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RESEARCH

A Technological Innovation To Conserve Tin Alluvial Mining: Subsurface Hydraulic Mining by BTM-SR-4 Equipment

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PT TIMAH (Persero) Tbk

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Abstract

Nowadays, surface hydrolic mining on tin alluvial has caused conflict with other interests. Due to a big mining area needed, the activity has conflict with plantation and local people gardens. Furthermore, activity of illegal mining has destroyed tin reserve and environment as well. Once the illegal mining is not managed properly, tin reserve of the company will decrease significantly, in addition, reclamation cost that must be beared by the company will increase significantly. Approach to manage conflict through negotiation on land use has not given a significant outcome. As the result, the company experiences a very difficult situation to make a mine planning, both short term and long term. Technology of subsurface hydrolic mining offers a mine activity with minimal land clearing and avoid to open overburden. Currently, PT Timah (Persero) Tbk has succeeded to study and examine the technology through operating a pack of equipment named BTM-SR4. Besides awareness on environment, due to its ability to mine on spotted tin deposit, the technology is able to increase tin reserve. Other good news are to decrease mining cost due to not opening over burden and to decrease reclamation cost. All of above good points will support sustainability of the company.

Keywords: subsurface hydrolic mining, sustainability, conserve, tin reserve, environment

1. Introduction

It is known that tin is massively found in a tin belt well known as South East Asia Tin Belt. In Indonesia, it extends from the island of Karimun, Kundur, Singkep, Tujuh, Bangka, and Belitung in the furthest southeast area.

Generally, the tin deposit scattered in Indonesian tin belt is tin alluvial deposit or also known as secondary deposit. This type of tin alluvial deposit is mined using open pit hydraulic mining method (Figure 1). This method is conducted firstly by stripping the overburden using mechanical equipment such as excavator and bulldozer, then hydraulically excavating the ore, by spraying and sucking, followed by ore concentration process using tin washing equipment.

The implementation of regional autonomy in 2000s led to some significant effects on tin mining in Indonesia. Along with the territorial development in Bangka Belitung Islands, there emerged certain problems that hinder the company from conducting tin mining using open pit mining method.

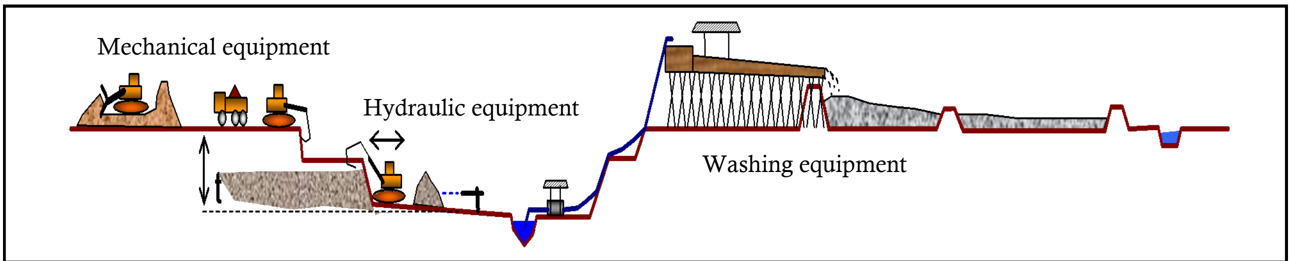


Figure 1. Open pit hydraulic mining on alluvial tin.

LIPI

One of the problems is the difficulty in doing land acquisition in the region of mining license (IUP) owned by the company in which there are also plantation owned by both community and enterprises. The growing plant compensation for the land clearing for mining will be very expensive. Another problem is the damage of the reclaimed land by vast illegal mining and the increasing number of artisanal mining (Figure 2). The most significant impact from these issues is the damage of company's reserves and resources as well as the loss of the opportunity to get the values due to the loss of tin production.

Figure 2. The impact of illegal mining.

Eventually, the issue will hinder the companies from realizing and implementing good mining practices. Dialogues/negotiations with stakeholders and internal policies on mining management are expected to solve the problems; yet they are apparently not effective for such condition and situation.

