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DETERMINATION OF THERMAL ENERGY AND WASTES GENERATION RESULTING FROM INCINERATION OF ONE TON OF CRUDE OIL CONTAMINATED SOILS OF QURNA OIL FIELDS IN BASRA, IRAQ

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ABSTRACT

A theoretical study is presented to calculate the thermal energy and wastes generated from complete combustion of (1 ton/h) of Qurna crude oil contaminated soil in Basra city south of Iraq. Practical values which are valid in the literature are taken for the constituents of the soil and the crude oil. A multi chamber incinerator with capacity of (1 ton/h) is designed to incinerate the crude oil contaminated soils using diesel fuel to reach to (1200˚C) burning temperature. The resulted thermal energy was found to be (5.59 MW) which is sufficient to evaporate (9918.449 liter/h) of industrial wasted water using many of Shore VAP water evaporators systems. The resulting hazardous flue gases and wastes obtained were (CO_2=1773.46 kg/h, SO_2 = 13.58kg/h, H_2SO_4 =0.643125kg/h (350 ml/h)) using excess air ratios of 150% for solid wastes burning and 20% for diesel fuel burning.

Keywords: Contaminated Soil with Crude Oil, Treatment by Incineration Method, Multi Stage Incinerator Design, Thermal Energy, Hazardous Sulfuric Content with Flue Gases

1. INTRODUCTION

The contamination process of soil with crude oil occurs in the case of drilling process to get the crude oil or in the process of crude oil transportation Torero et al.

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(2003). The effect of crude oil on the soil and environment is dangerous as it causes many changes in the chemical and agricultural properties of the soil Wu et al. (2000) studied the effect of crude oil contamination on the chemical properties of soil in Qurna and Medynah cities in Basra government in south of Iraq. Chemical analyses for the contaminated soil from twenty different locations near the petroleum industry companies were made. The chemical properties that were investigated included organic material, Calcium Carbonate (lime), Calcium Sulphate (gypsum), degree of soil interaction (PH) and soil salinity (electrical conductivity) concentrations during two seasons in the year (Summer and Winter).

There are many different technologies applied to treat contaminated soil with crude oil such as chemical, physical, biological and thermal method (incineration). Almutairi (2016) used a physical process to wash the Kuwait contaminated soil with crude oil from resulting from the 2nd Gulf war actions using sea water and adding suitable detergents and centrifuge and vibrations with ultra-sonic waves as a new successful method to split soil from crude oil. This technology yet showed that large quantities of wasted water were produced in which it need to be treated. The biological method to treat the contaminated soil with crude oil using a certain kind of bacteria is more environmentally friendly and it is the best method but it is very slow (needs to many months) and it is not suitable for very hot climates (see Almutairi (2016)) such as that existing in the city of Basra which reaches to more than 50˚C in summer and it's temperature in January is above 20˚C (see Al-Musawi & Muhsin (2015) and Deeri & Al-Kaabi (2014)).

John & Swamy (2011) and Ganguly et al. (2017) designed a multi chamber incinerator to treat the medical wastes of many hospitals in India. They presented a detailed procedure for material and heat balance which is necessary to design a suitable multi chamber incinerator. The same procedure is considered in the current research.

An alternative method for crude oil contamination treatment is the incineration process. This method is quick, economical but with dangerous flue gases that need to be treated by modern off gas systems which are still in the laboratory development stages to make the incineration process more environmental friendly by converting the dangerous flue gases such as CO_2, SO_2 and H_2SO_4 vapor to useful materials and treat hot flue gases at (700 ˚C) while the current off gas systems treat flue gases at (40 ˚C) by cooling flue gases using a suitable heat exchanger (see Liemans & Thomas (2013), Al-Mamoori et al. (2017) and Al-Mamoori et al. (2020) and Ashadi et al. (2020)). The treatment of hazardous flue gases at high temperatures at industrial scale can give a chance to convert the thermal energy of hot flue gases from burning of hazardous wastes to electrical energy.

Hadi et al. (2023) studied theoretically and experimentally the utilization of hazardous wastes flue gases to produce electrical energy using a prototype small system with converted steam engine and a water tube boiler with capacity of (120 kg steam/hr) and their results showed that for small quantities of wastes it is more economical to utilize wasted thermal energy generated from the incineration process of hazardous wastes in evaporation of wasted industrial water rather than producing of electrical energy.

