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INVESTIGATION INTO ALTERNATIVE SLUDGE CONDITIONING PRIOR TO DEWATERING

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ABSTRACT

The principal objective of this work is to provide a more effective alternative for sludge conditioning prior to mechanical dewatering. The common use of polyelectrolytes often results in the final cake solids concentration not sufficiently high for the sludge to be beneficially reused or safely disposed. The pyrolysed domestic refuse (char) was used to increase the structural strength and permeability of biological sludges in order to increase final cake solids concentration. The laboratory experiments have proven that the mixture of char and a small quantity of polyelectrolyte (0.5 to 1kg per ton of dry solids), used as a conditioner prior to centrifugation and filtration tests, produced cake solids concentration superior to that obtained by using polyelectrolyte on its own. Laboratory dewatering by filtration with admixture of char and polymer, resulted in cake solids concentration of 30 and above 40 per cent.

KEYWORDS

Centrifugation; char; conditioning; dewatering; domestic refuse; filtration; polyelectrolyte; pyrolysis; sludge.

INTRODUCTION

The ability of mechanical equipment to dewater biological sludges is limited by the difficult nature of a sludge matrix. The efficiency of sludge dewatering is enhanced by the use of either chemical or physical conditioners.The most commonly used chemicals are synthetic polyelectrolytes. While the use of polyelectrolyte in the wastewater treatment industry represents the determining factor for the solids - liquid separation, it is not wholly justified by specific benefits in respect to a final cake solids concentration (Smollen, 1990).

Effect of polyelectrolyte on sludge dewaterability. A polyelectrolyte primarily serves as a coagulant in neutralizing colloid electrical charges directly and allowing aggregation to take place and secondary, as a bridging mechanism in floc formation (Shuster and Wang, 1977). However, polymers are consumed to a lesser extent in rebuilding floc fragments and improving existing floc strength, which is specially evident with high degrees of stirring (Eriksson, 1987). A floc strength is reduced as the floc is subjected to shear stresses in the pumps, centrifuges and other equipment which causes resuspension of previously formed flocs as the polymer flocculation is proved to be irreversible (Water Research Centre, 1979). In practice a resuspension or homogenization of a sludge matrix decreases its ability to dewater. A more developed external surface of the flocs increases its geometric porosity allowing a formation of channels for an effective drainage of water out of a sludge (Ganczarczyk and Rizzi, 1996).

It is generally accepted that the major influence of polyelectrolyte during the dewatering process can be observed in relation to a clarification function. Sludge compaction, for achieving higher cake solids concentration, is not affected to the same degree as the clarification function. Biological sludges are generally known to display high compressibility (Smollen, 1986). It results in sludge cake particles being deformed under pressure during the compression phase of mechanical dewatering which causes cake void closure and subsequent reduction in sludge filterability.

To investigate effect of polyelectrolyte on sludge dewatering laboratory centrifugation and filtration tests before and after addition of polyelectrolyte were carried out (Smollen and Miller, 1990). Both types of biological sludges: activated and anaerobically digested, after being obtained from different wastewater treatment plants, responded in a similar way which indicated that the addition of polyelectrolyte was of little assistance in achieving cake solids of a significantly higher concentration.

Carbonaceous material for improved final cake solids concentration. In order to retain permeability during sludge dewatering it is necessary that the sludge structure has a high resistance to compression. To increase the structural strength and permeability of sludges an alternative sludge conditioning method is needed. Physical conditioners can be used to deal with compressible sludge cakes. They are often referred to as skeleton builders because, when added to sludge, they form a permeable and rigid lattice structure that can remain porous under pressure (Zall *et al.*, 1987).

Solid additives are used mainly during the filtration processes. Sludge dewatering by filtration is not considered as a process of particle removal for clarification purpose but as a process for solids capture, for improved efficiency and cost reduction in sludge handling and disposal. Carbon with its high particle density acts as a weighting agent and as a seed for flocculation of the biomass. Clearly, denser carbon increases settling of solids and compaction, reducing the volume of sludge to be handled (Adams, 1975). It also improves the sludge quality for disposal purposes, e.g. where sludge could either be incinerated or act as a soil conditioner disposed of on land. The application of activated carbon is limited however, owing to the economics of powdered carbon and an associated increase in operation costs. Solid additives such as pulverised coal, cement kiln dust, and ash have been applied as filtration aids in an effort to achieve higher final cake solids concentration. According to the Polish invention (Przeworska *et al.*, 1985), carbonaceous residue, product of a degasified municipal refuse, can be used to substitute costly chemical flocculants.

