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Application of sewage sludge compost on highway embankments

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Abstract

More and more sewage sludge is being produced in China. Safe and economical methods for sewage sludge disposal should be found considering the increase in sewage treatment. In order to verify the feasibility of sludge disposal on newly built highway embankments, five treatments (0, 15, 30, 60 and 120 tons ha^{-1}) of sewage sludge compost (SSC) were added to a silty-clay embankment soil on the Xi-Huang highway. The results showed that amendment with SSC increased soil available N, available P, organic matter, cation exchange capacity, and water content, and decreased soil bulk density. Application of SSC enhanced ryegrass growth and reduced runoff and soil erosion. Heavy metal losses from sediments in runoff remained constant or decreased relative to the control until a rate of 60 tons ha^{-1} was exceeded, when heavy metal losses appeared to increase.

1. Introduction

Sewage sludge is a byproduct of sewage treatment processes (Singh and Agrawal, 2007). It is predicted that by 2010, 40–50% of the wastewater generated in China will be treated. This indicates that a dramatic increase in sewage sludge (SS) production will occur very soon (Science and Technology Bureau, 1995), and China will have to face the problem of how to dispose of the rapidly increasing amounts of this material. Sewage sludge disposal is an expensive operation that could result in environmental pollution due to its potentially harmful constituents (Elliott, 1986; Wang and Jones, 1994; Zhou and Gao, 1994).

Sewage sludge, also known as biosolids, characteristically contains high levels of the major plant nutrients, N and P, and is enriched with organic matter. This makes the land application of sewage sludge a common practice around the world (Gerhardt et al., 1997). There is general agreement on the positive effects of SS as a soil amendment on plant growth (Elliott, 1986; Couillard and Grenier, 1989; Albiach et al., 2001; Shober et al., 2003; Wei and Liu, 2005). However, benefits from sludge application on croplands have to be weighed against the potential hazards associated with certain sludge-borne constituents (e.g., heavy metals, pathogens, and organic contaminants). Retention of sludge-borne heavy metals in soils and their accumulation in plant tissues have caused concerns about the extensive use of SS on cropland (Jing and Logan, 1992). This has led to strict regulations aimed at the safe recycling of SS (McGrath et al., 1994). Application of sewage sludge to forests or greenbelts reduces the risks of potential toxins entering into the human food chain and thus possibly constitutes one of the safest options for sewage sludge disposal.

Highway embankments located on both sides of highways aim at protecting the roadbed. Plants growing on embankments help decrease pollution, provide a desirable touch of natural beauty, and protect the roadbed from soil erosion. Therefore, the growth of plants on this land is of great importance to highway management. However, embankment soil of newly-built highways is usually immature with bad soil structure and low nutrient content. This restricts the growth and development of grasses and

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counteracts the purpose of protecting the roadbed from erosion (Blunt and Doken, 1995). Therefore, amendments to improve soil properties of highway embankments, especially newly-built ones, are necessary. Furthermore, plants along highways are usually non-edible, which minimizes direct human exposure. In spite of the need, research about amending highway embankments with SS has received little attention.

The objectives of this study were to: (1) measure the effects of sewage sludge compost (SSC) on the physical and chemical properties of embankment soil; (2) measure the effects of SSC on the growth and development of plants on embankment; and (3) monitor and evaluate the environmental effects of SSC on embankment soil and plants.

2. Materials and methods

2.1. Characteristics of the sewage sludge compost

Sewage sludge was collected from the beds of the Xi'an Wastewater Treatment Plant at Xi'an City (Shaanxi Province, China) in August 1999. The Xi'an Wastewater Treatment Plant serves about 1 million residents by treating 160,000 m^3 of raw wastewater daily. About 35–40% of the total flow is contributed by industry. The treatment process is the Anoxic-Oxic (A/O) activated sludge process. The sewage sludge was composted with ground corn stalks (sieved through a 3–4 mm screen) and 2 cm-length corn stalks at a ratio of 5:2:3 by volume in September 1999. The SSC was sieved through a 2 cm mesh size before use. The physical, chemical, and biological properties of SSC and highway embankment soil are presented in Table 1. The concentration of Cd, Cu and Pb of the SSC was less than the Chinese sewage sludge criteria for agricultural use, although Zn was higher than the criterion. The death rate of roundworms was 100%, and the most probable number (MPN) of coliforms in 1 g of SSC was 20–100, lower than the Chinese guideline.