The aim of the present research is to design of a multi chamber incinerator with burning capacity of (1 ton/h) and determine the quantity of thermal energy released from burning (1 ton/h) of the contaminated soil with crude oil with ratio of (2:1) obtained from Qurna city in Basra government south of Iraq, this is a very important step towards using of wasted thermal energy in evaporation of wasted industrial water in a future research (under preparation). The comparison between many methods (Thermal, physical, chemical and biological) to treat the contaminated soil with crude oil and choice the best method for Iraqi environment is considered in a future research (under preparation).

2. THEORETICAL ANALYSIS

2.1. ASSUMPTIONS

1) Complete combustion process.
2) Air contains 23% O_2 and 77% N_2 by weight.
3) The organic material in soil contains (0.8 C+0.2 H).
4) The Iraqi crude oil in Basra contains only C, H and S.
5) The treatment process is done in July where average ambient temperature between (6 A.M. and 4 P.M.) is 45˚C.
6) The volume of any (1 kg/mole) ideal gas is equal to 22.4m3 at (0˚C and 1 atm).
7) The used fuel in burning process is diesel with chemical composition ($C_{12}H_{23}$) and burning temperature is 1200˚C.

2.2. CRUDE OIL CONSTITUTENTS

The Iraqi crude oil in Basra has relatively high Sulphur contains which is 2.1% by weight that produces acidic gases after burning like SOx and H_2SO_4 vapor (see IPCC. (2001)), the crude oil compositions are given in the following equation:

$$\%W_{crude\text{-}oil}=0.841C+0.138H+0.021S \qquad (1)$$

2.3. SOIL CONSTITUTENTS IN QURNA CITY

Depending on Al-Musawi & Mustafa (2019). experimental measurements, in the present research the data of Al-Jary site is taken to be the basis of this research calculations because Al-Jary site is located inside West Qurna petroleum factory and north to the 8th gas station and its soil constituents are given in the following equations:

$$\%W_{soil\text{-}summer} = 0.03683\,CaCO_3 + 0.01756\,CaSO_4 + 0.0067\,O.M. + 0.93891\,\text{others} \qquad (2)$$

$$\%W_{soil\text{-}winter} = 0.03699\,CaCO_3 + 0.01544\,CaSO_4 + 0.00692\,O.M. + 0.94065\,\text{others} \qquad (3)$$

The ratio of soil to crude oil was taken as (2:1) as in Almutairi (2016), to get weight fraction of 1 kg contaminated soil with crude oil in summer multiplying equation 1 by (1/3) added to equation 2 multiplied by (2/3) and by substituting (O.M. = 0.8 C+0.2 H) and rearrange the resulted equation gives:

$$\%W\ \text{contaminated soil (1 kg)} = 0.283906336\,C + 0.046893334\,H + 0.007\,S + 0.0245533\,CaCO_3 + 0.01170667\,CaSO_4 + 0.62594\,\text{others} \qquad (4)$$

The weight fraction of 1 ton of contaminated soil with crude oil is given in the following equation:

$$\%\ W\ \text{contaminated soil (1 ton)} = 283.906336\ C + 46.893334\ H + 7\ S + 24.5533\ Ca\,CO_3 + 11.70667\ Ca\,SO_4 + 625.94\ \text{others} \tag{5}$$

2.4. MATERIAL BALANCE

2.4.1. STOICHIOMETRIC CALCULATIONS

In equation (5) when the components are burned under (1200°C) the terms of C, H and S react with O_2 while the terms of $Ca\,SO_3$ and others are unchanged, the $Ca\,CO_3$ under (900°C) converts to Ca O and CO2as in the following equation:

$$Ca\,CO_3 \xrightarrow{900^{\circ}C} Ca\,O + CO_2$$

$$(40+12+16*3) \longrightarrow (40+16) + (12+16*2)$$

$$100\ \text{kg} \longrightarrow 56\ \text{kg} + 44\ \text{kg}$$

$$1\ \text{kg} \longrightarrow 0.56\ \text{kg} + 0.44\ \text{kg}$$

$$24.5533\ \text{kg}\ Ca\,CO_3 \xrightarrow{900^{\circ}C} 13.749848\ \text{kg}\ Ca\,O + 10.803452\ CO_2 \tag{6}$$

