Geosynthetics, J. Kuwano & J. Koseki (eds)

Case history – *In-situ* dewatering of lagooned sewage sludge using electrokinetic geosynthetics (EKG)

Jones, C.J.F.P. & Glendinning, S.
School of Civil Engineering and Geosciences, Newcastle University, UK

Huntley, D.T. & Lamont-Black, J.
Electrokinetic Ltd., UK

Keywords: electrokinetics, *in-situ* dewatering, sewage sludge lagoon, ePVD, innovative-geosynthetics

ABSTRACT: A recent field pilot trial has demonstrated the effectiveness and efficiency of using electrically conductive prefabricated vertical drains (ePVDs) to dewater lagooned sludge by an *in-situ* process. The trial demonstrated that the technology could dewater sewage sludge, raising the solids content from 10.5% to 27% whilst at the same time producing clean discharge filtrate water with a BOD < 3.0 mg/l and a COD of 50 mg/l. The power consumption was 43 kWhr/m^3. These data represent the first field trial of this technique and indicate that it can provide a viable economic solution to treating in situ lagoon sludges. The trial also indicated that significant further improvements in solids contents and reductions in power consumption are achievable at full scale.

1 INTRODUCTION

The concept of using electrokinetic geosynthetics to perform *in-situ* dewatering of sewage sludge lagoons was introduced by (Walker and Glendinning 2002). They noted that the predecessors of many water companies deposited thickened and or dewatered sludge in lagoons as a method of 'dealing with' the waste. One of the reasons for this approach was that space was available and alternatives were considered too expensive. The result is a legacy of sludge lagoons which present a major technical challenge and are costly to remediate.

A lagoon deeper than one metre will never effectively dry out in a temperate climate such as in the United Kingdom, (Idris *et al* 2002). Generally a crust will form beneath which will be sludge with a solids content of 12–15% which is stabilised on an annual basis by the effective balancing of evapotranspiration by rainfall recharge. Attempting to remove such material is difficult since it is too thick to pump and too thin to shovel. Current treatment methods include: wetting the sludge down until it can be pumped, the addition of dry material to permit it to be shovelled, or avoiding stabilisation completely by capping or encapsulating the lagoon. All of these methods are expensive and none meet emerging environmental requirements.

2 ELECTROKINETIC TREATMENT

The ability of electrokinetic phenomena (electroosmosis) to transport water, charged particles and free ions through fine grained, low hydraulic permeability materials was discovered by (Reuss 1809). The great advantage of electrokinetic treatment is that it can be up to 10^4 times faster than conventional hydraulic treatment methods and is particularly relevant to materials such as slurries and sludges.

2.1 *Electrokinetic geosynthetics*

Electrokinetic geosynthetics (EKGs) have been developed to implement and exploit the benefits of electroosmosis and to couple this with the established functions of geosynthetics such as drainage, reinforcement, filtration, separation and encapsulation. In the case of sewage sludge lagoon dewatering the EKGs used are a development of prefabricated vertical drains (PVDs) but do not require any surcharge loading. Electrokinetic PVDs (ePVDs) are formed from electrically conducting corrosion resistant materials combined with drainage and filtration elements.

3 LAGOON SLUDGE DEWATERING TRIAL

Two steel skips measuring 3.7 m long by 1.8 m wide by 1.6 m deep and lined with butyl rubber were used for the trial. These were filled with digested sewage sludge from a lagoon believed to be 60 years old. Standing water on the surface of the lagoon lowered the solids content to 10.5 per cent. Two arrays of Mk5 ePVDs were installed in the test skips. Skip A had a rectangular array and Skip B had a hexagonal array, Figure 1. The spacing of the electrodes determined the voltage gradient required for treatment, both arrays were equivalent having a 0.9 m anode – cathode spacing.

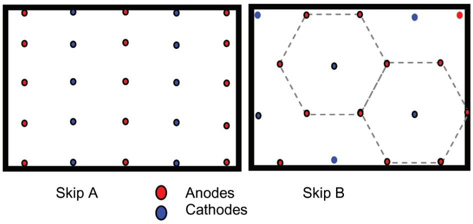

Figure 1. Electrode arrays in Skips A and B.

The function of electroosmosis is to move water towards the cathodes, and a method of extracting water from the cathodes is required. The system chosen was a siphon process formed from narrow diameter tubes equipped with nylon ball foot-valves. These were inserted into the bottom of the cathodes, connected to an external sump and primed by adding top water from the lagoon. The electrodes in each skip were connected in parallel to a timed intermittent DC supply. The initial power-up sequence raised the voltage to 30 V over a two hour period after which the supply was left unattended for 24 hrs a day, 7 days a week. The effects of electroosmotic flow in the form of wetting near the cathodes and drying near the anodes was immediately and visible when steady state current conditions had been established.

