The health impact of utilization of raw domestic sewage for vegetable cultivation in the suburbs of Asmara, Eritrea, was assessed. Results showed heavy contamination of vegetables by fecal coliforms and Giardia cysts as well as other pathogenic bacteria such as Shigella and Salmonella. Stool samples from 75 occupationally exposed farmers revealed that 45% of them were harboring Giardia cysts. Dietary intake of raw greens (lettuce, cabbage) grown on the raw sewage appears to cause giardiasis, amebiasis, and diarrhea in the farming community as well as in the surrounding area. Comparison of hospital data from the affected area with data from other areas of Eritrea indicated that agricultural use of untreated wastewater was the major cause of the increase in giardiasis and other gastrointestinal diseases. **Key words:** wastewater reuse; vegetable cultivation; giardiasis; amebiasis; diarrhea.

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Eritrea, situated in east Africa, has a total area of 124,320 square kilometers and a population of about 3.5 million. Ethiopia borders it in the south, Sudan in the West, Djibouti on the southeastern flank, and the Red Sea to the east. The capital city, Asmara, is 1,700 meters above sea level with a population of about 0.5 million. Water is a scarce commodity in rural as well as in urban Eritrea. Hence, untreated urban sewage is utilized for the cultivation of vegetables, including salad greens, in the peri-urban areas of Asmara. The untreated raw sewage flows through a stream called Maibella. The wastewater is likely to contain high levels of bacteria and parasitic organisms and other pathogens, as well as toxic heavy metals.1 Studies of the health impact of wastewater usage in different parts of the world reveal various gastrointestinal problems in the farming communities involved in this practice.2–6 In addition to the risk of contamination by direct exposure, consumption of undercooked or raw vegetables also poses a risk to health.7–9

**MATERIALS AND METHODS**

**Study Area**

The study was carried out around Asmara and its suburbs. Six sampling sites were selected along the Maibella stream, which carries the sewage load of Asmara. The sampling sites were located in a 12-km segment of the stream. The total area investigated was about 100 km². The sampling sites included areas in the towns of Sembel, Bar jima, Paradizo, Adsagadu, Unagudu, and Tsadachristian.

These localities are peri-urban areas of Asmara. The main crops that are grown here are green vegetables. The vegetables cultivated using sewage constitute the only source for local consumption for the community living in the town of Tsadachristian. Predominantly leafy vegetables such as lettuce and cabbage are grown in the wastewater, but others, including tomatoes and carrots, are also grown. The total area under cultivation runs into hundreds of hectares. However, there is no accurate estimate of the total area devoted to sewage farming. The wastewater is not pretreated. Flood irrigation irrigates the crops grown with the wastewater, increasing the likelihood of heavy bacterial contamination due to direct contact of exposed parts of the plants with the wastewater.

The number of farm workers exposed to wastewater is more than 500. The socioeconomic status and
hygienic practices of the farm workers are generally poor. They live in overcrowded conditions, with an acute water shortage, no adequate sanitation, low incomes, and inadequate disposal of wastes.

**Sampling Methods**

Samples of wastewater used for irrigation and vegetables grown in the irrigated fields were collected on a weekly basis for four months (May–August 2003) from selected sampling sites. Vegetable samples were collected in clean polyethylene bags. Steps were taken to avoid soil contamination. Water samples were collected in sterilized bottles. All samples were sent to the central laboratory in Asmara for analysis within two hours of collection. Each sample was collected in triplicate for avoiding sampling error.

Stool samples from farm workers were collected in sterile containers. The farm workers were instructed through local administration how to provide the samples. The samples were collected the following morning and examined for intestinal parasites and pathogens in the Central Health Laboratory in Asmara, which is also the national reference laboratory for Eritrea.

