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The application of a solar "hot box" to pasteurize toilet compost in Yosemite National Park

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Land managers today are continually searching for methods that promote sound and sustainable backcountry management techniques while decreasing costs and use of human resources. The public is also increasingly concerned over great expenditure for backcountry infrastructure projects including the construction of innovative toilet facilities (Voorhees and Woodford 1998). Past research has documented composting toilet technologies as a low-cost, efficient, and sustainable method of backcountry human waste treatment (Davis and Neubauer 1995; Land 1995a,b; Yosemite NP 1994; Mount Rainier NP 1993; Weisberg 1988; McDonald et al. 1987; Jensen 1985; Cook 1981; Leonard et al. 1981). While considerable research has demonstrated the operation and maintenance of composting toilets in the backcountry (fig. 1), few studies have explored proper methods and disposal of composting toilet end-product.

In 1996, the USDA Forest Service, San Dimas Technology and Development Center and the USDI National Park Service, Yosemite National Park, conducted a cooperative study in the development and operation of a passive solar insulated box (termed the "Hot Box") to treat the end-product from composting toilets used by hikers in the backcountry (fig 2, this page, and fig. 3, page 20). The study demonstrated that the Hot Box could consistently meet U.S. Environmental Protection Agency heat treatment requirements and produce a class-A sludge that could be surface-applied as outlined in 40 *Code of Federal Regulations* (CFR) Part 503 (Lachapelle et al. 1997). According to the regulation, this heat treatment is a function of time and temperature (fig. 4, page 21). The study demonstrated that the time-temperature requirement could consistently be met in Yosemite, an area that proved ideal because of high ambient air temperatures and consistent sunlight throughout much of the summer.

Field staff at the park tested the application of the Hot Box to pasteurize large quantities of end-product during the summers of 1997 and 1998. Field staff report that the Hot Box operated well and required minimal labor under optimal conditions. Previously, all of the end-product removed from backcountry toilets in Yosemite was sealed in plastic bags, deposited into designated dumpsters and then thrown away in a local landfill.

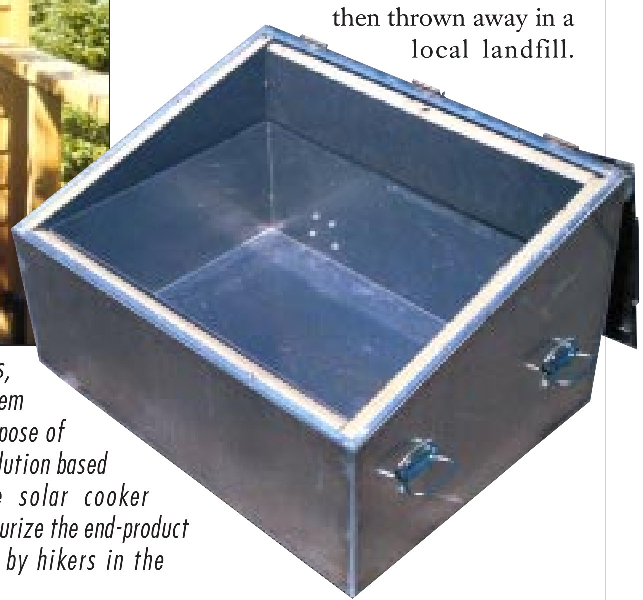
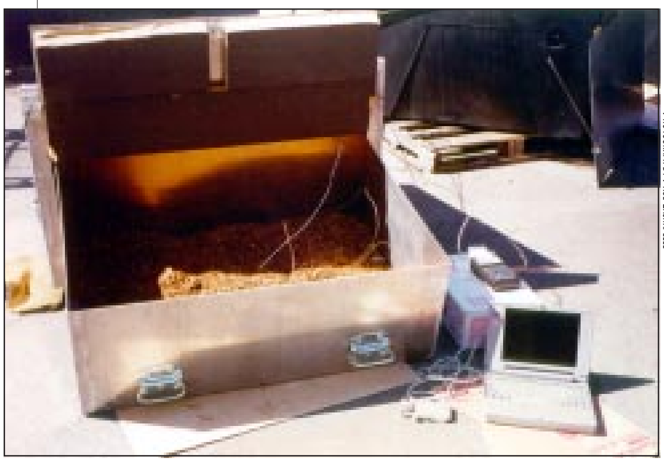


Fig. 1 (above). A convenience to backpackers, the composting toilet represents a problem for resource managers: How to safely dispose of the human waste? The authors offer a solution based on their research of the box-type solar cooker (fig. 2, right), which they tested to pasteurize the end-product from public composting toilets used by hikers in the backcountry.

See "Hot Box" on page 20

"Hot Box" continued from cover

Now the pasteurized end-product is surface-applied out of the park in local flower gardens near the park headquarters in El Portal.



PHOTOGRAPH BY PAUL LACHAPELLE

Figure 3. Two time-temperature data loggers were used to record and compare temperatures within the Hot Box. Temperature probes were inserted into various sections of the compost pile through a small hole in the back of the Hot Box. A laptop computer was used to download and display the data from the data loggers.

