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Design and Performance Investigation of a Solar- Powered Biological Greywater Treatment System in the Iraqi Climate

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Abstract:

The increase in population resulted in an increase in the consumption of water. The present work investigates the performance of a recycling solar- powered greywater treatment system for the purposes of irrigation, used to reduce the amount of waste grey water and reduce electricity consumption and reduce the costs of constructing large scale water treatment plants. The system consumes about 3814W per hour and provides water treatment about 1.4 m^3 per day. The proposed system is designed to residential, office and governmental buildings application. Tests are conducted in an office building at the Ministry of Science and Technology site in Baghdad. Laboratorial water samples testing analyses are conducted for measuring the COD, BOD_5, TDS, NH_4, NO_3-TN, TOC, TSS, pH and oil and grease content according to the Iraqi standards. Test results revealed a huge decrease in the values of BOD_5 and COD for readings for every15 days and for a period of 5 months by removing rate more than 90% and also noting the values of TOC by removing about 80%, this indicates that the results of Laboratory testing have proved the success of the treatment process. The research is divided into two parts, theoretical and practical. The theoretical one includes choosing the type and size of the equipment and the required tools for the treatment system. While the practical one covers implementing a laboratory-scale system for the proposed treatment system and conducting experiments and laboratory analyses of greywater samples.

Keywords: Aerobic treatment, Anaerobic treatment, Greywater**,** Solar- Powered, System Design**.**

Introduction:

Iraq suffers from many challenges that must be overcome to meet future increases in electrical demands and water, just as dangerous atmospheric deviation and poor administration. These anthropogenic and natural elements prompted the shorting of surface water, diminished groundwater levels, and the measure of contaminations in water has expanded quickly [1]. Greywater (GW) represents any wastewater discharged from laundry, shower, bath, hand basin, and kitchen, it comprises 75% of the wastewater volume produced by households so it represents a great potential source of water-saving[2].

Reused water and modern techniques of electricity generation are one solution to meet these challenges. Practical evidence reveals that renewable energy resources like solar, wind and biomass are not being currently utilized adequately in Iraq. Such energy sources would provide opportunities for sustainability of power and provide new jobs in the labor sector[3].

One of the primary sources of inexpensive energy is solar energy, accessible, abundant, non-polluting, sustainable, and one of safe energy resources has been widely utilized in the world in recent years to generate electric power with long lifetimes reaching 20 to 30 years[4]. Most researchers and sources discouraged to store grey water before re-usage since it affects the pathogen load of both raw and treated grey water .Many processes are employed to reuse water such as biological treatment. Biological treatment(especially, activated sludge process) is a very effective way of treating municipal and various types of industrial wastewaters with successful application at tropical and semi-tropical climates to change complex organic particles found in the wastewater into simple molecules and biomass[5,6]. They found that wastewater treatment was to be a feasible treatment technology by hybrid biological system constituting both anaerobic, aerobic, and proved successful for waste water. High removal efficiencies were obtained for COD (99.5%) and Total Kjeldahl Nitrogen (TKN) (99.3%)[7]. They noticed a COD evacuation of around half at 30 °C and the most extreme anaerobic degradability of 67 % from greywater. Therefore, anaerobic treatment was suggested as the first treatment step for grey water[8].

Water treatment is subjected to environmental determinants allowed in water to know it's suitable for the required use. The standard concentration of pollutants (COD, BOD_5, TDS, NH_4, NH_3-N, TSS) in water to irrigation according to Iraqi standard specification 4260 in 2012 is shown Table 1.

Table 1. Some characteristics of water for irrigation in mg/l[9].

Parameter	Concentration
Chemical oxygen demand (COD)	100
Biochemical oxygen demand(BOD_5)	40
Total dissolved solids (TDS)	2500
Ammonium(NH_4)	5
Nitrate nitrogen (NO_3-N)	50
pH	4-8.6
Oil & Grease	-

The experimental system works about 3 hours per day for 5 days a week and the amount of greywater in the building delivered day by day is around 100-120 liters. The water recycled by the greywater treatment system is used for irrigating plants in agriculture or other purposes to reduce the costs of constructing water treatment plants and pollution.

