Green mining: technical study of off-shore tin mining using cutter suction dredger in Bangka Island, Indonesia

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Abstract. According to government regulations regarding good mining practice, PT Timah Tbk and its partners have begun to develop offshore mining techniques using Cutter Suction Dredger (CSD). Therefore there is a need for a technical study of the application of CSD in offshore tin mining. The method used in this research is to observe field activities directly. Observation of mining data of mining design, dredging system and mapping of bathymetry. The process flow, production and tin ore recovery of mineral processing. Observation of the tailings disposal considers the minimal impact on the environment. The result is mining design using CSD applies a long face system with a combination of vertical digging. The opening angle of the two anchors amounting to 90-145° produces width snee of 40-55 m. This method is capable of producing an average rate of soil removal of 250 m³/hour. The floating mineral processing plant uses a three-stage jigging method with Circullar and Pan American types plus a shaking table resulting a washing tin recovery of 66%-90%. Considering bathimetry, the geotube embankment technique can control the spread of tailings. The conclusion is that the mining process using CSD is one step better in terms of implementing good mining practice.

1. Introduction
In the era of the industrial revolution 4.0, the availability of mineral resources for the needs of technology continues to increase globally. Therefore, the Indonesian government continues to improve governance in various sectors of the mining industry in order to meet market demand and increase national economy. One of them is the focus of the government that requires mining companies to continue to apply the rules of good mining (good mining practice) in accordance with government regulations. In 2017, PT Timah Tbk as a state-owned tin mining company launched a total mining program. This program focuses on exploration, mining techniques, associated mineral conservation and the mining environment [1].

One of PT Timah's programs is the development of marine mining technology using Cutter Suction Dredger (CSD). Some important aspects to be assessed are mining design, mineral processing systems and tailings disposal management. Therefore, in this study the researchers tried to examine the technical implementation of CSD to conform to the rules of good mining practice. The formulation of the problem in this research is how the right marine mining method is applied to CSD, tin ore washing in order to maximize the value of processing recovery and how to plan for the good management of tailings disposal at sea [2-5].
2. Literature Review

2.1. Good Mining Practice

According to Indonesia Minister of Energy and Mineral Resources Regulation number 26 of 2018 (Bourassa and Lacy, 2020), the principles of good mining practice include six aspects:

1. Technical mining
2. Mineral and coal conservation
3. Mining Safety and Health
4. Safety of Mining Operations
5. Environmental Management of Mining, Reclamation, Post-Mining and Post-Operation
6. Utilization of Technology, Engineering Capability, Design, Development and Application Mining Technology.

Meanwhile, according to Nurmi [5], the concept of green mining is built on 5 bases; (1) Promote Material and Energy Efficiency (2) Ensure Availability of Mineral Resources for Future Needs (3) Minimize adverse environmental and social impacts (4) Improve work and organizational practice (5) Ensure sustainable land use following mine closure.

2.2. Off-Shore Mining and Its Environment Impact

According to Bray [6] and Miedema [7] marine mining (dredging) is an underwater excavation activity (dredging) using a number of mechanical device systems installed on ships. Based on the location of marine mining is divided into two types, deep sea mining (shallow water) and shallow water (shallow sea). The type of marine mining influences the selection of mechanical devices to be used. The equipments that can be used in shallow marine mining are Cutter Suction Dredge (CSD), Bucket Ladder/Wheel Dregde, Bore Hole Mining (advance deposits) and others.

According to Baker [2] the environmental impact of offshore mining is physically caused by the effect of tailings dumps which can change the coastline. This has a particularly significant impact on shallow water areas. The sediment disturbance is reported to also expose marine organisms such as phytoplanton. Mining activities that can impact the marine environment are collection, separation, lifting, washing, at sea-processing, transport, extraction, tailing discharge [8].

2.3. Cutter Suction Dredger (CSD)

Cutter suction dredger is one type of dredger that is often used. CSD works with a dredging mechanism using a cutting head and a ground pump (Bray, 1979). Basic CSD operations rely on spud movements for forward and backward and both left and right anchors for sideways movements. As for several factors that affect the effectiveness of dredging performance according to Syafrullah [9] as in the equation below:

\[ wg = \frac{h}{d} \left( \frac{d}{vl} + \frac{l}{vg} \right) \]  

\( wg \): Time required for excavation of work surfaces (minutes)
\( h \): Depth of digging (meters)
\( d \): Depth of pressure ladder (meters)
\( vl \): Ladder suppression speed (meters / minute)
\( l \): Working surface width/Snee (meters)
\( vg \): side wire pulling speed (meter / minute)

To excavate a work block, several parameters that need to calculated are the spud replacement time (wS) and the ladder time (wL). Mineral processing using a system that is completely separate from the dredging vessels used [4],[10]:

(1) Land Based Mineral Processing Plant
   Applied to the dredging front condition not far from the land
(2) Floating Mineral Processing Plant.
   Applied to mining fronts that are far from the land.
3. Methodology

In this study researchers used the method of direct observation in the field. The observations included mining, processing and handling tailings. Because the researchers tried to examine technically some mining parameters using CSD. Observations on CSD include the mining design, the dredging system used, the excavation method and the mapping of the progress of the excavation / bathymetry. At the washing plant, observations were made in the processing flow and the achievement of production and recovery of tin ore. As for the handling of tailings, the observation of the distribution of tailings processed so that it can consider the concept of tailing disposal. All observations and studies were carried out during the CSD operation, from August 2019 to December 2019.

