CHARACTERIZATION OF A HORTICULTURAL PEAT FOR TREATING MINING WASTEWATER

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Summary

Contamination of soil, surface waters and groundwater by heavy metals is gradually on the increase especially in regions where exploitation of natural resources such as rocks and ores are supporting economic activities. This may not be unconnected with the highly sophisticated processes employed in a desire to obtain high purity materials, but also with the management of the accompanying waste generated by these activities. Peat has been identified as a cheap, natural and available material capable of adsorbing several heavy metals. Much work has been done with respect to the mechanisms of adsorption and by controlling the properties of peat in order to capture dissolved heavy metals. This paper investigates the surface characteristics of a poorly humified horticultural peat by XRD analysis in order to identify the distribution of inorganic ligands and organic compounds because these constituents of peat are significant in any sorption process and retentive capability for removing metallic ions in wastewater treatment.

Keywords
Adsorbent, Adsorbate, Heavy Metals, Horticultural Peat, Humification

1. Introduction

Peat is a spongy vegetable substance composed generally of mosses and aquatic plants in different stages of decomposition (Kerr, 1905). This partially fossilized plant matter is formed in the poorly oxygenated water of marshes, bogs, and swamps by microbial activities due to a greater rate of plant matter accumulation than rate of plant matter decomposition (Pérez et al, 2005). Peat may accumulate in the first few metres of the earth through the successive generation of plants, with the replacement of one type of bog vegetation by another and with the rate of growth and accumulation being variable and very slow (Dachnowski, 1912 and Pérez et al, 2005).

Several geo-hydrological factors have been identified as being responsible for the formation, accumulation and characteristics of peat. The chief topographical conditions favouring its formation are found in lentic environments where processes of stream erosion and sedimentation are slight or have been short lived, in shallow lakes and ponds that have not been much agitated by waves and sediments, and that are not drained by the deepening of channels near the heads of rivers and their tributaries. Climatic conditions may be the principal factor favouring peat formation (Dachnowski, 1912) while regional climate, the nature of the vegetation, water pH (acidity), and degree of metamorphosis may affect the characteristics of the peat (Brown et al, 2000 and Pérez et al, 2005).

Peat if properly handled has been described as gold (Kerr, 1905). The most significant use of peat today is as fuel for heating (Kerr 1905, Coupal and Lalancette1976, and Charman 2002). It is used in agriculture, being dug into soil to increase the soil's capacity to retain moisture and nutrients (Morin, 1988), and in flood mitigation, as occurs naturally with many peat swamps along the coast of

Malaysia. Peat swamps are natural water catchments capable of absorbing any overflow occurring in their vicinity (Charman, 2002).

The extent of peat decomposition plays a significant role in its use and its classification. Peat can be totally humified or poorly humified, depending on the level of decomposition or formation that its parent plants have undergone. It is classified primarily as fibric, hemic, or sapric peat, with fibric peats being the least decomposed and containing large amounts of undecomposed fibers, hemic peats being moderately decomposed, and sapric peats being the most decomposed. Wüst et al. (2002) proposed a peat classification which defined peat as consisting of 0 – 55% ash (by dry-weight), 55 – 65% muck, 65 – 80% organic-rich soil/sediment, and 80 – 100% mineral soil/sediment with organic matter.

Due to its unique combination of chemical and physical properties peat may act as a filter, a coalescent and an adsorbent, making it effective in treating wastewater by adsorbing and filtering pollutants (Pérez et al, 2005). Peat has a significant adsorption capacity for many dyes, metal ions, oil, and phosphate (Ho and Mckay, 1999). One of the earliest investigations on the adsorption of heavy metals by peat was by Coupal and Lalancette (1976), with a much wider application of peat earlier in the work of Leslie (1974) in which, peat was used in the treatment of dye house effluent. Leslie (1974) reported that pollutant heavy metals are actually removed and not changed into less offensive forms, a significant advantage in the use of peat over some other materials.

Peat is mainly organic and provides a unique material for developing an understanding of the mechanisms and factors capable of influencing trace metal binding onto organic matter. It can also be used to monitor metal contamination pathways and evaluate long-range metal transport (Twardowska and Kyziol, 2003).

