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The Consequences of Backcountry Surface Disposal of Human Waste in an Alpine, Temperate Forest and Arid Environment

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Abstract

Surface disposal of human waste by the smear method, a suggested but heretofore unexamined technique, was tested in three environments and examined for reductions in fecal mass and fecal indicator bacteria. Substantial reduction in fecal mass was observed after six and fourteen weeks of exposure in all environments, but extensive reduction in fecal indicator bacteria was observed in only the arid and alpine environments. Although based on these results, surface smears appear favorable to cathole techniques in terms of indicator bacteria reduction, the application of this method is limited by several other factors common to backcountry sanitation situations. It is therefore likely that surface disposal would only be applicable in very remote, low use, alpine and arid settings where lack of soil development precludes the use of catholes and carry-out techniques are otherwise impractical.

Keywords: backcountry sanitation; human waste disposal; outdoor recreation; wilderness management; catholes; recreation ecology

1. Introduction

While the overall literature on ecological consequences of outdoor recreation is robust and continues to grow (Leung and Marion, 2000; Buckley, 2004; Monz et al., 2010) very little research has examined the disposal of human waste in non-serviced, backcountry areas. This issue continues to be a primary concern for park and protected area managers. Cilimburg et al. (2000) in a review of the literature, state that while minimum-impact practices developed for backcountry sanitation include a variety of techniques including cathole methods (shallow soil burial), latrines, surface disposal and carrying-out of feces, the effectiveness of these methods is largely based on observations and common sense approaches rather than scientific evidence.

In our more recent review of the literature we found that there remains few studies to advance backcountry management practices on human waste disposal. Original work by Temple et al. (1982) and Reeves (1979) examined the effectiveness of cathole techniques and while some environmental variables affected fecal organism survival, enteric pathogens were present in substantial numbers at most sites one year later. These results suggest that cathole techniques present some risk to backcountry visitors, although burial limits the possibility of direct contact. More recently, two studies have examined the effects of digging catholes for human waste disposal on native vegetation (Bridle and Kirkpatrick, 2003) and the breakdown of toilet paper and tampons in catholes (Bridle and Kirkpatrick, 2005). These studies largely support the use of the cathole technique as digging and potential nutrient additions were found to have little long-term effect on plant communities. While significant decomposition of tissue paper was observed in some environments, the authors suggest carry-out techniques for these paper products, particularly in mountain environments.

Despite these investigations, many issues remain in regard to human waste management practices. First, while the literature abounds with investigations of the types and numbers of various microorganisms found in fresh human waste, little is known about their persistence in backcountry settings. Currently, over one hundred protozoans, bacteria and viruses have been identified in human wastes including *Giardia lamblia*, *Chryptosporidium parvum*, various coliform bacteria , and viruses such as Hepatitis A. (Cilimburg et al., 2000). The few studies conducted suggest that human wastes deposited on or in soils leads to the contamination of those soils by these organisms. Moreover, the most common disposal technique—catholes—may allow those pathogens to persist for some time (Temple et al., 1982). Second, published studies are limited to environments where feces can be buried in soil and do not provide any guidance for environments such as high alpine areas that lack soil of a significant depth to dig a cathole. Last, no published research has investigated the efficacy of other techniques, such as surface disposal. Surface disposal techniques have long been suggested as an option for highly trained backcountry campers in situations where catholes are impractical (e.g., Hampton and Cole, 2003; Temple et al., 1982). For example, Cilimburg et. al., (2000) recommended surface disposal (smearing) as a human waste disposal practice in areas where soil is absent or of marginal depth, provided that the site is not in a drainage or high use area. Surface disposal via smearing a thin layer of feces over rock surfaces is based on the suggestion that desiccation and increased exposure to environmental conditions decreases survival of fecal indicator organisms (Bitton and Harvey, 1992). Cilimburg et al. (2000) suggest that smears be spread thinly in order to expose the greatest possible surface area to the greatest amount of sunlight.

The objective of this study was to experimentally investigate the efficacy of surface disposal of feces in a range of environments in order to evaluate the appropriateness of this technique for minimum impact camping management recommendations. We examined the physical and bacterial attributes of fecal smears in an alpine, temperate forest, and arid environment in order to determine the appropriateness of this method at minimizing human health hazards, impact to the environment and affect on the recreation experience of other visitors.

