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A new natural method for sludge drying of wastewater treatment station—The case of Algeria

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ABSTRACT

This paper presents an experimental application aiming at reducing the sludge drying time in the STEP drying beds of domestic wastewater. This method works with the mixtures of sludge from the Souk Ahras city STEP at different percentages, and with natural material wastes such as scrap limestone flour (SLF) and/or refractory bricks flour based on magnesia (RBFM) from Hadjar Essoud (north eastern Algeria) cement furnaces. The applied experiment focused on mixtures testing for "mud-flour" varying between 12.5 and 100%. The achieved results for mixtures of 25% SLF and RBFM can be noted as: for the mud blindness from 0 to 20%, in the dry season (August, average temperature 34˚C), a globally estimated drying time of 1.5 d; for the mud blindness from 0 to 30% in the wet season (December, average temperature 16˚C), a substantial drying time in the range between 4 and 5 d. In a mixture of 25%, the sludge has been reduced to more than 95% of their initial weight (a reduction from 400 to 17 g). The results show two strong desirable aims of STEP sludge management; on the one hand the drying time reduction and its corollary of drying areas and deposit, and on the other hand the recycling of the waste limestone of cement plants.

Keywords: STEP; Cement plant; Waste; Sludge; Drying; Flour; Limestone bricks

1. Introduction

The history of drying goes back to the beginning of the last century in the field of industrial sludge in Japan, the United States and Europe [1]. However, it remains a universal research field aiming at the reuse of sludge in various fields mainly the production of energy and also much more in agriculture.

The sludge drying operation is a preliminary procedure compared to other treatments such as composting, incineration, or landfilling. The dehydration can be conducted on the basis of conventional mechanical methods, such as the evaporation of water, transpiration evaporation (TE), and percolation [2].

For this purpose, the technology known as sludge treatment has been used in Europe since the late 1980s for dehydration and sludge stabilization [3].

There are two major areas of sludge drying methods from STEP.

1.1. *The total drying procedure of total elimination of sludge after the thickener by evaporation*

(1) by a natural way (planted or unplanted drying beds), this method has shown evidence

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according to studies carried out by authors such as [2,4–10].

(2) by heat: in the current stream of the sludge treatment, the thermal drying is the last link in the chain of water separation from the solid fraction. This step of dehydration which consumes less energy is present in most installations (RECORD study no. 99-0217/1A2001). "This study aimed at completing the work done in 1998 and co-financed by ADEME, the water Agency Seine Normandy and GDF [RES98]." Among the methods of heat drying there are [11].

1.1.1. Solar drying

For small-and medium-sized wastewater treatment stations, solar drying is an effective solution for sludge dewatering. It reduces the volume and mass of dry sludge significantly, allowing to reduce the cost of transport and storage [12].

Many research studies have been conducted to achieve this aim; among the developed techniques, there is the conductive drying with agitation, there is also the solar drying under greenhouse (direct) and drying by radiation [12–21].

1.1.2. Drying by dryers

The thermal drying of sludge activation requires an intensive energy, it is a very costly process that should be optimized by preceding it by a mechanical sludge dewatering operation which is therefore of a paramount importance [22].

Among the developed dryers for pasty materials we cite the paddle dryer, thin layers dryer, and compact flash dryer [23–27].

1.2. The partial drying

Contrary and historically different methods of sludge from the thickener and dehydration have involved this type of drying and led therefore to a reduction of 50–80% of initial water volume [28–32].

The aim of this approach is to reduce the sludge drying time in drying beds where the current process takes place in a maximum time of 15 and 45 d, respectively in summer and winter.

The search for the shortest drying times of gross sludge from Souk Ahras STEP, where there is the best mixture in percentage of this sludge with natural material waste such as cement flour and refractory brick, containing magnesia from Hjar Essoud cement plant.

In this regard the search for natural drying methods complementing those mentioned above in the bibliography is undertaken to optimize the factors of time and space to dehydration and sludge stabilization.

In this perspective, the case of Souk Ahras sludge STEP is treated, producing in 2012, 23,346 t/y of sludge spread over an area of 8,712 m^2 of drying beds and 17,424 m^2 of disposal area (STEP Souk Ahras 2012).

