

STABILIZATION OF SLUDGE IN ZAKHO MUNICIPAL WASTEWATER BY ANAEROBIC DIGESTION FOR BIOGAS PRODUCTION IN KURDISTAN REGION, IRAQ.

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ABSTRACT:

Raw wastewater sludge samples were collected from two sanitary point sources in Zakho city wastewater pipes. Anaerobic digestion is utilized sludge stabilization as it was effective in reducing the volume of sludge and cheap source of clean biogas. The sludge of municipal wastewater of Zakho district is worth to be used for the generation of biogas and just 15–17 kg sludge produced 233 to 350 m³ gas in solid retention time of 18 and 24 day respectively. Suspended solid is close related to the amount of COD that removed from sludge and approximately 1 kg COD generate 0.5–0.55 Kg suspended solid in the water. Volatile solid (VS) /total solid (TS) ratio is 0.46 after anaerobic digestion which locate in the range of anaerobic lagoon stabilization. Anaerobic digestion lead to reduction in total solid of wastewater especially organic or volatile suspended solid. Specific gravity of the sludge solid is 1.5 which indicate that the sludge is stabilized by anaerobic digestion. Sludge volume index (SVI) indicate that the settleable biosolids are old, good quality and low turbidity. Sludge density index (SDI) increased from 1.83 to 2.9 ml/g after stabilization by anaerobic digestion. CO₂ and H₂S are reduced to zero after stabilization by anaerobic digestion. Nutrients N, P, Ca, Mg, Cl are elevated significantly in final stabilized sludge to be used as organic fertilizer, except sulfate is decreased to acceptable ranges after stabilization.

KEYWORDS: Sludge Stabilization, Biogas, Solids, Nutrients, Sludge density index SDI, Sludge volume index SVI.

1. INTRODUCTION

As the world consumption for renewable power and organic substances grow, organic wastes such as wastewater sludge could become one of the accessible supplies (Zhang, Hu et al. 2017). During the treatment of wastewater, products of latrine, and sludge, and bio solids are produced. sewage sludge contains treated wastewater as a residue (Koné 2010). It contains inorganic and organic substances, nutrients, and pathogenic microbes (Siebielska 2014). Untreated sludge should not be disposed of directly since it has odors, it mostly water, making transportation and disposal costly, and includes dangerous environmental contaminants and diseases (Johnson and Affam 2019).

Sludge processing is a key aspect of water resources recovery facilities (WRRF), with the goal of minimizing volume and odors as well as removing pathogens to render bio-solids (the ultimate product) reusable and /or disposable (Flores-Alsina, Ramin et al. 2021). Sludge processing railroads are comprised of a number of unit processes, including treatment, thickening dewatering, and reuse water handling (Metcalf, Tchobanoglous et al. 2013). The first treatment process is pre-treatment including (enzymatic hydrolysis and/or thermal, pasteurization), and the second is central part of the treatment process are chemical stabilization, biological stabilization anaerobic & aerobic digestion and composting (Feldman, Flores-Alsina et al. 2018), and the final stage is post-treatment stages include drying, gasification, conditioning, and incineration (Andreoli, Von Sperling et al. 2007).

Throughout stabilization processes used, the thermal chemical and biological techniques to reduce the unpleasant odors, organic matter, water content, and decrease the pathogen. Dewatering and thickening can decrease size and increase the total solids concentration (Makisha and Semenova 2018). Subsequent to stabilization, thickening is conducted, and dewatering is the final step of reduction of the volume before

ultimate disposition of stabilized sludge, mechanical process and bed drying (Kacprzak, Neczaj et al. 2017).

With existing and development technologies, sludge can be exploited as a source heat and energy (Kiselev, Magaril et al. 2019). Anaerobic stabilization, which entails the breakdown of organic material by a reaction process under absent oxygen condition, is one of the most conventional methods for sludge stabilization (Hanum, Yuan et al. 2019). Water (H₂O), methane (CH₄), Carbon dioxide (CO₂), The products of several bacteria's reactions during anaerobic digestion (Ghosh, Kumar et al. 2020). There are four biochemical stages to this process: hydrolysis, acetogenesis, fermentation, as well as methanogenesis: hydrolysis, acetogenesis, fermentation, as well as methanogenesis (Vanwonterghem, Jensen et al. 2014).

