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Strategies of Sludge Management in the Gaza Strip

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Author's contribution

The sole author designed, analyzed and interpreted and prepared the manuscript.

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Case Report

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ABSTRACT

The Gaza Strip is a limited area with high population density. Four wastewater treatment plants operate in the area which are overloaded and mismanaged. There are plans to construct three more wastewater treatment plants with overall capacity of 304,000 m^3/day which will make use of the activated sludge technology. The current research estimated the quantities of sludge and studies the possible options for disposal based on the Gaza Strip circumstances. It is estimated that 21,000 tons of dry solids per year will be produced in the Gaza Strip. The quality of existing sludge complies with the Palestinian Standards with respect to nutrients content and absence of heavy metals. The reuse of sludge in agriculture is the most feasible option for sludge disposal but, as the area of agricultural land is limited in the Gaza Strip, farmers throughout the Gaza Strip will need to be encouraged to use sludge.

Keywords: Sludge; management; reuse; the Gaza Strip; quality; quantity.

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1. INTRODUCTION

The Gaza Strip is one of the most densely populated areas in the world. The population was estimated to be 1,472,000 in 2005 [1]. Agricultural land comprises nearly 50% of the total area (365 km^2) of the Gaza Strip [2].

Several farmers in the Gaza Strip produce a limited amount of organic fertilizer; the main sources are cows, sheep, and poultry. The amount of organic fertilizers required in the Gaza Strip is around 795,000 m^3 per year, The quantity of organic fertilizers produced locally covers only 8.5% of local needs and the rest (91.5%) has to be imported [3].

Farmers in the Gaza Strip distribute organic fertilizers (raw animal Manure and agriculture waste) manually without using any mechanical equipment. This means that farmers have direct contact which could impact their health if the fertilizers are contaminated [4,5].

There are four wastewater treatment plants in operation in the Gaza Strip as shown in Fig. 1, which is nearly receives around 24 Million m^3 of waste water/year nearly free of contamination by heavy metals due to the limited industrial activities [6]. Sludge currently generated from these plants is difficult to quantify but is estimated to be around 3,300-5,000 tons/year on dry basis [7]. Most sludge removed from WWTPs in Gaza Strip is spread on land adjacent to the treatment plants, which may pollute the surrounding agricultural land, the groundwater aquifer and impact the health of the residents [8].

Three more wastewater treatment plants with a total capacity of 306,000 m^3 of wastewater /day are planned for 2017 to cover the Gaza. Activated sludge system is the proposed technology and a huge amount of sludge is expected to be generated daily from these plants.

