MICROBIOLOGICAL STUDIES OF ECOLOGICAL SANITATION IN EL SALVADOR

Christine L. Moe, Associate Professor, Department of International Health, Rollins School of Public Health of Emory University, 1518 Clifton Rd, Atlanta, GA 30322
Ricardo Izurieta, Research Associate, Department of International Health, Rollins School of Public Health of Emory University, 1518 Clifton Rd, Atlanta, GA 30322
Mark D. Sobsey, Professor, Department of Environmental Sciences and Engineering, University of North Carolina, Chapel Hill, NC 27599
Lana F. Cohen, Department of International Health, Rollins School of Public Health of Emory University, 1518 Clifton Rd, Atlanta, GA 30322
Steven A. Esrey, Senior Programme Officer, UNICEF, 3 UN Plaza, New York, NY 10017

Introduction

Many communities do not have the water, money and institutional capacity necessary to provide waterborne disposal of human fecal waste. Traditional pit latrines are not feasible in many areas because of high water tables, shallow bedrock or limited space. The goal of ecological sanitation is to safely treat human feces and provide a low-cost soil conditioner for use in agriculture. Double-vault urine-diverting (DVUD) toilets, and single-vault solar toilets store fecal waste for a period of time under conditions that are intended to promote thermophilic microbial decomposition (i.e., composting) or desiccation for inactivation of fecal pathogens. The treated biosolids are then removed and disposed of, or may be used for agricultural purposes. Although thousands of DVUD and solar desiccating toilets have been installed in different parts of the world, there are little scientific data on effective operation and maintenance procedures, performance characteristics, appropriate methods to monitor performance, microbial safety and agricultural value of the biosolids end product, and the risks of pathogen exposure and enteric disease associated with their use. Such data would facilitate optimum design and operation of these toilets to provide a safe, ecological, low-cost method of sanitation that minimizes the risks of enteric diseases from exposure to fecal contamination. The purpose of our study was to describe the performance characteristics, and use and maintenance practices associated with desiccating toilets in several communities in El Salvador, and to evaluate the microbiological safety of the end product. This presentation will report on the preliminary results of our study in seven communities in El Salvador, Central America.

Field Methods

We conducted a survey of 396 households with DVUD toilets and 33 households with solar toilets in six rural and one urban community in El Salvador. The toilets had been in operation for an average of 6.3 years, with a range of 1 to 18 years. The head of each household was interviewed in order to collect information on household demographics, water supply and treatment, toilet use and maintenance behaviors (such as type and amount of additives, storage time, additional treatment after removal from the vault, and use or disposal of the end product), problems with toilet use, and household knowledge and attitudes about the toilets and disease transmission. In addition, we conducted a sanitary inspection of the toilet and recorded information about design and construction, cleanliness, ventilation, and presence of additives. Finally, the vault not currently in use was opened from the top and biosolids samples were collected from the top, center and bottom of the pile using a core device. Households were asked when was the last time they used that side of the latrine in order to determine the age of the biosolids in the vault at the time of sample collection. The color and texture of each sample and the ambient temperature and temperature inside the pile were recorded at the time of sample collection.

Laboratory Methods

A series of physical and microbiological measurements were performed to assess microbial inactivation under the environmental conditions found in DVUD and solar toilets. Microbial indicators (fecal coliforms, Clostridium perfringens, somatic and male-specific coliphage) were selected as models for the survival of enteric bacterial, protozoal, helminth and viral pathogens. For each toilet, a composite sample was prepared by weight from the samples collected at the top, center and bottom of the pile. The composite sample was suspended in buffer (10% suspension) and then aliquoted for each of the physical and microbiological tests. Sample pH was measured by adding distilled water to the sample until it was possible to take a measurement with a standard pH probe. Moisture content was measured by comparing initial weight of a 10-50 gm sample of the composite sample that was put in oven at 103oC overnight and weighed the following day and weighed again until variation in the dried weight measurements was <4%. E. coli were analyzed using A1 broth and a multiple tube technique. C. perfringens were analyzed using iron milk media and a multiple tube technique. The fecal coliform and C. perfringens estimates per gram of sample were calculated using most probable number (mpn) tables. Somatic coliphage were measured as plaque forming units (pfu) on the CN 13 host, and male-specific coliphage were measured as pfu on the Famp host. An aliquot of each composite sample was archived at 4oC to test for the presence of Ascaris ova.