There are some limitations in the use of peat as an adsorbent material as natural peats have a low mechanical strength, a high affinity for water, poor chemical stability, and a tendency to shrink or swell (Couillard, 1994). However, Brown et al. (2000) have reported that thermal and chemical pre-treatment of peat can turn it into a suitable adsorbent material. A pelleting process and the development of immobilized biomass beads may also be employed.

The main solids' retention in peat occurs on the surface where a filtering layer forms due to surface sludge accumulation and this increases the retention capacity of particles independently of the peat type (Perez et al., 2005).

While the form of peat that has been extensively investigated and also employed as a commercial adsorbent in many applications is the poorly humified peat (Coupal and Lalancette, 1976, Chaney and Hundemann, 1979, Gossett et al., 1986, Malterer et al., 1996 and Ringqvist et al, 2002), the highly decomposed or highly humified peat (saprist) on the other hand has not been fully explored as an adsorbent material. This paper presents a characterization of a horticultural humified peat as a first step in a series of investigation targeted at the use of a highly humified and decomposed peat as an adsorbent for metals in wastewater.

In this study Inductively Coupled Plasma Mass Spectroscopy (ICPMS) was used in the identification and determination of the metallic composition of the peat and X-Ray Diffraction was employed in the surface analysis and analytical determination of some selected important properties of the peat that could influence its sorption capacity for the heavy metals Ni and Co.

2. Materials and Methods

2.1 Materials

A poorly humified horticultural peat sample that contained equal proportions of peat, classified on the von Post scale as H3 and H6, was obtained from a Newfoundland vegetation bog in St John's Newfoundland Canada for use in this study. This peat sample was dark brown to black in colour and the texture could be described as woody to loamy granular which might imply that the major class is woody and the source of the peat was mostly wood, according to Graham (1984). Poorly humified peat has been reported to be more permeable and have fewer fine particles than highly humified peat (Ringqvist and Öborn, 2002).

2.2 Peat Characterization

The physical parameters were determined for the sample of the poorly humified and horticultural peat. The pH and electrical conductivity were obtained by dissolving 1g of humified peat in 10mL of water and using a VWR 3000 model pH meter to measure the pH and the electrical conductivity. The moisture content was determined according to ASTM method D-2867 by drying a peat sample in an oven at $105\,^{o}C$ for 24 hours. The bulk density was determined using the method suggested by Morin (1988). The von Post scale classification was obtained from the supplier, Traverse Gardens, St. John's.

The total environmental package of the inductively coupled plasma mass spectrophotometer (ICPMS HP 4500) owned by the Earth Sciences Department at Memorial University of Newfoundland was used to determine the initial metallic content of the poorly humified horticultural peat.

The surface profiles of the constituent metallic, organic and inorganic substances of the natural, poorly humified peat and oven dried peat samples were obtained. This surface analysis was carried out using the powdered XRD equipment in the Earth Science Department, Memorial University of Newfoundland.

3. Results and Discussion

Table 1 shows some physical and chemical characteristics of the horticultural peat from St. John's Newfoundland, Canada. These physico-chemical parameters are consistent with previous results obtained for most fibrist peat with a low degree of decomposition.

Parameters	Values
Von Post Decomposition grade	3H (mixed with 6H)
Moisture content (determined at $105^{o}C$) %	82
Bulk density kg/m^3	0.62
pH	4.2
Cation Exchange Capacity (exchangeable Ca) meq/100g	45
Electrical conductivity (μm/s)	276

Table 1 Physico-chemical parameters of the horticultural peat.

From the results of the metallic content determination with ICPMS, it is seen in Table 2 that the poorly humified horticultural peat has enough active sites for possible cation exchange. The high amount Ca

shows that the exchangeable Ca can more easily be replaced by heavy metals compared with hydrogen ions that bond to the peat as strongly as if they had a valence of +3.

