Other Oxides Pre-removed from Bangka Tin Slag to Produce a High Grade Tantalum and Niobium Oxides Concentrate

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Abstract. Indonesia, as the second largest tin producer in the world, has a byproduct from the production of tin. This byproduct is in the forms of tin slag containing tantalum pentoxide (Ta₂O₅) and niobium pentoxide (Nb₂O₅). This study focuses on the recovery of tantalum pentoxide and niobium pentoxide from the tin slag. In the process, one part of the tin slag sample was sieved only (BTS), and the other was roasted at 900°C, water quenched and then sieved (BTS-RQS). Samples BTS and BTS-RQS were characterized by thermogravimetric analysis (TGA) and X-ray fluorescence (XRF). One part of BTS-RQS sample was dissolved in hydrofluoric acid (HF) and the other was dissolved in hydrochloric acid (HCl), washed with distilled water, then dissolved into sodium hydroxide (NaOH). Each sample was characterized by using XRF. The BTS sample produced the highest recovery of 0.3807 and 0.6978 % for Ta₂O₅ and Nb₂O₅, respectively, from the particle size of -1.00+0.71 and a fraction of 47.29%, while BTS-RQS produced the highest recovery of 0.3931 and 0.8994 % for Ta₂O₅ and Nb₂O₅, respectively, on the particle size of -0.71+0.350 and a fraction of 21%. BTS-RQS, dissolved with 8% hydrofluoric acid, yields tantalum pentoxide and niobium pentoxide with a ratio of 2.01 and 2.09, respectively. For the sample BTS-RQS dissolve first with 6M hydrochloric acid, washed with distilled water, then dissolved with sodium hydroxide 10M, the yield ratios are 1.60 and 1.84 for tantalum pentoxide and niobium pentoxide, respectively. In this study, it is found that the dissolution by using hydrofluoric acid 8% yields the best ratio.

Keywords: dissolution, Niobium pentoxide, Tantalum pentoxide, tin slag.

1. Introduction

Indonesia is the second largest tin producer in the world, with a production area located on the island of Bangka and Belitung. The number of tin smelters operating on Bangka and Belitung are 34 smelters, according to the organization for economic co-operation and development (OECD) in November 2012 [¹]

In tin production process, results byproducts such as tin slag-1 and slag-2. Tin slag-1 contains 20-30% Tin, while tin slag-2 contains 2-3% Tin. Tin slag-2 is a remelted tin slag-1 into reverberatory furnace
and containing transition metal oxides such as tantalum pentoxide (Ta$_2$O$_5$) and niobium pentoxide (Nb$_2$O$_5$) [2]. Tantalum pentoxide and niobium pentoxide can be extracted from this slag. Other than from tin slag, tantalum pentoxide (Ta$_2$O$_5$) and niobium pentoxide (Nb$_2$O$_5$) can be recovered by mining.

Tantalum pentoxide (Ta$_2$O$_5$) can be recovered from tantalite ore (oxides) [3], that can be found in the earth's crust of about 2 ppm [4]. While niobium oxide can be economically extracted from the deposit of pyrochlore and columbite, which can generally be divided into two types, namely: primary carbonatite deposits with contain of 0.5-0.7% Nb$_2$O$_5$ and enriched pegmatite deposits (carbonate mineral leaching products of primary carbonatite) that contains of 1.0-7.0% Nb$_2$O$_5$ [5].

Tantalum and niobium are in the 14 critical materials [6] so the focus of their recovery from tin slag will be an alternative option. For tantalum itself, it is now considered as midterm critical metal where the level of its availability is only until 2020 [3]. Efforts of obtaining tantalum and niobium from tin slags has been carried out by some previous researchers [2,7–13]. Tin slag from Indonesia has been informed to contain (Ta,Nb)$_2$O$_5$ at about 2.7% [2].

For comparison, the recovery of tantalum pentoxide (Ta$_2$O$_5$) and niobium pentoxide (Nb$_2$O$_5$) from the mine, we can refer to Anita project owned by Les Mineraux Crevier at the mine site in the Lac-Saint-Jean Quebec, Canada. Anita project has a measured reserves of approximately 25.8 million ton with niobium oxide of 0.196% and tantalum oxide of 234 ppm. Other than that, the mineral inferred resources are 15.42 million ton. These reserves are assumed to be a cut-off grade of 1,000 g/t Nb [14].

