STABILISATION OF WOOL SCOURING SLUDGE BY COMPOSTING.

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ABSTRACT

Wool scouring sludge is the solid waste product of anaerobic treatment of wool scouring effluent. It has a high wool grease content (13 - 16% of the dry weight, 45 - 55% of the organic matter), resulting in a low melting point (approx. 45°C). The low melting point, the putty-like physical properties and the odourous, unstable nature of the sludge makes it unsuitable for land application in its raw state. Composting of the sludge was investigated to ascertain its suitability as a treatment method for stabilising wool scouring sludge and improving its suitability as a soil amendment.

Composting was carried out in a computer controlled, laboratory scale, forced aeration, incubator system. Wool scouring sludge was rapidly compostable, reaching 47.1°C in 3 days. The temperature did not exceed 47.1°C. The mesophilic / thermophilic phase of the composting process required 21 days. Composting reduced the grease content of the waste by 37%, with the result that the composted waste could not be melted. The compost resulted in greater plant yields of radish and wheat than the original sludge.

1. INTRODUCTION

Wool scouring is the first stage of raw wool processing. This involves washing the wool to remove dirt, wool grease (lanolin), water soluble materials and contaminants, which together represent 36% of the original weight of the raw wool (Isaac, 1991).

While many methods for treating wool scouring effluent are under evaluation, the currently favoured method is via anaerobic lagoons. Anaerobic lagoons are the simplest of the biological methods of treatment and involve pumping the effluent through a series of lagoons. Pollutants are removed by settling and the action of naturally occurring microbes (Gibson *et al.*, 1981; Isaac, 1991). Due to the settling action, the lagoons have to be drained periodically, and the settled solids removed. The settled solids are called wool scouring sludge.

Wool scouring sludge has a low organic fraction (29 % of dry weight) and a high grease content (13 - 16% dry weight, 45 - 55% of the organic fraction). The sludge has a melting point of approximately 45°C, which makes it unsuitable for land application / soil amendment. This is especially so in Australia where soil surface temperatures regularly exceed 45°C. The waste has a physical structure resembling a putty, due to the high wool grease content. The sludge is odourous and unstable.

Composting was investigated to ascertain its suitability as a treatment method for stabilising wool scouring sludge. Theoretically, composting of wool scouring sludge was likely to be difficult due to its low melting point. Melting of the waste requires energy to overcome the latent heat of melting energy barrier. Once melted the sludge causes the interstitial area of the compost to decrease, thus interfering with aeration. These factors were expected to limit the maximum temperature during composting to 45°C, while 55°C is considered optimal for composting (Mathur, 1991).

Composting as a process has six basic requirements. These are structure of mass (in particular interstitial area), oxygenation, aeration, moisture, nutrients and microbes. The main process parameters are temperature, moisture and pH. Temperatures of 55 to 60°C are considered optimal for maximum reaction rate and pathogen reduction. A carbon to nitrogen ratio (C/N ratio) of 25 is optimal, and is considered the most important of the nutrient requirements (Mathur, 1991). The maximum moisture content recommended for sludge / wood shavings mixtures is 50% (Haug, 1980).

The aim of the research is to determine if composting is a suitable process for the stabilisation of wool scouring sludge. The first priority for successful treatment of the sludge is to lower the wool grease content of the sludge. This is expected to increase the melting point of the sludge compost, making the sludge more suitable for land application / soil amendment.

2. MATERIALS AND METHODS

A computer controlled, laboratory scale, forced aeration composting system was used for the experiment. The temperature control was set at, or below 55°C and functions by increasing the air flow rate, and thus cooling, if the temperature exceeds the set temperature (Hofstede, 1993).

Parameters measured during the composting process are given in Table 1. Evaporative moisture loss was measured by condensing the exhaust gas from the compost. By acidifying the condensate the loss of ammonia from the compost could be measured as the concentration of ammonium in the condensate.