As the principal objective of this work was to find an alternative for more effective sludge conditioning, char production from pyrolysis of domestic refuse was undertaken in order to examine its applicability for improvement in sludge dewatering.

EXPERIMENTAL METHODS

Domestic refuse source. The material used for char production was obtained from the Bellville Composting Plant in the form of shredded municipal solid waste. The waste was pre-selected , after the removal of glass and metal and was shredded before composting. The precomposted and sorted material was used for char production.

Equipment used for char production.The bench scale refuse burner used for production of pyrolysed char has an overall height of 700 mm with an external diameter of 440 mm. It consists of an outer casing with heater element, a specimen holder and a temperature control box. The specimen holder is made from mild steel and fits into the furnace without touching the inner walls where the elements are located. The two heater elements are located on a spiral groove running the length of the furnace. An insulated blanket is located between the furnaces' inner wall and the outer steel sheath. The temperature control box has the capacity to regulate temperatures of up to 1000°C.

Sludge samples. Samples of activated and anaerobically digested sludge were collected from different Western Cape Wastewater Treatment Plants. For comparative purposes unconditioned and conditioned sludge samples were grouped as follows: (a) no additives, (b) polyelectrolyte, (c) char, (d) char and polyelectrolyte. The addition of conditioning chemicals was calculated on the basis of the mass of chemical per unit mass of dry solids in the sludge. This was expressed in kilogram per ton of dry solids (kg/tds). Samples (b) were mixed with cationic polyelectrolyte in quantities of 3 to 5 kg per ton of dry solids, depending on the propensity of a sludge to flocculate. Samples (c) were mixed with char in ratio of 500 kg per ton of dry solids. Samples (d) the same as (c) but with admixture of polyelectrolyte in quantities of 0.5 to 1.0 kg per ton of dry solids.

Solids analysis. The standard solids analysis was used for determination of total solids concentration. The wet mass of the centrifuged sludge cake was determined prior to subsequent drying for 12 hours at 105°C. The concentration of total solids was expressed as mass per unit volume; i.e. g/l. Owing to the large numbers thus obtained and because of established practice, solids concentration was expressed as percentage by mass, with 1% being taken as 10 g/l.

Centrifugation test. Representative sludge sample of a convenient mass was transferred to a tared centrifuge tube and centrifuged at 3960 G. After 5 min of centrifugation the centrifuge was braked to stop as quickly as possible and the centrate immediately discarded.

Filtration test. The laboratory filtration was carried out in a stainless steel cylinder sealed off by means of a locking ring. Whatman 541 filter paper was placed in the cylinder and a sludge sample was subjected to a pressure of 3 atmospheres for 30 minutes.

Table 1. Results from laboratory centrifugation experiments

SLUDGE SAMPLE	CAKE SOLIDS CONCENTRATION (%)							
	No additives		**Polymer**		**Char**		**Polymer & Char**	
	Initial	**Final**	**Initial**	**Final**	**Initial**	**Final**	**Initial**	**Final**
Activated sludge: Athlone	0.6	8.9	0.7	7.8	0.9	12.4	0.9	11.4
DAF: Athlone	3.6	7.7	3.2	7.3	5.0	11.1	4.8	10.8
Activated sludge: Bellville	1.3	10.7	1.0	8.2	1.0	16.2	0.6	12.4
DAF: Bellville	1.8	11.6	1.9	12.7	2.9	17.1	2.8	15.5
Activated sludge: B/Quarry	3.4	9.5	3.0	8.3	3.5	13.3	4.7	17.6
DAF: B/Quarry	4.3	5.8	4.0	8.3	5.7	9.7	4.8	10.4
Anaerobic digestion: Athlone	3.2	11.2	2.6	14.0	3.4	33.3	3.6	20.0
Anaerobic digestion: Bellville (glucose-starch)	11.7	28.3	12.0	28.9	18.0	41.2	20.7	38.0
Anaerobic digestion: C/Flats	1.9	6.4	2.2	9.1	2.2	10.3	2.2	15.5
Anaerobic digestion: M/Plain	1.8	6.9	1.3	6.2	2.5	9.9	2.6	11.1

