Pathogenic Micro-organisms and Helminths in Sewage Products, Arabian Gulf, Country of Bahrain

OMAR M. AMIN, PHD

Abstract: Fecal and sludge samples from the Arabian Gulf country of Bahrain contained poliomyelitis and coxackie viruses, coliform bacteria, *Esherichia coli, Salmonella* spp., *Shigella sonni,* fecal streptococci, *Balantidium coli, Ascaris lumbricoides* and *Hymenolepis nana* eggs, and *Strongyloides stercoralis*. Sludge produced in the central sewage treatment plant is used for agricultural purposes and poses a threat to public health. Recommendations to reduce the potential health hazards are made. (Am J Public Health 1988; 78:314–315.)

Introduction

This report is based on the results of an investigation into the pathogenic potential of of sewage products in the island country of Bahrain during the autumn and winter of 1986–87.* Findings were compared with results of the most recent (1985) fecal sample surveys available.[1]

Methods

Of the approximately 400,000 people comprising the population of the 35 islands of Bahrain (678 kms^2) in the Arabian Gulf, most reside on the main island of Bahrain (50 by 13–26 kms). Extremes of daytime temperatures, relative humidity and rainfall are reached in winter (20°C, 83 per cent, 3.1 mm) and summer (40°C, 67 per cent, 0). A minimum of 14°C is reached in January. The population centers on the north end of the main island and on the adjacent smaller island of Muharraq are served by the Tubli Water Pollution Control Center (TWPCC) which now serves about 200,000 residents in its first phase of operation. The treatment process incorporates an extended aeration activated sludge process with tertiary treatment using dual media gravity filtration and chlorination. Raw wastewater discharged from several pumping stations at the inlet is screened, returned back to the flow, then passed through degritting facilities. The flow is then introduced into the aeration tanks, then discharged into the clarifiers for sludge settling. Settled sludge is reintroduced into aeration tanks to form activated sludge (0.4 per cent solids). Excess sludge from the clarifiers is introduced into the thickeners to form thickened sludge (4–5 per cent solids). Thickened sludge is spread over uncovered drying beds to allow for drying by evaporation. The dried sludge is collected and stockpiled in the open for later use as fertilizer. The final treated effluent is to be used for irrigation. Normally, no raw sewage is discharged into the sea.

Fecal samples from 18,064 subjects were examined at the Public Health Laboratory in 1985 using standard laboratory procedures under the direction of Dr. S.R. Dutta.

Helminth (ova, larvae and adults) and protozoan parasites were collected from activated, thickened and dried sludge samples using modified zinc sulphate flotation methods[2] by the author and assistants at the Bahraini Environmental Protection Laboratory and the TWPCC laboratory. Bacteria in dried sludge samples were analyzed by the Thames Water Authority, Reading, Berkshire, United Kingdom in July and November 1986; screening for viruses was done using the tissue culture infective dose method.** Viruses were isolated from thickened sludge at the Minnesota Veterinary Diagnostic Laboratories, College of Veterinary Medicine, St. Paul, under the direction of Dr. S.M. Goyal in January 1986.

Results and Discussion

The isolation of poliomyelitis and coxackie viruses from thickened sludge samples (Table 1) may have important public health implications depending on the age of the resulting dried sludge destined for agricultural use, moisture content, and temperature. Dried sludge was negative for viruses in samples tested after one year of storage. While occasional cases of paralytic polio are reported in Bahrain from year to year, no routine surveys to monitor its activity in the general population are done. A six-month survival time of enteric viruses in soil has been reported in considerably colder climates.[3] Infectivity of seeded polio and coxackie viruses was shown to decrease with loss of water until the solids content of the sludge reached about 80 per cent[4]; further evaporation caused a much more rapid decline in infectivity. Given the sludge exposure to sunlight and high temperatures characteristic of Bahrain, the survival time for viruses may be less than the upper limits quoted above.

Coliform bacteria, *Escherichia coli, Salmonella* spp., *Shigella sonni* and fecal streptococci were quantified from dried sludge of various ages (Table 1). The observed inverse relationship between bacterial counts and moisture content was actually a function of sludge age; moisture increased with longer storage. Moisture content of about 20 per cent was required to support growth of bacteria in raw sludge.[5,6]

The public health impact of the uncontrolled use of such contaminated dried sludge and the anticipated use of wastewater for irrigation is obvious. A twofold excess risk of enteric diseases was found in the 0 to 4-year-old age group during summer irrigation months associated with use of wastewater for irrigation compared to controls in the same Israeli kibbutz.[7]

Of the protozoans detected in the fecal samples, only *Balantidium coli* (observed in only two patients in 1985) was observed in disproportionately large numbers in activated sludge (Table 1). This discrepancy is probably caused by the ability of *B. coli* to reproduce outside the host system. How *B. coli* got into activated sludge in the first place remains unknown; its common hosts are swine and possibly monkeys, both of which are not to be found in Bahrain. The presence of *B. coli* in subsequent sludge samples was not substantiated and the chances of its possible transmission to human subjects via dried sludge is considered unlikely.

