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Physicochemical Characterization of Sewage Sludge of Gaza Wastewater Treatment Plant for Agricultural Utilization

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Abstract

The aim of this study is to evaluate the feasibility of using sewage sludge produced from Gaza wastewater treatment plant, as an agricultural fertilizer. The sludge studied was collected from Gaza Wastewater Treatment plant (GWWTP), as the accumulated one stated in the collection lagoons for a period of time more than six months. Before using, sludge was passed through several steps of processing, such as drying at sun light, cleaned off plant tissues and grinding to a proper size. The physicochemical analysis results showed that the sludge can be a valuable resource if used as a fertilizer and soil conditioner and can supply all micro and macronutrients necessary for plant growth since the results of the nutrients showed that the average TKN concentration was 5440 mg/kg and NH_4-N was 3594 mg/kg and NO_3-N was 125 mg/kg, these values showed rich content of nitrogen, where they are considered as essential nutrients. Potassium and Phosphorus are another essential nutrient with average value 525 and 213 mg/kg respectively. The total concentration of Cr, Zn, Cu, Pb and Cd meet regional and international standards for agricultural use, and they were, 119, 1660, 245, 92 and 2 mg/kg respectively.

Keywords:
Sewage sludge,
Gaza wastewater treatment plant,
Micro and macronutrients,
Agricultural fertilizer.

1. Introduction:

Sewage sludge/ bio-solids represent an increasing challenge all over the world. Gaza's wastewater treatment plants facilities are still vastly inadequate in sludge treatments, with a large amount of sewage being discharged into the environment without any treatments and without any control as sludge treatment is so expensive (Nassar *et al.*, 2003), In other words, none of the bio-solids is being reused in proper manner.

In Gaza, large amounts of sludge are being produced from Gaza wastewater treatment plants (GWWTP). It is accumulated in the closest sandy dunes surrounding the treatment plant causing serious hazards to the environment and its leachate infiltrates to the ground water causing serious contamination to the groundwater aquifer (possibility of contamination of heavy metals). In addition, the uncontrolled status has faced deterioration in both quality and quantity for many reasons, e.g. low rainfall, which led to a decrease in the recharge quantity of the aquifer, also, increasing the population, will deepen the problem (Nassar *et al.,* 2003). Sludge treatment facilities are almost absent and the sludge produced is removed from the ponds and left to be dried, partially depending on the season and the available area close to the treatment plant (Nassar *et al.,* 2008).

Currently, Palestine has no sludge management policy and the appropriate organizational setup for monitoring and control has not yet been established, although it is expected that these would be similar to that for effluent reuse. 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.

In the Gaza Strip, there is a large demand for organic fertilizers that is unsatisfied due to the costs and restrictions of supplies that have to be imported, it is estimated as 137590 liter of liquid fertilizer, and 2205 tons of solid fertilizer for the year 2013 (Ministry of Agriculture Report for Marketing, 2013), so there is an increasing trend of using sewage sludge in agriculture. 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 produce is suitable. There is lack of published works that describe the reuse of sludge and its physico-chemical impact and/or biological characteristics in Palestine especially in the Gaza Strip, and there are many farmers in Gaza use partially treated sludge such illegal and unmonitored use, and this action of contaminated sludge could create environmental and health problems.

