Recreation Tech Tips

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What's Burning in Your Campfire? Garbage In, Toxics Out

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For most overnight campers, camping and campfires seem to go together. Campfires are not only psychologically reassuring, they seem to offer an easy way to get rid of trash.

But after cooking dinner, is it wise to burn the garbage in your campfire? How benign are the fumes generated when you burn a cardboard box printed with colorful advertising or a resealable sandwich bag?

The Missoula Technology and Development Center (MTDC) analyzed gas emissions and ash content from 27 products that are commonly burned in campfires. The garbage items ranged from batteries to baby diapers.

Many toxic air pollutants and heavy metals are human carcinogens that may increase the incidence of cancer. Toxic pollutants can be inhaled, absorbed through the skin, or ingested in contaminated food or water. Laboratory research has documented the emissions of some toxic air pollutants from burning wood. Many of these compounds are known to be carcinogenic to humans. This informal study will discuss the most prevalent toxic pollutants released when wood is burned in a campfire and any major increases in pollutants when garbage is added to the campfire.

Garbage burned in a campfire can create fumes that campers inhale. The garbage may leave traces of heavy metals in the campfire ash. When the ash is scattered, as is common when cleaning up campfires, the ash may expose workers, animals, and plants to toxic metals. Garbage should not be burned in a campfire, but should be packed out and disposed of properly.

Analysis

Each of 29 simulated campfires (figure 1) in the study burned 107 grams of ponderosa pine branches and 43 grams of ponderosa pine needles. The campfires were conducted as open-air burns for the most realistic simulation of a campfire. Two campfires were burned without garbage items, establishing a baseline for levels of compounds in the smoke and ash of a campfire that just burned wood.

Small amounts of specific garbage items were added to each of 27 other campfires (table 1) when the fire was intense enough to consume the garbage. Typically, when the garbage was added to the campfire, the flames would diminish

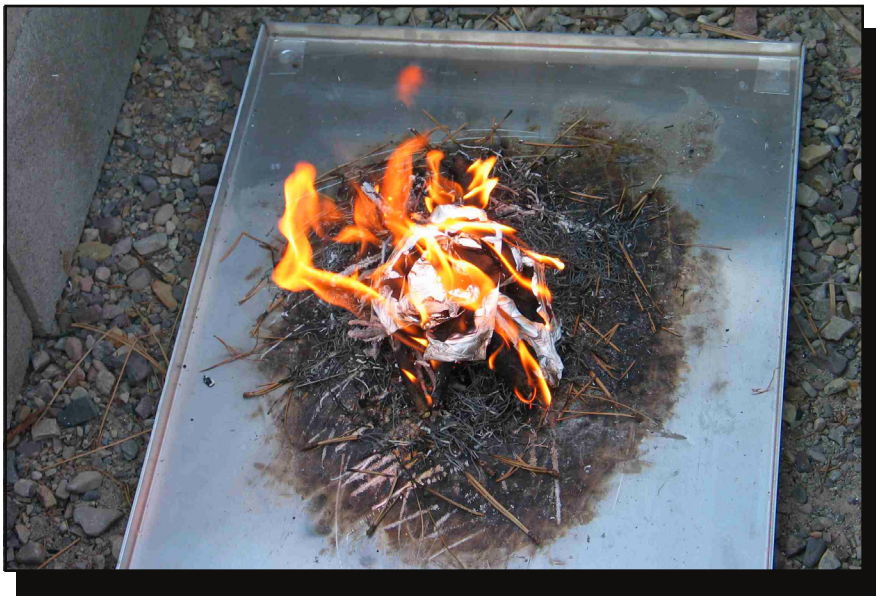

Figure 1—Aluminum foil burning in a simulated campfire.

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Table 1—Garbage items burned in 27 simulated campfires during the study.

