Journal of Environmental Sciences, 2014; Vol. 43, No. 2 : 225-235

UPGRADING THE CONVENTIONAL SAND DRYING BEDS FOR SLUDGE TREATMENT PROCESSES

Moharram Fouad*, Nora Wagih, and Hoda El-Gamal***

**Civil engineering department, Faculty of Engineering, Mansoura University, Egypt*

*** Research Scholar of Environmental Eng., Faculty of Engineering, Mansoura University*

ABSTRACT

A compressed air has been used to reduce the surface area of the sand drying beds and reduce the time of drying. Drying beds were used for dewatering sludge which produced from waste water treatment plant. A bench scale conventional sand drying beds has been supplied by a compressed air from its bottom. Several rates of the compressed air of values of 3.5, 3.0, 2.5 and 2.0 m^3/m^2*/day have been used. The previous air rates were used with different rates of water content of 45%, 82.5%, 105%, and 113%. The air was applied for short application time of maximum value of 10 minutes.*

From experiments which have done, the optimum effective time of using compressed air was found to be 2 minutes. No significant reduction in water contents of sludge due to any increase in using compressed air time. The ideal air rate of compressed air was found 3.0 m^3/m^2*/day. Decreasing the air rate than 3.0* m^3/m^2*/day does not lead to more reduction in water content percentage. The waste water treatment plants can use air pump from the bottom for drying beds in addition to the drying by evaporation due to the direct sun rays. Moreover the aeration time of drying of activated sludge in sand drying beds can decrease to be 82%-97% from its original sludge drying time.*

Key words : *Sand drying bed; Dewatering; Treatment; air rates; air aeration.*

INTRODUCTION

Generally, the main purpose of sludge treatment is to reduce its water content, to improve its properties and make it easy to handling. All organic degradation processes produce sludge (SASSE, 1998). Biological sludge does not have higher solids content than 2% to 10 % and therefore cannot be transported easily with simple equipment (SASSE, 1998). Sludge treatment and disposal is the sixth problem in the series of biological wastewater treatment (Cleverson *et al.*, 2007).Combined primary and secondary sludge from an activated sludge treatment plant contains about 2 % solids and hence 98% water (Heinss et al, 1999). The treatment of that waste presents high cost, around 25-65% of the total plant operating costs (Zhao and Kugel, 1997).

In United Kingdom, at 1991, it is estimated that 1.11 million ton of sludge are produced annually (CES,1993). Sludge drying beds are one of the simplest and oldest techniques for sludge dewatering (SANIMAS, 2005). The sludge is applied in a batch mode about once per week intervals in layers of no more than 20 to 30 cm. About 50 to 80 % of the initial volume is removed by percolation (Strauss and Montangero,2002).

The investment costs of sludge drying beds are moderate where land prices are low and filter material (sand) is locally available (SANIMAS, 2005). The rising costs and public sensitivity of sewage sludge disposal have provided considerable impetus to explore and develop strategies and technologies for minimization of sludge production (Wei *et al.,* 2003). The operation and maintenance of the sand drying beds was studied by (SANIMAS, 2005). Sludge drying beds and evaporation lagoons can be used not only to dewater a particular sludge, but also to dry it to a solids concentration of more than 50–60% (Lawrence *et al.,* 2007). Typical sand beds are spaces of 6m apart and return seepage to the treatment plant influent. Individual sections, nominally 8m x 30m, they easily produce a sludge cake with 25 – 40 percent solids and can exceed 60 percent solids with additional drying time (Eckenfelder *et al.,* 1981), (EPA, 1987 and Hammer, 1975).

The treatment plants in the Irbed area are designed with sludge drying beds. The experience showed that the sludge with a solid content of 4% can be consolidated by drainage and evaporation to 45 % suspended solid (SS) within 20 to 30 days (Husaini *et al.,* 2005), (WAJ, 2006). The disadvantage of sand drying beds was studied by (Clarke *et al.,* 1977), (EPA, 1987 and Hammer, 1975). By the application of sand beds covered with glass for drying pharmaceutical sludge it was found that the drying time was reduced by 25–35%, compared with that in conventional sludge drying beds (Bux *et al.,* 2002).

