International Journal of Environmental Studies and Researches (2023), 2(1):28-44

The Potential Reuse of Sewage Sludge for Agriculture Purposes (Case Study: North Gaza Emergency Sewage Treatment Plant (NGEST))

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Abstract

This study revealed a possible application for sewage sludge that had been shielded from the emergency sewage treatment facility in north Gaza (North Gaza Emergency Sewage Treatment Plant (NGEST)) for agricultural purposes and studied its effect on plant growth and soil properties. The sludge was dried in sunlight, and the plant tissues were cleaned and ground to an appropriate size. The results of the analysis showed that sludge can be used as soil fertilizer and can add nutrients for plant growth. The parameters were tested as pH, Electrical conductivity (EC), Total Dissolved Solids (TDS), faecal coliforms (FC), organic matter (O.M), nitrogen (N), phosphorus (P), chloride (CI), ammonia N, *E. coli*, faecal streptococcus, *salmonella*, total coliforms, Sodium Adsorption Ratio (SAR), magnesium, sodium chloride, and potassium. A practical experiment was conducted using agricultural containers to grow corn. Five treatments (0, 10,20, 25, 30% sludge) were used. Each experiment has three replicates. Finally, sludge-amended soil affects corn growth. The best treatment was when sludge was amended with the soil at a rate of 25% of the dry weight of the soil.

Keywords: Sewage Sludge, Partial use, Improvement, Soil, Agricultural soil

Introduction

The Gaza Strip (GS) is situated on the Mediterranean Sea coast in the southwest of the ancient Palestinian territory. It also shares a border with Egypt to the south. It has a 40 km seaside at the Mediterranean Sea with fine weather conditions. GS includes a total area of 365 square kilometers. Moreover, 2,166,269 people are living there **(Palestinian Central Bureau of Statistics, 2022)**. Safe disposal of human waste is essential to prevent the spread of fecal-oral diseases. Large population centers such as the GS (**Rafah, Khan Unis, Gaza City, Jabalya**) are particularly at risk to public health **(Ashour et al., 2009).** In some locations of the Gaza Strip, the amount of chloride in the water can reach over 2000 mg/L., and nitrate reaches (300 mg/L), due to pollution caused by wastewater intrusion and agricultural pesticides. However, the permissible percentage, according to the World Health Organization, is (250 mg/L) Cl, and (40 mg/L) NO^{3-} **(Qrenawi, and Shomar, 2020).** Sewage sludge (also known as bio solids) is the semi-solid residue left over after treating wastewater from industries or municipalities **(Kumar and Chopra, 2016**). SS, or sewage sludge, is a waste product of processing sewage from homes and other buildings, which may also include effluents from businesses and industries (**Williams, 2005**). **Table 1** shows what we should anticipate in terms of sludge production, sewage production, and population density in the year 2025.