The reduction of spatio-temporal factor is conditioned by an adequate drying that could be achieved through an approach combining different percentages of sludge from STEP from the town of Souk Ahras waste of calcareous origin (flour and cement refractory bricks based on magnesia cement plant of Hadjar Essoud located in the wilaya of Skikda in north eastern Algeria. This factory rejects 80–100 thousand t/y of cement and flour 80–120 t/y of scrap bricks refractory decommissioned after use.

In the current system, the time of stay in normal circumstances in beds is 15 and 45 d, respectively, in summer and winter.

2. Materials and experiment

The material used for carrying out the experiments is composed of:

Plastic boxes:

Thirty-eight boxes of the same volume (22 cm × 11 cm × 10 cm) were used for the drying Fig. 1.

2.1. Process of material preparation for the drying

2.1.1. Tools and equipment of measurements and weighing

(1) Plastic boxes of 22 cm^3 × 11 cm^3 × 10 cm^3 volume were used for drying different samples of mixtures of STEP sludge and waste from mixed cement.
(2) An electronic precise weighing machine and a thermometer

2.1.2. Souh Ahras STEP sludge and different wastes of HADJAR Essoud cement plant

(1) Gross sludge: 400 g of sludge (constant value) for all the trials
(2) The mixtures are made with cement flour waste and refractory magnesia bricks, the weights vary in increments of 50 (50–400 g). The mixtures percentages thus, vary from 12.5 to 100%.

Fig. 1. Plastic boxes.

Observation: A gross sludge control sample only is tested to read the drying time of this sample, it will be taken for this purpose as a reference.

2.1.3. The experimental conditions

The measures of drying degree (or dehydration) on each mixture are done every hour, we note then the evaporated quantity of water and this during 12 h (from 8 am to 20 pm) until the final drying, we noted that the drying time varied between 41 and 80 h; The same measurements are done again the next day and this until the full drying (the minimal and maximal hours recorded number was thus, respectively 41 and 80 h).

Observation: During the night, the drying measurements were made on a 12-h time interval, the quantity of water lost during the night period remained at most equal to the maximum quantity lost in 1 h during the daytime.

2.2. The used drying material

2.2.1. Cement flour

The cement manufacturing method (Hadjar Soud 2011 cement company laboratory cements Hadjar) consists of "cooking," at high temperature (1,400˚C), a mixture of limestone (≥70%), clay (18–20%) and the iron ore (2–3%), properly dosed and crushed as a "raw flour," if the flour contains more than 50% magnesium it is removed from the cement manufacturing process, this is actually the waste that will be used in our application with a view to obtain mixtures of different sludge blindness.

2.2.2. Magnesia-based refractory brick of cement plant furnace magnesia (rejected after use)

The chemical composition of this material is mainly magnesia based according to the laboratory analysis of Hadjar Soud cement company—2006, this composition is as follows:

(1) MgO% (magnesium oxide content 85–89).
(2) Al_2O_3% (aluminum oxide content (9–12).
(3) Fe_2O_3% (iron oxide content 0.5).
(4) CaO% (calcium oxide about 1.0).

These bricks for testing purposes were crushed to flour of magnesium dominance (from magnesia refractory brick flour: MRBF)

2.3. The blindness shapes

The experiment focused on three sludge blindness:

(1) Blindness 0% i.e. mud in liquid form during the summer period and winter.
(2) Blindness 30% dryness during cold period "December."
(3) Blindness 20% in hot period "August."

Table 1 shows, according to the test time and temperature, the drying times obtained for the various sludge mixtures percentages of Souk Ahras STEP, with cement plant waste materials such as cement flour (CF) and refractory bricks magnesia flour (RBMF).

3. Analysis and interpretation of the results

The results obtained in the various tests done under the conditions are shown below.

