PPU College of Engineering and Technology
The Home of Competent Engineers and Researchers

College of Engineering &Technology

Mechanical Engineering Department

Automotive Engineering

Graduation Project

Design and building a digester to ProduceBiogas in Rural Area

Studentsname

Eyad Abu Taha (081224)

&

Saleh Fataftah (080741)

Project Supervisor

Dr. ZuhdiSalhab

Hebron- Palestine

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Dedication

To our dear parents and families…………………………………………….

To whom who added any thing to the science…………………………....

To whom who have taught us any letter, word or information…………...

To our college and instructors……………………………………………….

To whom we love……………………………………………………………

We didicate this project

Project team

Abstract

This project concerns the building and design of home scale biogas generator from animal waste in rural area. Thus, the project is considered beside the design of the biogas generator, feasibility study for the production of biogas obtained from cattle dung. The importance of the project comes to shear in solving the problem of the global rising of the fuel cost. The aim is to design a generator to produce the methane gas through anaerobic treatment of cattle dung, taking into account all of safety issues.

The digester done in the cylindrical shape and it provides appropriate condition such as heating and mixing system to allow the bacteria to produce the biogas in short duration.

A sample of produced mixture has taken and tested a pH of the mixture was measured which is criterion of bacteria production with respect to the water temperature used of digester heating, The ph. measured value (6-7) are the best value and condition of biogas retention , the produced was tested and burned which utilized the purpose of this project.

Key Words: Biogas

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APPINDEXA

جدول (١) الخواص الطبيعية للماء عند درجات حرارة مختلفة

Temp. °C	Specific weight (γ) N/m^3	Density (ρ) kg/m^3	Dynamic viscosity (μ) Pa.s $10^3\ \mu =$	Kinematic viscosity (ν) m^2/sec $10^6\ \nu =$	Surface tension (σ) N/m $100\ \sigma =$	Vapor. Pressure $(h_v) = P/\gamma$ m	ÚÖ Ö Elasticity (E) N/m^2 $10^{-7}\ E =$
0	9805	999.0	1.792	1.792	7.62	0.06	204
5	9806	1000.0	1.519	1.519	7.54	0.09	206
10	9803	999.7	1.308	1.308	7.48	0.12	211
15	9798	999.1	1.140	1.141	7.41	0.17	214
20	9789	998.2	1.005	1.007	7.36	0.25	220
25	9779	997.1	0.894	0.897	7.26	0.33	222
30	9767	995.7	0.801	0.804	7.18	0.44	223
35	9752	994.1	0.723	0.727	7.10	0.58	221
40	9737	992.2	0.656	0.661	7.01	0.76	227
45	9720	990.2	0.599	0.605	6.92	0.98	229
50	9697	988.1	0.549	0.556	6.82	1.26	230
55	9679	985.7	0.506	0.513	6.74	1.61	231
60	9658	983.2	0.469	0.477	6.68	2.03	228
65	9635	980.6	0.436	0.444	6.58	2.56	226
70	9600	977.8	0.406	0.415	6.50	3.20	225
75	9589	974.9	0.380	0.390	6.40	3.96	223
80	9557	961.8	0.357	0.367	6.30	4.86	221
85	9529	968.6	0.336	0.347	6.20	5.93	217
90	9499	965.3	0.317	0.328	6.12	7.18	216
95	9469	961.9	0.299	0.311	6.02	8.62	211
100	9438	958.4	0.284	0.296	5.94	10.33	207

جدول (٢) الخواص الطبيعية للماء في الظروف الطبيعية

$\rho = 1000\ kg/m^3$	$\rho = 1\ gm/cm^3$	$\rho = 1.94\ slug/ft^3$	(ρ)
$\gamma = 9810\ N/m^3$	$\gamma = 981\ dyne/cm^3$	$\gamma = 62.6\ lb_w/ft^3$	)γ(
$\mu = 0.001\ Pa.sec$	$\mu = 0.01\ poise$	$\mu = 2.05\times10^{-3}\ lb_w.sec/ft^2$	(μ)
$\nu = 1\times10^{-6}\ m^2/sec$	$\nu = 0.01\ stoke$	$\nu = 1\times10^{-5}\ ft^2/sec$	(ν)
$E = 206\times10^7\ Pa$	$E = 206\times10^5\ dyne/m^2$	$E = 298\times10^3\ psi$	(E) Ù

Friction Losses in Pipe Fittings
Resistance Coefficient K (use in formula hf = Kv²/2g)

Fitting		LD	Nominal Pipe Size ½	¾	1	1¼	1½	2	2½-3	4	6	8-10	12-16	18-24
			K Value											
Angle Valve		55	1.48	1.38	1.27	1.21	1.16	1.05	0.99	0.94	0.83	0.77	0.72	0.66
Angle Valve		150	4.05	3.75	3.45	3.30	3.15	2.85	2.70	2.55	2.25	2.10	1.95	1.80
Ball Valve		3	0.08	0.08	0.07	0.07	0.06	0.06	0.05	0.05	0.05	0.04	0.04	0.04
Butterfly Valve								0.86	0.81	0.77	0.68	0.63	0.35	0.30
Gate Valve		8	0.22	0.20	0.18	0.18	0.15	0.15	0.14	0.14	0.12	0.11	0.10	0.10
Globe Valve		340	9.2	8.5	7.8	7.5	7.1	6.5	6.1	5.8	5.1	4.8	4.4	4.1
Plug Valve Branch Flow		90	2.43	2.25	2.07	1.98	1.89	1.71	1.62	1.53	1.35	1.26	1.17	1.08
Plug Valve Straightaway		18	0.48	0.45	0.41	0.40	0.38	0.34	0.32	0.31	0.27	0.25	0.23	0.22
Plug Valve 3-Way Thru-Flow		30	0.81	0.75	0.69	0.66	0.63	0.57	0.54	0.51	0.45	0.42	0.39	0.36
Standard Elbow	90°	30	0.81	0.75	0.69	0.66	0.63	0.57	0.54	0.51	0.45	0.42	0.39	0.36
	45°	16	0.43	0.40	0.37	0.35	0.34	0.30	0.29	0.27	0.24	0.22	0.21	0.19
	long radius 90°	16	0.43	0.40	0.37	0.35	0.34	0.30	0.29	0.27	0.24	0.22	0.21	0.19
Close Return Bend		50	1.35	1.25	1.15	1.10	1.05	0.95	0.90	0.85	0.75	0.70	0.65	0.60
Standard Tee	Thru-Flow	20	0.54	0.50	0.46	0.44	0.42	0.38	0.36	0.34	0.30	0.28	0.26	0.24
	Thru-	60	1.62	1.50	1.38	1.32	1.26	1.14	1.08	1.02	0.90	0.84	0.78	0.72
90 Bends, Pipe Bends, Flanged Elbows, Butt-Welded Elbows	r/d=1	20	0.54	0.50	0.46	0.44	0.42	0.38	0.36	0.34	0.30	0.28	0.26	0.24
	r/d=2	12	0.32	0.30	0.28	0.26	0.25	0.23	0.22	0.20	0.18	0.17	0.16	0.14
	r/d=3	12	0.32	0.30	0.28	0.26	0.25	0.23	0.22	0.20	0.18	0.17	0.16	0.14
	r/d=4	14	0.38	0.35	0.32	0.31	0.29	0.27	0.25	0.24	0.21	0.20	0.18	0.17
	r/d=6	17	0.46	0.43	0.39	0.37	0.36	0.32	0.31	0.29	0.26	0.24	0.22	0.20
	r/d=8	24	0.65	0.60	0.55	0.53	0.50	0.46	0.43	0.41	0.36	0.34	0.31	0.29
	r/d=10	30	0.81	0.75	0.69	0.66	0.63	0.57	0.54	0.51	0.45	0.42	0.39	0.36
	r/d=12	34	0.92	0.85	0.78	0.75	0.71	0.65	0.61	0.58	0.51	0.48	0.44	0.41
	r/d=14	38	1.03	0.95	0.87	0.84	0.80	0.72	0.68	0.65	0.57	0.53	0.49	0.46
	r/d=16	42	1.13	1.05	0.97	0.92	0.88	0.80	0.76	0.71	0.63	0.59	0.55	0.50
	r/d=18	45	1.24	1.15	1.06	1.01	0.97	0.87	0.83	0.78	0.69	0.64	0.60	0.55

TABLE A–1

Molar mass, gas constant, and critical-point properties

				Critical-point properties		
Substance	Formula	Molar mass, *M* kg/kmol	Gas constant, *R* kJ/kg·K*	Temperature, K	Pressure, MPa	Volume, m^3/kmol
Air	—	28.97	0.2870	132.5	3.77	0.0883
Ammonia	NH_3	17.03	0.4882	405.5	11.28	0.0724
Argon	Ar	39.948	0.2081	151	4.86	0.0749
Benzene	C_6H_6	78.115	0.1064	562	4.92	0.2603
Bromine	Br_2	159.808	0.0520	584	10.34	0.1355
n-Butane	C_4H_{10}	58.124	0.1430	425.2	3.80	0.2547
Carbon dioxide	CO_2	44.01	0.1889	304.2	7.39	0.0943
Carbon monoxide	CO	28.011	0.2968	133	3.50	0.0930
Carbon tetrachloride	CCl_4	153.82	0.05405	556.4	4.56	0.2759
Chlorine	Cl_2	70.906	0.1173	417	7.71	0.1242
Chloroform	$CHCl_3$	119.38	0.06964	536.6	5.47	0.2403
Dichlorodifluoromethane (R-12)	CCl_2F_2	120.91	0.06876	384.7	4.01	0.2179
Dichlorofluoromethane (R-21)	$CHCl_2F$	102.92	0.08078	451.7	5.17	0.1973
Ethane	C_2H_6	30.070	0.2765	305.5	4.48	0.1480
Ethyl alcohol	C_2H_5OH	46.07	0.1805	516	6.38	0.1673
Ethylene	C_2H_4	28.054	0.2964	282.4	5.12	0.1242
Helium	He	4.003	2.0769	5.3	0.23	0.0578
n-Hexane	C_6H_{14}	86.179	0.09647	507.9	3.03	0.3677
Hydrogen (normal)	H_2	2.016	4.1240	33.3	1.30	0.0649
Krypton	Kr	83.80	0.09921	209.4	5.50	0.0924
Methane	CH_4	16.043	0.5182	191.1	4.64	0.0993
Methyl alcohol	CH_3OH	32.042	0.2595	513.2	7.95	0.1180
Methyl chloride	CH_3Cl	50.488	0.1647	416.3	6.68	0.1430
Neon	Ne	20.183	0.4119	44.5	2.73	0.0417
Nitrogen	N_2	28.013	0.2968	126.2	3.39	0.0899
Nitrous oxide	N_2O	44.013	0.1889	309.7	7.27	0.0961
Oxygen	O_2	31.999	0.2598	154.8	5.08	0.0780
Propane	C_3H_8	44.097	0.1885	370	4.26	0.1998
Propylene	C_3H_6	42.081	0.1976	365	4.62	0.1810
Sulfur dioxide	SO_2	64.063	0.1298	430.7	7.88	0.1217
Tetrafluoroethane (R-134a)	CF_3CH_2F	102.03	0.08149	374.2	4.059	0.1993
Trichlorofluoromethane (R-11)	CCl_3F	137.37	0.06052	471.2	4.38	0.2478
Water	H_2O	18.015	0.4615	647.1	22.06	0.0560
Xenon	Xe	131.30	0.06332	289.8	5.88	0.1186

*The unit kJ/kg·K is equivalent to kPa·m^3/kg·K. The gas constant is calculated from $R = R_u/M$, where R_u = 8.31447 kJ/kmol·K and *M* is the molar mass.

Source: K. A. Kobe and R. E. Lynn, Jr., *Chemical Review* 52 (1953), pp. 117–236; and ASHRAE, *Handbook of Fundamentals* (Atlanta, GA: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 1993), pp. 16.4 and 36.1.

Physical characteristics of water
(at the atmospheric pressure)

B: Energy values in kcal/kg are given on a basis of 4.1868 J .**Values not normally used.**

Temperature	Pressure	Saturation vapor pressure	Density	Specific enthalpy of liquid water		Specific heat		Volume heat capacity	Dynamic viscosity
°C	Pa	Pa	kg/m3	kj/kg	kcal/kg	kj/kg	kcal/kg	kj/m3	kg/m.s
0.00	101325	611	999.82	0.06	0.01	4.217	1.007	4216.10	0.001792
1.00	101325	657	999.89	4.28	1.02	4.213	1.006	4213.03	0.001731
2.00	101325	705	999.94	8.49	2.03	4.210	1.006	4210.12	0.001674
3.00	101325	757	999.98	12.70	3.03	4.207	1.005	4207.36	0.001620
4.00	101325	813	1000.00	16.90	4.04	4.205	1.004	4204.74	0.001569
5.00	101325	872	1000.00	21.11	5.04	4.202	1.004	4202.26	0.001520
6.00	101325	935	999.99	25.31	6.04	4.200	1.003	4199.89	0.001473
7.00	101325	1001	999.96	29.51	7.05	4.198	1.003	4197.63	0.001429
8.00	101325	1072	999.91	33.70	8.05	4.196	1.002	4195.47	0.001386
9.00	101325	1147	999.85	37.90	9.05	4.194	1.002	4193.40	0.001346
10.00	101325	1227	999.77	42.09	10.05	4.192	1.001	4191.42	0.001308
11.00	101325	1312	999.68	46.28	11.05	4.191	1.001	4189.51	0.001271
12.00	101325	1402	999.58	50.47	12.06	4.189	1.001	4187.67	0.001236
13.00	101325	1497	999.46	54.66	13.06	4.188	1.000	4185.89	0.001202
14.00	101325	1597	999.33	58.85	14.06	4.187	1.000	4184.16	0.001170
15.00	101325	1704	999.19	63.04	15.06	4.186	1.000	4182.49	0.001139
16.00	101325	1817	999.03	67.22	16.06	4.185	1.000	4180.86	0.001109
17.00	101325	1936	998.86	71.41	17.06	4.184	0.999	4179.27	0.001081
18.00	101325	2063	998.68	75.59	18.05	4.183	0.999	4177.72	0.001054
19.00	101325	2196	998.49	79.77	19.05	4.182	0.999	4176.20	0.001028
20.00	101325	2337	998.29	83.95	20.05	4.182	0.999	4174.70	0.001003
21.00	101325	2486	998.08	88.14	21.05	4.181	0.999	4173.23	0.000979
22.00	101325	2642	997.86	92.32	22.05	4.181	0.999	4171.78	0.000955
23.00	101325	2808	997.62	96.50	23.05	4.180	0.998	4170.34	0.000933
24.00	101325	2982	997.38	100.68	24.05	4.180	0.998	4168.92	0.000911
25.00	101325	3166	997.13	104.86	25.04	4.180	0.998	4167.51	0.000891
26.00	101325	3360	996.86	109.04	26.04	4.179	0.998	4166.11	0.000871
27.00	101325	3564	996.59	113.22	27.04	4.179	0.998	4164.71	0.000852
28.00	101325	3779	996.31	117.39	28.04	4.179	0.998	4163.31	0.000833
29.00	101325	4004	996.02	121.57	29.04	4.179	0.998	4161.92	0.000815
30.00	101325	4242	995.71	125.75	30.04	4.178	0.998	4160.53	0.000798
31.00	101325	4491	995.41	129.93	31.03	4.178	0.998	4159.13	0.000781
32.00	101325	4754	995.09	134.11	32.03	4.178	0.998	4157.73	0.000765
33.00	101325	5029	994.76	138.29	33.03	4.178	0.998	4156.33	0.000749
34.00	101325	5318	994.43	142.47	34.03	4.178	0.998	4154.92	0.000734
35.00	101325	5622	994.08	146.64	35.03	4.178	0.998	4153.51	0.000720
36.00	101325	5940	993.73	150.82	36.02	4.178	0.998	4152.08	0.000705
37.00	101325	6274	993.37	155.00	37.02	4.178	0.998	4150.65	0.000692
38.00	101325	6624	993.00	159.18	38.02	4.178	0.998	4149.20	0.000678

Thermal conductivity of some common materials and products are indicated in the table below.