So far, the problem is addressed by establishing policies on mining management and dialogues with stakeholders. The solutions, however, have not led to the expected results. Another solution is searching for a mining technology capable to answer the problems. The solution should meet these criteria:

1. Minimum mining area
2. Minimum land clearing
3. No overburden stripping
4. Optimal ore excavation
5. Insignificant mining period
6. Minimum potential waste
7. Minimum reclamation
8. Maximum safety

The solution considered capable to accommodate those requirements is subsurface hydraulic mining. The mining method is expected to be a way out in solving the issues at hand and meet the aforementioned requirements (Figure 3).

For such solution (Figure 4 and 5), the Technological Research and Development Working Unit (Litbangtek) of PT. Timah (Persero) Tbk has conducted a research and developed a Borehole Mining equipment whose prototype is named BTM SR4. Borehole Tin Mining (BTM) type SR4 was designed in the end of December 2012 and was tested in February 2013 to September 2013. The testing was conducted to collect operational data in order to find out the economic value of mining using BTM equipment. The testing is still continued in operational scale up to this day.

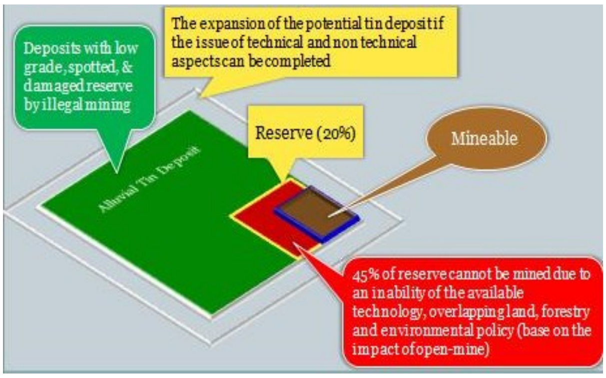


Figure 3. Condition of tin resources and reserves.

Figure 4. Issues of tin mining.

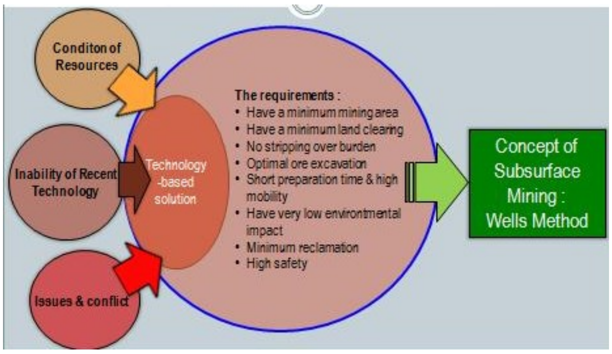


Figure 5. Problem solving by technological solution.

2. Mining Method Using BTM SR4

a. Equipment installation

First, make a hole about 6" in diameter (using hole maker), and then put a casing (6" PVC pipe) at the borehole up to the upper parameter of leaded layer depth. Put an iron ring at the lower end of the casing to bind the sling wire to prevent the casing from sliding down.

The borehole, equipped with the casing, is ready to perform, using BTM equipment. Before operating it, it is recommended to do preparations as follow:

1. Set up the tripod (Figure 6), equipped with tackle crane up to the center, to the borehole and make sure the tripod legs are equipped with iron pegs to prevent it from shifting.

Figure 6. Tripod.

2. Install overflow gutter to gather slurry, flowing up through the casing (Figure 7).

Figure 7. Overflow gutter.

3. Insert mining section (bit), whose inner part is connected to 2” iron pipe (Figure 8), into the borehole using tackle crane.

Figure 8. Mining section (bit).

4. Connect 4” and 2” iron pipes up to the desired depth (Figure 9).
5. Install the swivel at the upper part of the pipe (Figure 10).
6. Assemble the hoses (Figure 12).
7. Prepare the robin engine to supply additional water (Figure 13)

Figure 9. Connecting pipe.

Figure 10. Swivel.

Figure 11. Water pump engine.

Figure 12. 150 psi 3” (black) hose.

