Potential health hazard from human wastes in wilderness

Kenneth L. Temple, Anne K. Camper and Robert C. Lucas

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 overwinter 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.

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). How-

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
		Log_{10} 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
		Log_{10} 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

ever, 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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Evaluating agricultural land use change in Illinois

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ABSTRACT: The National Agricultural Lands Study (NALS) was tested for Illinois on the basis of a critique of Census of Agriculture data and statistics compiled by the Northeastern Illinois Planning Commission (NIPC). Census data were tested with the aid of rectangular coordinates from the Illinois State Geological Survey and other sources. Analysis of the Census data showed that those from the mail censuses (1969, 1974, and 1978) had exaggerated the extent of land in farms. This overcount was especially striking in the 1978 Census (1.5 million acres), forcing the conclusion that farmland had declined much more than Census data would indicate. NIPC data for the six counties in the Chicago metropolitan area showed rapid conversion to urban land use (45 percent in the 11 years from 1964 to 1975). This classical case of urban decentralization was accompanied by very slow population growth but a rapid rise in per capita real income, pointing to rising affluence as the driving force in land conversion. As a conclusion, the NALS estimates for rates of land conversion from agricultural to urban uses were upheld for Illinois.

THE National Agricultural Lands Study (NALS) was undertaken in 1979 to determine how much farmland in the United States was being converted to nonfarm uses and to identify means of reducing such conversion (*13*). Many critics of NALS have expressed skepticism about the land use data used in the study (*7*, *11*, *17*, *19*). Their contention is that the NALS data overstate the rate of urbanization, thus making farmland conversion appear more rapid than it actually has been (*7*).

We studied land use measurement data in Illinois in an effort to confirm or refute the NALS findings. We also examined land use trends in the Chicago metropolitan area to determine the causes of conversion pressures. Both aspects of our study permitted us to make several interesting conclusions about farmland conversion data and trends in Illinois, one of the nation's most important agricultural states.

Farmland conversion in Illinois

Underlying aggregate land use statistics are problems of data definition and measurement. Categorizing land use can create inconsistencies, for example, in distinguishing between forest and pasture. Measurement distortions can influence assessments of the magnitude of land conversion as well as trends in land use.

Farmland conversion in Illinois is of special interest because the state has some of the best farmland in the United States. Equally significant is the fact that conversion in Illinois has taken place against a backdrop of low rates in population growth. For decades, population growth in Illinois has been slower than in most other Midwest states. During the last decade, the state's rate of population growth, 2.8 percent (about 0.28 percent compounded annually), was among the slowest in the country (*26*). Between 1970 and 1980, net migration from Illinois amounted to 375,000 people. Yet farmland conversion appears to have accelerated during that time.

NALS listed an average of 106,000 rural acres in Illinois as land converted to urban, built-up, transportation, or water-related uses annually between 1967 and 1977 (*12*). This conclusion was based upon a comparison of 1967 and 1977 inventories of rural land by the Soil Conservation Service (*23*, *24*). In contrast, the 1978 Census of Agriculture indicated an amount of Illinois farmland that was virtually the same as in

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FACTORS AFFECTING RESPONSE TO NOISE IN OUTDOOR RECREATIONAL ENVIRONMENTS

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As the world gets more and more crowded, silence becomes a rarer and rarer natural resource. (Rennicke 1987, 27)

Rapid growth in outdoor recreation has resulted in increased visitation to forests, parks, and similar outdoor recreational environments. Unfortunately, however, people visiting these areas contribute noise characteristic of the urban, technological society from which they are trying to escape (Kennedy 1977; Thomas 1978; Brownridge 1986; Lucas 1986; Gordon 1987). While in these environments, individuals are exposed to a variety of natural sounds such as those of birds and streams, the sounds of people talking or setting up camp, and technological sounds, such as those of chain saws or aircraft overflights. Some of these sounds are considered pleasing and satisfying, while others are deemed annoying and distract from the quality of the recreational experience which people seek.

Because of the shortage of recreational land resources and increased demand for them, finding and maintaining suitable quiet areas has become a management problem for land resource managers. Conflicts frequently arise between those who wish to enjoy and preserve quiet areas, where natural sounds predominate, and those who wish to use mechanized equipment in such environments. Perhaps the most vivid example is the controversy about aircraft flights over the Grand Canyon, where recreationists are pitted against flight promoters. With the introduction of such mechanized sound sources, some of the very reasons for which Grand Canyon National Park was established are compromised. Similar conflicts, though less dramatic and acrimonious, occur at campgrounds when people have a party, turn the stereo on too high, or run the generator on their recreational vehicles.

Escaping noise and crowds is one of the significant benefits obtained from visiting forests, parks, wilderness areas, and similar types of outdoor recreational environments. Noise ranks fourth in importance of sixteen preference domains, after enjoying nature, physical fitness, and reducing tension, by users of wilderness and non-wilderness recreational areas (Driver, Nash, and Haas 1985). Kaplan and Talbot (Kaplan 1978; Kaplan and Talbot 1983) include the attributes of tranquility, peace, and silence in what they call 'restorative environments.'

As no extensive study has focused specifically on the evaluation of sounds in outdoor recreational environments, this paper has two main objectives: to describe and analyse the relationship between people's evaluation of sounds commonly heard in such environments and their measured dB(A) or loudness levels; and to discuss other factors which are related to the perception and evaluation of these sounds.

Previous Studies

Annoyance from noise and its disturbance of normal human activities in urban areas has received considerable attention. Kryter (1985) synthesized research on the reactions of people to community noise carried out over the past ten to twenty years. Data in these studies, derived from attitude surveys of annoyance, focused primarily on transportation noises, such as those from aircraft, street, and expressway traffic, and railroads. These social surveys on noise annoyance were conducted to assess the magnitude of noise pollution and to develop suitable noise ratings from which one could reliably predict the subjective response to the noise from a measurement of its physical characteristics (Schultz 1978). The accepted metrics for determining annoyance are various sound

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