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► To cite this version:

Mamdouh El Haj Assad, Maryam Almallahi, Yashar Aryanfar, Oussama Rejeb, Mahmoud Elgendi. Wastewater Treatment In UAE Using Geothermal Energy. Proceedings of International Conference on Computers and Industrial Engineering, CIE, Oct 2023, Sharjah, United Arab Emirates. <hal-04506066>

HAL Id: hal-04506066

<https://hal.science/hal-04506066v1>

Submitted on 15 Mar 2024

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WASTEWATER TREATMENT IN UAE USING GEOTHERMAL ENERGY

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ABSTRACT

Geothermal energy is the best natural, renewable resource through which wastewater can be treated and reused, serving many lives. This study discusses a proposed plan using geothermal energy to treat wastewater in the ORC system. Primary geothermal resources are water-related, with a temperature above 120 °C. In UAE, examined the areas through the magnetic survey in Al Ain and Ras AlKhaimah with 120 °C temperature in water samples collected from 3km depth from which 1000 megawatts of electricity can be produced to give off the supply to many residential houses. The temperature rises to 150 °C as we move deeper than 3 km underground. The same sources can be extracted through the planning system and utilized for wastewater treatment. Production well distributed the geo-fluid into a fraction that generates desiccant flow for dryer and remaining feed a small-scale ORC system. The installation of an auxiliary boiler is managed in the absence of a geothermal system. However, electricity is produced from the ORC system, used to supply wastewater to a treatment plant, and pumps the geo-fluid possible with a higher temperature than 150 °C. A thermal dryer and drying processes are used, and a global energy efficiency test is done. Inlet and outlet temperatures were managed, with 5 and 10 °C differences. The efficiency and economic status of the thermal and electric systems were observed and compared briefly in this study. The moisture removal of the sludge is above 90% in the design, as the outlet water content of the sludge is less than 10%. It reduces the mass of sludge by about 73.2%. In the Organic Rankine cycle, 150kW of electricity can be produced that will be used to pump geofluid in the drying section of the sludge and wastewater treatment plant. This can be an excellent alternative for energy efficiency and greenhouse gas reduction from wastewater treatment plants in the UAE.

Keywords: Wastewater, Renewable energy, geothermal energy, United Arab Emirates, Organic Rankine cycle.

1 INTRODUCTION

Renewable energy sources such as solar, wind, and geothermal use the processes of nature to create electricity. Their widespread adoption reduces the pollutants mitigates environmental impacts and helps create a more resilient and sustainable energy future [1-6]. Geothermal energy is renewable energy that is present inside the earth [7, 8]. This energy is also present in water, known as the geothermal fluid, which can be water in liquid, vapors, or mixture, mostly found more than 1 km below the earth's surface in depth. The energy travels to the earth's surface by convection and conduction while arising from the radioactive decay energy from the middle of the planet at a temperature up to 6650°C [9, 10]. Three essential elements in specific locations cause geothermal energy to occur on earth: permeable layer, heat source, and water. First, an impermeable layer trapped the rain and melted the snow's water, forming geothermal energy [11]. Several heating techniques include geothermal power plants, solar desalination, and solar stills [12-14].

Wastewater is a form of impure and polluted water that can be treated and cleaned through wastewater treatment, also known as sewage treatment [15, 16]. This method removes impurities from wastewater before reaching sediments or natural resources of water like freshwater or marine water [17]. Mainly water pollution is due to the drainage of polluted water into groundwater, while wastewater treatment is the primary method to control water pollution [18]. There are classical and conventional water treatment plants that can process further removal of toxic materials and organic solids. These technologies reduce water loss and recycle water quickly, causing global intentions. An environmental agency conducted an estimate of Abu Dhabi's water usage, and 72% of water emanates from groundwater, 21% from desalination, and 7% are mistreated from wastewater. However, the remaining treated water needs to be addressed. UAE has the primary water ingestion rates in the world, ranked by United Nations [19].

Using reusable energy sources to prevent power costs, geothermal energy is an alternative and operative way because its continuous availability and consistency make it more reliable than other methods. In the future, geothermal power plants will likely become dominant. Furthermore, great potential is awarded by geothermal energy due to its availability on islands and plate junctions [20]. Figure 1 shows the flowchart of wastewater treatment. This paper aims to provide wastewater treatment in the United Arab Emirates using geothermal energy.