**Analytical Procedures**

**Wastewater analysis.** A standard method\(^{10}\) was used for identification of coliforms and fecal coliforms (thermo-tolerant *E. coli*). The MPN (most probable number) technique and the filtration technique were adopted for the analysis. For presumptive tests lauryl tryptose sulfate broth was used. Incubation was carried out at 35° C for coliforms and at 44° C for thermo-tolerant fecal coliforms. MacConkey’s agar was used to isolate the pathogens. Identification of colonies was done by biochemical tests. For identification of Salmonella and Shigella, the method involving tryptone soya and selenate F enrichment was used. Suspected colonies were identified by biochemical tests and confirmed by serotyping.

**Vegetable analysis.** A wash method was adopted for microbiologic analysis of vegetable following the standard procedure of Feenstra et al.\(^{11}\) A vegetable of known weight free from soil contamination was washed with 1 liter of sterile water and the wash water was screened for fecal coliforms, *E. coli*, Salmonella, and Shigella.

**Stool examination for parasites.** To screen for intestinal parasites, direct smears were by microscopy.

**Socioeconomic and health survey.** A cross-sectional socioeconomic and health survey was carried out by administering questionnaires in Tigrinia (the local African dialect) to assess the health risks of the residents of the town of Tsadachristian. The residents of this town are mostly farmers and depend solely on the vegetables raised on farms irrigated with sewage. The health questionnaire included closed-ended questions about occupation, family size, source of drinking water, source of vegetables, intake of raw salad greens, disease pattern, etc. The questionnaire was administered at random to a target population of 20% of the population (200 households), i.e., approximately 1,000 of an estimated population of 5,025 in the town.

**RESULTS AND DISCUSSION**

The distribution of pathogenic and parasitic organisms in the vegetable samples is shown in Table 1 and the range of their distribution in the wastewater and in the vegetable samples is presented in Table 2. Heavy contamination of the vegetable samples was found at all the sampling sites. The source of the contamination is untreated sewage. Numbers of colonies of fecal coliforms, the indicator organism of sewage contamination, were severalfold higher than the WHO permissible limit (Table 2). Giardia cysts were detected in considerable amounts on samples of lettuce, tomatoes, and cabbage.

| TABLE 1. Contamination of Vegetables Grown Near the Sampling Sites with Pathogenic Bacteria and Giardia Cysts |
|---|---|---|---|---|
| No. Sampling Sites | No. Samples | Fecal Coliform Found | E. coli Found | Giardia Found |
| | | No. | % | No. | % | No. | % |
| Cabbage | 4 | 12 | 12 | 100 | 12 | 100 | 6 | 50 |
| Lettuce | 4 | 12 | 11 | 96.6 | 11 | 100 | 6 | 50 |
| Green vegetable | 4 | 12 | 12 | 100 | 11 | 100 | 3 | 25 |
| Tomatoes | 3 | 9 | 9 | 100 | 12 | 100 | 2 | 22 |
| Carrots | 3 | 9 | 6 | 66.6 | 9 | 100 | 0 | — |
| Cucumbers | 3 | 9 | 9 | 100 | 6 | 100 | 0 | — |
| **TOTAL** | 16 | 62 |

Among the intestinal parasites found, Giardia was the most significant. At least 45% of the farmers were found...
to be harboring Giardia cysts; however, other helminthic infestations were negligible, except for the presence of tapeworms in two cases. Surprisingly, no hookworms or roundworms were detected in the stool samples, although these parasites are very common in wastewater-farming communities in other parts of the world.5

The incidence of giardiasis was higher among the farmers when compared with that in the consumers in the affected area, which was found to be 7%. This result is comparable to findings in other studies carried out along similar lines in Pakistan by Feenestra et al.,12 and also elsewhere in Paris, where sewage-treatment workers were found to have a higher risk of giardiasis when compared with the general population.13

The major cause of the intestinal parasitic infestation among the farmers is very poor personal hygiene combined with frequent exposure to wastewater.

