# SILICATE SAND

## Aim

This report summarizes information about silicate sand product from EasyMining's Ash2Phos process and the waste code associated to this product.

## Background

Ash residue, i.e. silicate sand, will be produced in the planned Ash2Phos plants in Sweden and Germany.

In the Ash2Phos process, sewage sludge ash that contains Si, P, Ca, Fe, Al and Mg compounds as major fraction and other elements (including heavy metals) as minor fraction is leached with HCl solution. Constituents soluble in water and HCl are dissolved in this step.

P and Ca in the ash are effectively dissolved (at least 90 %) together with other elements. Some of the constituents are dissolved with less efficiency, e.g., only 15 % of the Fe in the ash and 50 % of Al is dissolved. The elements that do not effectively end up in solution are part of minerals or compounds with increased chemical stability and reduced solubility in the mildly acidic environment used (also see Table 4).

The undissolved fraction is referred to as silicate sand. This is separated from the ash leachate using filtration coupled with washing to remove all the residual acidic leachate and water-soluble fractions. The resulting material consists mainly of silica (quartz) and other silicates, iron oxide (hematite) and aluminium oxide but other minerals can be present as minor fraction. The silicate sand after filtration and washing is typically wet (40–50 % wt. dry content).

*Figure 1. Dried silicate sand product with about 15 % wt. hematite, which give it a reddish brown colour (case 1; see the text below)*

## Elemental composition and mineralogy

Two silicate sand products are shown here, which are representative for two plants that will use different ashes. Case 1 represent silicate sand representative for a Swedish plant. Case 2 represent silicate sand representative for a German plant that will mainly use ashes generated in Germany, which will be blended to achieve a desired composition for the input material. Blending of input material can also be considered to produce silicate sand product with a desired composition, i.e., a minimum content of silicates. Tables 1 and 2 below show the elemental composition for the major and minor elements in silicate sand samples obtained in the Ash2Phos process. Please note this is elemental content (and not, e.g, oxide content); Table 3 shows the mineralogy of such samples, determined using XRD analysis. Table 4 shows the water leachability of elements from silicate sand (case 1), which confirms the very low solubility of the constituents.

*Table 1. Compiled data on the major elemental content in dried silicate sand products generated in Ash2Phos pilot and laboratory trials. Analysis done by converting the elements in the sample into acid soluble compounds, followed by total dissolution of the sample in acid and ICP-MS analysis of the obtained solution. Also see table 3.*

| Element | Unit | Value (min – max) Case 1 | Value (min – max) Case 2 |
|---|---|---|---|
| Si | % | 26.8 – 28.2 | 22.4 – 28.3 |
| Fe | % | 13.9 – 14 | 21 – 22.5 |
| Al | % | 3.86 – 3.98 | 1.3 – 4.75 |
| Ca | % | 0.73 – 0.92 | 0.71 – 1.4 |
| K | % | 2.02 – 2.27 | 0.62 – 1.87 |
| Mg | % | 0.45 – 0.56 | 0.38 – 0.76 |
| Na | % | 0.65 – 0.88 | 0.17 – 0.45 |
| P | % | 1.2 – 1.22 | 0.88 – 1 |
| Ti | % | 0.78 – 0.81 | 0.5 – 0.78 |

*Table 2. Compiled data on the minor elemental content in dried silicate sand products generated in Ash2Phos pilot and laboratory trials. Analysis done by converting the elements in the sample into acid soluble compounds, followed by total dissolution of the sample in acid and ICP-MS analysis of the obtained solution (detection limit: ppb). NA = not measured.*

