Study of geothermal brine direct use for crude palm oil (CPO) factory in Indonesia

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Abstract. Palm oil is edible oil which extracted from the pulp of fruit of palm oil trees. The use of this oil is mainly for cooking purposes. In Indonesia, crude palm oil production has a huge role for Indonesia’s economics, because Indonesia is the largest crude palm oil producers in the world, with expected annual production of 27 million tons in 2017. In crude palm oil factories, there are several components, mainly in crude palm oil purifier, which would need some heating process. The heating temperature would need around 45-100 °C for purifying processes and around 140 °C for fruits boiling process. In the conventional crude palm oil factories, this heating process is conducted by an industrial boiler. This paper would propose a design for a crude palm oil factory modification from the conventional factory into a modified factory where the heating process would be using geothermal brine. A study case of using geothermal brine for CPO factory utilization is also conducted in Y geothermal field in Indonesia. The purpose of this research is to determine whether the geothermal fluids can substitute industrial boiler in CPO factory.

1. Introduction
Palm oil is edible oil which extracted from the pulp of fruit of palm oil trees (figure 1). Commonly it is combined or mixed with coconut oil to make highly saturated vegetable fat, which is also used for cooking purposes. Main usage of CPO is for cooking purposes and is largely used in South-East Asia, West Africa and some parts of Brazil. Commercial kitchens use it due to its low cost [8].

Palm oil production in the world is dominated by Indonesia and Malaysia. These two countries have produced around 85-90% from the total production of palm oil in the world [3]. Figure 1 will contain 5 biggest palm oil producer countries in the world, where Indonesia is the largest producer of palm oil in the world, as can be seen in table 1.

The Indonesian Palm Oil Producers Association (Gapki) [4] expects Indonesian crude palm oil (CPO) exports to reach 27 million tons in 2017 (up 1.6 percent from realization in the preceding year), or USD $18.90 billion in terms of export value (up 1.7 percent from the preceding year). Gapki projects Indonesia's CPO production at 35.5 million tons this year. Domestic consumption of palm oil products in Indonesia this year is estimated to reach 12 million tons (Indonesia-Investments, 2017). This makes palm oil production is very important to Indonesia’s economics.
Figure 1. Palm Oil Tree [5].

Table 1. CPO production from 5 biggest CPO producer countries in 2016 (Indonesia-Investments, 2017).

| Country  | CPO Production (metric tons) | Percentage of World's CPO Production |
|----------|------------------------------|-------------------------------------|
| Indonesia | 36,000,000                   | 61.22%                               |
| Malaysia  | 21,000,000                   | 35.71%                               |
| Thailand  | 2,200,000                    | 3.74%                                |
| Colombia  | 1,320,000                    | 2.24%                                |
| Nigeria   | 970,000                      | 1.65%                                |
| World     | 61,490,000                   |                                      |

Indonesia has a large potential of geothermal energy. Geothermal energy is used mainly by extracting heat from geothermal fluids (brine) to the surface through wells. In Indonesia, the utilization of geothermal energy is mainly for electricity through large scale geothermal power plant. Several geothermal fields in Indonesia have high enthalpy, thus, the brine produced in separator (liquid) still has a high enthalpy and can be used for other utilizations, such as ORC system or direct use utilization.

Conventional CPO factories use a boiler for heating process in some parts of palm fruits processing. The fuel is usually the bio-waste from the factory itself, such as palm fibers and palm shells. The idea of this paper is to modify the needs of boiler from conventional CPO factory and change the use of boiler into geothermal brine.

2. Methodology
Methodology used in this research is using heat transfer calculations to determine if the geothermal fluid conditions (pressure, temperature, scaling probabilities) are suitable to change the need of industrial boiler in CPO factory. The first step is to know how CPO factory works and the processes included in it. Then, the industrial equipment that need warm or hot water or steam from industrial are listed, along with the temperature and fluid phase needed. Then, the diagram for CPO factory using geothermal fluid is made. The flowchart is described in Figure 2.
For the study case if one field can support this design, first the geothermal fluid (brine) condition that will be utilized has to be measured. The temperature of brine must be higher than the minimum temperature needed in the design. If the condition met, scaling possibilities must be considered, than the maximum temperature of brine out of the CPO factory can be determined. Next, the need of hot water or steam in each equipment is calculated accordingly. Then, the capacity of CPO factory can be calculated, depends on the brine mass flowrate. The flowchart is described in figure 3.

![Flowchart](image)

Figure 2. Flow chart of method used to make diagram of CPO factory using geothermal brine.

Figure 3. Flow chart of method used for case study to determine if one field can use geothermal brine for CPO factory.

