

Processes and Techniques for the Treatment of Sewage Sludge

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Sewage sludge treatment routes are mostly well established in Austria, Germany and Switzerland. While there are different approaches, the problem or task of processing and handling sewage sludge is widely considered solved. So why is this a trending topic?

Sewage sludge is an invaluable source of secondary raw materials. It is a concentrate of hazardous substances as well as a resource with a high potential considering its phosphorus content. Phosphorus as well as phosphate rock are listed as critical raw materials. [7] It is obvious that the potential usage of sewage sludge as a fertilizer is a desired disposal solution. However, the material is also a sink for heavy metals, residual pharmaceuticals, bacteria, viruses and therefore a hazardous substance. Through hours of treatment and addition of a series of chemicals, waste water is cleaned and those substances are removed in order to maintain the quality of natural bodies of water. Using the sludge from wastewater treatment as a fertilizer means spreading dangerous substances after an effortful concentration.

Furthermore, the European Union imports phosphorus from Kazakhstan, China and Vietnam and phosphate rock from Morocco, Russia, Syria and Algeria. [7] The mining of phosphate rock often happens under severely dangerous conditions, negatively affecting workers as well as the environment. So in addition to an economic opportunity, reducing Europe's import dependency has a positive social impact. [7, 14]

Therefore, phosphorus recovery is on everyone's lips. There are several takes on how to recover phosphorus from sewage sludge, directly from waste water or from the ashes remaining after sludge combustion. But no matter the technique, the influence of this endeavour on the treatment routes of sewage sludge is immense. Several established routes are no longer viable if the recovery of phosphorus is desired and most approaches are not available on an industrial scale yet.

This work describes existing sewage sludge treatment processes and techniques, sheds a light on promising alternatives currently investigated and comments on the link to the phosphorus recovery step.

1. Sewage sludge treatment – An overview

In waste water treatment plants phosphorus is enriched in the sewage sludge along with a number of water contaminants. Most of the input phosphorus ends up in the sludge that consists of roughly 97 % water. For transportation and therefore economic reasons, the water has to be removed from the sludge. Commonly, thickeners, presses or centrifuges are used to remove 50 to 80 % of the water (in reality, rates are often much lower). In the water removed, phosphorus exists in the form of phosphates (orthophosphate) and can be recovered by wet chemical processes like precipitation. Since most of the phosphorus exists in the remaining sludge where it is bound biologically or chemically, chemical and/or thermal processes are required to achieve recovery rates over 80 %. [11]

The recovery rates, the purity of the recycling product and the procedural and financial effort increase proportionally. In order to fulfil legal requirements like the ones effective in Germany since 2017, combustion of sewage sludge is not enough. Therefore, the current processing routes have to be changed with a focus shift towards phosphorus recovery and utilisation.

In the following paragraphs, the current sewage sludge treatment typical for Austria, Germany, Switzerland is described and alternatives to existing processes currently investigated are presented.

Sewage sludge humification

Beside of the conventional sewage sludge dewatering with presses and centrifuges there is also an alternative process called sewage sludge humification. Hereby, the liquid sewage sludge is put into planted, sealed beds, where the drainage is determined by gravity and the evaporation performance of the plants. Additionally, a decomposition of contained organic fractions, forced by microorganisms and bacteria, takes place. The final product of sewage sludge humification is still a subject to the sewage sludge ordinance. This process is a cheaper alternative to conventional drainage and mainly used for small and medium sized plants. [2]

Thermal drying

The next step in sewage sludge treatment is the drying of the dewatered sewage sludge, which can be done in a separate drying unit or immediately before the thermal utilisation. The purpose of this drying process is to improve the calorific properties of the sewage sludge in order to increase the energy efficiency in mono or co-incineration plants. Sewage sludge granulate, which is the obtained product from the drying process, offers some advantages compared to dewatered sewage sludge (Figure 1). [10]

