BLENDS OF COMPOSTED BIOSOLIDS AND BOTTOM ASH AS POTTING MEDIA TO GROW ORNAMENTALS

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ABSTRACT

The experimental data confirmed that blending and class *A* biosolids and bottom ash from power plants produces material that meets the EPA's definition for an exceptional quality product and has properties suitable to grow ornamental plants. The tested blends had sufficient concentrations of major nutrients (NPK), low soluble salts content (EC), pH in range of 6.0 to 7.0, and the level of regulated metals (As, Cd, Cr, Cu, Hg, Mo, Ni, Pb, Se, Zn) well below current environmental limits. These blends were successful in supporting growth of petunias, geraniums, marigolds in a research greenhouse as well as poinsettias under normal production conditions in a commercial greenhouse. Comparing to control plants geraniums, petunias, and marigolds grown in biosolids/ash mixtures had darker leaves and showed no symptoms of nutrient deficiency. Besides looking healthier, marigolds grown in the tested blends produced much bigger biomass than the control. The poinsettia plants looked healthy, visually attractive, and were not significantly different from the plants grown in commercial mixes. Therefore, biosolids/ash blends are at least as effective as commercial mixes in supporting plant growth. Cost estimates reveled that the bottom ash/biosolids blends are cheaper than the commercial potting mixes and they can offer extra savings to a greenhouse (nursery) operators by decreasing fertilizer requirements.

INTRODUCTION

Compost produced form municipal sewage sludge (biosolids) can be successfully used as a component in container media (Chen et al., 1988). Compost used for this purpose must be of a consistent quality and fully mature (Inbar et al., 1993). The most important physical properties are high porosity and a pore size distribution to facilitate optimal air to water ratios. The desired pore size distribution can be achieved by establishing an appropriate particle size during blend formulation (Inbar et al., 1993). In addition, container media should have low level of soluble salts (EC), slightly acidic or neutral pH, high cation exchange capacity (CEC), maintain stable

volume, and have sufficient level of major nutrients (Inbar et al., 1993). Biosolids compost used by itself usually has too high level of soluble salts, too much available nitrogen, and may undergo volume reduction over time. Blending of biosolids compost with other materials (e.g., bottom ash from electrical power utilities) can produce mixes with low level of EC, sufficient concentrations of nutrient, and physical properties suitable to grow plants in containers.

The objective of this research was to evaluate performance of blends of class *A* biosolids (composted sewage sludge) and bottom ash from power plants and as potting mixes in an experimental setting and in a commercial greenhouse under normal production conditions. We tested a hypothesis that the experimental blends will be as effective as commercial potting mixes in growing various ornamentals (geraniums, petunias, marigolds, and poinsettias).

MATERIALS AND METHODS

Experiments in a research greenhouse: Composted biosolids from sewage treatment plants and bottom ashes from power plants in the Southeast US were blended to formulate mixes with biosolids to ash ratios of 1:1 (50% of compost), 1:2 (33%), and 1:3 (25% of compost). The resulting blends were used in a greenhouse to grow geraniums (*Pelargonium* spp.) and petunias (*Petunia x hybrida*). Seedlings of geraniums and petunias (3-5 inches tall) were obtained from a local garden center. A commercially available potting mix (blend of milled pine bark, sphagnum moss peat, perlite, and charcoal) was used as a reference potting medium. All treatments were watered every day with deionized water. No fertilizer was used during the first three weeks of the experiment. At the forth week, the control treatments received the first fertilizer dressing (a commercial plant feed) as recommended by the producer of the control potting mix. Plants grown in biosolids/ash blends were not fertilized. The experiment was conducted for five weeks and then pictures were taken and plant growth observations were made. In addition, the biosolids/ash blends with the ratios (by volume) of and biosolids to bottom ash 1:1 and 1:2 were used to grow marigolds (*Tagetes erecta* L) from seeds. The commercial potting mix was again used as a control. All treatments were watered every day with deionized water. No fertilizer was used during the first three weeks of the experiment. At the forth week, the control treatments received the first fertilizer dressing of 100 ml of 1% solution of commercial plant feed (N 15%, P 30%, K 15%, traces of B, Cu, Fe, Mn, Mo, Zn). The same amount of fertilizer was applied every week till the end of experiment. The control plants received jointly about 1 g of N, 2 g of P and 1 g of K per pot. The treated plants were fertilized twice during the last three weeks of the experiment, receiving about 0.5 g of N, 1 g of P and 0.5 g of K per pot. Marigolds were grown for about six weeks and then harvested to measure the biomass produced.

