Black Material Deposition in Surface Facilities During Commissioning in Muara Laboh Geothermal Field

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Abstract. Muara Laboh geothermal field is located in West Sumatra, Indonesia. The installed capacity is 80-85 MWe and already accomplished the Commercial Operation Date (COD) in December 2019. Prior to COD, several programs were conducted: pre-commissioning and commissioning programs. During these activities, some findings were encountered and one of the major findings was the black material deposit at several spots. The black material found from HP separator drain, condensate drain port and then ended up beneath the cooling tower basin. Based on the laboratory analysis, the SEM-EDX data shows that the material dominated by magnetite (Fe-Ox) and pyrite (FeS₂) for the strainer sample. Meanwhile, the sample from HP separator contains some amount of silica, Arsenopyrite, anhydrite, and carbon. The occurrence of Fe-Ox might indicate the source of the black material coming from industrial goods, which caused by steam flow activity during the pre-com and commissioning program. Thus, the fact that no black material found during well testing from all wells also supports the theory.

1. Introduction
Muara laboh geothermal field is a developed field with a generated capacity of 80-85 MWe net. The plant accomplished commissioning operation date (COD) on 16th December 2019. Prior to COD, the power plant underwent several major steps such as the pre-commissioning and commissioning program that started within the first quarter of 2019 and completed in the fourth quarter of 2019. During the pre-com program, several problems were encountered. One of the problems that caught big attention is the appearance of black material. The black material appeared in several spots which some of the spots became a major concern such as cooling tower basin.

2. Steam Above Ground System Muara Laboh
The Muara Laboh stage one consists of two phases of construction. The first phase is to utilize ML-A wells to produce 85 to 88 MWe gross. The second phase that expected to be completed on June 2020 will utilize the ML-F and ML-H wells that reduce the steam consumption from ML-A. The steam above ground system (SAGS) of Muara Laboh field is a conventional double flash system with two separators high pressure (HP) and one low pressure (LP) separator. The general description of the system is written as follows:

1. Two phase fluid from well pad A is naturally flows to the header then into two HP separators.
2. The steam from both separators HP goes through HP scrubber and ends up rotating the turbine blade.
3. Separated brine from HP separators is flashed using the level control valve (LCV) then goes to the LP separator.
4. Prior to LP separator, the flashed brine is also mixed with two phase fluid from letdown line and LP well. The LP steam ends up in the same turbine but on a different part.
5. The brine separated from the LP separator is injected as hot brine injection.
6. Steam from the turbine is condensed within the condenser and cooled off to ambient temperature then pumped to the cooling tower.
7. Droplets of condensate are stored within the cooling tower basin.
8. This cooling tower basin water is circulated back to the condenser, used as the wash water and some amount of condensate is injected back to the reservoir.

The simple schematic of SAGS is shown on Figure 1 [1].

2.1. Black Material Appearance in SAGS

When the pre-performance was initiated within the third quarter of 2019, black material only appeared within the condensate drain pot (CDP) before rock muffler and beneath the drain port of HP&LP separators. During the load test, the black material appeared within several locations such as:
- The CDP before scrubber
- Beneath the scrubber
- Turbine strainer both HP and LP. The material even clogged the strainer causing pressure increase. Due to clogging, the load test was suspended.
- Cooling tower basin. The black material causing the basin color change from green to black as shown in Figure 2
- Thermal pond. The thermal pond fluid source comes from the CDP, scrubber and cooling tower basin. Figure 3 shows the color change of the thermal pond.
3. Black Material Result Analysis

3.1. Physical Appearance
The black material found in huge quantities within CDP. On the visual, the material is black, reddish, soft, very fine grain as shown in Figure 4. The material smells like rust and it is closely attached to a magnet that indicates a magnetic material as shown in Figure 5. Some samples from HP&LP separator drain, CDP, scrubber, and turbine strainer were taken to be analyzed at ITB for Scanning electron microscopy with energy dispersive X-Ray Analysis (SEM-EDX) analysis. Due to the similarity of the result from CDP, scrubber and strainer, this paper only discusses the result from separator and strainer.
3.2. Scanning electron microscopy with energy dispersive X-Ray (SEM-EDX) analysis result

The SEM-EDX result from HP separator drain shown in (Figure 6, 7 and 8). Based on the report published in 2019, the SEM result shows the Fe and Silica plate. This plate then analyzed with EDX. The EDX analysis shows presences of Fe oxide that indicates the Fe-Ox mineral and silica.

The SEM-EDX result of the strainer shown in (Figure 9 and 10). Figure 9 shows the presence of Sulphur, while Figure 10 does not show any EDX peak of Sulphur but gold (Au) is present. The abundance of Fe and O indicate magnetite (FeO₄) while the Fe and S could indicate a pyrite mineral (FeS₂). Compared to the EDX analysis from HP separator, the strainer material doesn’t show any silica or arsenic related mineral. The existence of calcium and silica from HP separator might indicate the debris from well. However, black material from the strainer does not indicate any debris from well, only a deposition from the corroded pipe.
Figure 6. SEM analysis result from material from HP separator drain

Figure 7. EDX analysis result from material from HP separator drain (silica is present)
4. Source of Black Material
Based on the physical appearance, the very fine material that appeared at the strainer is a clear indication that it cannot be from the reservoir. Thus, this theory is also supported by well testing program that had been conducted in 2017 and early 2018 where no black material was found. Therefore, the two possible sources are from the casing and liner of wells or the piping system above ground.

The EDX result of HP separator that shows the presence of silica and arsenic might tell us a source from well debris or scaling amorphous silica. However, these two elements can only be found within the separator material. Moreover, any material from the well should be separated at the separator unless the density of the material is less than the steam. During the reliability run steam condensate sampling from the separator outlet, the black deposit stays beneath the sample bottle proving that the material density is bigger than the condensate.

The EDX analysis of black material strainer largely consists of iron, oxygen, and sulphur. The iron element can only be found within the pipe while Sulphur and the oxygen are from the NCG of steam condensate that mostly consists of CO$_2$ and H$_2$S. The most probable cause of the deposition until now is that the iron inside the pipe reacts with the condensate that contains some amount of H$_2$S and remaining O$_2$. According to [3], factors that affect the corrosion in the steam line are pH, presence of H$_2$S, and solid particles.
5. Summary
Muara Laboh geothermal field is a developed field with a generated capacity of 80-85 MWe net. Prior to COD, black material that caused plugging was encountered within the separator, CDP, strainer, thermal pond, and cooling tower basin. The black material sample was brought to ITB to be analyzed using the SEM-EDX. The result shows different results between the HP separator sample and the strainer sample. The separator sample indicates some of the brine related material and rust. On the other hand, the strainer sample indicates rust from the pipe material and condensate. The elemental mapping based on EDX result is shown in (Figure 11). In March 2020, no more black material coming out of the drain. However, some concerns are also left unanswered such as
• The frequency of black material appearance. Could the black material appear when the wells are shut in a longer period then back online?
• The current turbine condition after the material went through to the turbine blade.

**Figure 11.** Elemental map within the plant based on EDX result

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