Geochemistry of artifactual coarse fragment types from selected New York City soils

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Abstract

The coarse fragment (>2mm) content in six substratum horizons from two anthropogenic soil profiles in New York City was divided into natural rock fragments and human-made artifacts, and the latter sorted into types. The four most common types, asphalt, brick, concrete, and slag, were analyzed for several trace metals, as well as carbon, nitrogen, and sulfur. Asphalt fragments were relatively high in mercury and lead, while slag fragments were high in copper, lead, and zinc. To determine if any of the artifacts could be used as an indicator of the degree of soil contamination, the trace metal content in the fine earth fraction from each of the horizons was compared with the amount of each artifact present. Although the metal content of brick fragments was relatively low, the amount of brick present had highest correlation with fine earth trace metal content. High levels of carbon in asphalt and slag fragments indicate that the >2mm fraction can make a significant contribution of to the total carbon content in anthropogenic soils.

Key Words

Artifacts, technosols, urban soils, trace metals.

Introduction

The amount and type of coarse fragments are commonly described in soils but relatively few analyses have been conducted. Ugolini et al (1996) recognized the contribution of the soil skeleton, or coarse fragments, to the physical and chemical properties of soils. In a follow up report, Corti *et al.* (1998) proposed a classification system based on the degree of fragment alteration. Artifacts, or coarse fragments of human origin, are common in human altered soils, and can constitute a significant proportion of the soil. In WRB classification, soils with 20 percent or more (by volume, by weighted average) artifacts in the upper 100 cm of soil are placed in the *Technosol* Reference Soil Group; 10 percent or more merit a *Technic* intergrade qualifier. Classification of anthropogenic soils in the USDA-NRCS New York City Soil Survey separates those soils with less than 10 percent artifacts (clean fill) from those with greater than 10 percent. However, there has been little in the way of research on the direct effects of artifacts on soil properties. El Khalil *et al.* (2008) pointed out the contribution of the artifactual coarse fragments to the water soluble fraction of metals in some Moroccan soils.

Methods

Artifacts were selected from substratum horizons in two anthropogenic soil profiles in New York City, both located in city parks, in formerly wet areas covered (for at least 50 years) with tens of feet of artifact-laden fill materials. Samples 1 through 4 were taken from an Ebbets (Coarse-loamy, mixed, active, mesic Typic Eutrudepts) sandy loam in Kissena Corridor Park, Queens. Samples 5 and 6 were taken from a Laguardia (Loamy-skeletal, mixed, active, nonacid, mesic Typic Udorthents) sandy loam in Soundview Park, Bronx. Both soils had the weighted average of greater than 10 percent artifacts by volume (in the particle size control section) that is used to differentiate artifactual from "clean" soils in the New York City Soil Survey. However, only the Laguardia pedon met the 20 percent criteria for classification as a Technosol in WRB. The weighted average artifact content in the top 100cm for the Ebbets soil was 16 percent.

Two pedons were sampled by horizon and macromorphology described (Schoeneberger *et al.* 2002). Bulk samples were air-dried and sieved to <2-mm. The >2mm fraction was sieved and sorted into rock fragments and human-made artifacts. The latter were further separated into types, with four main groups: asphalt, brick, concrete, and coal slag. Laboratory analyses followed by codes were performed according to Burt (2004). Total C, N, and S was determined by dry combustion (6A2f) and calcium carbonate equivalent (CCE) by use of an electronic manometer to quantify gas evolution following acid contact in a closed vessel (6E1g). Total analysis of the <2-mm fraction and the artifact samples were determined by microwave digestion in concentrated HF, HNO_3, and HCl, with determination of elements by ICP spectroscopy (4H1b).

Results

Table 1 shows the depth in the soil profile, and the composition, by weight, of the six horizons. Substratum horizons were selected since a thin layer of cleaner, better quality topsoil for successful plant growth is commonly placed over the chunkier artifact-laden material in parkland. The artifact proportion of these horizons varies from 2.5 to 80.7 percent. In Table 2, the breakdown by artifact type, concrete makes up the largest proportion of artifacts overall, and slag the least.

Table 1. Depth (cm), fine earth, artifact, and rock fragment content (% weight), soil horizons.

Horizon	Depth	Fine earth	Artifacts	Rock frags
1	31-53	66.6	17.8	15.6
2	53-69	91.0	2.5	6.5
3	69-90	23.5	73.0	3.5
4	90-112	43.2	49.2	7.6
5	23-37	65.3	24.9	9.8
6	61-102	17.6	80.7	1.7

Table 2. Artifact type content (% weight), soil horizons.

Horizon	Asphalt	Brick	Concrete	Slag
1	1.9	0.5	12.2	0.5
2	1.2	0.1	0.6	0.1
3	0.7	0.1	71.3	0.3
4	6.1	0	39.2	2.9
5	4.4	10.2	5.7	1.6
6	1.2	14.9	57.3	1.3

The trace element content of the fine earth fraction in each of the six horizons is given in Table 3, along with the New York State Department of Environmental Conservation Soil Cleanup Objectives for unrestricted use. The fine earth values in each of the horizons exceed the Objectives for at least one element, lead. Values in horizons 4, 5, and 6 exceed the Objectives for all four metals.