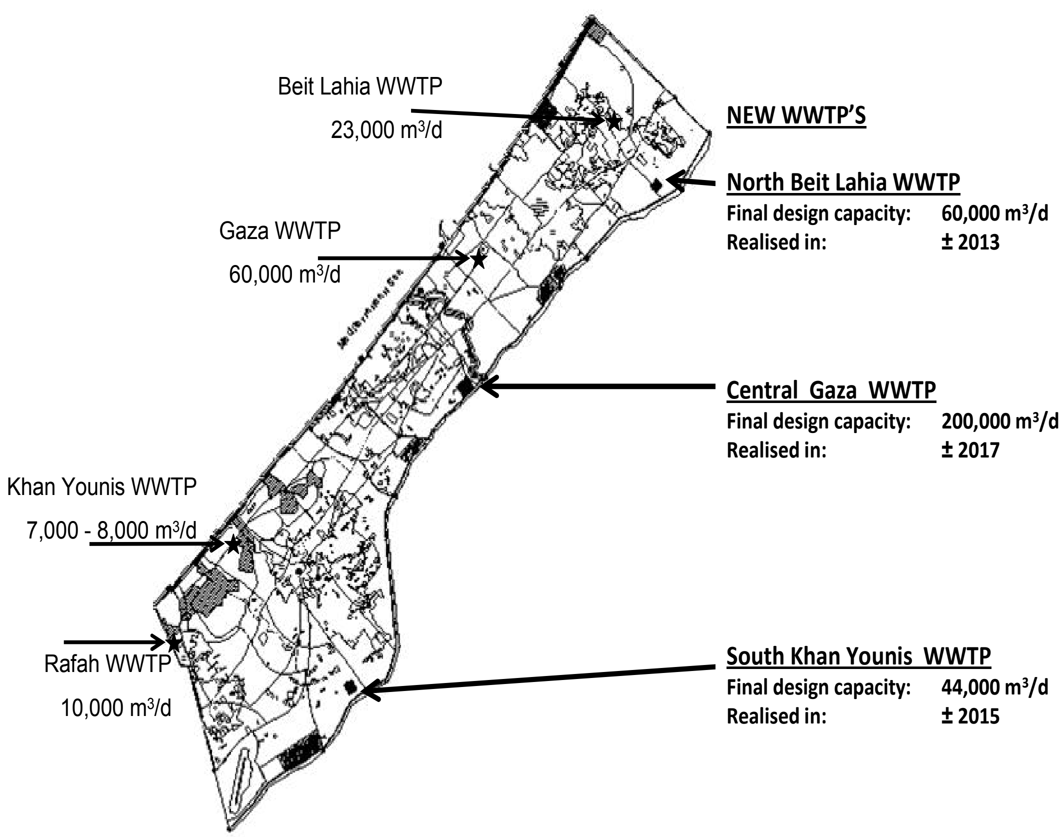

Fig. 1. Existing and planned WWTPs in the Gaza Strip

The author calculated the quantities of sludge in the Gaza Strip based on wastewater generated and treatment technology. The quality of sludge is determined based on review of previous studies. The author reviewed sludge management in many regional areas (Egypt, Jordan and Tunisia). Based on that, some alternatives of sludge management were proposed and then all options were assessed against Gaza Strip conditions and the most feasible ones were recommended.

2. SLUDGE QUANTITIES AND QUALITY IN THE GAZA STRIP

The new treatment plants are designed to treat a combined 304,000 m^3 of wastewater per day with 500 mg/l BOD_5. The author estimated the quantities of sludge based on the following:

$$Y_{obs} = \frac{Y}{1 + K_d \theta c}$$

$$Y_{obs} = \frac{Y}{1 + K_d \theta c} = \frac{0.5}{1 + 0.05 * 5}$$
$$Y_{obs} = 0.4 \text{mgVss/mgBOD}_5$$

Where;

Y_{obs} is observed growth yield, mg biomass formed, VSS/ mg BOD_5 utilized

Y is the yield coefficient = 0.5 mg VSS/mg BOD_5 removed

K_d is the biomass decay rate = 0.05d^{-1}
θc is the sludge retention time in days= 5 days

$$P_x = Y_{obs}\, Q\, (S_o - S)$$

Where;

P_x is sludge production Kg/day
S_o is the influent BOD_5 = 500 mg/l
S is the effluent BOD_5 = 30 mg/l
Q is the daily flow = 304,000 m^3/day

$$P_x = 0.4 \frac{mg_{biomass}}{mgBoD_5} * 304{,}000 \frac{m^3}{d} [500 - 30] \frac{mg.BOD_5}{L} .$$
$$\frac{10^3 L}{m^3} . \frac{1Kg}{10^6 mg_{biomass}} P_x \cong 57{,}152 Kg/d$$

Samples of sludge from the current Gaza WWTPs were analysed for physical, chemical and microbiological parameters to determine its agronomic value as well as its potential environmental and health implications. The Gaza WWTPs use trickling filter technology and sand drying beds for sludge drying. The samples were taken from accumulated sludge which is secondary sludge and relatively digested due to long storage time. The analyses as shown in Table 1 comply with the requirements of the Palestinian standards for sludge use.

Table 1. Sludge quality in the Gaza strip

Parameter	Units	Gaza sludge	Draft Palestinian standard
pH		7.20	
EC (ex. 1:2)	dS/m	3.8	
Dry solids	%	58.7	
Volatile solids	% ds	42.3	
N	% ds	2.0	
P	mg/kg ds	1,539	
K	mg/kg ds	1,408	
Zn	mg/kg ds	598	2,500
Cu	mg/kg ds	91	1,000
Ni	mg/kg ds	18	200
Cd	mg/kg ds	2.9	10
Pb	mg/kg ds	52	300
Cr	mg/kg ds	68	500
Faecal coliforms	MPN/g ds	117	<1,000/g ds
Salmonella	MPN/g ds	-ve	<8/10g ds
Nematode ova	No./g ds	-ve	<0.3/g ds

Source: [9,10,11]

The nitrogen and potassium contents of around 2% ds and 0.14% ds, respectively, are in the normal range for sludge but the phosphorus content is low (0.15% ds). Low P concentrations in sludge are not unusual in the Middle East, for instance in Egypt, P content is in the range 0.5 – 1.0% ds, compared with about 2% ds or greater in Europe. This is presumed to be due to a lower use of P-based detergents [10]. The high salinity of the sludge is due to the high salinity of potable water [12] and air-drying of the sludge ensures that all the salts are concentrated in the dry sludge.

3. SLUDGE MANAGEMENT IN NEIGHBORING COUNTRIES

Sludge management system in Egypt, Jordan and Tunisia have been reviewed and analyzed. Table 2 summarized sludge management in the three countries regarding sludge treatment methods, sludge disposal, laws and regulations, and institutional aspects. Based on Table 2 the following points are addressed:

3.1 Sludge Treatment

The main treatment technologies which are used are aerobic and anaerobic digestion, thickening and conventional sludge drying beds. It seems that the three countries (Egypt, Jordan and Tunisia) are interested in low cost systems which do not require high levels of skill.

