POSSIBLE CONCENTRATION AND DISPOSAL PROCESSES
FOR LOW LEVEL TREATMENT PLANT SLUDGE

by

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ABSTRACT

The problem of disposal of low level treatment plant sludge produced at the A.A.E.C. Research Establishment is discussed, possible methods of treatment and disposal are examined, and recommendations are made regarding suitable processes for Lucas Heights. The simplest and most economical method of disposal is to use solar energy to dry the sludge in large open pans and cap them when full.
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Table 1 Summary of possible sludge treatment and disposal processes for 15,000 gallons of 5% T.S. sludge per year.
1. INTRODUCTION

Effluent from active areas at Lucas Heights is collected in a series of Delay Tanks and pumped to the Treatment Plant for a scavenging-flocculation treatment. This is a continuous process, carried out in an industrial sludge-contact clarifier (Dorrco Hydro-treater) by adding a small laboratory controlled dose of alum (3 to 7.5 p.p.m. Al) and adjusting the pH to 6.0-6.5. Sludge with a solids content of 3.5-6.0% w/w is withdrawn at intervals. Approximately one gallon of sludge is produced for each 700 gallons of effluent treated.

The present rate of sludge production is between 200 and 300 gallons per week, depending on operating variables, and is not expected to increase significantly in the future. A production rate of 300 gallons per week or 15,000 gallons per year should therefore provide a satisfactory basis for estimates of future operations.

The sludge produced since the beginning of 1960 has been temporarily stored in 44 gallon drums. The total stored at 31st October 1963 was 34,000 gallons in 810 drums. Some of these drums are deteriorating badly and are expected to fail in the near future. It is therefore essential that a satisfactory method of concentration and disposal be selected and introduced before large scale re-drumming operations become necessary.

The total amount of contamination in the stored sludge is estimated to be 10 mc α activity, 400 mc β activity, and 3 kg beryllium. If conditions do not change greatly, the estimated yearly production would contain 200 mc activity and 1.5 kg beryllium.

The maximum radiation dose rate at the surface of the drums is 1 mrem/hr.

In general the contamination levels in the sludge are:

α activity : $10^{-6}$ to $10^{-4}$ μc/ml
β activity : $10^{-4}$ to $10^{-2}$ μc/ml
Beryllium : 20 to 50 p.p.m.

It is evident that the potential hazard of the sludge is low.

The method adopted for concentration and disposal should be cheap, simple, and safe. This report examines processes in use at overseas establishments, considers other processes which have been proposed for Lucas Heights and recommends suitable methods for dealing with both stored sludge and future arisings.

2. PRACTICE AT OVERSEAS ESTABLISHMENTS

The nature of the sludge and the methods of concentration and disposal at overseas establishments vary considerably. In general it is difficult to get detailed accounts of the methods, but the following brief descriptions do give some indication of how the problem is being dealt with.
2.1 Harwell

Blythe (1962) states that 2 per cent sludge produced at Harwell first undergoes freezing and thawing to improve filterability, and then is pressure or vacuum filtered to give a 20 per cent solids cake, which is packed in drums for sea disposal. Successful experiments have been carried out on centrifugal filtration, in which the sludge is collected inside the centrifuge bowl and both sludge and bowl are disposed of. The activity level of the sludge is similar to that of sludge from Lucas Heights.

2.2 Windscale

Sludge at Windscale is pumped to tanks constructed of one foot thick prestressed concrete and having a capacity in excess of 220,000 gallons (Glueckauf 1961). It concentrates by sedimentation and filtration through a shallow clinker bed and a vertical porous column covered with Vinyon filter cloth. This is the final disposal vessel. Final solids content of the sludge is only 3 per cent.

2.3 Mol Laboratories

Dejonghe (1958) states that at Mol the sludge is concentrated on sand filters, but gives no details of activity level or disposal procedures.

2.4 Oak Ridge

At Oak Ridge sludge is settled in a 16,000 gallon storage tank. The sludge, of similar activity to that from Lucas Heights, is then hauled in a 4,000 gallon tanker to a waste disposal pit in Conasauga shale (Cowser 1958). The advantages of pressure filtration into a closed filter bag over vacuum filtration on a rotary vacuum filter have been demonstrated in pilot plant work by Brookesbank (1963). However, the method was not developed further as no commercial equipment was available.

2.5 Russia

Voznesensky (1958) describes operations at one Russian installation, where 1-2 per cent sludge is discharged to specially constructed covered pits fitted with a quartz sand filter on sides and bottom. Filtration of the sludge is assisted by freezing in the winter followed by artificial thawing. It finally air dries to 90-92 per cent solids. When full the pit is covered with soil or cement. The sludge is more active than that from Lucas Heights.