- *1 W/(m.K) = 1 W/(m.°C) = 0.85984 kcal/(hr.m.°C) = 0.5779 Btu/(ft.hr.°F)*

Thermal Conductivity - *k* - *W/(m.K)*			
Material/Substance	Temperature - °C		
	25	125	225
Acetone	0.16		
Acetylene (gas)	0.018		
Acrylic	0.2		
Air, athmosphere (gas)	0.024		
Alcohol	0.17		
Aluminum	205	215	250
Aluminum Oxide	30		
Ammonia (gas)	0.022		
Antimony	18.5		
Apple (85.6% moisture)	0.39		
Argon (gas)	0.016		
Asbestos-cement board	0.744		
Asbestos-cement sheets	0.166		
Asbestos-cement	2.07		

Thermal Conductivity - *k* - *W/(m.K)*			
Material/Substance	Temperature - ^oC		
	25	125	225
Asbestos, loosely packed	0.15		
Asbestos mill board	0.14		
Asphalt	0.75		
Balsa wood	0.048		
Bitumen	0.17		
Bitumen/felt layers	0.5		
Beef, lean (78.9 % moisture)	0.43 - 0.48		
Benzene	0.16		
Beryllium	218		
Bitumen	0.17		
Blast furnace gas (gas)	0.02		
Brass	109		
Breeze block	0.10 - 0.20		
Brick dense	1.31		
Brickwork, common	0.6 -1.0		

Thermal Conductivity - *k* - *W/(m.K)*			
Material/Substance	Temperature - ^oC		
	25	125	225
Brickwork, dense	1.6		
Butter (15% moisture content)	0.20		
Cadmium	92		
Calcium silicate	0.05		
Carbon	1.7		
Carbon dioxide (gas)	0.0146		
Cement, portland	0.29		
Cement, mortar	1.73		
Chalk	0. 09		
Chlorine (gas)	0.0081		
Chrome Nickel Steel (18% Cr, 8 % Ni)	16.3		
Clay, dry to moist	0.15 - 1.8		
Clay, saturated	0.6 - 2.5		
Cobalt	69		
Cod (83% moisture content)	0.54		

Thermal Conductivity - *k* - *W/(m.K)*			
Material/Substance	Temperature - ^oC		
	25	125	225
Concrete, lightweight	0.1 - 0.3		
Concrete, medium	0.4 - 0.7		
Concrete, dense	1.0 - 1.8		
Concrete, stone	1.7		
Constantan	22		
Copper	401	400	398
Corian (ceramic filled)	1.06		
Corkboard	0.043		
Cork, regranulated	0.044		
Cork	0.07		
Cotton wool	0.029		
Carbon Steel	54	51	47
Cotton Wool insulation	0.029		

Thermal properties of water:

Temperature **- *t* -**	**Absolute pressure** **- *p* -**	**Density** **- *ρ* -**	**Specific volume** **- *v* -**	**Specific Heat** **- c_p -**	**Specific entropy** **- *e* -**
(^oC)	*(kN/m^2)*	*(kg/m^3)*	*10^{-3} (m^3/kg)*	*(kJ/kgK)*	*(kJ/kgK)*
0 (Ice)		916.8			
0.01	0.6	999.8	1.00	4.210	0
4 (maximum density)	0.9	1000.0			
5	0.9	1000.0	1.00	4.204	0.075
10	1.2	999.8	1.00	4.193	0.150
15	1.7	999.2	1.00	4.186	0.223
20	2.3	998.3	1.00	4.183	0.296
25	3.2	997.1	1.00	4.181	0.367
30	4.3	995.7	1.00	4.179	0.438
35	5.6	994.1	1.01	4.178	0.505
40	7.7	992.3	1.01	4.179	0.581

Thermal Conductivity - *k* - *W/(m.K)*			
Material/Substance	Temperature - ^{o}C		
	25	125	225
Acetone	0.16		
Acrylic	0.2		
Air (gas)	0.024		
Alcohol	0.17		
Aluminum	250	255	250
Aluminum Oxide	30		
Ammonia (gas)	0.022		
Antimony	18.5		
Argon (gas)	0.016		
Asbestos-cement board	0.744		
Asbestos-cement sheets	0.166		
Asbestos-cement	2.07		
Asbestos, loosely packed	0.15		
Asbestos mill board	0.14		
Asphalt	0.75		
Balsa	0.048		
Bitumen	0.17		
Benzene	0.16		
Beryllium	218		
Brass	109		
Brick dense	1.31		
Brick work	0.69		
Cadmium	92		
Carbon	1.7		
Carbon dioxide (gas)	0.0146		
Cement, portland	0.29		
Cement, mortar	1.73		
Chalk	0.09		
Chrome Nickel Steel (18% Cr, 8 % Ni)	16.3		
Clay, dry to moist	0.15 - 1.8		

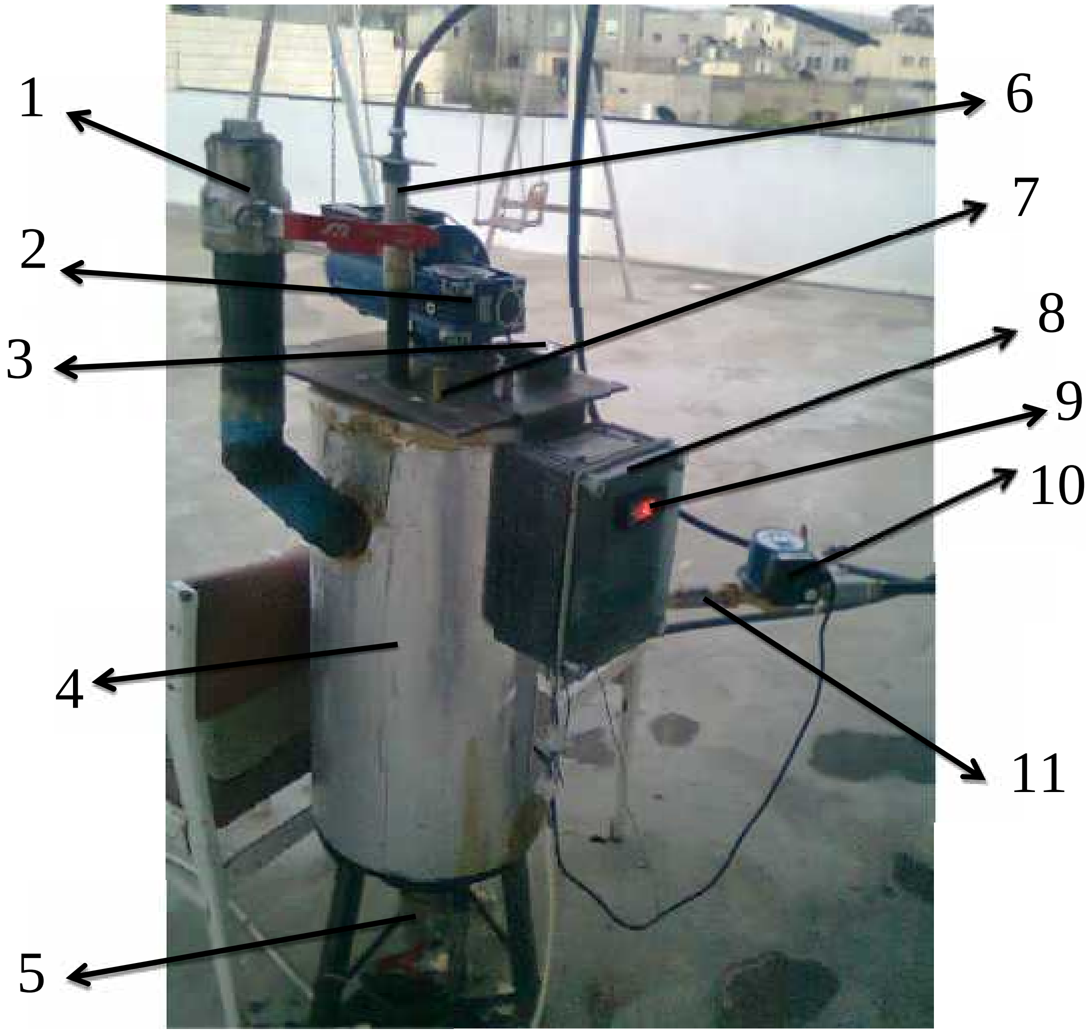
Clay, saturated	0.6 - 2.5		
Cobalt	69		
Concrete, light	0.42		
Concrete, stone	1.7		
Constantan	22		
Copper	401	400	398

TYPICAL FOULING FACTORS

COOLING WATER - Fouling Factors in [m^2K/W]

Conditions	cooling water < 50 ° C cooled fluid < 120 ° C		cooling water > 50 ° C cooled fluid > 120 ° C	
Water velocity	v < 1 m/s	v > 1 m/s	v < 1 m/s	v > 1 m/s
Type of Water				
Sea	0.00009	0.00009	0.00018	0.00018
Brackish	0.00035	0.00018	0.00053	0.00035
Cooling tower with inhibitor	0.00018	0.00018	0.00035	0.00035
Cooling tower without inhibitor	0.00053	0.00053	0.00088	0.00070
City grid	0.00018	0.00018	0.00035	0.00035
River mimimum	0.00018	0.00018	0.00035	0.00035
River average	0.00053	0.00035	0.00070	0.00035
Engine jacket	0.00018	0.00018	0.00018	0.00018
Demineralized or distilled	0.00009	0.00009	0.00009	0.00009
Treated Boiler Feedwater	0.00018	0.00009	0.00018	0.00018
Boiler blowdown	0.00035	0.00035	0.00035	0.00035

APPINDEX B



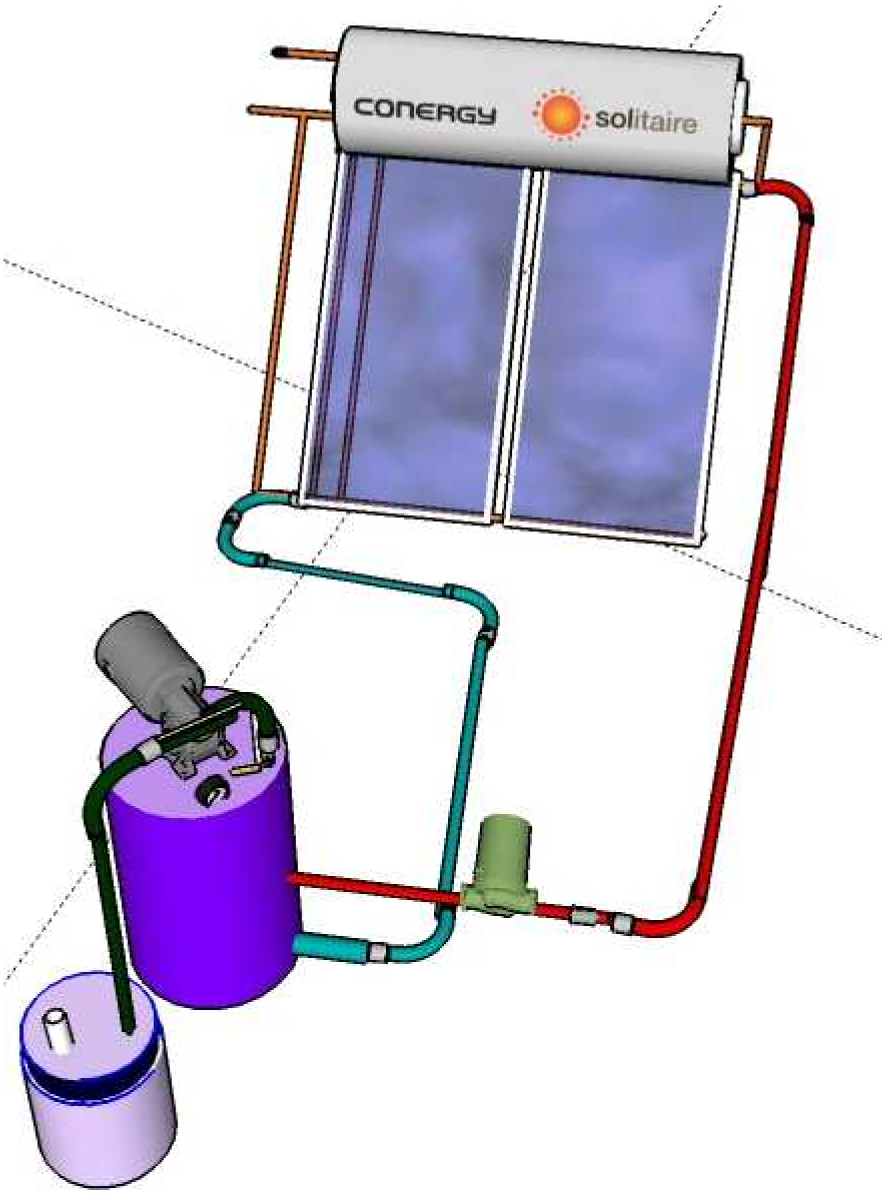
Three Dimensional view for prototype

Prototype operation manual:

1. Inlet ball valve.
2. Electric motor with gear (mixer).
3. Pressure gauge.
4. Digester.
5. Outlet valve.
6. Gas outlet.
7. Pressure relief valve.
8. Temperature controller.
9. Box contains contactor, timers, thermocouple temperature.
10. Circulating pump.
11. Water One way valve.

Operation Procedure:

1. Mixing about 10 kg of water with 10kg of animal waste manually out of the digester.
2. Inter it through the inlet pipe and close the inlet pipe.
3. Connect the pump cable to the electricity.
4. Connect the box cable to the electricity.
5. Check that all valves are closed and there is no leakage.
6. After the pressure start increase in the digester the gas outlet can be taken by the gas outlet valve and the gas then escape to the biogas collector (see appendix B).
7. Then the gas now is ready to use.



3D View of the process.

Chapter One

Introduction

1.1 General Outlook.

1.2 Importance of the Project.

1.3 Connections between the Project and Benefited Parties.

1.4 Literature Review.

1.5 Project Schedule.

1.6 Report Content.

Chapter One

Introduction

1.1 General Outlook

The need for energy is increasing continuously, because of the increase in demand of the fuel and high cost of life. The basic sources of this energy which we need in each house of Palestine is petroleum products and in addition of electricity; natural gas. All that energy sources are imported at high cost for our economy which slows our economy growth. So through this problem there is another alternative source of energy in Palestine which can be extracted from organic waste such as animal waste, vegetable waste human waste, Industrial waste and household waste in order to produce renewable source of energy called biogas.

Animal waste and human waste and household waste can effect human beings health and pollute the environment. The quantity of waste producing by animals and human generated per year in Palestine is very huge. For the matter of human waste and household waste and some of animal waste is problematic, because the disposal methods contaminate the environment and pose risk to public health.

The production of biogas from animal waste and human waste is one of the best ways to utilize it efficiently and economically. The data on the requirements of natural gas and availability of waste biogas sources in Palestine that the biogas obtained from animal waste and human waste may not replace natural gas completely. But, a substantial amount of natural gas can be obtained from animal waste and human waste, which would partly reduce the dependence on Import of natural gas.

Biogas is one of the best sources of energy. Gas from renewable biogas has the potential to reduce the amount of greenhouse gases and particulate matter. This is because the carbon contained in biogas derived gas biogenic and renewable.

1.2 Importance of the Project

1- The evaluation of animals wastes amounts possible to be used for the production of Biogas in Palestine.

2- The evaluation of economic and environmental reflections of the production of natural gas from the biological wastes locally.

3- Design and construction home scale unit to produce Biogas from animal's wastes.

4- The production of Biogas from animal's wastes locally and attempts to maximize the amount of biogas produced per unit time.
5- Produce biogas compression.
6- Supporting the contribution with local industry.

1.3 Connections between the Project and Benefited Parties

The project is oriented basically towards local industry, which gives information about the ability of production of biogas from animal waste and human waste. This project supports local industry from these sides:

1- Financial benefits from recycling of animals waste from organic waste.
2- Provide industrial investments changes in the field of collection and recycling of biogas wastes locally.
3- The help of public institution to develop policies required for health and environment protection in addition to encouragement and support local industry.

1.4 Literature Review

Biogas production and all related issue are well studied internationally. Sum literature review like [1], [2], [3], [4] and this history provide some studies about producing the alternative gas (biogas) from organic waste like animals waste and human waste with a limit study about the quantity of animal waste in small regions, a financial study to produce it.

1. Biogas production in India

The producing of biogas was developed India step by step from the last year to this day, the farmers organized themselves in a self sufficient system to produce biogas from organic waste.The examined the financial consideration to produce biogas they also determined the model of the processer, and studying the environmental impact.[1]

2. Biogas production at Michigan University

This project was done in University of Michigan in the mechanical Engineering department. The University of Michigan BLUE Lab was build a small-scale bio digester for testing optimal biogas production parameters and measuring gases produced. And they suggested about the required design and prototype a system to compress this gas.[2]

3. Chemical process of Biogas production

This project purposes to produce an alternative gas from used animals waste. They made a limit statistics of waste animals in small region in Palestine, they performed many experiments on the produced biogas and they compared many values such as, PH value, toxicity, with ASTM specifications.

4. Biogas in Palestine

This project was done in AL-Najah National University, the degree of master in science of physics by Ayoub Mohammad Eshraideh, under the supervision of DR. Muneer Abodeh and DR. Abdellatif Mohmed. This project purpose to study different properties of the biogas and the amount provides us with a great deal of information about digester. The floating drum type of digester was used in this project.[3]

5. Biogas continuous flow anaerobic digestion Project

It is planed to build home scale unit that can be used in every home by producing a biogas compression from animal waste and dealing with this gas and make suitable safety, should storage it and avoid any gas leakage.

1.5 Project Schedule

Table 1.1 Project time-schedule for the first semester

Process	**Week**														
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Collecting data and Literature															
Analyzing of data															
Industrial Plants Survey															
Home Survey															
Conclusion and Suggested Design															
Writing the Documentation															

Collecting data and literature were the first two stages, which started early and passed within eight weeks. Here, resources literatures, and researchers were carefully studied, discussed and analyzed.

Industrial plant and home survey took place as a third step, and started just after finishing collecting and analyzing data. Our team evenly distributed to cover the amounts of animals waste in Palestine, while the survey of home done by distributed a questionnaire which is our way to get the needed information.

Home survey and questionnaires results to be analyzed by simple proportional relations.

Table 1.2 Project time-schedule for the second semester

Process	**Week**														
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Belding the planet															
Planet Testing															
Biogas production															
Writing the Documentation															

1.6 Report content

This chapter presents the general idea of the project and its importance, in addition the field of application and specialization also, in addition conduct the literature reviews of the previous studies about this project, and this chapter also includes the time plan for all over the project.

Chapter two presents an introduction about biogas, historical perspective, the definition of biogas with the advantages of it, and inputs and their characteristics, then it describes anaerobic Digestion and the production of biogas, in addition of that the emission of biogas and finally Type of reactors

Chapter three present the basic summary of components required to build the anaerobic digester, in addition to that it provide principle of operation of the anaerobic digester, and presents factor affects biogas generation

Chapter four discuss the process of gas collector including compressed and storages and and purification it, that can be used in any home.