The Carbon reacts with oxygen as in the following equation:

$$C + O_2 \longrightarrow CO_2$$

$$12 + 32 \longrightarrow 44$$

$$1\ \text{kg}\ C + 2.667\ \text{kg}\ O_2 \longrightarrow 3.667\ \text{kg}\ CO_2$$

$$283.906336\ \text{kg}\ C + 757.178198\ \text{kg O2} \longrightarrow 1041.084534112\ \text{kg CO2} \tag{7}$$

The Hydrogen reacts with oxygen as in the following equation:

$$H_2 + O_2 \longrightarrow H_2O$$

$$1\ \text{kg}\ H_2 + 8\ \text{kg}\ O_2 \longrightarrow 9\ \text{kg}\ H_2O$$

$$46.893334\ \text{kg}\ H_2 + 375.146672\ \text{kg}\ O_2 \longrightarrow 422.04\ \text{kg}\ H_2O \tag{8}$$

The Sulphur reacts with oxygen as in the following equation:

$$S_8 + 8\ O_2 \longrightarrow 8\ SO_2$$

$$1\ \text{kg}\ S + 1\ \text{kg}\ O_2 \longrightarrow 2\ \text{kg}\ SO_2$$

$$7\ \text{kg}\ S + 17\ \text{kg}\ O_2 \longrightarrow 14\ \text{kg}\ SO_2 \tag{9}$$

The total stoichiometric quantities for O_2, CO_2 and H_2O from equations (6, 7, 8 and 9) are (1139.32487 kg, 1051.887986112 kg and 422.04 kg) respectively.

2.4.2. EXCESS AIR AND MOISTURE CALCULATIONS

The excess air to burn wastes in a multi chamber incinerator is 150% (John & Swamy (2011)). Thus, the excess O2 is calculated as follows:

O_2 (150% excess) = 2.5 * O_2 (stoichiometric) = 2848.312175 kg

Air required = O_2 / 0.23 = 12383.966 kg

N_2 = air required – O_2 = 9535.6538 kg

The moisture in the combustion air can be determined from the following equations (see Ganapathy (2015)) considering the average ambient temperature and relative humidity in July in Basra city are 45˚C and 43.2 % respectively (Deeri & Al-Kaabi (2014) and Al-Musawi & Muhsin (2015)):

$$\text{Moisture (air)} \;=\frac{0.622 * \text{Pw}(\frac{\text{kg}}{\text{cm2}}.\text{a})}{(1.033-\text{Pw})} \tag{10}$$

Where 1(kg/cm2.a) = 1 kpa/98.0665

$$\text{Pw=relative humidity*P(kg/cm}^2) \tag{11}$$

From thermodynamics tables Psat (45˚C) = 9.582 kpa = 0.097709 kg/cm2, Pw = 0.0422103, Moisture (air) = 0.0265 (kg H_2O/ kg air) and the quantity of moisture in air combustion is (0.0265 * 12383.966 = 328.175 kg H_2O).

2.4.3. H_2SO_4 FORMATION CALCULATIONS

From equation (9) the produced gas of SO_2 (1-3) % from it reacts with O_2 and converts to SO_3 (Ganapathy (2015)) in which it reacts with water vapor to form Sulfuric acid vapor that condenses under 150˚C and causes corrosion in the heat exchanger equipment (Ganapathy (1989)). The equations of H_2SO_4 formation are as follow:

$$SO_2 + 0.5\ O_2 \longrightarrow SO_3$$

$$64 + 16 \longrightarrow 80$$

$$(1\ \text{kg} + 0.25\ \text{kg} \longrightarrow 1.25\ \text{kg})\ \text{multiplying by } 0.03(3\%\ \text{of } SO_2)\ \text{gives:}$$

$$0.42\text{kg}\ SO_2 + 0.105\ \text{kg}\ O_2 \longrightarrow 0.525\ \text{kg}\ SO_3 \tag{12}$$

The SO_3 gas reacts with water vapor to form Sulfuric acid vapor as in the following equation (assumed all SO_3 converts to H_2SO_4):

$$SO_3 + H_2O \longrightarrow H_2SO_4$$

$$80 + 18 \longrightarrow 98$$

$$1\ \text{kg}\ SO_3 + 0.225\ \text{kg}\ H_2O \longrightarrow 1.225\ \text{kg}\ H_2SO_4$$

$$0.525\ \text{kg}\ SO_3 + 0.118125\ \text{kg}\ H_2O \longrightarrow 0.643125\ \text{kg}\ H_2SO_4 \tag{13}$$

The volume of Sulfuric acid after completely condensation at 150 ˚C can be calculated by substituting its mass over its density (1840 kg/m^3) to get nearly (350 ml).