8. The Borehole Tin Mining (BTM) type SR4 equipment is ready to operate (Figure 14).

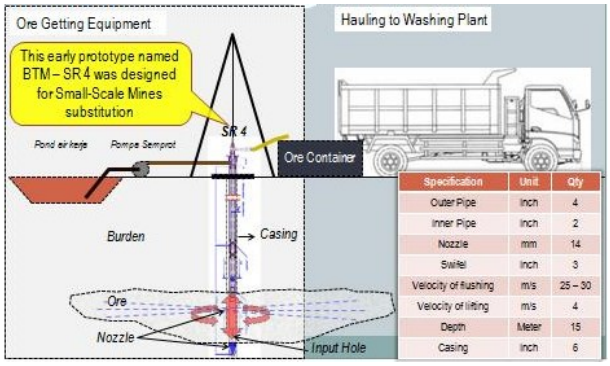
Figure 13. Robin engine.

Figure 14. BTM type SR4.

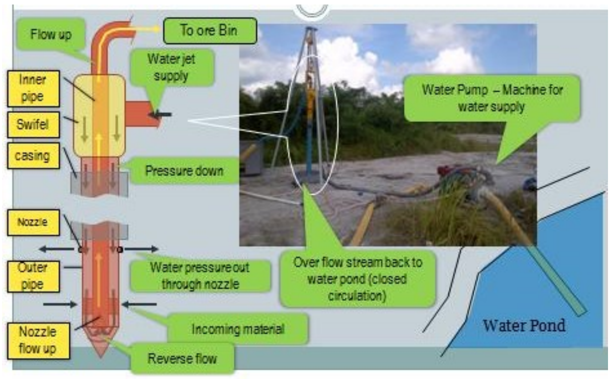
b. Working Principle

The working principle of BTM equipment is to shoot high-pressure water using water pump engine on the leaded layer (ore) (Figure 15). The water is shot through 4” iron pipe with two sideways, opposing nozzles to crush the material on the layer into slurry. The slurry then flows into the slurry inlet located in the mining section. Next the nozzles are shot to the surface to push the slurry up through the 2” iron pipe (inner).

BTM equipment does not require much effort to operate. If the solid in the slurry, flowing up to the surface, begins to lessen, the operator only needs to raise the BTM equipment using tackle crane and lower it by rotating the leaded layer slowly.



(a)



(b)

Figure 15. Working Principle of BTM SR4.

3. BTM Testing

a. Location

The Borehole Tin Mining (BTM) type SR4 equipment is tested in a mining operational scale in Lembah Nudur near the Tambang Besar Nudur 4, South Bangka. The location can be reached by two-hour driving from the central office of PT Timah (Persero) Tbk using vehicles (Figure 16).

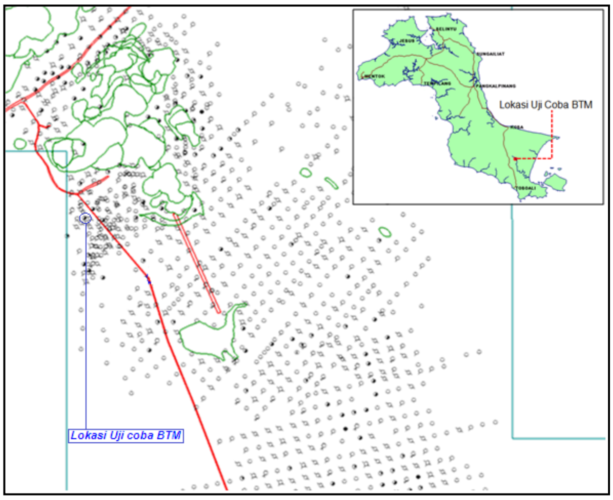


Figure 16. The location of the testing.

