INTISARI

Logam Tanah Jarang (LTJ) merupakan unsur vital dalam industri modern. Namun pasokan LTJ yang tidak memadai mendorong perlunya eksplorasi LTJ dari sumber alternatif. Beberapa penelitian pendahuluan menunjukkan abu layang batubara dari Indonesia berpotensi sebagai sumber LTJ.

Proses pemungutan LTJ dari abu layang batubara memerlukan informasi model keterdapatan (*mode of occurence*) LTJ. Penelitian tentang *mode of occurrence* dari abu layang batubara Indonesia masih jarang dilakukan padahal perbedaan *mode of occurence* LTJ mengakibatkan perbedaan proses pemungutannya. Oleh karena itu perlu dilakukan penelitian mengenai *mode of occurrence* dari abu layang batubara Indonesia.

Pemungutan LTJ melalui proses *leaching* asam telah banyak dilakukan namun hasilnya belum maksimal karena sebagian besar LTJ terkungkung dalam fasa gelas sehingga LTJ sulit bereaksi dengan asam. Fasa gelas dapat didestruksi menggunakan NaOH sehingga perlu dilakukan penelitian menggunakan *sequential leaching* NaOH-asam. Untuk mengurangi dampak lingkungan maka perlu dilakukan penelitian tentang penggunaan asam organik dalam proses pemungutan LTJ dari abu layang.

Ada 4 tahap penelitian yaitu (a) karakterisasi abu layang batubara untuk mengetahui jenis mineral serta *mode of occurence* LTJ, (b) proses pemisahan fisis untuk meningkatkan kadar LTJ dalam abu layang, (c) proses *leaching*/digesti NaOH untuk mendestruksi *aluminosilicate glass* yang mengungkung LTJ, (d) proses pemungutan LTJ melalui *leaching* asam.

Hasil karakterisasi menunjukkan abu layang didominasi *quartz, mullite, aluminosilicate glass, unburned carbon* dan oksida besi dimana LTJ diketahui terasosiasi dengan oksida besi dan *aluminosilicate glass.*

Pada tahap pemisahan fisis melalui pemisahan ukuran partikel, partikel berukuran kasar (+200 mesh) mengandung lebih banyak *unburned carbon* dibandingkan ukuran partikel yang lain sebaliknya ukuran partikel yang halus (-400 mesh) mengandung lebih banyak LTJ dan *iron bearing mineral* dibandingkan ukuran lainnya. Proses pengkayaan selanjutnya melalui *magnetic separation*, menunjukkan *iron bearing mineral* dan Ca-Fe *enriched aluminosilicate glass* dapat dipisahkan dari fraksi nonmagnetik. Proses pengkayaan melalui pemisahan ukuran partikel dan *magnetic separation* menyebabkan peningkatan kadar LTJ dalam abu layang dengan *Enrichment Factor* (EF) sebesar 1,23 dan *recovery* sebesar 71,21%.

Pada tahap ketiga dilakukan proses *leaching*/digesti dengan NaOH, diawali dengan mencari kondisi eksperimen optimum. Abu layang nonmagnetik berukuran lolos 400 mesh digunakan sebagai umpan proses digesti. Kondisi optimum diperoleh pada konsentrasi 10M, suhu 65°C, dan waktu reaksi 90 menit untuk rasio Liquid/Solid (L/S) konstan 10 mL/gram. Pada kondisi ini, efisiensi digesti Si dan Al berturut-turut sebesar 28% dan 32%. Proses digesti dapat meningkatkan kadar LTJ dalam *desilicated residue*, dengan *Enrichment Factor* (EF) sebesar 1,43 dan efisiensi digesti LTJ sebesar 8%. Proses digesti juga menyebabkan LTJ yang semula terkungkung di dalam fase *aluminosilicate glass* dapat terlihat lebih jelas dengan bantuan SEM EDS. Hasil SEM EDS menunjukkan LTJ terasosiasi dengan *calcite, quartz* dan *aluminosilicate glass*.

Tahap selanjutnya adalah proses pemungutan LTJ dari *desilicated residue* menggunakan asam anorganik (asam klorida dan asam sulfat) serta asam organik (asam sitrat). Hasil penelitian menunjukkan asam sitrat memiliki efisiensi *leaching* LTJ yang lebih tinggi (75,99%) dibandingkan asam klorida (8,06%) dan asam sulfat (30,81%) karena reaksi leaching dengan asam sitrat juga melibatkan proses pembentukan khelat.

Oleh karena itu untuk proses pemungutan LTJ dengan *leaching* asam dan uji kinetika *leaching* asam dilakukan menggunakan asam sitrat.

