Vertical Dispersal of Fecal Coliforms in Scranton Fine Sand

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ABSTRACT

A study was conducted to examine the extent of vertical dispersal of fecal coliforms when animal waste slurry percolates through Scranton fine sand, and the possibility of groundwater contamination as a result of such dispersal. Fresh cow manure slurry having an average coliform index of $2.4 \times 10^5$ cells/ml was allowed to percolate through a soil column lysimeter to groundwater table depths. The soil was obtained from a field adjacent to plots receiving this wastewater by sprinkler irrigation. Soil solutions were aseptically sampled at various depths within the columns after two weeks' dosing and were analyzed for fecal coliforms. Ninety percent removal of fecal coliforms from the slurry was accomplished by percolation in the first 13 cm of soil. Fecal coliforms could not be detected in the percolating slurry at a 48 cm depth in the soil. Under these conditions, groundwater could become bacteriologically polluted if it rose to a depth of 38 cm. Calculated values indicate that this could have been the case on at least 8 occasions during the period of March through July, 1972.

Additional Key Words for Indexing: Coliform index, percolation, groundwater contamination.

There is a national trend for large dairy cattle herds to be confined on minimum land areas near cities. The proper disposal of wastes produced by these herds is a growing problem since insufficient information is available about adequate treatment processes applicable to these large volumes of animal waste.

Land application as a means of disposal of animal wastes in Florida is being examined at the University of Florida Dairy Research Unit, located at Hague, Florida. Manure and washwater from approximately 170 cows is removed from a holding pen, collected, and used in the form of a slurry to irrigate forage crops (13). In this system, the nutrients are mineralized, assimilated by plants, and recycled as forage feed.

The downward dispersal of fecal bacteria with percolating wastewaters has been of serious concern since it may result in groundwater contamination by bacterial pathogens. A potential for bacterial contamination of groundwater exists in certain locations in Florida where the soil is well drained and the water table is high.

It is necessary to know the behavior of coliforms in soil, and soil-contaminated water, if they are to be used as the indicator of fecal pollution (16). The presence of coliform bacteria in undisturbed soil is disputed (12). Geldreich et al. (8) distinguished between coliforms of fecal origin (IMVGC series $+$ $+$ $+$ $+$) and soil origin ($-$ $+$ $+$ $+$). They emphasized the importance of recognizing this distinction when coliforms are used as an index of fecal contamination.

All evidence to date indicates that percolation through soil removes bacteria of fecal origin (4, 11). Coliforms below the 1.5-5.0 m depth have been observed but they are usually of soil origin rather than fecal origin (3). The extent of lateral movement by microorganisms in groundwater is poorly understood (9). Field studies using reed canary grass that had been irrigated with sewage effluent during the growing season indicated that percolation through the soil to a 1.2 m depth reduced the coliform index from 10 million per 100 ml to less than 10 per 100 ml and in most tests to less than 10 organisms per 100 ml (4).

Coliforms have appeared at a 1.2 m depth in the soil solution of California soils after three to eight months application of primary settled municipal sewage effluent (4). The effective particle size of the soil exerted an influence on the migration of the bacteria.
A "bacteriologically safe water," defined by the U. S. Public Health Service standards for drinking water as no more than 1 coliform in 100 ml (15), was produced by percolating settled sewage or final effluent through at least 1.2 m of Hanford fine sandy loam (4).

Several percolation studies have been conducted using lysimeters (4, 11). In one study, soil types of differing effective particle size received primary settled effluent within lysimeters (4). The examination of percolated effluents showed that the removal of coliforms by soil of a relatively large effective particle size was much less than that of finer soil, presumably due to less adsorption by less surface area and larger soil pore size. This study defined the problem associated with percolation of fecal contaminated wastewaters more clearly by demonstrating that different soils have different capacities to remove bacteria. There was no correlation between the infiltration rates of various soils and the corresponding removal of bacteria by the soil. A 1,000 fold reduction in coliforms occurred within the first 0.5 cm of topsoil, but at lower levels, Escherichia coli accumulated and reached a peak at a depth of 29 cm. The potential for groundwater pollution in contaminated soil due to a rising water table was suggested (4). In another lysimeter study (11), it was found that die-out of coliforms occurred at the manure crust of Miami silty loam receiving manure slurries. However, coliform populations at a 5 cm depth were greater than the populations applied. A 96% removal of coliforms within the first 35 cm was reported.

