Investigation of the immobilisation/mobilisation of nickel, copper, chromium and zinc following co-disposal of activated sewage sludge with synthetic refuse

George AC Ehlers[1*], Richard A Daneel[2] and Eric Senior[3]

[1]*Department of Biochemistry and Microbiology, Rhodes University, PO Box 94, Grahamstown 6140, South Africa*
[2]*International Centre for Waste Technology (Africa), School of Applied Environmental Sciences, University of Natal, Private Bag X01, Scottsville, Pietermaritzburg 3209, South Africa*
[3]*Environmental Technology Institute, Innovation Centre (NTU), 18 Nanyang Drive; 637723, Singapore*

Abstract

Laboratory microcosms were packed with synthetic refuse and waste activated sewage sludge in two ratios (4.1:1 and 4.1:2 v/v). The sludge was spiked (100 mg·ℓ^{-1} or 200 mg·ℓ^{-1}) with the salts of each of four heavy metals (Ni^{2+},Cu^{2+}, Cr^{3+} and Zn^{2+}). Subsequently, the metal concentrations were increased progressively. For all the microcosms, including an unperturbated control, unbalanced fermentations resulted as evidenced by low pH values. Thus, heavy metal presence was not the sole cause. The leached metal concentrations were in a consistent order with high Zn and Ni concentrations recorded compared with immobilised Cr and Cu. After 15 weeks of operation, despite extensive retention, increases in Cr, Ni and Zn were detected in the leachates following elevated loadings. Due to the high redox potentials (+2 to +170 mV), precipitation of the metals as insoluble sulphides was not attainable.

Introduction

Heavy metals are present in a range of industrial wastes together with industrial and household products. They are, therefore, components of household refuse (Knox, 1989). Since there is a wide variety in the chemical and environmental behaviour of heavy metals (Knox,1989), their fates in co-disposal landfills are of concern (Gregson et al., 1988).

In co-disposal landfills, potential heavy metal toxicities to micro-organisms may be maximised or minimised depending on the metal-binding capacity of a particular sludge (MacNicol and Beckett, 1989), the ion and organic constituent interactions (Babich and Stotzky, 1985; Fletcher and Beckett, 1987) and the specific dissolved metal species present and their concentrations (Mueller and Steiner, 1992).

This picture can be complicated further by the application of covering soil between the refuse cells and, more particularly, by the activity of microbial catabolic species. Clayey impermeable material, for example, is dominated by fermentative populations while respiratory microbial species attach to the more sandy soils (Chapelle, 1993). The former species catabolise complex organic molecules and release intermediates which, in turn, are oxidised by respiratory species by reducing available electron acceptors (oxygen, nitrate, manganese hydroxides, iron hydroxides, sulphate and carbon dioxide). As a consequence, redox gradients are generated. Heavy metal precipitations as sulphides are related indirectly to redox potential. Such precipitations play a key role in the immobilisation of heavy metals in the refuse mass.

For this investigation of immobilisation/mobilisation of heavy metals following co-disposal operation, four species (Ni^{2+}, Cu^{2+}, Cr^{3+} and Zn^{2+}) were chosen on the basis of their variable mobilities and presence in refuse and sewage sludge.

Materials and methods

Refuse

A synthetic refuse was prepared by combining equal volumes of shredded paper from a paper recycling plant and vegetable plus garden wastes. The moisture content of the refuse was determined by taking two samples (100 g each) and drying at 60°C for 72 h. The samples were weighed before and after drying and the moisture content was determined by the mass difference.

Sewage sludge

Activated sewage sludge was collected from the return channel of Darvill Sewage Works, Pietermaritzburg. The moisture content was determined as above after drying at 70°C.

Microcosm construction and operation of microcosms

Six glass columns (length 50 cm, i.d. 5.3 cm) were used (Percival and Senior, 1998). The microcosms were packed with synthetic refuse ± sewage sludge (Table 1). Two refuse:sewage sludge packing ratios of, 4.1:1 and 4.1:2 (v/v) were used (Percival, 1996), while the refuse-packing density was ~830 kg·m^{-3}.

Glass wool was placed at the base of each column to prevent refuse/sludge displacement. The columns were incubated in the dark at 30°C in a temperature-controlled box fitted with heating elements. Fermentation gases were vented from the microcosms via Zn acetate (0.1% m/v) gas traps to collect hydrogen sulphide as insoluble zinc sulphide. Leachate was recycled daily by removing 40 mℓ from the base of each microcosm with a hypodermic needle connected to a plastic syringe (20 ℓ) and reintroducing it to the top of the column.

* To whom all correspondence should be addressed.
☎(046) 603-8446; fax: (046) 622-3984;
e-mail: g00E3721@campus.ru.ac.za
Received 12 September 2000; accepted in revised form 1 August 2001.