Garbage item	Residue in the ash
No. 6 polystyrene clear plastic packaging (for doughnuts, cookies, and similar items)	Tar-like residue
No. 1 polyethylene terephthalate 20-ounce clear pop bottles (two)	Hard residue present
Baby diaper (one)	Black foam-like residue
Cigarette and candy wrappers	Aluminum wrapper intact
Snack-size chip bags	No visible residue
No. 6 polystyrene styrofoam cups (six)	Very hard black resin residue
Alkaline (two) and lithium (two) batteries	Blackened batteries left intact
Pieces of a fiberglass spinning rod and clear fishing line	Rod blackened but intact, line melted
Military Meal-Ready-to-Eat packaging with the expended heater packet	Hardened muddy-colored residue (from exterior package) and solid foil layers intact
Duct tape, masking tape, Kevlar tape, and strapping tape	Strings from Kevlar and strapping left intact; goo-like residue visible in ash
Packaging for freeze-dried meals (colored foil, plastic, plain foil)	Foil intact; hardened muddy-colored residue
White plastic lids (four) for disposable hot beverage cups	Yellow residue
Three white and three brown plastic forks and spoons	Yellow residue
Webbing, buckle, and padded strap from a backpack	Hardened black residue
No. 4 polyethylene terephthalate black plastic tray	Black residue
Peanut can with plastic lid (paper, foil, tin)	Tin was intact; some foil particles were intact
Nickel-cadmium batteries (three)	Batteries sizzled and one popped, but the batteries were intact
Colored cardboard box	Large particles left intact
Aluminum foil	Most of the foil left intact
Clear plastic sheet (Visqueen)	Yellowish hardened residue
Instant soup and hot cocoa packaging (paper, plastic, and foil)	Foil left intact
Hard plastic container (No. 5 polypropylene base, No. 4 low-density polyethylene lid)	Yellow residue
Plastic grocery produce bags and resealable plastic sandwich bags	Yellow residue
Plastic grocery carry-out bags: four No. 2 high-density poly-ethylene bags (three white and one blue)	Blue residue
Snack packaging (plastic and foil)	Yellow residue
Aluminum pop can	Can lost color but was mostly intact
Blue plastic plate with B2 marking on bottom	Hard, blue residue

and the campfire would start smoldering. The smoke was collected in stainless steel canisters (figure 2) for analysis.

Figure 2—Using canisters to collect gas samples from a simulated campfire for analysis with a gas chromatograph-mass spectrometer.

Organic compounds contain carbon atoms. Inorganic compounds do not.

The Rocky Mountain Research Station's (RMRS) fire chemistry unit in Missoula, MT, used a gas chromatograph-mass spectrometer to analyze the smoke samples. The gas chromatograph-mass spectrometer uses a library with thousands of known signature peaks to identify the organic chemical compounds in each canister. Of the 29 canisters analyzed, two were from the baseline campfires that just burned wood and 27 were from campfires burning specific garbage items in addition to wood.

Ash samples (figure 3) were collected from all the fires and analyzed for 29 inorganic elements. The ash was analyzed by the University of Montana geology department, which used an inductively coupled plasma optical emission-atomic emission spectrometer. The ash samples were dissolved in acid and fed into a plasma unit. Atoms in the plasma emit light with characteristic wavelengths, allowing each element to be identified.

Figure 3—Ash with some yellow residue left after burning four white plastic lids for disposable hot beverage cups.

Campfires with Wood, but No Garbage

Smoke—Many hazardous air pollutants and toxic metals are known to be human carcinogens that may increase the incidence of cancer. Air pollutants may have other effects on human health that are more difficult to measure, such as immunological, neurological, reproductive, developmental, mutagenic, or respiratory effects.

The hazardous air pollutants we measured in campfire smoke that are known to adversely affect human health were: acrolein (2-propenal), acetaldehyde, benzene, furan, naphthalene, styrene, toluene, and xylene. We did not analyze the smoke for toxic metals.

Benzene, naphthalene, styrene, toluene, and xylene are aromatic hydrocarbons, which are suspected carcinogens. Aromatic hydrocarbons also are severe eye, nose, and throat irritants. These compounds occur in petroleum products and automobile exhaust. They also are found in dyes and are used to produce a number of organic compounds. Benzene is a major component in tobacco smoke. Naphthalene is an ingredient in mothballs. Toluene and xylene occur in petroleum products and in dyes. Styrene is primarily used in the production of polystyrene plastics and resins.

Acrolein and acetaldehyde are aldehydes. Aldehydes are used for making dyes, resins, and plastics. Acrolein is toxic to aquatic organisms and acetaldehyde has been proven to cause cancer in animals. Studies have not proven whether these compounds cause cancer in humans.

Furan is on the U.S. Environmental Protection Agency's list of extremely hazardous substances. Furan is released into the air during incomplete combustion. It emits acrid smoke and irritating fumes.