The initial composition of the compost mixture was :
a) 13.2 kg (wet) wool scouring sludge
b) 3.3 kg (wet) wood shavings (Jarrah)
c) 1.45 L deionised water
d) 102.3 g urea (A.R. grade).

The C/N ratios and moisture contents of the components of the composting mixture are given in Table 2. The resulting initial compost mixture had sufficient interstitial air space to be aerated and had a C/N ratio of 25. The moisture content was 45%. Higher moisture contents (e.g. 50%) resulted in the compost mixture turning to a slurry, which could not be aerated. The experiment was run in duplicate.

Table 1 **Process parameters measured and the analytical methods utilised.**

Parameter	Method of analysis
Temperature	Pt temperature probe
CO_2 and O_2	In-line infra red detector and microfuel cell
% Moisture	drying at 110°C
% Volatile solids	Incineration at 550°C
Chemical oxygen demand in water extract (COD)	Chromic acid digestion, FAS titration
pH	1:5 compost:water, Hanna probe
Total organic carbon (TOC)	Chromic acid digest, spectrophotometric analysis
Total Kjeldahl nitrogen (TKN)	H_2SO_4 digest, spectrophotometric analysis
Evaporative loss	Condensate volume
N-NH_4^+ loss	Orion NH_3 probe
Grease analysis	1,1,1-Trichloroethane extraction
Substrate mass	Rotary scale

Table 2 **C/N ratios and moisture contents of the components for the composting mixture.**

Material	C/N ratio	% H_2O
Wool scouring sludge	32.0	48.4
Wood shavings	340	9.1
Urea (A.R. grade)	0.435	0

PLANT POTTING TRIALS

Determination of the growth yield of plants allowed a direct comparison of composted and fresh uncomposted sludge. Lancelin sand, a poor nutrient free sand, was added to free draining pots. Fresh sludge, initial compost mixture (sludge, wood shavings, water and urea) or final compost product were added to the surface of the sand, at an application ratio of 160 t/ha. A control using Lancelin sand only was used.

Each pot was repeated with and without nutrients. Nutrients added consisted of 40 mL, twice weekly of a 2.5 mL/L solution of 'Spring Fertilizer' (Faulding and Co.). Radish (Fireball) and wheat (Gremenya) were utilised, as they are fast growing, have small seeds, and represent both monocot and dicot plant types. 3 seedlings per pot were grown. Pots were watered twice daily. Two replicates of each pot were conducted. The plants were grown in a temperature controlled glasshouse.

3. RESULTS

TEMPERATURE PROFILE

The maximum temperature recorded in the composting incubators was 47.1°C on day 3 in incubator 2 (Figure 1). The volume of the compost mixture was observed to have decreased significantly (approximately 20%) by day 8, and as the temperature was decreasing, the compost was remixed. Remixing restored the pore volume of the compost and resulted in the temperature increasing. Mixing of the compost on day 18 produced no such temperature rise, and the composting process was assumed to have come to completion.