At another installation the sludge is dewatered in a centrifuge and then solidified with an equal volume of cement in waterproof lined trenches (Bolshakov 1958).

2.6 Marcoule

Bernaud (1958) states that at Marcoule 2 per cent sludge is filtered on shielded precoat filters to give 30-40 per cent solids. The sludge cake is packed in polythene lined metal drums which are then stacked in a protected area. This sludge is very active, the dose rate at the surface of the drums being 30-40 r/hr.
2.7 Discussion

Of the practices outlined above, four were considered for possible use at Lucas Heights.

(i) Discharge of thickened sludge into a pit as at O.R.N.L. is possibly the simplest and cheapest method of disposal available. However, a permanently high water table makes the Burial Ground at Little Forest unsuitable for this type of disposal.

(ii) The Russian practice of using pits with a filter lining is an extension of the O.R.N.L. method. It is unsuitable for Lucas Heights as no suitable site is available.

(iii) Dewatering on a sand filter bed as at Mol is simple and economical. It is especially attractive if the sludge can be allowed to dry and the bed eventually becomes the final disposal site. Consideration of this process led to the idea of solar evaporation discussed in the next Section.

(iv) Use of a pressure filter fitted with bags to contain the sludge as in the O.R.N.L. pilot plant is considered promising. It ensures that the sludge is dewatered as fully as possible and that it is enclosed for subsequent handling. This process is also discussed further in the next Section.

3. PROCESSES CONSIDERED FOR LUCAS HEIGHTS

The following methods have been considered for sludge concentration and disposal at the Research Establishment. Some of the methods have been investigated experimentally and where this has been done the relevant results are included.

3.1 Direct Burial

Direct burial is not feasible because of the nature of the Burial Ground (Section 2.7 (i)). However burial of raw sludge in drums may be quite safe. The drums could be expected to last for three years, during which time some decay would take place and the backfill would consolidate. Leaks from failed drums should be slow, and the sludge water, which contains practically no contamination, should gradually filter away, leaving the sludge solids behind. However, the uncertainty of the fate of the sludge, the high cost of drums, and the operational problems imposed by the nature of the burial ground make this method unacceptable, and it is not considered further.

Burial into lined trenches is considered uneconomical.

3.2 Thickening Followed by Mixing with Cement and Casting into Blocks

Thickening of sludge stored in drums reduces the volume to about 50% of the original value in a year. Experiments at Lucas Heights have shown that 100 ml of the thickened sludge can be
satisfactorily set with 130g of cement, giving a final volume of 140 ml. The 33,000 gallons at present stored would be reduced to approximately 20,000 gallons by thickening. This would require approximately 120 tons of cement for setting, costing approximately £2,000. The handling of the drums and the mixing and pouring of the treated sludge would probably cost a further £1,000. The simplest and cheapest method of casting for disposal purposes would be to pour it into a trench at the Burial Ground. The capacity of the trench would have to be approximately 170yd³, and excavation would cost about £200. Thus the total cost of disposal of the stored sludge would be about £3,200. It is not considered that a significant amount of activity would be released by leaching.

In view of the relatively high cost, solidification with cement is not proposed as a normal disposal procedure. However it would be a relatively simple method of disposal for that portion of the sludge currently stored in drums at the Burial Ground.

3.3 Vacuum Filtration Followed by Burial in Drums

Experimental work on Lucas Heights sludge has shown that its filtration rate is sufficient to make vacuum filtration practicable, either by leaf filters or a rotary filter. A filter-aid precoat does not appear to be necessary. The sludge cake produced would occupy about 25 per cent of the original volume and be about 20 per cent solids. Although a leaf filter would work satisfactorily, labour requirements would be high and contamination control difficult, so it is not considered further. A rotary vacuum filter would be expensive to install because of the ancillary equipment required and would probably have excess capacity for the present production. It should be able to cope with the backlog of stored sludge.

3.4 Pressure Filtration into Filter Bags

Consideration of the O.R.N.L. report led to some experiments on Lucas Heights sludge which indicated that it is quite amenable to pressure filtration.

A calico filter bag was enclosed in a section of 2 inch pipe 12 inches long, which had a perforated plate liner. Sludge was fed into the filter under controlled pressure. In all test runs the bag filled with a compact sludge cake which could be easily extracted and was firm to handle. In a typical run 3 litres of sludge (5.8% T.S.) was filtered in 3½ hours to give 560 ml of sludge (28.0% T.S.), that is 18.5 per cent of the original volume. The initial pressure was 2 p.s.i. and this was gradually increased to 40 p.s.i. In one run the pressure was raised to 100 p.s.i. without any sign of a "cut-off" in filtration rate.

A filter-aid precoat was used in one run but actually decreased the filtration rate.