Many published literatures confirm the feasibility of the design of a water treatment system working by photovoltaic (PV) panels. Where one research indicated, that water desalination by reverse osmosis photovoltaic powered systems are solutions for potential problems to the clean water in small communities[10]. Another research, was conducted in October 2005 to produce 764 L from a small scale PV-powered hybrid ultra-filtration-RO (UF) membrane filtration system of water per solar day with consumption of 3.2 kWh/m^3 average energy density, while of 7.4 mS /cm conductivity for treating of underground water, this test has appeared to endure well the power variation during clear sky days due to direct use of solar panels[11].

This work aims at designing an experimental solar-powered biological greywater treatment system for a building in the Ministry of Science and Technology, Baghdad/ Iraq.

Study area: **A** third-floor building of the Renewable Energies Directorate in the Ministry of science and technology in Baghdad/Iraq (33.31°latitude N and 44.36° W longitude) with annual solar radiation along the year is equal to 7114.44 MJ/m^2.year (5.4 kWh/m^2/day)[11] makes it a relatively sun-rich region.

System Design:

The design process of the system depends primarily on the environmental data of the site, greywater characteristics, quality, and need. Three significant parameters to an investigation of the required solar-powered system are the solar irradiance, the surrounding temperature, and the power load[5], taking into account that the solar radiation is variable with the time of the day, season, location, and weather conditions.

Biological Grey water treatment system components:

1. Anaerobic tank: Tightly closed, contains a submersible pump to circulate sludge for activation of anaerobic bacteria to the digestion of complex organic pollutants and converting them into simpler organic matters for easy treatment.
2. Aerobic tank: Contains a blower to pressurize oxygen and distribute it by fine bubble aeration to excellently improve the transfer efficiency of oxygen and allows for the deep exposure of water and air by strongly blending so that the chemical reactions between them could occur aeration helps to supply oxygen for remediation to microbial in greywater[5] and activation of aerobic bacteria for a breakdown of organic matter into carbon dioxide, biomass with removes other pollutants like phosphor and nitrogen.
3. PVC pipes & valves: Connecting the components and regulator of the flow.

Solar Powered system:

1. PV Panel: A mono-crystalline silicon photovoltaic (PV) module. It converts sunlight into DC electricity. Orienting due south at an inclination angle of 33° from the horizontal.
2. Deep cycle storage battery: Type AGM working to store electric energy with one-day autonomy. Designed to gradually discharge and recharge 80% of their capacity hundreds of times.
3. Charge controller: Type MPPT working to control the level of battery charge prevents battery

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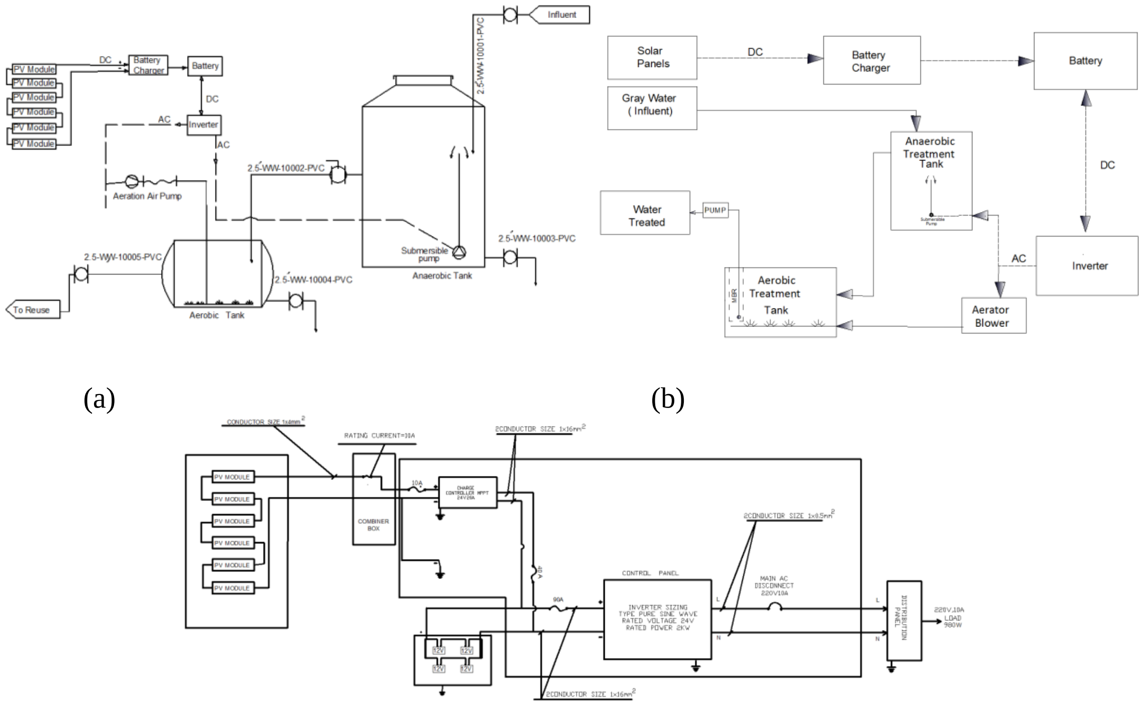
overcharging and didn't supply load if the battery voltage is low level.