Drainage through the sand beds is poor, due to plugging of the media and/or crushed under drain, causing a backlog of solids at the WWTP (EPA, 1987 and Hammer, 1975). Sludge contains a high concentration of solids, but its water content is still high. The operational controls the operation of a conventional sand drying bed is impacted (USEPA, 1979). Total drying time required depends on the desired final moisture content, and also relates to the means of removal and subsequent use. Ultimate bed sizing is a function of evaporation, solids application depth, and applied solids concentration (Metcalf and Eddy, 1991). The moisture contents of sludge fed to reactors were 97.0%, 94.6%, 92.9%, 91.1% and 89.0%. The void solid removal efficiency changed from 45.6% to 33.8%, as the moisture content of sludge fed to digester decreased from 97.0% to 89.0% (Fujishima *et al.,* 2000). These beds usually consist of 15cm to 30 cm (6in to 12 in.) of sand ranging in size up to 0.5 mm with graded gravel and drainpipes (AWWA, 1969a). For example, the performance of drying beds at the Jahra plant was studied by (Al-Layla *et al.,* 1980). The performance of these types of equipment could be improved by adding chemicals to the sludge as a conditioner (Karr, 1976).

EXPERIMENTAL SET UP AND PROCEDURES

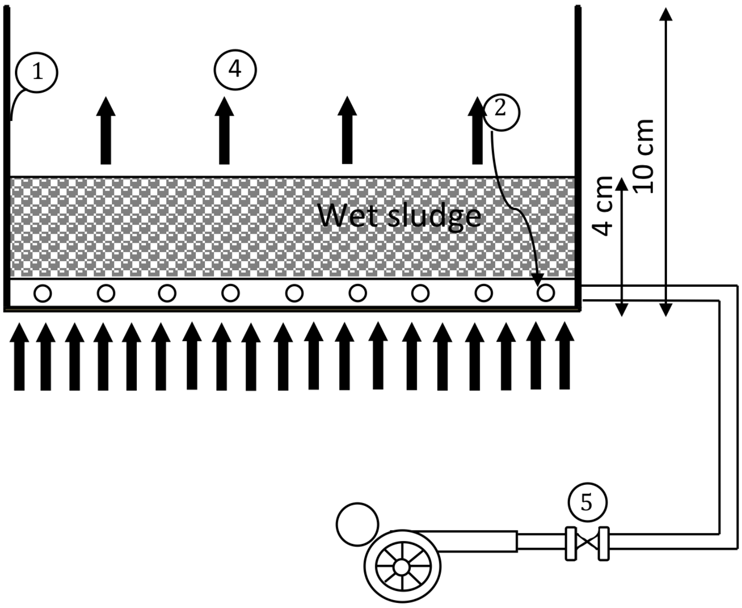
(a) The Experimental Set Up :

A bench scale set up is used in this study as shown in Fig.1. The main components of this set up are; small sludge tray used as sludge drying bed as shown in Fig.2 and air pump with adjustable rate. This sludge tray has a volume of 549 cm^3, surface area of 54.9 cm^2 and side depth of 10 cm. Further, this sludge tray has been equipped with a simple drain system of fine holes, which is placed on its bottom. The sludge drying tray was connected with air source. A small size pump model Ct 5203A with 220 – 230 V, 50/60 HZ, Power 550 W and velocity gradient of 14000min-1 is used as air source.

(b) Synthetic Sludge:

Raw sludge is collected from a local waste water treatment plant under normal circumstances. The raw sludge was obtained in dry case having low moisture content. Additional water was added to the dry sludge to obtain the desired water content. Several values of water content have been used for this study which simulated to the field conditions. Water content can be determined using equation 1. Water content obtained from experiments is shown in Table 1. Raw sludge was grained to small size before adding water.

$$WaterContent(W.C)\% = \frac{wetsludge(wt) - drysludge(wt)}{drysludge(wt) - tray(wt)} \qquad \text{Eq (1)}$$



Legend:-
1-Tray (V= 549cm3)
2- Under drain system
3- Air pump
4-Moist air
5- Control valve
6- Dry air

Fig (1) : Schematic diagram of the bench model set up.

