Evaluation of Porcelain Cup Soil Water Samplers for Bacteriological Sampling

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The validity of obtaining soil water for fecal coliform analyses by porcelain cup soil water samplers was examined. Numbers from samples of manure slurry drawn through porcelain cups were reduced 100- to 10,000,000-fold compared to numbers obtained from the external manure slurry, and 65% of the cups yielded coliform-free samples. Fecal coliforms adsorbed to cups apparently were released, thus influencing the counts of subsequent samples. Fecal coliforms persisted in soil water samplers buried in soil and thus could significantly influence the coliform counts of water samples obtained a month later. These studies indicate that porcelain cup soil water samplers do not yield valid water samples for fecal coliform analyses.

The survival and subsequent downward dispersal of fecal organisms applied to soil in raw manure slurry have recently been quantitatively described (2, 3). These findings indicated a high potential for groundwater contamination in areas where excessive numbers of fecal bacteria were applied to a well-drained sandy soil having a high water table. During the course of these studies, the use of porcelain cup soil water samplers placed in the soil at various depths to obtain underground water samples for coliform analyses was suggested. These samplers have previously been used to collect water samples for coliform analyses elsewhere (4, 5).

The purpose of this study was to determine if soil water samplers (1900-A, Soil Moisture Equipment Corp., Santa Barbara, Calif.) could be used to obtain valid water samples for fecal coliform analyses. A sampler consisted of a plastic tube terminating in a round-bottom, porous porcelain cup with a wall thickness of 0.24 cm and a pore size of 3 to 8 μm (Fig. 1).

Fresh cow manure slurry was obtained from a cement holding tank 30 min before it was to be applied on land as previously described (3). Settleable solids were allowed to separate for 1 h. The suspended solids were decanted and used as the source of fecal coliforms. Twenty soil water samplers were steamed for 10 min at 100 C, cooled to room temperature, and submerged in beakers containing decanted slurry. Ten samplers were connected simultaneously to a manifold, and a vacuum of 100 mm was applied to each sampler for 20 min until an approximate 200-ml sample was obtained. The fecal coliform numbers of these samples and the external slurry before applying suction were determined by the three-tube most-probable-number (MPN) and membrane filter (MF) techniques (1). Fresh slurry was added to the beakers when necessary.

After samples were removed from the samplers, the outer walls of the cups were scrubbed with steel wool, rinsed, and submerged in 2-liter beakers containing sterile deionized water. Samples (200 ml) were obtained and treated as before to determine fecal coliform numbers.

The cup conductance $K_{cp}$, a measure of the volume of water passing through the cup wall per unit of time per unit of pressure difference (ml/min/atm), was determined for each acid-washed sampler, in triplicate, by the method of Richards (6). The samplers were acid-washed to remove organic matter in the pores.

Fifty milliliters of sterile deionized water or fresh slurry containing $7 \times 10^7$ fecal coliforms (MPN) was added to each of two steamed and cooled samplers. The four samplers were stoppered and buried with the cups at a 30-cm depth in Arrendondo fine sand (Grossarenic Paleudalf). After 33 days, the samplers were withdrawn and the outer porcelain walls were cleaned with steel wool. The samplers were then submerged in sterile deionized water. A vacuum was applied to obtain 200-ml samples, and the fecal coliform numbers of the samples were determined.

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residual coliforms carried over in the water samples. These results indicated that the retention of fecal coliforms in the cups may significantly influence (at \( \alpha = 0.01 \) level) the counts of subsequent samples by the apparent desorption of fecal coliforms on or in the cups. Although the water outside the cups was sterile, samples obtained from four samplers yielded sufficient numbers of coliforms (>1,000 total coliforms/100 ml) to reject the water for use as "class 1 waters" (withdrawn for treatment and distributed as a potable supply) in Florida (7). There appeared to be an equal probability (0.2) that the residual MPN value may be either greater or less than the MPN value from the previous sampling.

If there were a constant level of reduction in fecal coliform numbers as the slurry passed through each cup, a simple conversion factor compensating for this constant loss might increase the usefulness of the samplers. On the contrary, the recovery of fecal coliforms (MPN) exhibited large variations from cup to cup. The estimate of the standard deviation (SD) among cups based on 20 samples (column 2, Table 1) was approximately 770 cells/100 ml. This could be an underestimate since the MPN values >2,400 (cups 14 and 18) were taken as 2,400 in calculating the estimate of 770. This SD value was sufficiently large to indicate that a simple conversion factor compensating for loss during suction would be unreliable.

