



# Cigarette butts may have low toxicity to soil-dwelling invertebrates: Evidence from a land snail

Hussan Gill, Kyler Rogers, Bilal Rehman, John Moynihan, Elizabeth A. Bergey \*

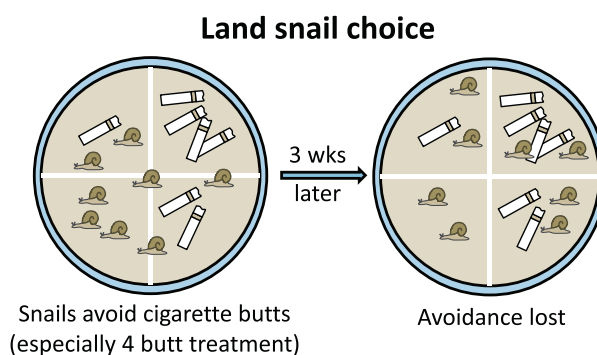
Oklahoma Biological Survey and Department of Biology, University of Oklahoma, Norman, OK 73019, USA



## HIGHLIGHTS

- Cigarette butts are commonly littered on the ground.
- Toxicity of cigarette butts to soil-associated organisms was unexplored.
- Cigarette butt effluent did not impact land snail survival, growth or feeding.
- Snails avoided fresh whole cigarette butts but avoidance subsided within a month.
- Cigarette butts may have low toxicity to soil-dwelling invertebrates.

## GRAPHICAL ABSTRACT



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## ABSTRACT

Cigarette butts are a common form of litter that is often deposited on soil, where toxins from butts may affect soil-dwelling organisms. We examined possible toxicity of cigarette butts to the woodland snail *Anguispira alternata* using a toxicity study with cigarette butt effluent and a lab-based habitat choice experiment in which snails could feed or rest on areas with different butt densities. No mortality occurred during the 32-day toxicity study, which used six effluent concentrations ranging from 0 to 4 butts/l (0 to 0.92 butts/kg of soil). Neither food consumption nor snail growth differed among the effluent concentrations. When provided a choice among four habitats with 0 to 4 cigarette butts, snails selected to preferentially rest in the 0-butt habitat and avoided the 4-butt habitat. This distribution pattern was strong during the first wk, but became weaker over time and largely disappeared by the end of the 3-wk experiment. Snails did not discriminate among butt densities when feeding. This is the first toxicity test using cigarette butts on soil-dwelling invertebrates. Declining aversion to cigarette butts over a 3-wk period may indicate declining toxicity of terrestrially deposited butts as they age, but further testing is needed.

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## 1. Introduction

Cigarette smoking produces chemically complex by-products. The toxicity of cigarette smoke, both directly to smokers and indirectly through second-hand smoke has been well documented and there is

increasing concern with thirdhand smoke, the residues left after smoke dissipates (Matt et al., 2011). A fourth component, cigarette butts, are also toxic (e.g., Booth et al., 2015; Lee and Lee, 2015; Slaughter et al., 2011) but this toxicity has received less study. Cigarette butts form a major litter type in urban areas (Bator et al., 2011; Moriwaki et al., 2009; Roder Green et al., 2014) and, because they can be moved by surface runoff into waterways, are also a litter problem along shorelines of lakes and oceans (Novotny et al., 2009; Register, 2000).

\* Corresponding author at: 111 E. Chesapeake Street, Oklahoma Biological Survey and Department of Biology, University of Oklahoma, Norman, OK 73019, USA.  
E-mail address: [lbergey@ou.edu](mailto:lbergey@ou.edu) (E.A. Bergey).

The toxicity of these butts is a newly recognized and growing area of interest, in part because of the high number of littered butts. Both the filters and unsmoked tobacco in cigarette butts contain a wide variety of chemicals (Moriwaki et al., 2009; Pelit et al., 2013; Shevchenko, 2012) rendering butts toxic (reviewed by Novotny and Slaughter, 2014). Worldwide, about 6.25 trillion cigarettes are smoked per year (2012 estimate; Ng et al., 2014) and although smoking prevalence is decreasing, population growth has resulted in increasing cigarette consumption between 2008 and 2012 (Ng et al., 2014). Much of the resulting mass of cigarette butts is deposited in the environment. Smokers often litter cigarette butts, in part because some smokers do not consider environmentally discarded butts to be litter (Bator et al., 2011; Patel et al., 2013; Rath et al., 2012). The cellulose acetate basis of filters is highly resistant to biodegradation and so much of the butt persists (Bonanomi et al., 2015; Puls et al., 2011) - and may continue to leach chemicals. Indeed, cigarette butts are considered hazardous waste (Barnes, 2011).

Laboratory toxicity studies have demonstrated that cigarette butts, in the form of aqueous leachate, are toxic to aquatic organisms; including microorganisms (*Vibrio fischeri*; Micevska et al., 2006), zooplankton (*Daphnia magna* and *Ceriodaphnia dubia*; Micevska et al., 2006; Register, 2000; respectively), mosquito larvae (*Aedes albopictus*; Dieng et al., 2011), tidepool snails (three species; Booth et al., 2015), frogs (*Xenopus laevis* larvae; Parker and Rayburn, 2017) and fishes [freshwater flathead minnows, *Pimephales promelas* and marine topsmelt, *Atherinops affinis* (Slaughter et al., 2011), and embryos of the Japanese rice fish *Oryzias latipes* (Lee and Lee, 2015)]. Acute toxicity occurs at levels as low as one cigarette butt per liter of water.

Despite the frequency of butt litter on land, land-based toxicity studies have been overlooked. In the one exception, house finches (*Carpodacus mexicanus*) incorporate shredded cigarette butts into their nests, which reduced nest-associated ectoparasites (Suárez-Rodríguez et al., 2013); indeed, house finches apparently adjust filter use in response to parasite levels (Suárez-Rodríguez and Garcia, 2017). Whether cigarette butts were toxic or repellent to ectoparasites was not mentioned in these studies. Incorporating cigarette butts in nests was associated with higher fledgling success but also a greater incidence of abnormalities in the nuclei of red blood cells, an indicator of toxicity (Suárez-Rodríguez and Macías Garcia, 2014).

Our research objective was to test for possible toxicity of cigarette butts to soil-associated invertebrates - targeting land snails. Many butts end up directly on the soil or mixed with leaf litter, where butts and effluent from butts can affect soil-dwelling invertebrates, including

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