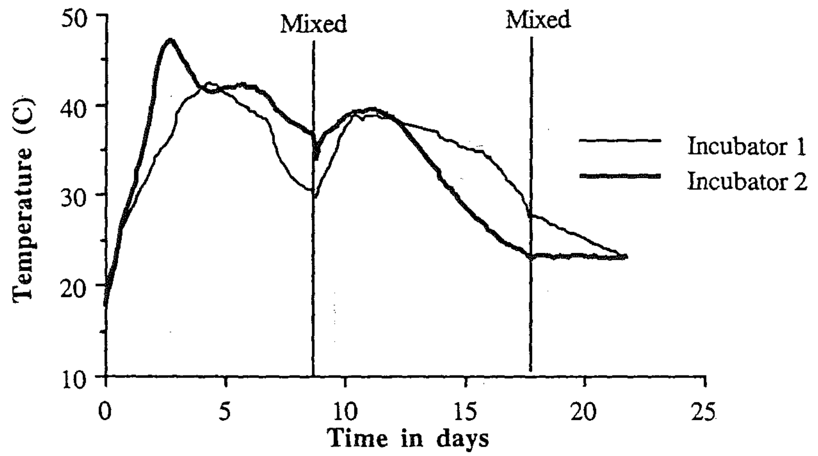

Figure 1 **Temperature profile during the composting of wool scouring sludge.**

GREASE REMOVAL

The grease content decreased linearly, up to day 14, from 11.4% to 6.1% (approximately), in both incubators (Figure 2). After day 14 the grease content remained relatively constant. The reduction in grease was 37% in the first 14 days. The grease content of the composted sludge was monitored for 56 days, to investigate whether the grease content varied during maturation of the compost. Temperature and O_2/CO_2 were measured for 21 days.

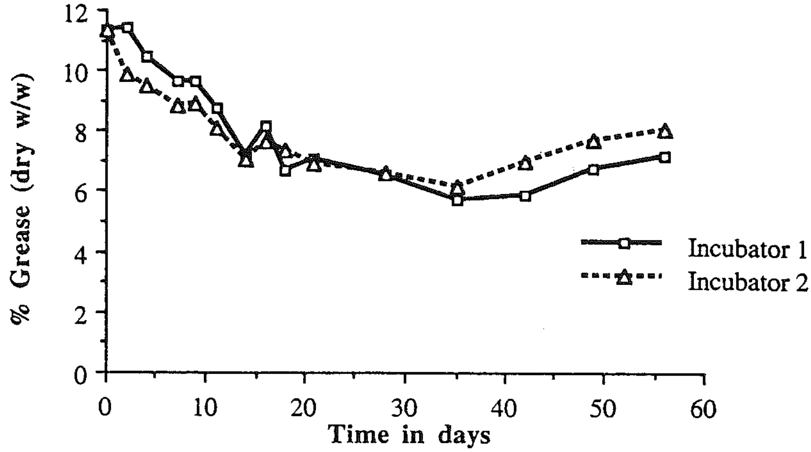

Figure 2 **Grease reduction during the composting of wool scouring sludge.**

RESPIRATION QUOTIENT DURING COMPOSTING OF WOOL SCOURING SLUDGE
The average concentrations of CO_2 and O_2 in the exhaust gases were approximately 3.5% and 16% respectively, in both incubators. Up to day 14 the respiration quotients (CO_2 produced / O_2 consumed) were 0.67 (approx.), after which they increased to above 1 (Figure 3).

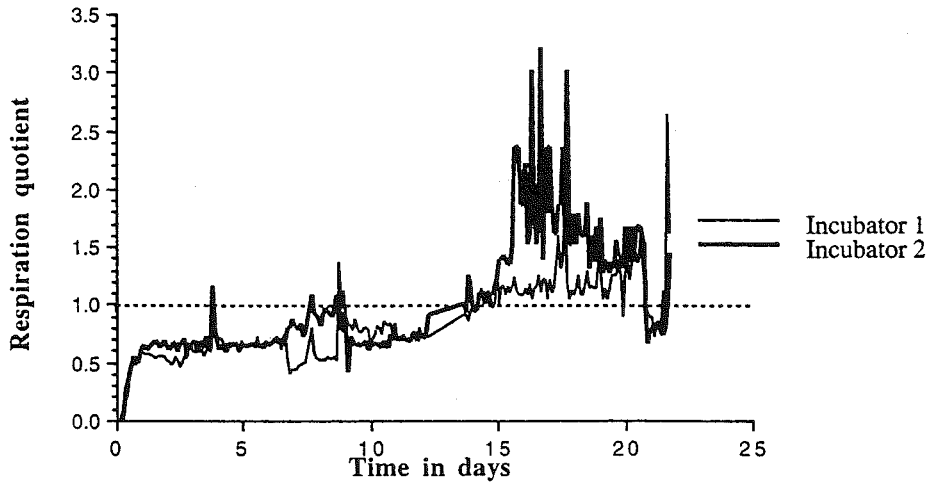

Figure 3 **Respiration quotient during composting of wool scouring sludge.**

pH AND ORGANIC MATTER
The pH of the sludge fell from the initial of 8, to between 6 and 7 between days 21 and 56. Results of TKN, TOC and volatile solids display evidence of error, as they all remained relatively constant. TOC and volatile solids should decrease during composting, with TKN increasing. The soluble COD (1:10 dilution) of the compost decreased, as expected, from 361 to 266 (± 2) mg COD/L at completion. Nitrogen loss from the compost as ammonia, was insignificant.