Metal extraction can be done by hydrometallurgy, pyrometallurgy and electrometallurgy. On simple hydrometallurgy can be done in liquid-liquid extraction [15–17] or the method of dissolution. This study uses the method of dissolution to reduce the other oxides content.

The challenge of this research is the dominant other oxides content with a total of 99.09% while the precious metal content is of less than 1%. Previous researches, that used tin slag with a total content of Ta$_2$O$_5$ and Nb$_2$O$_5$ over 2.7%, failed to describe the relationship of process to the decreasing content of other oxides [2,7–13]. The decreasing contents of other oxides on this study is expected to be the leading direction for the next processes in increasing contents of Ta$_2$O$_5$ and Nb$_2$O$_5$ of tin slags.

We will observe in this study the effect of sieving, roasting at 900°C-water quenching-sieving to the weight and content fraction of Ta$_2$O$_5$ and Nb$_2$O$_5$, and the effect of BTS-RQS dissolution with hydrofluoric acid and its relationship with yield ratio of Ta$_2$O$_5$ and Nb$_2$O$_5$. Furthermore, we will see the effect of dissolution with hydrochloric acid and sodium hydroxide as well as its relationship with yield ratio of Ta$_2$O$_5$ and Nb$_2$O$_5$.

2. Methodology

2.1. Feasibility study

To calculate the BTS potential reserved of tantalum pentoxide (Ta$_2$O$_5$) and niobium pentoxide (Nb$_2$O$_5$) we made a comparison between the BTS’s of PT Timah Tbk and Anita project. The assumed minimum production of PT Timah Tbk to be of 35,000 mt/year [18], and slag output of about 10% [19] so slag amount was about 3,500 mt/year.

2.2. Materials

Tin slag used in this research was provided by PT Timah Tbk, Indonesia. Initial tin slag characterization was done by XRF (Spectro Xepos Ametek), the results can be seen in Table 1. This study used HF (technical solution), and HCl and NaOH (pa, Merck).
2.3. Procedure of pre-removed of other oxides
First sample, Bangka tin slag sieved with sieve size +1; -1+0.71; -0.71+0.350; -0.350+0.063 and -0.063 mm, then each particle size was characterized by XRF.

Table 1. The initial characterization of Bangka tin slag.

|     | \( \text{Ta}_2\text{O}_5 \) (%) | \( \text{Nb}_2\text{O}_5 \) (%) | \( \text{SiO}_2 \) (%) | \( \text{CaO} \) (%) | \( \text{TiO}_2 \) (%) | \( \text{Al}_2\text{O}_3 \) (%) | \( \text{Fe}_2\text{O}_3 \) (%) | \( \text{ZrO}_2 \) (%) | El & Min.OO (%) |
|-----|--------------------------------|--------------------------------|----------------------|---------------------|-------------------|------------------------|-----------------|-----------------|----------------|
| BTS | 0.33                          | 0.64                          | 34.26                | 15.44               | 11.92             | 11.7                   | 8.84            | 4.78            | 12.06          |

*El & Min.OO = element & minor other oxides

Second samples, Bangka tin slag was roasted at a temperature of 900°C for 2 hours, water quenched and heated in the oven to demoisturized. The samples, then, sieved to the size of +1; -1+0.71; -0.71+0.350; -0.350+0.063 and -0.063 mm and each size particle was characterized by XRF. Both samples, BTS and BTS-RQS were analyzed with thermo gravimetric, Perkin Elmer STA 6000, to record the sample weight change as a function of temperature.

Dissolving with hydrofluoric acid has done by placing BTS-RQS into 4 pieces of plastic containers each of which weights 20 grams. Then, filled the plastic container with 100 ml of hydrofluoric acid with each of concentration of 4, 8, 16 and 32%. After 2 hours, each sample was rinsed with distilled water and characterized by XRF.

The other dissolutions were to put BTS-RQS into 16 beaker glasses, each of which weights 20 grams, then on every 4 beaker glasses filled with 100 ml of hydrochloric acid with each of concentration of 6, 8, 10 and 12 M, then immersed for 2 hours. After the hydrochloric acid dissolutions completed, the samples were rinsed with distilled water. For every 4 beaker glasses from different concentrations of hydrochloric acid, sodium hydroxide with a concentration of 6, 8, 10, 12M, respectively, was added and immersed for 20 hours. The sample code, type, concentration and solvent dissolution time are showed in Table 2.

