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Blending foundry sands with soil: Effect on dehydrogenase activity

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Abstract

Each year U.S. foundries landfill several million tons of sand that can no longer be used to make metalcasting molds and cores. A possible use for these materials is as an ingredient in manufactured soils; however, potentially harmful metals and resin binders (used to make cores) may adversely impact the soil microbial community. In this study, the dehydrogenase activity (DHA) of soil amended with molding sand (clay-coated sand known as "green sand") or core sands at 10%, 30%, and 50% (dry wt.) was determined. The green sands were obtained from iron, aluminum, and brass foundries; the core sands were made with phenol–formaldehyde or furfuryl alcohol based resins. Overall, incremental additions of these sands resulted in a decrease in the DHA which lasted throughout the 12-week experimental period. A brass green sand, which contained high concentrations of Cu, Pb, and Zn, severely impacted the DHA. By week 12 no DHA was detected in the 30% and 50% treatments. In contrast, the DHA in soil amended with an aluminum green sand was 2.1 times higher (all blending ratios), on average, at week 4 and 1.4 times greater (30% and 50% treatments only) than the controls by week 12. In core sand-amended soil, the DHA results were similar to soils amended with aluminum and iron green sands. Increased activity in some treatments may be a result of the soil microorganisms utilizing the core resins as a carbon source. The DHA assay is a sensitive indicator of environmental stress caused by foundry sand constituents and may be useful to assess which foundry sands are suitable for beneficial use in the environment.

Keywords: Beneficial use; Dehydrogenase; Green sand; Heavy metals; Resin binders; Soil microbial activity; Waste foundry sand

1. Introduction

Each year U.S. ferrous and non-ferrous foundries generate between 6 and 10 million tons of waste foundry sand (WFS) that can no longer be used to make metalcasting molds and cores. The majority of this sand is landfilled as non-hazardous waste in municipal and private landfills (only 2% is considered

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hazardous waste), with the exception of about 10% that is being beneficially used (U.S. EPA, 2002). The U.S. Environmental Protection Agency (EPA) estimates that much of this landfilled foundry sand can be used outside the foundry industry. Waste foundry sands are suitable for geotechnical applications (e.g., road bases and structural fills) and as an aggregate for manufactured products (e.g., cement, concrete, asphalt, and soil manufacturing) (U.S. DOT, 2003). The major component of the WFS is silica sand which may contain residual materials such as bentonite clay (western and/or southern), carbonaceous additives (e.g., seacoal), and resins used to bind core sands.

Although many states have beneficial use regulations for industrial byproducts, the most stringent state requirements apply when byproducts are being land applied or used as an ingredient in soil blends, amendments, or composts (U.S. EPA, 2002). In general this is because state regulatory agencies lack the necessary scientific data to make reasonable policy decisions regarding the beneficial use of WFSs in manufactured soils (e.g., horticultural soils, topsoil, and potting soil). Current regulations require that WFSs be tested using the Toxicity Characteristic Leaching Procedure (TCLP, U.S. EPA SW-846 method 1311) to determine if they are hazardous waste. According to the TCLP test, many foundry sands (especially molding sands from ferrous foundries) do not qualify as hazardous waste and apparently present little threat to ground waters (Ham et al., 1993; Ji et al., 2001).

Waste foundry sands can be used to produce manufactured soils and other agricultural products (Jing and Barns, 1993); however, potential WFS constituents, such as heavy metals and resins used to bind core sands, may impact soil microorganisms. In this study, we monitored the dehydrogenase activity (DHA) in soil that was blended with WFSs, specifically “green sands” (bentonite coated sands used to make metalcasting molds) from iron, aluminum, and brass foundries, and core sands that either contain phenol–formaldehyde, phenolic urethane, or furfuryl alcohol resins. Overall, the DHA assay may be a useful technique to identify WFSs that could cause negative impacts when beneficially used in the environment. Because of the high heavy metal concentrations usually found in brass green sands, green sands from iron and aluminum foundries appear to be the most amenable to beneficial use in manufactured soils or other environmental applications. This study also addresses the beneficial use of resin-coated core sands. Information obtained in this study will be useful to state regulatory agencies when developing beneficial use regulations for WFSs.

2. Materials and methods

2.1. Soil, silica sand, and foundry sands

The soil used in this study is a Sassafras sandy loam (Fine-loamy, siliceous, semiactive, mesic Typic Hapludults). Soil was taken from the Ap horizon of an agricultural field on the eastern shore of Maryland, passed through a 2-mm sieve and stored at 5 °C prior to its use. The soil has a pH of 6.2, organic matter content of 1.05%, electrical conductivity of 0.15 dS m^{-1}, and a maximum water holding capacity of 0.24 kg kg^{-1}.

The silica sand was obtained from U.S. Silica (Berkeley, WV) and is specifically graded for use as molding sand. The sand was 99.0–99.9% quartz by weight.

Foundry sands consisted of green sands and core sands. Tables 1 and 2 provide a description of the green and core sands, respectively. The particle size distribution (Fig. 1) of these materials was determined by pipette and sieving (Gee and Bauder,

Table 1
Description of green sands

Sample ID	Metal poured	Core binder system	Sample description
GS1	Iron	Phenol–formaldehye, furfuryl alcohol	Spent system sand
GS2	Iron	Phenolic urethane	Spent system sand
GS3	Aluminum	Phenolic urethane	Spent system sand
GS4	Aluminum	Phenol–formaldehye	Spent system sand
GS5	Brass	Core oil, phenol–formaldehyde, phenolic urethane	Excess system sand