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BTM equipment is tested on the borehole number 40 at the depth of 11.6 meters that consists of 12 layers (Whole of hole). The drill estimates that the level per high layer is located in the layers of 9 – 12 that is 1 meter in thickness for each. The levels at the layers of 9, 10, 11, and 12 are 0.534 kgSn/m^3; 0.826 kgSn/m^3, 1.030 kgSn/m^3 and 0.160 kgSn/m^3. BTM equipment is operated on those levels at the depth of 7.6 – 11.6 meters and the average ore level of 0.638 kgSn/m^3.

b. Testing

Testing for collecting operational data was conducted on August 28-29, 2013; September 2-5, 2013; and September 9-12, 2013. The ten-day testing obtained 24.47 hours effective running of BTM equipment and 21 jumbo bags full of ore. The size of jumbo bag is 0.9 m x 0.9 m x 0.9 m (0.73 m^3) (Figure 17). It shows that the ore obtained in the testing was about 15.33 m^3. The testing spent 78 liters of diesel fuel and 24 liters of premium fuel.

Figure 17. Jumbo bag.

The excavating and lifting capacity in the mining using BTM SR4 equipment can be seen in Figure 18 and 19.

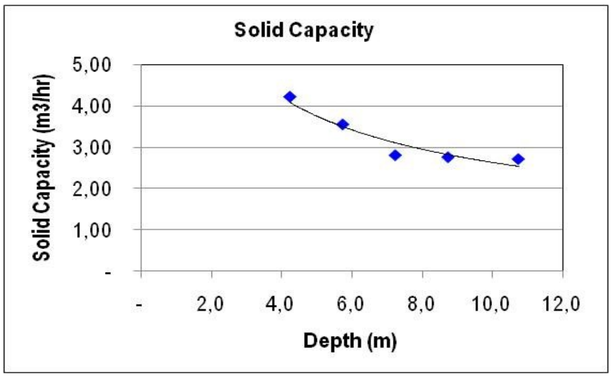

Figure 18. The excavating capacity of BTM SR4.

The ore obtained from the testing is transported to the Processing Plant (PPBT) in Mentok and mixed into one (composite). Composite ore (Feed BTM) is processed using Harz Jig with a separation step and the tailing is processed using Yuba Jig with a separation step. The product of Harz Jig is coded as concentrate and the product of Yuba Jig is coded middling meanwhile the tailing of Yuba Jig is coded tailing. Concentrate, middling and tailing obtained from the separation process are taken into samples each and then analyzed under microscope to find out the level and weight of Sn.

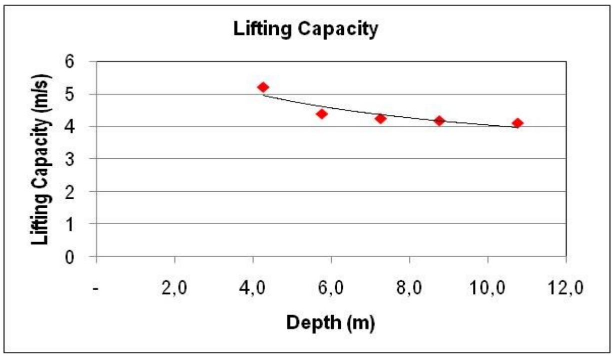

Figure 19. The lifting capacity of BTM SR4.

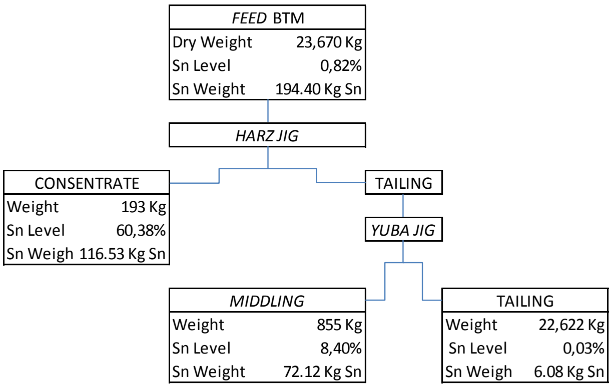

Figure 20. The processing result

Based on the microscope analysis, Sn weight obtained in Feed BTM at the level of 0.82% Sn is 194.4 kg Sn and the total of Sn weight obtained is 188.65 kg Sn (Sn concentrate added with Sn middling), leaving 5.75 kg of Sn tailing.