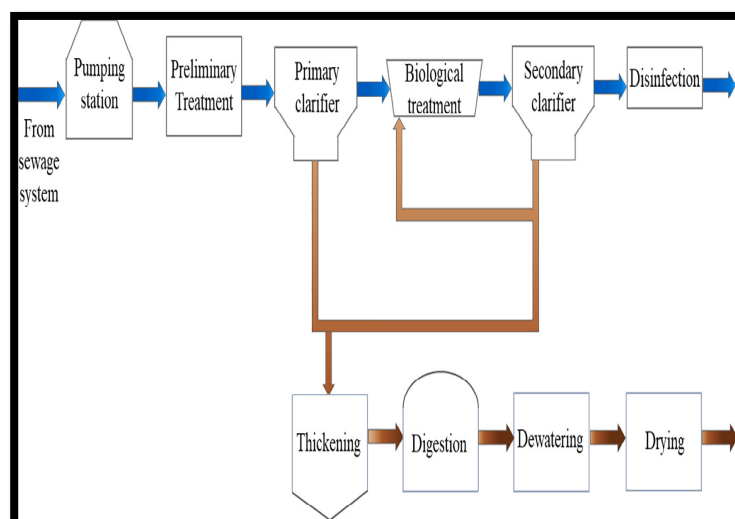


Figure 1: Flowchart of wastewater treatment

There are many sites available in the world to extract geothermal resources. Figure 2 shows the binary, dry steam, flashing, and total geothermal energy capacities [26]. The Global installed capacity of geothermal energy has shown interesting increasing trends, as shown in Figure 2.

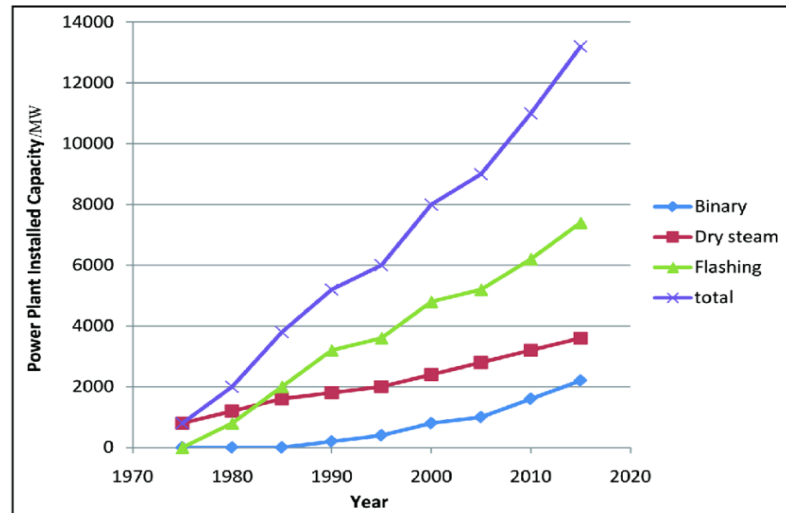


Figure 2: Globally installed capacity by type of geothermal power plant [21]

As stated by International Renewable Energy Agency (IRENA), geothermal energy's installed capacity is shown in Figure 3.

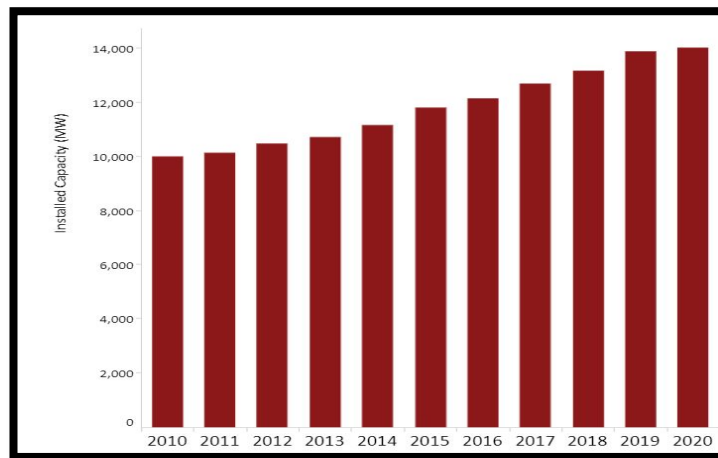


Figure 3: Installed capacity trends of geothermal energy [22]

2 METHODOLOGY

In this study, geothermal energy used for the treatment of wastewater is explained. Geothermal pumping and wastewater treatment are supplied to the plant through electric power, while the slurry produced from a wastewater treatment plant is dried by utilizing thermal energy. The design of the proposed system is presented in Figure 4. Around the world, primary geothermal resources are water-related with a temperature above 120°C [23], and this energy can produce thermal and electric power.