The averages of triplicate \( K_{20} \) values for each sampler (column 6, Table 1) indicated no evidence of a correlation between cup conductance and the recovery of fecal coliforms inside the cups. The standard deviation of the \( K_{20} \) value (0.858) was greater than \( \frac{1}{2} \) of the mean (1.505) for the 20 cups. This wide variation in cup conductance represented an undesirable characteristic of variable water-flow rates from cup to cup.

Fecal coliforms retained in the samplers persisted and significantly influenced the coliform counts of water samples obtained 33 days later. Approximately 1% of the viable fecal coliforms applied were recovered after this period (8.6 \( \times 10^9 \) cells recovered from 7.0 \( \times 10^7 \) cells inoculated). Fecal coliforms were not recovered from uninoculated samplers, so the soil surrounding the cups did not contribute fecal coliforms to the analyses.

A 99% reduction in numbers of fecal coliforms in a Scranton fine sand (Mollis Psammaquent) occurred within 14 days (3). The data suggested that mortality of fecal coliforms was more rapid in this soil than in the cups. Apparently, the cups protected the fecal coliforms from the soil environment.

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**FIG. 1. Soil water sampler.**

**TABLE 1. Cup conductance and fecal coliform counts after passing cow manure slurry (minus settleable solids) through porcelain cups**

| Cup no. | Counts of samples inside (cells/100 ml) | Residual counts (cells/100 ml) | Cup conductance \( (K_{20}) \) (ml/min atm) |
|---------|----------------------------------------|--------------------------------|---------------------------------|
|         | MPN  | MF  | MPN  | MF  |                      |
| 1       | 23   | 10  | <3   | <1  | 1.382                |
| 2       | <3   | <1  | ≥2,400 | 1,880 | 2.212               |
| 3       | <3   | <1  | ≥2,400 | 1,590 | 1.037               |
| 4       | <3   | <1  | <3   | <1  | 2.212                |
| 5       | <3   | <1  | <3   | <1  | 1.277                |
| 6       | <3   | <1  | <3   | <1  | 0.638                |
| 7       | <3   | <1  | 460  | 707  | 0.948                |
| 8       | <3   | <1  | <3   | <1  | 1.507                |
| 9       | 93   | 1,200 | ≥2,400 | 2,050 | 0.342               |
| 10      | 460  | 1,600 | 460  | 65   | 0.949                |
| 11      | <3   | <1  | <3   | <1  | 1.507                |
| 12      | 1,100 | 3,290 | 1,100 | 412  | 0.771                |
| 13      | <3   | <1  | <3   | <1  | 1.954                |
| 14      | ≥2,400 | 18,300 | 460  | 435  | 1.326                |
| 15      | 1,100 | 796  | 43   | 27   | 2.071                |
| 16      | <3   | <1  | <3   | <1  | 1.005                |
| 17      | <3   | <1  | <3   | <1  | 3.687                |
| 18      | ≥2,400 | 128,000 | 240  | 233  | 3.311                |
| 19      | <3   | <1  | <3   | <1  | 0.810                |
| 20      | <3   | <1  | <3   | <1  | 1.145                |

The fecal coliform numbers in fresh slurry were \( 2.4 \times 10^6 \) cells/100 ml and \( 1.1 \times 10^7 \) cells/100 ml as determined by the MPN and MF techniques, respectively. The counts obtained from suction samples are shown in Table 1. None of the fecal coliform counts obtained from suction samples were representative of the counts in the slurry (columns 2 and 3, Table 1). A 100- to 10,000,000-fold reduction in numbers of fecal coliforms was observed, depending on the sampler. Fecal coliforms could not be detected in 65% of the samples. In all cases, fecal coliforms detected by the MPN method were also detected by the MF method. The results of a statistical test indicated that most of the MPN values of the samples were significantly lower (at \( \alpha = 0.01 \) level) than the corresponding estimated value outside the cups. It is evident that loss of organisms occurred during passage through the cups.

The fecal coliform counts of the 200-ml samples obtained after transfer of cups to sterile water are presented in columns 4 and 5 of Table 1. Among the 20 cups, 9 (45%) contained...
Microbiological surveillance should be an important component of all experimental waste water renovation programs. Land application is currently an attractive alternative to the discharge of sewage effluent and animal wastes into surface waters. Results of this study indicated that soil water samplers with porous cups should not be used to obtain soil water samples for fecal coliform analyses.

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