Two samples of old stored sludge were filtered, one of which
filtered fairly well, the other very slowly. The filtrate from both contained reduced iron in solution which precipitated on contact with the air. It is thought that some of this iron precipitated in the filter bag, thus slowing down the filtration rate. If this is so, it may not be advisable to filter old sludge since it is all in the reduced state.

Preliminary calculations indicate that a filter press fitted with 10 bags of 22 inches diameter would filter about 200 gallons of sludge per three-shift day. Excess capacity would then be available to filter stored sludge if this was found to be practicable. The sludge in the bags would be sealed in 44-gallon drums for final disposal by burial.

To reduce the volume even further the bags of sludge could be dried before disposal. It might even be feasible to dry the sludge in the filter and then filter more sludge through the same bag.

There are no commercial pressure filters at present available which operate on this principle. It should be relatively simple to develop an economical unit which may be patentable and useful in some industrial applications.

3.5 Disposal into 440-gallon Concrete Tanks

Winsbury (1961/2) recommended that sludge be permanently stored in 440-gallon precast concrete tanks located on a suitable catchpond. He predicted that sludge stored in such a tank would tend to concentrate by direct evaporation from the surface and by evaporation from the surface of the tank after permeation through the concrete wall.

Two tanks were purchased for experimental purposes. One was fitted with a graded sand filter bed in the bottom, and both tanks were set up and used by the author for sludge storage. It soon became obvious that the filter tank concentrated more rapidly than the plain tank.

The experiment showed that the sludge concentrated in the plain tank to about 60 per cent of its original volume. The concentration was mainly by sedimentation, and removal of the supernate was thus necessary. Concentration was much more rapid in the filter tanks and the sludge was reduced to about 40 per cent of its original volume. Disregarding all considerations of the method of operation, 12 filter tanks or 18 plain tanks would be required each year to store 15,000 gallons of sludge. The full tanks would have to be stored on a prepared area as they cannot be easily moved when full.

This is not considered a particularly suitable method for final disposal of sludge because of the increasing number of tanks involved, the operational problems, and the comparatively high cost.
3.6 Solar Evaporation

Solar evaporation involves pumping settled sludge to a suitable drying bed and letting the water evaporate. When full of dried sludge the bed would be capped off with cement and a new bed formed on top of the old one. Alternatively the depth of the bed could be increased by raising the walls.

Experimental work has shown that at Lucas Heights an evaporation rate of 0.05 gal/ft$^2$ per day could be used as a basis for design. Thus evaporation of all the water from 15,000 gallons of 5 per cent sludge per year would require a drying bed of 780 ft$^2$.

In actual practice it would not be necessary to evaporate all the water from the sludge as a final sludge concentration of 80 to 85 per cent solids would be satisfactory. The fact that the evaporation rate varies over the year is not significant if the pan has sufficient capacity.

The bed would be fitted with a sliding cover for use during periods of rain, and between sunset and 2 hours after sunrise. It could also be used to protect the bed during high winds which might otherwise cause some spread of contamination. Alternatively a suitable wind break could be installed. The safety aspect of drying sludge in such a pan should be evaluated; preliminary testing has indicated that the hazard is very slight.

3.7 Calcination

Unpublished work by Frost (A.A.E.C.) has shown calcination to be practical. However it is more expensive than the other processes considered and is thought to be more suitable for sludge of higher activity. For these reasons it is not considered further.

3.8 Centrifugal Filtration

Centrifugal filtration has not been tried but should be possible as it is basically another type of pressure filtration. Disposal of the bowl each time, as in the Harwell experiments, would make the process very expensive. However it should be possible to design a cheap disposable liner for the bowl. Because of the development required and possible high cost of the equipment it is not proposed that this method be considered for low level sludge treatment. It may, however, be a suitable process for concentrating sludges of high activity.

3.9 Centrifugal Thickening

Limited experimental work by the author has indicated that concentration of sludge by a relative centrifugal force equivalent to that obtainable in commercial equipment is not sufficient to warrant further investigation. However if sludge were to be concentrated by solar evaporation, the removal of some of the water by centrifuging would decrease the size of the drying bed required and might be economically justified.
This method is not considered further at this stage.

4. **EVALUATION OF PROPOSED METHODS**

Of the nine processes discussed in Section 3, direct burial, calcination, centrifugal filtration, and centrifugal thickening are considered to be unsuitable for Lucas Heights and are not discussed further. A summary of the other five methods is presented in Table 1, indicating the probable final volume for ultimate disposal, costs, the expected life of the equipment, and the hazard involved. "Annual Operating Cost" includes depreciation averaged over the expected life of the equipment, and material, container, labour, power, maintenance, and burial costs.