2.1 The efficiency of the system

The efficiency of the whole system, η_{tot} , together with the thermal drying process and ORC unit, is deliberated as follows:

$$\eta_{tot} = \frac{\dot{m}_{w,ev} \times \Delta H_V + \dot{W}_{WWTP} + \dot{W}_{surplus}}{\dot{m}_{Geo,tot} (h_2 - h_{19})}$$

Where \dot{W}_{WWTP} = the electrical power supplied to the wastewater treatment plant $\dot{W}_{surplus}$ = the electrical surplus produced by the Rankine cycle $\dot{m}_{Geo,tot}$ = the mass of geo-fluid extracted from the production well h = the enthalpy. Therefore, the denominator of this equation equals the total power delivered to the system.

2.2 Input parameters and case study

The case study analyzed the geothermal resources used for wastewater treatment in Al Ain and Ras Al Khaimah in the UAE. Presently, a wastewater treatment plant with a membrane bioreactor system with the removal of organic matter is in the plan. A connective belt-type dryer is designed for easy handling and high flexibility for the sludge treatment [24]; sludge characteristics are mentioned in Figure 4. From different investigations, geothermal source data is derived. At the same time, the flow rate of geo-fluid is considered five l/s, with above 130° C temperature in the depth of 180m [25-27], used for power generation as 5kg/s. Firstly, sludge is dried using thermal energy. Then, thermal energy is calculated, and at the end, the recycled stream of geo-fluid is added to the input stream of the ORC system.

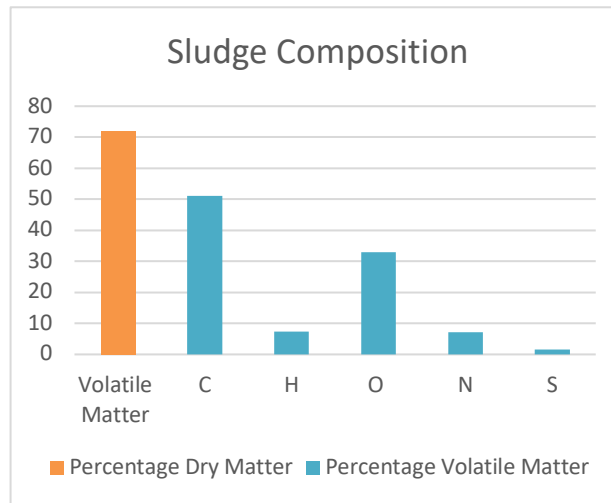


Figure 4: Sludge composition in wastewater treatment plant

3 RESULTS AND DISCUSSION

As discussed in the methodology, sludge drying has an outlet moisture content lower than 10% and reduces the mass of sludge to 73.2%, while the geothermal power gained from geo-fluid is 43.3 kW. The results of the recent study conducted for the ORC system show the thermodynamic and economic analyses mentioned in Tables 1 to 5.

Table 1: Temperatures of sludge and outlet

Temperatures	(°C)
Sludge Outlet Temperature	101
Desiccant flow Outlet Temperature	79.3

Table 2: Mass flow rates of the system

Mass Flow Rate	(kg/s)
Desiccant Inlet	0.767
Drying	0.18
ORC	4.82
Cooling water	51
R245fa	6.33

Table 3: Power output and input of the system

Power	(kW)
Turbine (Electrical) output	155
Pump (Electrical) input	5.37
Evaporator (Thermal)	1427
Condenser (Thermal)	1277

Table 4: The pressure of the evaporator and condenser

Pressure	(bar)
Evaporation	9.63
Condenser	1.84

Table 5: The moisture content of the sludge outlet

Moisture content	(%)
Sludge Outlet	6.5

Before inflowing the cleaning system, the desiccant flow outlet stream has been cooling. Thus air is preheated before the geothermal heat exchanger is entered; this recycled 13.8kW of heat without using any other resource and enhancing power output. Alternatively, the net power output from the ORC generates 150 kW of electricity. This electricity of amount 100kW is being used in the wastewater treatment plant and for geo-fluid pumping.

