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Short communication

Environmental quality of primary paper sludge

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Abstract

The reuse and recycling of waste paper sludge is increasing rapidly as far as the economical and positive environmental benefits are realised. In this study, primary sludge coming from a large production plant, located in the centre of Italy, was collected and the environmental quality of the sludge was assessed through geotechnical, physical and chemical analysis and leaching tests, as required by the Italian regulation on solid waste recovery. The results suggest that primary sludge from paper industry do not represent a major threat for the environment in regard to the heavy metal content. The use of this sludge for in situ applications appears an interesting avenue for an integrated management of waste from the paper industry.

Keywords: Waste management; Paper sludge; Heavy metals; Leaching; Permeability test

1. Introduction

The pulp and paper industry generates a considerable amount of wastewater from various processes in the production of pulp and the manufacture of paper. Primary and secondary treatment of this wastewater results in the production of considerable quantities of sludge [1]. The word "paper sludge" generally has a negative connotation with the general public and represents a potential source of dioxins and furans when chlorine is used to whiten the paper. The sludge of the paper industry can be divided into several categories: the waste paper sludge coming from the production of virgin wood fibre, called primary sludge; the waste paper sludge produced by removing inks from post-consumer fibre, called de-inking paper sludge; the activated sludge from the secondary systems, called secondary sludge; and combined waste paper and activated sludge, called combined sludge. Of the total solid waste produced by the whole Italian paper industry [2], 38% is primary sludge (Fig. 1). Currently 62% of all the solid waste of pulp and paper origin are disposed through landfilling (Fig. 2). The landfilling of waste paper sludge has become less feasible in recent years as environmental concerns have lead to rapidly increasing costs. Alternative uses of paper sludge were proposed by many authors [1,3,4] based on the good sorbent and pH-controlling capacity of this material. Paper sludge composition strictly depends on the manufacturing and effluent treatment processes at individual mills. However the use of paper sludge implies a scrupulous evaluation of their environmental quality. The suitability for the use of primary sludge of a paper mill plant, located in the centre of Italy, was evaluated from the chemical, physical and geotechnical characteristics of the material, and through leaching and permeability tests.

2. Material and methods

2.1. Chemicals

The paper sludge investigated was a primary sludge coming from the production of virgin wood fibre. The investigated paper mill plant produces 70 t/day of primary sludge. In the industrial process only calcium carbonate is used as a whitening agent. The three samples for the lab-scale test, each consisting of 70 kg of paper sludge, stored in HDPE containers, were taken at the end of the dewatering process in different periods of the activity of the plant. The laboratory analysis were performed sub-samples, in triplicate.

All the chemicals used for the leaching tests (acetic acid, NaOH supplied by Carlo Erba) were used as-received.

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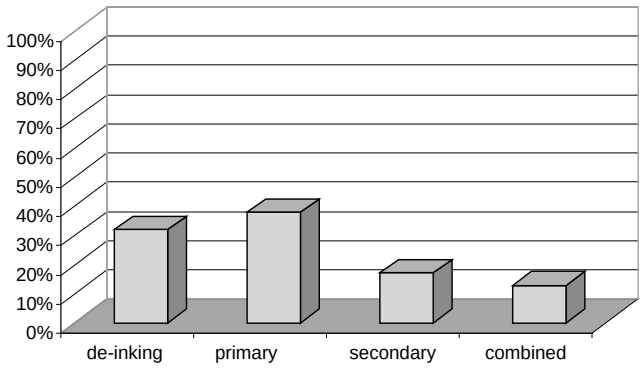

Fig. 1. Percent distribution of the sludges produced by the Italian industry of paper (on courtesy of Italian Paper Industry Association, 2000).

2.2. Analytical methods

The bulk density of the investigated material was determined by He pycnometer (Accu Pyc 1330, manufactured by Micrometrics). The carbonate content was measured by using a Dietrich-Fruhling calcimeter on a sample of 1 g, dried at 110 °C and put into contact with HCl (1:1). The quantity of CO_2 released in the reaction of carbonates with HCl gives the percent of $CaCO_3$ in the sample.

Two different leaching tests were performed on the paper sludge samples in order to assess the potential for metal release in different conditions. The first test is prescribed by the Italian regulation on solid waste [5], performed in deionised water with sequential extractions. The second test, TCLP (toxicity characteristics leaching procedure), is a US EPA [6] standard test performed in an acid environment, at low pH and constant agitation, and usually applied in the United States for the chemical characterisation of waste materials.