4. Inverter: A pure sine wave module, to convert DC power output into AC power. Inversion efficiency of 90%.

Configuration:

Design is classified according to how the system components are connected. Figure 1 shows a schematic diagram of the system. This system is separated from the plumbing of the sewage network and off-grid of national electricity.



(a) (b)

(c)

Figure 1. Schematic illustration of: (a) the solar- powered grey water treatment system diagram; (b) Flowchart of the research methodology (c) the electric wiring diagram

Sizing of Biological Grey water treatment system:

Head loss in pipes is determined from equation 1 that comes from Hazen- Williams and Darcy-Weisbach Equations as follows[12]:

$$Pd = \frac{10.67\, Q^{1.85}}{C^{1.85}\, d^{4.87}} \qquad (1)$$

Where **Pd** is the Head loss in a meter of water per meter of pipe and Q is the flow rate in the pipe (m^3/s), **C** is the friction coefficient (130 for PVC pipes) and **d** is the inside diameter of the pipe (m).

A modified Hazen - Williams equation 2, can also be used to find the head losses:

$$HL = 2.78 \times 10^{-6} \times F \times \frac{L}{D^{4.87}} \left(\frac{n \times q}{C}\right)^{1.85} \qquad (2)$$

Where **HL** Pressure head (m), **n** is the number of emitters, and **q** Emitter discharge (liter/ sec).

There are three performance parameters related to pump selection, first, daily demand is estimated dividing the daily demand by the number of hours the pump is required to work, second, the total head, which is calculated by:

Total Head = Static Head + Dynamic Head + Pressure Head (3)

The third parameters are Hmax. Suction Lift (m), determined by the formula shown below:

Hmax = A – NPSH - Hf - Hv - Hs (4)

Where **A** is the atmospheric pressure head (m) and **NPSH** is the suction x-sticks of the pump (m), _ **Hf** is the Friction loss in the suction pipe (m) and **Hv** water vapor pressure head (m).

$$Q = \frac{\pi}{4} D^2 \times V \qquad (5)$$

Where **Q** is the Flow rate in a pipe (m^3/ sec), **D** is the Pipe diameter (m) and **V** is the Velocity (m/s).

Sizing of Solar Powered system:

To determine the size of the solar-powered system components we need the amount of electric load required (kWh) for the system, that is calculated from power for each load, daily and weekly hours of operating, The total electric losses are 28.57%[13]. Table 2, shows the calculated total daily energy consumption in Watt-hours per day requirement for the solar- powered system.

Table 2. Devices and Daily Energy Consumption

Load	Qty.	Power For Each (W)	Total Power (W)	Total Electric Efficiency (13)	Hours Per Day	Days Per Week	Total Energy (Wh/Day)
Submersible Pump	1	800	800	71.428	6	5	3428.571
Air Blower	2	90	180	71.428	3	5	385.714
Daily Consumption			980		Total Average Energy consumption		3814.285

The Photovoltaic array sizing, which is the peak power of Photovoltaic, is mathematically calculated, using the daily average value of the global solar energy incident on the solar modules (Epv) by using the equation 6[13]**:**

$$E_{PV} = \frac{E_{LD}}{Eff(inv)\times Eff(charg.)\times Eff(pv)} \quad (6)$$

Where E_{LD} is the energy consumption (Wh/day), *Eff* (*charg.*), Eff(inv.) and *Eff* (*pv*) are the efficiency of the charger, inverter, and the solar module respectively.

$$A_{PV} = \frac{E_{PV(in)}}{E_{sr}} \quad (7)$$

Where A_{PV} is the area of photovoltaic array (m^2) and *Esr* is the solar radiation (W/m^2).

$$p_{pv} = PS_{STC} \times A_{PV} \times E_{ff(pv)} \times SF \quad (8)$$

Where P_{PV} is the maximum power of PV (W), *Ps(STC)* is the solar radiation at standard test conditions (W/m^2) and *SF* is a factor of safety, suggested to compensate for the electric losses.