The findings show that sludge is high in useful nutrients like nitrogen and phosphorus and low in harmful elements. Dry solids in the sludge are expected to be between 1-2 percent (**Nassar et al., 2006**). Samples of sewage sludge were retrieved from the Gaza Wastewater Treatment Plant, and their physical and chemical properties were investigated. The sludge was air-dried before being sieved to a particle size of 2 millimetres. A variety of sludge properties, including density, particle distribution, water holding capacity, void volume, pH, and conductivity, were determined by mathematical modelling. Although the bulk density is about 1.18 g/cm^3, the findings reveal that the real density is 2.12 g/cm^3 and the void volume is 50%. The grain size distribution shows that the most abundant sludge size was sand-like (630-200 m), followed by tiny silt-like (200-20 m) and the clay-like volume that does not surpass 20 m. The electrical conductivity of sludge is 2.49 ± 0.04 mS cm^1 and its pH is 6.78 ± 0.02. **(El-Nahhal et al., 2014).** The researchers studied the physico-chemical analysis to show that the sludge will be an effective tool if used as a compost or soil optimizer. Moreover, this may supply all the macro- and micronutrients required for plant development. The concentration of chromium (Cr), zinc (Zn), copper (Cu), lead (Pb), and cadmium (Cd) is less than the maximum allowed level according to international standards **(Meghari and Omar, 2017).** According to a study on farmers' attitudes about the usage of sludge in the targeted area, the local output of fertilizer within this geographic region is 66,800 m^3/year, which represents just 8.5% of the specified quantities. This implies that farmers must import 728,000 m^3 of fertilizer annually, at a cost of almost 10.2 million US dollars. The social survey conducted among nearly 300 farmers in Gaza demonstrate how the high cost and lack of availability of organic fertilizers may encourage farmers to use treated sewage rather than bringing in organic fertilizers. If sludge is managed properly and has positive outcomes, farmers who have never used it are willing to do so. If sludge is composted with domestically made and imported compost, it will also be used as a soil conditioner **(Nassar et al., 2009).** Most contaminants' concentrations in sewage sludge were discovered to be below the acceptable level. Surfactant and Toluene concentrations were higher than the standard values **(Schnaak et al., 1997).** Due to the potential for recycling vital components including organic matter, N, P, and other plant nutrients, sewage sludge application to the soil is growing in popularity (**Delgado, 2014).** Farmland may not require commercial fertilizers if sewage sludge is applied to the soil since it allows for nutrient recycling **(Sommers, 1977).** Sludges are organic fertilizers, therefore over time, the soil's fertility increased **(Archie and Smith, 1981).** However, and it is unwise to amend sludge. It may affect the soil's characteristics, particularly if it contains significant levels of metals and harmful substances. The amount of accessible P in the soil was enhanced due to ongoing sewage sludge (SS)applications. It was confirmed that compared to soil that received simply mineral fertilizer, there was an increase of almost 100%, even in soil that had a lower amount of SS (50 Mg ha^{-1}). Tropical climate soils typically have limited P avail-ability for plants **(Teles et al., 2017).** Despite the ongoing use of SS in tropical agriculture for ten years, the studied biogeochemical variables responded similarly to the planted areas with mineral fertilizers. In this study, a set of biogeochemical characteristics are used to evaluate how agricultural practices affect the environmental areas because these factors alone can produce results that are challenging to interpret. The alterations brought on due to SS use in agriculture were effectively assessed by the biogeochemical parameters utilized in this paper. According to the agronomic study, the SS was effective at sup-plying the corn crop with total P, partial N, and micronutrients **(Melo et al., 2018).** Previous data and researches on sewage sludge in the Gaza Strip are very limited. Therefore, this study aimed to determine the feasibility of using sludge in soil, assess its impact on plants, and determine the optimal percentage of sludge to add to the soil and use as an alternative source of fertilizer where possible.

Materials and methods

Sludge preparation: A study area

The source of the sludge is the North Gaza sewage treatment facility **(Fig. 1 and 2).** The samples were taken from the sludge accumulated in the store located in the east of the treatment plant.

Fig. 1. NGEST.

Fig. 2. Drying beds of sludge at NGEST.

Analytical methods

The sludge used in this experiment was hand ground, air dried, and cleaned of contaminants and stones. It then went through a 2 mm filter. From each container, soil samples were gathered at the beginning of the experiment. While, sludge ratios were introduced for each experiment. Physical, biological, and chemical characteristics of the sludge were inspected before the experiment as (pH, EC, TDS, Chloride, Sodium, Potassium, Magnesium & Calcium, SAR, Total Coli-form, Fecal Coliform, *E. coli.*, *Salmonella,* Fecal Strept., Ammonia N, P, N, Dry matter and O.M) and Heavy metals as (Zinc, Iron, lead, Copper, Chromium, and Cobalt). Then (mixtures of soil with sludge in different proportions) were examined through the length of the plants and the amounts of (pH, Bulk density, Particle density, sodium, potassium, calcium and magnesium, and chloride) added to the soil were calculated. The tests were compared with parameters analyzed for soil and sludge. Values are given as the mean ± standard deviation (n = 3).

Experimental setup

Experiment was conducted on a farm owned by the Al-Attar family located in Beitlahia in the northern Gaza Strip and the soil used in the project was from the land on which the experiment was conducted. Random samples were taken from the soil at a depth of 30 cm. The seeds were planted in the soil and transferred to the agricultural basins to experiment. The sludge source was taken from the NGEST. The sludge was treated by drying using sunlight to reach the appropriate quality. The dried sludge samples were mixed once again after being sieved through a 2 mm sieve. To ensure sludge homogeneity and corn seed was obtained based on the recommendations of the farmer and owner of the land. Corn seeds are shown in **(Fig. 7).** The corn was planted by hand using three seeds per hole in April 2022, then after the growth of these seeds.

Experimental design

Ones were selected for study by looking at and comparing the plants. Planting the crop was carried out using locally produced plastic, 15 containers are needed to cover the experiments and to repeat the experimental part. The pots were filled with the intended amount of sludge/soil mixtures as designed in **(Table 1**). Corn was grown in pots with a capacity of 20 liters, and the first experiment was soil without sludge, and sludge was added to the soil by 10, 20, 25 and 30%, and each experiment had three replicates **(Table 2).**

Table 1. Sewage sludge and wastewater quantities within the GS by 2025.