Many studies have been carried out on reuse of sludge for agriculture utilization, in this respect (Ahmed *et al.*, 2010) reported that the plant macro and micro nutrients as well as organic matter make sludge disposal in soil an attractive option. Nitrogen has received most attention and it is normally the most abundant sludge nutrient. One of the best alternatives to waste disposal is through the soil-plant system as a fertilizer. The experiment was applied on a calcareous soil. Using six different doses of a sewage sludge were treated. A crop barley (*Hordium Vulgare*, Giza 123) was grown in the amended soils. The application of sewage sludge to the calcareous soil lowered the pH of the soil, although the value always around 7.7-7.9 at the end of the experiment. In the barley plants it was observed that the higher the yield, the higher the nitrogen contents. Electrical conductivity rose with organic amendment. Also it improved the nutrient level of the soil, particularly nitrogen and available phosphorus. Also, (Roig *et al.* 2012), analyzed the systematic and periodical use, for 16 years, of anaerobically digested sewage sludge as an agricultural fertilizer by assessing the effects on some soil physical–chemical, functional, and eco-toxicological properties. They found that the input of sludge enhances soil properties proportionally to the application doses and/or frequency. The organic amendments increased the organic matter content (and its aromaticity), the soil nitrogen, and the microbial activity, improving carbon and nitrogen mineralization processes and some enzymatic functions. They showed that the maximum dose should be (40 mg ha^{-1} $year^{-1}$) no more. On the other hand, (Inderscience Publishers, 2009), studied the use of sewage sludge as fertilizer supplement for *Abelmoschus esculentus* plants by measuring physiological, biochemical and growth responses, This study was conducted to assess the usefulness of sewage sludge amendment (SSA) at 20% & 40% ratios for lady's finger (*Abelmoschus esculentus L. var Varsha uphar*) by evaluating the morphological, physiological, biochemical and yield responses. Lipid peroxidation, protein and antioxidant levels increased whereas photosynthetic rate, stomatal conductance and variable fluorescence ratio decreased in plants at higher SSA ratio. Biomass, yield and heavy metal concentration increased significantly at both the amendment ratios. The study suggests that SSA ratio below 20% could be an alternative option of fertilizers for good yield of lady's finger and also a useful management option for this solid waste. Also, (Jamali *et al.,* 2008), studied the use of sewage sludge on agricultural land provides an alternative for its disposal. Therefore, the aim of the study was to evaluate the feasibility of using industrial sewage sludge produced in Pakistan, as an agricultural fertilizer. The agricultural soil amended with 250 g/kg sewage sludge with or without lime treatment was used for the growth of the common local grain crop, maize (*Zea maize*). The mobility of the trace and toxic metals in the sludge samples was assessed by applying modified Standards, Measurements and Testing Program (formerly BCR) sequential extraction procedure. The single extraction procedure was comprised of the application of a mild extracting ($CaCl_2$) and water, for the estimation of the proportion of easily soluble metal fractions. The plant-available metal contents, as indicated by the deionized water and 0.01 mol/L $CaCl_2$ solution extraction fractions and the exchangeable fraction of the sequential extraction, decreased significantly with lime application because of the reduced metal availability at a higher pH, except in the cases of Cd and Cu, whose mobility was slightly increased. Sludge amendment enhanced the dry weight yield of maize and the increase was more obvious for the soil with lime treatment. Liming the sewage sludge reduced the trace and toxic metal contents in the grain tissues, except Cu and Cd, which were below the permissible limits of these metals. The experiment demonstrates that liming was an important factor in facilitating the growth of maize in sludge-amended soil. In addition, (Arslan *et al.,* 2009), studied the effect of mixing sludge with surface soil on soil physical properties and cotton yield, by using four treatments: (i) control; (ii) application of inorganic fertilizer according to the recommendation of the Ministry of Agriculture and Agrarian Reforms (MAAR); (iii) application of sludge equivalent to MAAR-recommended nitrogen application rate; (iv) application of sludge at double the rate used in (iii). The experiment was conducted at the Kamari Research Station in Aleppo-Syria. Organic matter in the top soil of the sludge treatments was significantly higher than in the control and mineral fertilizer treatments. Application of sewage sludge clearly improved the infiltration rate and soil water holding capacity because of the high water holding capacity of the applied sewage sludge compared the soil. Cotton yield increased with increasing sewage sludge application, and the highest yield (5400 kg cotton/ha) was obtained from treatment received sludge double crop N needs. In addition (Nassar *et al.,* 2009), studied Attitudes of farmers toward sludge use in the Gaza Strip, they said that the local production of organic fertilizer in the Gaza Strip is 66,800 m^3/year, which represents only 8.5% of the required quantities. This means that farmers have to import 728,000 m^3 of organic fertilizer per year, which costs around 10.2 Million US$. The social survey carried out for more than 300 farmers in the Gaza Strip shows that the scarcity of organic fertilizers and their high prices could encourage farmers to use treated sludge instead of importing organic fertilizers. The farmers who have not used sludge before are willing to use it if it is well treated and shows good results after application. Also sludge can be used as soil conditioner if it is composted as imported compost materials used in the Gaza Strip.