Table 3. Trace element content (mg/kg), soil horizons, with NYS Soil Cleanup Objectives, unrestricted use.

Horizon	Cu	Hg	Pb	Zn
1	22	.07	73	69
2	22	.14	132	65
3	48	.19	202	124
4	89	.42	248	195
5	60	.33	311	312
6	102	.44	1162	742
NYS DEC SCO	50	.18	63	109

Table 4 lists the mean and coefficient of variation for the trace element content of the four artifact types. Asphalt is relatively high in mercury, with an average value almost twice the soil Cleanup Objective. Slag has the highest copper and zinc contents, which exceed the Objectives by nearly two and more than six times, respectively. However, the variability in zinc was particularly high for slag, with values ranging from 17 to 3919 mg/kg.

Table 4. Trace element content (mg/kg), mean and (CV) values, artifact types.

	Cu	Hg	Pb	Zn
Asphalt	59 (.65)	.35 (.97)	111 (.53)	84 (.52)
Brick	25 (.39)	.04 (.38)	73 (.49)	126 (.80)
Concrete	29 (.32)	.07 (.65)	88 (.73)	110 (.73)
Slag	97 (1.28)	.13 (.48)	112 (.67)	653 (2.21)

Table 5 lists the correlation coefficients between artifact content and the fine earth trace metal content. This was an attempt to determine if the presence of any of the artifacts could be used as an indication of the degree of metal contamination of the soil. The amount of brick present generally has the best correlation with the four metals, especially lead and zinc, even though its content of these elements is relatively low. This may be due to the close association of brick with related construction debris, possibly finer sized, i.e., paints, metals, treated woods, which serve as a source of these elements. Asphalt or concrete, on the other hand, may come from street demolition.

Total artifact content also correlated quite well with fine earth trace metal content. The amount of slag present correlated best with fine earth copper content. Slag fragments had the highest copper contents of the artifact types.

Table 5. Correlation coefficients (r), artifact content & fine earth trace metal content.

n=6	Cu	Hg	Pb	Zn
asphalt	.400	.521	.179	-.052
brick	.615	.625	.866[b]	.906[c]
concrete	.557	.385	.462	.394
slag	.747[a]	.802[a]	.217	.316
total artifacts	.736[a]	.584	.662	.626

a= significant at .90 level; b=significant at .95 level; c=significant at .98 level

Table 6 lists the carbon, nitrogen, and sulfur contents of asphalt and slag. The high carbon content of asphalt fragments, and to a lesser degree slag, can be a significant addition to the total carbon content of the soil. Much of this addition, particularly in the case of slag, can be in the form of highly reactive and recalcitrant black carbon. The small amount of asphalt and slag fragments in the horizons 1 through 4 raised the carbon level in the top meter of the Ebbets soil from 14 to 16 kg C/m^2. Both the asphalt and slag are characterized by high C:N values, and comparatively high amounts of sulfur.

Table 6. Total C, N, and S (%), Mean and (CV) values, artifact types.

	C	N	S
asphalt	31.2 (.42)	0.3 (.53)	1.3 (1.95)
slag	4.4 (.49)	0.05 (.67)	0.1 (.93)

Conclusion

Chemical analyses of artifactual coarse fragments from New York City soils concur that this fraction contributes to the trace metal content of anthropogenic soils. Compared to New York State cleanup objectives, asphalt fragments were high in mercury and lead, while slag fragments were high in copper, lead, and zinc. The amount of brick present seemed to serve as the best indicator of trace metal content in these soils. High levels of carbon in asphalt and slag fragments indicate that the >2mm fraction can make a significant contribution of to the total carbon content in anthropogenic soils.

References

Burt RA (2004) 'Soil Survey Laboratory Methods Manual'. Soil Survey Investigations Report No. 42. (National Soil Survey Center: Lincoln, Nebraska).

Corti G, Ugolini FC, Agnelli A (1998) Classing the soil skelton (greater that two millimeters): Proposed approach and procedure. *Soil Sci. Soc. Amer. J.* **62,** 1620-1629.

El Khalil HC, Schwartz C, Elhamiani O, Kubiniok J, Morel JL, Boularbah A (2008) Contribution of technic materials to the mobile fraction of metals in urban soils in Marrakech (Morocco). *J. Soils Sediments* **8,** 17-22.

IUSS Working Group WRB (2006) 'World Reference Base for Soil Resources 2006'. World Soil Resources Reports No. 103. (FAO: Rome).

Ugolini FC, Corti G, Agnelli A, Piccardi F (1996) Mineralogical, physical, and chemical properties of rock fragments in soil. *Soil Science* **161,** 521-542.