Chapter Two

Biogas

Content:

2.1 **Introduction**

The industrial revolution in the recent year with the increase in population increases the demand for energy in a continues manner, and as it is known, the main source of used energy now a days in all aspects of daily life is restricted at most within petroleum, natural gas, coal, hydro and nuclear energy .

petroleum biogas continues to be a major fuel world wide. The most of this is utilized in the transportation sector. The major disadvantage of using petroleum- based fuels is that, day by day, the fossil fuel reserves are decreasing. Another disadvantage is atmospheric pollution created by the use of petroleum like diesel, gasoline etc, combustion is a major source of greenhouse gas. So many industrial countries began to search about alternatives of petroleum-based fuel. They suggest using solar, wind, water, and biomass energy, as a result of several researches it was discovered that the animals waste can be used as fuel by putting it in digester to produce gas was called biogas.

2.2 Historical perspectives

The idea that rotting vegetable and animals dunk gives off a flammable gas has been understood since the ancient Persians. In modern times, the first sewage plant was built in Bombay in 1859; an idea that was brought to the UK in 1895, when the gas produced was used to light street lamps.

This system was developed in the UK and Germany in the early 1900s for the treatment of sewage. Centralized drainage systems were being installed in many towns in Europe and anaerobic digestion was seen as a means to reduce the volume of solid matter in the sewage. The gas produced was occasionally used as a source of energy, especially during the Second World War. From figure 2.1, several sewage plants operate vehicles by Fuelling up with biogas from one of the first anaerobic digester Dunedin, New Zealand, 1979. [4]

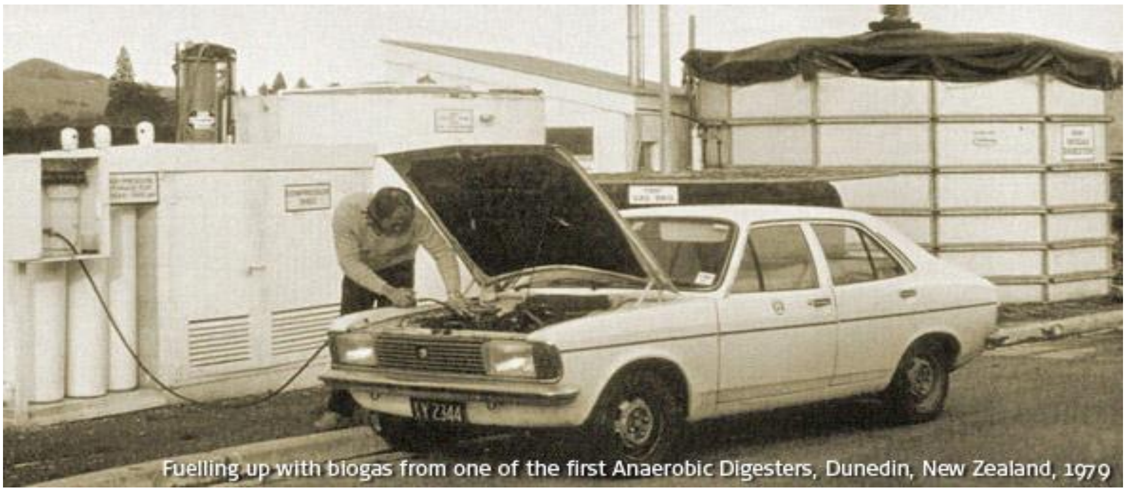


Figure 2.1: Fuelling up with biogas from one of the first anaerobic digester

.

The use of farm manure to generate methane was developed, again in Bombay, in the 1930s. It was only developed for use by Indian villagers in the early 1960s. This design, which used a floating steel gas drum, formed the basis of an ongoing Indian Government Outreach Programme to provide villagers with cooking fuel.

2.3 What is biogas?

Biogas is amixture of gas produced by methanogenic bacteria while acting upon biodegradable materials in an anaerobic condition. Biogas is mainly composed of 50 to 70 percent methane, 30 to 40 percent carbon dioxide (CO_2) and a small amount of other gases as shown in table 2.1. [5]

Table 2.1: Composition of biogas

Substances	Symbol	Percentage
Methane	CH_4	50 - 70
Carbon Dioxide	CO_2	30 - 40
Hydrogen	H_2	5 – 10
Nitrogen	N_2	1 - 2
Water vapor	H_2O	0.3
Hydrogen Sulphide	H_2S	Traces

Biogas is about 20 percent lighter than air and has an ignition temperature in the range of 650° to 750°. An odorless and colorless gas burns with clear blue flame similar to that of LPG gas. Its calorific value is 20 (MJ) per m^3 and burns with 60 percent efficiency in a conventional biogas stove and one cubic meter of biogas is equivalent to 1.613 liter kerosene or 2.309 kg of LPG or 0.213 kHz electricity and has an Air to Methane ratio for complete combustion is 10 to 1 by volume but explosion limit: 5 to 14 % in air.[5]

2.4 Inputs and their characteristics

Any biodegradable organic material can be used as inputs for processing inside the bio digester. However, for economic and technical reasons, some materials are more preferred as inputs than others are. If the inputs are costly or have to purchased, then the economic benefits of outputs such as gas and slurry will become low. Also, if easily available bio degrade able wastes are used as inputs, then the benefits could be of two folds: [6]

(a) Economic value of biogas and its slurry;

(b) Environmental cost avoided in dealing with the biodegradable waste in some other ways such as disposal in landfill.

One of the main attractions of biogas technology is its ability to generate biogas out of organic waste that are abundant and freely available. In case of Palestine, the cattle dung is most commonly used as an input mainly because of its availability. The potential gas production from some animal dung is given in table 2.2.

Table 2.2: Gas production potential of various types of dung [6]

Types of Dung	Gas Production Per kg Dung (m^3)
Cattle (cows and buffaloes)	0.023 - 0.040
Pig	0.040 - 0.059
Poultry (Chickens)	0.065 - 0.116
Human	0.020 - 0.028

In addition, other reasons for some materials are more preferred as inputs than others percentage of methane in biogas produced from animals and human waste.

2.4.1 Wet organic waste as feed for biogas plant:

1. Animal waste: manure, poultry manure, dung, sheep and goats, camels, horses, remnants of domestic birds and other.
2. Waste vegetable: corn, cotton rice straw, remnants of green houses, damaged fruit, and others.
3. Human waste: sewage, septic tanks, sewage and other.
4. Household waste: garbage, kitchen waste, food residue, residue processing fruits and vegetables and other.
5. Industrial waste: remnants of the dairy industry, food, drinks, and vegetable and fruit processing.

Since different organic materials have different bio-chemical characteristics, their potential for gas production also varies. Two or more of such materials can be used together provided that some basic requirements for gas production or for normal growth of methanogens are met. Some characteristics of these inputs, which have significant impact on the level of gas production, are described below. [6]

1. C/N Ratio

The relationship between the amount of carbon and nitrogen present in organic materials is expressed in terms of the Carbon/Nitrogen (C/N) ratio. A C/N ratio ranging from 20 to 30 is considered optimum for anaerobic digestion. If the C/N ratio is very high, the nitrogen will be consumed rapidly by methanogens for meeting their protein requirements and will no longer react on the left over carbon content of the material. As a result, gas production will be low. [7]

On the other hand, if the C/N ratio is very low, nitrogen will be liberated and accumulated in the form of ammonia (NH_4). NH_4 will increase the pH value of the content in the digester. A pH higher than 8.5 will start showing toxic effect on methanogen population.

Animal waste, particularly cattle dung, has an average C/N ratio of about 24 C/N ratio of some of the commonly used materials are presented in table 2.3.

Table 2.3: C/N Ratio of some organic materials[7]

Raw Materials	C/N Ratio
Duck dung	8
Human excreta	8
Chicken dung	10
Goat dung	12
Pig dung	18
Sheep dung	19
Cow dung/ Buffalo dung	24
Water hyacinth	25
Elephant dung	43

2. Dilution and consistency of inputs

Before feeding the digester, the excreta, especially fresh cattle dung, has to be mixed with water at the ratio of 1:1 on a unit volume basis (i.e. same volume of water for a given volume of dung).However, if the dung is in dry form, the quantity of water has to be increased accordingly to arrive at the desired consistency of the inputs (e.g. ratio could vary from 1:1.25 to even 1:2). [7]

The dilution should be made to maintain the total solids from 7 to 10 percent. If the dung is too diluted, the solid particles will settle down into the digester and if it is too thick, the particles impede the flow of gas formed at the lower part of digester. In both cases, gas production will be less than optimum.[7]

2.5General introduction to Anaerobic Digestion and the production of biogas

Anaerobic digesters (AD) is a biological process, which occurs naturally in environment with little or no oxygen. The microorganisms, which favor these environment, degrade organic matter and produce biogas, primarily methane and carbon dioxide. The unique ability of AD to provide both a treatment for organic wastes and a source of renewal energy.

Anaerobic digesters are commonly used for sewage treatment or for managing animal waste but almost any organic material can be processed in this manner, including waste paper, grass clippings, leftover food, sewage and animal waste.

It has two key advantages compared to competitive renewable energies. These are that it can utilize waste (and therefore heterogeneous biomass) as a feedstock and secondly the process is completely unobtrusive, unless there are accidental gas emissions, which are malodorous. The major disadvantage of anaerobic digestion, in common with other bio and fossil fuels, is the transport of feedstock and disposal of residuals after processing.

Biogas produced in anaerobic digesters consists of methane (50% –70%), carbon dioxide (30% –40%), and trace levels of other gases such as hydrogen, carbon monoxide, nitrogen, oxygen, and hydrogen sulphide. The relative percentage of these gases in biogas depends on the feed material and management of the process. [8]

The other product of AD is the digested, also referred to as the sludge or effluent. It can be rich in nutrients (ammonia, phosphorus, potassium, and more than a dozen trace elements) and, depending on the substrate digested and it is discuss the operation of anaerobic digesters in chapter 4.

2.6 Reactor types

2.6.1 Batch

Is the simplest, with the biomass added to the reactor at the beginning and sealed for the duration of the process. Batch reactors can suffer from odour issues, which can be a severe problem during emptying cycles. Although anaerobic treatment of animals waste has been adopted since the beginning of the twentieth century, yet conventionally, the anaerobic process is considered to be a slow process. Maintaining a high concentration of microbes in a reactor & preventing them from escaping with the effluents can obtain high rates of conversion.

2.6.1.1 Fixed Dome Plants

The fixed-dome plant consists of a digester with a fixed, non-movable gasholder, which sits on top of the digester. When gas production starts, the slurry is displaced into the compensation tank can see that from figure 2.2. Gas pressure increases with the volume of gas stored and the height difference between the slurry level in the digester and the slurry level in the compensation tank.[9]

Advantages:

Fixed – Dome Plants are the relatively low construction costs, the absence of moving parts and rusting steel parts. If well constructed, fixed dome plants have a long lifespan. The underground construction saves space and protects the digester from temperature changes. The construction provides opportunities for skilled local employment.

Disadvantages:

These are mainly the frequent problems with the gas-tightness of the brickwork gas holder (a small crack in the upper brickwork can cause heavy losses of biogas). Fixed dome plants are, therefore, recommended only where construction can be supervised by experienced biogas technicians. The gas pressure fluctuates substantially depending on the volume of the stored gas.

Even though the underground construction buffers temperature extremes, digester temperatures are generally low.

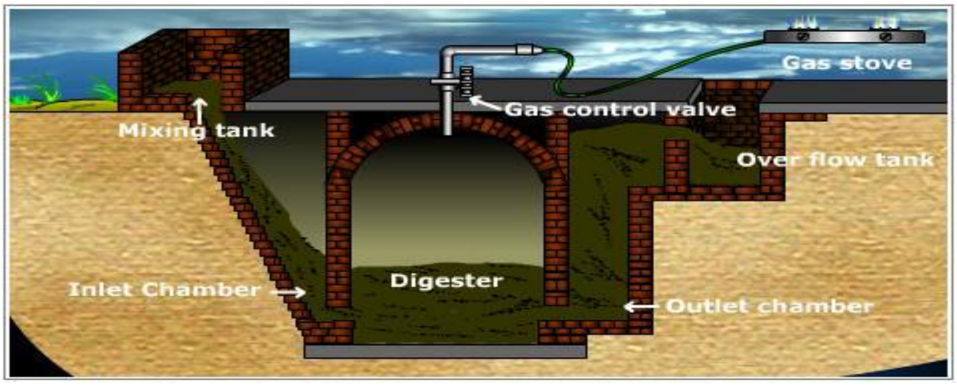


Figure 2.2: Fixed Dome Plants

2.6.1.2 Floating Drum Plants:

Floating-drum plants consist of an underground digester and a moving gasholder. The gasholder floats either directly on the fermentation slurry or in a water jacket of its own. The gas is collected in the gas drum, which rises or moves down, according to the amount of gas stored. The gas drum is prevented from tilting by a guiding frame. If the drum floats in a water jacket, it cannot get stuck, even in substrate with high solid content figure 2.3. [9]

Advantages:

Floating Drum Plants are the simple, easily understood operation the volume of stored gas is directly visible. The gas pressure is constant, determined by the weight of the gasholder. The construction is relatively easy, construction mistakes do not lead to major problems in operation and gas yield.

Disadvantages:

These Plants are high material costs of the steel drum, the susceptibility of steel parts to corrosion. Because of this, floating drum plants have a shorter life span than fixed-dome plants and regular maintenance costs for the painting of the drum.

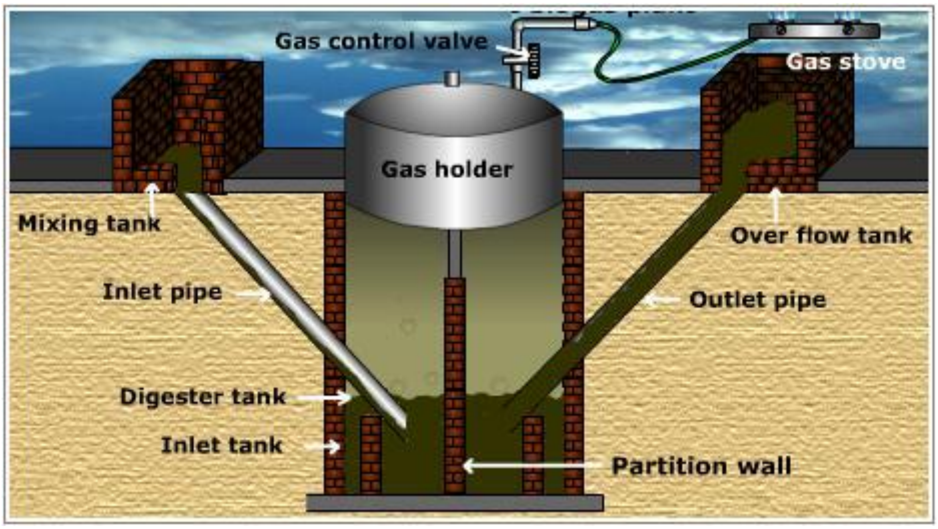


Figure 2.3: Floating Drum Plants

2.6.1.3 Balloon Plants

The balloon plant consists of a digester bag in the upper part of which the gas is stored. The inlet and outlet are attached directly to the plastic skin of the balloon. The gas pressure is achieved through the elasticity of the balloon and by added weights placed on the balloon (figure 2.4).[9]

Advantages:

Balloon Plants are low cost, ease of transportation, low construction sophistication, high digester temperatures, uncomplicated cleaning, emptying and maintenance.

Disadvantages:

It can be the relatively short life span, high susceptibility to damage ,little creation of local employment and, therefore, limited self-help potential.

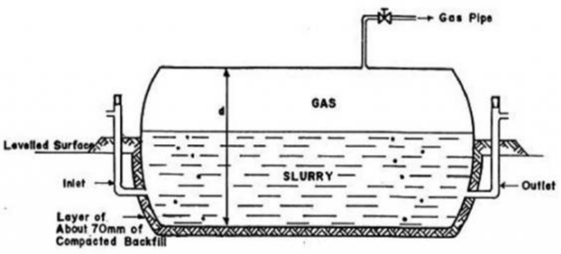


Figure 2.4: Balloon Plants

2.6.2 Continuous type

In the continuous process, which is the more common type, organic matter is constantly added to the reactor and the products are constantly removed, resulting in a much more constant production of biogas.

In continuously stirred tank reactors the content is continually charged and discharged and homogeneously mixed at all times. An agitator can be used to mix the contents; the power required for mixing varies according to the size and shape of the digester. Alternatively, in more innovative designs, mixing is performed by returning some of the biogas produced to the base of the reactor, so the bubbling gas causes the mixing, there by eliminating the need for moving parts inside the digester.

In this project, it is decided to build and design Continuous type of biogas And it will discuss this design in chapter 3.

Chapter Three

Biogas production and the operation of the Anaerobic Digester

Content:

3.1Introduction

The construction and production of biogas digester have become very important in recent years due to their wide advantage asymmetric study of different properties of biogas and its amount provides us a great deal of information about the digester. Thus, the appropriate nature and types of digesters are suitable for different area in Palestine.

The new design and the purpose of this anaerobic digester and other digesters are to produce combustible biogas, which can be burned to provide energy for a whole range of uses in this world. There is quite a bit of ideological interest in anaerobic digestion and biogas production, but in Palestine, there are a few attentions to this project. In general, many types of digester appeared in all the world, operated by conventional methods (fixed dome plate, floating drum plate, balloon type), but not sufficient to produce biogas, because of a longer Retention Time (RT) (also known as detention time) which is the average period that a given quantity of input remains in the digester to be acted upon by the methanogens. The RT in conventional methods needs more than 30 days to produce biogas.

The second and the third method for producing biogasare thestandard rate and the high rate.In the standard rate digestion process, the contents of the disaster are unheated and unmixed. Detention Time for standard rate digesters vary from 30 to 60 days. In high rate digesters, the contents are heated and mixed properly and the detention time is typically 15 days or less. A combination of the basic process known as the two-stage process. The function of the second stage is to separate the digested solids from the super liquor, however additional digestion and gas production may occur.