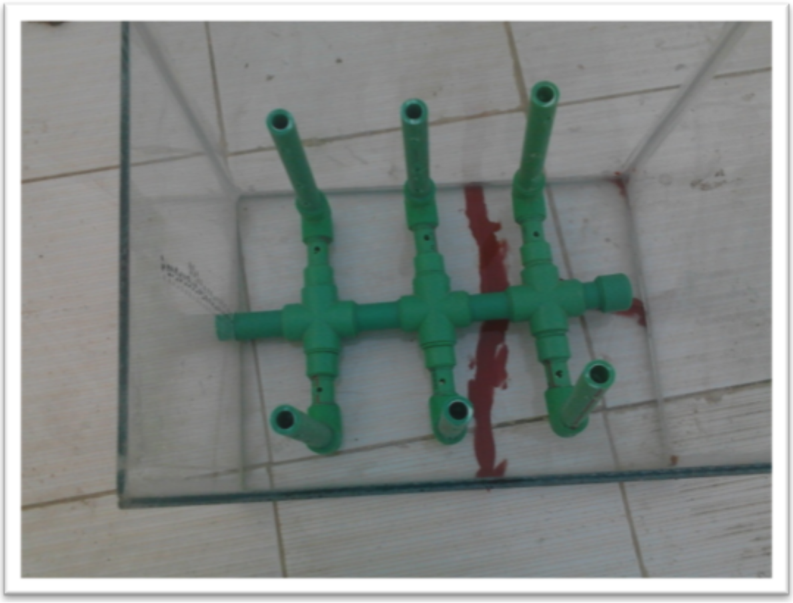


Fig (2) : Connection between under drain and side drain .

Table (1) : Different water contents of sludge .

No	Wet sludge wt (gm)	Dry sludge wt (gm)	Tray (wt)	W.C (%)
1	390	300	100	45
2	465	300	100	82.5
3	510	300	100	105
4	525	300	100	113

(c) Samples Preparation:

Four samples with different moister content have been prepared. Each sample has a constant solid weight of 200 gm. A different water quantity is added to each sample, and then the samples are well mixed. Four different water quantities are used. These water quantities are 50,100,150,200 gm. So after adding the water quantities to each sample, four different water contents are obtained. These water contents are 45%, 82.5%, 105% and 113% as shown in Table1. These water contents are similar to those recommended by (Heinss *et al.,* 1999) and (Fujishima *et al.,* 2000).

(d) Start-Up and Steady-State Operation:

After preparing the samples of sludge which have a constant solid weight and different water content the samples are placed in a drying tray of weight a 100 gm. So the net weights of samples including the drying tray are 390 gm, 465gm, 510 gm and 525gm after losing the extra water. Compressed air is connected to the drying tray. The compressed air inlet is located from the tray bottom and well distributed over the sample bottom as shown in fig 1. The original weight and after compression weight of each sample is estimated after 2, 4, 6, 8 and 10 min as shown in Table 1. Then wet sludge samples with water content 82.5 are used with different rates. Different rates of 3.5, 3.0, 2.5 and 2.0 m^3/m^2/day are used over the samples as shown in Table 3 . Also weights of samples are estimated after using air pump 2, 4, 6, 8 and 10 min as shown in Table 2.

RESULTS AND DISCUSSION

The results obtained from the carried out experiments can be classified in two parts separately as illustrated in the following paragraphs:

Effect of aeration retention time

Figure 3 presents the relation between the percentage reduction in water contents and the aeration time at initial percentage water contents of 45, 82, 105 and 113% of dry sludge. Several retention times (2, 4, 6, 8, 10 minutes) of using air pump are used. It is clear that the different water contents for wet sludge achieve reduction in water content percentage.

High reductions in water contents are appear in the first two minutes of using air pump. Increasing the retention time of using air pump does not lead to increase in percentage reduction in water content. The initial water content 105%, 82.5% and 45% have convergent results as shown in Table 2. In addition to that, the reduction in water content of the initial 113% water content is higher than the rest.