Sludge from wastewater is a great source of biogas and can be treated anaerobically to be used as a renewable energy resource (Petinrin and Shaaban 2015). Various types of sludge are generated from different treatment facilities in wastewater treatment plant (WWTP) (Wang, Feng et al. 2016). Primary sludge is made up of settleable solids that have been eliminated from raw wastewater during the primary sedimentation process (Herrera Melian 2020). Secondary sludge, also known as activated sludge, is produced by biological processes like the biological nutrient remover reactor or the microbe's system (Foladori, Andreottola et al. 2010). Primary sludge production is proportional to the quantity of settleable solids in untreated or raw wastewater, with 50–65 percent of these solids expected to settle and create primary sludge (Turovskiy and Mathai 2006). So the aim of this paper is to evaluate the efficiency of anaerobic digestion in stabilizing sewage sludge and to produce biogas (CH₄) and using as biofuel.

2. MATERIAL AND METHOD

2.1 Description Study area

Zakho is border town between Iraq and Turkey, where a huge border complex was constructed in Ibrahim Khalil, which is a suburb north to Zakho. Zakho district is located between 37° 22' to

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37° 00' N, 43°11' to 42°22' E in Duhok province. Kurdistan Region-Iraq.

2.2 Sampling Area and Sampling Point

Raw wastewater sludge samples were collected from two sanitary point sources in Zakho city wastewater pipes. The position of each sample was registered by using the Global positioning system (GPS), (S1) the first sludge sample was taken from Bedar municipall wastewater pipes located 37.1446' N, 42.6473' E and (S2) second sludge sample was taken from Abbasid 37.1442' N, 42.6921' E, designated as S1 and S2.

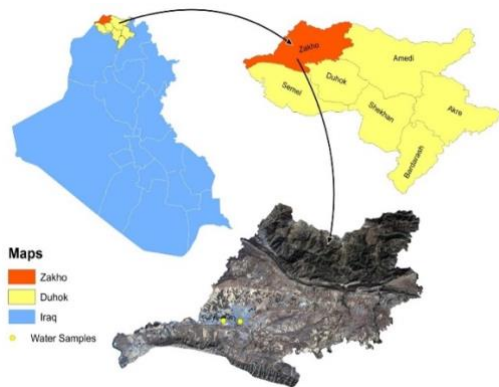


Figure 1. wastewater samples

2.3 Sample Collection method

Wastewater samples were collected from two locations (S1) and (S2) and transferred to plastic container (20 L), which precleaned thoroughly with non-ionic detergent, rinsed with tap water and after some time, soaked in 10% HNO₃, and lastly with distilled water. the samples were collected differently for biogas methane (CH₄) production and composting formation. According to Ademoroti (Ademoroti 1996), colour, pH, turbidity, conductivity, and temperature of wastewater sludge will be measured if samples revealing biodegradation characteristics. Samples were labelled cautiously, transported to the laboratory and stored at 4°C prior to analysis. Dissolved Oxygen (DO) and Biochemical oxygen demand (BOD) determined in waste water samples by using dark bottles through fixing of samples by using alkaline iodide, manganous sulphate and acidified for further steps in laboratory

2.4 Raw wastewater stabilization and biogas production

On 16 September of 2021 raw wastewater (S1) transported to laboratory, using the plastic container with a capacity of 20 L and filled up to 75% (15 L) with wastewater sludge sample under anaerobic digestion. Next, a gas measurement gage is tightly fixed to avoid gas leakage and held at temperatures 27.67 degrees Celsius to aid thermophilic bacteria in digestion and expedite the rate of biogas formation. As the gas gage rises, it indicates the formation of CH₄. On 15 October of 2021, raw wastewater sample (S2) transported to laboratory, the plastic container with a capacity of 20 ml but differently filled up the plastic bottle to 85% (17 L) with raw wastewater sludge sample and at temperature 29.45 degrees Celsius and hydraulic retention time for S1 18 days and for S2 24 days.

And the volume of gas produced is calculated from the volume of container that accumulated in as shown in figure 1.

Table 1. biogas production from wastewater sludge

Locati on	Amoun t of wastew	Tempera ture	Hydra ulic retenti on	Press ure (mbar)	Total Biogase s
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	ater sludge		time (HRT)		Product ion dm ³
Bedar	15 kg/l	27.67°C	18 day	28 mbar	232.36 dm ³
Abbas id	17 kg/l	29.45°C	24 days	34 mbar	348.54 dm ³

2.5 Analytical method

The assessment of many physicochemical and biological parameters, such as pH and Temperature Total solid (TS) (by evaporating method). Total volatile solid (TVS) where determined by igniting in muffle furnace to 550 ± 50°C. Fixed solid determined by this equation; Fixed solid= total solids – volatile solids. Total dissolved solid (TDS) was measured by filtering a specific volume of sludge by vacuum, then bring to dryness in a drying oven at 180 ± 2°C., Volatile dissolved solid (VDS) where measured by igniting the residue of TDS.

