

Moisture retention characteristics and volume reduction of municipal sludges

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Abstract

The efficiency of dewatering methods, which are used for volume reduction of municipal sludges, does not meet the requirements of the majority of waste-water treatment plants. However, process selection and efficiency can be improved by the development of a data base for sludge moisture retention characteristics and the factors affecting them.

In this paper the moisture retention characteristics of sludge are categorised and quantified in the light of existing laboratory drying techniques, as a basis for rational selection of dewatering techniques.

Introduction

Municipal sludges are hydrophilic by nature and typically have moisture contents of 99,7 to 98 %. This moisture is difficult to remove. In recent times the disposal of increasingly large volumes of this potentially noxious and hazardous material has resulted in larger energy inputs into volume reduction by dewatering, leading to a steady increase in overall costs.

The majority of the larger waste-water treatment plants make use of mechanical dewatering such as filtration and centrifugation – complex and expensive methods generally dictated by the fact that municipal sludges do not respond well to dewatering procedures.

The search for improved dewatering techniques is being pursued worldwide, with new approaches and associated equipment regularly appearing on the market. To appreciate the improved performance of the new systems it is necessary to identify the factors that control the dewatering capability of a device; this in turn requires an understanding of the water retention characteristics of sludges and their relation to the performance of the dewatering system.

This paper briefly reviews some sludge properties affecting dewaterability, the tests whereby these properties are determined and the manner in which these properties determine the selection of the optimum dewatering system.

Types of moisture which affect dewaterability

The liquid phase of sludges may be divided into a number of moisture types defined in terms of moisture to solids bond strength. The relative magnitudes of the moisture types influence the specific energy requirements for solids separation. Knowledge of these is a prerequisite for rational selection of the most cost-effective sludge volume reduction process.

On the basis of experimental data, Smollen (1986) distinguished the following categories of municipal sludge moisture content (Fig. 1):

- Free moisture – minimally bound to solids, removable by gravity separation.
- Immobilised moisture – floc-entrapped moisture characterised by low binding energy and removable by the application of energy in the form of mechanical dewatering (vacuum or pressure filtration, centrifugation etc.).
- Bound moisture – moisture absorbed by or strongly adsorbed onto individual sludge particles, removable by processes such as electro-osmotic dewatering and thermal drying.

- Chemically bound moisture – moisture bound to solids by strong chemical bonds and removable by thermal drying at temperatures above 105° C.

Quantification of moisture categories

Although various categories of moisture have been recognised in sludge dewatering, no specific laboratory quantification techniques have been available. Smollen (1986) recently proposed experimental procedures whereby the moisture types in municipal sludges can be categorised. These procedures are empirical, based

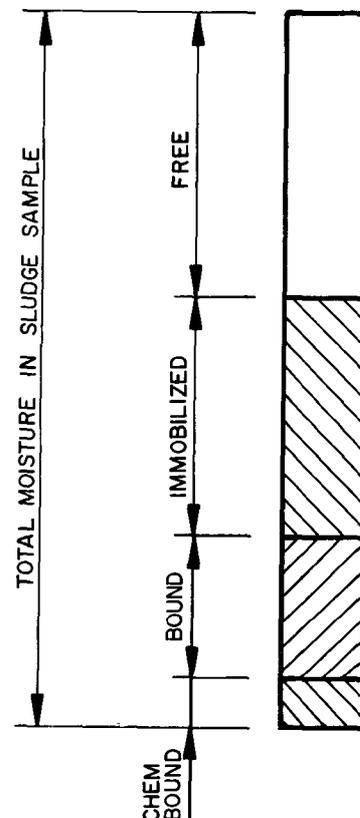


Figure 1
Categories of moisture in municipal sludges

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on observed behavioural trends. A sludge sample from a municipal waste-water treatment system is mechanically dewatered in the laboratory by vacuum filtration. The sludge cake is then dried at constant low temperature (30°C) at controlled humidity, following a specific procedure, until the cake shows no further loss in mass. Moisture loss is plotted vs. drying time (Fig. 2), and a drying rate curve is calculated (Fig. 3). The moisture content at point C in Figs. 2 and 3, at which the rate of moisture loss changes from a constant to a declining value, is termed the critical moisture content. This point theoretically defines the state at which all the immobilised moisture has been removed, and only bound moisture remains.