Table 2 confirms that the air pump use for 4, 6, 8 and 10 minutes give convergent results. After two minutes for initial water content 113%, the reduction in water content lead to 18 %. Addition to that after ten minutes the reduction in water content lead to 21%. By application of equation 2, the reduction in water content percentage after 2 minutes is 18% for initial water content 113%. Then the time of sludge drying can be reduced to 82% from its original time. Fig.3, the reduction in water content percentage is 3% for initial water content 45%. By application of the same equation for initial water content 45%, the reduction of sludge drying time is 97% from its original time. It gives the best efficiency for drying and reduces the aeration time up to 82 % to 97% at room temperature. The optimum time (two minutes) of using air pumped from the bottom can be attributed to some reasons. Upper layer of sludge could be dry by evaporation due to direct sun rays during the day light. The porosity of sludge was tight so the upper layer can dry easily. So the lower layer was hard to dry easily as a result of tight porosity.

Finally, due to using air flow from the bottom of the test section for two minutes, the reduction percentage in water content increases. Further, this reduction in water content is more effective in case of high initial water content. Moreover, any increase in time more than two minutes does not achieve more reduction in water content percentage. Figure 3 shows also initial reduction in water content after two minutes is approximately constant.

$$R = \frac{Co - C}{C} \% \qquad \text{Eq (2)}$$

Where:

R: reduction percentage.
Co: initial value of drying time.
C: final value of drying beds time.

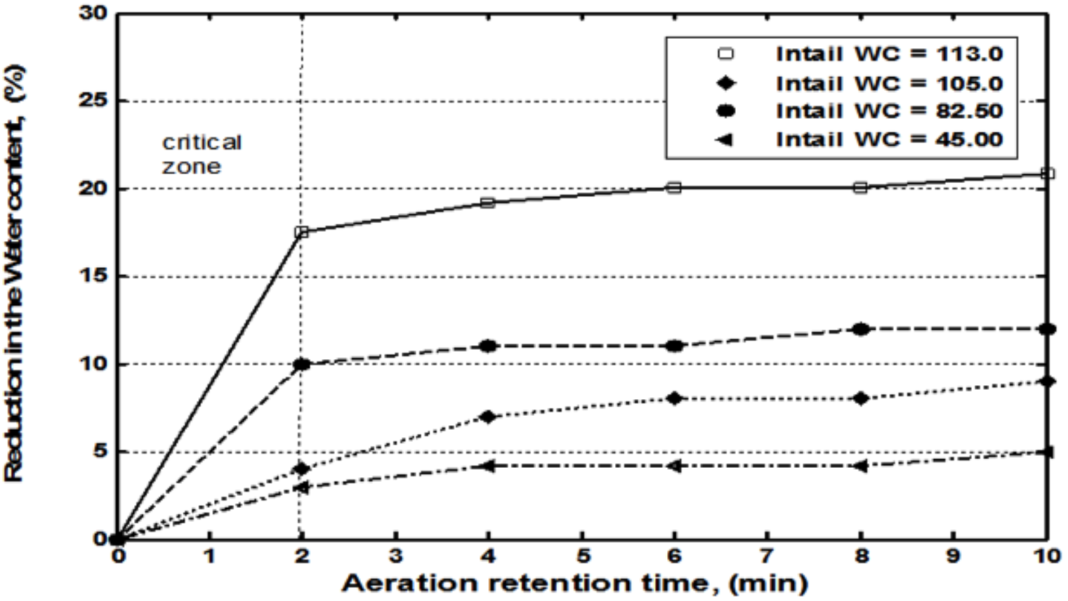


Fig. (3) : Reduction in water content due to air rate 3.0 m^3 for different water content of sludge with different retention time.

Table (2) : The effect of aeration in water content sludge with fixed air rate.

Time(min) / w. c%	2	4	6	8	10
45	43.68	43.12	43.12	43.12	42.75
82.5	74.25	73.42	73.42	72.60	72.60
105	100.8	97.65	96.60	96.60	95.55
113	93.2	91.32	90.38	90.38	89.45

Effect of air flow rate

Figure 4 presents the relation between the water contents and the aeration time for initial percentage water content of 45% of dry sludge. Also, it shows the effect of air flow rate in water content for initial water content of 45%. The air flow rate of 2 and 2.5 m^3\ m^2\day have convergent results. Also, the other air flow rate of 3 and 3.5 m^3\ m^2\day give convergent results.