	Northern Area	Gaza and Middle Area	Khan Younis and Rafah	Total
Population	318,892	1,385,860	1,205,676	2,910,428
Wastewater m^3/d	35,716	155,216	135,036	325,968
Sludge kg dry solids/day	6,107	26,542	23,091	55,740

Source: Assessment of current and future SS characterization in the GS **(Nassar and Afifi, 2006).**

Statistical analysis

Using Excel, the data was statistically examined, and use three repetitions of each sample were used to compute the mean, standard deviation, and T-test. The significant differences are those with P-values less than 0.05.

Table 2. Experimental design.

Trial	The percentage of sludge to the total volume	Number of Repetitions
T1	0% of sludge (Control)	3
T2	10%	3
T3	20%	3
T4	25%	3
T5	30%	3

Results And Discussion

To evaluate sludge, three NGEST samples were taken from more than one site in the sludge storage location. Parameters such as (pH, EC, TDS, FC, O.M, N, P, ammonia N, *E. coli*, *salmonella*, faecal coliforms, faecalstrept, total coliforms, SAR, magnesium and calcium, sodium, chloride, and potassium). The Table below summarizes the overall results for the mean of the samples test as seen in **(Table 3).**

It is clear that, in general, the sludge sample tested is viable and usable by comparison with typical values and with sludge samples used globally. The results correspond with Fytili, according to stabilization methods, dewatered sewage sludge (dry) typically contains 50–70% organic matter, (30–50%) mineral components including (1-4%) inorganic carbon, (3.4–4% N), (0.5-2.5% P), and significant amounts of other nutrients, including micronutrients **(Fytili and Zabaniotou, 2008) and (Samolada and Zabaniotou, 2014).**

Distribution of the particles in size of the Sludge sample

Particle size distributions in the sludge samples were calculated using the hydrometer technique. The ratio of particles between 630 and 200 nm is the largest at 85.0 percent, followed by the ratio of particles between 20 and 630 nm at 11.0 percent, and finally the ratio of particles less than 20 nm at 30.0 percent (4 percent). Based on the data, it seems that the sludge's constituent pieces are interconnected to grow to enormous sizes when compared to most other particles. One possible explanation for the outcome is that particles of gigantic size are really sand-sized. The hypothesis that the big-size fraction is made up of small-size particles that agglomerate in cementing ingredients to make them stable despite fractionation provides an explanation for these results. The provided findings are in agreement with **(Verawaty et al., 2013).** It looked at how granules evolved in aerobic granular sludge systems and discovered that they did settle into a similar critical size somewhere between 600 and 800 m **(Fig. 3).**

Table 3. Properties of sludge from NGEST.

NO	Analysis	Result
1	pH	6.8
2	Electrical conductivity (EC)ms/cm	6.8
3	Total Dissolved Solids mg/l as TDS	4350
4	Chloride meq/l as Cl-	140
6	Sodium meq/l as Na+	80
7	Potassium mg/l as K+	1580
8	Magnesium + Calcium meq/l as Ca+2 +Mg+2	80.5
9	Sodium Adsorption Ratio (SAR)	35
10	Total Coliform	1x104
11	Fecal Coliform	3x103
12	*E. coli*.	Neg
13	*Salmonella*	Neg
14	Fecal Strept.	2x104
15	Ammonia N mg/kg	7100
16	Phosphorus (P) mg/kg	13500
17	Nitrogen (N) mg/kg	8850
18	Dry matter %	12.1
19	Organic matter (O.M) %	51

Note: The results are based on the dry weight and the test is based on Palestinian Technical Instructions 2015-59 composting sludge intended for agricultural use.

Concentrations of sodium

At the studied quantities, there is a curve in the relationship between the amounts of sludge injected and the sodium concentrations **(Fig. 4).**

The relationship curve between the amounts of sludge injected and the sodium concentrations shown in **Fig. 4** isn't a linear relationship.