Table 2. Sample code, solvent type, concentration (%/M) and dissolution time (hours).

| Sample code | Type of solvent, Concentration (%/M) and Dissolution Duration (hours) |
|-------------|-------------------------------------------------------------------|
| F4          | Flouride Acid 4 %, 2 h                                            |
| F8          | Flouride Acid 8 %, 2 h                                            |
| F16         | Flouride Acid 16 %, 2 h                                           |
| F32         | Flouride Acid 32 %, 2 h                                           |
| A6B6        | Chrolide Acid 6M, 2 h continue Sodium Hydroxide 6M, 20 h           |
| A6B8        | Chrolide Acid 6M, 2 h continue Sodium Hydroxide 8M, 20 h           |
| A6B10       | Chrolide Acid 6M, 2 h continue Sodium Hydroxide 10M, 20 h          |
| A6B12       | Chrolide Acid 6M, 2 h continue Sodium Hydroxide 12M, 20 h          |
| A8B6        | Chrolide Acid 8M, 2 h continue Sodium Hydroxide 6M, 20 h           |
| A8B8        | Chrolide Acid 8M, 2 h continue Sodium Hydroxide 8M, 20 h           |
| A8B10       | Chrolide Acid 8M, 2 h continue Sodium Hydroxide 10M, 20 h          |
| A8B12       | Chrolide Acid 8M, 2 h continue Sodium Hydroxide 12M, 20 h          |
| A10B6       | Chrolide Acid 10M, 2 h continue Sodium Hydroxide 6M, 20 h          |
| A10B8       | Chrolide Acid 10M, 2 h continue Sodium Hydroxide 8M, 20 h          |
| A10B10      | Chrolide Acid 10M, 2 h continue Sodium Hydroxide 10M, 20 h         |
| A10B12      | Chrolide Acid 10M, 2 h continue Sodium Hydroxide 12M, 20 h         |
| A12B6       | Chrolide Acid 12M, 2 h continue Sodium Hydroxide 6M, 20 h          |
| A12B8       | Chrolide Acid 12M, 2 h continue Sodium Hydroxide 8M, 20 h          |
| A12B10      | Chrolide Acid 12M, 2 h continue Sodium Hydroxide 10M, 20 h         |
| A12B12      | Chrolide Acid 12M, 2 h continue Sodium Hydroxide 12M, 20 h         |
3. Results and discussions

3.1. Feasibility study result
With Anita Project’s economic parameter basic data, potential reserved calculation of tantalum pentoxide (Ta$_2$O$_5$) and niobium pentoxide (Nb$_2$O$_5$) from tin slag can be seen at Table 3.

**Table 3.** Comparative of potential reserves calculation project Anita and Bangka tin slag.

| Description          | Anita Projek | Bangka Tin Slag |
|----------------------|--------------|-----------------|
| Ta$_2$O$_5$ content  | 234 ppm      | 0.33%           |
| Nb$_2$O$_5$ content  | 0.196%       | 0.64%           |
| Measured reserve     | 25.8 million ton | 3,500 ton/year* |
| Inferred reserve     | 15.42 million ton |                |
| Mine Life            | 18 year      |                 |

* calculation in minimum production.

Slag Production of PT Timah Tbk 3,500-5,000 ton/year.

3.2. Initial Process of BTS
To simplify observation and discussion, other oxides were classified into two groups, one group was major other oxides (MOO) and another group that consisted of elements and minor oxides (EMO). Table 4 had the details data.

**Table 4.** Major Others Oxides and Element & Minor Other Oxides.

| Major Others Oxides (MOO) | Element & Minor Others Oxides (EMO) |
|---------------------------|-------------------------------------|
| SiO$_2$, CaO, TiO$_2$, Al$_2$O$_3$, Fe$_2$O$_3$, ZrO$_2$ | Na$_2$O, MgO, P$_2$O$_5$, S, Cl, K$_2$O, Sc, V$_2$O$_5$, Cr$_2$O$_3$, MnO, CoO, NiO, CuO, ZnO, Ga, Ge, As$_2$O$_3$, Se, Br, Rb$_2$O, SrO, Y, MoO, Ru, Rh, Pd, Ag, Cd, In, SnO$_2$, Sb$_2$O$_3$, Te, I, Cs, BaO, La$_2$O$_3$, Ce$_2$O$_3$, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Hf, WO$_3$, Au, Hg, Tl, Pb, Bi, Th and U |

Characterization of BTS with XRF can be seen at tabel 5. Particle size of -1.00+0.71 mm had the highest content of Ta$_2$O$_5$ and Nb$_2$O$_5$, that were 0.3807 and 0.6978%, each with a weight fraction of 47.29%.