Results and Discussion

Household size ranged from 1 to 23 persons with a median size of 5 people. We observed a range in the construction and quality of maintenance of the DVUD toilets. The most solidly constructed toilets had brick walls, metal roof and a door. The poorest toilets had walls patched together of plastic bags or palm leaves, a partial roof and no door. Most of the toilets had concrete risers/seats, but some had fiberglass or plastic risers/seats that were manufactured locally and are more comfortable, easier to clean and include a small seat for children. Almost 80% of the toilets we surveyed had a functional urine diversion system. There was a wide range in household knowledge, attitudes and practice associated with the DVUD toilets. A variety of additives were used in these systems: 80% of the households reported that they added ash, 65%

added lime, 12% added soil and 11% added sawdust to the toilets. Some households used more than one additive. Households reported using a single side of the toilet for 1 month up to 5 years. Most families used each vault for about 1 year before switching to the other side. The storage time for the biosolids we collected ranged from less than 1 month to more than 1 year according to the report of the household. About 50% of the households reported that they believed the end product to be safe by the time the vault was emptied, and only 12 households reported additional treatment of the end product after it was removed from the vault. One third of the study households reported that the end product was buried. An additional 13% reported that they used the end product for agricultural purposes around their house, and 1% of the households reported that they gave the end product to another user. Overall satisfaction with the DVUD toilet was good with 79% of households surveyed reporting that they were moderately to very satisfied with the system. Few households remembered receiving health education at the time the DVUD toilets were built as part of a community intervention.

The temperature of the stored biosolids ranged from 20-37.5oC with a mean of 27.2oC. These results indicate that these toilets are not "true" composting systems because they do not achieve the high internal temperatures (>50oC) typical of aerobic composting. The pH of the samples ranged from 5.1 to 12.8 with a mean of 9. The % solids was calculated as the dried weight divided by the initial weight. We observed a wide range in the % solids of the samples (2 - 98%, mean = 52%).

Microbial inactivation in these systems is expected to be a function of the temperature, pH and moisture content in the pile and length of storage time. High temperature, high pH and low moisture content will promote increased die-off of the microbial pathogens in excreta by physical and chemical processes. The range of physical conditions we observed in the field may explain the wide range in the microbiology results from the DVUD biosolids samples. Fecal coliform estimates ranged from undetectable levels (<2) to >1.6x107 mpn per gram of sample with a geometric mean of 58 mpn per gram. C. perfringens estimates ranged from undetectable levels (<2) to >1.6x107 mpn per gram of sample with a geometric mean of 9.6x103 mpn per gram. C. perfringens is a hardy, spore-forming anaerobe that may indicate the persistence of protozoa cysts and oocysts and helminth ova in the environment. Coliphage are indicators of the survival of enteric viral pathogens. Somatic coliphage concentrations ranged from undetectable levels (<5 pfu per gram) to 1.0x108 pfu per gram of sample, with a geometric mean of 51 pfu. Male-specific coliphage concentrations ranged from undetectable levels (<5 pfu per gram) to 1.3 x104 pfu per gram of sample, with a geometric mean of 5.8.

Further analyses examining the relationship between the physical conditions of the DVUD toilets, the reported operating practices and the concentrations of microbial indicators will be presented at the conference.

Summary

We observed a wide range in the quality and performance of DVUD and solar toilets in seven communities in El Salvador. Some of the toilets achieved conditions that promoted microbial inactivation and produced biosolids with low or no detectable levels of microbial indicator organisms. Other toilets were not functioning properly. Less than 20% of study households used the biosolids end product for agriculture. No single physical factor (pH, temp, moisture content, storage time) could predict microbial indicator concentration, suggesting that microbial quality is a function of multiple factors. Further research is needed to identify and understand the determinants of successful DVUD and solar toilet operation and the health education initiatives that are necessary to sustain successful operation in rural and urban areas.