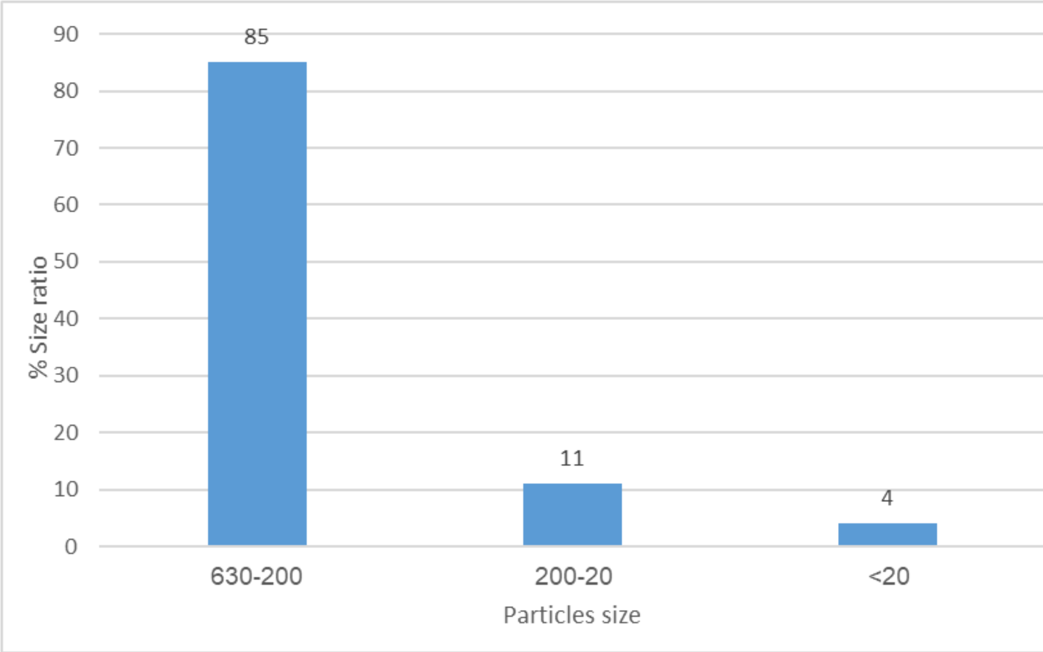

Fig. 3. Distribution of sludge samples' particle sizes.

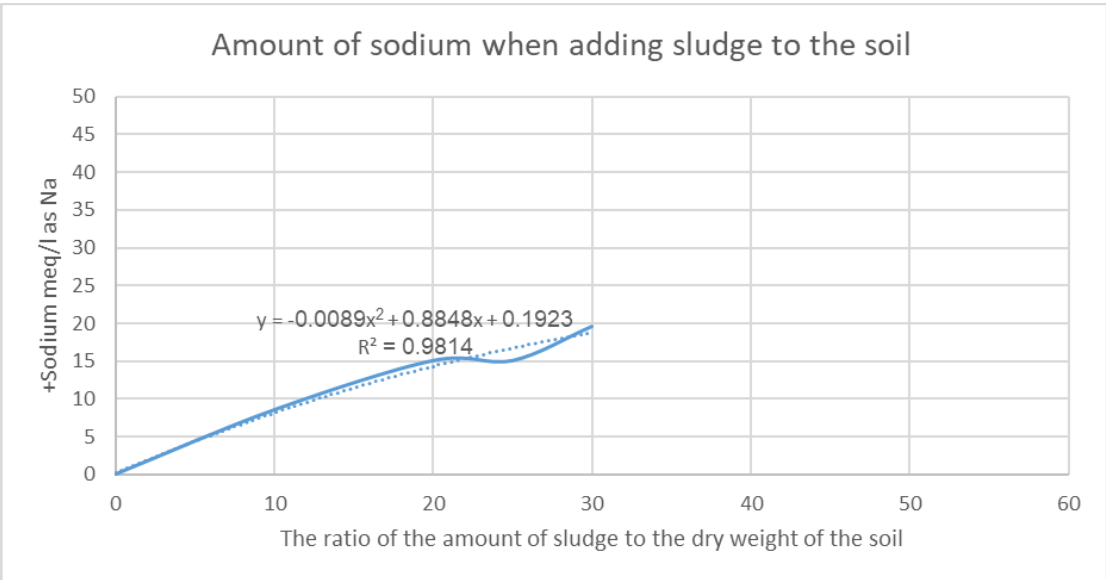

Fig. 4. The relationship between the amounts of sludge added and sodium.

Rather, it is a relationship of the second degree, and it is considered the best trend line and can be predicted for the amounts of sodium (Sodium meq/l as Na^+) expected to be added to the soil when adding sludge through the existing graph or equation that is accurate (because the coefficient of determination R= 98%). The various salts, of which sodium is more common, participate in the salinity, and high levels of sludge also participate in the salt accumulation. The sludge contains quantities of absorbable sodium, but it does not necessarily have to be high in total salts. It is said that sodium is high when the percentage of exchanged sodium is more than 15%, and sodium is considered harmful when the amount of exchangeable sodium is about 5%, and this is the highest level of sodium, and alkaline soils are harmful to plants.

