TECHNICAL REPORT

ISO/TR 22707

First edition
2023-07

Sludge recovery, recycling, treatment and disposal — Information on the processes and technologies for inorganic substance and nutrient recovery

Valorisation, recyclage, traitement et élimination des boues — Guide sur les procédés et les technologies de récupération des substances inorganiques et des nutriments

Reference number
ISO/TR 22707:2023(E)

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Foreword

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This document was prepared by Technical Committee ISO/TC 275, *Sludge recovery, recycling, treatment and disposal*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Inorganics and nutrient recovery is necessary to build a sustainable society; there are many studies and plants all over the world that demonstrate this concept. Above all, phosphorus recovery systems to produce fertilizer material are increasingly common and other nutrients recovery systems are now being developed.

This document provides a selected overview of various technologies and is based on country standards and guidance documents already in existence or under preparation, and documents provided by private organizations.

As inorganics and nutrient recovery knowledge and technology is developing rapidly, this document will therefore be reviewed regularly to reflect the advancing nature of the industry and technology.

Annex A provides examples of sewage sludge composition, which can help determine which element(s) can be recovered. Annex B provides case studies of nutrient recovery, including practical and emerging ones.

Sludge recovery, recycling, treatment and disposal — Information on the processes and technologies for inorganic substance and nutrient recovery

1 Scope

This document provides information on the processes and technologies for inorganic substance and nutrient recovery from sludge.

This document is applicable to sludge and products from urban wastewater collection systems, night soil, wastewater treatment plants for urban and similar industrial waters. It includes all sludge that can have either similar environmental or health impacts, or both.

Hazardous sludge from industry and dredged sludge are excluded from this document.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
ammonia stripping
method that removes ammoniacal compounds from water by making it alkaline and of aeration

3.2
calcium phosphate
salts that consist of calcium ions and phosphate ions

Note 1 to entry: Hydroxyapatite (HAP) is a form of calcium phosphate.

3.3
centrate
liquid product from a centrifugal dewatering device

3.4
hydroxyapatite
HAP
sparingly soluble salt that is generated from phosphate and calcium ions

Note 1 to entry: The general chemical formula of HAP is $Ca_{10}(OH)_2(PO_4)_6$.

3.5
incineration ash
residue of combustion

3.6
nutrient
element required by living organisms throughout the course of their lives in small quantities for a range of physiological functions

3.7
seed crystal
crystal employed as a nucleus to generate and grow crystals in the crystallization process

3.8
struvite
compound which is precipitated by magnesium addition to water with high concentration of phosphate and ammonium ions

Note 1 to entry: The chemical formula of struvite is $MgNH_4PO_4 \cdot 6H_2O$.

4 Methods of nutrient recovery from sludge

There are four methods for nutrient recovery from sludge, which are whole use, cleaning, separation and extraction.

a) Whole use: Whole use of sludge is a simple use method in which sludge, which is typically aerobically or anaerobically treated (e.g. compost), is directly applied to land as fertilizer or soil improver. This method can minimize the loss of the nutrients in the treatment process and can achieve the highest potential of utilizing the nutrients in sludge.

b) Cleaning: Cleaning is the process in which sludge has contaminants such as plastics or heavy metals removed by mechanical treatment or chemical extraction. The cleaned sludge can be handled in the same way as whole use.

c) Separation: Separation is the process in which sludge is divided into two or more different parts. Sludge is separated by physical or chemical parameters such as size, shape, specific gravity difference and chemical affinity. All or only the least contaminated part of separated sludge can then be utilized. In this method, sludge contains various nutrients.

d) Extraction: Extraction is the way in which only the target element is taken out as a compound using chemical actions. Fewer nutrients in sludge are made available or utilized through extraction processes than in whole use, cleaning and separation methods. However, the process has some advantages:

- reduces the storage volume of the nutrient;
- prevents contamination of the recovered material by hazardous elements;
- stabilizes the recovered materials as a chemical compound;
- improves the value of the recovered materials.

Precipitation, including stripping processes, can decrease the volatile nutrient content.

This document is focused on nutrients which can be recovered by extraction.

5 Phosphorus recovery

5.1 General

Phosphorus is an essential element for plant growth and is an important ingredient of chemical fertilizer products. The dry solid contents of sludge normally include more than 1,0 % phosphorus and it can reach 5,0 % of sludge under certain operating conditions, such as biological dephosphorization or anaerobic-anoxic-oxic processes.

On the other hand, the supply of phosphate ore in the global market is strongly influenced by political and economical issues and often gets unstable, as it is quite unevenly distributed globally. Therefore, studies and commercialization of phosphorus recovery from sludge is the most progressive area in inorganic and nutrient material recovery.

Phosphorus can be recovered from sludge using various chemical compounds. The phosphorus recovery process that is described in Clause 5 is summarized in Figure 1.