Figure 5 shows the system's efficiency that 10.5% is the first law of efficiency of the ORC, which is adjustable and considered a low-capacity temperature source. The drying process shows a small decline in the efficiency of the dryer which is 83.8%, compared to the dryer, with 84.4%. Also, the ORC system delivers an efficiency of 10.5%, and the system is driven by a low enthalpy geothermal source showing 11.5% efficiency.

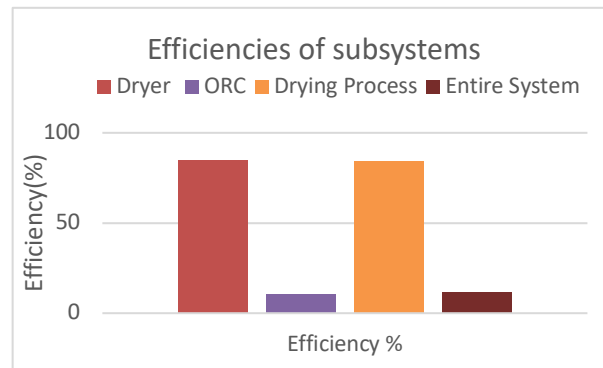


Figure 5: Efficiencies of subsystems

The developed system discussed in this study can be used in UAE to treat wastewater through geothermal energy. Subsequently, in these areas, electric energy supply and sewage sludge treatment are commonly severe challenges; the proposed layout efficiently addressed all these problems. This study suggested system is equipped with an electric generation facility to provide the electricity and use the extra generated heat for drying and heating purposes. The energy analysis is conducted using ASPEN plus. The comparison is drawn in Figure 6.

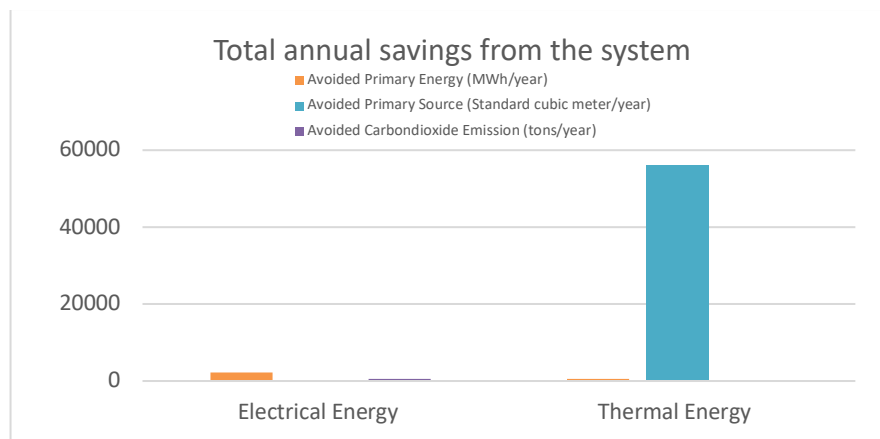


Figure 6: Annual savings of proposed system

4 CONCLUSIONS

The proposed scheme for a geothermal wastewater system can save thermal and electrical resources, reducing fossil fuel combustion and its emissions. The electricity produced in the system is 150 kW. The moisture content of the outlet stream is lower than 10%, and about

73.2% reduction in sludge mass happens, while 43.3kW geothermal power has gained from geo-fluid. 150 kW are supplied from Organic Rankine Cycle; 100 kW is utilized in pumping geo-fluid in the wastewater treatment plant and dryers. ORC system shows an efficiency of 10.5%, and the system driven by a low enthalpy geothermal source shows 11.5% efficiency. This suggested methodology can save up to 550 tons of CO₂ per year. This method also reduces the mass of sludge transferred in the system. As the geo-fluid temperature increases, the dryer and the drying process efficiency decreases. The developed system discussed in this study can be used in UAE to treat wastewater through geothermal energy. This study proposed system is equipped with an electric generation facility to provide the electricity and use the extra generated heat for drying and heating purposes.

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