Removal of coliforms having a population size of 10⁶ per ml was achieved by percolating the bacteria through 20 cm of Miami silty loam in a 1.2 m column lysimeter (11). A 99% reduction in numbers of coliforms was achieved by percolating the bacteria through 61 cm of sand in a similar lysimeter. No background contamination before deliberate dosing was reported.

This study examined the extent of downward dispersal of fecal coliforms when cow manure slurry was percolated through Scranton fine sand (Mollis Pamm-aquert), and the possibility of groundwater contamination resulting from such dispersal. An attempt was made to define the minimum safe distance between the soil surface and the water table following 2 weeks of simulated irrigation.

**EXPERIMENTAL METHODS**

A 91 cm plexiglass column lysimeter, 8 cm in diameter, was used to study removal of coliforms from cow manure slurry percolating through sandy soil to groundwater table depth (Fig. 1). The column was packed with Scranton fine sand obtained from a field adjacent to forage crops receiving cow manure slurry at the Dairy Research Unit. Deionized water was added to the packed column to saturate the soil. Soil solutions were then withdrawn from various depths throughout the sampling apparatus illustrated in Fig. 2 using disposable 2.5 ml syringes and No. 19 gauge needles. Brass wire mesh with a 0.5 mm pore size overlapping the open end of the glass sampling tubes prevented clogging of the orifice with soil during sampling. Number 2 rubber stoppers held the glass tubing in place on the column.

Fecal coliform populations in soil were determined by the 3-tube most probable number technique (1)

followed by confirmation on Eosine Methylene Blue agar (Difco) (8).

The first experiment was designed to determine the extent of vertical dispersal of fecal coliforms with percolating cow manure slurry. Soil solutions at various depths within the lysimeter were sampled and analyzed for background fecal coliform contamination. The column lysimeter then was allowed to drain. Fresh cow manure slurry was applied at an irrigation rate of 290 ml per week. This is equivalent to 5 cm of irrigation per week. An aliquot of the fresh slurry was sampled and analyzed for its coliform index. After two weeks, solutions were sampled from various depths and analyzed for fecal coliforms.

The second experiment was designed to determine the potential for groundwater pollution in contaminated soil due to a rise in the water table. The remaining waste water within the lysimeter was allowed to drain. Then the soil was sampled aseptically at various depths through the portholes with a surface sterilized spatula. The fecal coliform populations of these soil samples were determined and expressed on an oven-dried soil basis.

**RESULTS AND DISCUSSION**

The Florida Air and Water Pollution Control Commission (14) declared that the presence of coliforms in excess of 1,000 organisms per 100 ml is harmful to state waters prescribed for use as Class I Waters—public water supply. Water within this class may be
withdrawn for treatment and distributed as a potable supply. The presence of coliforms in excess of the above value is "deemed to be prima facie evidence of pollution of the waters of the State of Florida and the same is expressly prohibited" (14). This value has recently been justified by Geldreich and Borden (7) who examined the relationship of occurrence of fecal coliforms and Salmonella. The occurrence of Salmonella in water was 62.5% when the value of fecal coliforms was under 1,000 per 100 ml; the occurrence was 93.8% when the fecal coliform value was above 1,000 per 100 ml (17).

Populations of fecal coliforms at various depths in the soil column beneath a percolation trench and cow manure slurry are shown in Table 1. Background numbers of fecal coliforms in the soil before slurry dosing were less than 3 cells per gram and therefore were not incorporated into correction calculations.

Ninety percent removal (from 2.4 x 10^7 cells/ml in the slurry to 2.4 x 10^5 cells/ml in the percolate) of fecal coliforms was accomplished in the first 15 cm of soil. Fecal coliforms could not be detected in the percolating slurry at a 48 cm depth in the soil solution.

Multiplication of fecal organisms within the groundwater has not been ruled out. Multiplication of Enterobacter aerogenes occurred in stormwater that had a BOD of approximately 1 mg per liter (6). A BOD of 5 mg per liter was obtained from the bottom percolate of this same lysimeter (5).