The purpose of this project is to design and build an anaerobic digester to achieve the following criteria, the design should:

- ❖ Be built and used as a safety home scale unite.
- ❖ Attempt to maximize the amount of biogas produced per unit time.
- ❖ Be a continuous flow anaerobic digester. Thishas been specified because it seems that this will be the most practical design for continuous operation in a farm situation.
- ❖ Be simple and easy to understand so that the average person is able to grasp the function and theory behind each component of the design with only a small amount of guidance. The idea here is to encourage people looking at the design to think and understand the requirements for controlling anaerobic digestion and the continuous flow model.
- ❖ Be a durable, compact, versatile design, which is capable of being shifted around if necessary to be displayed.
- ❖ To be operated with a minimum of monitoring, regulating, and adjusting (in other words, be easy to operate).
- ❖ Attempt to reduce time and money costs associated with maintenance.
- ❖ Attempt to minimize the cost of setting up and running the digester without compromising the performance of operation or the other specifications of the brief.
- ❖ Look aesthetically pleasing as another mechanism to effectively sell the concept!
- ❖ Provide acceptable amount of safety.

The gas produced in an anaerobic digester is hopefully combustible, there are safety issues to firstly considered when designing and operating the digester. Adequate ventilation is required and be best way to ensure that the environment around the digester is well ventilated and to site the digester in an open area, preferably outdoors. This means that the digester must be weatherproof. Any possible ignition sources should be kept well away from the digester. For this reason, the location of the digester on a farm should be in a low traffic area away from maintenance sheds etc.

3.2 Basic Summary of components Required to build the anaerobic digester

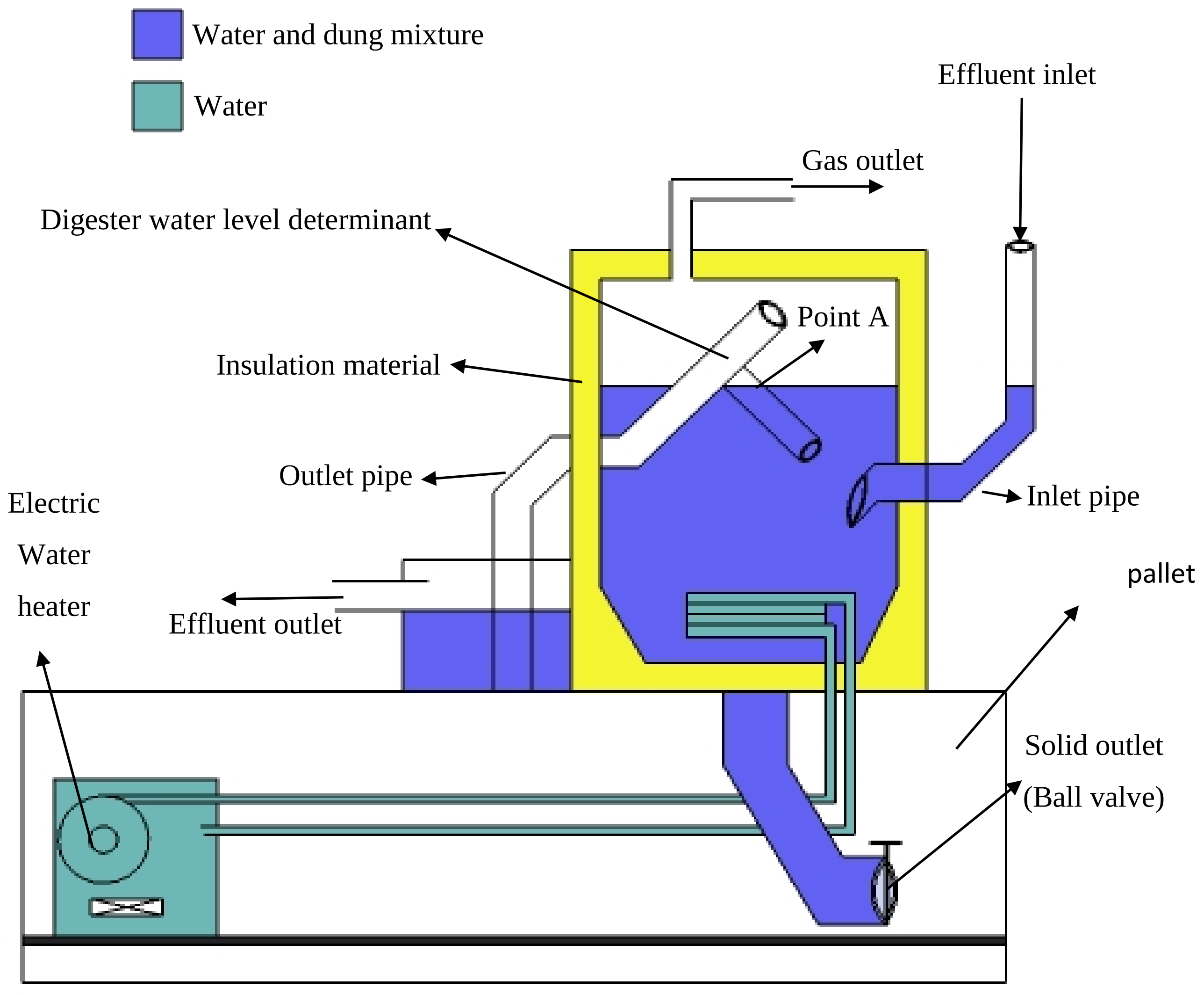


Figure 3.1: A proposed design (sketch) of the continuous flow digester.

3.2.1 Heating system - digester heating

The constant process temperature inside the digester is one of the most important conditions for stable operation and high biogas yield. Temperature fluctuations, including fluctuations are determined by season and weather conditions as well as local fluctuations. Large fluctuations of temperature lead to imbalance in the anaerobic process. [10]

A small electric heating element and a small pump, which will circulate warm water through a coil of 13 mm poly pipe inside the digester figure 3.4. Ultimately, on a large-scale digester, it would be best to use the gas produced from the digester to provide heating energy for the operation.

But in the Palestinian society and because of the high cost of living and to provide design with lowest possible cost, it will not use the pump and electric heating for two reasons first reasons to reduce project cost and the second reason the thermal efficiency is low.

It is decided that it use electric water Heaters from taking two pipes and connected it to the digester to maintain a constant temperature inside the digester.

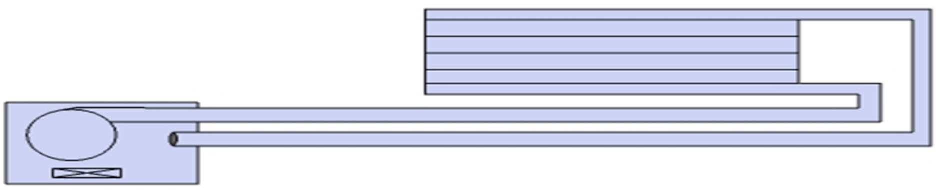


Figure 3.2: Shows the heater used inside the digester

3.2.2 The Digester Material

For the purpose of this project it will attend to design a home scale unite from this target it is planned to design small size anaerobic digester and it contains a two layers of material (insulation material, sheet of metal).

The yellow shaded area around the digester in figure 3.1 represents insulation. Insulation is mainly used to reduce heating costs and to help maintain a homogeneous temperature within the digester. In addition, it will use a sheet metal layer around the insulation as weatherproofing.

3.2.3 Ball Valve

It is located in the end of the outlet pipe under the digester in the bottom box, it closes when the digester is operating, and opens for purpose of out the solid after the biogas generation.

3.2.4 Inlet Pipe

The effluent inlet pipe is located on the right side of the digester. (figure 3.5), it is notice that the inlet pipe not cut off squarely where it ends inside the digester the microbes within the effluent solution are producing gases, which bubble up through the liquid to the gas cavity above. If the inlet pipe cut off squarely, gas may accumulate in the pipe and escape to the outside environment. And it also notice that the inlet pipe extends upwards beyond the level of the effluent in the digester. [11]

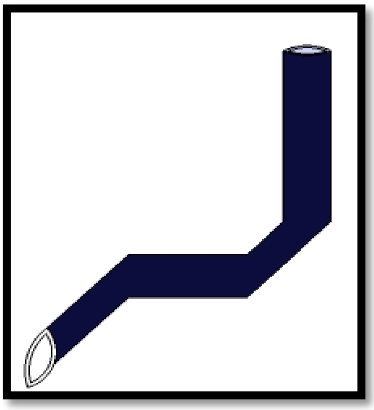


Figure 3.3: Shows the inlet pipe.

3.2.5 Outlet pipe

Outlet pipe enters the digester and extends up toward the top where there is a tee piece as seen in figure 3.6. The stem of the tee goes back down below the effluent level to avoid collecting surface scum from the effluent and to prevent gas escaping if pressure increases in the system. The point where the outlet pipe meets this pipe, the level of the effluent in the digested will be determinewith no pressure in the system (this point is labeled point A in Figure 3.1). The other side of the tee piece, which left open above the effluent level, serves two purposes. It allows any gas, which accumulates in the pipe to escape to the gas cavity, and it prevents a siphoning effect from occurring when the outlet pipe used to out the solid (Figure 3.6). [12]

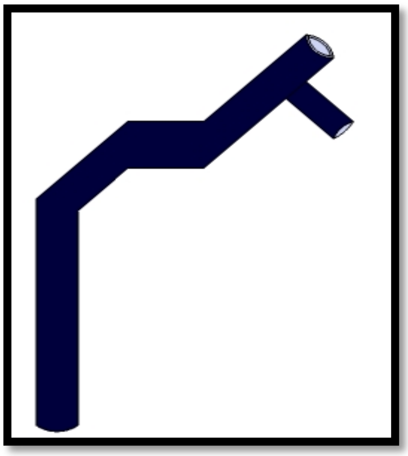


Figure 3.4: Shows the design of the outlet pipe.

3.2.6 Mixer

There are several benefits of mixing: maintaining contact between bacteria and the feedstock, even distribution of heat, avoiding scum and sediment formation, release of biogas bubbles trapped in the substrate.

3.2.7 Pressure Relief Valve

To allow pressure that exceeds a safe level to escape from the digester. And relief valve in this design is mounted in the cover of the digester. The manufacturer's specifications should provide the following information to enable the operating staff to control the gas system safely:

- The system works with normal operating pressure (mm water gauge).
- The rated gas flow capacity of the pipes.

3.2.8 Gas Pressure Gauges

Indicates the pressure in the gas system and assists in locating any blockages in the line. If a blockage occurs, a pressure reading downstream will register a lower pressure than that of a gauge upstream.

3.3 Principle of Operation of Continuous Anaerobic Digester

This type of digester designed for the purpose of producing the maximum amount of biogas by offer the required conditions of bacteria in active the chemical process. In addition, the purpose of this report is not to provide a method for the fabrication of the project produced (although a basic materials list will provide). [13]

Rather, this report will aim to identify key aspects of the design, concentrating on their function and the theory behind their function. Therefore, the aim of this report is to provide the reader with a basic explanation of the mechanics of a small, continuous flow anaerobic digester (figure 3.1)

The first step mixture is prepared out the digester manually by mixing water with the cattle dung (about 3/2 water with 1/3 dunk), or organic waste should be completely immersed in water and enter the mixture inside the digester by inlet pipe and continue this operation until the mixture appears on the left side of the digester in the effluent outlet (figure 3.1) and stop the entering if the outlet cavity fill with the mixture.

When the mixture of water and matter waste enter inside the digester,anaerobic microorganisms are starting reaction and digest organic materials (figure 3.7).

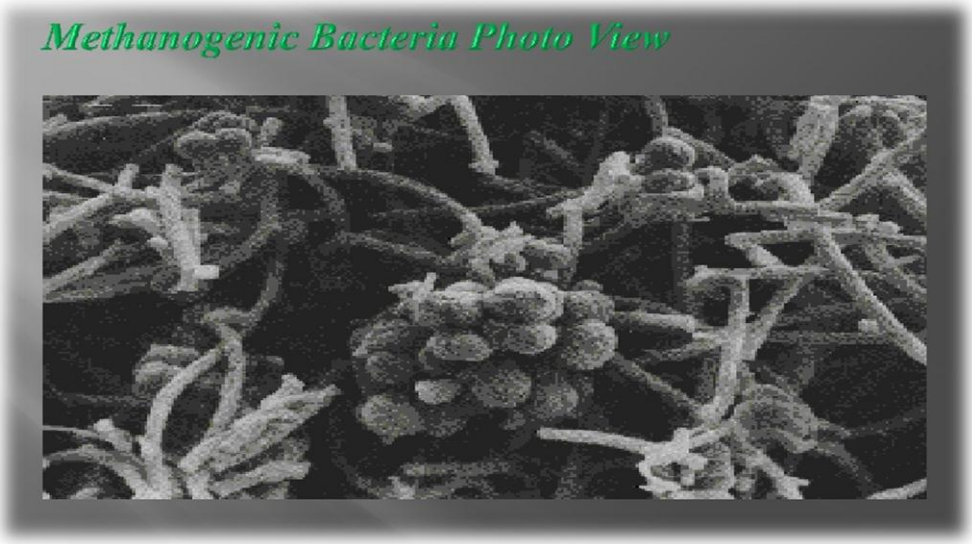


Figure 3.5: Methanogenic bacteria photo view.

In the absence of oxygen, anaerobic digestion breaks down readily degradable organic matter in a series of steps, where the product of one step becomes the substrate for the next step (figure 3.8). High lights the four main process steps: hydrolysis, acidogenesis, acetogenesis, and methanogenesis.

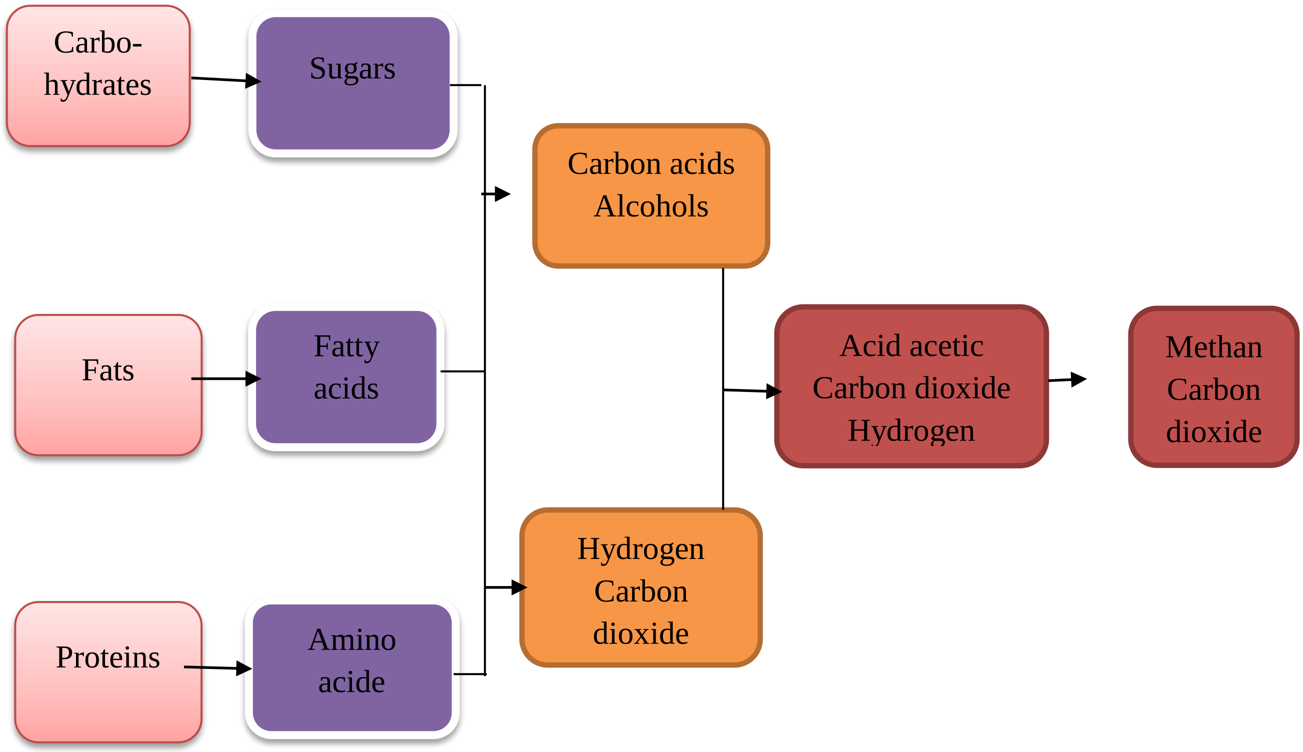


Figure 3.6: The main process step of AD.