Experiment in a commercial greenhouse: A pot experiment was conducted in the greenhouse of Greenhost Incorporated in King George, VA. Poinsettia cuttings (*Euphorbia pulcherrima* Willd. Ex Klotsch) were planted in 6" standard round pots on August 22, 1997. The experiment was ended on December 11, 1997— pots were removed from the greenhouse and pictures and measurements of plants were taken. The experimental design included various blends of composted biosolids from sewage water treatment facilities in the Southeast US and a bottom ash . The inclusion rate of biosolids in the blends was either 25% or 33% by volume. The blends were screened to a 1/4" particle size diameter before filling the pots. The treatments were replicated eight times in a completely randomized design.

Table 1. Concentrations of regulated elements (mg/kg, dry wt.) in blends of bottom ash and biosolids

Sample	As	Cd	Cr	Cu	Hg	Mo	Ni	Pb	Se	Zn
Control	0.1	0.9	0.6	4.0	0.05	0.2	1.8	3.0	<0.01	43
BA+B1 (1:1)	0.6	3.1	15	43	0.19	0.8	18	13	0.4	126
BA+B1 (2:1)	1.4	3.2	17	58	0.38	2.0	20	20	1.3	282
BA+B1 (3:1)	1.2	2.8	29	151	0.26	4.5	20	47	1.2	530
BA+B2 (2:1)	2.6	2.8	37	301	0.17	6.1	23	64	1.4	894
BA+B2 (3:1)	2.1	2.3	28	201	0.14	4.5	20	45	1.3	604
BA+B3 (2:1)	2.7	2.6	24	152	0.22	3.6	20	36	1.2	492
BA+B3 (3:1)	2.2	2.6	26	150	0.23	3.9	20	39	1.2	500
EPA-limits I	75	85	3000	4300	57	75	420	840	100	7500
EPA-limits II	41	39	3000	1500	17	18	420	840	100	2800

BA - bottom ash; B1 - biosolids I; B2 - biosolids II; B3 - biosolids III; EPA-I - maximum permissible concentration; EPA-II - maximum concentrations in an exceptional quality sludge.

The commercial potting mix, normally used in the greenhouse (sphagnum peatmoss + processed pine bark+fertilizer), was used as a control potting medium. All treatments were watered as needed (when 10% of plants showed first symptoms of water stress) using an overhead watering system. Fertilization with a nutrient solution was included in the watering schedule. Every 10 days about 200 mL 1% solution of commercial plant feed (N 15%, P 30%, K 15%, traces of B, Cu, Fe, Mn, Mo, Zn) was applied. The plants received jointly about 1.5 g of N, 3 g of P and 1.5 g of K per pot.

DISCUSSION OF EXPERIMENTAL RESULTS

Experiments in a research greenhouse: Concentrations of regulated trace elements in blends of biosolids and ash materials used to grow geranium, petunias, and marigolds were below the regulatory limits established by EPA (Table 1). Since composted biosolids were used in these blends, the tested potting mixes are regarded to be a class *A* materials and consequently they can be used for any purpose. Therefore, the biosolids/ash mixes are environmentally safe materials (low concentrations of trace metals and class *A* sewage sludge) and can be used for horticultural applications without restrictions. The tested geraniums and petunias looked healthy, had colorful flowers, and dark green leaves without any visible symptoms of toxicity. Comparing to control plants (grown in a commercial potting mix), geraniums and petunias grown in biosolids/ash mixtures had darker leaves without any visible symptoms of nutrient deficiency, apparently because of higher nitrogen (N) and phosphorus (P) concentrations in these mixtures than in the commercial potting mix (Table 2).

The blends used to grow marigolds had slightly acidic pH, higher than control mix content of main nutrients (NPK), and relatively low level of soluble salts (EC). Marigolds germinated well and grew very fast in biosolids/ash blends.