The initial purpose of reduction roasting of 900°C and water quenched of tin slag was to observe the effects of reduction roasting and water quenched on particle size reduction. But the experiment shown another results that there was a decreased content of EMO. Particle size reduction due to roasted 900°C and water quenched affected only about 2% by weight in 1.00 mm particles size and a significant affected on particles size smaller than 1.00 mm. The percentage decreased content of EMO was from 56.17%-16.44% to 20.84%-11:30%, this can be seen in Table 5 and Table 6.
Table 5. Size and oxides analysis of the initial tin slag.

| Particle size (mm) | Weight (gram) | Fraction (%) | Ta_2O_5 (%) | Nb_2O_5 (%) | ZrO_2 (%) | Al_2O_3 (%) | Fe_2O_3 (%) | TiO_2 (%) | CaO (%) | SiO_2 (%) | El & Min.OO (%) |
|-------------------|--------------|--------------|-------------|-------------|-----------|-------------|-------------|-----------|----------|-----------|----------------|
| +1.00             | 479          | 47.9         | 0.3239      | 0.6548      | 4.732     | 7.285       | 7.595       | 9.761     | 12.15    | 22.03     | 35.4683        |
| -1.00+0.71        | 472.9        | 47.29        | 0.3807      | 0.6978      | 4.951     | 7.77        | 9.124       | 11.59     | 13.59    | 24.3      | 27.5965        |
| -0.71+0.350       | 18.6         | 1.86         | 0.3393      | 0.6484      | 4.448     | 7.395       | 8.796       | 9.841     | 11.04    | 23.4      | 34.0923        |
| -0.350+0.063      | 23.1         | 2.31         | 0.2758      | 0.6059      | 4.212     | 11.77       | 8.706       | 9.872     | 12.26    | 35.85     | 16.4483        |
| -0.063            | 2.3          | 0.23         | 0.2937      | 0.3715      | 2.396     | 4.406       | 8.112       | 6.539     | 5.677    | 16.03     | 56.1748        |
| Weight loss       | 4.1          | 0.41         | -           | -           | -         | -           | -           | -         | -        | -         | -               |
| Total             | 1000         | 100          | -           | -           | -         | -           | -           | -         | -        | -         | -               |

Table 6. Size and elemental analysis of BTS-RQS.

| Particle size (mm) | Weight (gram) | Fraction (%) | Ta_2O_5 (%) | Nb_2O_5 (%) | ZrO_2 (%) | Al_2O_3 (%) | Fe_2O_3 (%) | TiO_2 (%) | CaO (%) | SiO_2 (%) | El & Min.OO (%) |
|-------------------|--------------|--------------|-------------|-------------|-----------|-------------|-------------|-----------|----------|-----------|----------------|
| +1.00             | 441.2        | 45.8         | 0.3475      | 0.7439      | 5.354     | 11.25       | 9.063       | 12.03     | 16.4     | 33.51     | 11.3016        |
| -1.00+0.71        | 221          | 22.9         | 0.3536      | 0.7981      | 5.641     | 10.55       | 9.28        | 11.53     | 15.48    | 34.1      | 12.2673        |
| -0.71+0.350       | 202.5        | 21.0         | 0.3931      | 0.8994      | 6.358     | 9.672       | 10.53       | 11.96     | 15.88    | 30.12     | 14.1875        |
| -0.350+0.063      | 71.2         | 7.4          | 0.3502      | 0.6343      | 4.412     | 10.27       | 9.84        | 11.51     | 14.85    | 32.19     | 15.9435        |
| -0.063            | 15.9         | 1.7          | 0.3303      | 0.6867      | 4.754     | 9.558       | 11.63       | 10.74     | 13.46    | 28        | 20.841         |
| Weight loss       | 11.8         | 1.2          | -           | -           | -         | -           | -           | -         | -        | -         | -               |
| Total             | 963.6        | 100          | -           | -           | -         | -           | -           | -         | -        | -         | -               |

3.3. Thermo gravimetric analysis on BTS

To observed thermal decomposition, the initial BTS and BTS-RQS was analyzed using TGA. The linear heating rate of TGA characterization was 10°C/min, from room temperature to a temperature of 900°C. The result was showed in Figure 1.

