A SAND LAYER DETERS BURROWING BY LUMBRICUS TERRESTRIS L.

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Burrows of anecic earthworms that penetrate the infiltrative surface of soil-wastewater treatment system trenches may contribute to preferential flow through soil macropores in septic system filter fields. Adding a layer of sand on the bottom of the trench, however, may discourage earthworm burrowing. In this laboratory study, we investigated if the particle-size distribution and position of a sand layer would inhibit burrowing by the anecic earthworm Lumbricus terrestris L. Three earthworms were added to the top of soil columns containing a 3-cm-thick sand layer covered with 2 mm of loamy B—horizon material and underlain by 9 cm of the same material. We repeated this experiment with earthworms placed below the sand layer. In another experiment, the sand layer was covered by 11.3 cm of soil material to investigate whether worms added to the surface would avoid crossing a sand layer embedded within the columns. No treatments in the surface sand layer experiments prevented all worms from establishing burrows. The worms added to the surface, however, took an average of 1.7 to 5 times longer (P < 0.05) to establish burrows, and earthworm mortality was greater in columns with a surface sand layer compared with the no-sand-layer controls. In the embedded-sand-layer experiment, no worms burrowed past the soil-sand interface, whereas all worms in the controls burrowed past the equivalent depth. Sand particle size distribution did not significantly affect earthworm burrowing. The results suggest that adding a layer of sand to the bottom of soil treatment system trenches may deter earthworms, but will not restrict burrowing. (Soil Science 2008;173:186–194)

Key words: Lumbricus terrestris, earthworms, sand, septic systems, wastewater.

MOST on-site wastewater treatment systems in the United States are soil treatment systems (US EPA, 2002, p. 1–1). In these systems, successful renovation is dependent on the soil having an appropriate hydraulic conductivity. Typically, the wastewater is pretreated in a septic tank, and the effluent is transmitted to gravel-filled trenches in the absorption field where the effluent infiltrates into the soil. As the effluent percolates through the soil, pollutants are removed by natural processes, including biologically mediated oxidation, chemical sorption, and physical filtration (Miller and Wolf, 1976). To ensure adequate renovation, the effluent must contact a great enough volume of soil for a sufficient period. In general, the lower the hydraulic conductivity, the greater the potential for renovation, provided the effluent does not overflow onto the soil surface.

In absorption fields, the hydraulic conductivity is particularly important at the trench-soil interface. Bacteria in this infiltrative surface grow under conditions of excess carbonaceous nutrients and store excess polysaccharides as slime capsules (Tyler et al., 1977). The slimy
bacterial films coating soil aggregates trap additional bacteria and particles, creating a "clogging zone" of reduced hydraulic conductivity (Otis, 1985; US EPA, 2002, p. 4-4). Ideally, the reduced infiltration through this zone will allow unsaturated flow of effluent through the soil below the trench, thus providing a greater volume of aerobic soil for renovation processes. Preferential flow of effluent in biopores (i.e., burrows, roots, etc) may contribute to incomplete renovation, particularly when the biopores intersect the infiltrative surface. Bouma et al. (1975) observed fresh earthworm excretions and large, open, vertical channels in the infiltrative surface of a soil-treatment trench bottom and attributed higher than expected flow rates of effluent into the soil to the dynamic system of large pores created by soil fauna. Mote and Buchanan (1994) also found evidence of the effects of macro pores intersecting the infiltrative surface. They reported that when soil at the bottom of a treatment trench was tilled, renovation was enhanced compared with an undisturbed trench bottom, suggesting that tilling disrupted the channels formed by roots and earthworms that might have otherwise intersected the base of the trench.

Earthworm-burrowing activity may have a significant impact on on-site soil renovation of household wastewater. Earthworm burrows affect soil hydrology, and their possible effects on septic tank effluent infiltration and movement in the soil may be greater than anticipated because earthworm population density can be elevated in the nutrient-rich environment near soil treatment trenches. Hawkins (2006) measured an average of 6.4 fold more earthworms and 5.4 fold more earthworm biomass within 1 m of soil treatment trenches than in the background (3.5–7.0 m from the trenches). Infiltration rates at the soil surface can be 4 to 10 fold greater in soils with earthworms than in soils without earthworms (Edwards and Bohlen, 1996, p. 209). In addition, Ehlers (1975) determined that water could infiltrate through an individual earthworm burrow at more than 100 mL/min (steady state), and Bouma et al. (1982) measured average steady-state infiltration rates of 140 mL/min in near-vertical individual earthworm channels up to 1.6 m deep.