4. Economic Analysis

a. Capital Expenditure (CAPEX)

Capital expenditure (CAPEX) for BTM SR4 equipment per month is about 6.8 million IDR. The needs of mining operational equipment using BTM SR4 equipment can be seen in Table 5.

b. Operational Expenditure (OPEX)

Operational expenditure (OPEX) of mining using BTM SR4 equipment per hour is about IDR 317,448 per hour. The components of operational expenditure can be seen in Table 6.

c. Cost of Goods Manufactured (COGM)

The total of overall operational expenditure (including the depreciation cost) per hour after added by Over Head is IDR 379,134 per hour.

Table 1. Analysis of Feed BTM Sample

MICROSCOPE ANALYSIS

Date	26/09/2013	**Example Origin**	FEED BTM
		Dry Ore Weight	23.670,00 Kg (Dry Weight)
		Sn Weight	194,40 Kg Sn
		Sn Level	0,82%

Size Fraction (mesh)			20#	50#	70#	100#	-100#	
Weight per Fraction (Kg)			12660	6793	2043	806	1367	
No.	MINERAL DESCRIPTION	S.G	% Original Weight	% Orginal Weight	% Original Weight	% Original Weight	% Original Weight	Total
1	Cassiterite	6,9	0,28	0,38	0,16	0,17	0,09	1,08
2	Ilmenite	4,5	0,00	1,26	0,27	0,05	0,06	1,64
3	Rutile	4,5	0,00	0,00	0,00	0,00	0,00	-
4	Monazite	4,8	0,00	0,00	0,00	0,00	0,00	0,01
5	Xenotime	4,8	0,00	0,00	0,00	0,00	0,00	-
6	Pyrit/Marcasite	4,8	0,95	1,04	0,15	0,03	0,04	2,21
7	Zircon	4,7	0,00	0,00	0,00	0,03	0,04	0,07
8	Topaz	3,5	0,00	0,00	0,00	0,00	0,00	-
9	Tourmaline	3,1	0,87	1,04	0,32	0,03	0,07	2,33
10	Quartz	2,6	51,39	24,97	7,73	3,09	5,48	92,66
11	Anatas	3,9	0,00	0,00	0,00	0,00	0,00	-
12	Spinel	3,8	0,00	0,00	0,00	0,00	0,00	-
13	Cinder	2,9	0,00	0,00	0,00	0,00	0,00	-
14	Rust of Iron	4	0,00	0,00	0,00	0,00	0,00	-
15	Siderite	3,8	0,00	0,00	0,00	0,00	0,00	-
16	Plumbogumite	7,5	0,00	0,00	0,00	0,00	0,00	-
17	Limonite	3,8	0,00	0,00	0,00	0,00	0,00	-
18	Hematit	5,2	0,00	0,00	0,00	0,00	0,00	-
19	Synthetic PB	11,5	0,00	0,00	0,00	0,00	0,00	-
	TOTAL		53,49	28,70	8,63	3,40	5,78	100,00

Table 2. Analysis of Concentrate BTM Sample

MICROSCOPE ANALYSIS

Date	26/09/2013	**Example Origin**	CONCENTRATE BTM
		Ore Weight	193,00 Kg
		Sn Weight	116,53 Kg Sn
		Sn Level	60,38%