BTS endothermic peak can be seen at about 600°C, its weight loss started at temperature of 100°C until the endothermic peak, while the increased of its weight began at a temperature of 700°C. BTS-RQS weight loss occured from the temperature of 100°C to about 900°C, refer to Figure 1(b), Table 5 and Table 6, this weight loss occured due to the oxidation of EMO.

Figure 1. (a) DTA and TGA chart from the initial Bangka tin slag. (b) DTA and TGA chart from the roasted 900°C and water quenched of Bangka tin slag.
3.4. The effect of HF and HCl+NaOH dissolution

3.4.1. The effect of HF dissolution
BTS-RQS dissolution with hydrochloric acid 8% produced the highest Ta$_2$O$_5$ and Nb$_2$O$_5$ content of 0.664% and 1.339%, with its yield ratio were 2.01 and 2.09, respectively, this can be seen in Figure 2 (a) and Table 7.

This dissolution shown that the higher HF concentration, the higher SiO$_2$ dissolution rate. This result was in line with SiO$_2$ dissolution on HF [20]. Dissolution with HF 32% will caused the increased SiO$_2$ content to 13.06%, this is due to the formation of solid SiO$_2$. This solid SiO$_2$ was the reason why weight loss value become 106.5%, which can be seen at Table 7.

Hydrochloric acid dissolved Fe$_2$O$_3$ well and TiO$_2$ slightly. HF 4, 8 and 16% were less successfully dissolving EMO and could not dissolve CaO, Al$_2$O$_3$ and ZrO$_2$. This information can be seen in Figure 2 (b).

![Figure 2](image_url)

**Figure 2.** (a) The effect of flouride acid concentration on Ta$_2$O$_5$ & Nb$_2$O$_5$ yield ratio. (b) The effect of flouride acid concentration to Ta$_2$O$_5$, Nb$_2$O$_5$ and others oxide content.

**Table 7.** Chemical Analysis of Flouride Acid Dissolved Residu.

| Sample Code | Total Pct WL* | Pct Pct | Pct Pct | Yield Yield | Loss Of |
|-------------|---------------|---------|---------|-------------|--------|
|             | Pct (initial) | T$_2$O$_3$ | T$_2$O$_3$ | T$_2$O$_3$ | T$_2$O$_3$ | T$_2$O$_3$ | T$_2$O$_3$ | Ignition |
| F4          | 76.0          | 0.33     | 0.578   | 1.75        | 0.64    | 1.080     | 1.69        | 38,653    |
| F8          | 56.5          | 0.33     | 0.664   | 2.01        | 0.64    | 1.339     | 2.09        | 30,589    |
| F16         | 55.0          | 0.33     | 0.091   | 0.28        | 0.64    | 0.133     | 0.21        | 34,707    |
| F32         | 106.5         | 0.33     | 0.160   | 0.48        | 0.64    | 0.584     | 0.91        | -1,8748   |

*WL = Weight Loss. ** Yield Ratio = content before process/content after process.

3.4.2. Effect Dissolution with HCl+NaOH
The dissolution BTS-RQS with HCl 6M and NaOH 10M produced Ta$_2$O$_5$ dan Nb$_2$O$_5$ content of 0.528 and 1.182%, respectively, with yield ratio for Ta$_2$O$_5$ and Nb$_2$O$_5$ were 1.60 and 1.85, respectively. HCl and NaOH dissolution graphics can be seen in Figure 3 and Table 8. Contents of Ta$_2$O$_5$ and Nb$_2$O$_5$
would have about twice the yield ratio if HCl dissolution were followed by NaOH with a particle size smaller than 0.150 mm or the particle size of between 0.180 and 0.150 mm [13].

HCl and NaOH can dissolved EMO well, but was less successful dissolving SiO$_2$, Fe$_2$O$_3$ and TiO$_2$. HCl and NaOH were not successfully dissolving CaO, Al$_2$O$_3$ and ZrO$_2$. this showed in Figure 4. Leaching of Indonesia tin slag with acid (HCl 2N and HF 0.14 N) and alkaline (NaOH 2N), which used a pyrex reactor with a double wall for hot water circulation, caused a weight loss of 46.3% with Ta$_2$O$_5$ and Nb$_2$O$_5$ final content of the leaching were 1.9 and 2.9%, respectively [2].