Ash—The ash samples were analyzed for 29 inorganic elements. The ash from campfires that just burned wood had high concentrations of barium (Ba), calcium (Ca), potassium (K), magnesium (Mg), and sulfur (S). The concentrations of highly toxic elements such as cadmium (Cd) and mercury (Hg) were barely within the detection limits of the instrument used to analyze the ash from campfires that just burned wood.

Campfires with Wood and Garbage

Smoke—The four products that released high levels of toxins in smoke and ash were:

- A broken fiberglass spinning rod
- A combination of cigarette and candy wrappers
- Nickel-cadmium batteries
- Alkaline and lithium batteries

Figures 4, 5, and 6 compare the garbage items that released more than two times as much benzene, styrene, and xylene as wood. Benzene, styrene, and xylene are common air pollutants produced by burning plastic.

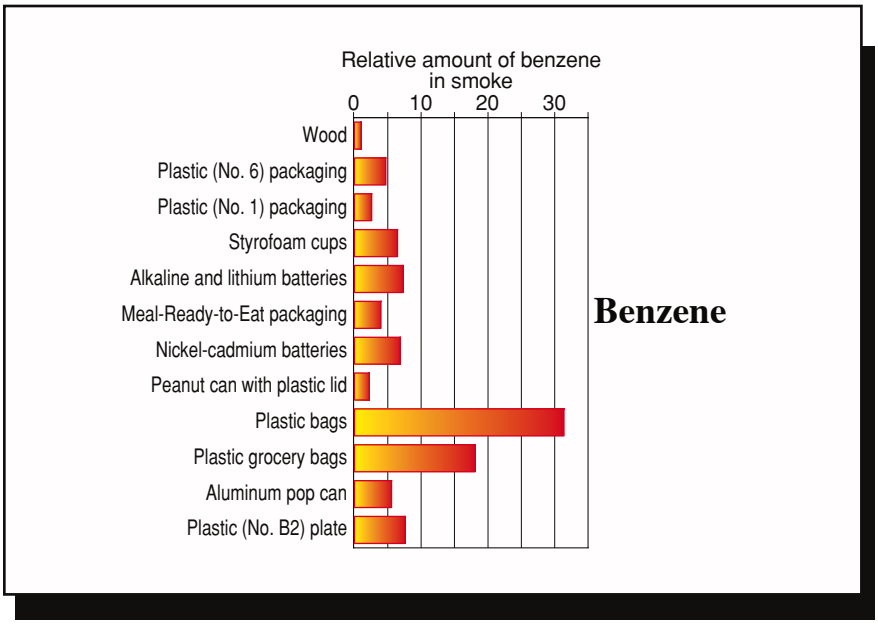

Figure 4—The amount of benzene—a suspected carcinogen—in a campfire's smoke increased, sometimes dramatically, when garbage items were added to the wood fire.

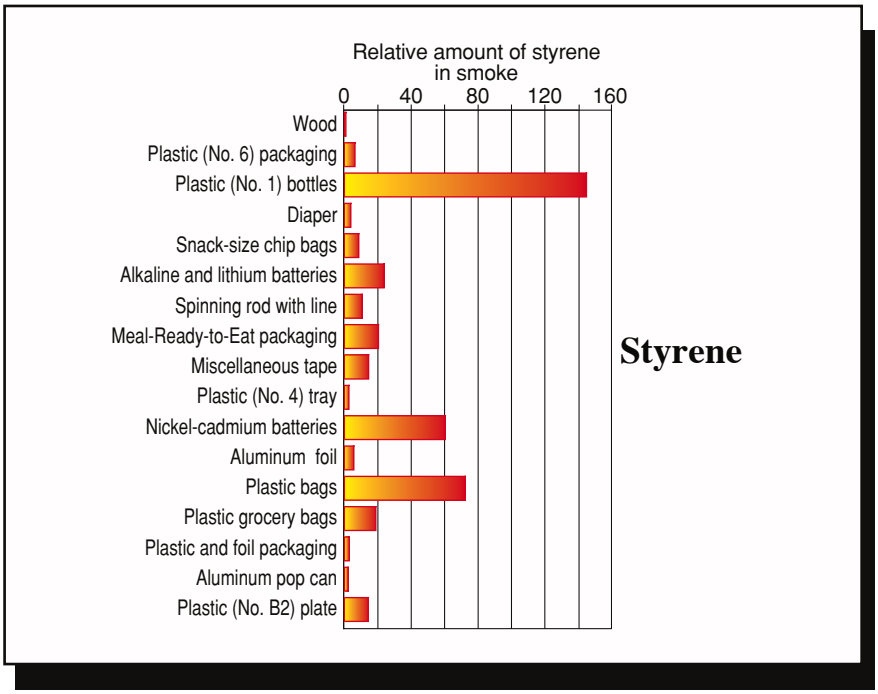

Figure 5—The amount of styrene—a suspected carcinogen—in a campfire's smoke increased, sometimes dramatically, when garbage items were added to the wood fire.