The final mass of SO_2 is (14 kg – 0.42 kg = 13.58 kg), the final mass of O_2 in flue gases is (2848.312175 kg – O_2 stoichiometric (1139.32487 kg) – O_2 consumed in Sulfuric acid formation (0.105 kg)= 1708.882305 kg).The final mass of H_2O vapor in flue gases is (422.04 kg (eq. 8) + 328.175 kg (moisture) – 0.118125 kg consumed in Sulfuric acid formation = 750.096875 kg).

2.5. HEAT BALANCE

2.5.1. TOTAL HEAT INPUT FROM WASTES QI

The high heating value (H.H.V.) emitted from burning 1 ton of contaminated soil with crude oil where its constituents are listed in equation (5) can be evaluated from Dulong equation as follow (see Abd-Alrazak (2008)):

$$\text{H.H.V.}=33960\,C+14421\,(H_2-\frac{O2}{8})+9400\,S \quad (14)$$

The total input heat (Qi) can be evaluated as listed in table (1) depending on equation (5).

Table 1

Table 1 Computation of Input Heat

	Component	Mass (kg/h)	H.H.V. (KJ/kg)	Heat (MJ/h)
1	C	283.906336	33960	9641.46
2	H	46.893334	14421	676.24877
3	S	7	9400	65.8
4	$CaSO_4$	11.70667	0	0
5	$CaCO_3$	24.5533	0	0
6	Others	625.94	0	0
		1 ton/h		10383.50877 MJ/h

2.5.2. TOTAL HEAT OUT BASED ON EQUILIBRIUM TEMPERATURE OF 1200˚C

The output heat Qo represents the sum of radiation loss, heat to ash, heat to dry combustion products and heat to moisture in which they can be evaluated as follow:

1- Radiation loss = 5% of input heat = 0.05* Qi = 519.175 MJ/h.

2-Heat to ash = mash * cpash * (1200-Tamb) (15)

Where mash = m (Ca O) + m ($CaSO_4$) + m (others) = 651.396518 kg/h

and cpash = 0.381 kJ/kg.˚C (see John & Swamy (2011)) and Tamb = 45˚C, substitute in equation (15) to get heat to ash = 286.6503 MJ/h.

3- Heat to dry combustion products (N_2, O_2 residual, CO_2, SO_2 and H_2SO_4)

Qdp =mdp * cpdp * (1200-Tamb) (16)

Where mdp = m N_2 + m O_2 residual + m CO_2 + m SO_2 + m H_2SO_4 = 12310.647255 kg/h, cpdp = 1.086 kJ/kg.°C (see John & Swamy (2011)) and Tamb = 45°C, substitute in equation (16) to get Qdp = 15441.6141713 MJ/h.

4- Heat to moisture = mmoisture*cpmoisture*(1200-45) + mmoisture * hfg (17)

= 750.096875 *2.347*1155+750.096875*2460.3

= 3878.8147 MJ/h.

From equations above Qo = 20126.2541713 MJ/h = 5.59 MW.

2.5.3. NET HEAT AND REQUIRED AUXILIARY FUEL

Qnet = Qi – Qo= -9742.7454013 MJ/h = mdiesel* H.H.V. (diesel)

The negative sign means need to add auxiliary fuel, there is 5% heat radiation loss from burning fuel, H.H.V. for diesel is 44.8 MJ/kg and density of diesel is 0.845 kg/liter. The mass of diesel can be computed as follow:

mdiesel = 1.05*9742.7454013/44.8 = 228.3456 kg/h

Vdiesel = 228.3456/0.845 = 270.23 liter/h.