2. Materials and Methods

2.1. Experimental Approach

The efficacy of the fecal smear technique (Hampton and Cole, 2003; Cilimburg et al., 2000) was examined in three environments popular for backcountry camping. In each location, replicate smears were applied to flat rock surfaces and exposed to the ambient environmental conditions for an 11-14 week period during the popular summer camping season. Precautions were taken to control for various factors that could influence the experimental trials such as disturbance from animals and visitors, and prior contamination of the study locations with fecal indicator organisms. During the study, the remnants of the fecal smears were examined for changes in fecal organisms and in total mass while the adjacent soil was examined for the presence of fecal indicator organisms. These measurements provide an assessment of the effectiveness of surface smearing to limit possible human health concerns through the reduction of fecal indicator organisms and visitor experience impacts through the reduction of fecal mass.

2.2. Study Sites

Sites for experimental work were located in south-central Washington State, USA. The alpine and temperate forest site were located in Mount Rainier National Park, while the arid site was located near the city of Yakima, WA on land managed by the USDA Forest Service, Naches Ranger District.

The alpine study site was located above treeline at an elevation of approximately 2,500 m in Mount Rainier National Park at the first major fell field approximately 400m east of the trail to Camp Muir. It was purposefully established in a somewhat remote area so it would not be readily noticeable and thus attract visitor attention. Weather conditions at Paradise, Mt. Rainier NP during the study period were an average temperature of approximately 11 C and 180 mm of precipitation.

The lower elevations of Mount Rainier National Park are classified as a temperate forest—generally warm in the summer months with abundant rainfall—so a location at Longmire, near the Longmire Wastewater Treatment Plant location was selected. During the study period (June through September) at the Longmire the mean temperature was 14.0 C and 106 mm of precipitation. The arid site in the nearby Yakima Valley had a mean temperature of 18.9 C and 45 mm of precipitation

2.3. Sample Preparation and Analysis

Fecal specimens used in the study were those of the lead author. Initial fecal specimens were deposited directly into Zip-Loc bags over a six-day period and refrigerated at 4.5° C prior to transport to the study site. The study used the Longmire Wastewater Treatment Plant laboratory for analysis.

Prior to smearing the fecal material on rocks, each of the sites were prepared by removing all rocks from the area in order to expose mineral soil. These prepared areas measured between 0.45-0.60m^2. Following clearing, a sample of the mineral soil was taken from the center of the cleared area and tested for background levels of fecal indicator organisms. Small, flat rocks were obtained from nearby and tare weighed prior to feces being smeared onto the rock. Following tare weighing, 2mm - 3 mm of feces for thin smears and 5-7 mm for thick smears was placed onto the surface. At each study site, separate smears were used for the weight loss experiment and the microbiological assessments since periodically small samples of feces had to be removed for microbiological testing. Surface soil samples were obtained immediately adjacent to the edge of the rock every two weeks during the exposure period to test for fecal indicator organisms. In the temperate and arid environments, rock smears were placed in metal dog crates eliminate possible effects of coprophagious animals.

Small samples (2.5g to 3.3g) of fecal material were removed and tested for the presence of fecal indicator organisms at two-week intervals during the study period. Analysis of fecal coliform, fecal streptococcus, *Escherichia coli* and *Pseudomonas aeruginosa* was performed by standard membrane filtration (0.45µ) and incubation techniques on the appropriate media (APHA 1992). Re-hydration of the soil and fecal samples was performed aseptically with ~ 1.0 gram of sample (to the nearest 0.0001g) and 99 ml buffered, sterile water shaken periodically over a 1 hour period. Sterility testing of the analytical water and of the membrane filtration equipment was accomplished by filtering sterile, buffered distilled water and placing the filters on each of the media. Positive controls were analyzed by using fresh sewage influent obtained from a nearby sewage treatment plant.

3. Results

Our results show that in all environments, a relatively rapid decrease in fecal mass occurs (Table 1). For example after 6 weeks, across all environments remaining smears exhibited approximately an 82-95% weight loss of material. Continued exposure resulted in a decrease of material to the end of the experimental periods. Eleven weeks in the alpine environment resulted in a 97-99% reduction in weight and fourteen weeks in the temperate and arid environments resulted in a 93-97% reduction. In most cases, small amounts of fecal matter remained visible on the rock surfaces at the end of the experimental period, except in the alpine environment where no material was visible at the end of the study.