Fixed dissolved solid (FDS) determined according to this equation, Fixed dissolved solid= total dissolved solids – volatile dissolved solids. Total suspended solid (TSS) was measured by rinsing Whatman filter paper in distilled water then dried and weighted, then a specific volume of waste water filtered through this filter and dried again and the difference in filter paper wight were measured. Settleable solid measure by graduated cylinder of I L mark with thoroughly mixed wastewater sludge and allowed to settled quietly for 3 hours to be the volume settle solid.

Sludge volume index = Settleable solid in ml per liter x 1000/ Mg/l suspended solid. Sludge density index = 1/ Sludge volume index. Carbon dioxide (CO₂), Hydrogen sulphide (H₂S), Were measured according to (Brunner 1978),(Vietti 1971),(Carranzo 2012). Dissolved oxygen (DO), 50 ml of sewage water added to DO bottle, 1 ml of activated sewage sludge containing nutrient like CaCl₂, FeCl₃, MgSO₄, 1 ml of phosphate buffer (KH₂PO₄, NH₄Cl, Na₂HPO₄, K₂ HPO₄) to maintain pH=7.2 + diluted to 900 ml with distilled water and further saturated with O₂ bubbling air. 200 ml of diluted sewage water from DO bottle, 1 ml H₂SO₄, 2 ml MnSO₄, 3 ml KOH-K-Na₃, starch indicator. The dark brown color in the conical flask is due to iodine which is equivalent DO present in 200 cm³ of diluted sewage water before incubation the end point of titration is blue to colorless and recorded (V). DO = V × N × 8 × 100/ Volume of sample (ml). V =Volume of titrant sodium thiosulphate, N =Normality of titrant sodium thiosulphate.

Biological oxygen demand (BOD), all steps used for DO are used for BOD, and then incubated at 20°C for 5 days. And 5 days later 25 ml of diluted sewage water from BOD bottle, 1 ml H₂SO₄, 2 ml MnSO₄, 3 ml KOH-K-Na₃, starch indicator. The pale brown color in the conical flask is due to iodine which is equivalent DO remained in 25 cm³ of diluted sewage water after incubation the end point of titration is blue to colorless. BOD = (V1- V2) × N × 8 × D.F × 100/ Volume of sample (ml). V1= amount of DO1, V2= amount of DO5, N= Normality of titrant sodium thiosulphate. Chemical oxygen demand (COD), Determination of COD, 10 ml of the sample was taken in a reflux flask, and 5 mL of potassium dichromate solution with 1 L mercuric sulphate solution was thoroughly mixed. Antidumping beads were added to control boiling of the solution. To this, 15mL of concentrated sulphuric acid containing silver sulphate was added through the open end of the condenser carefully and mixed by swirling motion. The reflux apparatus was operated for around 1 hour and allowed to cool, added 25 ml distilled water. To the resulting solution, three drops of the ferroin indicator were added, and finally titrated with standard ferrous ammonium sulphate to an end point where blue-green colour changed to reddish-brown. Chemical oxygen demand (COD) of the blank sample was then calculated. COD = (Vb- Vs) × N × D.F × 8 × 1000/ Volume of sample (ml). Vb= volume consumed in titration with blank preparation, Vs= volume consumed in titration with sample preparation, N= normality of ferrous ammonium sulphate solution, D. F= Dilution factor, were analyzed according to(Carranzo 2012), (Mishra and Mahanty 2012).

Nitrates NO_3^- , measured nitrate by phenoldisulphonic acid method, by spectrophotometer (model: Jenway 6320D UV/Visible) spectrum spectrophotometer. The standard graph is plotted by taking concentration along X-axis and the spectrophotometric readings (absorbance) along Y-axis. The value of nitrate is found by comparing absorbance of sample with the standard curve and expressed in mg/L (Taras 1950). Sulphate (SO_4^{2-}), determined by turbidimetric method, turbidimeter (model: AL250 T-IR). The firstly prepared the Standard sulphate solution, and then prepared the sample; 100ml of the sample is filtered into a Nessler's tube containing 5ml of conditioning reagent. About 0.2g of barium chloride crystals is added with continued stirring. A working standard is prepared by taking 1ml of the standard, 5ml of conditioning reagent and made up to 100ml, to give 100 NTU. The turbidity developed by the sample and the standards are measured using a Nephelometer according to (Sharma and Kaur 2017).