2.5.4. PRODUCTS OF COMBUSTION FROM AUXILIARY FUEL

Considering the chemical formula for diesel as (C12H23) in which it burns according to the following equation:

$$C_{12}H_{23} + 17.75\ O_2 \longrightarrow 12\ CO_2 + 11.5\ H_2O$$

$$167 + 376 \longrightarrow 528 + 207$$

$$1\ \text{kg}\ C_{12}H_{23} + 3.4\text{kg}\ O_2 \longrightarrow 3.16\ \text{kg}\ CO_2 + 1.24\ \text{kg}\ H_2O$$

$$228.3456\ \text{kg}\ C_{12}H_{23} + 776.37504\ \text{kg}\ O_2 \longrightarrow 721.572096\ \text{kg}\ CO_2 + 283.148544\ \text{kg}\ H_2O \quad (18)$$

In burning fuel 20% excess air can be taken and the required quantities can be determined as follow:

O_2 (excess 20%) fuel = 1.2 *776.37504 kg = 931.65 kg, in which 776.37504 kg is reacted with fuel and 155.275 kg exit as residual O_2 with flue gases.

Air excess (fuel) = O_2 / 0.23 = 4050.6523 kg and N_2 = 3119 kg and air moisture = 4050.6523 * 0.02625 = 106.33 kg which is added with 283.148544 kg to get the total mass of moisture of the fuel. The final fuel burning equation with 20% excess air is as follow:

228.3456 kg/h diesel + 3119 kg/h N_2 + 931.65 kg/h O_2 + 106.33 kg/h moisture

3119 kg/h N_2 + 155.275 kg/h O_2 + 721.572096 kg/h CO_2 + 389.478544 kg/h H_2O (19)

2.5.5. THE FINAL EQUATION FOR REACTANTS AND PRODUCTS

1 ton/h contaminated soil with crude oil + 228.3456 kg/h diesel (270.23 liter /h) + 3779.962175 kg/h O_2 + 12654.653825 kg/h N_2 + 434.505 kg/h H_2O (air moisture) $\xrightarrow{1200\ ^{\circ}C}$

12654.653825 kg/h N_2 + 1864.157313 kg/h O_2+ 1773.46 kg/h CO_2 + 1139.575419 kg/h H_2O + 651.396518 kg/h ash as{11.70667 kg/h $Ca\ SO_4$ + 13.749848 kg/h Ca O+ 625.94 kg/h others} + 13.58 kg/h SO_2 + 0.643125 kg/h $H_2\ SO_4$ (350 ml/h) + Qo (5.59 MW) (20)

The total mass input from reactants in equation (20) equals to(18097.4666 kg/h) and the total mass output from products in equation (20) equals to(18097.4662 kg/h) which equal to the sum of (651.396518 kg/h ash) and (17446.069682 kg/h flue gases). The flue gases total mass is the sum of (16306.494263 kg/h dry products) and total moisture of (1139.575419 kg/h). The weight fraction for flue gases can be given in the following equation:

% Wflue-gases = 0.725358 N_2 + 0.106852 O_2 + 0.1016538 CO_2 + 0.06531989 H_2O + 0.0007783988 SO_2 + 0.0000368636 $H_2\ SO_4$ (21)

The volume fraction of flue gases can be found by computing the volume of each gas (using ideal gas law) and the total volume of flue gases, the volumetric flow rate of each gas can be determined as in the following equation:

$$Vgas = mgas * \frac{22.4*(Tg+273)/273}{Molecular\ weight\ of\ gas} * \frac{1}{3600} \quad (22)$$

The molecular weight of flue gases (N_2, O_2, CO_2, H_2O, SO_2 and H_2SO_4) are (28, 32, 44, 18, 64 and 98) respectively and the volume of each gas are (15.17322, 1.95577188, 1.35317616, 2.1254759, 0.0071236966 and 0.0002203205) m^3/s respectively and the total volume of flue gases equals to 20.6149879 m^3/s. The volume fraction for flue gases can be given in the following equation:

% Vflue-gases = 0.736028 N_2 + 0.094871 O_2 + 0.06564 CO_2 + 0.103103 H_2O + 0.0003455591 SO_2 + 0.0000106873 H_2SO_4 (23)

2.5.6. DESIGN OF MULTI CHAMBER INCINERATOR

The multi chamber incinerator contains primary and secondary chambers, to design the primary chamber for a multi chamber incinerator of burning capacity of (1 ton/h). Consider the volume of contaminated soil with crude oil of mass 1 ton is nearly equal to (1 m^3) and the volume of heap is (5 m^3) as follow:

Vprimary chamber = L * B * H= 5 m^3

Assuming a suitable depth of 2.2 m (H) and assume (L/B = 1.5/1) then:

Area = volume / depth = 5/2.2 = 2.3 m^2 = L*B = 2.3 B2 therefore:

B = 1.238 m and L= 1.857 m.