Background

The development of backcountry composting toilet methods resulted from the need to reduce impacts including surface water pollution at overnight sites. Research of backcountry composting systems began in the mid-1970s and focused on sites with up to 2,000 overnight visitors per season (Fay and Walke 1977; Ely and Spencer 1978). Composting technologies became increasingly popular as research documented the ineffective break-down of coliform bacteria using the "cat-hole" disposal technique (Temple et al. 1982) and as certain composting toilet technologies were shown to be a low-cost and effective solution to human waste treatment and disposal (Leonard and Fay 1979; Leonard and Plumley 1979). Thermophilic composting (also termed batch or bin) and mesophilic composting (also termed moldering or continuous) have been used with varying degrees of success in numerous national parks (Yosemite, Mt. Rainier, Olympic, Grand Canyon) and national forests (White Mountain, Green Mountain).

The aim of any composting technology is to optimize conditions for microbial growth. Combining the proper amount of carbon (also termed "bulking agent" and usually consisting of wood chips or shavings), moisture, ambient heat, and oxygen enhances the living conditions within the compost pile for natural oxygen-using microorganisms (aerobes). These aerobes use human waste as a food source and consequently, the waste decomposes over time into a soil-like substance. Disease-causing organisms (pathogens) within the human waste are reduced or eliminated due to competition, natural antibiotics, nutrient loss, and heat. The human waste and the carbon are in most cases manually mixed in an enclosure or sealed bin. The term end-product refers to the composted woodchips and human waste. The composting process functions optimally with a carbon to nitrogen ratio of 25-35:1 and a moisture content of 60% (Davis and Neubauer 1995). The aim of thermophilic composting, which requires frequent mixing and high woodchip input (approximately 1 kg [2.2 lbs.] of carbon to 1 liter [~1 qt.] of human waste), is to kill pathogens quickly and with hot temperatures. These temperatures result from microbial activity and can exceed 45°C (113°F). Once a sufficient amount of human waste has been collected, a compost "run" is started and can take up to several weeks to complete. Mesophilic composting in comparison is a long-term method that can take years to effectively reduce pathogens within the waste. This method differs from thermophilic composting because the frequency of mixing and the amount of carbon added are considerably lower with temperatures within the waste pile ranging from 10°- 45°C (50°- 113°F).

However, complete pasteurization of composting toilet end-product by either treatment method can never be guaranteed and depends on the quality of field staff maintenance and site conditions. Heat treatment, such as the Hot Box can provide, is one method to ensure pathogen reduction and meet 40 CFR Part 503. Consequently, the Hot Box can help in a number of ways. First, if land management policy dictates that the end-product can be surface-applied at the backcountry toilet site, significant savings in transportation costs could result. Additionally, the biophysical and social impacts from using either pack animals or helicopter resources could be reduced. Second, while land management policy may dictate that the end-product be transported outside of a protected area boundary, heat-treated compost is less of a health and safety issue to field staff. End-product that is heat-treated in the backcountry would be a considerably lower health hazard to field staff regarding accidental spillage during transport or disposal. Since, for example, a fundamental tenet of the Wilderness Act states that the wilderness area be "protected and managed so as to preserve its natural conditions" (Wilderness Act of 1964, Sec 2c), surface-applied compost in these areas could be problematic. Unquestionably, increased nutrient levels resulting from on-site disposal could upset natural species assemblages by shifting the competitive advantage to invasive nonnative plant species. However, in areas with less stringent land policies, surface application of treated composting toilet end-product could be appropriate. For instance, there are several national forests where both mesophilic and thermophilic composting toilet end-product has been approved for on-site disposal. Nevertheless, state laws may be more restrictive than federal policies and therefore the land manager should review all applicable regulations. Third, if the end-product cannot be surface-applied at the site and the Hot Box cannot be used in the field because of staffing or ordinance issues, landfill disposal savings could result. Lastly, the treated end-product could be reintroduced into the composting toilets as bulking agent which would reduce the amount of additional bulking agent needed.

Hot Box description and application

The Hot Box is a nearly air-tight container that allows solar short-wave radiation or light energy to pass through the glazing. The contents of the Hot Box absorb the light energy and convert it to long-wave radiation or heat energy, which becomes trapped inside the box. The 1996 USFS/NPS study demonstrated that temperatures of over 100°C (212°F) can be achieved and temperatures of 88°C (190°F) can be sustained for several hours.

The outside walls, floor, and removable tray are fabricated from an approximately 0.5-cm thick (0.2 in) aluminum sheet. A single transparent Lexan® Thermoclear polycarbonate sheet is used as the solar

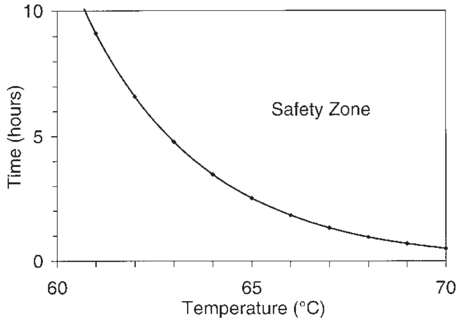


Figure 4. U.S. Environmental Protection Agency 40 Code of Federal Regulations (CFR) Part 503 time-temperature relationship for the heat-treatment of sewage sludge.