Concentrations of potassium

At the studied quantities, there is a curve in the relationship between the amounts of sludge injected and the potassium concentrations **(Fig. 5).**

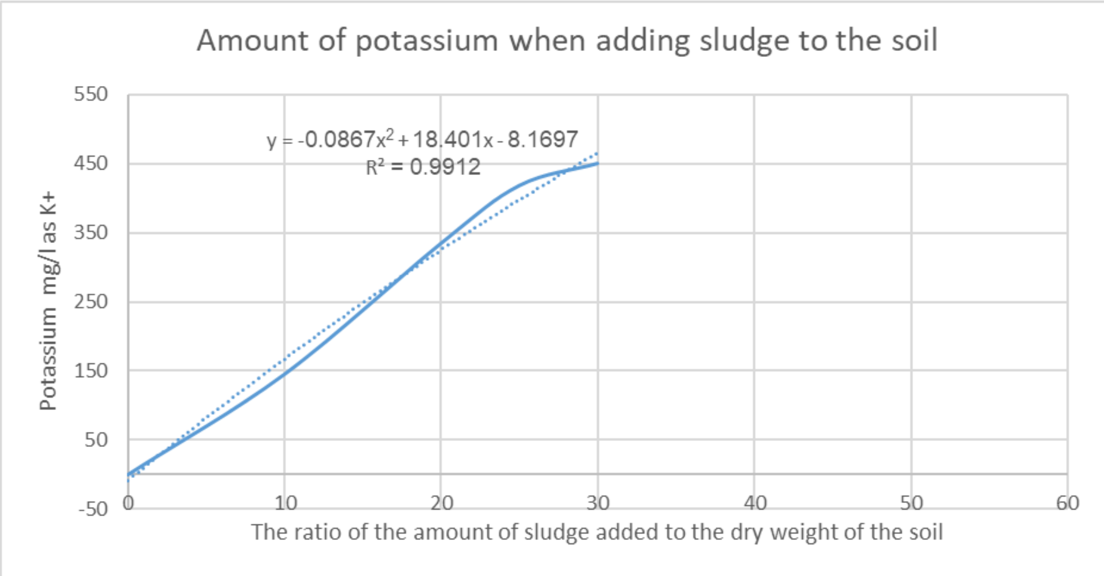

Fig. 5. The relationship between the amounts of sludge added and Potassium.

The relationship curve between the amounts of sludge injected and the potassium concentrations shown in **Fig. 5** isn't a linear relationship. Rather, it is a relationship of the second degree, and it is considered the best trend line and can be predicted for the amounts of potassium (potassium mg/l as K^+) expected to be added to the soil when adding sludge through the existing graph or equation that is accurate (because the coefficient of determination R= 99%. Because it is absorbed by plants more readily than any other element and because it is the major cation in plants, potassium is a crucial and significant element for soil and plants. Luxury spending like other elements, potassium does not penetrate the chemical makeup of plants; instead, it exists as an inorganic salt as well as a potassium salt of organic acids. Potassium is essential for the movement of protein and glucose throughout the plant, and it has an impact on how well carbohydrates are stored in the storage organs.

Concentrations of calcium and magnesium

At the studied quantities, there is a curve in the relationship between the amounts of sludge and the calcium and magnesium concentrations **(Fig. 6).**

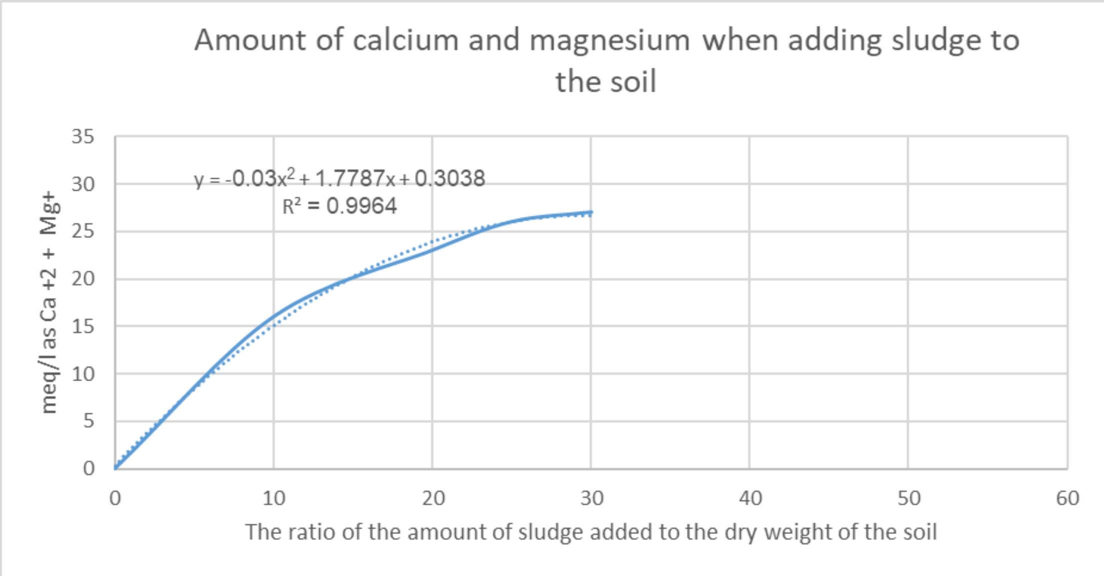

Fig. 6. The relationship between the amounts of sludge added and calcium and magnesium.