Impact of Vegetable Contamination on the Health of Consumers

Responses to the socioeconomic and health survey questionnaire revealed that the impact of contaminated vegetables cultivated along the wastewater stream is considerable, since the entire population of 5,025 residents of Tsadachristian, about 8 km west of Asmara, was solely dependent on the vegetables grown in fields irrigated with untreated wastewater. The average family size was more than seven. Approximately 60% of the heads of households were farmers. Half of the people surveyed were using groundwater for drinking, while others depended on tank water supplies from the municipalities. Raw salad greens were a common feature of the diets of the households (90%).

The local diet includes regular intake of raw salad greens, chiefly lettuce, cabbage, and tomatoes. The typical diet of the average Eritrean adult is shown in Table 4.

The majority of the population (52%) was less than 19 years old; the rest (46.9%) were adults. Complaints of diarrhea and fever predominated among both children and adults. The incidences of diarrhea were 48.9% in children and 38.8% in adults. Diarrhoea with fever was reported by 10%, and 5% had respiratory ailments or colds.

The pattern of morbidity was determined based on hospital data obtained for the affected town of...
Tsadachristian for three years (1998–2001) and compared with data from other major towns of Eritrea such as Dakamare and Keran, which have populations of more than 76,000 and 23,000, respectively. The socioeconomic conditions, diets, and nutrition conditions of the people residing in these towns are almost similar to those of Tsadachristian, and ground water is their sole source of drinking water (Figure 2). However, unlike the people who live in Tsadachristian, the residents of these two major towns are free from the impact of sewage-grown vegetables in their diets as reflected in the numbers of giardiasis cases recorded in the hospital records of these towns, which were considerably less compared with Tsadachristian (Figure 2).

Thus, in 1998–2001 the number of reported cases of giardiasis was disproportionately high in Tsadachristian, where raw salad greens and vegetables raised on untreated sewage form the basis of the regular diet.

The percentage incidences of giardiasis in Tsadachristian, two other major towns of Eritrea, and the nation are shown in Figure 3. During 1998–2000 the percentages of giardiasis in the other two towns and in the nation averaged less than 1% in adult populations, while Tsadachristian averages were 4.78–8.12% during the period of the study.

Studies elsewhere in the world suggest drinking water as a major route for Giardia infestation, but the water of the town did not contain Giardia cysts, although high coliform counts were detected in drinking water samples (Table 5). Therefore, the contribution of contamination of drinking water to giardiasis may be less significant when compared with the consumption of raw vegetables contaminated with sewage in this geographic area. Apart from giardiasis, other gastrointestinal diseases, including amebiasis and diarrhea, were found in high percentages in Tsadachristian when compared with other towns of Eritrea and the national average (Figures 4 and 5). The incidences of amebiasis and diarrhea in Tsadachristian were higher than those in Karen and Dekamare.

The vegetable samples obtained from the Tsadachristian area uniformly had very high levels of bacterial contamination, especially with fecal coliforms and E. coli (Table 2). Many strains of E. coli are pathogenic and may cause acute or chronic diarrhea. It is likely that many pathogenic bacteria responsible for diarrheal diseases in the community exposed to sewage were present in wastewater as well as in the vegetable samples but were not detected during the period of this study. Similarly, the trophozoite that causes amebiasis was not detected in the vegetable samples during this study, but it is likely that contaminated vegetables would also contribute as a major factor in the spread of amebiasis. Several epidemiologic studies conducted elsewhere in the world provide accounts of enteric infections resulting from the use of untreated wastewater in agriculture.

This is the first such report from this geographic area and, therefore, calls for urgent remedial measures in evolving strategies for health risk management. Detailed research needs to be initiated on the disinfection of vegetables as an immediate short-term measure to prevent the periodic recurrence of giardiasis, amebiasis, and acute diarrheal diseases both in consumers
and among the farming communities. Other strategies might include crop restriction and farrow irrigation to minimize direct contact of wastewater with the crops raised on the sewage farms. Pretreatment of wastewater in oxidizing ponds can be effective in the semi-arid part of this country. A comprehensive health education program should be also initiated regarding the risks involved among the farming community and the general population of the use of untreated wastewater for raising agricultural crops.

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References