2. Materials and Methods:

2.1 Study area:

The source of the sludge was from Gaza Wastewater Treatment plant, as from both primary and secondary sludge produced in the treatment plant.
The sludge was collected from the accumulated one stated in the collection lagoons for a period of time more than six months.

Figure 1 *Gaza Wastewater Treatment plant (GWWTP)*

Figure 2 *The drying beds of the sludge at GWWTP*

2.2 Sludge Processing:

The collected sludge samples were processed to reach appropriate quality, such as drying at sun light and grinding to reach size (0.0117 inches). The sludge used in the experiment was dried by air for three months to ensure stabilizing. Sludge was cleaned off plant tissues, and stones. Sludge was grinded manually by mortar pestle, then sludge passed through a 2mm sieve. The tests were performed at constant dry weight. The chemical and physical properties were determined for sludge sample.

2.3 Sludge analysis:

Sludge samples were analyzed for triplicate according to Methods of soil analysis (Page *et al.* 1982), & Devices and methods of analysis of water and soil (Yosef, 1999). pH was measured by pH meter, Equivalent amounts of the sludge sample and de ionized water are mixed and shaken, then, the pH of the solution is measured using pH meter. EC was measured by Laboratory method, Equivalent amounts of the sludge sample and de-ionized water are mixed and shaken, then, the EC of the solution is measured using EC meter. Cation exchange capacity (CEC) for the sludge sample was performed by washing with deionized water, then the cations are extracted by sort of ammonium acetate, the equivalence of the replaced ammonium is equal the CEC of the sample in 100g. The ammonium is evaluated by Total Kjeldahl nitrogen (TKN) instrument. TKN, Kjeldahl method was used to determine the amount of organic and ammonium nitrogen. The organic nitrogen in the sample is converted to ammonium nitrogen by digestion in acidic media, then the original ammonium nitrogen and the converted ammonium nitrogen is distilled in a basic media and collected. Then the ammonium nitrogen is measured by Nesslerization method. Na and K were measured by Flame Emission photometric method, 10g of the sludge sample is mixed with 50 ml of ammonium acetate solution, the desired metals are extracted, after filtration, the filter is used for the evaluation of the desired metal. Ca and Mg were measured by Replacement of Exchangeable cations, 10g of the sludge sample is mixed with 50ml of ammonium acetate solution, the desired metals are extracted, after filtration, the filter is used for the evaluation of the desired metal (Here, EDTA titration for sodium and then Mg-Calculations). PO_4-P was measured by Vanadomolybdophosphoric method, 2.5 gram of soil and 50 milliliters of 0.5 M sodium bicarbonate solution are shaken for 30 minutes. The mixture is then filtered through Whatman filter paper and the ortho-phosphate in the filtered extract is determined colorimetrically at 400 nm by adding Vanadomolybdophosphoric reagent. NO_3 was measured by colometric method, 10g The sample of the soil is extracted using 2M KCl solution, then the nitrate nitrogen is determined photochemically by means of sodium salicylate method (Merk, Darmstadt, 1974). Organic matter, Carbon in sludge is determined by the reaction with acidic dichromate ($Cr_2O_7^{2}$). The oxidation step is then followed by titration of the excess dichromate solution with ferrous sulfate. The OM in the sludge is calculated using the difference between the total volume of dichromate added and the amount of unreacted dichromate determined through titration with ferrous sulfate after the reaction. Metals & Heavy metals (Ag, Al, As, Ba, Cd, Co, Cr, Cu, Fe, Li, Mn, Ni, Pb, Sr, and Zn), were measured by using Inductivity coupled plasma (ICP) method, 1.0 g of each homogenized sample was digested in 10.5 ml of concentrated HCl (37%) and 3.5 ml of concentrated HNO_3 (67%) in 50-ml digesting flask. The samples were digested (12 h) and then heated to 160 °C on sand bath until a complete extraction had taken place (3 h). After cooling, the solutions were diluted with distilled water in 50-ml volumetric flasks, filtered and kept in 100-ml polyethylene bottles for analysis. Samples were analyzed by Agilent Technologies 700 series (ICP/OES) for the metals and heavy metals.

