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Heavy Metal Distribution in Anaerobic Sludges

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NOTE
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Abstract

On the basis of a depuration system, by anaerobic processes, for wastewaters which contain variable amounts of copper, nickel, and zinc, a study is made of the distribution of these cations betwen the solid sludge and the supernatant liquid of the effluent. In all the experiments, amounts approximating 90% of the metals existing in the substrate were retained in the solid sludges, a very small amount of the metals remaining in the clear liquid of the effluent.

INTRODUCTION

Anaerobic digestion has been a relatively widely used method in the last few years for effective treatment of wastewaters with a high concentration of organic matter, such as urban wastewaters and those from agro-alimentary industries.

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However, technological advances resulting in reactors with greater retention capacity for microorganisms and a wider knowledge of microbic technological bases are permitting a broadening of the scope of application to effluents with a low organic content and from different industrial origins (*1*).

On the other hand, there are several kinds of exploitation which can be practiced with effluents coming from anaerobic treatments, one of these being direct appliction as fertilizer. The agronomic value of this is due to the high content of such macro- and micronutrients as nitrogen, phosphorous, and potassium, and high proportions of organic matter (*2*).

Its use is also of interest from an economic point of view because of the increasingly high price of synthetic fertilizers and because of the erosive effect which an excessive consumption of these has on physicochemical properties in the soil.

Among the characteristics of the effluent, the presence of heavy metals influences profitability. If these are found in excessive concentration, they can give rise to phytotoxic action by accumulating in the plant, and subsequently progress to trophic chains (*3, 4*).

Significant amounts of heavy metals and other toxic substances can reach depuration plants either by inorganic contaminants sporadically collected in urban sewer systems or in the integrated treatment of liquid effluents of varying origins. Similarly, biological treatments of wastewaters give rise to a natural concentration of treated waste, and high amounts of nonbiodegradable elements such as heavy metals are accumulated in sludges (*5*).

In this work a study is made of the distribution of the heavy metals copper, nickel, and zinc in the different phases of the effluent proceeding from an anaerobic digester operating under complete mixture conditions.

MATERIAL AND METHODS

The experiment was carried out on a laboratory scale by using a series of complete mixture digesters without recycling, submerged in baths thermostated at 35 ± 1°C and mechanically agitated.

The digesters were fed with a 2% by weight prepared glucose solution with 1.635% of volatile solids, to which was added the minimum necessary proportion of nitrogen and phosphorus in the form of urea and sodium diphosphate, respectively, for adequate development of the microorganisms (*6*). The load speed of the digesters was 0.408 (kg volatile solids/m^3 digester and day), which corresponds to a retention time of 40 days for the substrate. Once the digesters had been started up in the absence of heavy metals and stability had been reached in the depuration system, the inclusion of heavy metals was carried out by adding a certain amount of each cation (Cu, Ni, and Zn), individually and in mixtures, to the daily feed to the digesters according to the experimental design appearing in Table 1.

The selection of these cations is due to the fact that they are very frequently present in depuration plants (*7*).

The distribution of cations in the effluent was studied to analyze their concentration in the supernatant liquid and their total concentration in the effluent. The difference between these values determined the amount of cation associated with the solid sludge (either with the cellular mass or in insoluble form). Atomic absorption spectroscopy was used for analysis.

Experimentation with each digester and for each metal tested was 60 days.

RESULTS AND DISCUSSION

A direct consequence of the presence of heavy metals in a wastewater treatment by anaerobic processes is a drop in the degree of depuration obtained, which is related to the type of cation and its concentration.

Table 1 reports the most important changes observed in the variables which measure the stability of the system and in the degree of depuration (relationship between organic matter in the effluent and the influent).

Table 1 shows the distribution of metals in the sludge (associated with the intracellular mass or precipitated) and the metal/solid sludge relationship. Similarly, Fig. 1 shows the percentage of metal retention by the sludge compared with the initial concentration of each of the metals.

When the metal tested is copper, retention by the sludge is very high—between 96 and 98%—and it grows as the concentration in the effluent increases.