The required capacity of the storage battery is calculated by the equation 9[13]:

$$CB = \frac{E_{LD} \times Days of Autonomy}{E_{ff(Bat)}\times DOD \times V_B} \quad (9)$$

Where *CB* is the capacity of the battery (Ah), *Eff (Bat.)* is the storage battery efficiency, *DOD* is the depth of discharge and *VB* is the battery voltage (V).

The charge controller Sizing is calculated by[13]:

Solar charge controller rating = ISC × number of string × SF (10)

Where Isc is the short circuit current (A).

Inverter sizing = Total power ×SF (11)

The wire section area (m^2) is calculated by the equation 12 :

$$Vd = \frac{\rho l}{A} \times I \times 2 \quad (12)$$

The multiplication by 2 accounts for total circuit wire length. Where ρ is the resistively of wire (Ω/m^2), *A* is the wire cross-sectional area (m^2), *I* am the electric current (A), and *l* is the wire length (m)**.**

Specifications and equipment:

The specifications and equipment in operating the proposed system are listed in Table 3.

Table 3. Specifications of materials and components of the experimental system.

Description	Specification	Quantity
	Greywater System	
Anaerobic tank	Capacity is $1m^3$, Made of HDPE, Vertical Cylindrical Shape.	1
Aerobic tank	Capacity is $0.5m^3$, Made of HDPE, Horizontal Cylindrical Shape.	1
Submersible pump	Lowara DL90, Cast Iron, Capacity is 24 m^3/h, 220 AC, Power 0.8 kW.	1
Air blower	$5.4m^3$/h, Pressure 0.2bar, 220 AC, Power 90W.	2
Pipes	Made of PVC, Diameter 2.5 inch	
Valves	Made of PVC, Gate and Check Valves, Diameter1.5, and 2 inches.	
	Solar-Powered system	
Solar Panel	Mono-Crystalline Solar Panel 12V, Maximum Power Rating at STC (Pmax) is 180Watt, Isc is 6.95A.	6
Storage Battery	12 Volt,150Ah, Works at Temperature Between -20C° to 60C°.	4
Charge Controller	12VDC / 10 Amp.	1
Inverter	Input Voltage 12 VDC, Output Voltage 220VAC, 500Watt, Rated Power 2.8 A.	1
Wires	Size 1x1.5mm² (AWG #16) Size 1x6 mm² (AWG #10) Size 1x10 mm² (AWG #8)	
Fuse with Holder	12Volt, 7Amp	
Class R	12Volt, 40Amp	
Main Circuit Breaker	1-Pole, 220VAC,10Amp	
Combiner Box	Model PSPV (131 x 92 x 35)mm	
Control Panel	Compact System Enclosures (600x800x400)mm	
Battery Rack	According to Mechanical Drawing	

Experimental Setup:

A small-scale model of a greywater treatment system is constructed in laboratory compliance with the real conditions with restricted capacity (5 liters every 8 hours). The treatment consists of two stages, first, plastic basin, to the anaerobic reactor whose capacity is 10 liters, and contains mixer 250 rpm and 4 liters of sludge from the Al- Rostamia sewage station in Baghdad. Second, glass basin, to the aerobic reactor with a capacity of 25 liters, consists of a biological reactor integrated with polyethylene Membrane Bioreactor (MBR) (pore0.08 µm, a flux of 0.5l/m^{2}hr), the mixed liquor suspended solids (MLSS) concentration is (6000-7000 mg/l) and air compressor (70 l/min, 0.25 bar) with distributing by fine bubble aeration.

Sample collection: Samples of greywater were collected from the sink of the building by plastic bowel of 20 liters capacity and sent to a small scale of laboratory testing.

The experimental setup components and process schematic are shown in (Figs. 2 and 3 respectively.

(a)

(b)

Figure 2. Experimental setup a Lab. scale grey water treatment plant, (a) Anaerobic Digester, (b) Aerobic Digester.