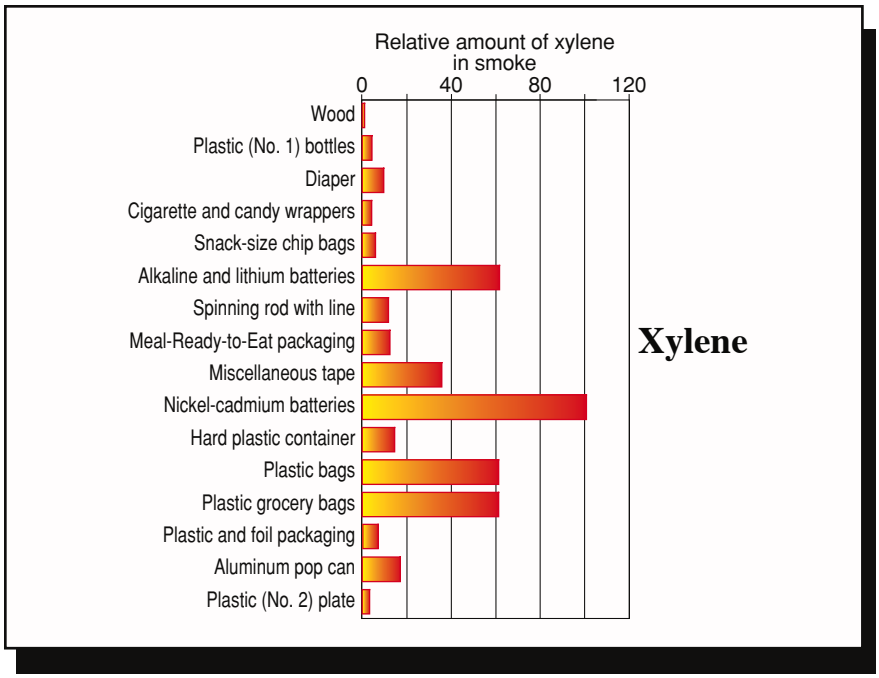

Figure 6—The amount of xylene—a suspected carcinogen—in a campfire's smoke increased, sometimes dramatically, when garbage items were added to the wood fire.

Toluene is abundant in the smoke of campfires that just burn wood. Only nickel-cadmium batteries (figure 7) released more toluene in smoke than wood. The fire was not large or hot enough to burn the batteries completely. If the batteries had been burned in a hotter fire, they could have released more chemical compounds.

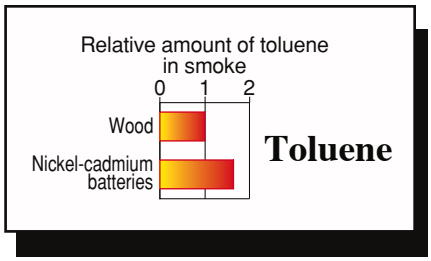

Figure 7—Nickel-cadmium batteries were the only garbage item that released more of the toxin toluene—a suspected carcinogen—than wood when burned in a campfire.

Only a small amount of acetaldehyde was released from campfires that just burned wood, but campfires that burned four different garbage items released large amounts of acetaldehyde (figure 8). The garbage items were:

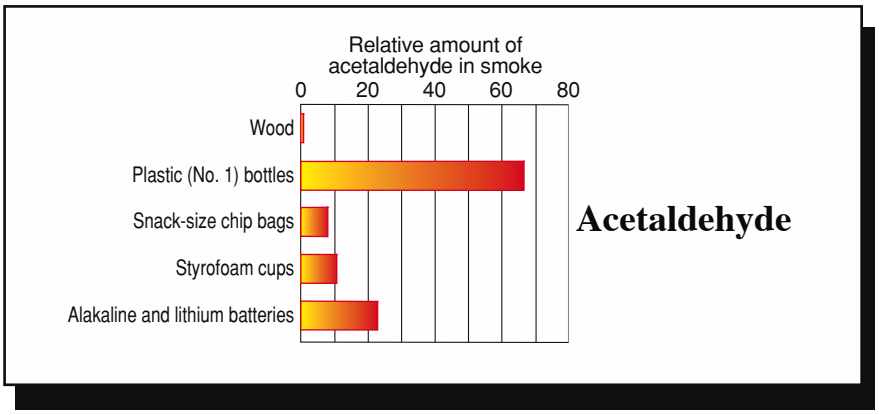

Figure 8—Compared to several garbage items, wood releases just a small amount of acetaldehyde when it is burned in a campfire. Acetaldehyde causes cancer in animals.

- Alkaline and lithium batteries
- Styrofoam cups
- Snack-size chip bags
- Clear plastic pop bottles

Acrolein is a major air pollutant and is a severe irritant to the eyes and nose. Burning plastic bags released large amounts of acrolein. Other products that released acrolein were styrofoam cups and alkaline and lithium batteries (figure 9).

When plastic bags were burned in a campfire, furan emissions were seven times higher than emissions from campfires that just burned wood (figure 10).

Campfires burning nickel-cadmium batteries and aluminum foil released more than four times as much naphthalene as campfires that just burned wood (figure 11).

Ash—Many elemental metals occur naturally in the Earth's crust and in rocks. Small amounts of many of these metals are necessary to support life. But in larger amounts, they may be toxic.

Several elemental metals that can be toxic to humans, animals, and plants were detected at elevated levels in campfires that burned garbage. They were

- Cadmium
- Lead
- Beryllium
- Mercury

Cadmium dust is carcinogenic to humans and animals. Cadmium is used in batteries and dyes. High levels were detected in the ash from campfires that

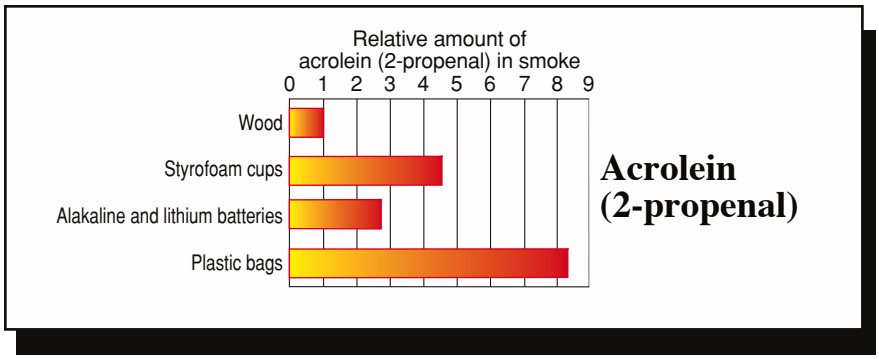

Figure 9—Very high amounts of the air pollutant acrolein (2-propenal) were released when plastic bags were burned in a campfire. Acrolein is toxic to aquatic organisms.

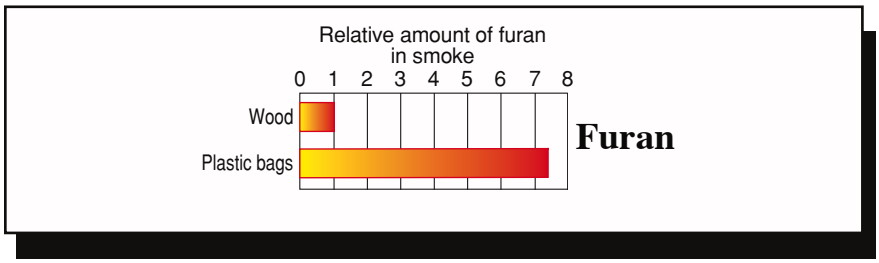

Figure 10—Emissions of furan were seven times as high when plastic bags were burned in a campfire than when the campfire just burned wood. Furan is on the U.S. Environmental Protection Agency's list of extremely hazardous stubstances.