3.3.1 Hydrolysis

The initial step is usually considered to be “hydrolysis”. The waste materials of animal origins consist mainly of carbohydrates, lipids, proteins and in organic materials. Large molecular complex substances (polymers) are solubilized into simpler ones (mono- and oligomers) with the help of extra cellular enzyme released by the bacteria. This stage is also known as polymer breakdown stage.[14]

Lipids ⟶ *fatty acids, glycerol*
Polysaccharide ⟶ *monosaccharide*
Proteins ⟶ *amino acids*

3.3.2 Acidogenesis

During acidogenesis, the products of hydrolysis are converted by acidogenic (fermentative)bacteria into methanogenic substrates. Simple sugars, amino acids and fatty acids aredegraded into acetate, carbon dioxide and hydrogen (70%) as well as into volatile fatty acids(VFA) and alcohols (30%).[14]

3.3.3 Acetogenesis

Products from acidogenesis, which can not be directly converted to methane by methanogenic bacteria, are converted into methanogenic substrates during acetogenesis. VFA and alcohols are oxidised into methanogenic substrates like acetate, hydrogen and carbon dioxide. VFA, with carbon chains longer than two units and alcohols, with carbon chains longer than one unit, are oxidized into acetate and hydrogen. The production of hydrogen increases the hydrogen partial pressure. This can be regarded as a "waste product"of acetogenesis and inhibits the metabolism of the acetogenic bacteria. During methanogenesis, hydrogen is converted into methane. Acetogenesisand methanogenesis. usually run parallel,as symbiosis of two groups of organisms.[14]

3.3.4 Methanogenesis

The production of methane and carbon dioxide from intermediate products is carried out bymethanogenic bacteria. 70% of the formed methane originates from acetate, while the remaining 30% is produced from conversion of hydrogen (H) and carbon dioxide (CO_2), according to the following equations:[14]

Acetic acid ⟶ *methane + carbon dioxide*
Hydrogen + carbon dioxide ⟶ *methane + water*

This operation will provide an empty cavity in the top of the digester that the gas can accumulate, the gas formed in the bottom of the digester under the water by anaerobic digestion by bacteria and move to the top of the digester which bubble up through the liquid to the gas cavity above and its pressure will build up smoothly.

When the digester is operating, there is an amount of oxygen existing in the digester and in the first three days, this period is sufficient toget out the oxygen, and the production of gas will mean that the system will be under a small amount of pressure. This gas pressure may push the effluent level of the mixture down, forcing the effluent back up the pipe. Therefore, outside the digester; the inlet pipe must extend above the effluent line to contain the liquid under operating conditions. Inside the digester, the inlet pipe must also extend a sufficient distance below the effluent line to allow for the situation where the gas pressure increases, forcing the effluent level down (Figure 3.9 under pressure).

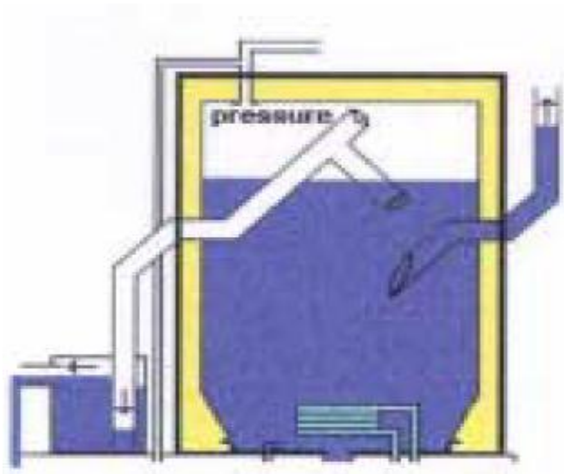


Figure 3.7: Showing the effect of the pressure on the system.

The outlet pipe feeds into the effluent retention sump (figure 3.1). This device acts as a large 'S' bend. It provides a reserve of liquid in the case of a vacuum occurring inside the digester, liquid will be sucked into the digester rather than air (Figure 3.10). Such a situation may arise when the solid valve opened. It is of paramount importance that outside air (containing oxygen) not allowed to get inside the digester. This is logical when you consider that anaerobic digestion means digestion in an environment absent of oxygen and finally the compressor used to re-circulate gas through the digester for the purpose of agitation.

Figure 3.8: Shows the effects of vacuum on the system.

The following chart summarize the prosess operations:

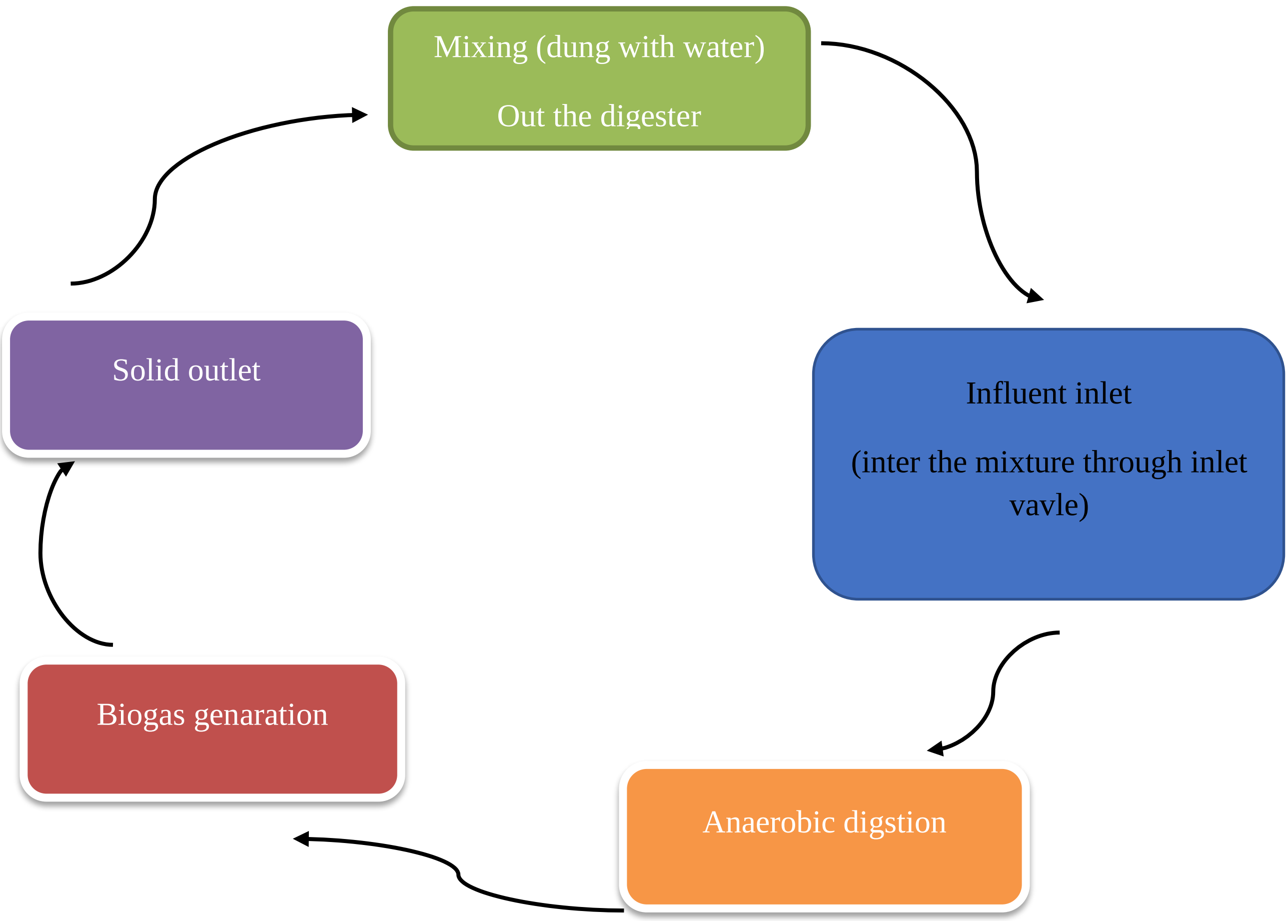


Figure 3.9: Shows the flow chart of the process

3.4 Factor affects biogas generation

Many facilitating and inhibiting factors play a significant role role in the process. Some of these factors are discussed below.

3.4.1 Temperature

The gas production is inactive in extremely high and low temperatures. The optimum temperature is 35 C^0. When the ambient temperature goes down to 10 C^0, gas production virtually stops. Satisfactory gas production takes place in the mesophilic range, between 25 $C^0$to 35 C^0. when the temperature is increasing the gas production is increasing between temperature 18 C^0 degrees to 35 C^0(figure 3.12).But when the temperature located between 37 C^0 to 45 $C^0$the gas production is decreasing.[15]

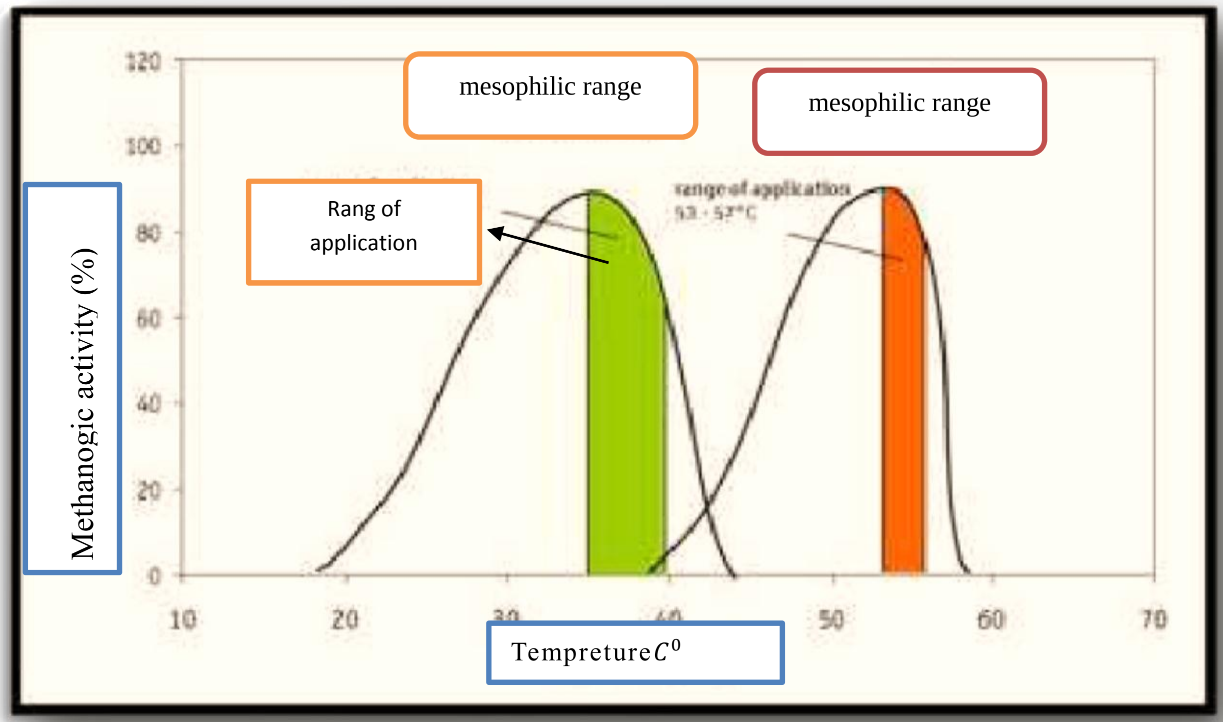


Figure 3.10: Relationships between temperature and gas production.

3.4.2 A carbon-nitrogen ratio

Expresses the relationship between the quantity of carbon and nitrogen present in organic materials, Materials with different C/N ratios widely differ from Biogas production by 12 of materials, table 3.1 show the material used and C/N ratio.[7]

Table 3.1: Shows the material used and C/N ratio.[7]

Material	C/N ratio	Material	C/N ratio
Fruit Waste	35:1	Vegetable Waste	12-25:1
Grass Cuttings	12-25:1	Food Waste	20-30:1
Tree Leaves	30-80:1	Fresh Sewage	11:1
Cow Manure	20-25:1	Tree Wood Chips	500-700:1
Paper	170-200:1	Fat & Oil	90:1
Poultry Manure	15:1	Rice Straw	50:1

Two of the most important nutrients are carbon and nitrogen and a critical factor for the raw material choice is the overall C/ N ratio. In practice, the best ratio of a C/N ratio to producing biogas is close to 30:1 for achieving an optimum rate of digestion. Then from the table 2.1 we choice cow manure because it is available and it contains 20-25:1 C/N ratio this ratio is nearly too optimum ratio of producing biogas and if the nitrogen content in ammoniacal form is less the bacterial, growth is affected and the process slows down.[7]

3.4.3 PH value

The pH in a biogas digester is also a function of the retention time, then the optimum biogas production achieved when the pH value of input mixture in the digester is between six and eight. In addition, efficient digestion occurs at a pH near neutrality. However, low pH inhibits growth of the methanogenic bacteria, gas generation, and Bicarbonate of soda can added to maintain a consistent PH.

3.4.4 Retention time

Retention time (also known as detention time) is the average period that a given quantity of input remains in the digester to act upon by the methanogens. In a cow dung plant, the retention time calculated by dividing the total volume of the digester by the volume of inputs added daily,the retention time is also dependent on the temperature and up to $35\ C^0$, the lower the retention time. At high temperature, bio-digestion occurs faster, reducing the time requirement, the lower the retention time. Thus a 20 liter digester is fed at 4 liters per day so that the volume of digester is constant the retention time is 5 days.[15]

3.4.5 Proportion of solids to water

This was found to be not more than 10 per cent for optimum operation of digester to ensure sufficient decomposition of ‘volatile solids’ and rate of production of gas.

3.4.6 Volumetric organic loading rate

This can be expressed as kg Vs per volume per day based on the percentage weight of organic matter added each day to the digester volume. Digester loading rate percentage= (Percent of organic matter in feed)/ (Retention Time).

Chapter four

Gas collecting and safety

Content:

4.1 Introduction

In previous chapters light is concentrated on the anaerobic digester and its material well used. In this chapter, the light well concentrated in the gas collector that used to hold the gas output from the digester, and the safety used in this type of digester.

4.2 Biogas collector

The gas outlet on top of the digester that discussed in chapter 3 in figure 3.2 goes to the gas inlet on the collector below (Figure 4.1)

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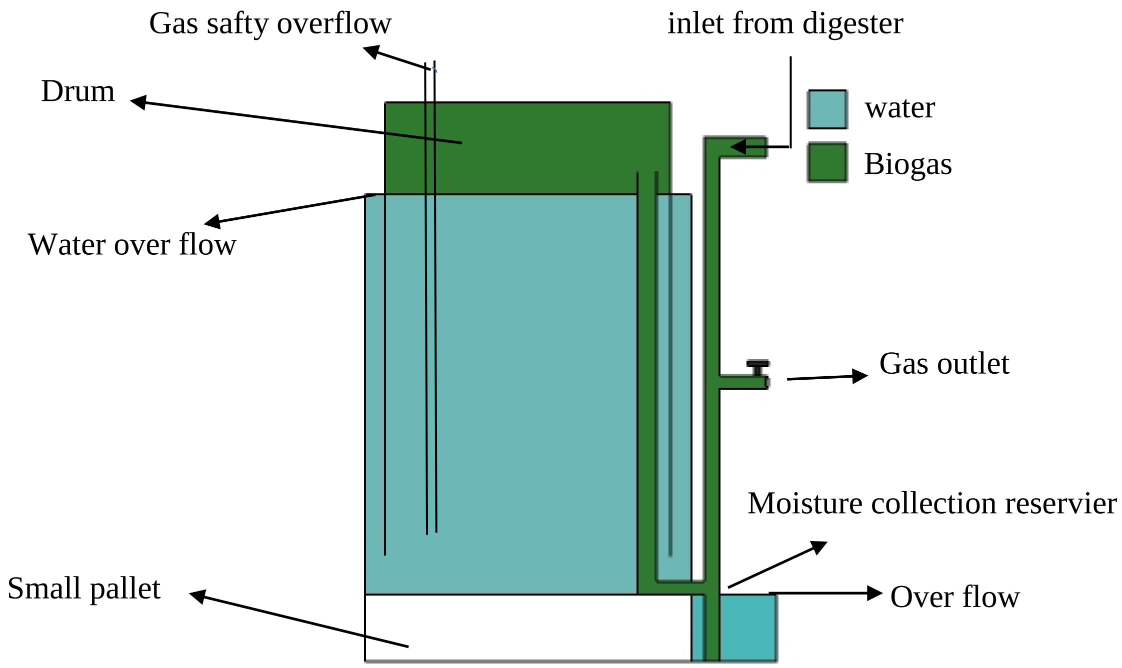

Figure 4.1: A plan diagram of the gas collector used in this project.

The gas collector shown above is a drum that is inverted and inside another drum filled with water. The water acts as a barrier, preventing the gas from escaping from the drum. This device provides a simple gas storage area with a variable volume. The real beauty of this design is that no gas pump is required to shift the gas from the digester to the collector. It simply fills from gas pressure built up in the digester. This part of the design offers significant savings in initial capital costs, running costs, and monitoring costs.

When the gas flows out of the digester and into the collector inlet pipe, it is moving from a warm environment to the cooler outside temperature. The warm environment allows the air to be highly humidified. As the temperature falls, the moisture is no longer able to be suspended in the air and it condenses on the sides of the pipe. If this moisture is allowed to accumulate in any part of the system, it can cause blockages which may lead to increased pressure and possibly even ruptured pipes or vessels. For this reason there is a moisture collection reservoir at the bottom of the inlet pipe in figure 4.1. This device serves two purposes to capture and prevent any build up of water in the tube and to prevent the gas collection vessel from sucking air in the case that a vacuum is created in the pipe. The moisture collection vessel has an overflow to prevent too much water from collecting.

The gas collection tube has an overflow tube which allows excess gas to be vented off well above ground level. This is simply a tube which extends from about 5Omm above the bottom rim of the gas collection drum and travels up through the top of the drum. When the collection drum is full, the bottom of the overflow tube is exposed from the water and the gas is able to escape. The tap shown in figure 4.1 is the main gas outlet where the gas can be tapped off and utilized.

4.3 Safety used in this type of digester

The gas produced in an anaerobic digester is very dangerous, there are safety issues to firstly consider when designing and operating the digester. This requires a many list of safety measures that should be read with great care before a biogas system is built. [14]

- When opening a biogas digester for cleaning or repairing, don't use candles or smoke cigarettes. For light inside the digester.
- If the rotten egg smell of biogas is noticed in a room, immediately open doors and windows in order to get rid of the trapped gas before looking for the leak. And it should shut the gas off at the gate valve just after the gas storage tank to keep biogas from feeding the fire.
- All piping and equipment must be sealed properly to prevent gas from escaping to the outside.
- Children must be taught not to play with fire close to biogas systems, in case there are any gas leaks which could cause a fire or explosion.
- Brass gate valves and pipes used in biogas systems must be of a lead-free type. The hydrogen sulfide in biogas will destroy lead, which will cause gas leaks.
- No smoking or oper flames should be allowed near digesters and gas storage tank, especially when chicking for gas leaks.

