Potential health hazard from human wastes in wilderness

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ABSTRACT: Shallow burial of feces, recommended to backcountry recreationists, does not result in quick destruction of intestinal pathogens. Samples of feces inoculated with two bacteria, Escherichia coli *and* Salmonella typhimurium, *were buried at two depths at four sites in Montana's Bridger Range. Both bacteria survived in large numbers during the summer and fall.* Salmonella *persisted over winter at all sites;* Escherichia *persisted at some sites. Depth of burial had no effect on persistence, and differences among sites were minor. Management implications are discussed.*

NO data exist with which to estimate the potential health hazard from shallow burial of human feces, a recommended practice, in wilderness areas, particularly areas where recreation is concentrated (*1*). There have been many studies on the survival of intestinal bacteria, including some virulent pathogens, in soil (*8*). But most such studies involve procedures that depart radically from the simple burial of feces as commonly practiced in wilderness areas.

The frequent advice given to wilderness visitors to use shallow, individual burial (the "cat-hole" method) is based on untested assumptions of soil ecology. Under good composting conditions, feces mixed with soil promotes rapid growth of soil microbes (*2, 7*), and alien organisms disappear over time. However, a buried fecal specimen, in contact with soil but not mixed with it, does not represent an ideal composting situation. Many wilderness soils also differ markedly in their microbial populations from the agricultural soils frequently used in tests (*8*).

We tested the survival of two intestinal bacteria in an actual fecal sample buried under conditions approximating actual soil disposal but which would allow us to retrieve the entire sample and count the bacteria. The procedure allowed us to count the bacteria in the presence of the normal fecal microbes. Our tests were conducted at several elevations where field conditions resemble those of many wilderness areas in the northern Rockies. Tests were run during two summers and one winter. Reported here are the results of these tests during the second summer and the following winter, a sample burial time of nearly 51 weeks.

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Study area

Our study sites were located in the Bridger Range north of Bozeman, Montana—a mountain environment similar to much of the wilderness in the northern Rockies but close to the lab so that samples could be dug up, returned to the lab, and counting begun in a single day. Descriptions of all but site 6, a new site, and preliminary results were reported elsewhere (*8*).

Four of the six sites representing extremes in elevation and vegetation differences were selected for the final study. Site 1 was at 2,730 meters (8,960 feet) on a saddle between two peaks, with extreme exposure and a nearly continuous mat of dwarf forbs. The soil was a sandy loam (pH 6.97). Site 4, at 2,377 meters (7,800 feet), was in a spruce-fir forest on a dry-limestone site. Samples were buried in duff (pH 5.17). Site 5 was in a steep meadow at 2,005 meters (6,580 feet), with a very mixed flora on a loam (pH 5.35). Site 6 was located at 1,880 meters (6,160 feet) in a small meadow on a damp alluvial terrace with scattered subalpine fir. The soil was a deep loam (pH 5.84). The predominant native plant species at site 6 were *Agrostis* and *Bromus*. There was considerable *Phleum pratensis* also, which is not native. Other common plants included *Carex*, *Geranium*, *Rudbeckia*, *Achillea*, *Potentilla*, *Delphineum*, *Galium*, *Heracleum*, *Mertensia*, and *Fragaria*.

Study methods

We followed the survival of two intestinal bacteria in a sample of feces buried in soil at each site. Each sample was prepared by making a slurry of feces in water, inoculating that slurry with known large numbers of each bacterium, and then sandwiching a portion of this fecal slurry between two layers of soil in a plastic cup. The soil came from the particular burial site. The cups were perforated to allow movement of water, microbes, and small soil organisms.

One bacterium was a strain of *Escherichia coli* that had been genetically altered to grow in the presence of streptomycin and nalidixic acid. This permitted it to be distinguished from *E. coli* normally present in feces. The other bacterium was *Salmonella typhimurium*, which was not present in the feces sample before inoculation. *S. typhimurium* belongs to a genus that frequently causes intestinal infections.