Earthworm species can be classified into three ecological groups, epigeic, endogeic, and anecic, based on their burrowing and feeding habits (Edwards and Bohlen, 1996, p. 113). Epigeic species’ burrowing activity is usually restricted to the upper few centimeters of soil. Endogeic species make largely horizontal burrows and are usually present in the upper 10 to 15 cm of soil. Anecic species form vertical burrows, sometimes branched, that open at the soil surface and descend deep into the soil. The burrows created by anecic earthworms such as Lumbricus terrestris are of particular concern in soil renovation because they can greatly affect soil hydrology. These large vertical burrows can act as preferential flow paths that may allow effluent to be transmitted to groundwater before renovation processes are complete. Burrows of L. terrestris can be up to 12 mm in diameter and 2.4 m deep (Edwards and Bohlen, 1996, p. 198).

Moreover, Jones et al. (1993) reported that when L. terrestris were added to soil columns dosed regularly with septic tank effluent, the steady-state flux density of effluent through the columns increased from 1.9 to 2.9 to 5.3 to 12.4 μm s⁻¹. When this test was conducted on columns with added Lumbricus rubellus Hoff. (an epigeic species), the flux increased from 2.3 to 2.7 to 4.8 to 10.3 μm s⁻¹.

Addition of a sand layer to the bottoms of soil treatment trenches may be one way of reducing preferential flow of effluent through earthworm burrows. The benefits of a sand layer may be two-fold. First, the sand could enhance unsaturated flow by partially filling existing earthworm-created macropores. Bouma et al. (1982) observed that applying a 5-cm-thick layer of sand to the soil surface reduced preferential movement of surface-applied water through macropores.

Second, the sand may serve to discourage earthworms from burrowing through the infiltrative surface and forming new macropores. Earthworms are absent or rare in coarse-textured soils, which may be caused by low water-holding capacity and organic matter (Edwards and Bohlen, 1996, p. 146) or physical abrasion to their bodies (Lee, 1985, p. 54). Guild (1948, 1951) determined that earthworms are most common in loams and less common in heavy clays and gravelly sands. More recently, Hendrix et al. (1992) correlated earthworm abundance to silt content and observed significantly higher earthworm numbers in moderately to severely eroded sandy clay loams than in less-eroded soil with higher sand content. Other researchers have found a positive correlation between clay content and earthworm abundance (Nordstrom and Rundgren, 1974; Baker et al., 1992).

If earthworms are deterred by sand, adding a layer of sand to the bottom of soil treatment
trenches may prevent earthworms from penetrating this infiltrative surface. Although we are concerned about the effect of macropores on renovation of septic tank effluent, we realize we cannot reproduce the conditions in and around a soil treatment trench in the laboratory. Therefore, we have limited our work to fundamental questions that can be tested in the laboratory to determine if further investigation into the possibility of sand as a deterrence mechanism is warranted for soil treatment trenches or other applications such as golf courses, site restoration, and tile drains in agricultural fields. Therefore, our objective was to investigate the effect of a sand layer on *L. terrestris*' burrowing activity in soil columns. Specifically, we evaluated whether *L. terrestris* could burrow through a sand layer from both above and below the layer, whether *L. terrestris* would avoid burrowing through a sand layer if given an alternative, and whether the particle size distribution of sand used had an effect on burrowing. We hypothesized that *L. terrestris* would not cross a 3-cm-thick layer of sand in any of our experimental conditions.

**MATERIALS AND METHODS**

**Experimental Design**

Four separate laboratory experiments were conducted to determine if *L. terrestris* would burrow through a 3-cm-thick layer of sand within columns of loamy soil (Fig. 1). For each experiment, there were three replicate no-sand-layer control columns and three replicate experimental treatment columns. Three *L. terrestris* were added to each column for a total of 9 worms for the control and 9 worms per experimental treatment. Because we were only interested in whether *L. terrestris* would burrow through the sand layer, the columns were sized just large enough for the worms to establish burrows, thus the depth of soil was less than what would be typical in field conditions.