Figure 5 shows the relation between the reduction in water contents and aeration time due to different air flow rate for sludge with initial water content of 45% of sludge. Application air flow rates of 2, 2.5, 3, 3.5 m^3\ m^2\day from the bottom of tray, the obtained results are tabulated in Table 3. Considering air flow period for 10 minutes for different air flow rate. The reduction in water content reaches 6% using air flow rate of 2.5 m^3\ m^2\day. Whereas using air flow rate of 3 m^3\ m^2\day reaches its optimum value. The reduction in water contents, which equal to 16% due to this rate. Accordingly, the air flow rate of 3.0 m^3\ m^2\day is shown to have medium results between the air rates of 2.5and 3.5 m^3\ m^2\day.

It is clear that; air flow rate of 3.5 m^3\ m^2\day has a significant effect in the reduction in water content. But it is more convergent in results to the air flow rate of 3.0 m^3\ m^2\day. Both air flow rates of 3 and 3.5 m^3\ m^2\day have convergent results in reduction in water content. From the other side under the same operational conditions, reduction in water content is slight change for the both rate of 2.0 and 2.5 m^3\ m^2\day. During the retention time, reduction in water content using rates of 2.0 and 2.5 m^3\ m^2\day have been 5 and 7 % respectively.

Finally, the optimum air flow rate which causes the ideal reduction in water content is 3 m^3\ m^2\day. Any decrease in air flow rate than 3 m^3\ m^2\day does not give the required reduction in water content.

Table (3) : The effect of air flow rates on the sludge water content.

Time(min) Air rate (m^3)	2	4	6	8	10
3.5	34.5	37	39	40	42
3.0	37	39	40	42	43
2.5	42	43	43	44	44.5
2.0	43	44	44	44.5	45

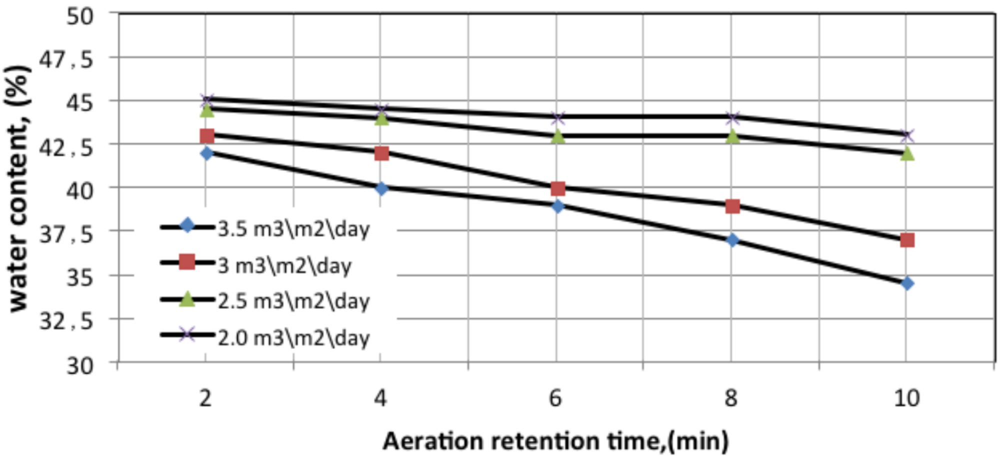


Fig. (4) : Effect of air flow rate on water content (initial water content 45%).

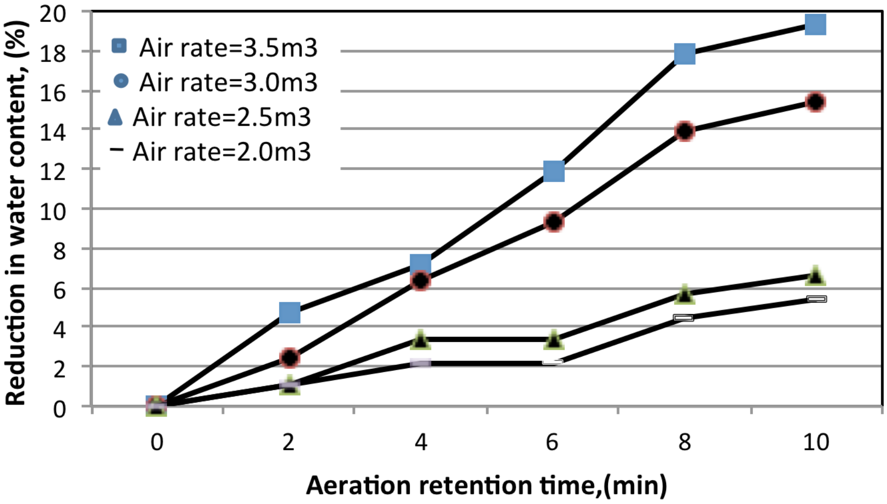


Fig. (5) : Reduction of water content due to different air flow rate for initial water content of 45% of sludge with different retention time.