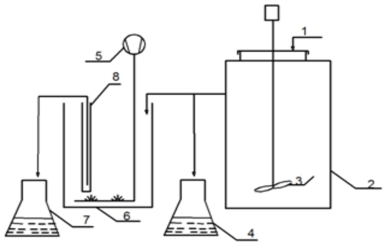


Figure 3. Schematic illustration of the pilot plan Laboratory:1 - Grey water inlet; 2-Anaerobic vessel; 3-Electric mixer; 4,7-Test bottles; 5- Air blower; 6– Aerobic vessel; MBR.

Process Description:

Grey water, wasfed into a tightly closed vessel (2) rotated by mixer (3) for a period about 4 to 5 days. Water from vessel (2) entered in a vessel (6) and the oxygen pressurization was done by an air blower,for a period of about 10 to 12 hours. Samples collected for the analysis are were taken by bottles in 4, 7.

Testing Procedures:

The parameters estimated for the samples at the examination site included pH, chemical oxygen demand (COD), biochemical Oxygen Demand (BOD_5),total nitrogen (TN), total natural carbon (TOC), ammonia (NH_3) and total suspended solids (TSS). The analyses investigation is done according to the standard strategy for assessment of water and wastewater analysis[14,15],using the following Testing devices: 1-COD Meter: Determination of COD in water samples in a period of time, 2- Suspended Solids Analyzer: measurement of suspended solids in aqueous solutions, 3- UV- Spectrophotometer: determining organic compounds and possible contaminants in our water sources, 4- pH meter: It's indicates acidity or alkalinity of water samples, 5- Digester: The samples are put in the digester to measure total P, N in period of times, 6- Photo Flex: Used for measuring the principles of TP and TN for the grey water in periods of time after digesters it, 7- TOC analyzers: Used for measuring total organic carbon in water samples Fig.4 shows the shapes and colors of water samples before and after treatment.

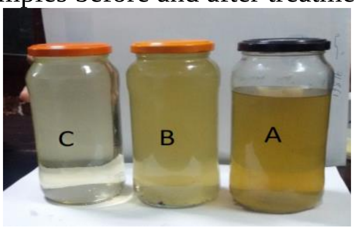


Figure 4. Changes in color and turbidity of greywater samples, A: Raw greywater sample; B: Same greywater after treatment in an anaerobic vessel; C: The same greywater after treatment in Aerobic vessel.

Results and Discussion:

Eleven experiments were conducted in the laboratory from May to October 2019 at temperatures of 20 -30 ^{0}C. Laboratory testing for concentrations of pollution in greywater samples before and after treatment are shown in Tables 4, 5 and 6.

Table 4. Concentrations of pollution materials in influent (minimum and maximum value) in mg/l.

Parameter	May	June	July	August	September	October
COD	934	1322	1100 -1200	900	950 -1100	970 -1000
BOD	280	397	330 - 360	270	285 - 330	291 - 370
TN	65	53	50 - 60	50	50 - 52	50 - 52
TOC	181	200	180-200	175	180 -185	170 - 185
NH_3	42	45	40 - 45	40	40 - 45	40 - 42
TSS	345	310	325 -380	330	315 - 320	325 - 370
pH	6.3	7.1	6 - 6.3	6.5	7.2 - 7.5	6.2 - 6.4

Table 5. Concentrations of pollution materials after anaerobic treatment (minimum and maximum value) in mg/l.

COD	250 - 434	400 - 425	375	310 - 320	370 - 400	250 - 434
BOD	165 - 300	270 - 292	273	210 - 412	212- 250	165 - 300
TN	53 - 65	50 - 60	50	50 - 52	52	53 - 65
TOC	94 -163	150 -160	146	113 -120	116 - 150	94 -163
NH_3	53 - 65	50 - 60	50	50 - 52	50 - 52	53 - 65
TSS	34 - 85	42 - 73	21	60 - 90	33 - 65	34 - 85
pH	7 - 7.4	7 - 7.2	7.1	7.45	7.3	7 - 7.4

Table 6. Concentrations of pollution materials after aerobic treatment (minimum and maximum value) in mg/l .

							Efficiency of removal %
COD	50-95	80	85-90	27-40	30-50	30-35	90-97
BOD_5	16-30	25.6	27 -29	9-29	11-18	85-92	89-97
TN	5	6	7-8	6-8	7-9	7-8	84-92
TOC	19-36	30	32-34	10 -15	11 -19	11-13	80-94
NH_3	Nil	Nil	Nil	Nil	Nil	Nil	-
TSS	Nil	Nil	Nil	Nil	Nil	Nil	-
pH	8-8.1	8.3	8.1-8.8	9.16	9	8.5	-

As shown in Fig. 5,the results of testing the characteristics of greywater analysis are dissimilar from one test result to another. This highly variance of characteristics is influenced by daily lifestyle[16]. Two tests were conducted in months from July to September, and three tests in October, that explains the existence of more than one point in the curves in these months.