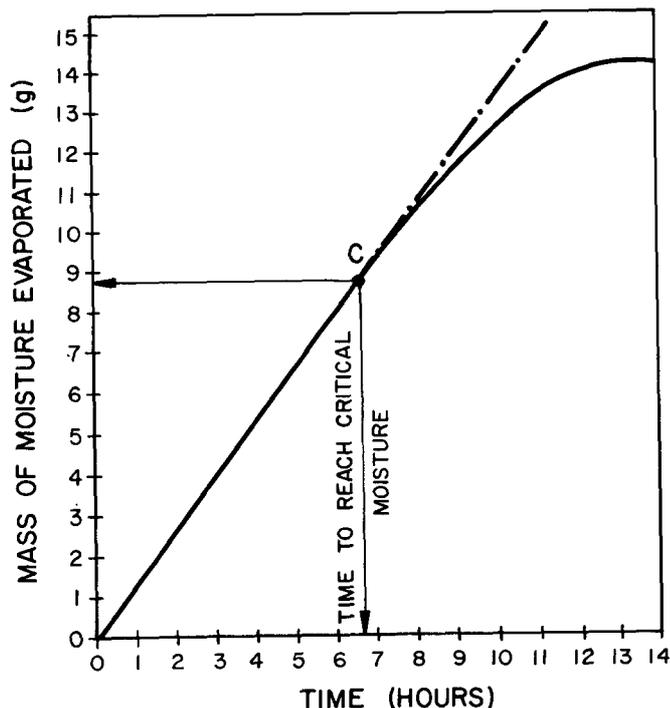


Figure 2
Evaporated moisture versus time

In addition to identifying the limiting conditions for the immobilised and bound moistures, the drying test can also provide other indications as to the dewatering characteristics of a given sludge:

- The drying time required for sludge cake to reach the critical moisture content may be read from the curves and by comparing these times for different sludges, a data base can be established, relating this measurement to the efficiency of the different dewatering processes. For rational comparison it would be necessary to standardise the method of mechanical dewatering prior to the drying test. Smollen (1986) used laboratory vacuum filtration, but this procedure has not yet been perfected. It is not necessarily the system to be preferred; other methods such as laboratory centrifugation may prove to be superior.
- The dried cake may provide a visual qualitative assessment of cake consistency, for example: activated sludge float from a DAF unit, upon test drying, acquires a leathery, shiny, cohesive appearance, whereas anaerobically digested fruit-processing waste sludge, on drying, yields a crumbly sludge cake. Dried cake description should be standardised, and correlated with the relative efficiency of the different dewatering processes.

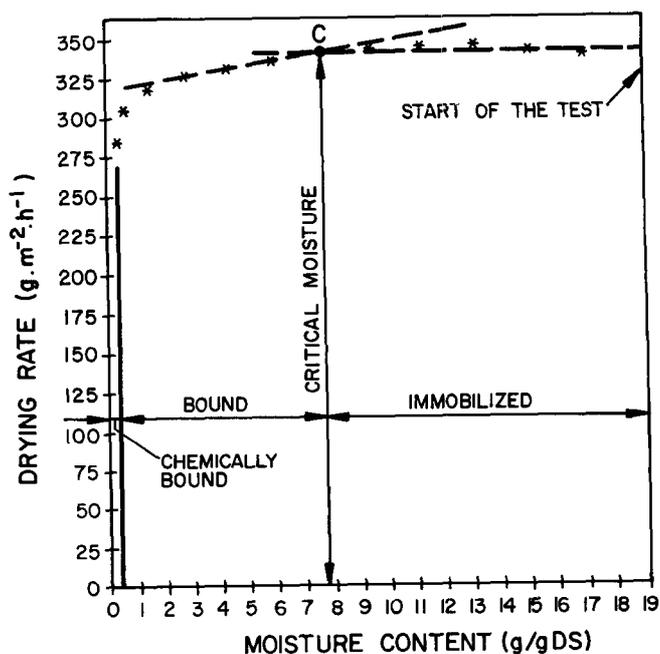


Figure 3
Drying rate curve

Sludge volume reduction required

Figs. 4 and 5 graphically illustrate the relationship between moisture content and volume reduction. It is clear that moisture content reduction results in a very considerable reduction in the volume of sludge to be handled. By merely lowering its moisture content to 90 %, sludge with an original moisture content of 95 % is reduced to 50 % of its original volume (Fig. 4). The initial reduction is readily achieved, the water removed being of the "free moisture" category. Once the free moisture is removed, greater energy is needed to remove the "immobilised moisture", held to the solids particles by stronger attractive forces.