Of the helminth species reported from fecal samples of the general population, *Ascaris lumbricoides* and *Strongyloides stercoralis* were reasonably well represented in dried sludge samples (Table 1) but for different reasons. The high reproductive potential of *Ascaris lumbricoides* (200,000 eggs/day) probably contributed to the recovery of a

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Address reprint requests to Omar M. Amin, PhD, Professor of Biological Sciences, University of Wisconsin-Parkside, Box No. 2000, Kenosha, WI 53151-2000. This paper, submitted to the Journal June 19, 1987, was revised and accepted for publication September 8, 1987.

**Faber, NS, Colbourne JS, Thames Water Authority, London

TABLE 1—Analysis of Fecal and Sludge Samples for Pathogenic Micro-organisms and Helminths in Bahrain, 1985–87

Organisms Recovered	Fecal Samples No. (%) Positive	Activated Sludge Range (mean)/1 ml (N = 18,064 exam)	Thickened Sludge No. of Isolates (N = 12 samples)	Dried Sludge‡ No. or Range (mean)/gm(s)
Viruses				
Poliomyelitis type 2	(+)	(+)	2	0
Coxackie type B-5	(+)	(+)	4	0
Bacteria				
Coliform	(+)	(+)	(+)	5.4×10^3/1 gm
Escherichia coli	(+)	(+)	(+)	3.5×10^3/1 gm
	(+)	(+)	(+)	1400/50 gms (Sample 1)
	(+)	(+)	(+)	15/50 gms (Sample 2)
	(+)	(+)	(+)	fl/50 gms (Samples 3, 4)
Salmonella, Shigella	752 (4.16)†	(+)	(+)	+/50 gms (Samples 1, 2)
Fecal Streptococci	(+)	(+)	(+)	1750/50 gms (Sample 1)
	(+)	(+)	(+)	15/50 gms (Sample 2)
	(+)	(+)	(+)	9/50 gms (Sample 3)
	(+)	(+)	(+)	5/50 gms (Sample 4)
Protozoa				
Balantidium coli	±	66–528 (234)	?	—
Helminth (ova)				
Ascaris lumbricoides	1,398 (7.74)	+	+	0–48 (21)/10 gms
Hymenolepis nana	48 (0.26)	(+)	(+)	0–1 (1)/10 gms
Helminth (larvae, adults)				
Strongyloides stercoralis	109 (0.60)	+	+	0–5 (3)/10 gms

±: rare; +: observed but not quantified; (+) presumably present based on subsequent recovery in thickened or dried sludge; ?: presence not substantiated; 0: absent.

†Includes one isolate of each of *Salmonella typhi, S. paratyphi-B* and *Shigella sonni* and 749 of *Salmonella* serogroups B, C1, C2, D, E1, E2, E4, G1, G2, H, I, K.

‡Summer 1985, 1986 samples examined for viruses and bacteria: coliform and first *E. coli* samples of undetermined age; sample 1: sludge taken directly from drying beds (10% moisture); sample 2: sludge stored for 1 month (20%); sample 3: sludge stored for 6 months (50%); sample 4: sludge stored for 9 months (37%). January 1987 samples stored for 2–4 months (14%) were examined for protozoans and helminths.

considerable number of eggs in dried sludge (up to 48 eggs/10 gms). The observation of viable eggs (after incubation at 25°C for one to two weeks) obtained from our dried sludge samples and the known ability of eggs to survive in the soil and remain infective for as long as 10 years have been reported.[8,9]

The recovery of up to five *S. stercoralis* adults and/or larvae per 10 gms of dried sludge is largely attributed to the multiplication of worms in the free living state. Free living females were observed in dried sludge samples as well as from soil and shallow pools elsewhere which were sampled for other studies. The latter locations must have been contaminated by infected sewage sources. The wide dissemination of free living *S. stercoralis* beyond the range of TWPCC was clearly demonstrated on various occasions. The build-up of free living populations of *S. stercoralis* in the above settings will continue to present a permanent source of infection to humans upon contact. This also applies to dried sludge irrespective of how long it is allowed to "dry" in the moist heat of Bahrain; sludge "dried" for nine months contained 37 per cent moisture (see footnotes in Table 1).

Some sludge stored for as little as three months is hauled away to private farms for use as fertilizer and soil conditioner. The risk of transmission of enteric viruses, *Salmonella* and other pathogenic bacteria, *A. lumbricoides* and *S. stercoralis* discussed above are real. The inadequate treatment and uncontrolled distribution and use of dried sludge will aggravate the level of community infection with these diseases particularly those known to be present in significant proportions, e.g., *Salmonella* and *A. lumbricoides* (Table 1).

Our findings, considered with other reports, suggest that to reduce potential health hazards, the stockpile time should be extended to one year. However, problems with *S. stercoralis* and *A. lumbricoides* have to be closely and routinely monitored. Additional treatment of sludge is also indicated. Composting with vegetable matter could be done but "cooking" the sludge is preferred for control of helminth infections. Criteria for sludge pasteurization as currently applied in Switzerland and Germany at 70°C for 30 minutes[10] may offer a considerable margin of safety.

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