| Element | Unit | Value (min – max) Case 1 | Value (min – max) Case 2 |
|---|---|---|---|
| As | mg/kg | 6.1– 13 | 5– 20 |
| B | mg/kg | NA | 1000– 2000 |
| Ba | mg/kg | 1440 – 2000 | 1500– 1800 |
| Be | mg/kg | < 0.5 | 1.1– 1.3 |
| Cd | mg/kg | <0.5 | < 0.7 |
| Cl | mg/kg | < 1000 | < 1000 |
| Co | mg/kg | 10– 12 | 6– 35 |
| Cr (tot) | mg/kg | 140– 180 | 100– 280 |
| Cu | mg/kg | 320– 400 | 400– 1100 |
| Hg | mg/kg | < 0.1 | < 0.2 |
| Mn | mg/kg | 170– 220 | 160– 700 |
| Mo | mg/kg | 3– 9 | 5– 25 |
| Ni | mg/kg | 65– 80 | 25– 150 |
| Pb | mg/kg | 42– 70 | 7– 50 |
| S | mg/kg | 600– 3300 | 900– 9500 |
| Sb | mg/kg | 14– 17 | 5– 22 |
| Sc | mg/kg | 3– 5 | 0.9– 4 |
| Sn | mg/kg | 67– 82 | 80– 200 |
| Sr | mg/kg | 300– 550 | 110– 290 |
| V | mg/kg | 40– 50 | 15– 60 |
| W | mg/kg | 16– 25 | 7– 12 |
| Y | mg/kg | 9– 12 | 3– 11 |
| Zn | mg/kg | 940– 1400 | 430– 4300 |
| Zr | mg/kg | 160– 200 | 130– 170 |

*Table 3. Mineralogy of dried silicate sand products generated in Ash2Phos pilot and laboratory trials. Analysis done using XRD (detection limit 1-2 %wt.).*

| Mineral | Chemical formula | Case 1 | Case 2 |
|---|---|---|---|
| Quartz | $SiO_2$ | x | x |
| Hematite | $Fe_2O_3$ | x | x |
| Magnetite | $Fe_3O_4$ | | x |
| Albite | $NaAlSi_3O_8$ | x | x |
| Microcline | $KAlSi_3O_8$ | x | x |
| Talk | $Mg_3Si_4O_{10}(OH)_2$ | | x |
| Muscovite | $KAl_2[AlSi_3O_{10}](OH,F)_2$ | x | x |
| Anhydrite | $CaSO_4$ | | x |

*Table 4. Water leachability of elements from dried silicate sand (case 1) at liquid-to-solid ratio 10:1 volume: weight. The leaching test has been performed according to SS-EN 12457-2. Element quantification was done using ICP-MS analysis of the obtained leachate (detection*

*limit: ppb). Determination of dissolved fluoride, chloride, nitrite, bromide, nitrate and sulphate was done by ion chromatography.*

| Element | Unit | Value for Case 1 |
|---|---|---|
| As | µg/l | 20.4 |
| Ba | µg/l | 26.9 |
| Cd | µg/l | <0.05 |
| Cr | µg/l | <0.5 |
| Cu | µg/l | 2.32 |
| Hg | µg/l | <0.02 |
| Mo | µg/l | 16.7 |
| Ni | µg/l | 10.1 |
| Pb | µg/l | <0.2 |
| Sb | µg/l | 2.98 |
| Se | µg/l | 33.7 |
| Zn | µg/l | 16.1 |
| pH | | 6.2 |
| Temp. pH measurement | °C | 24.2 |
| Conductivity | mS/m | 35.4 |
| Temp. cond. Measurement | °C | 24.9 |
| DOC | mg/l | 1.15 |
| Cl | mg/l | 5.82 |
| F | mg/l | <0.200 |
| SO4 | mg/l | 53.4 |

## Morphology

The silicate sand after washing is wet (40 – 50 % wt. dry content). The sand has a reddish-brown colour, which is given by the hematite ($Fe_2O_3$) particles. Removal of hematite (using, e.g., acid leaching) also removes this characteristic colour, making the sand grey.

Table 5 shows the particle size distribution of silicate sand samples based on laser diffraction measurements.

*Table 5. Particle size distribution of silicate sand samples based on laser diffraction measurements of samples stirred with water (to assure a good dispersion of the particles).*

| | Unit | Case 1 | Case 2 |
|---|---|---|---|
| d10 | Microns | *3.59* | *5.01* |
| d50 | Microns | *34.6* | *36.1* |
| d90 | Microns | *139* | *120* |

Figure 2 shows the appearance of silicate sand particles under an optical microscope.