RESULTS AND DISCUSSION

Laboratory results obtained from centrifugation and filtration tests are summarised in Tables 1 and 2 respectively.As it can be seen the addition of polyelectrolyte on its own produced the lowest cake solids concentration. Improved filtration was observed when char was added substituting the polymer addition. The best results were obtained from filtration tests after an addition of the mixture of char and polymer. The improvement in final cake solids after centrifugation (Table 1) was not as significant as after filtration tests (Table 2). Difficult to dewater activated and anaerobically digested mixture of primary and activated sludge after filtration reached an unusually high cake solids concentration in a region of 30 and above 40 percent dry solids. Judging from the initial solids concentration, the increased final cake solids was not attributed to the presence of added char (Table 2). The results indicate that a mixture of char and polyelectrolyte produces a beneficial effect in conjunction with anaerobically digested sludges. This finding is very important as anaerobically digested mixtures of activated and primary sludges create major handling and disposal problems due to their poor dewaterability (Smollen, 1986).

Table 2. Results from laboratory filtration experiments

SLUDGE SAMPLE	CAKE SOLIDS CONCENTRATION (%)							
	No additives		**Polymer**		**Char**		**Polymer & Char**	
	Initial	**Final**	**Initial**	**Final**	**Initial**	**Final**	**Initial**	**Final**
Activated sludge: Athlone	0.6	32.2	0.7	25.4	0.9	28.9	0.9	36.6
DAF: Athlone	3.6	10.5	3.2	18.9	5.0	19.0	4.8	32.8
Activated sludge: Bellville	1.3	23.7	1.0	19.1	1.6	35.6	0.6	36.0
DAF: Bellville	1.8	25.8	1.9	12.7	2.9	38.6	2.8	36.4
Activated sludge: B/Quarry	3.4	10.2	3.0	17.7	3.5	28.0	4.7	29.0
DAF: B/Quarry	4.3	8.3	4.0	14.9	5.7	17.7	4.8	32.9
Anaerobic digestion: Athlone	3.2	11.8	2.6	14.8	3.4	21.3	3.6	41.1
Anaerobic digestion: Bellville (glucose-starch)	11.7	28.3	12.0	22.2	18.0	29.1	20.7	68.8
Anaerobic digestion: C/Flats	1.9	2.3	2.2	17.6	2.2	12.8	2.2	34.7
Anaerobic digestion: M/Plain	1.8	5.2	1.3	10.6	2.5	28.6	2.6	41.3

Mechanism of synergy between char and polyelectrolyte. Use of an admixture of pyrolysed domestic refuse (char) and a polyelectrolyte represents an innovative approach in sludge conditioning prior to mechanical dewatering. After the observation of improved efficiency in sludge filtration, this conditions has been attributed to the synergy which takes place between flocculating agents and sludge particles. The addition of char, which is a relatively inert material, forms a porous, permeable and rigid lattice structure. The addition of polyelectrolyte results in a loose structure in flocculated sludge with a large quantity of different space cavity voids. Char addition therefore acts as a skeleton builder resulting in larger and stronger sludge particles. The rigid structure created by char gives strength to resist attraction from forces applied during the process of dewatering by filtration, while the increased particle size achieved by the inclusion of polyelectrolyte improves filtration by reducing the viscous drag per unit weight of particle.

CONCLUSIONS

Laboratory filtration and centrifugation tests were carried out on sludge samples conditioned with: (1) polyelectrolyte, (2) pyrolysed domestic refuse (char) and (3) an admixture of char and small qualities of 0.5 to 1.0 kg/tds of polyelectrolyte. Based on the results the following conclusions were drawn:

- the use of polyelectrolyte on its own resulted in the lowest cake solids concentration
- the best cake solids concentration in a region of 30 and 40 percent was obtained after laboratory filtration of the addition of a char and polymer mixture

- the synergy between char and polymer occurs increasing the structural strength and permeability of dewatered sludge
- the synergy influences the efficiency of dewatering by centrifugation to a lesser degree than the process of filtration
- the most significant increase in final cake solids concentration was achieved when an admixture of char and polymer was added to an anaerobically digested mixture of primary and activated sludges

The method of using a mixture of char and polyelectrolyte must, however, be tested under field conditions. Future work is needed to include such measurements as surface area and pore sizes, in order to determine all the optimum operational variables for the production of char characterised by the highest possible porosity.

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