Table 2. Physical and chemical properties of blends of bottom ash and biosolids

Sample	pH	EC mS/cm	B.density g/cm^3	N %	P %	K %	Ca %
Control	6.5	0.09	0.24	0.2	0.01	0.05	0.28
BA+B1 (1:1)	6.3	1.07	0.51	0.80	0.12	0.05	0.10
BA+B1 (2:1)	6.5	0.54	0.37	0.50	0.42	0.10	0.35
BA+B1 (3:1)	6.6	0.43	0.38	0.39	0.33	0.08	0.28
BA+B2 (2:1)	6.5	0.94	0.44	0.59	0.47	0.07	0.69
BA+B2 (3:1)	6.7	0.74	0.43	0.46	0.37	0.06	0.53
BA+B3 (2:1)	6.7	2.65	0.46	0.66	0.66	0.12	0.95
BA+B3 (3:1)	6.8	2.03	0.44	0.51	0.51	0.10	0.74

BA - bottom ash; B1 - biosolids I; B2 - biosolids II; B3 - biosolids III;
EC - electrical conductivity

Table 3. Growth response of marigolds to application of bottom ash/biosolids as potting media

Treatment*	Plant height cm	Fresh biomass g/pot	Dry biomass g/pot	No. of buds number/pot
Control	$17.0^a \pm 1.0$	$11.3^a \pm 1.8$	$7.8^a \pm 0.3$	$1^a \pm 1$
BA+B1 (1:1)	$53.3^b \pm 3.2$	$266.7^b \pm 10.3$	$59.3^b \pm 9.0$	$24^b \pm 6$
BA+B1 (2:1)	$52.0^b \pm 3.6$	$252.4^b \pm 52.7$	$56.1^b \pm 14.2$	$18^b \pm 5$

BA - bottom ash; B1 - biosolids I;
*Means followed by various letters are significantly different at $P<0.05$

The tested marigolds were toller, had more flower buds, and produced 15 to 25 times bigger biomass than the control plants (Table 3). This strong effect of ash/biosolids blends on the test plant growth and development is apparently related to a higher content of nutrients than in the control mix (Table 2), a higher germination index of the tested blends, and possibly suppressing plant diseases by compost (Hoitink and Faky, 1986).

Experiment in a commercial greenhouse: Concentrations of trace elements in the blends of the bottom ash and biosolids met requirements for an exceptional quality product (Table 1). The final mix is a class *A* material and consequently can be distributed and used without restrictions. The blends had higher content of the main nutrients (NPK) than the control mix and an acceptable levels of soluble salts (Table 2). The heights, mean per plant bract cluster counts, and the mean diameters of a largest bract cluster of poinsettia plants grown in biosolids/ash blends (treated plants) were not significantly different from those of the control plants (Table 4). Aesthetically, the treated plants were as appealing as the control poinsettias. Visually, telling the difference between the treated and control plants would not be possible. Therefore, the hypothesis that the blends of bottom ash and biosolids are as effective as commercial potting mixes in supporting growth of Poinsettia plants, was confirmed by the experimental results.

Table 4. Morphology and growth response of poinsettia plants to application of bottom ash/biosolids blends as potting mixes

Treatment	Plant height* *cm*	Number of * bract clusters	Diameter of the* largest cluster *cm*
Control	29.8±2.1	6.0±0.8	26.8±3.8
BA+B1 (2:1)	27.7±2.3	5.3±0.5	23.5±2.3
BA+B1 (3:1)	24.3±2.5	6.5±0.6	22.3±2.2
BA+B2 (2:1)	27.3±3.8	5.7±0.6	26.3±1.5
BA+B2 (3:1)	28.0±0.1	5.0±0.0	29.0±0.1
BA+B3 (2:1)	24.5±0.7	6.0±0.0	23.5±0.7
BA+B3 (3:1)	30.5±6.4	5.0±0.0	22.5±0.7

BA - bottom ash; B1 - biosolids I; B2 - biosolids II; B3 - biosolids III
*Differences are not significant at $P<0.05$.

GUIDELINES FOR PREPARING POTTING MIXES

The composted biosolids used for preparation of potting mixes must be highly stable (C:N ratio around 10; low rate of respiration) and must pass a growth test (e.g., germination test ≥70%). The final blend should include about 60-75% of bottom ash by volume. If the biosolids used have higher contents of nutrients (e.g., N > 1.5%) and higher contents of soluble salts (EC > 6.0 dS/m), more bottom ash (75%) is recommended. The content of nutrients (N, P, K, Ca, Mg, B, Cu, Fe, Mn, Mo, and Zn) in the resulting blend should be identified. Content of N, P, K, Ca, and Mg should be reported. This information is necessary to evaluate fertilizer requirements, if any. The final pH of the blend should be in a range of 5.5-8.0. The final product must have consistent properties. The soluble salts of the final horticultural substrate (after mixing bottom ash and biosolids together) should be in a range of 0.5-3.0 dS/m (Table 5). Elevated levels of soluble salts can be reduced partially by leaching, but this extra step would increase the cost of blend preparation. The moisture content should be 35-50% because a product that is too dry can be hydrophobic (resists wetting) and one that is too wet can be difficult to handle and mix. Mixes containing varying amounts of organic matter may be used; however, the organic matter content of a specific blend should be consistent. Particle size (texture) of the blend can vary based on the pot/container size. Usually, coarser products may be appropriate for use in larger containers. Typically, a product with the particle size distribution from 1/4 to 1/2" is recommended.