Metal	Concentration (ppm)	Metal	Concentration (ppm)
Ca	2743	Pb	3.19
^{54}Fe	971	V	2.34
Ti	97.76	Ce	1.47
Zn	87.66	Ni	0.69
Mn	27.27	La	0.6
Sn	7.96	Cu	0.33

Table 2 Metal Concentration in the horticultural peat sample

The XRD scans for the natural, poorly humified peat and oven dried peat samples are shown in Figures 1a and 1b. The structure of a crystalline solid is such that the arrangement of its atoms result in planes which are able to diffract X-rays and how this occurs determines the characteristics of the solid (Coles, 1998).
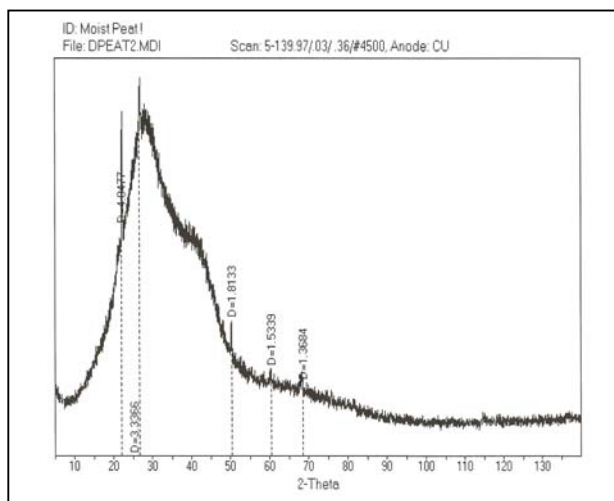

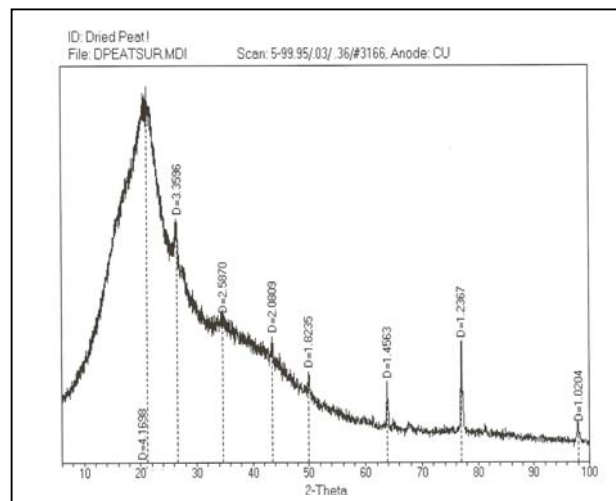
Fig. 1a XRD analysis of a moist peat sample   Fig. 1b XRD analysis of dried peat sample

The XRD analysis showed clearly that the peat sample behaved as if it were a clay sample as the profile showed that by drying, the obvious lack of peaks in the moist peat sample was improved upon with clear peaks in the dried sample. Given the presence of some peaks in the moist horticultural peat, this sample can be considered to be quite unsaturated in spite of the fact that the moisture content is as high as 82%. Since the peat may still take up more moisture this would allow sufficient contact between the peat particles and heavy metal ions present in wastewater without further drying of the peat before treatment.

The XRD analysis was inconclusive as the identification and the distribution profile of the inorganic ligands and organic compounds on the surface of the horticultural peat were not completed. While the surface characteristic obtained is consistent with some earlier results for a poorly humified peat, the abundance of any group has not been established.

As Perez et al. (2005) reported a surface sludge accumulation on the surface of peat was largely responsible for increasing the solids' retention in peat, independently of the peat type it is conceivable that this increase in retention might to some extent be also independent of peat particle size. The

parameters that may affect the surface characteristics and the sorptive capacity of peat need to be investigated in terms of the chemistry of interactions and quantities of substances present.

4. Conclusion

Poorly humified horticultural peat has been used as an adsorbent in various works. The surface characteristics which give an insight into the chemistry of the adsorption processes have not been fully explained. This work has shown that further surface analysis using more efficient technique is needed in order to show the distribution of inorganic ligands and the organic compounds that constitute the particle surface. These constituents may be involved in complexation reactions at the surface of the peat when used in adsorption experiments for the removal of heavy metals. The adsorption of nickel and cobalt is known to increase significantly by decreasing peat particle size but if the distribution of the surface inorganic ligands and organic compounds is established their chemistry may predominate particle size distribution in overall peat efficiency during sorption processes.

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