Table 1
Blindness sludge, waste materials, test period and temperature, mixture percentage, and drying time

Blindness (%)	Period	Hajar Essoud cement plant waste material	Hajar Essoud cement plant waste material mixtures with Souk Ahras STEP sludge								Observation: drying time (h)	
			0%	12.5%	25%	37.5%	50%	75%	1,100%	Fig. no.		
			Mixture drying time in hours								Min	Max
0	Winter (December) average temp. 16°C	Cement flour	200	92	92	106	114	114	115	1	92	200
		Refractory brick magnesia flour (RBMF)	200	106	104	108	108	111	152	1	104	200
	Summer (August). average temp. 34°C	Cement flour	104	40	38	40	41	42	42	2	38	104
		Refractory brick magnesia flour (RBMF)	104	38	38	39	39	41	44	2	38	104
30	Winter (December) average temp. 16°C	Cement flour	176	107	106	113	128	152	164	3	106	176
		Refractory brick magnesia flour (RBMF)	176	112	110	128	128	128	164	3	110	176
20	Summer (August)	Cement flour	80	42	41	42	68	68	68	4	41	80
		Refractory brick magnesia flour (RBMF)	80	42	40	42	42	42	42	4	40	80

3.1. Blindness sludge 0 and 20% in the summer period

In summer and at an average temperature of 34˚C, it turns out, for blindness sludge 0 and 20%, that the best drying time (shortest) is 38 and 42 h (1.5 and 1.6 d), respectively, for the mixtures of 25 and 12.5% cement plant waste material (cement flour and refractory brick magnesia flour (RBMF).

3.2. Blindness sludge 0% winter period

In winter, the drying time is relatively longer compared to the summer. We have recorded for a blindness of 0%, a drying time of 92 and 104 h (3.8 and 4.3 d), respectively, for cement flour and refractory bricks flour based on magnesia (RBFM).

3.3. Blindness sludge 30%, winter period

In winter, for a blindness of 30% mixed sludge in each of the two wastes at the rate of 25%, the shortest sludge drying time was at 106 and 110 h (4.4 and 4.6 d), respectively, for CF and RBFM.

4. Eco-environmental impact analysis

The cardinal concern of this contribution in addition to the technical aspects related to the drying time, cannot overshadow an eco-environmental aspect that is based on the management of 48,000 tonnes/year of gross sludge produced by the souk Ahras sludge STEP. This quantity of sludge require for dehydration and, if we retain a mixture of 25%, some 11,000 tonnes of one of the two types of waste (CF or RBFM).

This objective recommends to initiate a search for technological tool in order to implement an integrated tool for automatic or hybrid implementation to ensure a homogeneous mixture of "sludge-waste" defined above.

5. Constraints and recycling perspectives of RBFM

For the use in the STEP sludge drying, the RBFM should undergo a complex operation of fine crushing, of adequate packaging suitable for transport with regulatory requirements. This series would annihilate the expected operational benefits of recycling of all or a part of 120 t/y of waste of RBFM got from Hadjar Essoud cement plant.

Notwithstanding this technical economic constraint for the use of this waste in the STEP sludge drying, its interest can be, however, for the production of composite material dedicated to building and/or other sectors, this suggestion could lead to an applied research in the field of materials science.

6. The eco-environmental possibility of cement flour (CF)

This waste is estimated to be 80,000 t/y from which 12,000 t/y will be collected and transported over a distance of 150 km for their use in the sludge drying of Souk Ahras STEP. Assuming the cost of transporting this waste, its recycling for sludge drying, present an eco-environmental advantage and even meet the wanted objective. This feasibility could extend over the other STEP of Skikda and Annaba located, respectively, 30 and 40 km far from the site of Hadjar Essoud cement plant.

7. Conclusion

In this experimental research approach, the obtained results show that the best mixture for each of the two wastes CF and RBFM would be 25%; it should be noted that in this mixing ratio:

In hot period, the sludge dryness at 0 and 20%, the obtained shortest drying time was 1.5 d. However, in winter, for a sludge of 0 and 30% blindness, the shortest drying time relative to the CF and RBFM ranged globally between 4 and 5 d.

Compared to the experimental situation, the temporal reduction obtained from the experiment give significant links ranging from 1/10 to 1/9, respectively, for summer and winter period.

Globally, these results translate on the one hand, the elimination in an optimal time, the pollution generated by the sludge of the STEP, potential sources of various nuisances and, on the other hand recycling 14% of limestone flour rejected by the cement plant.

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