PLANT POTTING TRIALS
Composting of the wool scouring sludge resulted in a significant increase in the plant yield of wheat and radish (Figure 4). The initial compost mixture (sludge, wood shavings, water and urea) resulted in death of the radish plants, possibly due to the urea added.

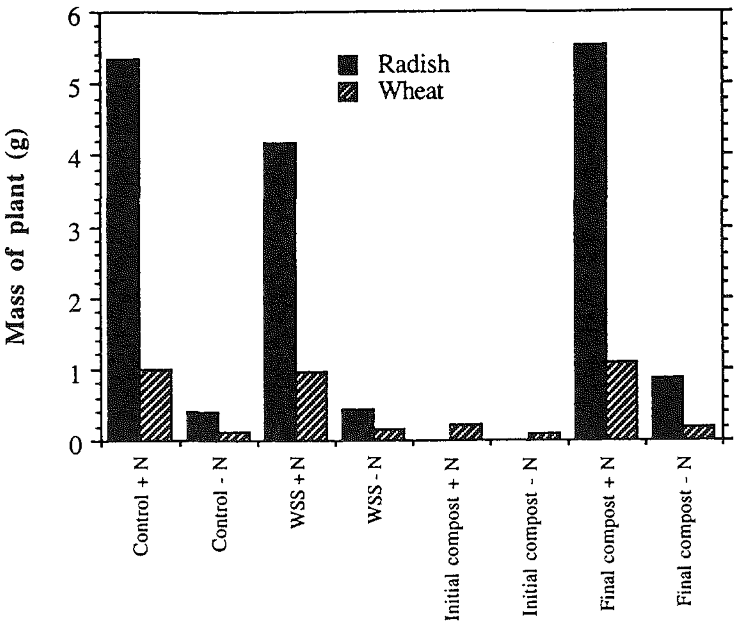

Figure 4 **Plant growth, for wool scouring sludge, of radish and wheat in sand with surface applied sludge.**
WSS is the pure untreated wool scouring sludge. Initial compost and final compost refers to the compost mixture (sludge, wood shavings, water and urea) before and after composting.

4. DISCUSSION

The failure of the temperature in both wool scouring sludge incubators to achieve thermophilic conditions was possibly due to the melting point of wool scouring sludge (approx. 45°C). This melting point is controlled by wool scouring sludges largest organic constituent, wool grease. Wool grease (primarily lanolin, melting point of 38 - 42°C) accounts for 45 - 55% of the volatile solids in wool scouring sludge.

Theoretically the increase in temperature above 45°C during the composting of wool scouring sludge is difficult, due to the energy required to overcome the temperature barrier caused by the latent heat of melting. When melted, the interstitial area of the compost decreases, thus limiting aeration and as a result limiting the composting reaction. Thus the maximum temperature expected during composting of wool scouring sludge was 45°C. This hypothesis was confirmed by the maximum temperature of 47.1°C reached during composting.

During composting of the wool scouring sludge the interstitial space was reduced due to a collapse of the composts structure. This was likely to be due to the lowered viscosity of the waste at higher temperatures, affecting the structure of the compost. The reduced aeration of the compost resulted in a fall in composting rate, as displayed by the fall in temperature after day 5. When the composting mass was remixed, the interstitial area was restored, and the temperature increased (Figure 1). Thus regular mixing of the wool scouring compost is considered essential.