Ideally, the removal of the different categories of moisture should be accomplished by different unit processes: free moisture by thickening, immobilised moisture by mechanical dewatering and bound moisture by thermal drying.

It will be seen from Fig. 5, that the original volume of 1 000 l with a moisture content of 95 % has been reduced to 333 l with a moisture content of 85 %, as a result of the removal of free water through thickening.

Immobilised moisture is then removed by mechanical dewatering to give a final volume of 125 l with 60 % moisture content. In practice, the volume reduction shown in Fig. 5 is rarely achieved, even with the aid of chemical conditioners, since most of the time the free moisture fraction is not completely removed during the thickening stage. The dewatering equipment treating the thickening sludge thus simultaneously but unintentionally performs two functions: thickening and mechanical dewatering - thereby decreasing its efficiency.

Selection of dewatering methods

In dewatering municipal sludges the important sludge cake characteristics are:

Moisture content

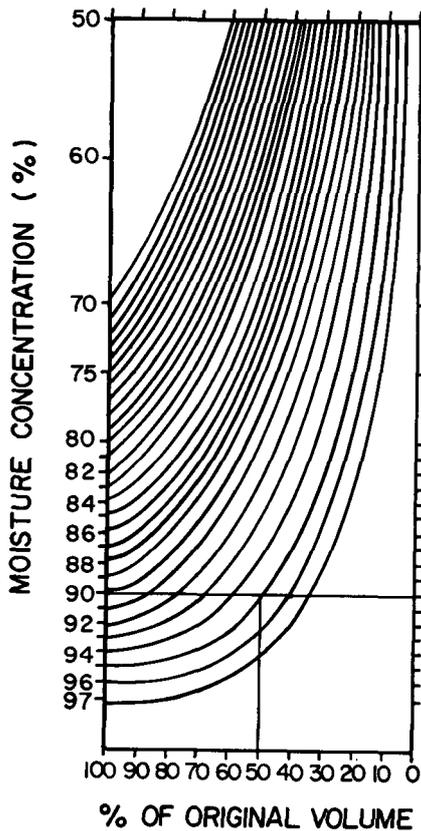


Figure 4

Moisture content versus volume reduction (Schmidtke, 1978)

- immobilised

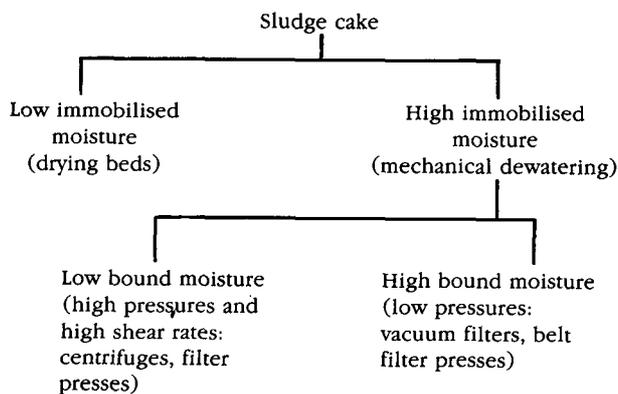
- bound

Appearance

- cohesive
- granular

Generally speaking, high immobilised moisture content is associated with long drying time and cohesive cake appearance.