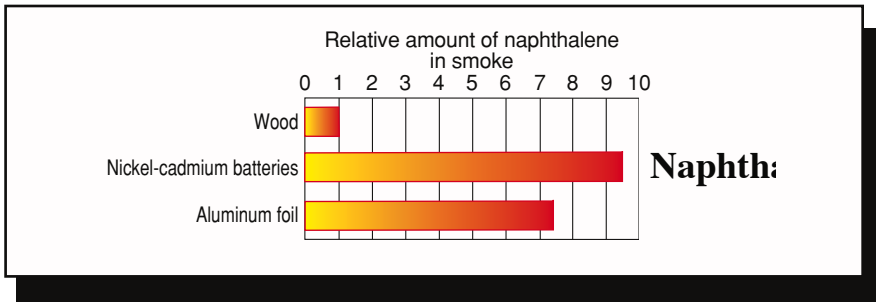

Figure 11—Campfires burning nickel-cadmium batteries and aluminum foil released much more naphthalene—a suspected carcinogen—than campfires that just burned wood.

burned nickel-cadmium batteries and in smaller amounts from campfires that burned a colored cardboard box and alkaline and lithium batteries (figure 12).

Although there is only limited evidence that beryllium causes cancer in humans, there is evidence that it causes cancer in animals. Beryllium levels were barely detectable in the ash from campfires that just burned wood. High levels of beryllium were detected in the ash of campfires that burned nickel-cadmium, alkaline, and lithium batteries (figure 13).

Lead is a suspected carcinogen and may affect the lungs and kidneys. Small amounts are present naturally in certain soils. Lead is used in storage batteries and for pigments in paint. A small amount of lead was detected in the ash from campfires that just burned wood. However, almost 10 times more lead was detected in the ash from the campfire that burned a broken fiberglass spinning rod. Additional garbage items that left elevated amounts of lead in the ash (figure 14) were:

- Nickel-cadmium batteries
- Packaging for freeze-dried meals
- Plastic forks and spoons
- Snack-size chip bags
- White plastic lids for disposable hot beverage cups

Exposure to high levels of mercury results in permanent nervous system and kidney damage. Mercury levels were barely detectable in the ash from campfires that just burned wood. The only garbage items that left more than three times as much mercury in the ash were cigarette and candy wrappers.

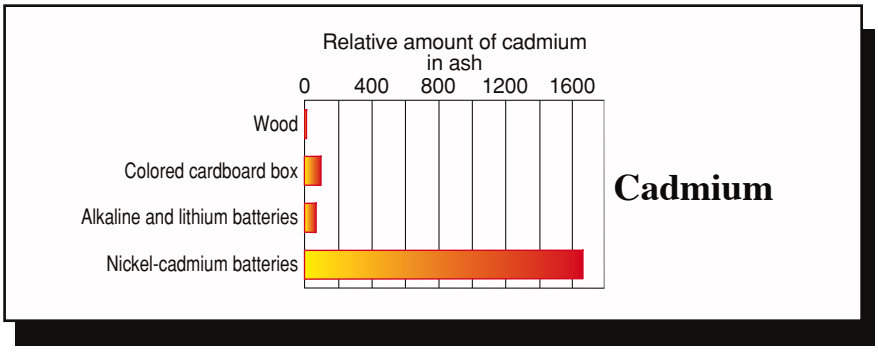

Figure 12—Nickel-cadmium batteries, colored cardboard, and alkaline and lithium batteries left higher levels of cadmium in the ash than did a campfire that just burned wood. Cadmium dust is carcinogenic to humans and animals.

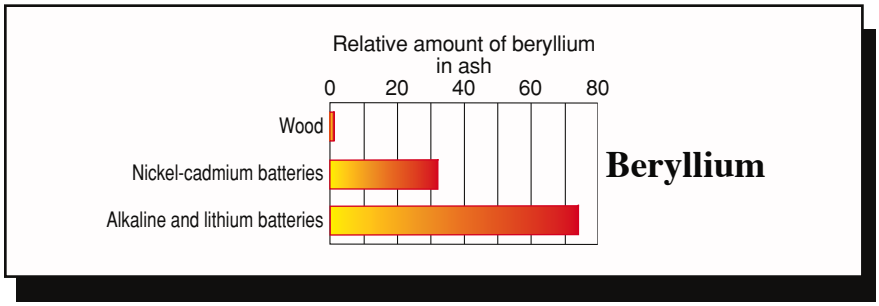

Figure 13—Ash from a campfire that burned nickel-cadmium and alkaline and lithium batteries had high levels of beryllium, which causes cancer in animals. Beryllium levels were barely detectable in the ash when the campfire just burned wood.