Table 1
Physical and chemical properties of the soil (0–20 cm) and SSC

Items	Soil	SSC	Chinese quality standards
Sand (50–2000 μm) (g kg^{-1})	67		
Silt (2–50 μm) (g kg^{-1})	702		
Clay (<2 μm) (g kg^{-1})	230		
Bulk density (g cm^{-3})	1.46	0.88	
Total Nitrogen (%)	0.044	1.76	
Total Phosphorus (%)	0.038	1.23	
Available Nitrogen (mg kg^{-1})	8.5	101	
Available Phosphorus (mg kg^{-1})	1.58	36.4	
Organic matter (g kg^{-1})	4.98	352	
CEC (mmol kg^{-1})	33.0	–	
pH	7.95	6.78	
Cd (mg kg^{-1})	0.18	3.72	20[a]
Cu (mg kg^{-1})	28.1	156	500[a]
Pb (mg kg^{-1})	37.7	61.9	1000[a]
Zn (mg kg^{-1})	40.4	1105	1000[a]
Coliforms (MPN/g)		20–70	<100[b]
Death rate of roundworm (%)		100	95–100[b]

All values based on dry weight.
[a] Chinese sewage sludge criteria for agricultural use (GB4284-84), Soil pH ⩾ 6.5.
[b] Chinese control standards of urban wastes for agricultural use (GB 8172-8).

2.2. Site and climatic conditions

The field study was conducted on a highway embankment of the XiHuang highway (Xian to Huangling) with a total length of about 180 km. The highway, which was built in 1999, is located in Huangling County of Shaanxi Province. The area is located in the Loess Plateau of China. Perennial ryegrass (*Lolium multiflorum* Lam) was planted on the embankment in 1999. Soil in this area is a clay-loam and has inherently low fertility and poor structure. The physical and chemical properties of the soil are presented in Table 1. The embankment soil was tamped during construction, except for the surface (about 15–20 cm depth) to allow plant growth. The slope gradient is 28° and the embankment length along the diagonal is about 6 m (See Fig. 1). The total annual rainfall is approximately 620 mm and the annual mean temperature is 9.4 °C.

The low precipitation and silty-clay soils limits percolation to groundwater, and the depth to groundwater is over 10 m. As a result, this study did not examine the potential impacts of SSC on groundwater quality.

2.3. Experimental design

The experiments were carried out in a randomized complete block design with a total number of 15 plots; each plot measured 5 m × 6 m. Adjoining plots were separated with a 10 cm-high wood wall. A big iron barrel was fixed at the end of each plot to collect highway runoff in 2003 (See Fig. 1). Five SSC treatments were used (three replicates per treatment): (1) treatment A_0 (control, no SSC); (2) treatment A_{15} (15 dry tons SSC ha^{-1}); (3) treatment A_{30} (30 dry tons SSC ha^{-1}); (4) treatment A_{60} (60 dry tons SSC ha^{-1}); (5) treatment A_{120} (120 dry tons SSC ha^{-1}). The water content of SSC was about 38%. The SSC was applied to the surface of the embankment on 15th April, 2001, 12th April, 2002 and 14th April, 2003 just after the ryegrass turned green in the spring. Topsoil, runoff, and plant samples were collected and analysed in 2003.

2.4. Sample collection

Soil samples were taken from the 0–20 cm layer using an auger. Samples were weighed and then air-dried to constant weight prior to sieving through a 2 mm sieve.

Runoff was collected in iron barrels in 2003; total runoff volume and total sediment weights were measured. Sediments were air-dried and then sieved through a 1 mm sieve.

Plant biomass was determined by harvesting a 1 m × 1 m area of perennial ryegrass in each plot on 15th July, 2003. Above-ground mass (termed shoots) and roots were separated manually.