The relationship curve between the amounts of sludge injected and the calcium and magnesium concentrations shown in **Fig. 6** isn't a linear relationship. Rather, it is a relationship of the second degree, and it is considered the best trend line and can be predicted for the amounts of calcium and magnesium (meq/l as Ca^{+2} & Mg^{+2}) expected to be added to the soil when adding sludge through the existing graph or equation that is accurate (because the coefficient of determination R= 99%. Magnesium is a crucial component of photo-synthesis because it creates the core atom of chlorophyll. Without enough magnesium, a plant would start to extract chlorophyll from decomposing leaves. The pallor of the leaves, or yellowing be-tween the veins of the leaves, with the veins maintaining their green color, results from this, giving the leaves a marbled appearance.

Calcium is an important factor in plant growth. It is one of the essential secondary fertilizer components that is crucial for both soil and plant nutrition. It is a stationary component within the plant. The plant obtains the calcium it needs from soil rocks, sludge, or fertilizers.

Heavy metals in sludge

It is clear in **Table 4** that the (Zn) value in the sample of sludge (630.5 mg/kg). This value is in accordance with the standards (Palestinian, EU, US) the maximum permissible limit respectively (2500, 1222, 1740) and (Fe) value in the sludge (10741 mg/kg). No maximum value in standards (Palestinian, European, American) to be compared. And the (pb) value in the sludge (62.55 mg/kg). This value is in accordance with the standards (Palestinian, EU, US) the maximum permissible limit respectively (300, 124, 500). And the (Cu) value in the sludge (125.15 mg/kg). This value is in accordance with the standards (Palestinian, EU, US) the maximum permissible limit respectively (1000, 337, 850). And the (Cr) value in the sludge (53.65 mg/kg). This value is in accordance with the standards (Palestinian, EU, US) the maximum permissible limit respectively (500, 141, 890). And (Co) value in the sludge

Table 4. Heavy metals of sludge.

Element	mg/Kg	Palestinian Standard (mg/kg) ds	EU (mg/kg) ds	US (mg/kg) ds
Zinc mg/Kg as Zn	630.5	2500	1222	1740
Iron mg/Kg as Fe	10741	-	-	-
lead mg/Kg as pb	62.55	300	124	500
Copper mg/Kg as Cu	125.15	1000	337	850
Chromium mg/Kg as Cr	53.65	500	141	890
Cobalt mg/Kg as Co	3.65	-	-	-

Source: (Water Authority and Environmental Quality).

(3.65mg/kg) No maximum value in standards (Palestinian, European, American) to be compared.

All organisms in the food chain, from microorganisms to plants and animals and ultimately humans, are impacted by heavy metals that enter the environment. Heavy metals are especially harmful since they tend to accumulate underground, there are two categories of heavy metals. In the first category, elements like cadmium, lead, and mercury pose a significant threat to human and animal health while posing less of a threat to plant life. The second group of metals, including copper, zinc, and nickel, are more harmful to plants than they are to animals and humans when present in excess. Heavy metal pollution has far-reaching consequences, including alterations to the food web, plant toxicity, and groundwater contamination. Heavy metals decrease soil fertility, impede soil enzymatic activity, and alter soil pH when the allowable concentration level is surpassed. Sewage sludge can be treated chemically or biologically to eliminate heavy metals **(Latosińska et al., 2021).**

We can conclude that the results of heavy metal concentrations in the sludge were below the maximum allowable value for agricultural use. It can be used without causing any future environmental damage based on the value in the table, which has been compared with international and Palestinian standards.

The results are consistent with Kumar in study's conclusion that sewage sludge, or biosolids, generally varies in features and contains pathogens, hazardous metals, and organic and inorganic compounds. Due to its extensive use in nutrient supply, energy generation, soil amendment, and other processes, it is frequently regarded as a resource. Anaerobic digestion is used to extract the wastewater from the sewage sludge, which contains about 1% wastewater when it enters the sewage treatment facility for treatment. After mechanical drying, sewage sludge has around 80% moisture and 20% dry matter at the production vent. Diverse organic and inorganic components, as well as trace amounts of heavy metals like iron (Fe), chromium (Cr), manganese (Mn), zinc (Zn), mercury (Hg), lead (Pb), nickel (Ni), cadmium (Cd), and copper (Cu), among others, can be found in sewage sludge. These factors limit the use of sludge in agriculture since their buildup harms the ecosystem and the food chain in particular **(Kumar & Chopra, 2012; Kumar & Chopra, 2016).**