Samples were refrigerated up to two days before burial but were prepared and buried as quickly as possible. Forty-eight plastic cups were buried at each site, half at a depth of 5 centimeters (1.97 inch), the other half at a depth of 20 centimeters (7.87 inch), measured to the top of the cup. Three cups were retrieved from each depth at weekly or biweekly intervals over a period of eight weeks. One set was left over winter, from July 23, 1980, to July 13, 1981—nearly 51 weeks. The samples were plated on appropriate microbiological counting agar on the same day they were dug up. Results were expressed as the number of each bacterium per gram of original feces. Each figure is the average of duplicate counts on each of three replicate sample cups (6 counts).

Details of our experimental procedure have been published elsewhere (*8*).

Discussion of results

Tables 1 and 2 present survival data for *E. coli* and *S. typhimurium*. The results were disappointing in every respect:

- Bacterial numbers remained on a plateau for several weeks during the summer and were still appreciable at eight weeks.
- *Salmonella* survived overwinter much better than anticipated from the final data during the previous summer.
- Depth of burial made no difference.

Survival of both bacteria at such high levels suggests that the same may be true for many intestinal pathogens. It is important to note that we used bacteria in feces sandwiched between soil layers and not bacteria mixed with soil, or sewage sludge mixed with soil, as in most previous work on the survival of intestinal bacteria (8). Even after eight weeks, millions or tens of millions of bacterial cells per gram of the initial fecal sample remained. The feces of a person with an intestinal infection would have as many bacteria or more; our data are probably conservative.

Depth of burial had no effect on survival. The data for the two depths were so much alike that the samples from 5 and 20 centimeters could legitimately be combined. When graphed, the depth curves were indistinguishale.

Site did not make the difference we expected. The results seemed to apply to all elevations and exposures on this mountain. There were some differences in counts among sites, but these were not significant.

Initial numbers of *E. coli* were much higher than numbers of *Salmonella*, but survival was better for *Salmonella*, a genus containing many human pathogens.

Bacterial counts during the last three weeks of the summer suggested that the bacterial populations were entering an exponential decline, something we hoped would happen much earlier. We could not check this adequately because snowfall closed the area early in the fall. The over-winter counts of hundreds or thousands of bacteria per gram of feces do not fit such an exponential decline. Given the absence of data during those 43 weeks, we can only speculate that the populations did indeed decline exponentially, but that this decline was halted by freezing and that the samples remained in refrigeration with little change until after snowmelt in the following June and July. Swabey (7) provided examples of exponential drops in bacterial counts in soil. Snow melted on site 6 several weeks earlier than on site 1, but this did not result in lower counts after the winter. Evidently the population was on a second plateau that would enter a final decline during the second summer.

What is the reason for the plateau during the summer? Perhaps feces protect the bacteria. When bacterial cultures are preserved by freeze-drying, any one of a number of sterilized complex organic materials is routinely added to improve viability, including milk, blood, and even soil. Some of the organic materials in feces may similarly protect bacteria. If a disposal method could be devised that mixed soil and feces, then the usual complex of composting reactions should result in a more rapid decline of the intestinal organisms. However, it is difficult to imagine backcountry recreationists instituting such a practice.

In zones warmer than Montana, the exponential population decline probably would be completed during the season. Whether it would also start sooner is uncertain.

Table 1. *Escherichia coli* counts in feces buried at four sites and at two depths.

Site	Depth (cm)	*Escherichia coli counts by week* 0	1	2	3	4	5	7	8	51
		Log₁₀ of cell numbers/gram								
1	5	9.55	8.08	8.24	8.15	8.16	8.13	7.44	7.20	1.39
1	20	9.55	8.11	8.22	8.14	8.19	8.15	7.45	7.19	2.10
4	5	9.55	7.99	7.87	7.76	7.80	7.82	7.44	7.16	1.22
4	20	9.55	7.97	7.81	7.85	7.77	7.83	7.45	7.16	*
5	5	9.55	8.13	8.27	8.21	8.38	7.95	6.94	6.69	*
5	20	9.55	8.18	8.73	8.16	8.17	7.95	6.97	6.69	*
6	5	9.55	8.77	8.67	8.56	8.46	8.40	7.44	7.06	2.07
6	20	9.55	8.75	8.70	8.58	8.45	8.41	7.40	7.56	2.34

*Actual count was zero.

Table 2. *Salmonella typhimurium* counts in feces buried at four sites and at two depths.