The first experiment, referred to as the single-treatment surface-sand-layer experiment, tested whether earthworms added to the soil surface could burrow through a layer of Quikrete® medium commercial-grade sand (Table 1). The sand layer was placed 0.2 cm from the surface of the soil column to require the worms to cross the sand to establish their burrows (Fig.1A). The 0.2 cm of soil placed above the sand layer ensured that the earthworms would have enough soil material to avoid initial exposure to the sand but not enough soil to cover themselves in an attempt to delay burrow establishment. The experiment was terminated when all worms either crossed the sand layer or died on the surface.

The second experiment, referred to as the multiple-treatment surface-sand-layer experiment, was similar to the first except that three sands types of differing particle-size distribution were compared (Table 1). The goal was to compare the effect of different readily available sands on the ability of earthworms to avoid initial exposure to the sand but not enough soil to cover themselves in an attempt to delay burrow establishment. The experiment was terminated when all worms either crossed the sand layer or died on the surface.

**TABLE 1**

<table>
<thead>
<tr>
<th>Sand material</th>
<th>VCS</th>
<th>CS</th>
<th>MS</th>
<th>FS</th>
<th>VFS</th>
<th>TS</th>
<th>Silt + Clay</th>
<th>Textural class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quikrete medium commercial-grade sand</td>
<td>14.9</td>
<td>39.0</td>
<td>42.1</td>
<td>3.5</td>
<td>0.0</td>
<td>99.4</td>
<td>0.6</td>
<td>Coarse sand</td>
</tr>
<tr>
<td>Quikrete All-purpose sand</td>
<td>20.3</td>
<td>14.4</td>
<td>31.0</td>
<td>32.8</td>
<td>0.9</td>
<td>99.3</td>
<td>0.8</td>
<td>Coarse sand</td>
</tr>
<tr>
<td>Concrete sand (ASTM C33)</td>
<td>18.0</td>
<td>27.2</td>
<td>37.6</td>
<td>15.1</td>
<td>1.4</td>
<td>99.2</td>
<td>0.8</td>
<td>Coarse sand</td>
</tr>
<tr>
<td>Mason sand (ASTM C144)</td>
<td>4.6</td>
<td>24.0</td>
<td>58.6</td>
<td>12.4</td>
<td>0.2</td>
<td>99.8</td>
<td>0.3</td>
<td>Sand</td>
</tr>
</tbody>
</table>

1VCS indicates very coarse sand (1.0–2.0 mm); CS, coarse sand (1.0–0.5 mm); MS, medium sand (0.5–0.25 mm); FS, fine sand (0.25–0.10 mm); VFS, very fine sand (0.10–0.05 mm); TS, total sand (0.10–2.0 mm).

**Fig. 1.** Design of soil columns. A, Surface-sand-layer column. B, Embedded-sand-layer column.
terminated when all worms either crossed the sand layer or died on the surface.

The third experiment was similar to the second, except that three earthworms were added below the sand layer by placing them about midheight in the lower soil layer during column construction. Thus, this experiment tested the ability of the earthworms to cross multiple types of sand from below, which is important because we are concerned with penetration of soil treatment trenches from below. Unlike the first two experiments, failure to cross the sand layer would not necessarily result in death during the experiment, and a predetermined experiment duration (3 weeks) was selected based on the burrowing time in previous experiments.

The fourth experiment, referred to as the embedded-sand-layer experiment, tested whether the worms would avoid crossing a sand layer if given enough soil to establish burrows above the sand. The columns used in this experiment had an additional 11.1 cm of soil placed on top of the sand layer (Fig. 1B). The same three sand types used in the second and third experiments were compared, and the worms were placed on top of the columns. Thus, the worms could avoid crossing the sand layer by terminating their burrows at or above the soil-sand interface. The duration of this experiment was the same as the third experiment.

**Column Construction**

For the surface-sand-layer experiments, 18.5-cm-tall cylindrical Polyvinyl chloride (PVC) columns with a 10.7-cm inside diameter were constructed by joining two 9.25-cm long pipe couplings with duct tape. Couplings were used because they have a 0.3 × 0.3-cm ring (i.e., a slight protrusion) in the center of their inside wall that discouraged earthworms from preferentially burrowing along the wall of the column to minimize ingestion or contact with the sand (Fig. 1). To ensure adequate aeration, the bottoms of all columns were covered with cheesecloth, and then they were placed in a tub containing a 7-cm-thick layer of sand. Afterward, loamy soil was added to the columns to a depth of 9.0 cm, and a 3-cm-thick sand layer was placed on top of the soil. The sand layer extended 0.2 cm above the protrusion. Finally, a 0.2-cm layer of soil was placed on top of the sand. The total depth of the material inside the columns was 12.2 cm (Fig. 1A).