3. Results and discussion:

In order to evaluate the sludge of GWWTP, samples were taken from the accumulated bonds at the GWWTP. Parameters such as pH, EC, TKN, (Na, Ca, K, and Mg) as cations exchangeable in addition to PO_4-P, $CaCO_3$, NO_3 and organic matter were analyzed. On the other hand metals and heavy metals were evaluated, Table 1 summarizes the overall results of the measured parameters.

Table 1 *Characteristics of sludge from GWWTP*

Parameter		Sludge
pH		6.552
EC	µS/ cm	7160
CEC	meq/100g	22.7
TKN	mg/kg	5440
NH_4-N	mg/kg	3594
Na	mg/kg	1000
Ca	mg/kg	1569
K	mg/kg	525
Mg	mg/kg	1623
PO_4-P	mg/kg	213
$CaCO_3$	%	4
NO_3-N	mg/kg	125
C/N		44/1
O.M	%	50
H.M (Total)		
Ag	mg/kg	11
Al	mg/kg	8215
As	mg/kg	8
Ba	mg/kg	233
Cd	mg/kg	2
Co	mg/kg	3
Cr	mg/kg	119
Cu	mg/kg	245
Fe	mg/kg	9755
Li	mg/kg	4
Mn	mg/kg	132
Ni	mg/kg	24
Pb	mg/kg	92
Sr	mg/kg	369
Zn	mg/kg	1660

Table 1 *Characteristics of sludge from GWWTP*

Parameter	Sludge

Note: The results based on dry weight.

3.1 pH:

Soil pH is important, since it influences how easily plants can take up nutrients from the soil. Nutrients are more available at the soil pH range of 6.5–7.

It was found that the pH of sludge samples taken from GWWTP was slightly acidic, and it was in the accepted range to be reused in agricultural according to EQA standards (Environmental Quality Authority) (EQA, 2005).

The importance of pH value of sludge is the solubility of heavy metals in sludge samples and pH-dependent. Accordingly, acidic media may enhance the solubility of heavy metals in sludge samples and make them dynamically toxic. Thus, high risk may be associated with acidic pH range and the opposite is true for alkaline pH.

3.2 Salinity:

Soil Salinity is used to indicate soluble salt concentration in soil, as crops only remove small amounts of salt, (Heidarpour *et al*., 2007). Saline soils exert severe stress on plants; Salt-affected soils are more common in arid and semi-arid regions than in humid areas. Salt-affected soil is adversely changed by the presence of soluble salts. Saline soils contain enough soluble salt to limit plant growth while sodic soils contain excessive exchangeable sodium that destroys soil structure. Saline-sodic soil is excessive in both soluble salts and exchangeable sodium and thereby interferes with normal crop growth.

Salinity value of the sludge samples was 7160 µS/cm, and sodium was 1000 mg/kg as shown in Table 1. This may be due to the accumulation of high soluble salts in the sludge samples due to the nature of sludge which was kept for six month at least which led to evaporate water and concentrate the salinity, Also results indicated that the sludge cannot be applied in all agricultural crops due to this high salinity. But some plants are tolerant for high content of salinity as *Zea maize*.