The results are consistent with Nassar in the investigations reveal that sludge is rich in nutrients like nitrogen and phosphorus and practically free of heavy metals **(Nassar & Afifi, 2006).**

Heavy metals such as Fe, Zn, Cd, Cu, Ni, and Pb were found in higher concentrations in sewage sludge, according to research by **Alcantara et al. (2009).** Cd, Cr, Cu, Fe, Pb, and Zn were all found in higher concentrations in sewage sludge, correlating with previous research by **Kumar and Chopra (2014).**

In agreement with our study, heavy metal leaching from sewage sludge and compost is consistently below a particular threshold, according to **Jin et al. (2014),** and found that the concentrations of As, Cr, Pb, Cu, Ni, and Zn in sewage sludge were less than 4% of their total content. **Qi et al. (2011),** found that dewatered sludge had much higher leach abilities of As, Cr, Pb, Ni, and Zn than soil. Total Zn concentration was elevated in sewage sludge without becoming unsafe for human consumption. Sewage sludge was found to increase soil concentrations of nutrients and heavy metals including Cd, Cr, Cu, Mn, and Zn by a statistically significant difference. Metal levels were found to be well below those allowed in soil **(Kumar et al., 2016),** and this was in line with our results.

Effect of Sludge/soil mix on the Growth of Corn

Table 5, Fig. 7 and 8 shows the application of sludge to the field experiment and its graphic representation.

Table 5. Average height of plants compared to the ratio of sludge to soil.

The percentage of sludge to dry weight of soil	Average corn height
0	120±6.5
10	127±7.5
20	134±11.9
25	147±8.9
30	136±3.1

Fig. 7. Growth of corn plants during the experiment.

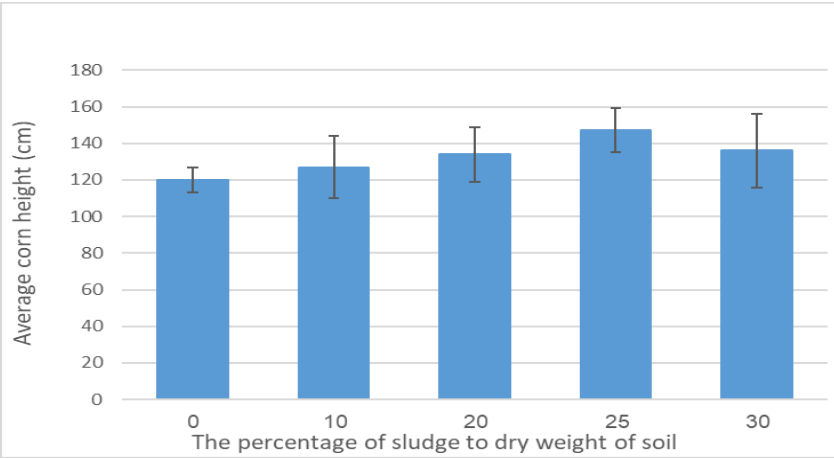

Fig. 8. Average height of plants compared to the ratio of sludge to soil.

The addition of sludge in different proportions enhanced the growth of corn plants. But the percentage of sludge (10 and 20%) increased the percentage of (EC, Total Coliform, and Cl) and this negatively affects the growth of plants, but in re-turn, a percentage of nutrients phosphorous, potassium, sodium, calcium, and magnesium were added to the soil. But the added percentage (10 and 20%) was useless compared to the percentage of adding sludge by 25% because it added (greater quantities of nutrients to phosphorus, potassium, sodium, calcium, and magnesium compared to the percentage of additive EC, Total Coliform and Cl), which had a positive impact on plants.

It is clear that the percentage of sludge (30%) increased the percentage of (EC, Total Coliform, and Cl) and this negatively affects the growth of plants, but in return, the highest value was added to the percentages approved in the experiment of nutrients phosphorus, potassium, sodium, calcium, and magnesium. However, the amounts of (EC, Total Coliform, and Cl) increased, which led to the ineffectiveness of the quantities of nutrients com-pared to the amounts of inhibitors. Statistically, the results were 25%, and the increase in the height of corn plants was greater. While the growth rate of corn has slowed only by 30%. As can be seen, the maximum application rate (30%) did not result in a high level of production while the treatment (25%) produced the corn with the highest average length-height (cm), which was 145 cm, and statistical analysis shows that the null theory is incorrect by analyzing the data of a standard sample with a 25% sample. While the result of statistical analysis is that the null theory is correct by analyzing the data of the normative sample with a 10- 20- 30% sample.

