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EFFECTS OF ADDITION OF 1000 ppm Cu, Ni, Pb AND Zn ON CARBON DIOXIDE RELEASE DURING INCUBATION OF SOIL ALONE AND AFTER TREATMENT WITH STRAW

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ABSTRACT

A sandy soil of pH 6·0 was treated with 1000 ppm levels of Cu, Zn and Pb (as oxides) and Ni (as sulphate) and held moist for two months. The treated and control soils were then set up for aerobic incubation for 12 weeks at 30°C with and without the addition of 0·5% ground straw. CO_2 release during incubation from soils without added straw was decreased somewhat by all metallic elements. CO_2 release from soil plus straw was unaffected by Zn, but was decreased somewhat by Pb and, to a fair extent, by Cu and Ni. The apparent mineralisation of straw-C was decreased considerably by Cu and Ni and increased somewhat by Pb and Zn. Results are discussed in relation to Morgan- and EDTA-extractable levels of the metallic elements.

INTRODUCTION

Javillier (1941) reported on the effects of addition of up to 10 ppm levels of metallic elements on decomposition of organic materials in soils. However, no work appears to have been reported on the effects of high levels of metallic elements such as could occur through application to soils of mining and industrial wastes or of sewage residues from treatment works serving industrial areas. The decomposition of plant residues in soils is an important part of the carbon biocycle and any factor inhibiting this process would tend to result in accumulation of plant residues in undecomposed or partially decomposed form.

Pollutants containing metallic elements may have toxic effects initially on microbial activity if these elements are in soluble, and hence probably 'available', form. However, soils in the usual pH range for plant growth should have the ability to decrease the level of available forms of metallic elements by precipitation and/or complexing with soil organic matter. It is this aspect of the effects of metallic

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elements with which the present study is concerned. The metallic elements as oxides (or sulphate in the case of Ni, since no pure oxide was available) were mixed with the soil and the mixtures were held moist for two months in order to simulate the ploughing in of potentially pollutant residues followed by a delay period. The soils were then set up for incubation with and without the addition of straw in order to determine organic matter decomposition by measuring CO_2 release. Cereal straw residues are commonly used in this way in order to increase soil organic matter content.

MATERIALS AND METHODS

The soil used was a 'Bagshot Sand' (5·5% clay, 12·0% silt) from a cultivated area, which was air-dried and ground to pass a 2 mm sieve. The soil had pH 6·0 (in water) and contained 0·18% total nitrogen and 2·2% total organic carbon. Extraction with boiling 6N HCl, followed by analysis of the extracts by atomic absorption spectroscopy, showed that the soil contained 18 ppm Cu, 6 ppm Ni, 35 ppm Pb and 74 ppm Zn. Separate bulk samples of soil (500 g) were mixed with finely ground (less than 200 mesh-sieve) CuO, $NiSO_4$, PbO and ZnO (reagent grade) to add 1000 ppm of the metallic elements on the dry soil basis. The treated soils and untreated (control) soil were placed in pots and held at room temperature (18°–20°C) for two months with addition of water to maintain the moisture content between 40% and 50% maximum water holding capacity. The soils were then air-dried and rubbed through a 2 mm sieve and their pH determined after shaking with water. For incubation, 10 g portions of the treated and control soils in triplicate were placed in glass tubes and wetted to 50% saturation. The BaO_2 (Cornfield 1961) was used for aeration and for absorption and measurement of CO_2 released during incubation of the stoppered tubes at 30°C for 12 weeks. Another series was set up after mixing with 0·5% w/w finely-ground oat straw (40·0% C, 0·32% N). After incubation one tube of each soil was shaken with water for pH measurement. Another replicate was shaken with 20 ml Morgan's reagent (0·5 N acetic acid–0·75 N sodium acetate) and the third replicate with 20 ml 0·1 N EDTA–Na (pH 7·0) for 2 min and the filtrates analysed for the applied metallic elements by atomic absorption spectroscopy.

RESULTS

Table 1 shows CO_2 release over 12 weeks of incubation of the treated soils and after addition of 0·5% oat straw. In the soil without straw treatment all metallic elements significantly decreased CO_2 release, with Ni and Pb having significantly greater effects than Cu and Zn. The percentage of soil-C mineralised is shown in column (*ii*).