The minimum and maximum values of COD (900–1300 mg/l), BOD_5 (270 –350 mg/l) as shown in influent on Fig.5, reduced to COD (27-95 mg/l), (BOD_5 9 mg/l) after aerobic treatment to allowable limit in table (1). The highest deviation in the values of some analyses is observed in the months from August to October. It can be noted that the average BOD_5 / COD ratios is about 30% in greywater, the possible explanation of this ratio can be the high amount of surfactants present in the influent and proves the need 4 to 5 days to the digestion of complex materials such as organic and inorganic compounds and to be ready to anaerobic treatment, ratio rising to 70% after an anaerobic treatment, which means removal 70% of COD at different loading rates of organic and completed the process of digestion. The term of BOD_5 / COD ratio refers to a great biodegradability to all types of greywater. In untreated wastewater, this ratio is the range from 0.3 to 0.8 and to be effectively treatable by biological method, if the ratio greater than 0.5[17,18].

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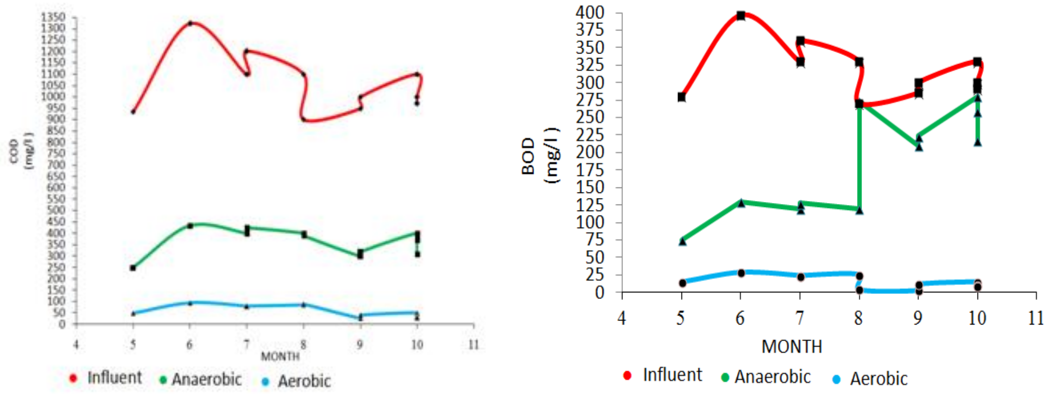

Figure 5. Comparison curves for the monthly variation of concentration of pollutants COD and BOD_5.

Research of the nutrients showed that, the nutrients are also higher in greywater resulting in the rise of nitrogen content in raw water originated from protein contained in food residues, household cleaning products. The results are shown in Fig. 6. Total nitrogen was reduced by 86% due to the nitrification process occurring in aerobic digestion. No touching change in concentrations of TN and NH_3 was noticed for anaerobic digestion .This is attributed to the absence of complex substances that cause easier digestion.

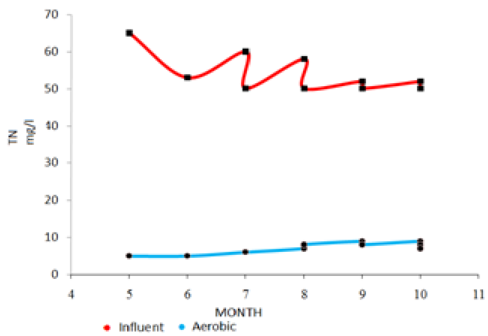

Figure 6. Comparison of the monthly variation in concentration of pollutant TN (mg/l).

TOC is one of the most important composite parameters in the assessment of the organic pollution of water that includes all contents of carbon compounds (as one mass) dissolved, un-dissolved organic substances in water and sediments[19]. The comparison shown in Fig. 7 reveals that the slight decrease in the concentration after anaerobic digestion is about 18 %, and the maximum achieved an increase of concentration to 85 % after aerobic digestion which is due to using bio-filtration.