For the first test 80 ml of sludge and 400 ml of deionised water were used (solid:liquid = 1:5). For both tests triple samples of the liquid phase were taken.

The concentrations of metals in the samples obtained from the leaching procedure were determined by atomic absorption spectroscopy (Perkin Elmer 3030B). The oedometric cell [7] permeability tests were performed with variable hydraulic head on small dimension samples.

The compressibility of the paper sludge was investigated through an oedometric test [7] performed with increasing loads (50, 100, 200, 400 and 800 kPa). Every load was maintained for 24 h.

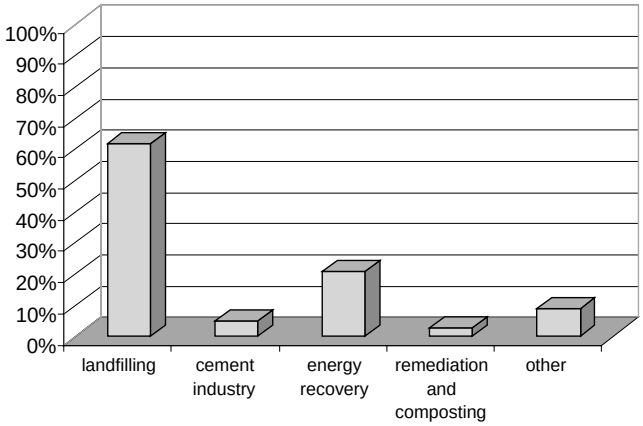

Fig. 2. Final destinations of the sludges produced by the Italian industry of paper (on courtesy of Italian Paper Industry Association, 2000).

3. Results and discussion

3.1. Physical and chemical characteristics

The bulk density is low and the water content is extremely high due to the fact that cellulose fibres are the principal constituent of the investigated material (Table 1). The presence of a great amount of water in the material, even after the de-watering process, has a strong influence on the permeability and compressibility as reported in the following paragraphs. The good sorbent and pH neutralising capacity of the primary sludge from the paper mill [1,3] is mostly due to the high calcium carbonates (>40%) content. The value of specific density of 2.260 g/cm^3 was obtained with a standard deviation of 1×10^{-4}.

Table 1
Chemical and physical characteristics of the paper sludge sample

Bulk density, γ (g/cm^3)	1.476
Specific density, γ_s (g/cm^3)	2.260
Water content, w_i (%)	88.29
$CaCO_3$ content (%)	40.5

Table 2
Results from the leaching test performed according to the procedure prescribed by the Italian regulation on solid waste [4]

	Regulatory limit (mg/l)	Average concentration (mg/l)
Metal		
Cd	0.005	<0.002
Ni	0.01	<0.010
Zn	3	0.800
Cr	0.05 (total)	<0.020
Cu	0.05	<0.020
Pb	0.05	<0.010
pH	5.5–12	7.37

Table 3
Results from the leaching test performed according to the TCLP procedure [5]

	Regulatory limit (mg/l)	Concentration (mg/l)
Metal		
Cd	0.025	<0.02
Ni	0.040	0.01
Zn	0.050	0.01
Cr	0.100	0.02
Cu	0.025	0.02
Pb	0.100	<0.01

Table 4
Results from the oedometric test [6]

Vertical load (kPa)	Sample height, $2H$ (cm)	Pore index, e	Compressibility coefficient, m_v (kPa^{-1})	Oedometric modulus, E (MPa)
0	2	1.691	2.62E−03	0.38
50	1.761	1.338	1.12E−03	0.89
100	1.672	1.207	8.97E−04	1.11
200	1.538	1.009	5.66E−04	1.77
400	1.384	0.781	3.36E−04	2.98
800	1.222	0.542		
400	1.229	0.552		
200	1.244	0.575		
100	1.253	0.588		
50	1.264	0.604		

3.2. Leaching tests

The results of the tests performed are reported in Tables 2 and 3. For both tests, the values are below the regulatory limits. As expected, the concentrations of metals in solution obtained for the TCLP test (Table 3) are higher since larger amounts of heavy metals are released in acid conditions (pH 2–4).

3.3. Permeability tests

Permeability values of 9×10^{-12} m/s were obtained in the oedometric cell with a load of 800 kPa after 24 h. The hydraulic conductivity values remained in the range of 10^{-9} to 10^{-11} m/s for lower loads and are typical of a low-permeability material, such as clay. The low permeability may favour primary sludge used as landfill cover.