The trial lasted from April to June 2005 during which time regular measurements were taken of current and sludge levels. Underperformance of some siphons caused a reduction in the overall dewatering efficiency.

4 RESULTS

The main result from the trial was the transformation of wet sludge into stiff cake, Figure 2. Figure 3 presents the change in the volume of the sludge for Skips A and B determined by measuring the level of the surface of the sludge. The data shows that Skip A had a measured volume reduction of 23% and Skip B 30%.

The quality of the discharge water is shown in Table 1. These show that in both cases the quality of the discharge water was high, especially so for Skip

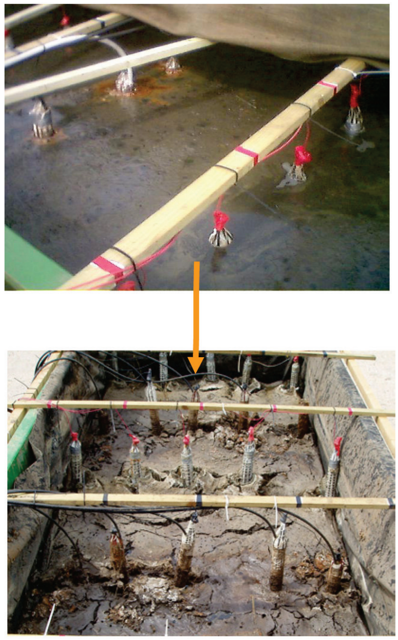

Figure 2. Change in condition of sludge from start to finish.

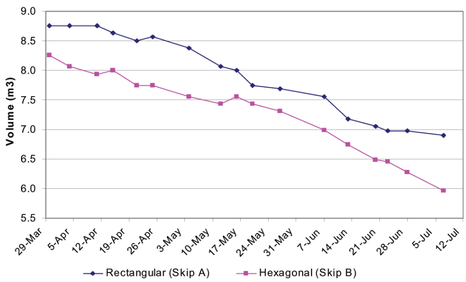

Figure 3. Changes in volume of sludge in skip A and skip B.

Table 1. Water quality of discharge during electroosmosis.

Sample	Ammonia mg/l as N	pH	Suspended solids mg/l	BOD 5 Day mg/l	COD mg/l
Skip A	2100	12	13	170	690
Skip B	2100	12	<3.0	<3.0	250

B, which produced suspended solids of <3.0 mg/l and a COD and BOD of 250 and <3.0 mg/l respectively. Of potential concern was the high pH level of the discharged water. Deviations of the pH away from the near neutral starting value of 7.4 were caused by electrolysis reactions at the electrodes such that the anode became acidic and the cathode became alkaline.

The current drawn is shown in Figure 4 which shows that the array in Skip A drew more current than Skip B and that the rate of decay of current was higher in Skip A.

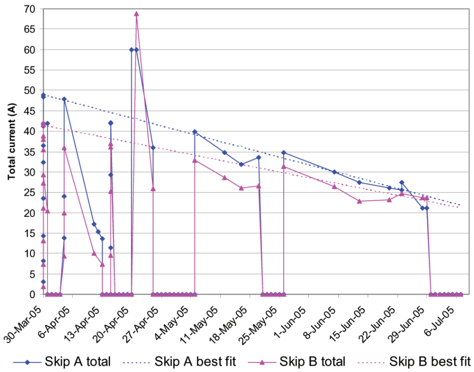

Figure 4. Current drawn by the electrode arrays during the trial.

4.1 *Decommissioning*

Decommissioning of the trial was accomplished by removing the electrodes, sampling the dewatered sludge and carrying out detailed multileveled (depths of 150 mm, 400 mm and 700 mm) surveys of shear strength, water content and conductivity using a probe meter. These data are presented in Table 2. They show that Skip B had a slightly lower water content and sludge electrical conductivity than Skip A, but that the latter showed slightly higher values of shear strength and solids content.

Table 2. Sludge material condition measured during post treatment excavation.