Planet Design

Chapter Five

Content:

Chapter Five

Planet Design

5.1 Biogas Overview

With today's increasing demand for fuel and it's continually rising cost , biogas is becoming an extremely attractive fuel option .also , to deal with the problem of pollutions , there is a need for alternative fuel in today's society. Biogas is alternative fuel has low emissions during used and manufacturing, and it is attractive solution because of the low cost.

Biogas process consist of mixing animal waste and water manually out of the digester (in the ratio 1:1) and organic waste should be completely immersed in water and enter the mixture inside the digester by inlet pipe. When the mixture of water and matter waste enters inside the digester, anaerobic microorganisms are starting reaction and digest organic materials In the absence of oxygen and take into account the all optimum condition such as heating at tempreture of 35 and with insulating digester tank and using a mixing system to distribute the heat inside the tank. anaerobic digestion breaks down readily degradable organic matter in a series of steps, where the product of one step becomes the substrate for the next step High lights the four main process steps: hydrolysis, acidogenesis, acetogenesis, methanogenesis. And after few days the biogas will produced and used in for different usage.

5.2 Individual component

5.2.1 Choosing Tank material (Digester)

Different materials can be used for tanks which are compatible with chemical materials, it is recommended to use stainless steel or carbon steel. [16]

In Palestine, many various types of material that can be used for making metallic tanks are available; the most available one with low cost is the galvanized steel. Galvanized steel is called so, because it is coated with zinc. This choice is to reduce production costs and to force people use available equipment's within the same region.

Thus; this plant is to be designed using galvanized steel tanks. Also, it should be realized that those tanks can be operated within a suitable life time that can last for about 10 years, those tanks can firmly resist corrosion and decay effects in addition to rigidity. The thickness of outer surfaces of tanks is about 2 mm to serve the previous target.

For choosing the thickness of tanks are used: [26cbb]

Sy: for steel is 334 MPa

$$P = \rho \times g \times h; \qquad 5.1$$

Where:

P: pressure on walls (pa).

g: Gravity acceleration (m/s^2).

ρ: Density of gas (Kg/m^3).

H: height of highest tank which is settling tank (m).

$$\sigma = p \times \frac{(d_i + t)}{2t} \qquad 5.2$$

Where:

t: thickness of tank (m).

d_i: Inside diameter (m).

σ: Tangential stress (Pa).

By taking factor of safety is 2 which is enough to achieve a safe operation for workers around the tanks:

$$F.S = \frac{Sy}{\sigma_{all}} \qquad 5.3$$

$$\Rightarrow \sigma_{all} = \frac{Sy}{F.s} = 167\ MPa$$

To calculate pressure due to the Wight of the mixture:

$P = 920 \times 9.81 \times 2.02 = 18230.9\ Pa$ = 0.1823 bar.

To calculate the pressure in the tank due to the gas generation:

Theoretical calculations on the volume of biogas and the concentration of methane and carbon dioxide can be done using the following general equation (the Buswell equation) based on the content of C, H, O, N and S: [17]

$$C_cH_hO_oN_nS_s + \{(4c - h - 2o + 3n + 2s)/4\}\ H_2O \rightarrow$$
$$\{(4c - h + 2o + 3n + 2s)/8\}\ CO_2 + \{(4c + h - 2o - 3n - 2s)/8\}\ CH_4 + nNH_3 + sH_2S$$

By Taking the Protein ($C_5H_7O_2N$) and from Buswell equation:

c=5, h=7, o=2, n=1 (s=0)

$C_5H_7O_2N$ + [(4 × 5-7-2 × 2+3 × 1) /4] H_2O → [(4 ×5-7+2 × 2+3 × 1) /8] CO_2+ [(4x5+7-2 × 2-3 × 1) /8] CH_4

This lead to the following equation:

$C_5H_7O_2N$ + 3 H_2O → 2.5 CO_2 + 2.5 CH_4

And from this equation 1 mol protein ⟺ 2.5 moles CH4.

From the Ideal gas law:

$$P \times V = n \times R \times T \qquad 5.4$$

Where:

P: absolute pressure of the gas (atm).

V: volume (L)

n = amount of substance (mol).

R = gas constant (L atm/ K mol).

T = absolute temperature (K).

$$P = \frac{\mathbf{nRT}}{\boldsymbol{V}} = \frac{\mathbf{2.5 \times 0.0821 \times 313}}{\mathbf{12.3}} = 5.268 \text{ bar}$$

Total pressure = 0.1823 + 5.268 = 5.5 bar = 5.5 × 10^5 pa

To find the thickness of the tank:

$167 = 5.5 \times 10^5 \times \frac{(1.2+t)}{2t} \Rightarrow t = 4.6 \times 10^{-3} = 0.0046m.$

So in order to reserve the rigidity of the tank and to take into account the life surface of these tanks. We choose the thickness 5 mm. In addition to that is available in the market.

5.2.1.1 The family digester design

To select the appropriate digester with simplest design, single stage digestion, low construction cost and lower technical problems that could be operated and repaired by the family itself. The best choice is a continuous System with total volume 500 liters. The proposed design of family .digester is shown in the figure (5. 1).

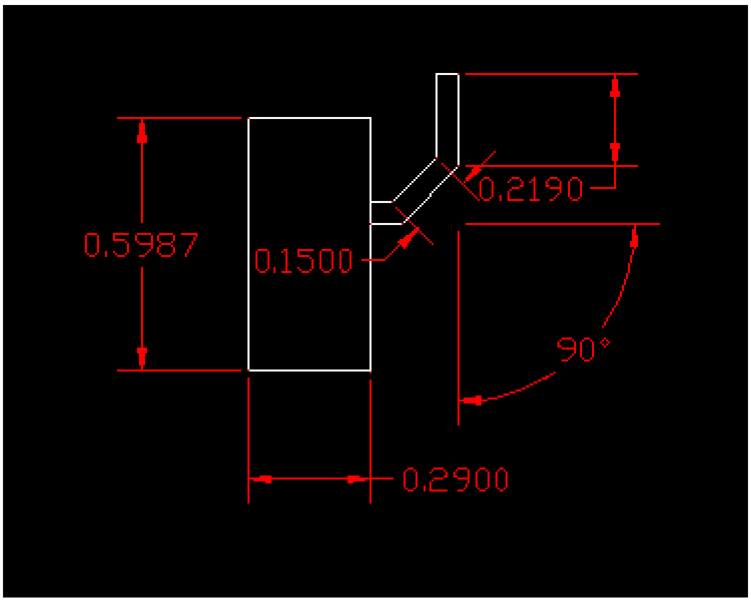

Figure 5.1: simplest design

5.2.2 Main Storage Tank (Biogas collector)

The gas collector is a drum that is inverted and inside another drum filled with water. The water acts as a barrier, preventing the gas from escaping from the drum. This device provides a simple gas storage area with a variable volume. The real beauty of this design is that no gas pump is required to shift the gas from the digester to the collector. It simply fills from gas pressure built up in the digester. This part of the design offers significant savings in initial capital costs, running costs, and monitoring costs. This tank handle up to about 20 liters water and gas, the two tanks have diameter of 25 cm and height of 40 cm and the upper tank have a diameter of 20 cm, and height of 40 cm.

5.2.3 Heating system

To calculate the required amount of water to heat the mixture from 20 C^0 to 37 C^0 , the amount of heat mixture is equal to amount of heat by water. [18]

$$Q_{mix} = m_{mix} \times C_p \times (\Delta T) \quad 5.5$$

Where:

Q: Heat flow in (KJ).

C_p: Specific heat at constant pressure (KJ/kg.C).

ΔT: The temperature difference.

$$knowing\ that\ m = 10\ kg\ and\ for\ cattle\ manure\ \ C_p = 1.9925$$

T_1 = 20,T_2 = 37

Q_{mix} = 20 × 1.9925 × (37-20) = 677.45KJ.

$$Q_{water} = m_{water} \times C_{p(\,water)} \times (\Delta T) \qquad 5.6$$

$$667.45 = m_{water} \times 4.18 \times (50-35)$$

m_{water} =10804.62 kg

By assuming the heating time 6 hour:

$$\dot{m} = \frac{10804.62}{6} = \frac{10804.62}{6 \times 3600} = 0.5\ kg/s$$

And we know the water density (ρ) @ 40 C^0 equal 992.2 kg/m^3

$$\text{V} = \frac{m}{\rho} = \frac{0.5(kg)}{992.2\ (\,kg/m^3)} = 5 \times 10^{-4}\ m^3/s$$

= 0. 5 L/s = 30 L/min = 8 gpm.

5.2.3.1 Pump Selection

Because the used of solar heating and heat exchanger inside the digester and it have medium temperature (40 °C- 60°C), so it is needed to have a recirculating pump. That recirculating pump can be selected due to main parameter that should be calculated first. Such parameters are as follows:

- Flow rate
- Total head
- Power required

The velocity of the fluid = $\frac{Q}{A}$ 5.7

There is a simple calculation for computing the total head and the flow rate in order to select a suitable pump for this purpose. [19]

Flow rate (Q) = 8 gpm.

Total head= Head loss due to friction + static head

$$= \frac{5 \times 10^{-4}\ (m^3/s)}{\frac{\pi D^2}{4}} = \frac{5 \times 10^{-4}\ (m^3/s)}{4.9\times 10^{-4}} = 1.02 \text{ m / s}$$

Where:

Q: Flow (m^3).

A: Pipe area (m^2).

$$\text{Re} = \frac{V \times D}{v} \quad 5.8$$

$$= \frac{1.02 \times 0.025}{0.727\times10^{-6}}$$

= 35075.6 so the flow is turbulent

Where:

Re: Reynolds number.

V: Fluid velocity (m/ s).

D: Pipe diameter.

v: kinematics viscosity of water (m^2 /s)

Relative roughness = D/ε = $\frac{0.025}{1.5\times 10^{-4}} = 166.6$ 5.9

Then from moody diagram by knowing **D/ε, Re** we can get the ***f*** value: Figure (5.1)

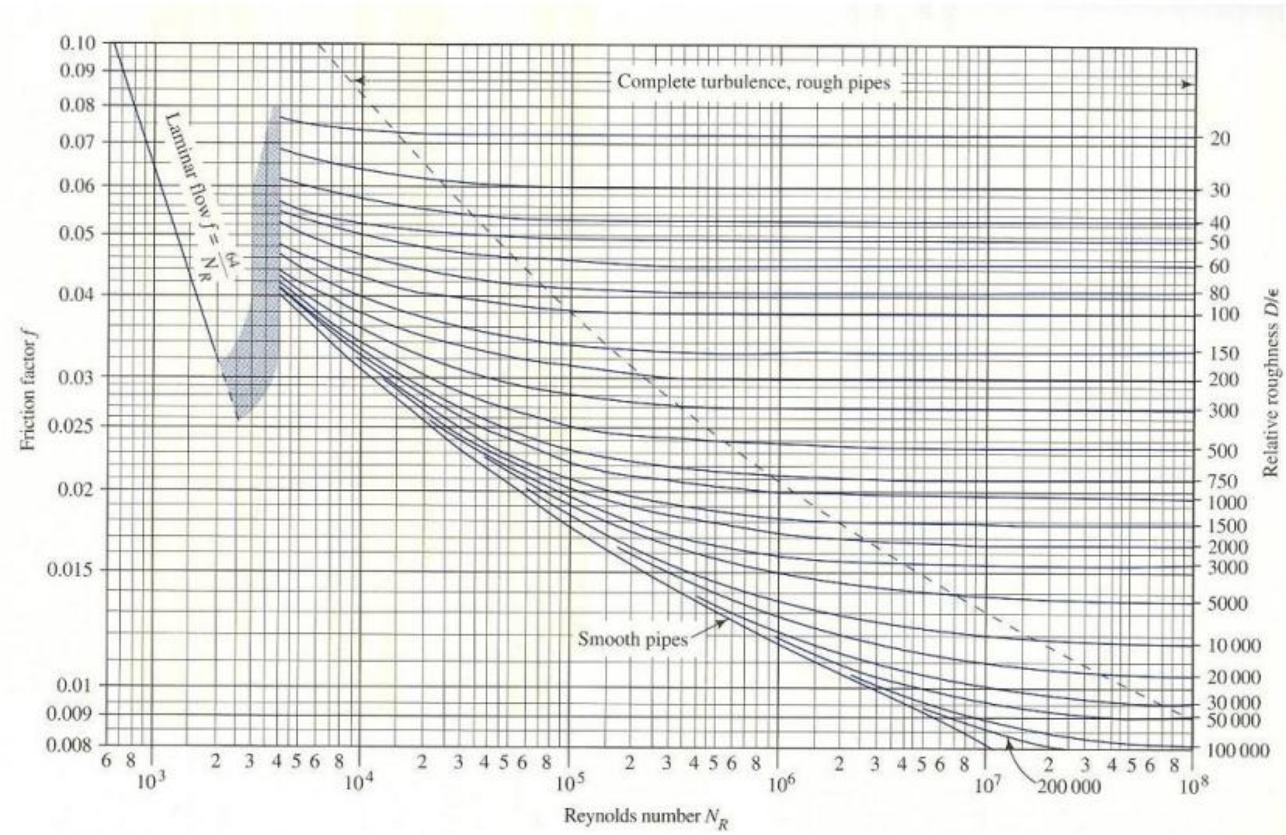

Fig 5.2 Moody diagram

f = 0.032 from moody diagram.

$Le = \frac{K\times D}{f} = \frac{0.75\times 0.015}{0.032}$ = 0.351 m 5.10

Where:

Le: Factor of fitting.

F: Friction factor for laminar flow.

K: Factor of fitting.

$H_1 = f \times \frac{L}{D} \times \frac{V^2}{2g}$ 5.11

H_{static}= 0.0 for recirculation's pump.

Where:

H_1: Kinematics head (m).

The equivalent length is

L = 11 + 5 + 2 × (7 + 4× 0.351) = 34m

$H_L = \frac{0.032 \times 34 \times 1.02^2}{0.025 \times 2 \times 9.81}$ = 2.3 m.

H_{static}= 0.0 for recirculation's pump.

Total head = 2.3 m.

A pump is required, having the following characteristics:

H= 2.3 m, Q= 8 gpm

P (kW) = $\frac{P \times Q}{600}$ 5.12

Where:

P: power (KW).

P: Pressure (bar).

Q: Flow rate (L/min).

$$P\ (kW) = \frac{1 \times 27}{600} = 0.045\ kW.$$

5.2.4 Mixer design:

The time required to insure a complete mixing process of the animal waste with a water about 60 minute, when a speed of 45 rpm.

In order to choice a mixer for required process there are a some main equations that should be used to determine specification rpm speed and dimensions of the mixer.Fig5.2 [20]

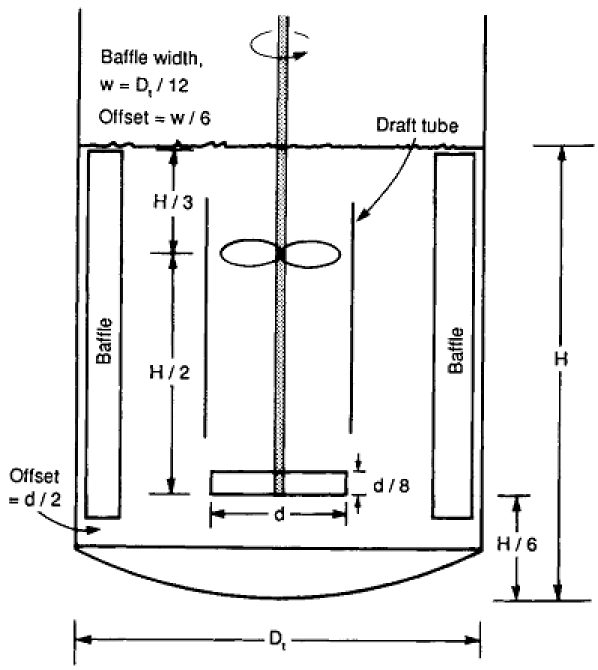

Figure 5.3 Schematic design of tank provide with mixer

The following figure illustrates the relationship between power number and Reynolds number, each curve has impeller blade width /diameter ratios, the power number can be calculated as being proportional to this ratio.fig5.3

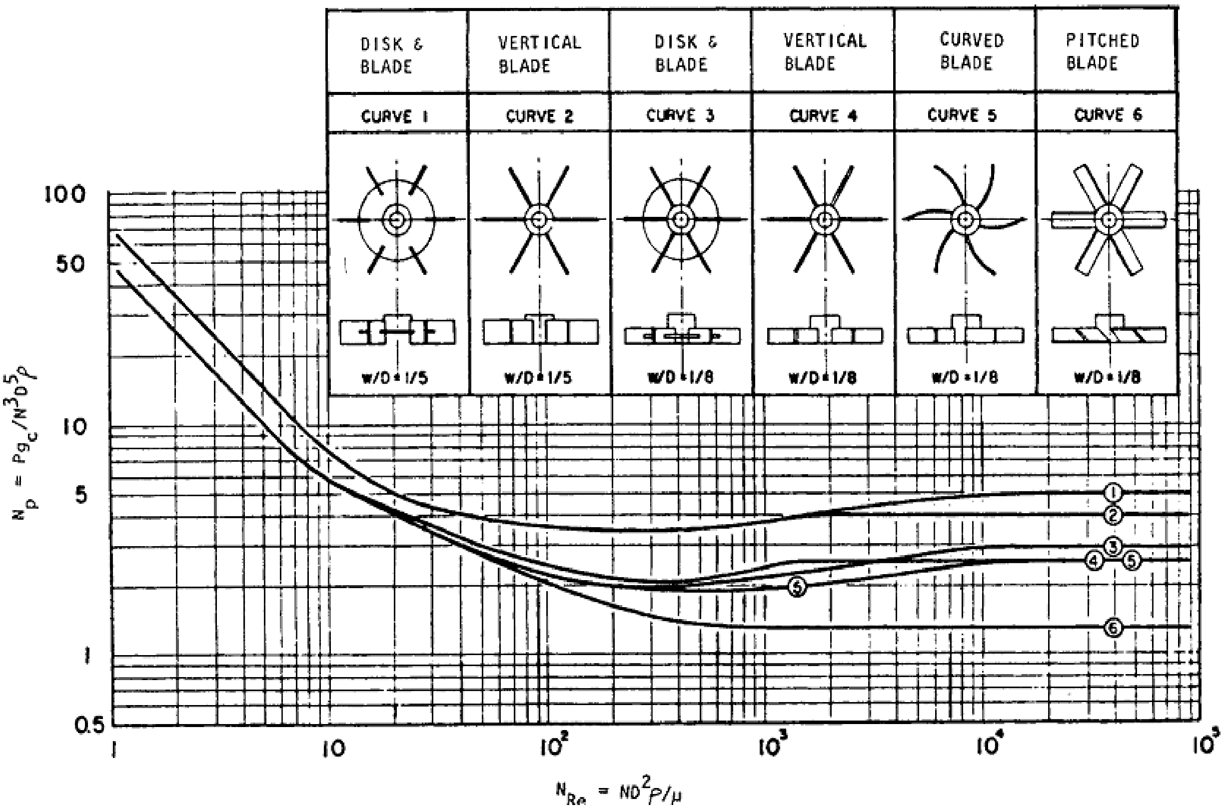

Figure 5.4 Correlations for mixing power number vs. Reynolds number

The following figure show the relationship between Reynolds number with impeller discharge coefficient, also; each curve appeared on the same graph has a ratio between impeller diameter and tank diameter.