For the embedded-sand-layer experiment, 28.8-cm-long cylindrical PVC columns were constructed by joining three 10.7-cm inside diameter, 9.25-cm long couplings with duct tape. Treatment and filling of these columns were similar to the surface sand layer columns except that an additional 11.1 cm of loamy soil was placed on top of the sand layer. When filling was complete, the total depth of the material inside the columns was 23.3 cm (Fig. 1B).

The soil material used in all experiments was collected from the B horizons of a Peridge soil (fine-silty, mixed, active, mesic Typic Paleudalfs). Subsoil B-horizon material was used because soil treatment trenches often extend into this horizon. The sample contained approximately 230 g kg⁻¹ sand, 260 g kg⁻¹ clay, and 1.5 g kg⁻¹ organic C (Jones et al., 1993). The soil was air dried, crushed, mixed, and sieved with less than or equal to 2-mm-diameter fraction retained for addition to the columns. Soil material was added to the columns in thin layers (approximately 1 cm) and remoistened by spraying water on each layer to achieve a moist friable consistence. The water content of the soil material was approximately 19% by weight (measured at the conclusion of the experiment), and the bulk density (oven dry) was approximately 1.18 g cm⁻³. Sand was also added to the column in layers and moistened by spraying. Quikrete medium commercial-grade sand was used in the single-treatment surface-sand layer experiment, whereas the columns in all other experiments had layers of Mason sand, Concrete sand, or Quikrete® All-purpose sand (Table 1). The water content of the sand was approximately 2% by weight (measured at the conclusion of the experiment), and the bulk density was approximately 1.21 g cm⁻³.

**Column Operation and Observations**

In all experiments, three *L. terrestris* (90 worms per m²) (Canadian Nightcrawlers from DMF Bait Co., Waterford, MI) were added to each treatment or control (no sand layer) column. The tops of the columns were covered with perforated plastic wrap to prevent the worms from escaping. The columns were observed at least once a day. For experiments in which worms were added to the soil surface, burrows were considered established when the worms were no longer visible. Worms that died on the surface were removed upon first observation, and the date of death was recorded. Dead worms were not replaced. Partially
decayed grass clippings were added as a food source in roughly equal amounts to the top of each column after worms in all columns established burrows. Litter was not added to columns in which worms were placed below the sand layer because the litter would have obscured observation of activity at the surface of the soil. Water was added to the columns as needed to maintain a moist friable soil consistency. An air temperature of about 22 °C was maintained, and the columns were lighted for 7 to 8 h daily with overhead fluorescent lights.

In the surface-sand experiments where worms were added to the soil surface, columns were dismantled, and live worms were counted after all worms had either established burrows or died on the surface. The single-treatment experiment lasted 7 days, and the multiple-treatment experiment lasted 15 days. In the surface-sand experiments, where worms were added below the sand layer, a count was conducted for burrow openings at the surface, burrows that terminated at the lower sand-soil interface, live worms, and torpid worms at 3 weeks. A “torpid worm” was defined as a worm that initially showed no movement upon handling, but was determined to be alive after prodding with tweezers. In the embedded-sand-layer experiment, columns were dismantled, and burrows were examined at 3 weeks. The location where each burrow terminated was recorded as above the upper soil-sand interface, at the upper soil-sand interface, within the sand layer, or below the sand layer. In the no-sand layer control columns, burrow positions were classified based on the equivalent location in the treated columns. The number of live worms was also recorded.

**Data Analysis**

In all experiments, replicates were combined and treated as a single sample. For the surface-sand-layer experiments, where worms were added to the top of the columns, the average time until burrow establishment in each treatment and control was calculated. These means were then compared using either Student's t test or analysis of variance with \( P \leq 0.05 \) selected as the minimum level accepted for significance. The number of worms that established burrows in each treatment and control group was totaled, and percent survival after burrow establishment (i.e., the fraction of worms that established burrows and survived to the end of the experiment) was calculated. Days until death were determined for the worms that died on the surface of columns. When worms were added below the sand layer, the number of burrow openings on the surface and at the lower sand-soil interface was totaled, and percent live, dead, and torpid worms were determined. In the embedded-sand-layer experiment, the number of live worms and the number of burrows in each category were totaled for each treatment type and the control columns.