![Figure 3. The effect of chloride acid (a) 6M (b) 8M (c) 10 M (d) 12 M on concentrate variation of NaOH and Ta$_2$O$_5$ & Nb$_2$O$_5$ yield ratio.](image)

Table 8. Chemical Analysis of HCl and NaOH Dissolved Residu.

| Sample Code | Total Pct WL* | Pct Ta$_2$O$_5$ (initial) | Pct Ta$_2$O$_5$ (final) | Pct Nb$_2$O$_5$ (initial) | Pct Nb$_2$O$_5$ (final) | Yield Ratio** | Yield Ratio** | Loss of Ignition |
|-------------|---------------|---------------------------|------------------------|--------------------------|------------------------|---------------|---------------|------------------|
| A6B6        | 70.5          | 0.33                      | 0.5037                 | 1.53                     | 0.64                   | 1.19          | 1.86          | -3               |
| A6B8        | 74.5          | 0.33                      | 0.5261                 | 1.59                     | 0.64                   | 1.175         | 1.84          | -3               |
| A6B10       | 71.5          | 0.33                      | 0.5283                 | 1.60                     | 0.64                   | 1.182         | 1.85          | -3               |
| A6B12       | 72.5          | 0.33                      | 0.4547                 | 1.38                     | 0.64                   | 0.9705        | 1.52          | 36,304           |
| A8B6        | 77.0          | 0.33                      | 0.4412                 | 1.34                     | 0.64                   | 0.94          | 1.47          | 30,496           |
| A8B8        | 74.0          | 0.33                      | 0.3475                 | 1.05                     | 0.64                   | 0.8586        | 1.34          | 44,465           |
| A8B10       | 76.5          | 0.33                      | 0.4814                 | 1.46                     | 0.64                   | 0.9795        | 1.53          | 26,217           |
| A8B12       | 79.0          | 0.33                      | 0.4889                 | 1.48                     | 0.64                   | 0.9876        | 1.54          | 20,425           |
| A10B6       | 80.0          | 0.33                      | 0.3264                 | 0.99                     | 0.64                   | 0.8234        | 1.29          | 42,218           |
| A10B8       | 82.0          | 0.33                      | 0.3753                 | 1.14                     | 0.64                   | 0.8916        | 1.39          | 35,494           |
| A10B10      | 83.0          | 0.33                      | 0.4434                 | 1.34                     | 0.64                   | 0.9901        | 1.55          | 22,12            |
| A10B12      | 83.0          | 0.33                      | 0.3823                 | 1.16                     | 0.64                   | 0.8885        | 1.39          | 33,061           |
| A12B6       | 91.0          | 0.33                      | 0.35                   | 1.06                     | 0.64                   | 0.8509        | 1.33          | 28,087           |
| A12B8       | 91.0          | 0.33                      | 0.2918                 | 0.88                     | 0.64                   | 0.7947        | 1.24          | 39,887           |
| A12B10      | 91.0          | 0.33                      | 0.3982                 | 1.21                     | 0.64                   | 0.9137        | 1.43          | 24,512           |
| A12B12      | 84.5          | 0.33                      | 0.3818                 | 1.16                     | 0.64                   | 0.9993        | 1.56          | -3               |

*WL = Weight Loss. ** Yield Ratio = content before process/content after process.
Figure 4. The effect of chloride acid (a) 6M (b) 8M (c) 10 M (d) 12 M on concentrate variation of NaOH to Ta$_2$O$_5$, Nb$_2$O$_5$ and others oxides content.

4. Conclusions and suggestions
Potential reserved of tantalum pentoxide (Ta$_2$O$_5$) and niobium pentoxide (Nb$_2$O$_5$) from BTS can be used as an alternative potential revenues for Bangka and Belitung province.

The roasted at 900$^\circ$C and water quenched can be reduced EMO content. BTS-RQS produced the highest contents of Ta$_2$O$_5$ and Nb$_2$O$_5$ with dissolution of HF 8%, also, the dissolution with HCl 6M and NaOH 10M produced the highest contents of Ta$_2$O$_5$ and Nb$_2$O$_5$.

To dissolved SiO$_2$ and Fe$_2$O$_3$, HF was better than with HCl+NaOH. HF and HCl+NaOH did not dissolve CaO, Al$_2$O$_3$ and ZrO$_2$. BTS-RQS dissolution with HF diluted less EMO, while with HCl 6% and NaOH 6.8 and 10% showed lower contents of SiO$_2$, Fe$_2$O$_3$ and TiO$_2$.

For further research, researcher will need do roast above 900$^\circ$C and water quench to see the effect of it. The next, researcher will need investigate that solid residu from HF 8% dissolution, redissolved in HCl 6M and NaOH 10M to reduce EMO content.

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