An increase in nickel concentration in the effluent produces a decrease in the metal associated with the solid effluent, going from 92% for 5 mg/L to 81% for 30 mg/L. These results are in agreement with the data obtained for nickel toxicity in the disgestive system, which increased to 10 mg/L and was almost stable between 10 and 30 mg/L (*8*).

On the basis of these results, a parallelism is detected between retained metal and toxicity for the system, as confirmed in the work of other authors (*9*).

TABLE 1
Experimental Design, Changes Observed in Control Variables, Degree of Depuration, Amount of Metal Retained by the Sludge, and the Relationship between Them[a]

Heavy metals	Concentration (mg/L)	pH	VA	Depuration (%)	Cations in solid effluent (mg/L)	*R* (g/kg)
Cu	20			81	19.1	5.40
	40	↓	↑	54	39.3	4.82
	70	↓	↑	19	68.8	4.62
Ni	5			76	4.6	1.05
	10	↓	↑	38	9.1	1.33
	30	↓	↑	17	24.1	1.56
Zn	200		↑	57	191.6	22.37
	445	↓	↑	36	409.8	31.25
	600	↓	↑	19	517.9	34.26
Cu-Ni-Zn	10-2.5-100			65	9.2-2.4-97.7	
	20-5.0-200		↑	37	19.0-4.5-191.9	
	30-7.5-300	↓	↑	29	28.7-6.3-279.6	

[a]↑ Increase, ↓ = decrease, blank = no change. VA = Volatile acids (mg acetic acid/L). *R* = Ratio of heavy metals/solid effluents. Control experiment: pH 7.25, VA = 216, depuration = 93%.

Tests with zinc showed similar results. A very low concentration of metal in solution was observed, giving rise to retentions greater in all cases than 92% with regard to the concentration in the influent.

The behavior of metals in mixtures is similar to what is shown separately, as indicated by the results in Table 1.

CONCLUSIONS

The anaerobic depuration systems studied retain proportions greater than 90% of the heavy metals which remain associated with the biomass or in an insoluble form (in the sludge). Parallel to this, contamination of an inorganic nature is greatly reduced in the hydric component of the effluent.

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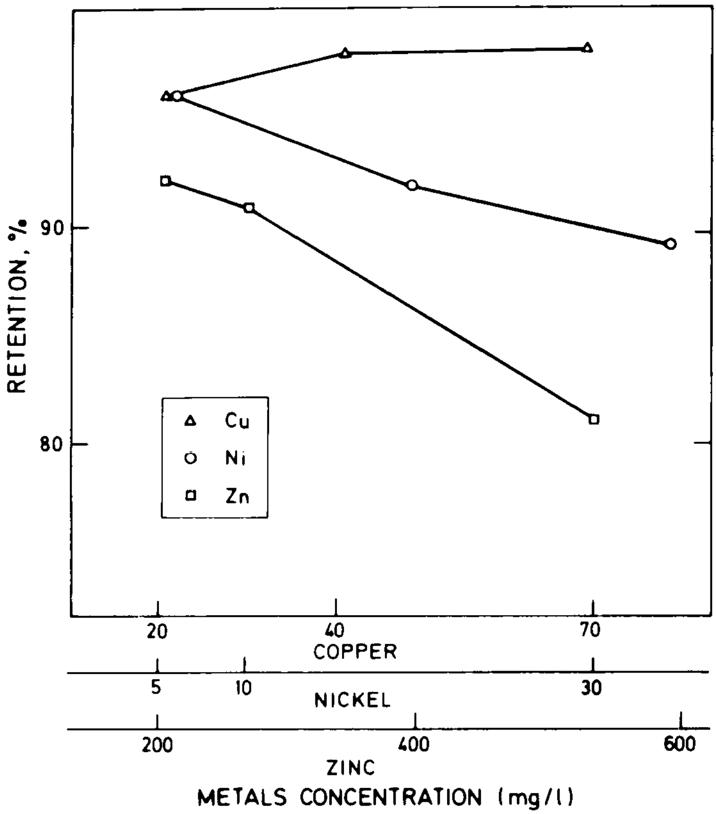

FIG. 1. Proportion of metals retained by the sludge compared to the concentration of metal in the digester.

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