Phosphate (PO_4^{3-}); analyzed by spectrophotometric method, by spectrophotometer (model: Jenway 6305 UV/Visible) spectrum spectrophotometer. prepared the stock solution and standard solution according to, 40ml of the filtered sample was pipetted into a 50-mL calibrated flask, 8 ml of mixed reagent and about 4-5 drops of stannous chloride reagent were added diluted to volume with distilled water. After about 10 min but before 12 min, the colour developed was measured photometrically at 690nm and calibration curve was prepared. A reagent blank was always run with same treatment with distilled water as sample. The value of phosphate was obtained by comparing absorbance of sample with the standard curve and expressed as mg/L (Habibah, Sri Dhyanaputri et al. 2018). Chloride (Cl^-) by titration (Mohr's method), Total hardness, Calcium hardness, and Magnesium hardness determined by EDTA method (Ojoawo and Udayakumar 2015), and Alkalinity analyzed by titration method (Jenkins, Morgan et al. 1983).

2.6 Statistical analysis

The data submitted to SPSS software (SPSS, 2019); both t-test procedures independent and paired samples for comparison between sites and within sites, respectively were used; also, the correlation between the studied characteristics (elements) were applied, in addition to descriptive statistics (George and Mallery 2019).

3. RESULTS AND DISCUSSION

The modern consumptive style of life raised the stress and increased the use of clean water for personal cleaning as well as in industrialization. Tremendous amounts of municipal waste water is created each day. This wastewater is 97% water and the remains are organic and inorganic waste that mainly accumulated in the bottom of drains and pipes as sludges. The sludge removal from wastewater considered the most important and hard tasks in water treatment. FAO organization reported that the habitants in Iraqi Kurdistan Region especially in Duhok and Zakho city probably use more water for daily consumption than the other parts of world. So huge amounts of sludge are accumulated in open drains of Zakho municipal wastewater net. Sludge is the source of bad odorous and turbidity of waste water and also make visual pollution and gives bad impression about city cleanness.

In developed countries they invest in sludge for biogas and energy producing by anaerobic digestion as the majority of waste in water is organic and can be broken down by both aerobic bacteria to carbon dioxide and to methane gas by anaerobic bacteria. According to (Arthur and Brew-Hammond 2010) higher retention time and bigger digester size will generate higher biogas levels. Anaerobic digestion is a biological process of multiple stages that end up in producing biogas that contain 60-70% methane and 30-40% CO_2 by volume and other stable solid and liquid effluents, and the solid retention time (SRT) for mesophilic digester is usually

between 15 to 30 days and the longer SRT, the more reduction in volatile solid reduction (Tchobanoglous 2014).

As indicated from Table 1 and Figure 2 the sludge of municipal wastewater of Zakho district is worth to be used for the generation of biogas and just 15 -17 kg sludge produced 233 to 350 m^3 gas in solid retention time of 18 and 24 day respectively. Anaerobic stabilization of sludge become common among the most facilities of wastewater recovery as it was effective in reducing the volume of sludge and cheap source of clean biogas around world. There are three main methods for sludge stabilization which are biological method by utilizing specific bacteria to degrade organic solids, chemical stabilization by using chemical oxidation of organic matter, and thermal stabilization by stabilizing organic fractions by heat. From these three methods the biological stabilization is most acceptable as it was the least expensive and eco-friendly practice. The part of organic solids that incorporated in the microbial biomass during degradation is called biosolids. Mesophilic anaerobic stabilization is more popular than aerobic stabilization because it is more efficient. Another advantage of anaerobic digestion is the concentration of macronutrients as nitrogen and phosphorous that can be used directly as organic fertilizer in fields and lawn or as ingredients in compost making which otherwise end up to river and water bodies to cause eutrophication.



Figure 2. collection of biogases from anaerobic digestion of sewage sludge.

Table 2 shows the positive effects of anaerobic stabilization in improving the sewage sludge parameters. According to (Sakaveli, Petala et al. 2021) total solid, volatile solid, alkalinity, COD, nitrogen of Anaerobically Digested Sludge decreased and pH and electrical conductivity of Anaerobically Digested Sludge increased. Sludge refer to the solid By-product that remain in water after treatments and comprise only 1-2% from water volume but require 20% to 60% of total cost of operating treatment system. Both biological and chemical oxygen demands are used as function of sludge production as well as indicators for the organic matter removal and stabilization of sewage sludge and both significantly reduced by anaerobic digestion.

