BALTIC INDUSTRIAL SYMBIOSIS

Generic case

SYMBIOSES WITH FERRIC SLUDGE

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THE MAIN POINTS

Industrial symbiosis with ferric sludge creates both economic and environmental benefits. The resource occurs in considerable quantities and can be utilized in biogas production or wastewater treatment.

At Danish waterworks, pumped groundwater is oxygenated to remove especially iron and manganese. During the oxygenation, ferric sludge precipitates; it mainly consists of iron (hydr) oxides. Ferric sludge is also called ferric water, waterworks sludge, flushing water sludge and water supply sludge.

In Denmark, there are 2600 waterworks; most of them generate ferric sludge, which is managed in various ways. Typically, ferric sludge is considered a waste product to be disposed of as easily and cheap as possible. In many cases, ferric sludge is sent to landfills costing considerable fees.

UTILIZATION

Since ferric sludge mainly consists of compounds of iron, there are good examples of utilization of this residual at wastewater treatment plants and biogas plants. Iron can be used for precipitation of phosphorus, reduction of sulfur hydrogen in biogas and limiting smell from sewage pressure lines.

GREAT SAVINGS

Waterworks can send its ferric sludge to recipients who can benefit from the resource directly. Thus, waterworks achieve savings on disposal, while the receiving companies can achieve savings as a result of operation optimization and reduced need for alternative chemical additives.

Through industrial symbiosis, ferric sludge can be turned into a valuable resource rather than a waste product. Such symbiosis cooperation is also advantageous for the bottom line; it strengthens competitiveness, reduces operating costs, and contributes to environmental gain.

FERRIC SLUDGE

At Danish waterworks, pumped groundwater is oxygenated through traditional water treatment.

The purpose of this treatment is mainly to precipitate dissolved metal ions. The metals precipitate as slightly soluble salts, which are retained in filters. The filters are washed regularly, and at most of the Danish waterworks, the rinsing water goes through a settling tank or seeps into a lake or a ditch.

In these cases, this ferric sludge accumulates and must be disposed of regularly. Others, especially smaller waterworks, discharge rinsing water directly to the sewer system or in some cases, a watercourse.

There is no well-established practice for the handling of generated ferric sludge at waterworks; it depends on traditions and local conditions.
It is widespread to suck ferric sludge by a pump directly from a settling tank several times a year. "Lakes" are emptied of ferric sludge which is then drained in sludge drying beds before shipment. Dry matter content fluctuates from quite a few percent up to 80 percent.

Ferric sludge consists predominantly of iron oxides and - hydroxides, but usually contains other metal oxides, such as manganese and aluminum oxides, and several trace metals, including arsenic.

> The amount of ferric sludge depends mainly on the iron content in groundwater, which
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> varies considerably in Denmark. Nationwide, the amount of ferric sludge has previously been estimated to 2500 tons of dry matter content a year. A survey indicates that annual production of ferric sludge varies geographically ranging from 0.5 to 15 kg of dry matter content per 1000 m3 produced water with an average of 4.7 kg of dry matter content per 1000 m3. The amount depends on the iron content in the inflated water.

The organic content is up to 5% of dry matter content. Additionally, ferric sludge contains a small amount of phosphorus.

At waterworks, ferric sludge is generally perceived as a waste product to be eliminated as easily and cheap as possible.

UTILIZATION

The current practice of ferric sludge disposal varies considerably among waterworks.

Often, ferric sludge is sent to landfill – just like always and it works. However, it is relatively expensive for the waterworks. Another reason that ferric sludge is landfilled can be specific substances which appear in too high concentrations. However, there are alternative disposal methods for ferric sludge, where costs can be reduced and where the resource achieves a value as it can be utilized.

FERRIC SLUDGE FOR BIOGAS PLANTS

At biogas plants, the content of hydrogen sulphide (H2S) in biogas is reduced. It is done to protect the gas engine, reduce unpleasant smells and/or increase the purity of the finally produced gas when upgrading it to natural gas quality. There are several desulphurization technologies for biogas, e.g. by using a biological sulfur filter or by adding iron chloride to the reactor. In the latter case, sulfur is bound by dissolved iron, which is thus removed from a gas phase. Additionally, the iron precipitates dissolved phosphorus, which is an advantage in digesters at a wastewater treatment plant, where the content of phosphorus in the reject water must be as low as possible.
Furthermore, this phosphorus precipitation can contribute to higher phosphorus concentration in the fiber fraction during the separation of digestate, which in some cases can be pursued.