Size Fraction (mesh)			20#	50#	70#	100#	-100#	
Weight per Fraction (Kg			34	61	41	40	17	
No.	MINERAL DESCRIPTION	S.G	% Original Weight	% Original Weight	% Original Weight	% Original Weight	% Original Weight	Total
1	Cassiterite	6,9	16,74	24,54	15,32	15,97	6,87	79,45
2	Ilmenite	4,5	0,00	0,85	2,10	1,53	0,31	4,80
3	Rutile	4,5	0,00	0,00	0,00	0,00	0,00	-
4	Monazite	4,8	0,00	0,00	0,47	0,20	0,09	0,75
5	Xenotime	4,8	0,00	0,00	0,00	0,00	0,00	-
6	Pyrit/Marcasite	4,8	0,55	1,61	1,21	0,68	0,16	4,21
7	Zircon	4,7	0,00	0,00	0,27	1,21	1,01	2,49
8	Topaz	3,5	0,00	0,00	0,00	0,00	0,00	-
9	Tourmaline	3,1	0,07	0,28	0,23	0,04	0,05	0,68
10	Quartz	2,6	0,18	4,55	1,68	0,92	0,29	7,62
11	Anatas	3,9	0,00	0,00	0,00	0,00	0,00	-
12	Spinel	3,8	0,00	0,00	0,00	0,00	0,00	-
13	Cinder	2,9	0,00	0,00	0,00	0,00	0,00	-
14	Rust of Iron	4,0	0,00	0,00	0,00	0,00	0,00	-
15	Siderite	3,8	0,00	0,00	0,00	0,00	0,00	-
16	Plumbogumite	7,5	0,00	0,00	0,00	0,00	0,00	-
17	Limonite	3,8	0,00	0,00	0,00	0,00	0,00	-
18	Hematit	5,2	0,00	0,00	0,00	0,00	0,00	-
19	Synthetic PB	11,5	0,00	0,00	0,00	0,00	0,00	-
	TOTAL		17,55	31,84	21,28	20,55	8,79	100,00

Table 3. Analysis of Middling BTM Sample

MICROSCOPE ANALYSIS

Date	26/09/2013	**Example Origin**	MIDDLING BTM
		Ore Weight	855.000 Kg
		Sn Weight	72.119 Kg Sn
		Sn Level	8.4%

Size Fraction (mesh)			20#	50#	70#	100#	-100#	
Weight per Fraction (K			176	456	111	66	46	
No.	MINERAL DESCRIPTION	S.G	% Original Weight	% Original Weight	% Original Weight	% Original Weight	% Original Weight	Total
1	Cassiterite	6.9	3.88	4.21	0.91	1.06	1.03	11.10
2	Ilmenite	4.5	0.00	0.00	1.41	1.08	0.64	3.13
3	Rutile	4.5	0.00	0.00	0.00	0.00	0.00	-
4	Monazite	4.8	0.00	0.00	0.00	0.00	0.00	-
5	Xenotime	4.8	0.00	0.00	0.00	0.00	0.00	-
6	Pyrit/Marcasite	4.8	1.10	2.07	0.76	0.45	0.28	4.66
7	Zircon	4.7	0.00	0.00	0.00	0.40	0.85	1.25
8	Topaz	3.5	0.00	0.00	0.00	0.00	0.00	-
9	Tourmaline	3.1	0.21	0.00	0.16	0.24	0.07	0.67
10	Quartz	2.6	15.36	47.07	9.78	4.45	2.53	79.19
11	Anatas	3.9	0.00	0.00	0.00	0.00	0.00	-
12	Spinel	3.8	0.00	0.00	0.00	0.00	0.00	-
13	Cinder	2.9	0.00	0.00	0.00	0.00	0.00	-
14	Rust of Iron	4.0	0.00	0.00	0.00	0.00	0.00	-
15	Siderite	3.8	0.00	0.00	0.00	0.000	0.00	-
16	Plumbogumite	7.5	0.00	0.00	0.00	0.00	0.00	-
17	Limonite	3.8	0.00	0.00	0.00	0.00	0.00	-
18	Hematit	5.2	0.00	0.00	0.00	0.00	0.00	-
19	PB Buatan	11.5	0.00	0.00	0.00	0.00	0.00	-
	TOTAL		20.55	53.35	13.02	7.68	5.40	100.00

Table 4. Analysis of Tailing BTM Sample

MICROSCOPE ANALYSIS

Date	26/09/2013	**Example Origin**	FEED BTM
		Dry Ore Weight	23.670,00 Kg (Dry Weight)
		Sn Weight	194,40 Kg Sn
		Sn Level	0,82%