Numbers of fecal coliforms in the soil after draining were examined to determine the potential for contaminating a rising groundwater table. The population of fecal coliforms at 5 cm below the soil surface was greater than the population in the slurry (Table 1). This increase was not as extensive as that reported in California (4). The numbers were similar in soil solution samples at depths below 48 cm. According to these data, groundwater could become polluted from a legal standpoint in terms of its bacteriological quality if it rose to a depth of 38 cm. This would be the minimum safe distance between the soil surface and the water table. Assuming a prerainfall groundwater table depth of 76 cm, a rise in the groundwater table of 38 cm could be caused by 3.2 cm of rainfall. This calculation is based on the finding that 2.5 cm of rainfall will raise the groundwater table 30.5 cm in this soil (13). Daily rainfall data were collected from 2 different locations within the Gainesville area by the Department of Environmental Engineering Sciences.

### TABLE 1—VERTICAL DISPERAL OF FECAL COLIFORMS THROUGH SCRANTON FINE SAND IN A CYLINDER LYSIMETER RECEIVING COW MANURE SLURRY.*

<table>
<thead>
<tr>
<th>Depth of sampling (cm)</th>
<th>Fecal coliform populations</th>
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<tr>
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<td>Background contamination</td>
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<td>58</td>
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*Fecal coliform population of fresh slurry = 2,400/cell/ml.

Original data in Table 1 did not scan properly. Data are as follows (Sampling depth (cm); background coliforms/cells/ml; coliforms in soil solution cells/ml; and coliforms in soil cells/g): [at 0 depth: <3, 240,000, <3], [at 3 cm depth: <3, 110,000, 350,000], [at 13 cm depth: <3, 24,000, 28,000]; [at 28 cm depth: <3, 4,300, 5,200]; [at 38 cm depth: <3, 1,500, 2,500]; [at 48 cm depth: <3, <3, <3]; [at 58 cm depth: <3, <3, <3]; [at 93 cm depth: <3, <3, <3].

and Agronomy. Daily rainfall values at both locations were greater than 3.2 cm on at least 8 occasions during a 5 month period (from March through July, 1972). These data suggest that on at least 8 occasions during this period the groundwater was below Class 1 quality standards.

Underground dispersal of bacterial pollutants with percolating slurry is important in wastewater renovation systems. This study, using a soil lysimeter, indicated that fecal bacteria do disperse downward with percolating slurry. Frequent irrigation of Scranton fine sand with raw slurry may lead to groundwater contamination when the groundwater table lies within 76 cm of the soil surface.

The high coliform index of the mature slurry implies a risk for farm laborers employed in handling these wastewaters and any vegetation that has encountered these wastewaters. Enteric pathogens sprayed onto vegetation may survive and infect animals grazing on the contaminated vegetation. This problem was recognized as a result of the occurrence of a salmonellosis outbreak in a dairy herd that had been grazing on pasture which had been sprayed three weeks previously with a slurry of farm wastewaters (10).

Agriculturists are attempting to treat and renovate contaminated wastewaters as a part of their commitment to maintain a quality environment. Effective treatments may be possible due to the ability of soil to improve the bacteriological quality of percolating wastewaters. Results of this study demonstrated a possibility of groundwater contamination by applied agricultural wastewaters. Sound recommendations can be based on these results. If the groundwater serves as a source of drinking water for the farm community, it should be properly chlorinated to insure freedom from enteric pathogens. A chlorine residual of 1.3 mg per liter after 15 minutes should be satisfactory (2). If the pH of the groundwater is higher than 7.0 and the temperature lower than 20°C, additional chlorine or contact time may be required. Periodic bacteriological surveillance of the drinking water should be a required part of any renovation program.

Babbitt and Baumann (2) recommended that underdrains be used to collect percolating wastewaters and divert them from entering groundwater if the groundwater table lies within 1.2 m from the surface. Problems involving clogging of underdrains may make this method unsatisfactory in certain locations in Florida depending on soil properties.

Experimental facilities may be used in the future to investigate the feasibility of incorporating the wastewater slurry into a large holding tank to allow an extended thermophilic anaerobic digestion prior to application on the land. This may reduce the risk of spreading enteric pathogens in a way analogous to the anaerobic digester of conventional sewage treatment plants.

Our studies on a pilot scale irrigation system show that vertical dispersal of fecal bacteria is a problem which should be considered and controlled in the design and operation of a waste treatment process involving sprinkler irrigation on land.

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LITERATURE CITED