Dissolved oxygen is not increased during stabilizations as the process is done in close anaerobic condition and microorganisms continuously consume dissolved oxygen while pH slightly increased at the end of stabilization and may be due to the total solubilization of cleaning agent as detergent and bleach that contain alkaline elements as phosphorous and sodium. Low oxygen levels are linked to a lot of organic matter pollution (Prasad, Rajput et al. 2006). Total solid of sludge refer to the undissolved solid that cannot be filtered and dissolved solid that filtered and remain after dryness and both referred as total dry residues.

Table 2. comparison between both sites.

Wastewater sludge Characteristics	Before stabilization	After stabilization
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Biological oxygen demand (BOD)	40.0 ± 7.7 mg/l	29.0 ± 4.5 mg/l
Chemical oxygen demand (COD)	2005.0 ± 1243. mg/l	742 ± 243mg/l
Dissolved oxygen (DO)	1.55 ± 0.15 mg/l	1.10 ± 0.3406 mg/l
PH	7.40 ± 0.6 mg/l	7.96 ± 0.39 mg/l
Total solid	9000.0 ± 1208. mg/l	6517± 1006 mg/l
Total dissolve solid (TDS)	6072. ± 1053 mg/l	5500 ± 1536 mg/l
Total suspended solid (TSS)	2404.0 ± 983 mg/l	1020 ± 203 mg/l
Total volatile solid (TVS)	4408 ± 669 mg/l	3000 ± 713 mg/l
Total fixed solid (TFS)	4508± 562 mg/l	3525 ± 309 mg/l
Volatile dissolved solid (VDS)	2817± 678mg/l	2141± 644 mg/l
Fixed dissolved solid (FDS)	3291± 430mg/l	2958 ± 377 mg/l
Settleable solid	129± 6 ml/l	97± 8 ml/l
Sludge volume index (SVI)	50± 10 ml/g	33± 0.3 ml/g
Sludge density index (SDI)	1.83 ± 0.7 ml/g	2.9 ± 0.2 ml/g
Carbon dioxide (CO₂)	68.0 ± 6.633 mg/l	00.00 mg/l
Hydrogen sulphide (H₂S)	15 ± 2. mg/l	00.00 mg/l
Total alkalinity	285 ± 33 mg/l	300± 35 mg/l
Chloride (Cl⁻)	86 ± 24 mg/l	282± 111 mg/l
Total hardness	190 ± 2 mg/l	210± 5 mg/l
Calcium Ca⁺²	23.400 ± 1.9738 mg/l	31± 0.4 mg/l
Magnesium Mg⁺²	31± 1.8 mg/l	48± 2 mg/l
Electrical conductivity	806 ± 47µS/cm	6445± 2472 µS/cm
Temperature	26± 2°C	23 ± 1.3°C
Nitrate NO₃⁻	30 ± 3 mg/l	38± 3 mg/l
Sulphate SO₄⁻²	337 ± 17mg/l	225 ± 17 mg/l
Phosphate PO₄⁻³	2.6 ± 0.7 mg/l	6.6 ± 3 mg/l

Both total solid and dissolved solid are reduced to three quarter of its initial weigh by anaerobic digestion as revealed from Table 2. Suspended solid is the colloidal fine fraction that remain suspending in water without being settled or flouted and close related to the amount of COD that removed from sludge and approximately 1 kg COD generate 0.5-0.55 Kg suspended solid in the water. Total solid (TS) comprises of both dissolved solid (DS) and suspended (SS) solid and each of them divided to inorganic or fixed solid (FS) and to organic or volatile solid (VS). The ratio of (VS) / (TS) serve as good indicator of the load of organic matter and the degree of digestion within the sludge. For present study (VS) / (TS) ratio is 0.46 after anaerobic digestion which locate in the range of anaerobic lagoon stabilization. The use of water for domestic purpose as well as the release of organic pollutant are much more in Abbasid quarter than Bedar quarter, so the all studied parameters is higher in Abbasid than Bedar quarter.