Vprimary chamber = 1.857 m *1.238 m* 2.2 m = 5 m^3 (24)

The volume of the secondary chamber of the multi chamber incinerator that satisfy (1 second) resident time for flue gases at (1200 ˚C) can be estimated from equation (22) for dry products (molecular weight for air = 29) and moisture (molecular weight = 18) then:

Vsecondary chamber = Vdp + Vmoisture = 18.877 + 2.125 = 21.002 m^3/s.

This procedure is the same as that used by John & Swamy (2011), they assumed that dry products have the properties of air while if dry products considered uniquely the volume of secondary chamber is equal to the total volume of flue gases (20.6149879 m^3/s) that used to compute volume fraction of flue gases in equation (23) which is more accurate value than (21.002 m^3/s).

3. RESULTS AND DISCUSSION

The results obtained from the current research are valid in equations (20, 21, 23 and 24) where the thermal energy, weight and volume fractions of the flue gases, mass and volume rate of diesel fuel, resulted ash components and dimensions of the multi chamber incinerator are given.

3.1. THERMAL ENERGY

From equation (20) the resulted thermal energy is (5.59 MW), as wasted heat which is dissipated as radiation loss and in ash and as thermal content in flue gases (in dry products and moisture), the useful thermal energy is carried with flue gases, by cooling the flue gases using forced convection (in a suitable heat exchanger to ambient temperature) and condensation of moisture at (100˚C and 1 atm) but at this temperature the sulfuric acid vapor is condensed at 150˚C and its volume of (350 ml) causes corrosion at the cold parts from the heat exchanger at the time between cooling the flue gases from (150˚C to 100˚C) then the moisture of (1139.575419 kg/h) begins to be condensed and mixed with sulfuric acid condensed liquid.

Cooling flue gases to ambient temperature is firstly necessary to treat dangerous flue gases using suitable designed industrial off gas system and secondly it is best to get more thermal energy but the problem of sulfuric acid condensation and its corrosion effects preventing to cool flue gases under 200˚C. Modern researches treat flue gases at 700˚C successfully but they still in laboratory scale and may be they can reach industrial scale about 2030, at that time it can be used more wasted thermal energy by cooling flue gases to ambient temperature.

3.2. RESULTED WASTES

The resulted wastes from incineration process of contaminated soil with crude oil are ash and flue gases as in equation (20). The ash has mass of (651.396518 kg/h) and its volume is less than the primary volume of the contaminated soil by nearly (1/3) where it can be treated and disposed after it cooled to ambient temperature.

The mass of flue gases is (17446.069682 kg/h) and the dangerous components are (1773.46 kg/h CO_2, 13.58 kg/h SO_2 and 0.643125 kg/h H_2SO_4). The mass of flue gases is big because of big excess air necessary to burn solid wastes (150%) compared with excess air necessary for burning liquid fuel (20%), the weight and volume fractions of flue gases are valid in equations (21 and 23) respectively, the quantity of N_2 represents more than 70% in weight and volume fraction and that causes firstly need of more fuel to reach (1200˚C) where (270.23 liter/h) of diesel fuel is needed and secondly large incinerator dimensions is needed because of the large volume of resulted flue gases (21.002 m^3/s). To solve this problem, modern researches use oxy-combustion method to prevent N_2 gas and in the same time this method is economic in fuel consumption and leads to less CO_2 emissions because less fuel is needed.

4. CONCLUSIONS

1) The design of multi chamber incinerator, the primary chamber dimensions are (1.857 m * 1.238 m * 2.2 m = 5 m^3), the secondary chamber volume is (21.002 m^3/s). A diesel fuel ($C_{12}H_{23}$) is used with volumetric rate of (270.23 liter/h).
2) Treatment of soil with incineration method is quick and economical yet it produces hazardous flue gases in which completely treatment at high temperatures (700˚C) is still in laboratory research development.
3) The resulted thermal energy is (5.59 MW) which is sufficient to evaporate (9918.449 liter/h) of industrial wasted water using many of Shore VAP water evaporators systems.
4) The incineration products are 651.396518 kg/h ash and 17446.069682 kg/h flue gases.

CONFLICT OF INTERESTS

None.

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