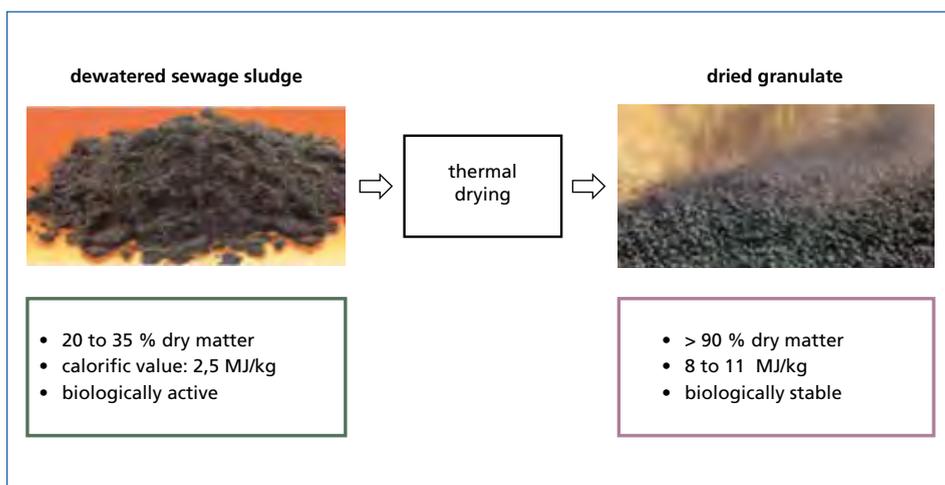


Figure 1: Sewage sludge before and after drying

Source: Geyer, J.: Klärschlamm-trocknung in Deutschland – Stand und Perspektiven. In: Thomé-Kozmiensky, K. J.; Beckmann, M. (Eds.): Energie aus Abfall, Band 10. Neuruppin: TK Verlag Karl Thomé-Kozmiensky, 2013, pp. 927-948

A common problem that comes along with thermal drying is the large amount of energy which is required to fulfil this task. However, if it is possible to provide the required energy by integrating the process in an intelligent energy network, an environmentally friendly energy source can be obtained. An alternative is solar sewage sludge drying. In this process sewage sludge is spread on a large area, which is covered like a glass house. The dehydration is done by applying an appropriate air flow and circulation of the sewage sludge. The only significant disadvantage of this method is the fact that it asks for a large area and takes a lot of time. [10]

Thermal utilisation

There are several possibilities for the thermal utilisation of dewatered and dried sewage sludge. In mono-incineration plants, mostly a stationary fluidised bed is used to combust the sewage sludge in order provide thermal power. Other methods use deck ovens, vertical ovens or grate furnaces instead of the stationary fluidised bed. The thermal treatment leaves sewage sludge ash with a P_2O_5 content of up to 23 %. Another example of thermal utilisation is the co-incineration of sewage sludge in the cement industry, in waste incineration plants or in power plants, where it is used to substitute primary energy sources. The gasification of the sewage sludge in a fixed bed or the pyrolysis in a rotary tube or screw reactor are also alternative methods for thermal processing. [13, 17]

In addition to the thermal utilisation, there are also approaches to recycle sewage sludge (substance-based utilisation). These are essentially limited to use in landscaping and for use in agriculture. In 2015, about 1.80 million t of sewage sludge were disposed in Germany. [1]

2. Situation in Germany, Austria and Switzerland

In Germany, Austria and Switzerland the current situation in sewage sludge treatment differs considerably. In Austria, sewage sludge is currently thermally utilised to an extent of approximately 50 % while the usage in agriculture, due to the presence of other recycling options such as composting, is very low at below 20 %. [3] The majority (almost 70 %) of the thermally recycled portion is combusted in mono-incineration plants. [8] This is the first major difference to Germany and Switzerland (almost 100 % thermal recovery), where about 50 % of the thermally treated sewage sludge are utilised in power plants, waste incineration plants or cement plants. Figure 2 gives an overview of the sewage sludge treatment situation in Germany. [12, 14]