3.4. Oedometric test

A high compressibility of the paper sludge was measured (Table 4 and Figs. 3 and 4). The oedometric modulus (Table 4) has a linear increase when an increasing load is applied, thus leading to a linear behaviour. The compressibility coefficient (Table 4), as mentioned above, is relatively high, probably due to the fact that cellulose fibres are the main constituent of the samples. It was observed that the primary sludge investigated, did not exhibit any swelling behaviour,

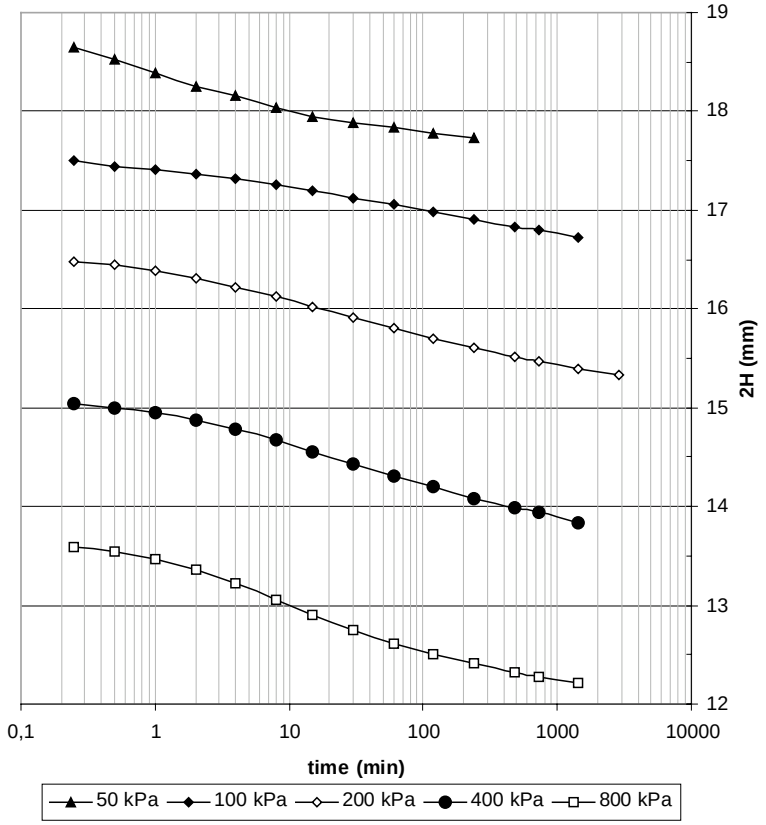

Fig. 3. Results from the oedometric test: deformation vs. time for different load increments.

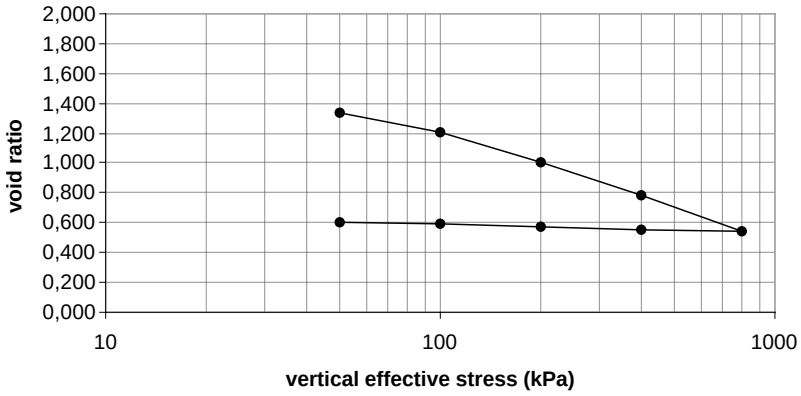

Fig. 4. Results from the oedometric test: void ratio vs. vertical effective stress.

which is an interesting characteristic for the use of paper sludge in landfill closures.

4. Conclusions

The results suggest that the primary paper sludge does not represent a major threat for the environment in terms of heavy metal release. The physical, chemical and geotechnical characteristics appear comparable to those of low-permeability cohesive soils usually used in landfill covers. In addition, the pH-controlling action related to the high content of carbonates of this material, due to the use of $CaCO_3$ as a whitening agent in the industrial process, can be useful in acid-mine drainage treatment and in the removal of heavy metals in solution.

In conclusion, the recovery and reuse of paper sludge appears to be an interesting avenue for an integrated management of wastes from the paper industry. However, this study only dealt with a specific type of paper sludge (primary sludge), and it is recognised that the possibility for the reuse of other products (i.e. de-inking and secondary sludge) has to be investigated.

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