Anaerobic digestion lead to the reduction of total solid in wastewater especially organic or volatile suspended solid. The specific gravity of mineral or fixed solid is 2.5, whereas for organic or volatile solid is 1(Crites, Tchobanoglous et al. 2000), therefore the specific gravity of solid in sludge can be computed from this equation, specific gravity of solids = $1/(FS/TS)/2.5+(VS/TS)/1.0$. So, the specific gravity of the sludge solid can be calculated from given parameters in Table 2 and its 1.5 which indicate that the sludge is stabilized because it locates in the range of standard stabilization pond sludge values and the reduction of total volatile solid is 32%. Settleable solids are large enough in size and weight to be settled in a period of one-hour time and usually counted as a

part of suspended solid. As shown in table 2 settleable solids compose a small fraction from suspended solid and indicate that the majority of organic solids undergrows aerobic degradation in surface lateral small drains before it reaches the main drain of wastewaters.

Sludge volume index (SVI) or Mohlman index is a quotient between the volume of sludge produced in half hour in one litter and the dried weight of sludge settled and it range between 50-150 ml/g and used as quality indicator for biosolid produced(Szeląg and Gawdzik 2016). The high values of SVI indicate unstable treatment and increase of filamentous bacteria population in sludge as well as turbidity increased in treated water (Gawdzik, Szeląg et al. 2016). As indicated from Table 2 the obtained results about SVI indicate that the settleable biosolids are old with good quality and low turbidity. Sludge density index (SDI) is also used as indicator for settleable solid characteristics and how good is the separation of solid from water and the higher value of SDI, the better settling quality of biosolid and as indicated from table to SDI increased from 1.83 to 2.9 ml/g after stabilization by anaerobic digestion. Carbon dioxide which is the main causes of global warming and climate change can be reduced by treating sewage sludge with anaerobic digestion and converting the majority of evolved gas to from sludge digestion to methane that can be captured and utilized as a clean source of renewable energy(Muntau, Lebuhn et al. 2021).

As declared from table 2 the efficiency of anaerobic digestion is very effective as it reduced the emission of CO₂ to zero after stabilization the sludge by anaerobic stabilization. Hydrogen sulfide is main impurities that formed during anaerobic digestion of sewage sludge and may cause toxicity to methanogenic bacteria if sulfate content is high in raw sludge as sulfate reduction purple bacteria compete with methanogenic bacteria and reduce production of biogas. Due to the presence of sulfur-containing molecules in substrates (Adeniran, Aina et al. 2016). As table 2 shows that the production of H₂S is little and reduced to zero after stabilization by anaerobic digestion. Alkalinity is the ability of water to neutralize acids, alkalinity in anaerobic digestion may cause problems for methanogenic bacteria if it exceeds 300 mg/l as methanogenic bacteria are sensible to small change in pH and alkalinity is close related to the format volatile acid in acidogenesis stage that form organic acid that feed acetogenic bacteria (Palacios-Ruiz, Méndez-Acosta et al. 2008).

in general alkalinity reduce the creation of volatile organic acid and shorten the time of digestion of and higher methane production(Lens, Klijn et al. 2003). Fortunately, the alkalinity in present study is less than 300 mg/l as shown in table 2 to impact on the performance of methanogenic bacteria. Another beneficial effects of stabilization by anaerobic digestion is the concentration of essential macronutrients in the final stabilized sludge as nitrogen in the form of nitrate, phosphorous in the form of PO₄⁻, calcium and magnesium and essential micronutrients as chloride, sodium, iron, copper, and many others. This stabilized sludge can be used as organic fertilizer an amendment for agricultural soil deficiency of nutrients and increase in crops and vegetables yields. As shown in Table 2 all these nutrients are elevated significantly in final stabilized sludge except sulfate is decreased as its amounts is very high before anaerobic digestion and minimized to acceptable ranges after stabilization. The hardness of wastewater attributed to the presence of calcium and magnesium salts and as shown in Table 2, both Ca and Mg are in low concentration, so the hardness of wastewater is soft even before anaerobic digestion. Table 3 shows the differences between wastewater characteristics released for domestic municipal sewer in two location within the Zakho district in Bedar and Abbasid quarters.