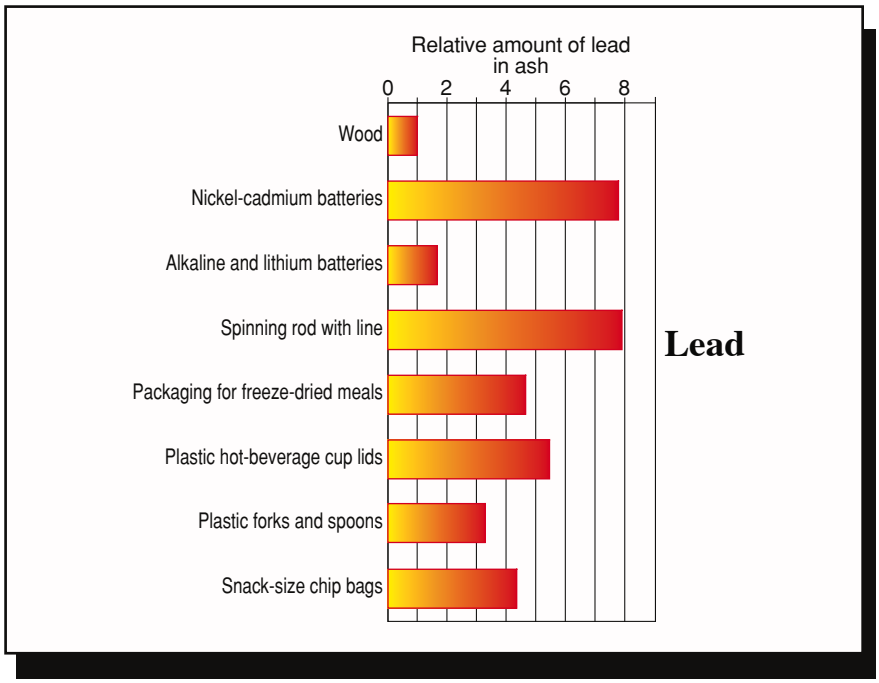

Figure 14—Some garbage items left elevated levels of lead—a suspected carcinogen—in the ash compared to a campfire that just burned wood.

Conclusions

We could find no studies on the contribution of toxic air pollutants from garbage burned in a campfire to short- or long-term health effects on humans or animals. This study shows that even campfires that just burn wood release a significant amount of air pollutants. Adding garbage to the campfire increases many of these air pollutants.

The ash left from a campfire that just burned wood is made up mainly of nontoxic elements. When garbage is burned in the campfire, toxic elements in the ash are greatly increased. Anyone handling the ashes from a campfire should wear gloves to reduce their exposure to toxic materials.

Several factors determine whether exposure to toxic air pollutants and elemental metals will pose health effects and how severe those effects will be. Some factors are: the amount and length of exposure; how it enters the body; and characteristics of individuals, such as age and gender.

This study was performed to simulate a campfire. The amount of pollutant produced by wood fires changes as the fires burn. A study conducted under controlled conditions that took the combustion efficiencies of different fuels into account could produce different results than those of this informal study.

The common-sense summary of the results of this study is: **Do not burn garbage in a campfire! Pack it in, pack it out.**

Acknowledgments

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About the Author

Mary Ann Davies received a bachelor's degree in mechanical engineering with a minor in industrial and management engineering from Montana State University in 1988. She worked in the Pacific Northwest Region as a facility engineer and as a tramway engineer. Mary Ann has worked in fire management as a crewmember and as a crewboss. She worked for 5 years with the Rocky Mountain Research Station in the fire chemistry and fire behavior groups before coming to MTDC in 1999.

Library Card

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Describes the results of an informal study during which samples of smoke and ash were collected from two campfires that just burned wood and 27 campfires that burned specific items of garbage in addition to the wood. Some of the items of garbage included plastic bags, disposable batteries, a fishing rod, a colored cardboard box, and the foil packaging used for freeze-dried foods. Even campfires that just burn wood release a significant amount of air pollutants, but when garbage is added to a campfire, the levels of many harmful air pollutants increase. The ash from a campfire that just burns wood primarily contains materials that are not toxic. When garbage is added to the campfire, increased levels of toxic materials are left in the ash.

Keywords: air quality, ash, batteries, camping, carcinogens, heavy metals, metallic elements, plastic bags, pollutants, recreation management, smoke, toxic substances, trash, wood

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