Size Fraction (mesh)			20#	50#	70#	100#	-100#	
Weight per Fraction (K			12660	6793	2043	806	1367	
No.	MINERAL DESCRIPTION	S.G	% Original Weight	% Original Weight	% Original Weight	% Original Weight	% Original Weight	Total
1	Cassiterite	6,9	0,28	0,38	0,16	0,17	0,09	1,08
2	Ilmenite	4,5	0,00	1,26	0,27	0,05	0,06	1,64
3	Rutile	4,5	0,00	0,00	0,00	0,00	0,00	-
4	Monazite	4,8	0,00	0,00	0,00	0,00	0,00	0,01
5	Xenotime	4,8	0,00	0,00	0,00	0,00	0,00	-
6	Pyrit/Marcasite	4,8	0,95	1,04	0,15	0,03	0,04	2,21
7	Zircon	4,7	0,00	0,00	0,00	0,03	0,04	0,07
8	Topaz	3,5	0,00	0,00	0,00	0,00	0,00	-
9	Tourmaline	3,1	0,87	1,04	0,32	0,03	0,07	2,33
10	Quartz	2,6	51,39	24,97	7,73	3,09	5,48	92,66
11	Anatas	3,9	0,00	0,00	0,00	0,00	0,00	-
12	Spinel	3,8	0,00	0,00	0,00	0,00	0,00	-
13	Cinder	2,9	0,00	0,00	0,00	0,00	0,00	-
14	Rust of Iron	4,0	0,00	0,00	0,00	0,00	0,00	-
15	Siderite	3,8	0,00	0,00	0,00	0,00	0,00	-
16	Plumbogumite	7,5	0,00	0,00	0,00	0,00	0,00	-
17	Limonite	3,8	0,00	0,00	0,00	0,00	0,00	-
18	Hematit	5,2	0,00	0,00	0,00	0,00	0,00	-
19	Synthetic PB	11,5	0,00	0,00	0,00	0,00	0,00	-
	TOTAL		53,49	28,70	8,63	3,40	5,78	100,00

Table 5. Capex

No	Description	Total	Unit	Price/Unit	Total Price	Age (Month)	Price/Month
1	BTM Equipment	1	Set	IDR 135.000.000	IDR 135.000.000	36	IDR 3.750.000
2	Water Pump (26HP/2200RPM)	1	Set	IDR 5.000.000	IDR 5.000.000	12	IDR 416.667
3	Robin Engine (9HP)	1	Set	IDR 2.650.000	IDR 2.650.000	12	IDR 220.833
4	4" Soil Pump	1	Set	IDR 3.000.000	IDR 3.000.000	12	IDR 250.000
5	6" PVC Pipe	2	Pcs	IDR 400.000	IDR 800.000	2	IDR 400.000
6	150 PSI Hose	6	meter	IDR 650.000	IDR 3.900.000	12	IDR 325.000
7	4" Spiral Hose	10	meter	IDR 55.000	IDR 550.000	6	IDR 91.667
8	2,5" Spiral Hose	10	meter	IDR 40.000	IDR 400.000	6	IDR 66.667
9	Selang Karpet	30	meter	IDR 52.000	IDR 1.560.000	6	IDR 260.000
10	Clamp and Other Accessories	1	Lumpsum	IDR 1.000.000	IDR 1.000.000	6	IDR 166.667
11	Suction Strainer	2	Pcs	IDR 125.000	IDR 250.000	6	IDR 41.667
12	Safety Helmet	4	Pcs	IDR 79.000	IDR 316.000	12	IDR 26.333
13	Safety Spactacle	4	Pcs	IDR 62.000	IDR 248.000	12	IDR 20.667
14	Safety Boot	4	Pair	IDR 270.000	IDR 1.080.000	12	IDR 90.000
15	Glovers	4	Pair	IDR 3.000	IDR 12.000	1	IDR 12.000
16	Jumbo Bag	50	Sheet	IDR 80.000	IDR 4.000.000	6	IDR 666.667
	Total				**IDR 159.766.000**		**IDR 6.804.833**