3. Conventional CPO factory
Palm oil industry consists of the following five stages: plantation, CPO mills, palm kernel oil mills (PKO mills), refinery factories and others. Fresh fruit bunches (FFBs) from palm oil plantation are transported to a CPO mill, in which CPO, kernel, and bio-wastes are produced. Then kernel and CPO are transported to a kernel factory and a refinery factory where palm oil products are produced [2]. This paper will modify the CPO mill part, which consists of several stages as described below [7]. The conventional CPO mill factory can be represented in figure 4.
3.1. **Weight Bridge**
In this bridge, the palm fruits are weighed along with the truck carrying them. The truck is weighed before and after carrying palm fruits to determine the palm fruits’ weight.

3.2. **Palm Fruits Sorting**
In this stage, the palm fruits are sorted by the quality and ripeness of the fruits. The ripeness of the fruits would affect its palm oil content. After sorting process, the palm fruits would be distributed into a loading ramp and then into the palm fruits sterilizer station.

3.3. **Palm Fruits Sterilizer**
In this sterilizing process, there would be a significant amount of steam needed to heat up the sterilizer. The steam is streamed down from a boiler. The steam has 2.6 to 3 bar pressure with 140 °C temperature. This sterilizing process takes 90 minutes. Palm fruits sterilizer is 26 m long and has diameter 2.1 m on average. Inside the sterilizer is a 10 mm wearing plate that is used to hold the steam from boiler. Under the sterilizer there are holes to dispose the condensate water. This process can produce condensate with 0.5% of palm oil content.

3.4. **Oil Processing from Palm Fruit’s Pulps**
After sterilizing process, there are some stations to extract oil from palm fruits’ pulps, those are:

- **Digester.** This process separates the pulp and the nut from palm fruits. This process needs steam with stable temperature around 80 – 90 °C.

- **Screw Press.** This screw press will extort the pulps from digester to get the crude palm oil. This process separate oil with pulps’ fibers and nuts. The crude palm oil will be streamed to oil purification station, and the fibers and nuts will be delivered to the kernel station. This screw press would need hot water. Usually the hot water is taken from condensate water in sterilizer.

3.5. **Crude Palm Oil Purification**
The purification process consists of:

- **Sand Trap Tank.** After screw press process, the crude palm oil still contains water, oil, and mud. These processes will traps sands contained in the crude palm oil. The sand trap tank temperature is stable at 95 °C.

- **Vibro Separator.** This process filters the crude palm oil from the remaining fibers or other dirt that can get in the way while purifying the crude palm oil.

- **Vertical Clarifier Tank (VCT).** Filters the crude palm oil from the remaining fibers or other dirt with gravitational force.

- **Oil Tank.** Store the oil temporarily before purifying. The temperature is stable at 95 °C, with oil tank capacity 10 tons/hours.

- **Oil Purifier.** Reduce the water content in the crude palm oil with centrifugal force. This process needs 95 °C temperatures.

- **Vacuum Dryer.** Helps reducing water content in oil.
- **Sludge Tank.** A temporary storage for sludge (crude palm oil that still has solid dirt and other liquid substances other than oil) before being processed in the sludge separator. The temperature is stable at 90 - 95 °C.

- **Cleaner (Sand Cyclone and Brush Strainer).** Traps sands in sludge to simplify the next process.

- **Sludge Separator.** Separate the oil in sludge with centrifugal force.

- **Storage Tank.** Store the CPO before being delivered or sold. The storage temperature is stable between 45-50 °C.

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**Figure 4.** Diagram of conventional CPO factory.

4. **CPO Factory Modification**

From the previous explanation about conventional CPO factory processing stages and instruments, parts that need steam or hot water are:

1. Sterilizer needs steam with 140 °C temperatures.
2. Digester needs heat exchanger to keep the temperature stable at 80 – 90 °C.
3. Screw Press, uses condensate water from sterilizer to help the extortion process.
4. Sand Trap Tank needs heat exchanger to keep the temperature stable at 95 °C.
5. Oil Tank, needs heat exchanger to keep the temperature stable at 95 °C.
6. Oil Purifier, needs heat exchanger to keep the temperature stable at 95 °C.
7. Sludge Tank, needs heat exchanger to keep the temperature stable at 90 – 95 °C.
8. Storage Tank needs heat exchanger to keep the temperature stable at 45 – 50 °C.

Steam and hot water needed in these parts can be replaced by geothermal fluids. The geothermal fluid from well has to be separated from liquid and vapour phase. This is important to calculate the heat and flow rate needed for the geothermal brine for the design. This design can be done if the geothermal fluids meet some requirements, such as the steam temperature is minimum 140 °C with a particular steam flow rate (depends of the palm fruits sterilizer design). The hot water needed in digester can be extracted from sterilizer water condensate. It can also be extracted from geothermal brine from separator. Heat needed in the other parts can utilize the geothermal brine from separator. Thus, the CPO factory modification design can be represented by figure 5.

![Diagram of modified CPO factory using geothermal brine.](image)

Figure 5. Diagram of modified CPO factory using geothermal brine.