Results of the fecal smear microbiology are presented in two separate analyses; one after six weeks of exposure in which a full comparison across all three sites is possible and another after fourteen weeks where data from the temperate and arid sites are available. It should be noted that the study sampled and analyzed indicator bacteria at two-week intervals. The results are presented here at select time intervals for ease of comparison and interpretation and are supported by the trends observed with the additional samples (Ells and Lee, 2000a, 2000b, 2000c). After six weeks, substantial reductions in all indicator bacteria were observed in both the alpine and arid environments, with reductions in bacterial counts ranging from 91% to none present (100% reduction). In the temperate environment, while a reduction in fecal coliform and fecal streptococcus was observed, a substantial increase in *E. coli* was observed. At 14 weeks, nearly complete elimination of fecal organisms was observed in the arid environment, with substantial increases in counts of fecal streptococcus and *E coli* in the temperate environment.

Surface soil samples obtained at all sites at the initiation of the study showed no evidence of prior contamination with fecal indicator organisms. In the alpine study, a total of 46 soil samples were tested over the duration of the study for presence of fecal organisms with two samples testing positive for very low levels of fecal coliform (counts= 8 and 2) and one sample showing a presence of fecal streptococcus (count=2). Similar results were found in the arid site with only one sample out of fourteen showing a small number of fecal streptococcus (count= 30). Although counts remained relatively low, more samples showed contamination at the temperate with six out of fourteen samples showing some contamination. In all cases across all environments, no soil contamination was evident at the conclusion of the study.

4. Discussion

The above results suggest several conclusions in regard to the use of smearing techniques in non-serviced, backcountry areas. First, in all environments examined, exposure of smears resulted in a substantial decrease in fecal mass in a relatively short period of time. Some material remained visible after 14 weeks in all cases except for one smear in the arid environment (Table 1). Second, in the arid and alpine environments, microbiological analyses suggest that smearing may be an effective way of reducing the presence of fecal bacteria—presumably this is accomplished through desiccation and exposure of the fecal material to sunlight. These results contrast with the available literature on catholes (Temple et al., 1982) which indicates a persistence of two common intestinal pathogens in high concentrations after 8 weeks and lower, but still substantial concentrations one year later. Smearing, as postulated in both the scientific (Temple et al., 1982; Cilimburg et al., 2000) and some minimum impact literature (Hampton and Cole, 2003) clearly does result in a more rapid destruction of fecal indicator organisms than cathole techniques. A final conclusion is that smear techniques are likely not effective in all environments as is illustrated by our results in the temperate environment. In this case, we speculate that conditions during the study period were not dry enough to result in elimination of organisms but instead resulted in marked increases, on a concentration basis.

While these results are encouraging and supportive of the smearing technique in backcountry and wilderness settings, we caution that these results are preliminary, are based on a limited number of replicates and environment types, and that approach is limited by several other considerations in backcountry sanitation. Cilimburg et al., (2000) suggest that proper minimum impact decisions regarding human waste disposal should be based on a framework of four criteria, namely: minimizing direct contact including insect vectors of pathogen transmission, limiting possible contamination of water sources, maximizing pathogen destruction and minimizing the effects on the visitor experience and aesthetics. Using this framework to examine our study findings for smearing, the available data for catholes and the practical considerations for both techniques, some overall conclusions are warranted. First, while smearing does result in a substantial and relatively rapid destruction of fecal indicator bacteria, it must be performed only in settings where contamination of water sources, possibility of direct contact, insect transmission and visitor experience impacts will be at an absolute minimum. Very remote, low use, alpine and arid environments, far away from established travel routes, where soil development is very limited or non-existent appear to be the most plausible settings. Second, from a management perspective, it is doubtful whether most backcountry travelers would be amenable to or capable of using this technique as it does involve some handling of feces, raising personal hygiene concerns. Clearly only the most highly trained and dedicated minimum-impact practitioners should adopt this technique. Moreover, even in settings where smearing may be possible, practitioners should consider whether modern carry out disposal options, such as the use of Wag Bag waste kits (Phillips Environmental Products, Inc., Belgrade, MT, USA) are a viable option. Last, we continue to support the use of catholes in settings where soils are sufficiently developed to properly bury feces and adequate area exists to accommodate use levels. Although fecal indicator organism reduction may be limited with catholes as previously described, other disturbances, including damage to vegetation (Bridle and Kirkpatrick, 2003), aesthetic impact, direct contact and water contamination appear to be minimal. In addition, visitors are likely to comply more readily with the cathole technique given that it has been a common practice for quite some time (Cilimburg et al., 2000; Hampton and Cole, 2003).