Table 6. Opex

No	Description	Total	Unit	Price/Unit	Total Price	Hour	Price/Hour
1	Fuel for Water Pump (26HP/2200RPM)	78	Liter	IDR 10.700	IDR 834.600	24,47	IDR 34.107
2	Fuel for Robin ENgine (9HP)	24	Liter	IDR 6.500	IDR 156.000	24,47	IDR 6.375
3	Maintenance and *Sparepart*	1	Lumpsum	IDR 3.000.000	IDR 3.000.000	250	IDR 12.000
4	Borehole Making	1	Lumpsum	IDR 12.000.000	IDR 12.000.000	250	IDR 48.000
5	Preparation	1	Lumpsum	IDR 2.000.000	IDR 2.000.000	24,47	IDR 81.733
6	Transportation	1	Lumpsum	IDR 3.600.000	IDR 3.600.000	250	IDR 14.400
7	Proccesing	1	Lumpsum	IDR 5.000.000	IDR 5.000.000	48	IDR 104.167
8	Employee's Wage	4	Person	IDR 3.000.000	IDR 12.000.000	720	IDR 16.667
	Total				**IDR 38.590.600**		**IDR 317.448**

Table 7. COGM Calculation

No	Parameter	Value	Unit	Description
(a)	Effective operating hour	24.47	Hour	The result of the testing
(b)	Tin ore processing (PPBT) Result in Mentok	194.4	kg Sn	concentrate+ middling+ tailing
(c)	Total Price	379,134	IDR/hour	Including the depreciation cost and Over Head
(d)	COGM	47,723	IDR/kg Sn	d = c / (b / a)

Table 8. BEG Calculation

No	Parameter	Value	Unit	Description
(a)	Ore Concentrate price	50,000	IDR/kg Sn	Particular target
(b)	Effective running hour	250	hour	Assumption/month (2 Work Shifts)
(c)	Effective running hour	24.47	hour	The result of the testing
(d)	Ore Level (drill data)	0.638	Kg Sn /m^3	Average level of layers 9 - 12
(e)	PPBT Result in Mentok	194.4	kg Sn	concentrate+ middling+ tailing
(f)	Bank Earth Moving Rate	12.45	m^3/hour	f = e / d / c
(g)	Total Price	379,134	IDR/hour	
(h)	Break Even Production	7.58	Kg Sn/hour	h = g / a
(i)	Ore BEG	0.609	Kg Sn/m^3	i = h / f
(j)	Earth Moving Price	30,447	IDR/m^3	j = g / f

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Based on the calculation above, it is known that the Cost of Goods Manufactured (COGM) of mining using Borehole Tin Mining type SR4 equipment is about IDR 47,723 per kg Sn.

d. Break Even Grade (BEG)

The price assumption of Ore Concentrate based on particular target set in this research is IDR 50,000 per kg Sn and the assumption of the effective running hour of BTM equipment is 250 hours per month. Based on those assumptions, the calculation of BEG of mining using Borehole Tin Mining type SR4 is shown in Table 8.

Based on the table above, it is known that the Ore BEG for mining using Borehole Tin Mining type SR4 is 0.609 kgSn/m3 or equal to BEG Overall 0.2 kgSn/m^3. Meanwhile, if using Ore Concentrate price according to Work Plan and Budget (RKAP) year 2013 that is IDR 90,210/KgSn, Ore BEG obtained for mining using Borehole Tin Mining type SR4 equipment is 0.338 kgSn/m^3 or equal to Overall BEG 0.11 kgSn/m^3.

5. Conclusions

Based on the operational testing, it can be concluded that mining using Borehole Tin Mining (BTM) type SR4 method is very efficient and has high mobility yet low impact due to:

a. Minimum mining area
b. Minimum land clearing
c. No overburden stripping
d. Optimal ore excavation
e. Very low environmental impact
f. Minimum reclamation
g. Maximum work safety
h. A solution for overlapping land use issue

Therefore, this method has met the criteria expected to be the solution of the problems explained. It is expected that, as a short term measure, BTM SR4 can be applied as the substitute of small-scale mining applied by the society to ensure the work safety and reduce environmental damage in the future. As a long term measure, it is expected that technological development is conducted in wider scale using more modern technology to work both on land and under water.

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