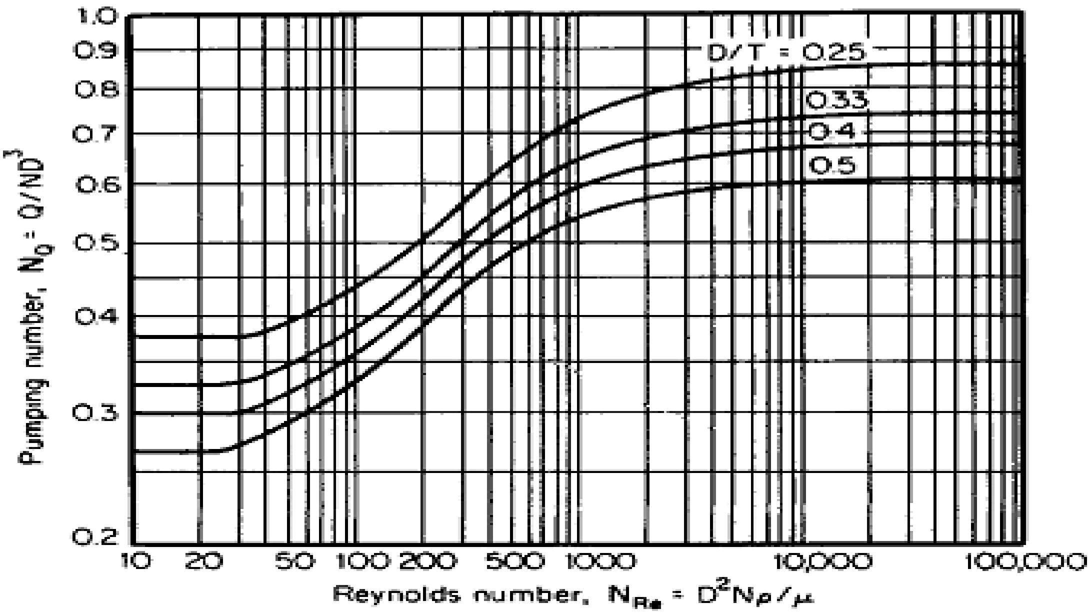

Figure 5.5 Discharge coefficients for 45 pitched blade turbine vs. impeller

Reynolds Number

For standard design of blender and its relationship with dimensions of mixing tank:

Z= T 5.13

$T = \left(\frac{4\times V}{\pi} \right)^{\frac{1}{3}}$ 5.14

$D = \frac{T}{3}$ 5.15

$W = \frac{D}{8}$ 5.16

$D = \frac{T}{3} = \frac{0.48}{3} = 0.16$ m.

$W = \frac{D}{8} = \frac{0.48}{8} = 0.06$ m.

Where:

Z: Height of oil level in the tank (m).

T: Diameter of mixture (animal dunk with water) in tank (m).

D: impeller diameter (m).

W: impeller thickness (m).

$$S = 2 \times \pi \times r \times \tan(\beta)$$

$$R = \frac{D}{2} = \frac{16}{2} = 8 \text{ cm.}$$

$$S = 2 \times \pi \times 0.08 \times \tan(45) = 0.03$$

$$C = \frac{Z - S}{2} \qquad 5.17$$

Where:

S: distance between the two impeller's centroid (m).

C: The distance between the bottom of the tank and the first impeller.

β: blade titling angle .

$$N = \frac{Q}{N_{Q \times D^3}} \qquad 5.18$$

Where:

N: impeller speed rev/sec.

Q: Pumping capacity (discharge flow m^3 / s).

N_Q : Impeller discharge coeffitent.

D: impeller diameter (m).

Assume that Q = 0.0016 m^3/s, & Re > 4× 10^3

From figure 5.5:

N_Q = 0.55

N = $\frac{0.0016}{0.55 \times 0.16}$ = 0.72 rev/s.

D = $\sqrt[3]{\frac{Q}{N_{Q} \times N}}$

= $\sqrt[3]{\frac{0.0016}{0.55 \times 0.72}}$ = 0.16

To chick the validity of Reynolds number whether it is right or not

Re = $\frac{\rho \times \mathrm{N} \times D^3}{\mu}$ 5.19

$= \frac{992.2 \times 0.72 \times 0.16^2}{0.653 \times 10^{-3}} =$ 280064

And so , it is concluded that Reynolds number holds .

The required power for the mixer can be calculated as the following:

$$P = 10^{-3} \times N_P \times \rho \times N^2 \times D^5 \quad 5.20$$

$= 10^{-3} \times 1.687 \times 700 \times 0.72^3 \times 0.16^5$ = 186.5 W $\cong 0.25\ HP$

Where:

P: Power dissipation (kW)

N_p : Dimensionless power number.

P: Density of oil (kg/m^3).

N: impeller speed (rev/sec).

D: impeller diameter (m).

Power number is a result of multiple two factors from figure 5.4 and figure 5.6.

N_p = 0.55 × 1.25 = 0.6875

By assuming mechanical losses due to the use of gears:

P= 1.25 × 187 =234W

5.2.5 Design of helical coil heat exchanger

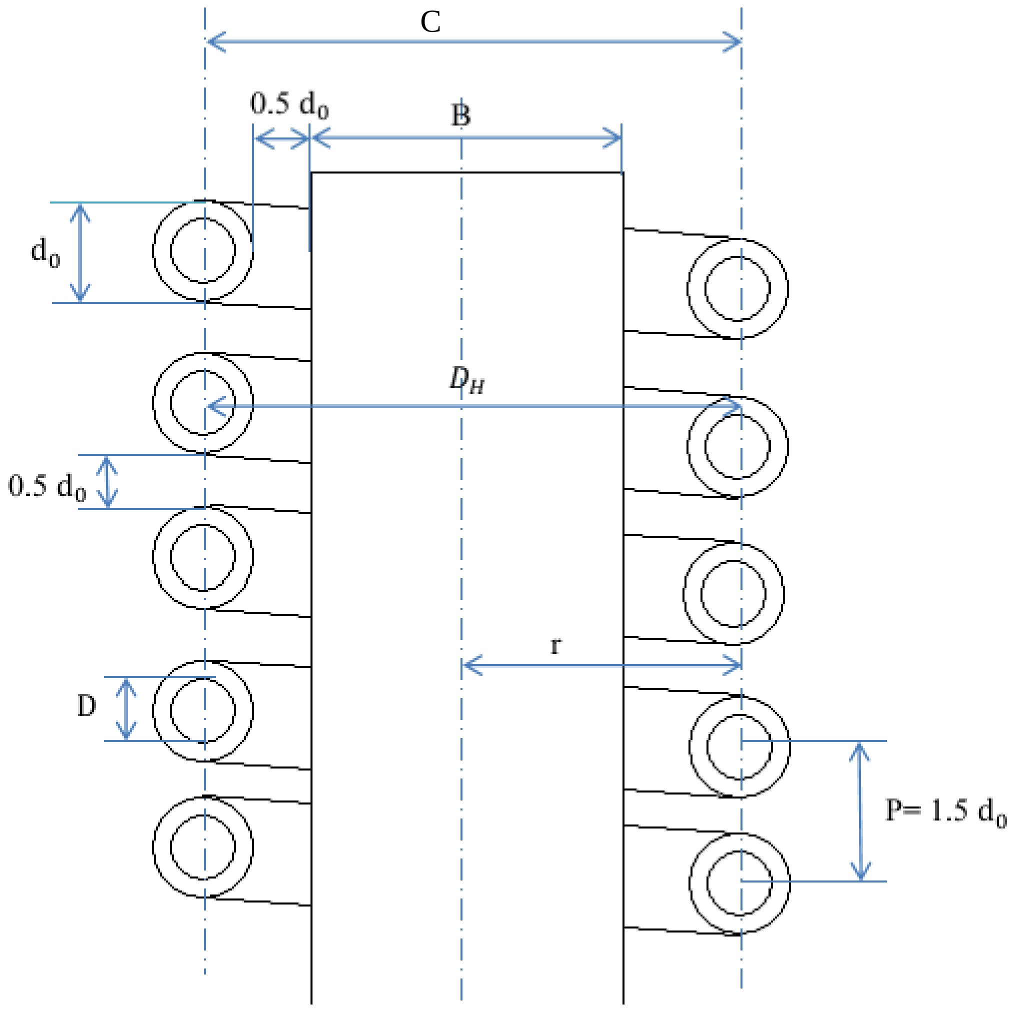

Fig 5.6 Schematic cutaway view of an HCHE

- **The geometry of the HCHE: [21]**

C = 0.157 m, D = 10 mm, B = 0.121 m, d_0 = 12 mm, P = 18 mm, D_H = 0.133 m, r = 0.0665.

To calculate the shell side heat transfer coefficient h_0 ,

$$L= N \times \sqrt{(2\,\pi \times r)^2 + P^2} \qquad 5.21$$

L= $N \times \sqrt{(2\,\pi \times 0.0665)^2 + 0.018^2}$ = 0.418 N.

Where:

N: theoretical number of turns of helical coil.

R: The average radius of helical coil.

L: The length of the helical coil needed to form N turns.

The volume available for fluid flow in the annals

$$V_f = V_a - V_c \tag{5.22}$$

Where:

V_f: Volume available for fluid flow in the annulus (m^3).

V_a: Volume of annulus (m^3).

V_c : Volume occupied by N turns of coil.

$$V_a = \frac{\pi}{4}(C^2 - B^2) \times P \times N \tag{5.23}$$

= $\frac{\pi}{4}(0.157^2 - 0.121^2) \times 0.018 \times N$

= 1.414×10^{-4} N.

$V_c = \frac{\pi}{4}(d_0^2 \times L)$

= $\frac{\pi}{4}(0.012^2 \times 0.418\,N) = 4.727 \times 10^{-5}$.

$V_f = 9.413 \times 10^{-5}$

The shell side equivalent diameter is:

$$D_e = \frac{4 \times V_f}{\pi \times d_0 \times L} \quad 5.24$$

Where:

D_e : Shell side equivalent diameter of coil (m).

d_0 : The outside diameter of a coil (m).

$$= \frac{4 \times 9.413 \times N \times 10^{-5}}{\pi \times 0.012 \times 0.418 \times N} = 0.0238 \text{ m.}$$

The mass velocity of the fluid is:

$$G_s = \frac{M}{\frac{\pi}{4}(C^2 - B^2) - (D_{H2}^2 - D_{H1}^2)} \quad 5.25$$

$$= \frac{1800}{\frac{\pi}{4}(0.157^2 - 0.121^2) - (0.145^2 - 0.121^2)} = 632466.6 \text{ kg}/m^2h$$

Where:

M: Mass flow rate of fluid (kg/h).

G_s : Mass velocity of fluid (kg/m^2h).

D_{H2}: Inside diameter of helix (m).

D_{H1}: Outside diameter of helix (m).

The Reynolds number is:

$$N_{Re} = \frac{D_e \times G_s}{\mu} \quad 5.26$$

Where:

N_{Re}: Reynolds number.

D_e: Shell side equivalent diameter of coil (m).

G_s : Mass velocity of fluid (kg/m^2h).

μ: Fluid viscosity (kg/ (m).(h)).

$$= \frac{0.01 \times 632466.6}{2.4} = 2529.866$$

$$h_0 = 0.6\,\frac{D_e}{K} \times\ N_{Re}^{0.5} \times\ N_{Pr}^{0.31} \qquad 5.27$$

Where:

D_e: Shell side equivalent diameter of coil (m).

N_{Re}: Reynolds number.

N_{pr}: Prandtle number.

$$N_{Pr} = \frac{C_P \times \mu}{k} \qquad 5.28$$

$$= \frac{0.998 \times 2.5}{0.495} = 5.04.$$

$$h_0 = 0.6\,\frac{0.495}{0.0238} \times\ 2529.86^{0.5} \times\ 5.4^{0.31} = 1036.35.$$

Compute h_{io}, the heat transfer coefficient inside the coil.

The fluid velocity is:

$$u = \frac{q}{A_f} \qquad 5.29$$

Where:

q: volumetric flow rate of fluid (m^3/h).

A_f: Cross section area of the coil(m^2).

U: fluid velocity (m/h).

$$q = \frac{M}{\rho} = \frac{1800}{992.2} = 1.814\ m^3/\text{h}. \qquad 5.30$$

$$A_f = \frac{\pi}{4}\ (D^2)$$

$$= \frac{\pi}{4}\ (0.01^2) = 7.8\times\ 10^{-5}\ m^2.$$

$$u = \frac{1.8}{7.8 \times 10^{-5}} = 23256.4 \text{ m/ h}.$$

the Reynolds number (tube side then):

$$N_{Re} = \frac{D \times U \times \rho}{\mu} \qquad 5.31$$

$= \dfrac{0.01 \times 23256.04 \times 992.2}{2.5}$ = 92300.

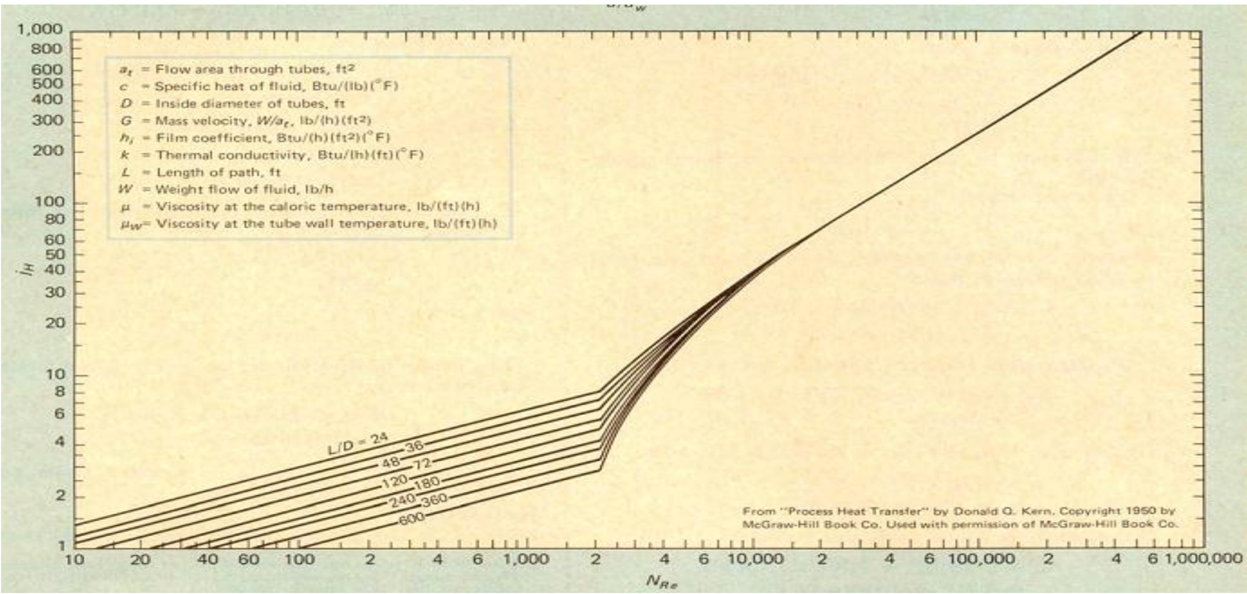

Figure 5.7 : Colburn factor vs, reynold number for tube side heat transfer .

From figure 5.1 the Colburn factor for heat transfer (J_H) equal 230

the heat transfer coeffisiont inside straight tube based on inside diameter (h_i)

$$h_i = J_H \times \frac{K}{D} \times N_{pr}^{\frac{1}{3}} \qquad 5.32$$

Where:

J_H: Colburn factor for heat transfer.

h_i: Heat transfer coefficient inside straight tube based on inside diameter (kcal/$h.m^2$.°C).