5. Conclusions

Results of experimental trials of surface disposal of human waste in backcountry settings reveal that this technique is effective at reducing fecal indicator organisms and in reducing fecal mass over a fourteen-week period. While favorable in fecal indicator reduction compared to catholes, the application of this technique is limited by several factors that include direct contact by other visitors and hygiene concerns. Currently, surface disposal is likely only to be effective when practiced by highly trained minimum impact campers in remote settings where the possibility of visitor contact is minimal.

6. Acknowledgements

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Table 1. Weight loss of fecal smears in alpine, temperate and arid environments

Environment	Smear	Initial Smear Weight (g)	Remaining weight (g) and weight loss (%)			
			After 4 weeks	After 6 weeks	After 11 weeks	After 14 Weeks
Alpine (N=3)	A (thin)	29.6	11.9 (-60%)	5.2 (-82%)	0.3 (-99%)	
	B (thick)	37.7	3.6 (-91%)	6.7 (-82%)**	0.8 (-97%)	
	C (thick)	44.9	27.1 (-40%)	2.1 (-95%)	No smear remaining	
Temperate	A (thin)	28.4	3.7 (-87%)	3.6 (-87%)	3.5 (-88%)	2.0 (-93%)
(N=2)	B (thick)	34.1	1.7 (-95%)	1.7 (-95%)	1.7 (-95%)	0.9 (-97%)
Arid (N=2)	A (thin)	28.4	2.8 (-91%)	3.7 (-87%)**	Scale failure*	2.0 (-93%)
	B (thick)	34.1	1.8 (-95%)	1.7 (-95%)	Scale failure*	0.9 (-97%)

* Scale failure at this location on this date.

** Increases in weight were due to precipitation.

Table 2. Survival of fecal indicator organisms in fecal smears after 6 weeks of exposure in an alpine, temperate and arid environment

		Count per gram feces and percent reduction[1]			
Environment	Smear	FC	FS	Ec	Pa
Alpine (N=3)					
Initial count (cells/g)		6,302,000	380,000	7,388,000	109
Remaining count (cells/g)	A (thin)	8,907	6,453	5,454	0
	B (thick)	7,600	6,173	5,279	0
	C (thick)	10,569	6,322	5,531	0
Average reduction or increase (%)		-99.8	-98.3	-99.9	-100
Temperate (N=2)					
Initial count (cells/g)		2,550,000	271,000	43,600	0
Remaining count (cells/g)	A (thin)	112, 310	42,680	157,230	0
	B (thick)	0	0	0	
Average reduction or increase (%)		-97.8	-92.1	+260	
Arid (N=2)					
Initial count (cells/g)		240,000	44,000	58,000	
Remaining count (cells/g)	A (thin)	0	45	225	
	B (thick)	0	7673	0	
Average reduction or increase (%)		-100	-91.2	-99.8	

[1] FC= Fecal Coliform; FS=Fecal Streptococcus; Ec=*Escherichia coli*; Pa= *Pseudomonas aeruginosa*

Table 3. Survival of fecal indicator organisms in fecal smears after 14 weeks of exposure in a temperate and an arid environment

		Count per gram feces and percent reduction[1]			
Environment	Smear	FC	FS	Ec	Pa
Temperate (N=2)					
Initial count (cells/g)		2,550,000	271,000	43,600	0
Remaining count (cells/g)	A (thin)	384,180	706,050	436,090	0
	B (thick)*	N/A	N/A	N/A	
Average reduction or increase (%)		-92.4	+160	+900	
Arid (N=2)					
Initial count (cells/g)		240,000	44,000	58,000	
Remaining count (cells/g)	A (thin)	0	235	0	
	B (thick)	0	0	0	
Average reduction (%)		100	99.7	100	

[1] FC= Fecal Coliform; FS=Fecal Streptococcus; Ec=*Escherichia coli*; Pa= *Pseudomonas aeruginosa*

* No smear remaining