5. Case Study: Y Geothermal Field
Y geothermal field is a water-dominated geothermal field in Indonesia. This field can be reached by 3 hours travelling by car from the nearest palm oil farm. In the Y geothermal field, the brine out of separator is being reviewed to see if the brine characteristics can be utilized for this modified CPO factory design. Condition out of separator can be described in the table 2.
Table 2. Brine conditions out of separator.

| Parameters                                      | Value          |
|------------------------------------------------|----------------|
| Separator Pressure                              | 11.3 bara      |
| Brine Temperature Out From Separator            | 185 °C         |
| Brine Mass Flow Rate Out From Separator         | 110 kg/s       |
| SiO2 Content                                    | 723 mg/kg      |
| Separator Distance to Injection Well            | 7 km           |

The brine temperature meets the minimum requirement for this CPO factory modification; thus, the brine from the separator at this field can be used for the source of steam and hot water needed. The pipeline for the brine used will be tapped from the injection line by directing it first to CPO factory, then redirecting it back to injection well for brine re-injection. That is why minimum temperature needs to be determined to prevent silica scale formation in injection well by using the equation (1) [1]:

$$\log Csat = -\frac{731}{Tsat} + 4.52$$ (1)

$Csat$ is the silica saturation concentration (mg/kg) and $Tsat$ is saturation temperature. Only then the Silica Saturation Index (SSI) could be determined by using the equation (2):

$$SSI = \frac{C}{Csat}$$ (2)

$C$ is the measured silica concentration (mg/kg). The common limit for SSI is between 1.2 – 1.5 [6]. By using SSI 1.5 and the previous formulas, it is known that minimum brine injection temperature is 125 °C. In order to prevent scale formation, the minimum temperature limit needs to be increased by ±10 °C with an assumption there would be temperature loss of the brine’s temperature from the factory to the injection well. So it is decided that the minimum outlet temperature of brine from the factory is 135 °C. This CPO factory modification for Y geothermal field use flasher to flash the liquid phased brine from separator into steam, which would be needed in sterilizer. The flasher has the characteristics as described in table 3.

Table 3. The characteristics of the flasher design.

| Parameters     | Value          |
|----------------|----------------|
| Pressure       | 6.50 bara      |
| Temperature    | 161.98 °C      |
| Liquid enthalpy| 684.08 kJ/kg   |
| Steam enthalpy | 2759.60 kJ/kg  |
| Steam fraction | 4.93 %         |
| Steam flowrate | 5.42 kg/s      |
| Liquid flowrate| 104.58 kg/s    |
With these specifications the CPO factory modification diagram can be described in figure 6. The detailed in and out temperature and flowrate for each equipment that need heat are described in table 4.

![Diagram of modified CPO factory in Y geothermal field.](image-url)

**Table 4.** The detailed in and out temperature and flowrate for each equipment

| Parameters     | Input Temperature (°C) | Output temperature (°C) | Phase   | Mass flowrate (kg/s) |
|----------------|------------------------|-------------------------|---------|----------------------|
| Sterilizer     | 161.98                 | 141.98                  | steam   | 5.42                 |
| Digester       | 141.98                 | 112.90                  | liquid  | 5.42                 |
| Screw Press    | 120.00                 | 100.00                  | liquid  | 5.42                 |
| Sand Trap      | 161.98                 | 140.00                  | liquid  | 26.15                |
| Oil Tank       | 161.98                 | 140.00                  | liquid  | 26.15                |
| Oil Purifier   | 161.98                 | 140.00                  | liquid  | 26.15                |
| Sludge Tank    | 161.98                 | 140.00                  | liquid  | 26.15                |
| Storage Tank   | 140.00                 | 135.00                  | liquid  | 104.58               |
6. Conclusions and Discussion

The conclusions for this study are:

1. Geothermal brine have the possibility to be utilized to change the use of industrial boiler in CPO factory.
2. In Y geothermal field, this design can be used to change the use of industrial boiler in CPO factory by flashing the geothermal brine through a flasher to produce steam and hot water which is needed for processing stages in CPO factory. The flasher pressure to produce the needed steam and water ratio is 6.5 bara.

However, this modified CPO factory design is still in a basic, simple model. A more detailed study is needed to determine several things, such as:

1. Pressure and temperature loss in factory fluid pipelines to determine whether the P-T loss is negligible or not.
2. Temperature loss from CPO factory to the injection well pipeline with detailed heat transfer calculations to prevent silica scaling.
3. Pressure loss from CPO factory to the injection well pipeline to determine type of injection (gravity or using pump).
4. Economical study of this model compared to the conventional CPO factory using boiler.
5. Economical study of this model compared to if the brine is used for electricity/power plant utilization instead.
6. Advantages or disadvantages of the design in matter of time effectivity of CPO processing.
7. A study if this model can be used for Corporate Social Responsibility (CSR).

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