The following diagram broadly summarises the drying characteristics associated with different dewatering methods:



Consider the following examples of different dried sludge cake moisture content:

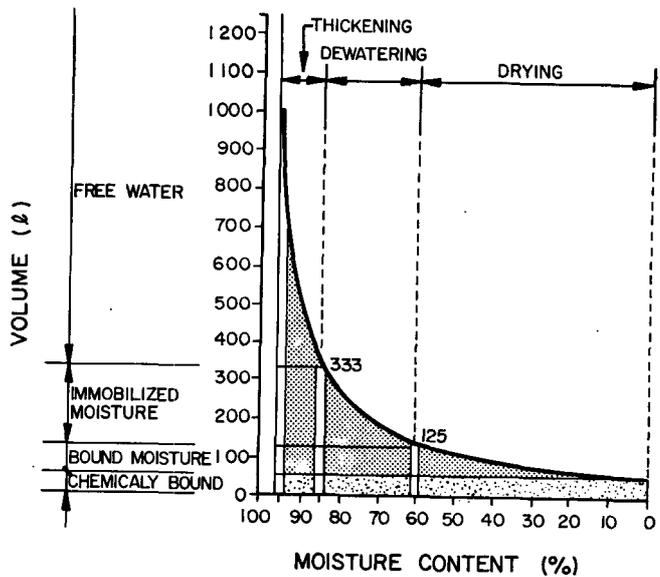


Figure 5

Moisture reduction: comparison of moisture removal by different dewatering processes

(i) Anaerobically digested fruit-processing waste

Immobilised moisture content	2,24 g H ₂ O/g dry solids
Bound moisture content	1,20 g H ₂ O/g dry solids
Dried sludge cake appearance	granular

(ii) Heat-treated - Zimpro primary sludge

Immobilised moisture content	2,46 g H ₂ O/g dry solids
Bound moisture content	2,68 g H ₂ O/g dry solids
Dried sludge cake appearance	granular

(iii) Anaerobically digested mixture of primary and secondary sludge

Immobilised moisture content	8,58 g H ₂ O/g dry solids
Bound moisture content	3,00 g H ₂ O/g dry solids
Dried sludge cake appearance	cohesive

(iv) DAF activated sludge

Immobilised moisture content	4,1 g H ₂ O/g dry solids
Bound moisture content	5,4 g H ₂ O/g dry solids
Dried sludge cake appearance	cohesive

Regarding the choice of dewatering technologies, Examples (i) and (ii) suggest the use of drying beds in view of the low immobilised moisture content and granular sludge cake appearance.

Example (iii) indicates use of mechanical dewatering by filter press or centrifuge owing to the high immobilised but low bound moisture content and cohesive cake appearance. Example (iv) also suggests mechanical dewatering, but in view of the high bound moisture content, vacuum filter and belt press will be more appropriate than high pressure and high shear rate equipment such as centrifuge and filter press.

Conclusions and recommendations

Owing to the low efficiency of currently used sludge dewatering systems the requirements of waste-water treatment plants relating to sludge volume reduction are seldom met. This is due not only to the inherent limitations of the dewatering systems but also to a lack of a rational basis for the selection of dewatering techniques appropriate to specific sludges. The most important sludge property affecting efficiency of a dewatering system is sludge moisture retention capacity which directly governs the degree to which a sludge can be dewatered.

Based on a laboratory drying technique the moisture content of municipal sludges was quantified and categorised as follows: free moisture; immobilised moisture; bound moisture; and chemically bound moisture.

In addition to delimiting the different categories of moisture, the drying test also provides other information. The drying time required to reduce the moisture content to the critical level, and visual assessment of the dried cake consistency are the parameters which can be related to the efficiency of the different dewatering processes.

In essence, low immobilised moisture content, usually associated with short drying time and granular (crumbly) appearance of dried cake calls for the use of drying beds. High immobilised

moisture content and cohesive sludge cake appearance calls for mechanical dewatering. High immobilised moisture content may be accompanied either by low or high bound moisture content. With low bound moisture content, equipment which can be operated under high pressures and high shear rates is recommended, whereas with high bound moisture better results may be expected using vacuum and belt filter presses.

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References

- SCHMIDTKE, N.W. (1978) *Sludge thickening, conditioning and dewatering fundamentals* Wastewater Tech. Centre, EPS. Canada.
- SMOLLEN, M. (1986) Categories of moisture content and dewatering characteristics of biological sludges. *Proceedings of the 4th World Filtration Congress*, Ostend (Belgium), 22-25 April.