3.3 Nutrients:

Nitrogen (N) is considered a major or macronutrient element and ranks fourth in importance among essential elements with carbon. The nitrogen concentration of most crop plants averages (2-4%). The form used by plants depends in part on rainfall, soil pH, and the age of the plant. High amounts of nitrogen stimulate shoot growth more than root growth probably because N is needed to make chlorophyll besides the genetic proteins and cell walls needed by all cells. However, an adequate supply of N promotes deep and numerous roots due to the greater leaf area providing energy for growth (Ward, n.d).

The results obtained showed that the average TKN concentration was 5440 mg/kg and NH_4-N was 3594 mg/kg and NO_3-N was 125 mg/kg, It is a high content of nitrogen, but it is an essential nutrients as the Allowed range (dry solids) of nitrogen concentration of Fertilizer Value of Sludge for Agricultural Use (EQA, 2003).

C/N ratio is one of the most important chemical properties of soils and composts, for microorganisms, carbon is the basic building block of life and is a source of energy, but nitrogen is also necessary for such things as proteins, genetic material, and cell structure.

Results obtained in table 1 showed that the C/N was 44:1. The result slightly exceed the Allowed range (dry solids) of C/N of Fertilizer Value of Sludge for Agricultural Use <35:1(EQA, 2003).

Potassium is another essential nutrient for plants, which is required in large quantities for the proper growth and production. Results obtained in table 1 showed that the average available K was 525 mg/kg. This result for potassium (dry solids) is lower than the guidelines values assigned by EQA For Potassium of Fertilizer Value of Sludge for Agricultural Use (0.5–2%). (EQA, 2003).

Phosphorus is absorbed by plants roots in the orthophosphate form, generally as $H_2PO_4^-$ or HPO_4^{-2}. The amounts of these ions in the soil solution are determined by soil pH as shown in Figure 3. At pH 7.2, there are approximately equal amounts of these two forms in solution. Maximum solubility of calcium phosphate minerals occurs at about the same pH, therefore maximum plant available P occurs at approximately pH (7.0). It is mobile in the plant and redistributes from older to younger plant parts as demand changes. As pH changes in either direction, P availability is decreased (Tisdale *et al.,* 1993).

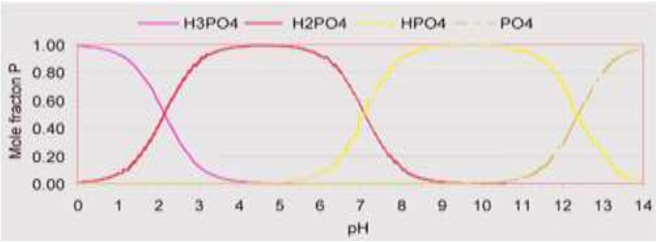

Figure 3 *Influence of pH on the distribution of orthophosphate*

Phosphorus is another one of the three most essential nutrients for plants, the average PO_4-P concentration was 213 mg/kg. The result for Phosphorus (dry solids) is lower than the guidelines values assigned by EQA For Phosphorus of Fertilizer Value of Sludge for Agricultural Use (1.5 – 2%). (EQA, 2003).

3.4 Organic matter and CEC:

Organic matter (O.M) influences physical and chemical properties of soils. In some soils O.M may be responsible for nearly half of the cation exchange capacity (CEC). It is also important in maintaining the stability of soil aggregates. According to (Ross *et al.,* 1995), CEC less than 3 meq/100 g in sandy soils corresponds with low organic matter, while CEC of the sandy soil higher than 25 meq/100 g corresponds to high organic matter. Further, soil organic matter will develop greater CEC at near neutral pH than under acidic conditions.

Microbes in the soil also utilize O.M as a food source. Also microbiological activity improved after application of sewage sludge (Vieira, 2001).

Organic matter is one soil constituent that helps maintain aggregate stability. The resins and scums present in organic matter help bind particles together to form aggregates. Organic matter (OM) influences physical and chemical properties of soils.

The results obtained for CEC was 22.7 meq /100 g and the result of organic matter was 50%. These results showed were agreement with Ross. (Ross *et al.,* 1995)and the results of organic matter was in the range recommended by EQA (>40%). (EQA, 2003).