3.2 Sludge Disposal

In Tunisia and Egypt, most sludge is utilized for agricultural purposes while in Jordan; sludge is only disposed to landfills. It is intended in all countries to utilize sludge in agriculture and to benefit from the nutrients available.

3.3 Laws and Regulations

The legislation on sludge use in different countries varies greatly. For example, in Egypt the Ministry of Agriculture limits the use of the sludge as a fertilizer in restricted cultivation of uncooked crops, citrus, mango, cotton, green beans, provided that the quantities used not exceed 5 tons/acre/year with official and valid permission from the Ministry according to farm size.

3.4 Institutional Aspects

The three countries pay attention to reuse of treated wastewater in agriculture where laws and regulations are clear and well defined. The institutions vary from national to regional and local levels. Such arrangements could depend on the size and population of the country.

4. SLUDGE USE LIMITATION

According to Palestinian environment quality authority [11] Sludge may be used for the following purposes:

- Soil conditioning of land not used for agricultural purposes;
- Land under preparation for planting productive trees and field crops;
- Grain crops that will be dried before human consumption;
- Field crops that will be harvested and dried naturally before use as animal feed.
  And will not be used for:
- Vegetable or flower production;
- Land cultivated with productive trees that are inter-planted with vegetables;
- Domestic gardens, and for recreational and open areas with public access.

5. SLUDGE MANAGEMENT OPTIONS

The author studied many sludge management options as follows:

5.1 Agricultural Use

Sludge from WWTPs could provide an attractive alternative fertilizer option. It is the residue of suspended solids in sewage after being settled and separated through wastewater treatment processes [13]. Sewage sludge contains all the elements essential for the growth of higher plants especially nitrogen and phosphorus along with organic matter which may resemble those in animal manure and organic composts. Sludge recovered from wastewater treatment plant (WWTP) can be used as a soil conditioner, providing organic matter to soil and thus improving soil physical properties in a manner similar to other organic-based soil amendments [14,15]. Also, sludge can serve as a partial replacement for expensive chemical fertilizers [16].

Table 2. Experience of sludge treatment and disposal in Egypt, Tunisia and Jordan

Item	Egypt	Jordan	Tunisia
Sludge disposal	Most of the produced sludge is utilized in agriculture and as soil conditioner	Sludge is only disposed to landfills; no sludge is utilized in agriculture.	Sewage sludge is mainly used for agricultural purposes and sludge market is not organized. Sludge is supplied to the farmers at low cost compared with other organic fertilizers. Sludge is given to the farmers at the treatment plants, where dried sludge is hauled by the farmers who use it for their agricultural land.
Laws and regulations	There have been no strict regulations for sludge utilization. Although, the Egyptian Environmental Agency and Ministry of Agriculture recently issued informal regulations regarding the handling and disposal of sludge	The Jordanian Standards JS 1145/1996 is adopted regarding sludge reuse in agriculture. The main elements of the standards are: Treatment method. Quality inspection Heavy metals concentrations and Pathogenic pollution limits.	Official control and regulation of sludge quality and use does not exist.
Institutional aspects	Responsibilities for Water quality management including sludge treatment and disposal are shared by a wide range of governmental institutions at the national, regional and local levels of the government of Egypt supported by a number of NGOs such as scientific Institutions, Universities and others which play a role in policy formation and implementation.	Reuse of sludge in agriculture is regulated by the Jordanian Standard JS 1145/1996. The legislation appoints the Water Authority of Jordan and the Department of Environment and Health to monitor the compliance to the law.	The responsibility of wastewater and reuse in agriculture is shared by many Ministries: the Ministry of Environment and Land Management, the Ministry of Agriculture, the Ministry of Public Health and the Ministry of Tourism.

Source: Adapted from [17]

In Gaza, there is an unsatisfied demand for organic fertilisers, as use is restricted by the limited local production of animal manures and the high cost of imported products from Israel [18,19]. There is little experience of sludge use in Gaza, and as with any new product, it will take time to become established but a high take-up may be anticipated if the product is suitable The evaluation of the potential 'market' for sludge carried out previously indicated that farmers may be willing to use and pay for sludge [20,21]. The draft Palestinian standards for sludge would restrict sludge application to 10 tds/acre/y; this is considered to be an appropriate limit in relation to nutrient additions and crop requirements.

5.2 Landfill Disposal

The disposal of sludge to landfill has been a popular option in many countries due to its low cost, simplicity and ease of disposal. The codisposal of sludge with solid waste would be technically feasible if the sludge has sufficiently low moisture content (<65%) when the environmental impacts are predicted to be small [22].