**RESULTS AND DISCUSSION**

**Surface-Sand-Layer Experiments**

**Worms Added to the Surface**

In the single-treatment surface-sand-layer experiment, all earthworms established burrows. The earthworms in the control columns, however, constructed burrows five times faster than those that were forced to burrow through the sand (Table 2). Similarly, in the multiple-treatment surface-sand-layer experiment, the earthworms took significantly longer to establish burrows in each of the three sand types than in the no-sand layer control columns (Table 2). In this experiment, however, one worm in each of the sand-layer treatments died after failing to establish a burrow 9 to 12 days after being placed in the columns. In addition, mortality of the earthworms after they established burrows was greater for those that burrowed through Mason and All-purpose sand than those that burrowed through Concrete sand and in the control columns. These observations suggested that the sand layer deterred, but did not prevent, burrow establishment by *L. terrestris*.

Most of the burrows were located near the edge of the column. However, because of the protrusion in the PVC pipe, the worms were not able to establish their burrows directly against the wall of the PVC pipe as was observed in some preliminary experiments conducted without a protrusion. The worms seem to favor burrowing along the walls of the pipe, regardless of the presence of a sand layer. We speculate that this is in part caused by the limited space provided.

With all sand types, the segments of most of the burrows that passed through the sand layer were lined with soil. These burrow segments in the sand layer appeared rigid and remained intact upon removal of the sand at the end of the experiments (Fig. 2). Anecic earthworms frequently line their burrows with a mixture of
TABLE 2

Performance of earthworms (*L. terrestris*) added to the surface of soil columns consisting of loamy soil and a 3-cm-thick sand layer 2-mm from the surface, or loamy soil only (control)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Burrow establishment</th>
<th>Survival after burrow establishment</th>
<th>Average time until burrows established</th>
<th>Time until death of worms that did not establish burrows</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Worms</td>
<td>%</td>
<td></td>
<td>days</td>
</tr>
<tr>
<td></td>
<td>Single treatment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>9</td>
<td>89</td>
<td>1a $^5$</td>
<td>-</td>
</tr>
<tr>
<td>Medium Sand</td>
<td>9</td>
<td>89</td>
<td>5b</td>
<td>-</td>
</tr>
<tr>
<td>Multiple treatment</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>9</td>
<td>100</td>
<td>3a</td>
<td>-</td>
</tr>
<tr>
<td>Mason Sand</td>
<td>8</td>
<td>75</td>
<td>5b</td>
<td>9</td>
</tr>
<tr>
<td>Concrete Sand</td>
<td>8</td>
<td>100</td>
<td>6b</td>
<td>12</td>
</tr>
<tr>
<td>All-purpose Sand</td>
<td>8</td>
<td>88</td>
<td>8b</td>
<td>9</td>
</tr>
</tbody>
</table>

$^1$Burrows were considered established when worms were no longer on the surface of columns.

$^2$Worms that established burrows and survived within the columns until the end of the experiment, which was 7 days in the single-treatment experiment and 15 days in the multiple-treatment experiment.

$^3$Within experiments, means followed by the same letter are not significantly different ($P \leq 0.05$).

Ejected soil and mucus, and the portion of the surrounding soil affected by this activity is referred to as the drilosphere (Edwards and Bohlen, 1996, p. 197). In the case of *L. terrestris*, these linings are generally 1- to 2-mm thick but are relatively thin and patchy in the upper 2 to 3 cm of their burrows (Stehouwer et al., 1993). In our experiments, the presence of these linings near the soil surface stabilized the burrow segments that passed through the sand layer and perhaps minimized contact with the abrasive sand grains when the worms traversed their burrows to forage on the surface. Worms that failed to establish burrows and died all had bloody mouths and large sand grains adhering to the sides of their bodies (Fig. 3). In addition, one worm that died on the surface of an All-purpose sand-treated column had a large grain of sand lodged in its mouth (Fig. 3). These observations suggested that ingestion or contact with the types of sand tested was deleterious to earthworm survival.