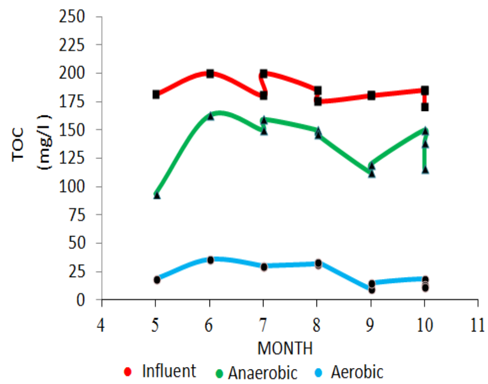

Figure 7. Comparison of the monthly variation in concentration of pollutant TOC (mg/l).

Figure 8 shows that the higher concentration of solid particles in the influent, is about 310-380 mg/l to 21-90 mg/l which may settle out onto a bottom of the streambed that can prevent sufficient oxygen transfer and death of organisms. After anaerobic digestion, a reduction to 21-90 mg/l resulted after anaerobic treatment.

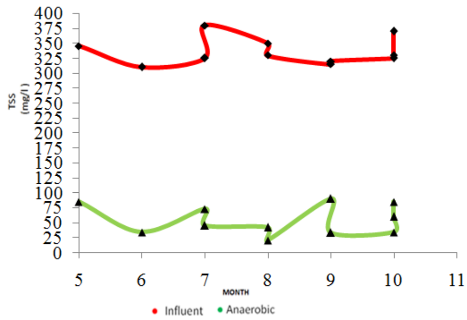

Figure 8. Comparison of the monthly variation in concentration of pollutant TSS (mg/l).

The pH variety influences the release or adsorption of each metal(Like Cd, Ni, Cr_{total}, Pb, Cu and Zn) into sediment fraction where the High pH has lowered the desorption of metals and possesses high buffering capacity against acidic conditions that may be created as a result of wastes accumulation[20]. The pH values, as shown in Fig. 9, in influent were between 6 and 6.6 that means the

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acidic or alkaline of the greywater because of higher concretion of total organic carbon (TOC) that contributes fundamentally to the acidity of water and sediments through organic acids and biological activities that are initiated by the adsorption of light (as catalyst) and water [21]. Values are elevated to 15%,23% after anaerobic digestion treatment (between 7.1 to 7.3), and aerobic (between 8 to 9.1) treatments, respectively, which indicates the alkalinity of treated water. This is due to the absence of complex materials that leads to easier anaerobic digestion process without changes in TN and NH3 contents, as previously shown in Fig. 6.

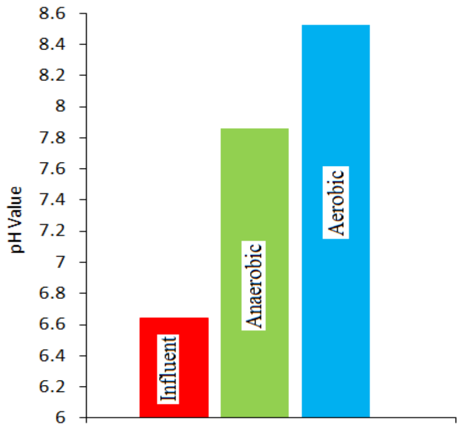

Figure 9. Average of pH value from May to October 2019.

Figure 10, compares the average removal efficiency characteristics of physical and chemical pollutants in each stage of treatment. Maximum values attained at the aerobic treatment stage are COD (90%-97%), BOD_5 (89%-97%), TOC (80%-94%), and TN (84%-92%).Results appear the major role of existence membrane bioreactor (MBR). Besides, it removed all NH_3 and TSS, whereas low values for removal efficiency to TOC (20%-24%), and TN(5%-10%) are attained in the anaerobic treatment stage. Previously[22,23], it has been proved that the grey water treatment process using biological treatment has reduced and disappeared most of the pollutants, it was consistent with the Iraqi guidelines and determinants for reuse of water. The analysis also indicates that water does not contain oils, fats, grease, and that the total dissolved solids TDS have been 2000 ppm.