TABLE 1

EFFECTS OF PRETREATMENT WITH 1000 PPM Cu, Ni, Pb AND Zn ON CO_2 RELEASE DURING INCUBATION (12 WEEKS AT 30°C) OF SOIL ALONE AND AFTER TREATMENT WITH 0·5% STRAW. PPM RESULTS ARE ON A DRY SOIL BASIS

Treatment	(*i*) *soil alone* CO_2 *release* (*ppm*)	(*ii*) *soil alone* % *soil-C mineralised*	(*iii*) *soil + 0·5% straw* CO_2 *release* (*ppm*)	(*iv*) CO_2 *from straw* (*iii*)–(*i*) (*ppm*)	(*v*) % *straw-C mineralised*
nil	4482[a]	5·5	7859[a]	3377[c]	46·1
Cu	3726[b]	4·6	5227[c]	1501[d]	20·4
Ni	3426[c]	3·4	4724[d]	1298[d]	17·7
Pb	3514[c]	3·5	7301[b]	3787[b]	51·0
Zn	3747[b]	4·6	7813[a]	4066[a]	55·0

Within each column, values with the same superscript are not significantly different at $P < 0{\cdot}05$

In the straw-treated soils CO_2 release was greater than from soils without straw treatment. Zn had no significant effect on CO_2 release, Pb decreased it to a moderate extent whilst Cu and Ni decreased it considerably. The apparent release of CO_2 from straw (column *iv*) was obtained by subtracting the value for each soil without straw from the corresponding value where straw was added. It is seen that the apparent release of CO_2 from straw was increased somewhat by Pb and Zn and decreased considerably by Cu and Ni.

Pretreatment with metallic element compounds and incubation with and without the addition of straw did not alter soil pH by more than 0·3 units.

Table 2 shows that incubation with straw increased Morgan- and EDTA-extractable forms of Cu and Ni but had no effect on or decreased both extractable forms of Pb and Zn.

TABLE 2

EFFECT OF STRAW ADDITION ON LEVELS OF MORGAN- AND EDTA-EXTRACTABLE METALLIC ELEMENTS AFTER INCUBATION OF SOILS PRETREATED WITH 1000 PPM METALLIC ELEMENTS: RESULTS IN PPM ON DRY SOIL BASIS

Extractant	*Straw added*	*Treatment*			
		Cu	*Ni*	*Pb*	*Zn*
Morgan	no	39	85	200	308
Morgan	yes	79	273	158	305
EDTA	no	227	253	709	668
EDTA	yes	373	549	638	673

The control soil contained 0·1, 0·1, 2·8 and 6·5 ppm Morgan-extractable and 1·8, 1·6, 18·8 and 10·0 ppm EDTA-extractable Cu, Ni, Pb and Zn respectively.

DISCUSSION

A previous experiment on mineral nitrogen changes during incubation of this soil after addition of 0·5% straw showed that mineral nitrogen was present after

all periods of incubation up to 12 weeks. This indicates that the N-mineralising capacity of the soil was sufficiently high so that mineral nitrogen was not limiting the rate of decomposition of straw. Another experiment in which this soil was incubated with straw after its pH had been altered (by previous moist treatment after addition of varying levels of $CaCO_3$ or $Al_2(SO_4)_3$) showed that the extent of variation of pH (not greater than 0·3 units) occurring in the present experiment could not have directly affected CO_2 release. Thus the changes in CO_2 release due to treatments with metallic element compounds can be attributed to the effects of the added metals. In addition, the possibility that changes in C-mineralisation due to pretreatment with Ni as sulphate may have been due to the sulphate portion of the added salt is unlikely, since Sindhu (1967) found that the addition of even five times this amount of sulphate (as $CaSO_4$) had negligible effects on C-mineralisation.

Toxic effects of high concentration of elements on the activity of heterotrophic organisms attacking organic matter are probably due to their ability to compete with essential elements (Mn, Fe, Mg) for the active sites (—SH, —NH_2, =NH) of enzymes. This competitive inhibition would account for the significant decreases in C-mineralisation of the native soil organic matter. Ni and Pb were slightly more inhibitory than Cu and Zn in this respect.

Straw addition eliminated the toxic effect of Zn and decreased the toxic effect of Pb on overall CO_2 release. This effect was not correlated with Morgan- or EDTA-extractable forms of Zn, which were hardly affected by the straw treatment, but was correlated roughly with the somewhat decreased extractable levels of Pb due to straw. However, the release of CO_2 from straw was apparently increased by both these elements. The calculation of CO_2 released from straw was made on the assumption that the rate of mineralisation of native organic-C (soil-C) was not affected by the presence of decomposing straw. The apparent stimulating effect of Pb and Zn on mineralisation of straw-C may be due to the ability of less easily decomposable straw fractions (lignin and modified protein–lignin association) to 'fix' these two elements in a form less 'available' to the heterotrophic organisms.

On the other hand, overall CO_2 release due to Cu and Ni was decreased, to a fair extent, by the straw treatment. These effects were related to the increased levels of Morgan-extractable Cu and Ni, in particular, and to increased EDTA-extractable forms of both metals. This decrease was accounted for by decreased rate of release of CO_2 from straw.

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