*Worms Added Below Sand Layer*

In the experiment in which the earthworms were placed below the sand layer, the worms did not immediately burrow to the soil surface. At the end of the experiment, there were 10 burrow openings on the surface in the control and 8 to 11 openings in the treatments (Table 3). Thus, some of the earthworms must have made burrows with multiple openings at the soil surface. There were 3 burrow openings at the lower sand-soil interface in all columns except in one Concrete

Fig. 2. Intact burrow that was within sand layer of a column shown after most of the sand was removed. Side view (A) and top view (B) have white arrows pointing to the burrow.
one or more worms may have made multiple openings through the sand layer. Although survival rate was high in the control and treatments, the significantly higher mean percentage of dead or torpid worms in the Concrete and All-purpose treatments (Table 3) suggested that the sand in these treatments had a negative effect on earthworm vigor. In the long-term, these earthworms would probably not survive. In an actual field application of a sand layer at the base of a soil trench, the sand layer could potentially lead to a reduction in the population of anecic earthworms.

**Embedded-Sand-Layer Experiments**

In the experiment where the sand layer was placed 11.3 cm below the soil surface, all worms in the treatment and control columns established burrows. No obvious difference was observed in how fast the worms in the various treatments established burrows. When the columns were disassembled after 3 weeks, burrows of 8 out of 9 worms in the control group terminated at a depth corresponding to within the sand layer in the treated columns. The ninth burrow in the control group terminated at a depth below the equivalent depth of the sand layer in the treated columns. In the treated columns, there were no burrows within or below the sand layer, and most burrows terminated at the upper soil-sand interface (Table 4). Some burrows seemed to bend horizontally across the surface of the sand before terminating. Only one worm in the Mason sand and one in the Concrete sand perished after burrow establishment during the course of the experiment (Table 4). This experiment does not provide conclusive evidence that worms will not burrow through sand if given the choice to avoid sand by burrowing exclusively in soil, but it does suggest that a sand layer deters worms because no worms burrowed past the soil-sand interface. In

<table>
<thead>
<tr>
<th>Treatment</th>
<th>At soil surface</th>
<th>At lower sand-soil interface</th>
<th>Survival</th>
<th>Average dead or torpid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>10</td>
<td>9</td>
<td>100</td>
<td>0a</td>
</tr>
<tr>
<td>Mason sand</td>
<td>11</td>
<td>9</td>
<td>89</td>
<td>11a</td>
</tr>
<tr>
<td>Concrete sand</td>
<td>8</td>
<td>8</td>
<td>78</td>
<td>78b</td>
</tr>
<tr>
<td>All-purpose sand</td>
<td>9</td>
<td>9</td>
<td>67</td>
<td>56b</td>
</tr>
</tbody>
</table>

1Worms that initially showed no movement upon handling, but responded to prodding with tweezers.

2Within column, means followed by the same letter are not significantly different ($P \leq 0.05$).
contrast, all worms burrowed within or below that depth in the controls. There was no obvious difference in the effect of the sand types investigated on burrowing.

CONCLUSIONS AND IMPLICATIONS

In our experiments, *L. terestris* was able cross a 3-cm-thick sand layer from both above and below, but we observed reduced rates of burrow establishment, more torpid and dead worms, and failure to penetrate the sand when soil above the sand layer was available for burrow establishment; therefore, sand must provide some mechanism of deterrence. As mentioned previously, low moisture and organic matter (Edwards and Bohlen, 1996, p. 146) or physical abrasion (Lee, 1985, p. 54) may explain the scarcity of earthworms in course-textured soils. Perhaps the lack of structural integrity of burrows built with sand is also a factor. Although the mechanism of deterrence was not explicitly tested here, our results suggest that physical abrasion is an important factor.

Regardless of the deterrence mechanism, the addition of a sand layer to the bottoms of soil treatment trenches may be one way of reducing preferential flow of effluent through earthworm burrows. Deterring earthworms from burrowing through trench bottoms may help ensure adequate wastewater renovation because earthworm burrows intersecting the trench bottoms likely reduce the volume of soil the effluent is exposed to before it reaches the groundwater. Field experiments are needed to test this hypothesis, and further research is necessary for determining the type and thickness of sand most effective for deterrence.

Further research could also look at the long-term effects of the sand layer on earthworm survival. It seems that the earthworms that burrowed through the sand were weakened by the effort and in the long-term might not have survived. The results of this study suggest that adding a layer of sand to the bottom of soil treatment system trenches may deter earthworms, but will not prevent them from burrowing if necessary for their immediate survival.

REFERENCES