Biological and chemical oxygen demand in Abbasid quarter is higher than in Bedar that gives an indicator of intensive organic release with waste water in this area, therefore the pH values also declined 1 unit in Abbasid than Bedar quarter as a result of intensive release of various acidic pollutants. Total solid and other parameters related with as total dissolved and suspended solid, total volatile solid, total fixed solid, fixed suspended solid, fixed dissolved solid, settleable solid, sludge volume index, and sludge density index all are recorded to be higher in Abbasid than Bedar quarter after and before

stabilization for the same intensive release of sewage sludge in this area inside Zakho district. reduction of VS, BOD, COD is used as a stand-alone indicator of digester efficiency, but it can also be included in other calculations (Meegoda, Li et al. 2018). The evolution of first greenhouse gas carbon dioxide is reduced to zero in both sides after stabilization indicating that the anaerobic digestion is effective in sludge treatment and eliminating the bad effects of carbon dioxide. As shown in table 2 alkalinity and hardness in both sites are equal before stabilization and significantly increased after stabilization as the solubility of calcium and magnesium is increased after stabilization and both alkalinity and hardness may need further

treatments if the water intended to be used for irrigation or drinking. Throughout anaerobic digestion hydrolysis takes place and organic matter, potassium, phosphate, calcium, magnesium, and sulphur are released to the bulk liquid (Mai, Kunacheva et al. 2018). Essential macronutrient as nitrate, phosphate, calcium, and magnesium are approximately equal before stabilization and significantly increased after stabilization as the organic fraction in sludge decomposed and released addition amounts of these nutrients that can be used as organic fertilizer for soil. Sulfate in both sites is high before stabilization and reduced after stabilization as it converted to hydrogen sulfide gas and liberated to the air, but remained in acceptable range sore sulfur content in sludge and organic fertilizer.

Table 3. comparison within both sites.

Wastewater sludge Characteristics	Bedar (S1)		Abbasid (S2)	
	Before stabilization	After stabilization	Before stabilization	After stabilization
Biological oxygen demand (BOD)	36± 0.6 mg/l	22 ± 0.6mg/l	44 ± 0.6 mg/l	36 ± 0.6 mg/l
Chemical oxygen demand (COD)	870 ± 6 mg/l	520 ± 6 mg/l	3140 ± 3 mg/l	963.33 ± 1.667 mg/l
Dissolved oxygen (DO)	1.6 ± 0.06 mg/l	0.8 ± 0.06 mg/l	1.5 ± 0.06 mg/l	1.4 ± 0.06 mg/l
PH	8.0 ± 0.0 mg/l	8.31 ± 0.06 mg/l	6.81± 0.006 mg/l	7.61± 0.006 mg/l
Total solid (TS)	7900± 58 mg/l	5600 ± 58 mg/l	10100 ± 58 mg/l	7433 ± 9 mg/l
Total dissolved solid (TDS)	5111 ± 0.6 mg/l	4100 ± 58 mg/l	7034± 0.6 mg/l	6900 ± 58 mg/l
Total suspended solid (TSS)	1508± 0.6 mg/l	2700 ± 58 mg/l	3300± 58 mg/l	3100 ± 58 mg/l
Total fixed solid (TFS)	4000 ± 58 mg/l	3250 ± 29 mg/l	5017 ± 44 mg/l	3800.0 ± 58 mg/l
Total volatile solid (TVS)	3800 ± 29 mg/l	2350 ± 29 mg/l	5017 ± 44 mg/l	3650 ± 29mg/l
Volatile dissolved solid (VDS)	2583± 388 mg/l	1700± 29 mg/l	3433 ± 44 mg/l	2583 ± 388 mg/l
Fixed dissolved solid (FDS)	2900 ± 29 mg/l	2733 ± 176 mg/l	3683 ± 0.6 mg/l	3183 ± 192 mg/l
Settleable solid	124 ± 0.6 ml/l	90 ± 0.6 ml/l	135 ± 0.6 ml/l	105 ± 0.6 ml/l
Sludge volume index (SVI)	60 ± 0.006 ml/g	33 ± 0.006 ml/g	41± 0.2 ml/g	39 ± 0.6 ml/g
Sludge density index (SDI)	1.2 ± 0.06 ml/g	2.7 ± 0.06 ml/g	2.4 ± 0.06 ml/g	3 ± 0.006 ml/g
Carbon dioxide (CO ₂)	62 ± 0.6 mg/l	00.00	74.00 ± 0.577 mg/l	00.00
Hydrogen sulphide (H ₂ S)	21 ± 0.06 mg/l	00.00 mg/l	27 ± 0.006 mg/l	00.00 mg/l
Alkalinity	255 ± 0.6 mg/l	470 ± 0.6 mg/l	315 ± 0.6 mg/l	725 ± 0.6 mg/l
Total hardness	192± 0.6 mg/l	286 ± 0.6 mg/l	188± 0.6 mg/l	270 ± 0.6 mg/l
Ca ⁺²	22± 0.06 mg/l	30.5 ± 0.06 mg/l	25 ± 0.6 mg/l	31 ± 0.06 mg/l
Mg ⁺²	33 ± 0.006 mg/l	50± 0.06 mg/l	30 ± 0.6 mg/l	46 ± 0.006 mg/l
Electrical conductivity (EC)	764 ± 6 µS/cm	4188 ± 6 µS/cm	849 ± 0.06 µS/cm	8703 ± 0.06 µS/cm
Temperature	27.67 ± 0.3°C	25 ± 0.0°C	24 ± 0.6°C	23 ± 0.06°C
Nitrate (NO ₃ ⁻)	27 ± 0.06 mg/l	29.5 ± 0.06 mg/l	33 ± 0.006 mg/l	36 ± 0.006 mg/l
Sulphate (SO ₄ ⁻²)	322 ± 0.6 ppm	241 ± 0.6 ppm	353 ± 0.6 ppm	210± 0.6 ppm
Phosphate (PO ₄ ⁻³)	2 ± 0.006 mg/l	4 ± 0.006 mg/l	3.3 ± 0.006 mg/l	9.4± 0.006 mg/l