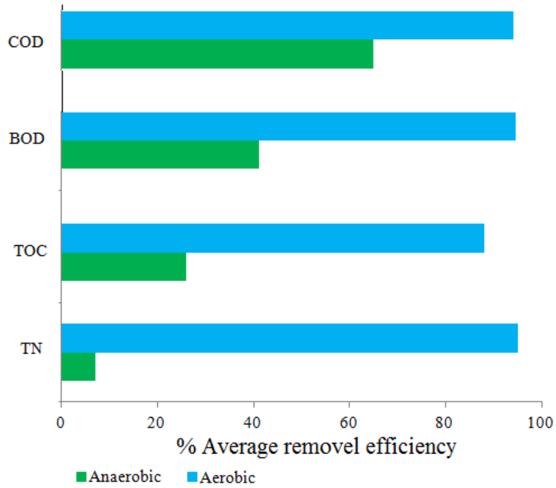

Figure 10. % Average removal efficiency and concentration of pollutants from May to October 2019

Conclusions:

The Solar-powered grey water treatment system is constructed locally from materials available in the local market. The following conclusions are drawn:

- The application of the proposed system in the Iraqi conditions is effective and feasible due to the availability of solar radiation and the shortage in supply water, especially in summer.
- It is possible to combine the small systems of the grey water treatment system and the solar-powered system to reduce the costs of constructing water treatment plants, saving water, electric consumptions, and decreasing environmental pollution resulting from the use of fossil fuels.
- It is possible to add other units to the system to make them suitable for drinking and washing, but this will increase the cost.
- This system will recycle about 70% of the water that can be discharged into the drains that can be used after being treated for irrigation, car wash, and in bathrooms.

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Authors' declaration:

- Conflicts of Interest: None.
- We hereby confirm that all the Figures and Tables in the manuscript are mine ours. Besides, the Figures and images, which are not mine ours, have

been given the permission for re-publication attached with the manuscript.

- Ethical Clearance: The project was approved by the local ethical committee in Ministry of Science and Technology.

Authors' contributions statement:

Hashim A. Mahdi and Hassan Naji Salman AL-Joboory conceived of the presented idea, developed the theory, performed the system design and computations, verified the analyses and results, wrote and revised the final manuscript. All authors contributed in the construction and preparation of the experimental set up. Akram G.Abdula, Alia A. Hameed and Aseel K. Rasheed performed the experimental lab tests of the water samples. All authors discussed the results and contributed to the final manuscript

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تصميم وفحص أداء منظومة حيوية لمعالجة المياه الرمادية تعمل بالطاقة الشمسية في الأجواء العراقية

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دائرة الطاقات المتجددة ،وزارة العلوم والتكنولوجيا ، بغداد، العراق

الخلاصة:

أدت الزيادة في عدد السكان إلى زيادة في استهلاك المياه. يبحث العمل الحالي في أداء نظام معالجة المياه الرمادية الذي يعمل بالطاقة الشمسية لإعادة التدوير لأغراض الري، ستخدم لتقليل كمية المياه الرمادية المهدرة وتقليل استهلاك الكهرباء وتقليل تكاليف إنشاء محطات معالجة المياه على نطاق واسع. يستهلك النظام حوالي 3814 واط في الساعة ويوفر معالجة للمياه حوالي 1.4 متر مكعب في اليوم. تم تصميم النظام المقترح لتطبيق المباني السكنية والمكتبية والحكومية. أجريت الاختبارات على أحد مباني وزارة العلوم والتكنولوجيا في بغداد. تم إجراء تحليلات اختبار عينات المياه المخبرية لقياس COD ، BOD5 ، TDS، NH4 ، NO3-TN، TOC، TSS، الأس الهيدروجيني ومحتوى الزيت والشحوم وفقًا للمعايير العراقية. أظهرت نتائج الاختبار انخفاضًا كبيرًا في قيم BOD5 و COD للقراءات كل 15 يومًا ولمدة 5 أشهر بمعدل إزالة أكثر من 90٪ وكذلك ملاحظة قيم TOC بإزالة حوالي 80٪ ، وهذا يشير إلى نتائج أثبتت الاختبارات المعملية نجاح عملية المعالجة. قسم البحث إلى قسمين، نظري وعملي. يتضمن الأسلوب النظري اختيار نوع وحجم المعدات والأدوات المطلوبة لنظام المعالجة. بينما يغطي الجانب العملي تنفيذ نظام مقياس مختبري لنظام المعالجة المقترح وإجراء التجارب والتحليلات المختبرية لعينات المياه الرمادية..

الكلمات المفتاحية : معالجة هوائية، معالجة لاهوائية، مياه رمادية، قدرة شمسية ،تصميم منظومة .