# TEACHER GUIDE

## Phosphate Recovery

### Students’ age

The experiment is suitable for students aged 10–17 years old.

### Time required

60 min

### introduction

#### Background

Humans settled into farming communities about 12,000 years ago and began to cultivate crops and keep livestock. This caused a rapid increase in population in agricultural areas. Before the transition to agriculture, there were between 5–8 million hunter-gatherers on earth. Within the next 10,000 years, by around the year 1 AD there were 250 million farmers.

To be able to grow crops in the same place year after year, the soil must be nourished to replace nutrients that have been removed when crops are harvested, or which have leached away due to precipitation. Some form of fertilizer is therefore a prerequisite for human farmer communities to be able to grow enough food. For a long time, manure from animals was the most important source of nutrition. People also learned to use green manure, growing legumes that fix nitrogen from the air which can then be ploughed back into the soil.

In the 19th century, the Chincha Islands, a series of small islands off the coast of Peru, suddenly became of interest to European businessmen. The islands were covered with thick layers of bird droppings, so-called guano, which contains nitrogen, phosphorus, and potassium. It never rains on the Chincha islands so large deposits of guano built up which could be “harvested” for use as fertilizer. Europeans started fertilizing with guano in the 19th century, making it possible to grow much more food, which resulted in a rapid increase in population.

During the second half of the 20th century, the use of commercial fertilizers increased as artificial fertilizers were invented. The most common are NPK fertilizers, which contain nitrogen, N, phosphorus, P and potassium, K.

Phosphate-containing minerals are used to make commercial fertilizers. Morocco, China, and the United States together have 90 % of the world's phosphorus reserve. China and the United States do not export phosphorus, as they believe they will need it themselves. Morocco therefore has almost a monopoly on the export of phosphate-containing minerals. The EU's only phosphorus mine is located in Siilinjärvi, Finland. The world's phosphorus resources are thus very limited and there will soon be a shortage of this important substance. Researchers claim that as early as 2033 we will reach "peak phosphorus", i.e., the time for which production begins to decline. The EU has put phosphorus on its "critical raw material list" (<https://eur-lex.europa.eu/legal-content/SV/TXT/HTML/?uri=CELEX:52020DC0474&from=EN>).

Just like in manure, phosphorus is found in human feces. One way to take advantage of it is to spread sewage sludge from treatment plants in the fields. In Sweden, about a third of the sludge is used for such spreading. The other two thirds contain too much pollution to be used in agriculture.

Now environmentally friendly technology, where phosphorus is recycled from the ash from sewage sludge is developed by the company EasyMining. Through several process steps, environmentally hazardous metals such as lead, cadmium and mercury are separated out from the waste.

This teaching unit is designed as Step-by-Step Instruction. The original task was developed by IKEM, the innovation and chemical industries in Sweden, in collaboration with the company EasyMining[[1]](#footnote-2) for the Swedish Chemistry Day 2020.

#### Preparation of the “sludge ash”

Suggestion for preparing the sludge ash: Use a small ziplock bag or jar for each group of students. Add 10 mL sand (grain size 0.5–1 mm), 5 mL of Na2HPO4(s) and 1 pinch of magnetite, Fe3O4(s) or iron filings.

#### Preparation of the calcium chloride solution

For the 0.8 mol/L calcium chloride solution, mix 22 g of calcium chloride with 250 mL of water.

#### Procedure

In the first step a magnet is used to separate the black magnetic compound, which consists of magnetite, Fe3O4, from the sludge ash. The magnetite represents the heavy metals from which the sludge ash needs to be purified. In the next step, the sand is filtered. The sand represents the non-water-soluble compounds. The remaining filtered solution contains dissolved Na2HPO4 (aq). When the calcium chloride solution is added to this solution, the following reaction takes place:

CaCl2(aq) + Na2HPO4(aq) à CaHPO4(s) + 2NaCl(aq)

The white precipitate consists of calcium hydrogen phosphate, which can be used to nourish plants. Additionally, the waste containing sand and iron oxide can be reused to make “sludge ash”.

### Results and discussion (Example)

The students organize, interpret, and communicate experimental results using tables, graphs and/or charts.

#### Example answers to the questions

1. Magnetic properties of the black contamination of Fe3O4(s), or iron filings.
2. It is more efficient to repeat the purification process with small volumes several times, than to use a larger volume once. This increases the yield.
3. The product contains CaHPO4(aq). It could be used to nourish the plants at home or in the classroom.
4. Use this question to discuss the need of phosphorus. See background. There are many sources for more information on the internet.

### Risk Assessment

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| **List significant hazards** | **Describe what could happen** | **Precautionary measures** | **Measures to be taken if something goes wrong** |
| Icon  Description automatically generated Strong magnet | Could be dangerous if swallowed. | Be aware when teaching younger students. | Contact hospital for medical treatment. |
| Calcium chloride, CaCl2(s) | **H319** Causes serious eye irritation | Wear googles. (Not a risk for the students. Only for the technician or teacher preparing the experiment.) | Rinse eyes and skin with water if ... |

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| **Disposal and any other comments** | The waste could be used to nourish plants. Excess of calcium chloride can be poured out in the sink. Used filters can be thrown into the waste bin. If possible, the filtered sand and the separated iron oxide can be reused to make new “sludge ash”. |
| **In case of emergency** |  |

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| **Date of assessment** | 06-03-2023 | **Written by** | CheSSE | **Class / lesson** | EXAMPLE |

1. [Welcome to EasyMining](https://www.easymining.se/) [↑](#footnote-ref-2)