K: thermal conductivity of fluid (kcal/$h.m$.°C).

$= 230 \times \frac{0.495}{0.01} \times 5.04^{\frac{1}{3}}$ = 19519.85 Kcal/ (h) (m^2) (C^0)

the heat transfer coeffisiont inside the coil tube (h_i) corrected for coil.

h_{ic} =h_i [1 + 3.5 ($\frac{D}{D_H}$)] 5.33

Where:

h_{ic}: The heat transfer coeffisiont inside the coil tube (h_i) corrected for coil based on inside diameter Kcal/ (h) (m^2) (C^0).

D_H: Average diameter of helix.

=19519.85 [1 + 3.5 ($\frac{0.01}{0.133}$)] = 24655.57 Kcal/ (h) (m^2) (C^0) .

The heat transfer coefficiont based on out side diameter of the coil

h_{i0} =h_{ic} ($\frac{D}{d_0}$) 5.34

Where:

h_{i0}: The heat transfer coeffisiont inside the straight tube (Kcal/ (h) (m^2) (C^0).

h_{ic}: The heat transfer coeffisiont inside the coil tube (h_i) corrected for coil based on inside diameter Kcal/ (h) (m^2) (C^0).

=24655.57 ($\frac{0.01}{0.012}$) = 20546.14 kcal/(h) (m^2) (C^0)

To calculate the overall heat transfer coeffisiont it should find the thikness of the coil wall :

X = ($\frac{d_0 - D}{2}$)

Where:

X: Thickness of coil wall (m).

$= (\frac{0.012 - 0.01}{2}) =$ 0.001 m.

The fouling factor ,R_t & R_a ,depend on the nature of the liquid , presence of suspended matter in the liquids the operating tempreture and velocities of the fluids , in the case , both R_t & R_a are 8.2×10^{-4} kcal/(h) (m^2) (C^0) .The thermal conductivity of copper is k_C = 14 kcal/(h) (m^2) (C^0).

Using eq:

$$\frac{1}{U} = \frac{1}{h_0} + \frac{1}{h_{io}} + \frac{X}{K_c} + R_t + R_a \qquad 5.35$$

$$\frac{1}{U} = \frac{1}{1036.35} + \frac{1}{20546} + \frac{0.001}{344} + 1.04 \times 10^{-4} + 1.04 \times 10^{-4}$$

= 815.7

where :

U: Overall heat transfer coeffiont kcal/(h) (m^2) (C^0).

h_o: Heat transfer coefficient outside coil (kcal/$h.m^2$.°C).

h_{i0}: The heat transfer coeffisiont inside the straight tube (Kcal/ (h) (m^2) (C^0).

K_c:thermal conductivity of the coil wall (Kcal/ (h) (m) (C^0).

X: Thickness of coil wall (m).

to determine the required area:

$$A = \frac{q}{U \, \Delta t_c}$$

5.36

Where:

A: area of heat transfer (m^2).

Q: heat load (kcal/h).

U:Overall heat transfer coeffiont kcal/(h) (m^2) (C^0).

Δt_c: Corrected log-mean-tempreture diffrance (C^0).

$$\Delta t_{lm} = \frac{[(Tin_{water} - Tin_{mixture}) - (Tout_{water} - Tout_{mixture})]}{\ln((Tin_{water} - Tin_{mixture})/(Tout_{water} - Tout_{mixture}))} \quad 5.37$$

$$= \frac{[(50 - 20) - (35 - 32)]}{\ln((50 - 20)/(35 - 32))} = 10\ ℃$$

To account for rependiculer flow, the correction factor is 0.99, so that

$\Delta t_c = 0.99 \times 10 = 9.9$ ℃

The heat load is :

$A = \frac{Q}{U\ \Delta t_c}$

To find Q:

$Q = m \times C_p \times (\Delta T)$ 5.38

$= 1800 \times 0.998 \times (50 - 35)$

= 26946 Kcal/h

The required area is :

$A = \frac{26946}{815.7 \times 9.9} = 3.34\ m^2$

The number of turns of coil required :

$$N = \frac{A}{\pi \times d_0 \times (\frac{L}{N})} \quad 5.39$$

$$N = \frac{3.34}{\pi \times 0.12 \times (\frac{0.418 \times N}{N})} = 11$$

$$H = N \times p + d_0 \quad 5.40$$

$= 11 \times 0.018 + 0.012 = 0.21$ m.

L = $0.4189 \times N = 4.6\ m.$

Where:

N:theoritical number of turn of helical coil.

H: hight of the cylender (m).

5.2.6 Pipe selecting

In this project, a galvanized steel pipes where used due to low cost, available in local market, 1 inch diameter , with fitting 1 inch diameter also ,PVC piping can be used also but for safety and provide higher service life it is better to select galvanized steel piping .

5.3 Plant safety

Like any project, safety must be applied to prevent risks for human and environment, since this project used a high flammable material .sun of the rules that may be apply are :

1. By using the relief valve when the pressure on the tank access to maximum limit, the relief valve will open.

2. A space of firing required around the tank for fire fighting access.

3. Ventilation system.

4. No other operations in the room with the equipment.

5. using the over flow tube in the biogas collector.

5.4 Project prototype

Prototype has been implemented to represent the process of biogas production it has a two tank , digester and collector tank respectively in addition to heating system ,mixing system and pump .The prototype has a biogas production range of about 40 liter . The dimensions and the operating manual are mentioned in appendices. (For detail see appendix).

Chapter six

Biogas Testing

Content:

Chapter six

Biogas Testing

6.1 Introduction

This chapter aims to provide an indication that produced biogas can be used an alternative fuel. Thus, it must be passed through several specification test; these tests are mainly based on ASTM standard, and compared with those for commonly used biogas. In ASTM standard, physical and chemical properties are measured and compared with reference standards that related to biogas.

The ASTM tests for biogas are several; in this project only basic tests were obtained from Petropal experimental lab. With help of eng. Nancy sayara, the head of lab. Given the lack of the required instruments. Note that all biogas sample from animal waste.

6.2 Specification Tests of Biogas

The basic tests as follows:

- PH test.
- Pressure Relief Valve test.
- Leakage test

6.2.1 PH Test

The pH in a biogas digester is also a function of the retention time, then the optimum biogas production achieved when the pH value of input mixture in the digester is between six and eight. In addition, efficient digestion occurs at a pH near neutrality. However, low pH inhibits growth of the methanogenic bacteria, gas generation, and Bicarbonate of soda can added to maintain a consistent PH.

This test aimed to determine the retention time that the methanogenic bacteria start to produce the biogas,

Figure 6.1 PH meter

Apparatus

Sample of mixture (animal waste and water), PH meter, Beaker.

Test Procedure:

1- Prepare the sample of mixture, and prepare the ph tester.
2- Connect the electrode to the ph tester.
3- Put the electrode into the sample and read the ph value in the ph tester.

Results:

Table 6.1 shows the results for PH of mixture sample (animal waste and water).

Table 6.1 PH Test Results

Sample	PH
A	8.3
B	8
C	7.7
D	7.6
E	7.5

The average ph value = 7.6

The optimum biogas production achieved when the pH value of input mixture in the digester is between six and eight. So this test result is acceptable. (For detail see appendix B)

6.2.2 Pressure Relief Valve test

Pressure relief valve allows pressure that exceeds a safe level to escape from the digester. And relief valve in this design is mounted in the cover of the digester. This test aimed to calibrate the relief valve at 5 bars.

Figure 6.2 Pressure relief valve

Apparatus

Compresses, pressure gage.

Test Procedure:

1- Turn on the compresses and put the compresses air pipes to the outlet valve in the digester.
2- Allows the air compresses to flow to the digester and take into account checks the gas pressure gage.
3- When the pressure in the digester exceeds a safe level, the relief valve allows the air to escape from the digester.

Results:

Relief valve is open when the pressure in the digester access to 5 bars.

6.2.2 Leakage test

This test aimed to check any leakage of air in the system.

Apparatus

Compresses, pressure gage, soap.

Test Procedure:

1- Compressed the digester at 4 bar.
2- Check all fitting, bearing, screw, valves and flange for leakage.
3- Mixed the soap with water and put it to all parts of digester such as flange, fitting.

Results:

It found that the air are leaks from the flange a under the digester and gear flange it solves this problem by using rubber gasket above the flange, and under the gear flange and using VRT adhesive.

6.3 Gas Production

The data used in this experiment:

- Type of digester continuous system
- Capacity of digester 40 L.
- Dry organic waste 10 kg.
- Water added 10 liter.
- Duration time 6days.

From the ideal gas law

$$P \times V = M \times R \times T$$

P: Pressure generated in the digester (pa).

V: Volume of gas in digester (m^3).

M: mass of gas (kg).

R: gas constant (*J/kg K*).

T: Temperature in digester (k).

6.3.1 Experiment result

The experiment started on 18/5/2013 and finished on 28/5/2013, for 8 day, the table and figures below illustrate the measuring result (PH value and biogas productivity) according to the result in table 6.2.

To calculate the amount of gas in the digester at 1 bar :

$$M = \frac{P \times V}{R \times T}$$

$$= \frac{1 \times 10^5 \times 0.012}{518.2 \times 308} = 0.008 \text{ kg} \approx 8g.$$

Table 6.2: experiment result.

No of days	**date**	**PH**	P(bar)	biogas (g)
1	11-may-2013	9.5	0	0
2	12-may-2013	9	0	0
3	13-may-2013	8.3	0.1	0.75
4	14-may-2013	8	0.2	1.89
5	15-may-2013	7.7	0.5	3.76
6	16-may-2013	7.6	0.80	6.5
7	17-may-2013	7.5	1	8
8	18-may-2013	7.4	1.5	11.2
9	19-may-2013	7	2	15

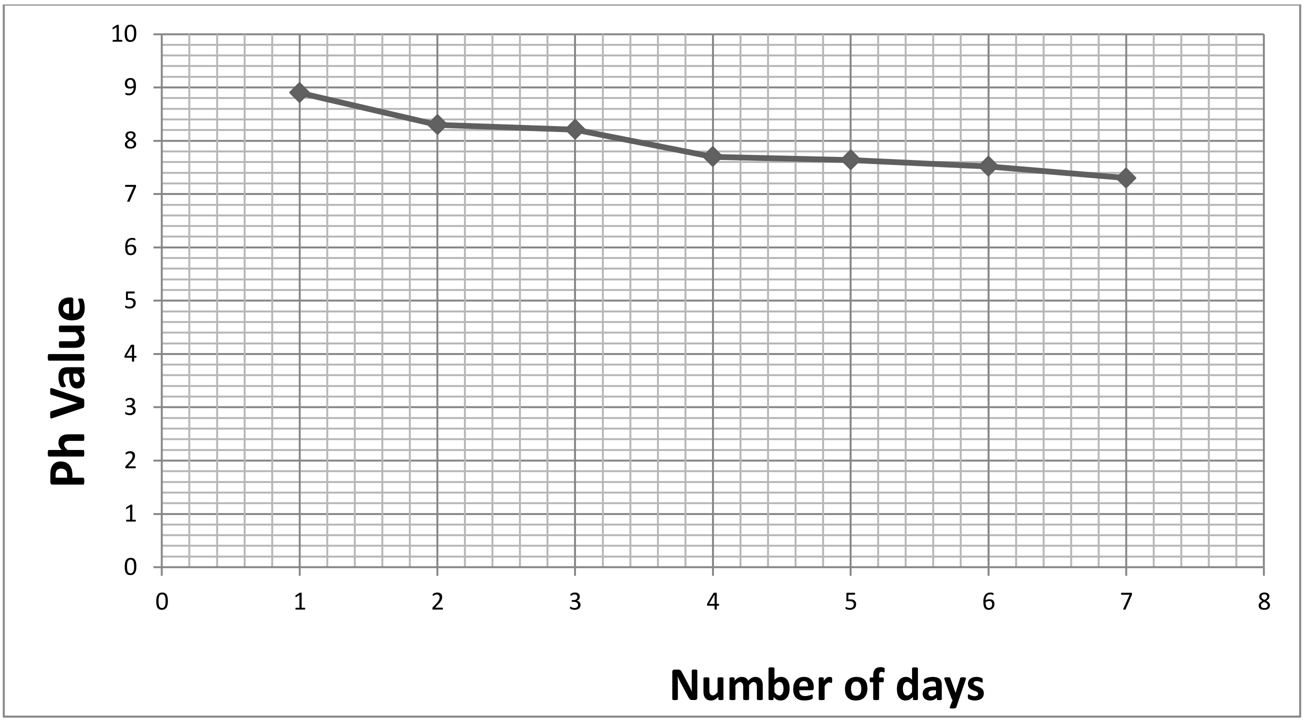

Figure 6.3: The result of the daily rate production of biogas.

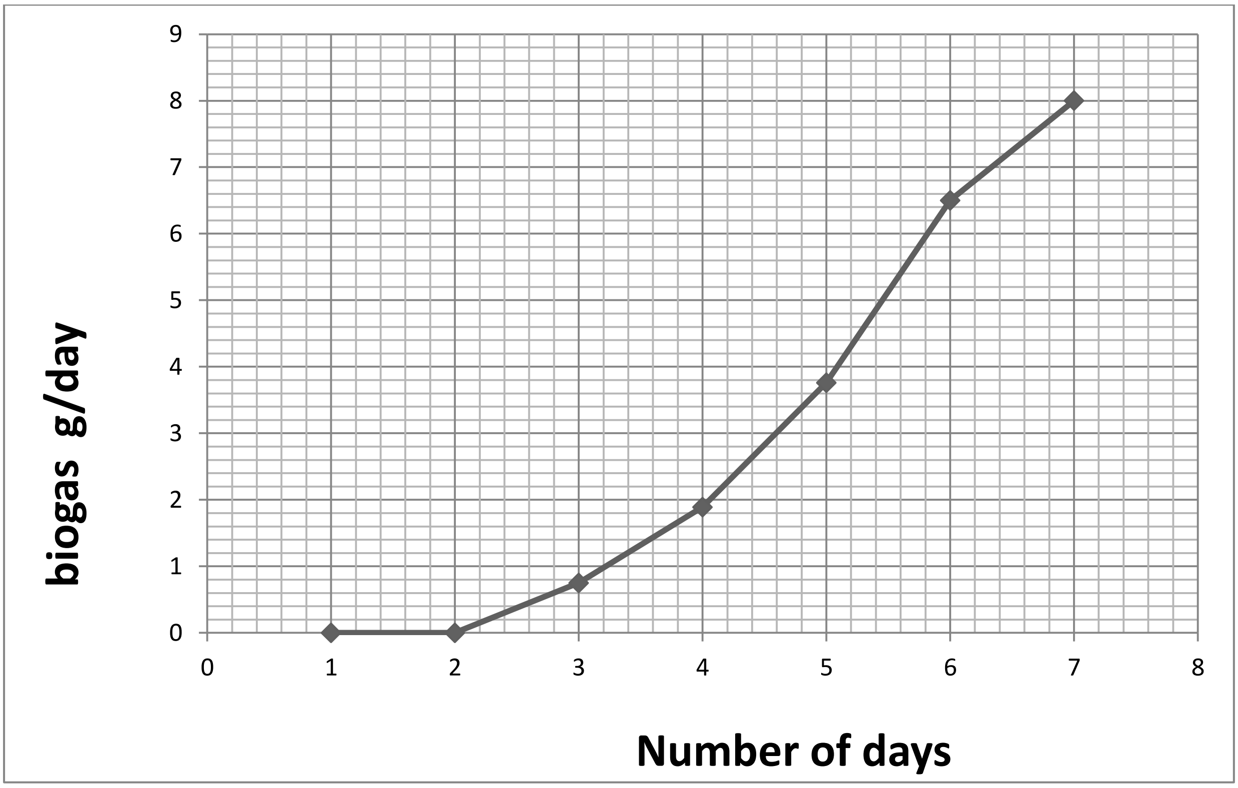

Figure 6.4: The result of the daily PH record.

Chapter Seven

Conclusions and Recommendations

Content:

7.1 Conclusions:

1. Biogas production needs simple raw material that can be found in large quantities.

2. There are good resources to produce a biogas in the rural area according to quantities that was surveyed, such as animal waste.

3. Under a certain condition temperature (35℃ - 40 ℃), PH value (6-7) the gas production can be increase by using heating system and mixing and insulation material around the digester ; this leads to fast the process and reduce the retention time (6-7 day).

4. It can be used the biogas for cooking by building a suitable digester that match to the amount of gas required and regulate the gas output into the home by using a pressure regulator.

5. Dealing with the biogas is very dangerous and need a large attention

6. During the experiment it is found that the biogas production increases gradually as the PH closely to the neutral (7).

7. The main disadvantage of using the digester in the home is the bad odor when, opening the digester for cleaning and maintenance.

8. Biogas is a source of renewable energy usually contains about (50 - 70 %) CH_4, (30 – 40 %) co_2, and other gases and one cubic meter of biogas is equivalent to 1.613 liter kerosene or 2.309 kg of LPG or 0.213 kHz electricity and has an Air to Methane ratio for complete combustion is 10 to 1 by volume but explosion limit: 5 to 14 % in air.[5].

7.2 Recommendations

1. Help of formal and local institutions to spread awareness about the best way to dispose animal waste and the duration of using it.
2. Formal and local institutions need to put regulation to prevent dispose animal waste in the soil.
3. Using unrefined biogas fuel primarily in heating and electrical systems.
4. The finding of this research seems to indicate that the methane yield was satisfactory and courageous; therefore, it is recommended that digester can be used to supply methane to home, after using pressure regulator to meet the house utilities such as cooking, lighting, heating and other.
5. Appropriate authorities should courage and aid to spread this type (continuous digester) in villages and towns famous of breading cows and sheep.

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