CONCLUSIONS

Drying beds take a large area on waste water treatment plants. In addition to that, it is a harmful to human so it should be treated. One of this treatment ways is drying of sludge in direct sun rays. But this way effect only on the upper layer of sludge because of fine voids sludge. The main problem there is the drying of lower layer. Depending on different retention time of using air pump and variable air flow rate, the air pump was used to overcome this problem. Based on the obtained results, the following points could be concluded:

1. Using compressed air for two minutes especially for high water content, reduces water content by 18%.

2. The effective aeration time not exceed 2min, where any increase in aeration time than this value does not lead to reduction in sludge drying rate.

3. The suitable rate of air must not decrease below 3.0 m^3/ m^2/ day.

4. The aeration time can reduce up to 82 % to 97% from its original drying time at room temperature.

REFERENCES

Al-Layla,M.A.; Ahmad,I.S. and Middlebrooks,E.J. (1980) : Handbook of Wastewater Collection and Treatment, Water Management Series. London: Garland STPM Press.

AWWA Research Foundation (1969a): Disposal of Wastes from Water Treatment Plants - Part 2, Section 1, Report on What Is Known. Jour. AWWA.

Bux,M.; Baumann,R.; Quadt,S.; Pinnekamp,J. and Mühlbauer, W. (2002) : Volume reduction and biological stabilization of sludge in small sewage plants by solar drying. *Drying Technology*. 20 (4-5), 829–837.

CES; (Commission in Environmental Science Limited) (1993): UK Sewage Sludge Survey. Final Report. CES, Gateshead.

Clarke,W.J.; Viessman,W.; Hammer,Jr. and Hammer,M.J. (1977): "Water Supply and Pollution Control", 3rd edn. New York: Harper & Row.

Cleverson,V.A. Marcos,V.S. and Fernando,F. (2007) : Publisher: IWA Publishing, Publication date: 1/5/2007, Series: Biological Wastewater Treatment Series, Pages: 260.

Eckenfelder,W.W. and Santhanam, J.C. (1981) : Sludge Treatment; Pollution Engineering and Technology Series No. 14. New York: Marcel Decker.

EPA (1987) : "Dewatering Municipal Wastewater Sludge", Report No. EPA/625/ 1–87/014 Washington DC: U. S. Environmental Protection Agency.

Fujishima,S.; Miyahara,T. and Noike,T. (2000): Vol 41 No 3 pp 119–127 © IWA Publishing 2000.

Hammer,M.J. and John Wiley and Sons. (1975) : Water and Wastewater Technology. New York.

Heinss,U.; Larmie,S.A. and Strauss,M. (1999): Characteristics of faecal sludges and their solids-liquid separation. EAWAG SANDEC (Swiss Federal Institute for Environmental Science and Technology, Department of Water and Sanitation in Developing Countries.

Husaini,I.A.J.; Abu-Shrar, T.M. and Mrayyan,B. (2005) : Assessment of the application of treated water and sewage sludge in productive agriculture: A case study from northern Jordan. *Water and Environment Journal.*, 19 (4), 394 – 403.

Karr,P.R. (1976): "Factors Influencing the Dewatering Characteristics of Sludge", Ph. D. Dissertation, Clemson University, South Carolina.

Lawrence,K.; Wang,Y.L.; Nazih,K. and Shammas,G.P. (2007): Sakellaropoulos , Handbook of Environmental Engineering Volume 6, 2007, pp 403-430, Local Environmental Action Plan for the Municipality of Gazi Baba.

Metcalf and Eddy. (1991): Wastewater Engineering, Treatment, Disposal and Reuse, Third Edition McGraw-Hill, Inc., New York, N.Y.

SANIMAS (2005): Informed Choice Catalogue. BORDA and USAID.