Site	Depth (cm)	*Salmonella typhimurium counts by week* 0	1	2	3	4	5	7	8	51
		Log₁₀ of cell numbers/gram								
1	5	6.88	6.63	6.85	6.69	6.71	6.57	6.42	6.15	2.60
1	20	6.88	6.80	6.82	6.63	6.72	6.57	6.41	6.12	3.11
4	5	6.88	6.77	6.59	6.54	6.55	6.65	6.41	6.07	3.24
4	20	6.88	6.70	6.54	6.55	6.56	6.64	6.43	6.09	3.47
5	5	6.88	6.73	6.76	6.68	6.58	6.44	5.82	5.55	3.25
5	20	6.88	6.77	6.71	6.70	6.67	6.44	5.84	5.57	3.40
6	5	6.88	6.78	6.77	6.59	6.55	6.42	6.02	5.69	3.22
6	20	6.88	6.77	6.69	6.62	6.59	6.41	6.00	5.72	3.15

Management implications

Considerable ingenuity has been devoted to developing procedures for composting feces in backcountry (4). In remote, primitive areas, an organized waste disposal system that requires personnel and equipment is not feasible. There may be a potential health hazard in such circumstances. From our data, it is unrealistic to hope for a rapid die-off of intestinal bacteria in cat-holes. This being so, we must anticipate an even longer survival time for some intestinal viruses (9). Pathogens might be transferred to later campers in three ways: by direct contact with feces, by insects, or by water. Each of these possibilities should be minimized.

A study of the behavior of organized camping groups (Sierra Club outings) in wilderness areas has shown that (a) selection of a site for feces disposal is given low priority even by experienced group leaders; (b) members of a group tend to use a common, general area close to camp for feces disposal even when the leader fails to designate such a site; and (c) surface disposal occurs but is rare at group campsites (6). The more common groups of friends or family are unlikely to handle waste disposal as well as organized groups. Thus, all three modes of disease transmission are possible.

Major health problems associated with waste disposal have not been reported by wilderness managers, although *Giardia* infections are being diagnosed much more often. The potential danger seems clear, however.

Surface disposal renders feces subject to drying and to dispersal, both of which accelerate bacterial destruction. Surface disposal might be acceptable where human use is so low to make it esthetically unobjectionable. There probably is no significant health hazard at such low levels of wilderness use. However, surface disposal increases the chances of insect transmission of disease and also poses the possibility of water contamination after heavy rain. In areas with more than very light use, surface disposal clearly is unacceptable.

Burial minimizes insect transmission and direct contact. Deeper burial does so more effectively, but the possibility of water contamination remains. Varying the depth of burial within the limits of the cat-hole technique probably has little influence on water transmission, although contact with groundwater is undesirable. Most studies have shown little visitor impact on water quality even in heavy-use areas (5). However, King noted increased coliform counts in lake water adjacent to campgrounds in the Boundary Waters Canoe Area (*3*), and we observed that some pit toilets in that same area were improperly placed with regard to drainage. If this is the case in a carefully planned pit toilet scheme, the haphazard placing of cat-holes by a large camping party must sometimes result in water pollution.

The idea that shallow burial renders feces harmless in a short time is fallacious. It should not be the basis for recommendations on waste disposal. Burial at sufficient depth or far enough away from campsites to prevent direct contact with feces by subsequent campers is needed to prevent the spread of disease. From a Sierra Club study on feces disposal in wilderness (*6*), it is obvious that modification of camper behavior is needed to accomplish this goal. The alternative is acceptance of a small but real health hazard or a reduction in numbers of visitors at heavily used campsites.

Present recommendations—one brochure states that biological disposers will take care of wastes "in a few days"—are partly responsible for inadequate attention to this problem by campers. An educational program may have positive results. Distance from the campsite and from water drainage courses; the dispersal of cat-holes; and careful, complete burial should be emphasized. The location of campsites and their use level should reflect these requirements.

The use of latrines is a separate subject with its own problems (*1*, *4*), including increased chance of insect transmission and water pollution. A regularly used latrine will have a continual population of bacteria and viruses. Latrines might be considered for locations with concentrated use, especially by large groups. In wilderness areas, the appropriateness of such concentrated use seems questionable in any case.

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