The grease content of the waste decreased by 37% during the first 14 days of composting. While pure wool scouring sludge and the initial composting mixture (the starting material, consisting of wool scouring sludge, wood shavings, urea and water) melted at temperatures of about 50°C, the final product of composting could not be melted. Thus it would be expected that decreases in the interstitial area, necessitating mixing, would only occur to a large degree in the first 14 days of composting, when the grease content was high.

The variations of the concentrations of O_2 and CO_2 in the exhaust gases during composting of wool scouring sludge indicate an interesting, but explainable point. In both incubators, during the first 14 days, the ratio of CO_2 produced to O_2 consumed was approximately 2 : 3 (Figure 3), while it was initially anticipated that the respiration quotient would be 1. The theory that the quotient was constant at 1 was stated by Schulze (1964; Diaz *et al.*, 1993). It was as follows:

$$CH_2O + O_2 \rightarrow CO_2 + H_2O$$

giving a 1 : 1 ratio of CO_2 produced to O_2 consumed. Thus material having a basic formula of CH_2O, CO_2 production to O_2 consumption will be 1 : 1. However grease has the basic formula $(CH_2)_n$. Thus the following stoichiometric relationship will apply:

$$2\ CH_2 + 3\ O_2 \rightarrow 2\ CO_2 + 2\ H_2O.$$

Thus the CO_2 production to O_2 consumption will be 2 : 3. The period that the respiration quotient was 0.67 (up to day 14) coincided with the time of highest grease reduction. Thus the theory was confirmed by the findings.

Composted wool scouring sludge resulted in a significantly greater plant yield than un-composted wool scouring sludge. If temperatures were allowed to exceed normal summer temperatures, which are greater than the melting point of the sludge, a greater disparity may be evident. Melting, then cooling of the sludge results in a hard layer of sludge forming on the surface of the soil, which may limit water movement into the soil. This is yet to be investigated in detail.

5. CONCLUSION

Composting of wool scouring sludge was deemed successful for stabilising the sludge. Although temperatures in the wool scouring sludge incubators did not reach the 55°C recommended for optimum sludge to compost conversion rate and pathogen reduction (Mathur, 1991), it did rapidly increase to 45°C (approx.). As the waste was no longer able to be melted after composting, the primary objective of composting of wool scouring sludge was achieved. The wastes physical properties were also far more suited to its use as a soil amendment. The composted waste was odourless and stable, and was particulate in texture.

It is important to note that wool scouring waste is not human waste and as a result the high temperatures required for pathogen reduction (55°C - Mathur, 1991) may not be as critical as it is for human wastes. Pathogen studies are an area for further research.

Provided pathogen reduction is not critical for the use of wool scouring sludge as a soil amendment, composting of wool scouring sludge is a viable stabilisation process.

6. REFERENCES

Diaz, L. F; Savage, G. M.; Eggerth, L. L.; Golueke, C.G. 1993. *Composting and Recycling Municipal Solid Waste.* Lewis Publishers. California.

Gibson, J. D. M.; Morgan, W. V.; Robinson, B. 1981. Wool scouring and effluent. *Wool Sci. Rev.* 57 : 36.

Haug, R. T. 1980. *Compost Engineering - Principles and Practice.* Technomic Publishing Co. Lancaster.

Hofstede, H. T. 1993. *Use of Bauxite Refining Residue to Reduce the Mobility of Heavy Metals in Municipal Waste.* PhD Thesis. Murdoch University. Western Australia.

Isaac, D. 1991. *Anaerobic treatment of wool scouring effluent.* Honours Thesis. Murdoch University. Western Australia.

Mathur. S. P. 1991. Composting Processes. In:*Bioconversion of Waste Materials to Industrial Products* (Ed. Martin, A.M.). Elsevier Applied Scence.

Schulze, K. F. 1964. Rate of Oxygen Consumption and Respiration Quotients during the Aerobic Composting of Synthetic Garbage. *Compost Sci.* 1 : 36.

The above research was conducted as part of the Honours Thesis '*Vermicomposting Versus Composting in the Treatment of Anaerobic Sludges*' by Barrie Watson (1993).