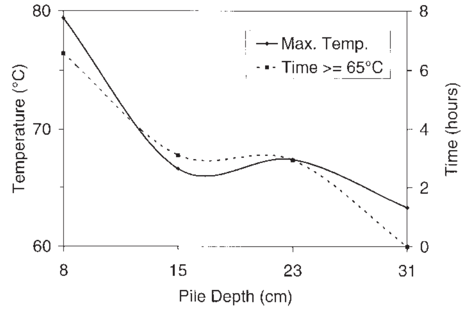


Figure 5. Comparisons are made between pile depths, the maximum temperature attained and the duration in hours at or above 65°C. Moisture content of the compost pile is equal (33.5 %). Temperature readings are taken from the middle of the compost pile.

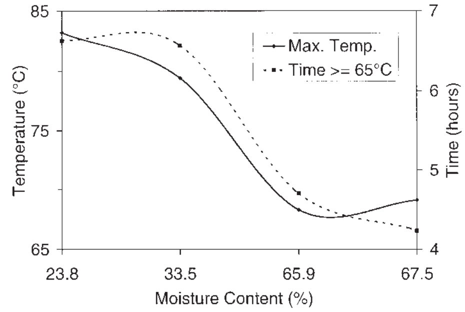


Figure 6. Comparisons are made between percentages of moisture content, the maximum temperature attained and the duration in hours at or above 65°C. All pile depths are equal (8 cm). Temperature readings are taken from the middle of the compost pile.

glazing and is bolted at an angle specifically designed to maximize the angle of incidence during the summer solstice for the chosen latitude (at Yosemite, 38 degrees north latitude, a 15 degree angle was chosen). This angle could be adjusted for other locations. The inside walls and floor are insulated with 5-cm (2-in) poly-isocyanurate closed-cell foam. A door is positioned at the back of the Hot Box in order to gain access to the tray. The original Hot Box measured 122 cm x 94 cm x 69 cm (48.1 in x 37 in x 27.2 in) at the highest end and 46 cm (18.1 in) at the lowest end. Four new Hot Boxes, measuring 122 cm x 122 cm x 61 cm (48.1 in x 48.1 in x 24 in) at the highest end and 20 cm (7.9 in) at the lowest end, have recently been built and appear to be more efficient because of their larger glazing and decreased internal air volumes.

Yosemite field staff operated the Hot Box during the 1997 and 1998 summer seasons at the park headquarters in El Portal, which is outside the park. Yosemite contains six backcountry composting toilets that collectively produce approximately 20 cubic meters (700 cubic ft) of end-product per year. Traditionally the end-product has been transported outside the park boundary.

End-product is transported in double plastic bags by pack animals to trailheads and then trucked to El Portal. Approximately 9 cubic meters (300 cubic ft) were pasteurized in 1998. Field staff emptied a portion of the bags into the Hot Box tray and allowed the compost to pasteurize for up to one week. One operator required one-half hour per day, two days per week, to perform this task. The 1996 USFS/NPS study concluded that pile depths of 12 cm (4.7 in) or less and two and one-half hours of direct sunlight with ambient air temperatures exceeding 28°C (83°F) were most effective at meeting the time-temperature requirement (fig. 5). Additionally, a moisture content of 60% or less allowed for maximum temperature attainment (fig. 6). Field staff would mix the end-product in the Hot Box tray several times during the heat-treatment process to ensure thorough pasteurization. After pasteurization, the finished compost was again bagged and brought to local flower gardens and spread thinly on the surface. Operators reported that the pasteurized compost resembled mulch and not human waste in both texture and odor, and was therefore more tolerable to work with.

Conclusion

The passive solar Hot Box has been used for two field seasons in Yosemite National Park, a location that is shown to be ideal to effectively pasteurize the compost from backcountry toilets. This application stems from the 1996 USFS/NPS study that demonstrated the use of the Hot Box as an effective method of pasteurizing the end-product from composting toilets. Field staff report that the developed Hot Box technology requires a minimum level of attention and maintenance by the operator and produced a compost that is dryer and appears less offensive to handle and transport.

While stringent regulations may negate the possibility that finished compost be surface-applied in wilderness and national park areas, the Hot Box holds tremendous potential to save either transportation costs and associated impacts in areas where the end-product can be surface-applied on-site, or disposal costs where the end-product must be transported and disposed off-site. This passive technology can serve as a sound and sustainable backcountry management technique, alleviating impacts, costs, and extensive use of human and animal resources, while providing an added safety margin to field personnel.

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Photo by Kathie Meyer

Figure 4. In the spatially and temporally variable environment of the desert, resources such as rain and the annual plants that germinate in response to precipitation fluctuate widely. This photograph, taken in Joshua Tree National Park, shows how abundant annual plants can be in some years. In other years or places germination may be sparse or absent. Animals like the desert tortoise need strategies to cope with these large variations in productivity.

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