SASSE,L.B. (1998): DEWATS. Decentralised Wastewater Treatment in Developing Countries. Bremen: Bremen Overseas Research and Development Association (BORDA).

Strauss,M. and Montangero,A. (2002): FS Management – Review of Practices, Problems and Initiatives. London and Duebendorf: DFID Project R8056, Capacity Building for Effective Decentralised Wastewater Management, Swiss Federal Institute of Aquatic Science (EAWAG), Department of Water and

Sanitation in Developing Countries (SANDEC).

USEPA: United States Environmental Protection Agency (1979): Office of Research and Development, “Process Design Manual for Sludge Treatment and Disposal”, 625/79-011 Cincinnati, Ohio.

WAJ. Water Authority of Jordan (2006): Wastewater treatment in Jordan, annual report.

Wei,Y.; Van,H.R.T.; Borgerb,A.R.; Eikelboomb,D.H. and Fana,Y. (2003): Minimization of excess sludge production for biological wastewater treatment. *Water Research*, 37 (18), 4453-4467.

Zhao,Q.L. and Kugel,G. (1997) : Thermophilic/mesophilic digestion of sewage sludge and organic waste. *Environmental Science and Health*, 31, 2211-2231.

Received on 10 / 9 / 2013

الملخص العربى

تحسين طبقات التجفيف الرملية التقليدية لعمليات معالجة الحمأة

محرم فؤاد* نورا وجيه هدى الجمل***

* قسم الهندسة المدنية ,كلية الهندسة ,جامعة المنصورة

** باحث ماجستير هندسه تكنولوجيا وادارة البيئة ,كلية الهندسة ,جامعة المنصورة

فى هذا البحث تم استخدام الهواء المضغوط لتقليل المساحة السطحية لاحواض التجفيف الرملية للحمأة المنتجة من محطات معالجة مياه الصرف الصحى بالاضافة الى ذلك محاولة تقليل زمن التجفيف. تم تجهيز نموذج معملي لأحواض التجفيف الرملية وزود بمصدر للهواء المضغوط من اسفل .وتم استخدام معدلات مختلفة من الهواء المضغوط بقيم ٣,٥ و ٣,٠ و ٢,٥ و ٢,٠م^{٣}/م^{٢}/اليوم. وتم تطبيق هذه المعدلات المختلفة من الهواء المضغوط على محتوى مائى مختلف لعينات الحمأة المنتجة. وكانت المحتويات المائية بالنسب الاتية ٤٥ و ٨٢,٥ و ١٠٥ و ١١٣٪ كذلك تم تطبيق الهواء المضغوط لمدد تبدأ من دقيقتين حتى ١٠دقائق.

وقد اكدت التجارب ان الزمن الفعال لاستخدام الهواء المضغوط يجب ألا يزيد عن ٢دقيقة وأن الزيادة فى زمن استخدام الهواء المضغوط لا يعطى زيادة مماثلة ملحوظة فى تقليل المحتوى المائى لعينات الحمأة. كما وجد ايضا انه لا يوجد انخفاض ملحوظ فى نسبة تقليل المحتوى المائى اذا قل معدل تطبيق الهواء عن ٣ م^{٣}/م^{٢}/اليوم. وأخيرا فانه يمكن تخفيض زمن التجفيف لأحواض التجفيف الرملية للحمأه المنتجة من محطات معالجة الصرف الصحى لتصل إلي نسبة تترواح من ٨٢ - ٩٧٪ من الزمن الأصلى المطلوب للتجفيف وبالتالى يمكن تحسين خصائص أحواض التجفيف الرملية.

JOESE 5

UPGRADING THE CONVENTIONAL SAND DRYING BEDS FOR SLUDGE TREATMENT PROCESSES

Moharram Fouad*, Nora Wagih, and Hoda El-Gamal***

**Civil engineering department, Faculty of Engineering, Mansoura University, Egypt*

*** Research Scholar of Environmental Eng., Faculty of Engineering, Mansoura University*

Reprint

from

Journal of Environmental Sciences, 2014; Vol. 43, No. 2 : 225- 235

---

http://env.mans.edu.eg/journals/jes

P-ISSN 1110-192X
e-ISSN 2090-9233