according to local conditions. Everywhere there is a need for community participation at all stages in planning, implementation and maintenance, and a recognition of the role of women in such activities (WHO 1993).

While many Nile delta villages share the characteristics and problems of the two study settlements, the needs, resources, and physical conditions which need to be considered in water and sanitation interventions vary from settlement to settlement. In the Nile valley south of Cairo levels of access to potable water and household latrines, and the overall rural standard of living is much lower than it is in the delta; here the balance of strategies might be different.

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