For case studies, refer to Clauses B.1 to B.11.

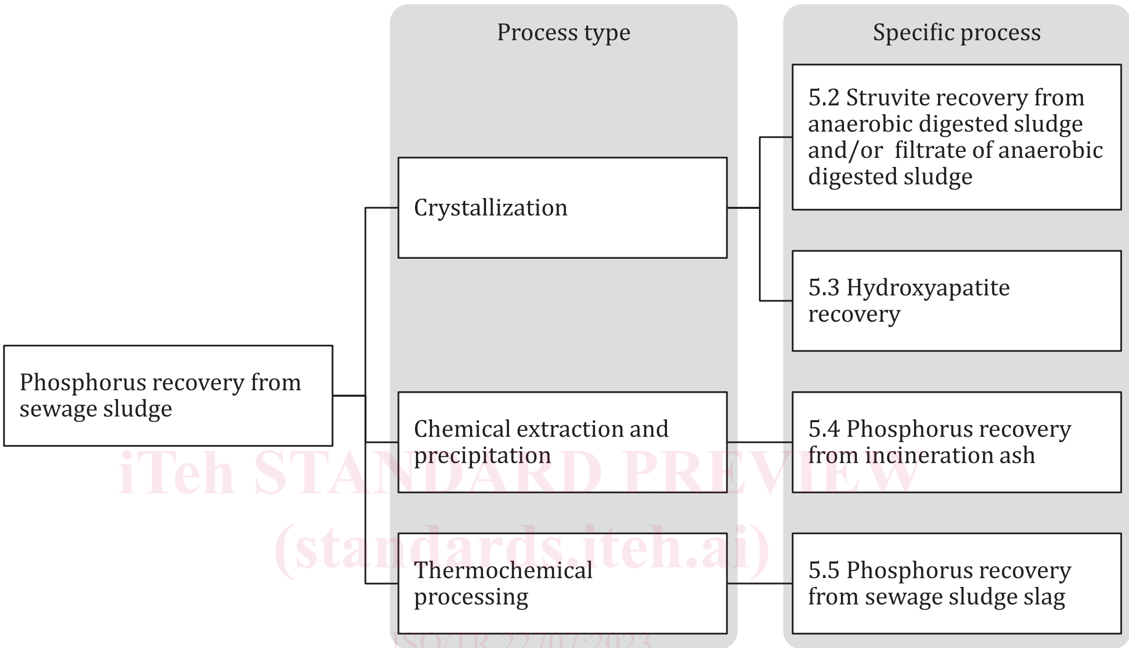


Figure 1 — Summary of phosphorus recovery process

5.2 Struvite recovery from either anaerobic digested sludge or filtrate of anaerobic digested sludge, or both

5.2.1 Principle

The principle of the struvite recovery process are based on the chemical precipitation carried out in a crystallizer followed by particle separation. The chemical reaction for struvite is:

$$PO_4^{3-} + NH_4^+ + Mg^{2+} + 6H_2O \rightarrow MgNH_4PO_4 \cdot 6H_2O$$

This reaction is the same as the scale formation which is frequently observed in anaerobic sludge treatment facilities. The difference of struvite recovery from scale formation is well-controlled chemical dosing, pH control and particle separation. After the application of this process, much less scale formation is likely to occur in treatment facilities.

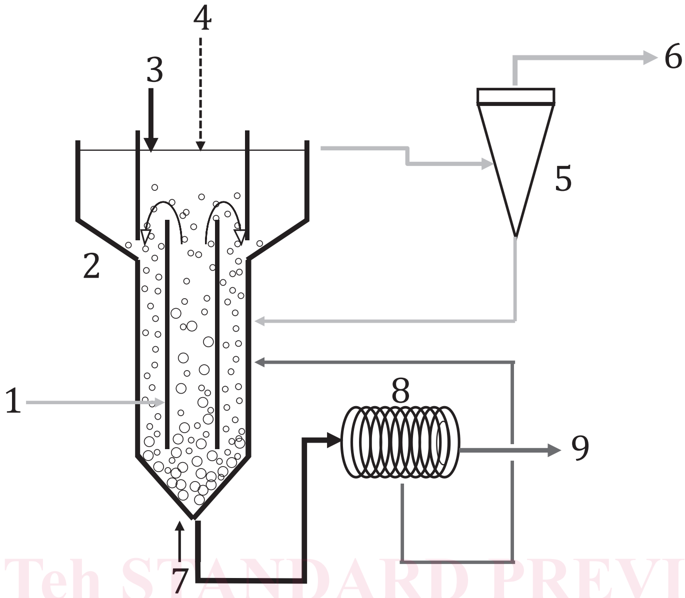
Recovered struvite can be used as delayed release fertilizer because of its low solubility.