The industrially produced iron chloride or the used alternative desulphurization technology can, however, be replaced in whole or in part by adding ferric sludge, due to its high iron content.

Under the reducing conditions in a biogas reactor, ferric sludge dissolves efficiently, and iron is activated and precipitates together with phosphorus and sulfur. Biological filters are another widespread gas desulphurization technology, and in this case, the addition of ferric sludge can reduce the filter loading, which requires less maintenance. Such a desulphurization system can be more flexible by having ferric sludge stored, and it can be added to biomass with particularly high sulfur content.

At the same time, ferric sludge can increase pH, which can be advantageous for biogas reactors with too low pH. Several Danish biogas plants apply ferric sludge in the biogas process.

FERRIC SLUDGE FOR CLEANING SYSTEMS

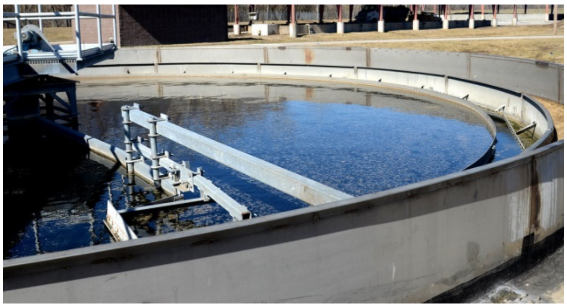
The collaboration between waterworks and treatment plants has become closer because often they are brought together in the same organization. As a result, it has become widespread among waterworks to send ferric sludge to treatment plants. As a starting point, it is an obvious place to get rid of the residual, as it has no negative effect on the process in the treatment plant, where large amounts of sludge are routinely processed, and the ferric sludge will constitute a minimal part of the final sludge production.

Ferric sludge can also have a positive effect on a purification process; since iron precipitates phosphorus retained in sewage sludge and is not discharged together with reject water to a watercourse or the like. Of the same reason, it is a standard practice to add industrially produced iron or aluminum chloride to the purification process. But it has been shown that the iron content in ferric sludge can have the same effect.

However, the effect is limited, since the ferric sludge applied directly to aerobic processes in a treatment plant is slightly soluble, why most of the iron is not reactive. Research is ongoing on how the effectiveness of added ferric sludge can be increased on a commercial scale, as it is currently limited how much precipitating chemical can be replaced by adding untreated ferric sludge.

Additionally, treatment plants can advantageously add ferric sludge to wastewater to reduce unpleasant smell which is a result of hydrogen sulphide formation. It can often be favorable for wastewater pipes located far from a wastewater treatment plant with limited wastewater flow. As in the case with the biogas plant, ferric sludge is soluble in the reducing environment of the sewage pipe and thus iron reacts efficiently with sulfur, which does not degas. If waterworks are coincidentally located close to such a wastewater line, it will have the same effect to divert ferric sludge/water directly to the sewer.

Through a symbiotic collaboration, the waterworks can get rid of this residual product, and the water treatment plant receives an easily manageable waste product which is also valuable, as it can replace a limited amount of the industrially produced chemical with phosphorus precipitation at the water treatment plant as well as reduce sulfur hydrogen in the sewage system.



ALTERNATIVE UTILIZATION

In a few cases, ferric sludge can be applied in agriculture. There are some new methods of using this residual which are not commercialized yet, but probably will be relevant in the near future. Ferric sludge can reduce leaching of undesirable substances from contaminated soil as well as improve water quality in lakes with high phosphorous concentration.