From the summary it is obvious that the cheapest and simplest process is solar evaporation in open pans. Solidification in cement is obviously more expensive than the others and is eliminated on this score.

The other processes are essentially equal as regards cost, but storage in 440-gallon concrete tanks is not favoured because of the increasing number of tanks to be accommodated. The cost of both filter processes includes a relatively high labour content. However since it is considered that the present operating staff would be sufficient for either process, there would be no actual cost for labour content, making both these processes considerably cheaper than indicated. The cost could be further reduced by approximately £250 per annum by burying the filter cake without drums.

5. **CONCLUSIONS**

Sludge produced at Lucas Heights is not particularly hazardous. However, because of the volume accumulating, it is imperative that a method of treatment and disposal be decided on in the near future.

The method adopted should be cheap, simple, and safe; the most attractive process is to dry the sludge in large open pans, capping the pans when full. The next most attractive method is to filter the sludge into bags in a special pressure filter and dispose of the sludge and bag by burial.

6. **RECOMMENDATIONS**

The sludge to be treated is considered in three categories:

1. **Approximately 12,000 gallons of sludge stored at the Burial Ground.**

As it is doubtful whether the drums would stand transport back to the site it is recommended that this sludge be solidified with cement in trenches at the Burial Ground. It is thought that this operation, although expensive should be carried out as an experiment to test the feasibility of the method and to give experience in large scale disposal operations. It could also assist Health and Safety Division in their evaluation of the Burial Ground.
The estimated cost of the operation is £1,250.

(ii) **Approximately 22,000 gallons stored at the Treatment Plant**

A suitable catchpond of area of 200 ft$^2$ is available at the Treatment Plant, and would only require the addition of a sliding cover and some minor modifications to convert it to a drying pan. It is recommended that this catchpond be converted to a drying pan and that the stored sludge be progressively dried as an experiment to determine the best method of operation and to enable Health and Safety Division to conduct a hazards survey on the operation. The estimated cost of the additions to the catchpond is £400 and it would take approximately 1½ years to treat the 22,000 gallons stored.

(iii) **Future Arisings**

To treat the sludge which will be produced while the above experiments are being conducted it is recommended that a pressure filter incorporating filter bags be designed and procured. This is justified on the basis that it will be used for at least 1½ years, after which it may still be used, or may then be required to filter sludge from the proposed Medium-High Level Treatment Plant. The estimated cost of this equipment is £900.

It is recommended that the final method or methods of disposal should be selected after actual operating experience with the above processes.

7. **ACKNOWLEDGEMENT**

The author would like to acknowledge the assistance of Mr. G.F. Coleman and Mr. R.S. Davis in the experimental work.

The helpful suggestions of Mr. E.D. Hespe and Mr. L.H. Keher during experimental work and preparation of this report are also gratefully acknowledged.

8. **REFERENCES**


TABLE I
SUMMARY OF POSSIBLE SLUDGE TREATMENT AND DISPOSAL PROCESSES FOR 15,000 GALLONS OF 5% T.S. SLUDGE PER YEAR.

<table>
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<tr>
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<tbody>
<tr>
<td>Thickening followed by mixing with cement and casting into blocks in Burial Ground</td>
<td>12,600</td>
<td>300</td>
<td>5</td>
<td>1,500</td>
<td>low</td>
<td>Operations would depend on weather and ground water conditions at Burial Ground.</td>
</tr>
<tr>
<td>Filtration on Rotary Vacuum Filter, drumming, and burial.</td>
<td>3,750</td>
<td>3,000</td>
<td>10</td>
<td>1,000</td>
<td>low</td>
<td>Filter would have excess capacity available.</td>
</tr>
<tr>
<td>Pressure filtration into filter bags, drumming, and burial.</td>
<td>3,000</td>
<td>1,000</td>
<td>10</td>
<td>1,000</td>
<td>low</td>
<td>Filter would have excess capacity available.</td>
</tr>
<tr>
<td>Disposal to 440-gal concrete tanks located on suitable catchpond.</td>
<td>9,000</td>
<td>200</td>
<td>1</td>
<td>1,150</td>
<td>low</td>
<td>Would eventually require a large storage area.</td>
</tr>
<tr>
<td>Disposal to 440-gal concrete tanks with filter bottom located on suitable catchpond.</td>
<td>6,000</td>
<td>150</td>
<td>1</td>
<td>1,950</td>
<td>low</td>
<td>Would eventually require a large storage area.</td>
</tr>
<tr>
<td>Evaporation of water by solar heat in large open pan with movable cover. Pans sealed when full.</td>
<td>1,750</td>
<td>780</td>
<td>3</td>
<td>400</td>
<td>low but needs assessing</td>
<td>New pan to be built every three years</td>
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