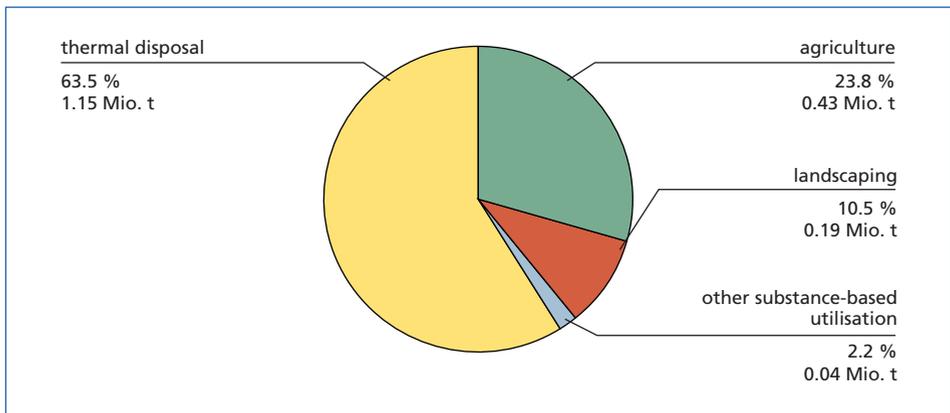


Figure 2: Sewage sludge treatment situation in Germany

Compare: Bergs, C.: Die neue Klärschlammverordnung (AbfKlärV) – *Phosphorrecycling ante portas*; 8. VDI-Fachkonferenz Klärschlammbehandlung; Rotenburg a. d. Fulda; October 2017

Since 2006 there is an additional regulation in Switzerland that prohibits the usage of sewage sludge on agricultural land. Since 2007, newly built plants must also allow phosphorus recovery, and since 2016, a ten-year transitional period has been set for the mandatory recovery of phosphorus from phosphorus-rich waste. [15]

In Germany, the corresponding regulations came into force in 2017. Depending on the size of the wastewater treatment plants, there are defined transitional periods in which agricultural usage is still permissible. However, the regulations also call for concepts for the phosphorus recovery and their implementation. The next step will be Europe-wide rules as the EU-fertilizer regulation and the results of the STRUBIAS working group, which wants to enable the market entry of struvite, pyrolysis and ash-based products. [1, 15]

From our point of view, these regulations are currently causing a trend towards mono-combustion, and therefore an increase in the importance of drying methods and incineration plants. Thus, the methods for phosphorus recovery from the ash begin to gain importance.

3. Legal situation

Since June 2005 the disposal of sewage sludge in Germany in landfills is only allowed after mechanical-biological or thermal treatment. The recycling of sewage sludge and the corresponding limiting values are regulated in the sewage sludge ordinance and the fertilizer law. These rules, based on water and chemicals legislation, already lead to a reduction of the pollutants. Since May 2014, phosphorus has been included in the list of critical raw materials by the EU. In order to improve the conservation of resources and to recover the phosphorus that is contained in the sewage sludge, as well as to further restrict the pollutant input into the soil, the reorganization of the ordinance of sewage sludge utilization became law on October 3rd 2017 in Germany.

The new ordinance adds new rules, for example for landscaping or the prohibition of the spreading of sewage sludge with wastewater from potato processing. Additionally, it defines obligations for phosphorus recycling. It demands phosphorus recovery for phosphorus contents of more than 20 g/kg dry matter sewage sludge and for plants with a capacity of more than 100,000 or 50,000 population equivalents after the end of a transitional period. [1, 4, 15]

4. Phosphorus recovery

The changing legal framework has put all stakeholders under immense pressure. The criticality of the resources involved has led to over 50 processes for phosphorus recovery described in literature over the past few years. Their technological readiness level varies widely, from discarded ideas to (semi-)industrial application. [15] A general overview is described in respective literature. The processes all have in common that their products and recovery rates have to fulfil legal requirements but also need to be situated in an appropriate environment. Metallurgical processes, for instance, will not be found at small, communal waste water treatment plants whereas wet-chemical approaches might not be desirable for current co-combustion facilities. Factors that have to be taken into account in addition to recovery rates and power demand are therefore:

- application environment: It is important to keep in mind that there is no *best* phosphorus recovery process. The market that is forming is highly competitive, but the spectrum of treatment approaches is so wide that it is unlikely for one of them to be found in all areas of application. Different approaches are viable in different surroundings, ranging from recovery from waste water to the thermochemical recovery from ashes or slags.
- product quality: Phosphorus recycling products must be available to plants if they are destined to be used for fertilizer production. Regulations controlling the approval of mineral fertilizers, chemical transport regulations (e.g. REACH) and many more have to be taken into consideration. Furthermore, products like phosphoric acid are not only used in the fertilizer industry. If food, chemical and pharmaceutical industries are considered potential buyers, requirements can become even more challenging. [9]

The following Figure 3 is based on a figure provided by the DPP (German Phosphorus Platform) and gives a very short overview of existing approaches. [15]

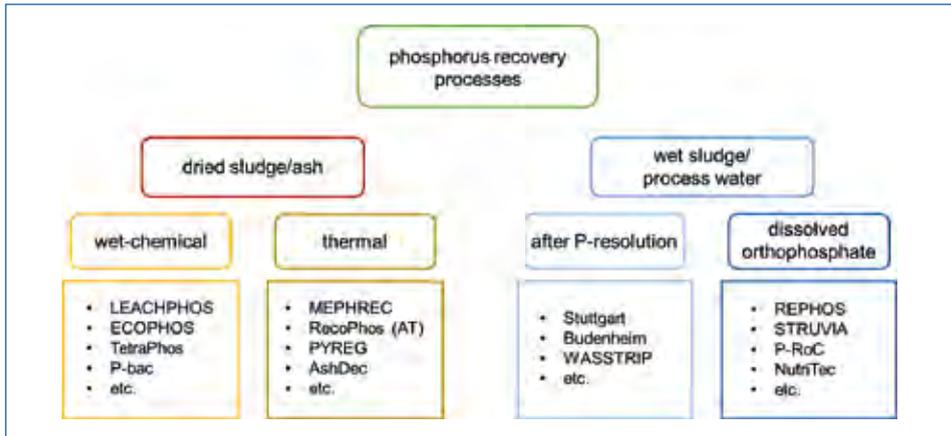


Figure 3: Phosphorus recovery processes – an overview

Compare: Schnee, R.: Phosphor-Recycling: Utopie oder realistischer Ansatz; 8. VDI-Fachkonferenz Klärschlammbehandlung; Rotenburg an der Fulda; October 2017

Since the focus of this article is the treatment of sewage sludge rather than the phosphorus recovery, an example is described for a thermal sludge treatment process that could simultaneously function as a pre-treatment step for the recovery of phosphorus: The 2-stage RecoPhos process.

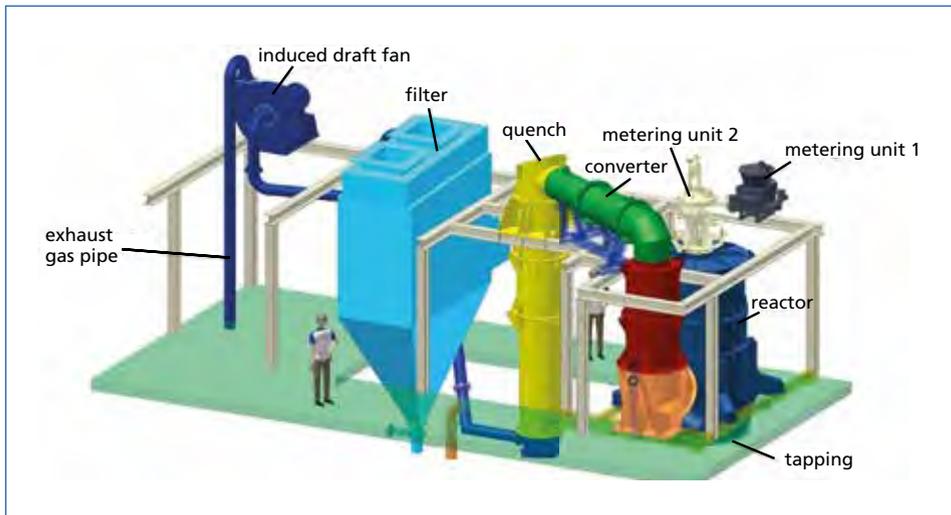


Figure 4: Flash Reactor

Source: Delfs, N.; Kofler, M.; Geier, B.; Rimser, A.; Raupenstrauch, H.; Bürgler, T.; Pilz, K.; McDonald, I.; Werner, A.: The Flash-Reactor as Special Melting Unit for Powdery Materials in DSG (Dry Slag Granulation) Application; BHM; issue 156 (9); pp. 343-346; Austria; 2011