However, codisposal cannot be recommended as a routine outlet for the sludge as this would significantly reduce the limited landfill capacity in the Gaza Strip. Landfill disposal of sludge should only be regarded as an emergency measure for sludge that is too contaminated for agricultural use but such circumstances are expected to be very unusual.

5.3 Incineration of Sludge

Incineration of sludge, preferably with energy recovery, can be justified as the best practicable option where other reuse opportunities are not available. However, this is only feasible on a large-scale, has high capital and operating costs and requires considerable technical ability. In addition, about 30% of the sludge solids remain as ash, which requires disposal to landfills. There is very limited capacity for the disposal of waste in Gaza due to limited land allocated for land filling [23]

A centralised co-incineration plant for sludge and solid waste could provide an appropriate scale of operation in Gaza, and would partially solve the difficult solid waste disposal problems. However, international experience has shown that such combined incineration plants are technically difficult and expensive to operate and are unlikely to be an attractive option in the foreseeable future.

5.4 Combustion of Sludge

Combustion of sludge as a part-replacement fuel in energy intensive industrial processes, such as cement production, is increasingly practiced worldwide where there are suitable industries near to the WWTP. This not only provides a small reduction in fossil fuel CO_2 emissions but also there is usually no hazardous ash for disposal as this becomes combined with the product. However, there are no suitable industries in Gaza, and although the Gaza power station is close to the WWTP, this would not be able to utilise sludge as a supplementary fuel [22].

5.5 Sea Disposal of Sludge

Sea disposal of sludge is no longer an acceptable option and generally prohibited by national legislation and international agreements, although a few countries continue this practice. In the Europe Union, this has been prohibited since 1989, and in the context of the Mediterranean Sea, marine disposal of sludge is contrary to the Barcelona Agreement.

6. Options Assessment

The land area of the Gaza Strip is small in relation to the current population and the overall population density will increase as the population is projected to continue expanding at a high rate. This will result in Increasing pressure on agricultural land for urban development, increasing quantities of sludge and diminishing capacity to utilise all sludge as the availability of agricultural land reduces. Projections indicate that there will come a point when it is physically impossible to utilise all of the sludge on agricultural land within the Gaza Strip.

The combined capacities of the three regional WWTPs will be about 304,000 m^3/d (North 60,000, Central 200,000, South 44,000), which would be sufficient to irrigate 7600 acres at an average peak gross demand of 4 mm/d. Regional sludge production at the assumed wastewater design flows is estimated at about 21,000 tds/y (assuming no digestion).

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Nevertheless, it is considered improbable that the limited agricultural land in the Gaza Strip can provide sufficient capacity to reliably use all of future sludge production. Disposal of sludge to landfill is discounted. Incineration of sludge would not be technically feasible for the scale of future sludge production due to high capital and

operating costs and the high level of technical expertise required.

Assuming the nutrient content of the sludge from the existing Gaza WWTP is reasonably representative of that of the future sludge from the new WWTP, the maximum application rate would be limited by dry solids addition since the N content is less than 2% ds. Consequently, sludge applied at the maximum proposed rate of 10 tds/acre would apply 200 kg N, 15 kg P (34 kg P_2O_5) and 14 kg K (17 kg K_2O) per acre.

An intensive marketing campaign will be necessary, including demonstration field trials programmes, targeted advertising campaigns, provision of farmer advice, among others, in order to optimise farmer take-up of sludge use.

Currently, Palestine has no sludge management policy and the appropriate organisational setup for monitoring and control has not yet been established. The adoption of appropriate standards for the use of treated sludge in agriculture is an essential step in this regard in order to codify institutional responsibilities.

Sludge cannot be regarded as a commercial product that will reliably provide revenue; sludge is essentially a waste product of wastewater treatment. Farmers may be expected to pay for the transport of sludge and this represents a cost saving since the operator would otherwise have to cover the costs for alternative disposal, although, essentially there are no other means of disposal.

Reducing the sludge management component of the general water tariff is only feasible by commercialising sludge, achievable when demand exceeds supply but this is unlikely to be the case in the Gaza Strip as the capacity to utilise sludge is limited due to the restricted area of agricultural land available.

Extension and public information programs should also accompany the introduction of sludge to develop awareness and understanding and to make the potential ‘market’ receptive to a new product.

7. CONCLUSION AND RECOMMENDATIONS

The following key conclusions and recommendations are addressed:

- The reuse of sludge in agriculture is the most feasible option for sludge disposal but, as the area of agricultural land is limited in the Gaza Strip, farmers throughout the Gaza Strip will need to be encouraged to use sludge.
- Aspects of the sludge reuse standards should be reconsidered as these are unnecessarily restrictive (all vegetable crops excluded). This significantly increases the potential area of land on which sludge may be used.
- The N- content of existing sludge is only 2.0–2.5% which is low compared with other organic fertilizers. Using anaerobic digestion to stabilise the sludge and increase the N- content is recommended.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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