There are two types of crystallizer processes: agitation by air or mechanical agitation.

Both methods of crystallization are employed in commercial operations. Wastewater employed for this process is a filtrate of anaerobically digested sludge (ADS) or ADS itself and industrial wastewater containing phosphate and ammonium. Under optimum operating conditions, dissolved phosphorous recovery can reach more than 80 % using this process.

5.2.2 Schematic diagram

Schematic diagrams for an air fluidized crystallizer and a mechanical agitator are shown in Figures 2 and 3. An influent such as a filtrate of ADS, and/or ADS, is mixed in the reactor with magnesium (Mg) salt and struvite granules (as seed crystal). Alkalising chemicals such as sodium hydroxide solution can be added for pH control.



Key

1 ADS or ADS liquor
2 phosnix reactor
3 $Mg(OH)_2$
4 NaOH
5 liquid cyclone
6 treated sludge or liquor
7 air
8 rotary sieve
9 struvite

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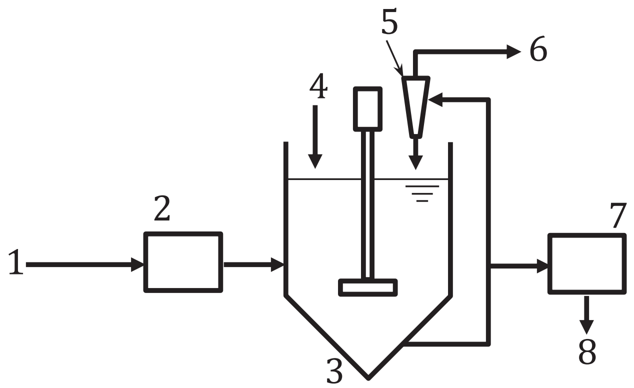
Figure 2 — Schematic diagram of a fluidized bed reactor



Key

1 digested sludge
2 trash removal equipment
3 crystallization reactor
4 $Mg(OH)_2$
5 struvite separator (cyclone)
6 treated sludge
7 washing/drying equipment
8 recovered struvite

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Figure 3 — Schematic diagram of a stirred tank reactor

5.2.3 Operating conditions

The key factors influencing struvite recovery rates are inflow concentrations of phosphate and ammonium, the dosing rate of magnesium ions, alkalinity and pH.

The concentration of phosphate needs to be higher than 50 mg/l of P, preferably over 100 mg/l of P and ammonia over 300 mg/l of N. From an economical point of view, the pH needs to remain in the range of 7,5 to 9,0. Various Mg compounds can be used as a source of Mg including, $Mg(OH)_2$, $MgCl_2$ and $MgSO_4$. Seawater can also be used as a source of Mg.

5.2.4 Characteristics of recovered products

Recovered struvite is crystalline with few impurities. Its shape depends on the above discussed operating conditions, including pH, temperature, agitation and the retention time of struvite particles in the crystallizer.

5.3 Hydroxyapatite recovery

5.3.1 Principle

The principle of hydroxyapatite (HAP) recovery process is based on chemical precipitation carried out in a crystallizer followed by particle separation. The chemical reaction for HAP is:

$$10Ca^{2+} + 6PO_4^{3-} + 2OH^- \rightarrow Ca_{10}(OH)_2(PO_4)_6$$

HAP recovery systems require well-controlled chemical dosing, pH control and particle separation.

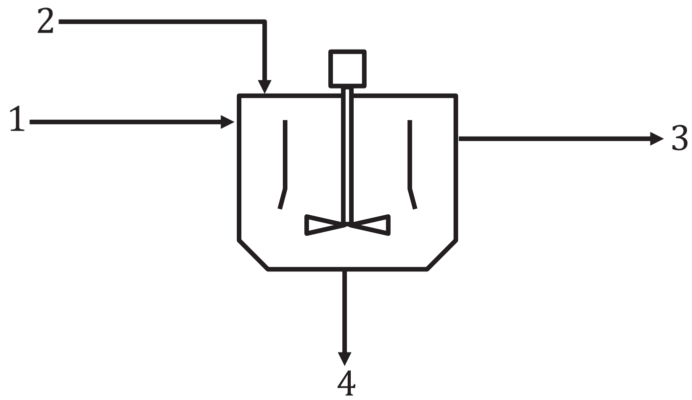
Recovered HAP can be used as raw material for fertilizers.

A crystallizer is a type of mixing reactor employed in commercial operations. The applicable wastewater for this process will be black water (human faeces and urine), industrial wastewater containing phosphate and filtrate from sludge treatment processes.

Under general operating conditions, dissolved phosphorous recovery can reach 70 % through this process.

5.3.2 Schematic diagram

A schematic diagram for a crystallizer is shown in Figure 4. Influent such as filtration liquid, calcium chloride and HAP granules (as seed crystal) are mixed in the mixing reactor. Sodium hydroxide solution is added for pH control.