3.5 Metals and Heavy Metals:

Heavy metals are generally less available to plants in soils of high pH and high CEC compared with soils of low pH and low CEC (FAO, 2003).

Metals and Heavy metals of sludge used in this work was analyzed by preparing appropriate sample and analyzed at Heidelberg laboratory in Germany by Agilent Technologies 700 series (ICP/OES).

Although there are no treatment facilities for sludge within the treatment plants, heavy metals contamination from industrial wastewater is not probable since the limited number of factories presented in the Palestinian territories (Shomar *et al.*, 2004).

Results indicated that (Cr, Cd, Ni, Cu, Pb, Zn) meet the maximum permissible heavy metals value According to (EQA, 2003), and meet also regional standards as Egypt and Jordan, and international standards as USEPA. This show a good agreement with the results obtained by (Shomer, 2004) as the sludge in general is clean of heavy metals.

Results indicated that As exceed the Palestinian standard but meet regional and international standards as Egypt and Jordan, and USEPA.

Some of heavy metals are not illustrated in Palestinian standard but illustrated in Jordan standard like Co and meet this standard. Some of heavy metals are not illustrated in all standards like (Ag, Al, Ba, Fe, Li, Mn, Sr).

Conclusion:

The study concludes that physicochemical analysis show that the sludge can be a valuable resource if used as a fertilizer and soil conditioner and can supply all micro and macronutrients necessary for plant growth. The total concentration of Cr, Zn, Cu, Pb and Cd meet regional and international standards for agricultural use.

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الخواص الكيميائية والفيزيائية للحمأة الناتجة من محطة الصرف الصحي في غزة لاستخدامها لأغراض الزراعة

كان ينظر في الماضي لحمأة الصرف الصحي كنوع من النفايات الخطرة والتي قد تسبب مخاطر جسيمة على البيئة ناهيك عن العصارة التي قد تتسرب إلى المياه الجوفية مما يعمل على إمكانية تلويث المياه الجوفية. ومؤخرا أجريت العديد من الابحاث العلمية التي جعلت من هذه الحماة مصدرا اضافيا للسماد المستخدم في الزراعة.

الهدف من هذه الدراسة تقييم إمكانية استخدام الحمأة المنتجة من محطات معالجة مياه الصرف الصحي في غزة كسماد زراعي. تم جمع الحمأة من محطة غزة لمعالجة المياه العادمة (GWWTP)، من كلا الأحواض الابتدائية والثانوية. الحمأة المستخدمة في التجربة هي المتراكمة لفترة من الوقت لما يزيد عن ستة أشهر، قبل الاستخدام، مرت الحمأة على عدة خطوات مثل التجفيف في ضوء الشمس، والغربلة والطحن. أظهرت النتائج أن الحمأة يمكن أن تكون مصدرا قيما إذا ما استخدمت كسماد ومحسنا للتربة، ويمكنها أيضا تزويد التربة بكل المغذيات اللازمة لنمو النبات، حيث أظهرت نتائج المغذيات أن متوسط تركيز TKN كان 5440 ملغ/كغ ومتوسط NH4-N 3594 ملغ/كغ ومتوسط125 NO3-N مغ/كغ، وهي نسبة عالية من النيتروجين، وتعتبر من المغذيات الضرورية للنبات. وايضا يعتبر كلا من البوتاسيوم والفوسفور من المواد الغذائية الأساسية للنبات بمتوسط 525 ملغ/كغ و213 ملغم/كغم على التوالي، وتعتبر هذه القيم ضمن النطاق المسموح به من قيمة الأسمدة من الحمأة المعدة للاستخدام الزراعي. وأيضا يعتبر التركيز الكلي من الكروم، الزنك والنحاس والرصاص والكادميوم ضمن المعايير الإقليمية والدولية للاستخدام الزراعي.

كلمات مفتاحية:
حمأة الصرف الصحي،
محطة غزة لمعالجة مياه الصرف الصحي،
المغذيات الصغرى والكبرى،
والأسمدة الزراعية.