COST ESTIMATES

The overall cost of preparing potting mixes from biosolids and bottom ash include cost of biosolids, cost of bottom ash, freight cost, and cost of blending and screening. The wholesale price of high quality composted biosolids in urban area is around $6-$8 per cubic yard without delivery. An average freight rate of composted biosolids in urban area, where trucking is somewhat competitive, is $5.00 per cubic yard up to distance of 30 miles. Since both bottom ash

Table 5. Recommended properties of biosolids-based potting mixes

pH	5.5-8.0
Soluble Salts (EC)	≤3.0 dS/m
Nutrient Content	
Nitrogen (N)	0.2-1.0 %
Phosphorous (P)	0.1-1.0 %
Potassium (K)	0.1-0.5 %
Water Holding Capacity	150-250 %
Bulk Density	0.3-0.5 g/cm^3
Moisture Content	30-50 %
Organic Matter Content	30-70 %
Particle Size	passes ½ inch screen

Trace elements..... must meet exceptional quality concentrations as stated in the US EPA's 503 Regulations (see the data below, the concentrations are in mg/kg):

As	Cd	Cr	Cu	Hg	Mo	Ni	Pb	Se	Zn
41	39	3000	1500	17	18	420	840	100	2800

and composted biosolids have similar bulk densities (800-1400 lb per cubic yard), hauling cost of bottom ash will be comparable with that of composted biosolids. Therefore, it does not matter whether bottom ash is transported to the location of biosolids for blending and screening or *vice versa*, the freight cost will be the same. In addition, it reasonable to assume that a source of biosolids will be found within a radius of 30 miles from a source of bottom ash, and a wholesale customer will be within a radius of 30 miles from a blending operation. That is why the cost estimate (Table 9) is based on freight cost of \$5.00/yd^3. If these distances are greater than 30 miles, the freight cost may be too high to make the blending operation and wholesaling bulk product competitive and profitable. In such a case, marketing of a bagged product, with a higher profit margin, should be considered. Assuming a 30-mile hauling distance, the production cost of one cubic yard of a bottom ash/biosolids potting mix would be about \$12.50 (Table 9). If this product is sold to a customer at wholesale price of \$15.00 (at 20% gross profit margin), the overall cost to a costumer would only be about 57% of total cost of purchasing a commercial potting mix. Therefore, use of bottom ash/biosolids potting mix in production of ornamentals is not only feasible technically but it can be profitable as well. In the experiment described, full a fertilization program was applied to all treatments, simply because the tested pots were included in the normal greenhouse operation structured for plants that did not have nutrients in their growing media (commercial potting mix). Bottom ash/biosolids potting mixes provide nutrients for about 6-8 months of plants growth and do not need fertilization. Because fertilization is not needed when bottom ash/biosolids potting mixes are used, extra savings for a greenhouse or nursery operator can be realized.

SUMMARY AND CONCLUSIONS

Blending class *A* biosolids and bottom ash from the electrical power utilities produces materials that meet the Federal EPA's definition for an exceptional quality product and have physical and chemical properties suitable to support plant growth in a greenhouse under research and production conditions. These products are approved for unrestricted distribution and can be used as potting mixes without a special permit. Geraniums and petunias grown in biosolids/ash blends had darker leaves without any symptoms of nutrient deficiency. Marigolds growing in blends of bottom ash/biosolids produced significantly higher biomass and had more flower buds than the control plants. The tested blends also were successful in supporting growth of poinsettia under normal production conditions in a commercial greenhouse. The performance of tested blends and a commercial potting mix as to produce healthy and visually attractive plants was not significantly different. Biosolids used as a component of potting mixes should be highly stable, contain high levels of nutrients, and have low concentrations of soluble salts. The inclusion rate of biosolids in the potting blends should be in a range of 25-33%. The biosolids/ash potting mix can be priced very competitively comparing to prices of commercial potting mix and still be a profitable. The need for fertilization will be substantially reduced when biosolids/ash potting mixes are used which means that a greenhouse or nursery operator can make savings not only on purchase of a product but also on operations by cutting cost of fertilization.

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