Leaching menggunakan asam sitrat pada kondisi optimum 0,75 M asam sitrat, suhu 94ºC, rasio L/S 35 mL/gram, dan waktu reaksi 60 menit menghasilkan efisiensi *leaching* LTJ sebesar 74,81%. Proses pemungutan LTJ yang didahului proses digesti dengan NaOH, terbukti dapat meningkatkan kadar LTJ di dalam *desilicated residue* seperti yang telah dijelaskan sebelumnya. Akibatnya efisiensi *leaching* LTJ dari *desilicated residue* meningkat sebesar 240,58% dibandingkan jika tanpa proses digesti NaOH. Parameter kinetika *leaching* Cerium (Ce), Lanthanum (La), Yttrium (Y) dapat didekati dengan model *Avrami* dengan *phase-spesific constant* (m) Ce, La, dan Y sebesar 0,07; 0,08; 0,06 dan energi aktivasi Ce, La, dan Y masing-masing sebesar 6,3 kJ/mol; 6,83 kJ/mol dan 7,79 kJ/mol.

Kata kunci : Logam Tanah Jarang, abu layang batubara, *mode of occurrence*, digesti, *leaching* asam sitrat

ABSTRACT

Rare Earth Element plus Yttrium (REY) is a vital element in modern industry. Due to its limited supply, the exploration of REY from alternative sources is needed. From several studies that have been conducted, coal fly ash (CFA) from Indonesia is potential as REY sources.

Understanding how REE occurs in CFA is essential for designing an effective method for recovering REY from CFA, whereas its information in Indonesian CFA) is still rarely carried out. Therefore, it is necessary to research the mode of occurrence of Indonesian coal fly ash.

The REY's recovery process from fly ash through the acid leaching process has been carried out in many ways, but the results still have not been optimum because REY is entrapped in the glass phase. As a result, it is difficult for REY to react with acids. The glass phase can be destroyed using NaOH. Therefore it is necessary to conduct research using acid-base sequential leaching. In order to reduce the environmental impact, it is necessary to research organic acids application for REY recovering from fly ash.

This research will be carried out in 4 steps, namely (a) characterization of coal fly ash, (b) the physical separation process to increase the REY content in fly ash, (c) leaching / alkaline digestion process to digest the aluminosilicate glass, (d) REY recovery through acid leaching.

The results of coal fly ash characterization showed that fly ash was dominated by quartz, mullite, aluminosilicate glass, unburned carbon, and iron-bearing minerals. REY is distributed in aluminosilicate glass and Fe-oxide.

In the particle size separation, coarse-sized particles (+200 mesh) contain more unburned carbon than other particle sizes. On the contrary, the fine particle size (-400 mesh) contains more REY and iron-bearing minerals than other sizes. The subsequent enrichment process through magnetic separation shows that iron-bearing minerals can be separated from the nonmagnetic fraction. The enrichment process through particle size separation and magnetic separation increased the REY content in fly ash with an Enrichment Factor (EF) of 1.23 and recovery of 71.21%.

In the third stage, an alkaline (NaOH) leaching process was carried out to find the optimum experimental conditions. The. non-magnetic fly ash with a size of -400 mesh is used as feed for the digestion process. The optimum conditions were obtained at a concentration of 10M NaOH, a reaction temperature of 65°C, for 90 minutes reaction time, in a constant Liquid / Solid (L/S) ratio of 10 mL /gram. The digestion efficiency of Si and Al at this condition was 28% and 32%, respectively. The digestion process also increased the REY content in desilicated residue, with an Enrichment Factor (EF) of 1.43 and REY digestion efficiency of 8%. The REY, which was initially encapsulated in the aluminosilicate glass phase, can be seen more clearly using SEM-EDS after the digestion process. SEM-EDS results show that REY is associated with calcite, quartz, and aluminosilicate glass.

The next stage is REY recovery from the desilicated residue using inorganic acids (hydrochloric acid and sulfuric acid) and organic acids (citric acid). The results showed that citric acid had a higher REY leaching efficiency (75.99%) than hydrochloric acid (8.06%) and sulfuric acid (30.81%). This is due to the formation of chelates on leaching reaction with citric acid. Therefore, citric acid has been. chosen as a lixiviant in REE recovery through acid leaching and is also used for kinetics evaluation.

Citric acid leaching at an optimum condition of 0.75 M citric acid, temperature 94ºC, L / S ratio 35 mL/gram, and reaction time of 60 minutes have leaching efficiency of 74.81%. The process of REY recovery, which is preceded by digestion with NaOH, can increase REY concentration in the desilicated residue, as previously explained. As a result, the leaching efficiency of REY from the desilicated residue increased by 240.58% compared to if the fly ash was not processed through digestion. The kinetic parameter of leaching Cerium (Ce), Lanthanum (La), Yttrium (Y) following Avrami model, with phase-spesific constant (m) of Ce, La, and Y was 0,07; 0,08; 0,06, respectively. The activation energies of Ce, La, and Y each of 6.3 kJ / mol; 6.83 kJ / mol and 7.79 kJ / mol

Keywords: Rare Earth Elements, coal fly ash, mode of occurrence, digestion, citric acid leaching.