Key

1 filtration liquid
2 calcium chloride
3 effluent
4 HAP

Figure 4 — Schematic diagram for HAP recovery

5.3.3 Operating conditions

The key factors influencing HAP recovery are inflow concentrations of phosphate, carbonate ion, the dosing rate of calcium ions, alkalinity and pH.

The concentration of phosphate is required to be around 50 mg/l of P. From an economical point of view, the pH needs to remain in the range of 7,5 to 9,0.

5.3.4 Characteristics of recovered products

Recovered HAP is a crystalline structure with few impurities. Its shape depends on the above discussed operating conditions including pH, temperature, agitation and the retention time of HAP particles in the crystallizer.

5.4 Phosphorus recovery from incineration ash

5.4.1 Principle

When advanced wastewater treatment technologies have been employed, phosphorus tends to increasingly concentrate in sludge. As a result, incineration ash from sewage sludge contains almost the same concentration of phosphorus as that of natural phosphate ore, shown in Figure 5. Sewage sludge ash is expected to be one of the alternative sources of phosphorus for depletion in the future.

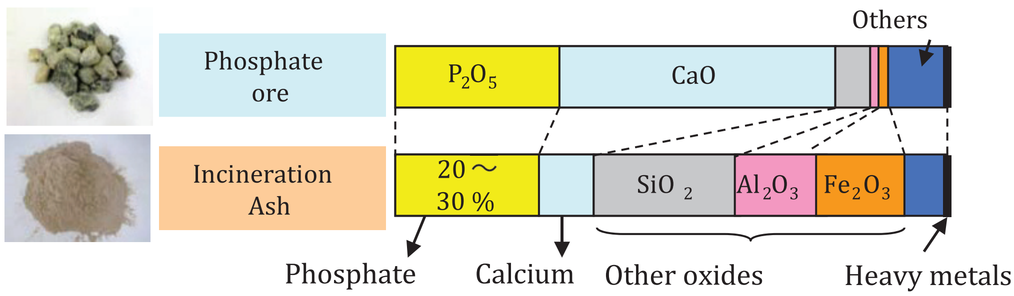


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Figure 5 — Composition comparison between phosphate ore and incineration ash

Phosphorus recovery from incineration ash can be achieved by means of a chemical reaction, which is leaching and precipitation. Leach is performed under both alkaline and acidic condition.

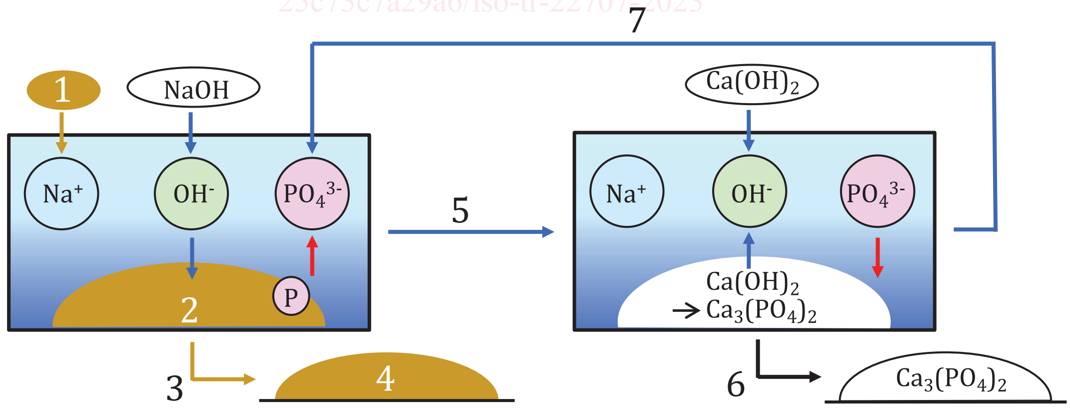
Sewage sludge ash can be used directly as a P fertilizer. This direct utilization, however, is only possible for sewage sludges with a low level of contamination. See Clause B.8.

5.4.2 Alkaline treatment

5.4.2.1 Schematic diagram

A schematic diagram of the phosphorus recovery process from incineration ash is shown in Figure 6, which consists of two reaction tanks.

In the first reactor, phosphate is extracted from the incineration ash by using alkaline solution. In the second reactor, phosphorus-rich sediment is precipitated by adding slaked calcium ($Ca(OH)_2$) into a solution taken from the first reactor. The solution after collecting phosphorus-rich sediment is recycled and returned into the first reactor.



Key

1 ash
2 incinerated ash
3 extraction
4 neutralized ash
5 PO_4^{3-} rich solution
6 precipitation
7 circulation of recycled solution

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Figure 6 — Schematic diagram of phosphorus recovery from incineration ash