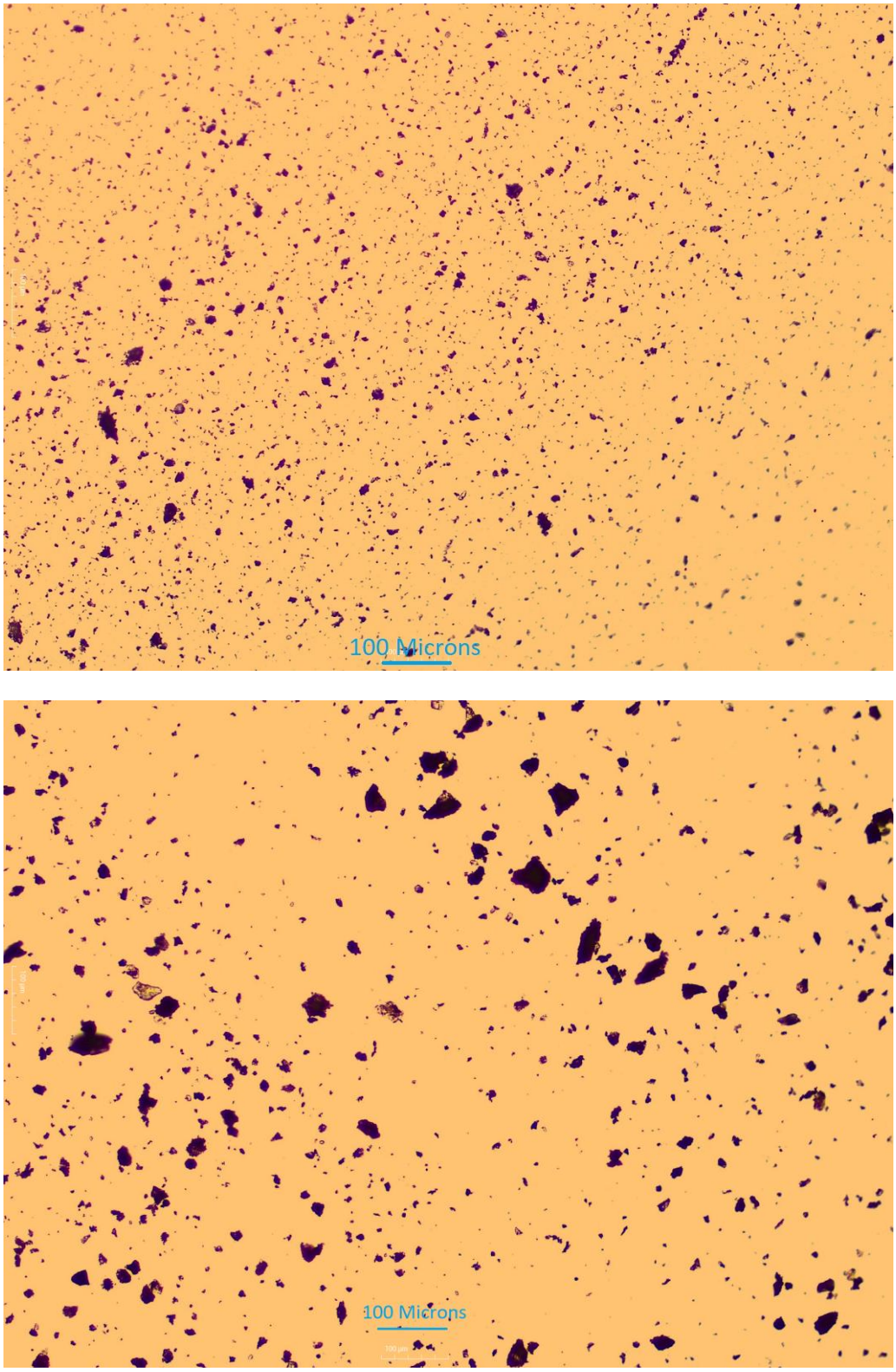


*Figure 2. The appearance of silicate sand particles under magnification. Please note the scale line which corresponds to 100 µm. Top picture: case 1. Bottom picture: case 2.*