The electrical conductivity is high in both sites particularly in Abbasid before stabilization as inhabitant use high amount of table salt in food and further elevated after stabilization as the solubility of its impurities are increased by anaerobic digestion and required treatment before to be used for irrigation to avoid salinization of soil.

Table 4. correlation and significant of wastewater sludge.

Wastewater sludge Characteristics	Correlation	Significant
BOD-after & BOD-before	.996	.000
Ca-after & Ca-before	.965	.002
Chloride-after & Chloride-before	.999	.000
CO ₂ -after & CO ₂ -before	-	-
COD-after & COD-before	1.000	.000
Sludge volume index-after & Sludge volume index-before	.896	.016
Dissolved solid-after & Dissolved solid-before	.998	.000
DO-after & DO-before	-.336	.515
EC-after & EC-before	.991	.000
Fixed Dissolved solid-after & Fixed Dissolved solid-before	.639	.172
Total fixed Solid-after & Total fixed Solid-before	.947	.004
Total hardness-after & total hardness-before	.921	.009
Hydrogen sulfide-after & Hydrogen sulfide-before	.999	.000
Mg-after & Mg-before	.937	.006
Nitrate-before & Nitrate-after	1.000	.000
pH-after & pH-before	.986	.000
Phosphate-after & Phosphate-before	1.000	.000
Settleable solid-after & Settleable solid-before	.983	.000
Total Solid-after & Total Solid-before	.998	.000
Sulphate-after & Sulphate-before	-.997	.000
Suspend Solid-after & Suspend solid-before	.941	.005
Temperature-After & Temperature-before	.952	.003
Turbidity-after & Turbidity-before	-1.000	.000
Total alkalinity-after & Total alkalinity-before	1.000	.000
Volatile Dissolved-after & Volatile Dissolved-before	.704	.118
Sludge volume index-after & Sludge volume index-before	-1.000	.000
Total volatile solid-after & Total volatile solid-before	.998	.000

Table 4 shows the correlation coefficient of sewage sludge parameters before and after stabilization showing the presence of positive correlation between parameters before and after stabilization by anaerobic digestion and indicating that the anaerobic stabilization is so effective in the treatment of sewage sludge for either reducing or elevating the most important characteristics of wastewater and sludge toward the acceptable and better ranges.

4. CONCLUSIONS

The sludge of municipal wastewater of Zakho district is worth to be used for the generation of biogas. The anaerobic ion is so effective in the treatment of sewage sludge for either reducing or elevating the most important characteristics of wastewater

and sludge toward the acceptable and better ranges. The stabilization by anaerobic digestion is so effective tool for improving the most chemical properties of wastewater especially in increasing the amount of macro essential nutrients like N, P, Ca, Mg and S in the final sludge produced to be used as organic fertilizer. The electrical conductivity is high in Zakho municipal wastewater before stabilization as inhabitant use high amount of table salt in food and further elevated after stabilization as the solubility of its impurities are increased by anaerobic digestion and required treatment before to be used for irrigation to avoid salinization of soil. Some character like alkalinity, hardness, and electrical conductivity need further treatment to improve in order to use this treated water safely for irrigation. The main limitation of this kind of studies is the leakage of proper facilities of waste water treatment in Iraqi Kurdistan region. This study will focus attraction of local authorities to pay more attention toward environmental issues and to seek of ecofriendly sources of clean energy like free sludge.

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