In a first step the Flash Reactor is used as an alternative unit for the combustion of sewage sludge. Dried sludge can be fed to a reactor, that is into the flame of a natural gas/oxygen burner. The organic compounds contained enable an energy self-sufficient combustion and are destroyed. Halogens, heavy metals, sulphur and all volatile compounds are removed and respective exhaust gas cleaning must be applied. The rest of the sludge is slagged. Its basis is CaO and SiO_2 , but the slag still contains iron from precipitation salts in the form of Fe_2O_3 . The phosphorus from the sewage slash is also still contained in the slag. The reactor is depicted in Figure 4. [6]

The slag can further be treated in the RecoPhos plant constructed in an EU-project (Recovery of Phosphorus from Sewage Sludge and Sewage Sludge Ashes with the thermo-reductive RecoPhos-Process, funded under FP7 – Environment, ECO-Innovation between 2012 and 2015 [5]). A reactor made of refractory materials is filled with graphite cubes that are inductively heated to roughly $1,600\text{ }^\circ\text{C}$. The slag (or ash from other mono-combustion processes) is fed to the reactor, melts in the first part and a thin film moving down the graphite bed is formed. Under reducing conditions, phosphorus compounds are reduced to the elementary, gaseous form (P_4 , dissociated to P_2), post-combusted and hydrolysed, so that phosphoric acid is produced. The reactor is shown in Figure 5. [16]

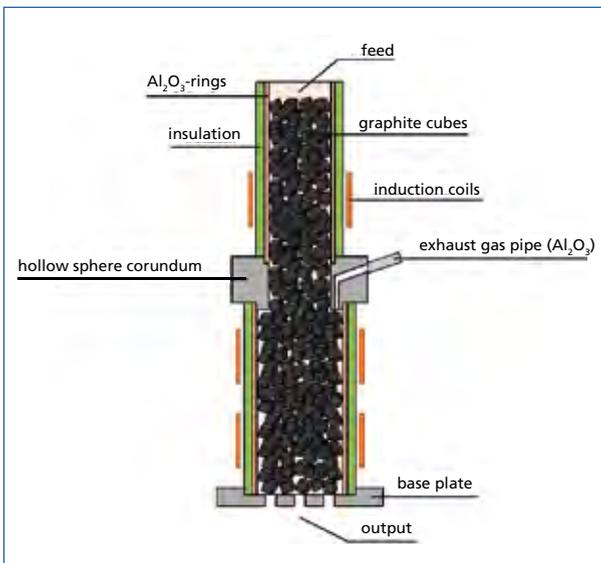


Figure 5:

RecoPhos reactor

The remaining slag is a high purity silicate slag and the iron oxides are reduced to the metal form. Since gaseous phosphorus and liquid iron react to phosphides, the contact time must be kept to a minimum, which is why gas is continuously removed from the reactor. With the help of this process (using ashes from fluidised bed mono-combustion of dried sewage sludge, one-step process), all phosphorus compounds could be reduced (>99 %) and roughly 75 % could be recovered in the form of phosphoric acid. [16]

5. Summary and outlook

In conclusion, it can be said that the legal pressure has the potential to decrease the import dependency of the European Union on a long-term scale. However, many measures still have to be taken to apply promising sewage sludge treatment and phosphorus recovery processes on an industrial scale.

There will be no *best* process or process chain, but a variety of solutions suitable for different application environments. The conventional sewage sludge treatment route will transition into the preparation step for phosphorus recovery schemes and therefore, the treatment of sewage sludge is no challenge that has already been conquered.

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