4. Result

4.1. Mining Design and Dredging Method of Cutter Suction Dredger

The CSD mining design refers to the dredging method with a separate digging system and mineral processing plant. The mineral processing system uses a land based mineral processing plant and a floating mineral processing plant. Slurry Run of Mine from the Dredge Ship is transferred through a 16 "HDPE pipe to the Mineral Processing Plant.

CSD uses a long face system with a vertical digging method. In the long face system, soil excavation will be done as wide as the workspace (snee) has been determined based on the distribution of reserves. Long face system is more suitable to be applied in the mechanism of CSD to maximize mining recovery so that it is in accordance with the rules of mineral conservation. The width of the CSD workspace is very dependent on the opening of the two anchors. The two safe anchor openings applied to CSD are at least 90 degrees and a maximum of 145 degrees. With the opening values of the two anchors, the maximum snee width is 50 - 60 meters.

The rock profile to be mined has an impact on the digging method that will be applied safely. Rock that collapses easily coupled with the selection of improper digging methods will pose fatal risks such as a ladder being pinched, broken up to the sinking of a dredger. Then digging methods applied in CSD are vertical digging and benches digging. In vertical digging, CSD will dredge the top soil (overburden) to the lowest soil, rich in tin (kaksa) with a depth of 14-20 meters below sea level. This method considers the dominant hard sand layer (sand, coarse sand and gravel). Following is the long face system scheme and the vertical digging method applied to CSD:
The bathymetry mapping is needed to evaluate the CSD parameters to work optimally. The width and depth of digging, slope, cubication and rate of soil bank removal are parameters that can be calculated by mapping bathymetry of dredging. Mapping of CSD using two methods, the realtime mapping method and after dredging. Each method uses a ladder gauge and an echo sounder. The following is a display of work underwriting bathymetry from August 2019 to December 2019:

Based on bathymetry mapping data, the average CSD soil removal rate is 227.5 m3/hour BCM. The smallest value is 97.9 m3/hour and the largest is 388.7 m3/hour. Based on this data the csd real cubication capacity does not reach the minimum amount of capacity that is 70% of the installed capacity (525 m3/hour). As for what caused the decline in soil removal due to technical constraints such as the CSD dredging method, the asynchronous capacity of the CSD and washing plant, engine hydraulic problems and leakage in the CSD-washing plant pipeline.

4.2. Mineral Processing

The mineral processing method in CSD is designed to obtain maximum mineral recovery. The washing plant is applied in the method of jigging and shaking table. The run of mine slurry from CSD is then sized using a rotary screen. The undersize slurry then begins to increase its lead content using a jig and shaking table system. CSD applies three stage of primary and secondary jig processes with circular jigs and clean up using shaking tables and pan american jigs.

Slurry will separated from the sand material and gravel on the rotary screen. The next step is the separation of the undersize slurry from the mineral impurities by the method of jigging and shaking table. Primary jigs consist of three circular jigs with each jig capacity of 250 m3/hour. The Primary Jig concentrate is then processed at the secondary process stage using one circular jig unit with the same
capacity. While for the clean up process the concentrate uses a shaking table and tailings using a pan american jig.

![Flow process of washing plant.](image)

**Figure 6.** Flow process of washing plant.

Based on the data in the table below, the highest level of tin ore production in December was 2556.65 kg with the volume of excavated land bank at 3799.62 m³. Whereas in August the production only reached 2146.15 kg with the highest BCM volume of 25058.95 m³. This is because in December CSD has effectively dredged tin-rich layer based on exploratory drilling data on the hard layer with tin grade of 0.6 - 0.9 x 1000 kg/m³. In conclusion, the recovery value is quite high, that is 66%-90%.

| Month        | Soil Volume (m³) | Work Hours | Tin Ore Production (kg) |
|--------------|------------------|------------|-------------------------|
| August 2019  | 25058.95         | 111.89     | 2146.15                 |
| September 2019 | 9264.83       | 61.32      | 1783.75                 |
| November 2019 | 18615.98       | 70         | 631                     |
| December 2019 | 3799.62        | 13         | 2556.65                 |

**4.3. Tailing Disposal**

Tailings Disposal functions so that the management of tailings processing results is still limited to the stages of the disposal area restriction. Limitation of the tailing disposal area is done by geotube embankments. In the Floating Mineral Processing Plant, tailing disposal will be managed in a special area with closed circulation taking into account the direction and speed of waves and ocean currents. This allows widespread seawater pollution due to tailings to be controlled. Whereas the Tailings Mineral Processing Plant Floating (for example South Raga CSD) will still be discharged into the sea, but in a limited area so that it can be controlled.

This method is one step better when compared to conventional dredgers or CSD where mineral processing is integrated directly on dredging. In conventional methods the extent of tailings pollution can be spread. This is due to the high mobility of dredgers when dredging overburden. Following is the tailing disposal scheme in CSD:
5. Conclusion
Cutter Suction Dredge is a mining technique that is still in the testing phase so that its effectiveness is still in the stage of further study. The implementation separation system of the mining and processing plant strongly supports the acquisition of high recovery and mineral conservation principles. The marine tailings disposal is considered better than conventional methods. For further research there needs a technical evaluation to increase the rate of soil removal by CSD. There is a need to study the addition of a tailings washing system from the three primary jigs so that the recovery value can be maximized. As for tailings disposal, environmental parameters are monitored. CSD is technically more suitable for mining characters that are close to the coastline, shallow sea water, low grade and disseminated tin reserves.

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Acknowledgement
We gratefully acknowledge the funding from Universitas Bangka Belitung through the RKAKL FT for the publication of this paper.