Skip	Level in skip (mm)	Shear Strength (kPa)	Conductivity (mS/m)	Water content (% v/v)	% dry solids
A	150	9.7	188	77	27.6
	400	12.7	208	79	
	700	13.3	218	79	
B	150	7.8	258	72	24.2
	400	10.9	224	72	
	700	13.4	213	73	
Initial values both skips		1.5	250	90	10.5

Shear strength and solids content are generally related to each other and inversely related to water content and conductivity. Therefore there is an apparent paradox in the data in that the results from Skip A seem better than Skip B but the latter had a greater volume reduction. The reason of this was that Skip A was subjected to a short period of reverse polarity which influenced the shear strength and solids contents measurements from Skip A. Thus all electrodes in Skip A had at some point experienced the drying effects of being anodes, whereas in Skip B some electrodes had only ever been cathodes.

5 ANALYSIS

The data showed that both electrode arrays proved effective at raising the solids content and reducing the volume of sludge. However, the hexagonal array in Skip B produced faster dewatering, with greater maintenance of electrode current density and lower overall unit volume power consumption.

In achieving a 30% volume reduction in Skip B a power consumption of 128 kWhr/m^3 (of wet sludge) was required. This figure can be adjusted downwards by quantification of the following factors:

- Ineffective removal of water, which would lead to (i) reduced volume (ii) longer than necessary treatment duration.
- Addition of water during the filling of the skips. At 10.5% dry solids the sludge was wetter that the sludge in the lagoon.
- Edge effects including (i) excessive current along the sludge/butyl liner contact (caused by water concentration due to ineffective water removal from some cathodes) and (ii) electrical field distortion resulting in a disproportionate number of electrodes at the edge of the overall array and thus part of 'partial cells'

Quantification of these factors provides an estimate of the 'true' power consumption for effective treatment:

- Grading the performance of siphons, and comparing this to the current drawn through the associated cathodes, showed that effective water removal from all cathodes would have the effect of reducing the overall current for the array by approximately 33%;
- Removing the surface excess water could produce a saving of 42–52%; and
- Accounting for edge effects (using an example of an array of 100 × 100 electrodes) would yield a saving of approximately 7%.

Compounding these factors yields an overall power saving of approximately 2/3. This means that the initial estimate of 128 kWhr/m^3 required to reach a volume reduction of 30% could be adjusted to 43 kWhr/m^3. This could be further refined as more effective water removal would create a faster rate of volume reduction and thus shorten the overall treatment time. Therefore, with the present understanding of the system and using a figure of £0.055/kWhr it is estimated that the power costs for treatment would be £2.36/m^3. This does not include the power required to pump excess surface top water from the lagoon prior to treatment. It is further noted that electroosmotic efficiency (volume of water moved per unit charge) varies according to voltage gradient such that a higher voltage gradient produces more rapid flow but is less efficient. The voltage gradient used in the trial was low relative to historically common values so there is scope to improve on the speed of treatment or to have a higher voltage over a larger electrode spacing to reduce the number of electrodes, (Mitchell 1993).

6 CONCLUSIONS

Electrokinetic prefabricated vertical drains present a viable alternative for *in-situ* dewatering of lagoons containing sewage sludge (or other difficult materials). In addition to ePVDs, all materials and practices required to perform such a treatment are already available amongst standard civil engineering practices.

The cost of power for treatment is low at approximately £2.36/m^3 plus the cost of pumping excess water prior to treatment.

The removal of top water prior to treatment is likely to lead to improved electroosmotic dewatering and hence a higher final solids content and greater shear strength. Walker and Glendinning (2002) showed that starting with a solids content of 19%; this could be raised to 42% with an overall volume reduction of 57% and an increase in shear strength from 1 kPa to 42 kPa.

The voltage gradient used in the trial was low and there is scope to improve on the speed of treatment or to have a higher voltage over a larger electrode spacing to reduce the number of electrodes.

ACKNOWLEDGEMENTS

The assistance and support of Severn Trent Water Ltd., Engtex AB (Sweden) and WJ Groundwater Ltd. in undertaking the trial are gratefully acknowledged.

REFERENCES

Idris, A., Yen, O.B., Hamid, M.H.A and Baki A.M. (2002) Drying kinetics and stabilisation of sewage sludge in lagoon in hot climate. Water Science & Technology, Vol 46 (9) pp 279-286. IWA Publishing.

Mitchell, J.K. (1993) Fundamentals of Soil Behaviour. 2nd Edn., Pub. John Wiley & Sons Inc, New York, USA.

Reuss, F.F. (1809) Sur un nouvel effect de l'électricité glavanique. Mémoires de la Societé Impériale des Naturalistes de Moscu, 2, 327-337.

Walker, J. and Glendinning, S. (2002) *In situ* dewatering of lagooned sewage sludge using electrokinetic geosynthetics (EKG). Proceedings of the 7th European Biosolids and Organic Residuals Conference, Wakefield, UK.