Statistical analysis results

Each sample was tested and compared to the average; the results showed that there is no statistical difference in the addition of sludge to the soil except in the addition of 25% of the sludge.

The results of the statistical analysis of 25% of the sample.

The result of the analysis for the 25% sample was compared with the control sample. Seen the **(Table 6).**

The T-test tested the average corn height for the control sample with the average corn height sample (25%) sludge; the results were as follows (the mean of corn height for the control sample and corn height sample (25%) sludge the value respectively (145.3, 119) and the variance of corn height for control sample and corn height sample (25%) sludge the value respectively (122.33, 57) and the number of observations in two samples (2) and the Pearson correlation (0.508) and the (Hypothesized Mean Difference =0) and the degree of freedom (n-1=2 and the T-test (t Stat= 4.69) > (t Critical two-tail =4.3) and the (P(T<=t) two-tail = 0.042) < (P-values =0.05), this means that there is statistical significance.This means that there is a difference between the height averages of corn plants for the control sample compared to that sample of 25% sludge. This indicates that there is a feasibility to using 25% of sludge because it affects the height of corn plants significantly.

This indicates that higher amounts of nutrients were obtained in the soil compared to the original soil and that the added sludge affected the soil by increasing the EC ratio, increasing the amount of TDS, increasing the amount of Cl, increasing the SAR ratio, and increasing the amount of Total coli-form, Faecal coliform, and Faecal Strept. This negatively affects the soil and plants' growth, but the amount of added nutrients is greater than the amounts of added inhibitors, which led to an in-crease in the height of plants and the feasibility of adding sludge by 25%.

The optimum Sludge/soil Mixture

The optimum ratio of the sludge/soil mixture was 25% according to the results of plant formation and chemical, physical, and biological examinations. So this study focused on this

Table 6. NGEST T test for control sample with sample (25%).

t-Test: Paired Two Sample for Means		
	25	0
Mean	145.3333	119
Variance	122.3333	57
Observations	3	3
Pearson Correlation	0.508954	
Hypothesized Mean Difference	0	
Df	2	
t Stat	4.696062	
P(T<=t) one-tail	0.021238	
t Critical one-tail	2.919985	
P(T<=t) two-tail	0.042476	
t Critical two-tail	4.302652	

ratio to assess the impact of sludge use on the chemical and physical characteristics of soil in parallel with the soil 0% were studied as control samples. The only percentage (25% of the sludge), which was the result of the statistical analysis of the data, was that there was a statistical significance for the average height of corn plants compared to the control sample. It was observed that the increase in weight is directly proportional to 25% of the sludge/soil mixture, and this could be due to the nutrients present in the sludge **(Bozkurt and Yarilgaç, 2003).** Then a decrease in weight was observed, and it could be due to the higher salinity present in sludge

The Ben M'hidi University Center ran a green-house pot experiment in 2002–2003 to investigate the results of various SS concentrations on the soil characteristics and yield of the Jaidor variety of barley **(Boudjabi et al., 2008).** The treatments included 20, 40, and 60 t ha^1 of sewage sludge as organic fertilizer, 35 and 70 kg/ ha of urea as mineral fertilizer, and a check (without fertilization). The outcomes demonstrated that at the application rate of 40 t /ha of sewage sludge, the crop's reaction to the majority of variables was extremely effectively represented **(Boudjabi et al., 2008).** Sludge increases biological activity in the soil and contains a high amount of organic matter that can help preserve soil organic matter **(Stamatiadis et al., 1999).** Sludge application thereby enhances soil quality as a substrate for plant growth and reduces soil erosion .Plant productivity is increased by adding SS to the soil.

The crop's aboveground biomass is significantly affected by the SS. It is therefore appropriate to use it to produce fodder crops. The physical, chemical and biological aspects of the soil are also positively impacted by the SS. It supplies macro- and microelements to the soil, which enhances the structure and water holding ability of the soil and meets the needs of various crops **(Boudjabi et al., 2008).**

Conclusion

Based on the results of this research, sludge can be considered a suitable alternative to soil fertilizers, because it does not change the main characteristics of soil but improves soil properties. Sludge adds to the soil quantities of phosphorous, potassium, sodium, and many other elements. In our experiment, it was the optimal amount of sludge that positively affects plant growth. When the sludge was added at 25% of the soil's dry weight, the concentrations of the elements that were examined in the sludge were less than the maximum allowable according to the Palestinian and international standards for agricultural use.

Acknowledgment

The authors wish to thank Innovation Initiative Research Grant Program 2022 for funding and supporting the research project (MEDRC project No.: 22-IN-05).

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