EXAMPLE 2 – UTILIZATION OF FERRIC SLUDGE AT WASTEWATER TREATMENT PLANTS AND WASTEWATER SYSTEMS

SK Forsyning (a water supplier) operates waterworks and wastewater treatment plants in Slagelse Municipality. SK Forsyning's two waterworks produce a total of 1 million m3 water annually and generate approx. 40 m3 ferric sludge. The ferric sludge is picked up by SK Forsyning's suction vehicles and supplied to the wastewater treatment plant in Korsør.

It significantly reduces the cost of ferric sludge disposal, and at the same time, the ferric sludge contributes to phosphorus precipitation. Additionally, one of the utility's waterworks discharges its ferric sludge directly to the wastewater system. It has resulted in a reduced hydrogen sulphide production in the concerned wastewater system. Work is currently underway on the possibility of dosing ferric sludge for long wastewater pipes. The ferric sludge is regularly analyzed to ensure that the final sludge product lives up to all requirements upon subsequent use of the residual on agricultural land.

EXAMPLE 1 – FERRIC SLUDGE UTILIZATION AT BIOGAS PLANTS

Nysted Biogas produces biogas by utilizing manure and another organic waste as substrates.

Additionally, the plant receives ferric sludge from regional waterworks in Vesterborg. Through the regular supply of ferric sludge to the plant's mixing tank, the biological sulfur filter can be facilitated and thus requires less maintenance. It plays an especially important role in the biomass supply, which results in particularly high sulfur content in the gas (e.g. sugar).

In 2013, the local waterworks delivered, for a small fee, 250 m^3 of ferric sludge (11-13% of dry matter content) to Nysted Biogas, approx. 50 m^3 of which were delivered by the regional waterworks in Vesterborg. Waterworks are required to provide an analysis of their ferric sludge every year so that Nysted Biogas can ensure that it lives up to all requirements related to the subsequent supply of the degassed material to agricultural land. Both parties are satisfied with the cooperation, and Nysted Biogas would like to receive more ferric sludge.

ECONOMIC PROFIT

Waterworks' costs of ferric sludge disposal can, in many cases, be significantly reduced. In Denmark the ferric sludge landfill charge, incl. transport is up to EUR 147 per ton. If a landfill charge is EUR 94 per ton, EUR 3,347 per 1 million m3 of produced water will be saved annually. This amount depends on the iron content of the soil, the dry matter content of the disposed ferric sludge, the landfill price and a possible fee at biogas- or wastewater treatment plants. The amount can thus range from a few thousand to over 134,000 euro.

It is advantageous to cooperate with a wastewater treatment plant on the utilization of ferric sludge, especially if the two companies are brought together in the same organization. The exchange of ferric sludge, in this case, will be free and at the same time, has a limited positive effect for the treatment plant, which in the long term can be possibly increased and can reduce the cost of additive chemicals. Transportation costs can often be reduced as waterworks and wastewater treatment plants are usually located relatively close to each other, and the necessary facilities for transportation of sludge products already exist.

By adding ferric sludge, biogas plants can reduce the cost of biogas desulphurization. Depending on the applied desulphurization technology, they can achieve savings by means of a limited need for chemical additives, maintenance and use of sulfur filters as well as increased flexibility. The biogas industry struggles in many cases with a fragile economy, so any kind of financial optimization at a biogas plant can help to make its production more profitable. Thus, waterworks which forward their ferric sludge to biogas plants can also expect reduced expenses, as the resource achieves value at the biogas plant. Usually, a biogas plant has its own transport facilities for sludge. Overall, a mutually beneficial agreement can be established between a biogas plant and waterworks.

ENVIRONMENTAL VALUE

Industrial symbiosis has a variety of environmental benefits compared to landfill considered as the lowest level in the waste hierarchy.

By exchanging ferric sludge, waterworks and wastewater treatment plants can reduce, to a certain extent, production and transportation of industrial precipitation chemicals. The transport distance can, in most cases, also be reduced, limiting greenhouse gas emissions.

Biogas plants can reduce production and transportation of industrial precipitation chemicals or use of other desulphurization technology and possibly, phosphorus precipitation. At the same time, a limited amount of phosphorus contained in ferric sludge will be recycled. Since phosphorus is a scarce and necessary resource in agricultural production, it is not intended to end up in landfills. Additionally, ferric sludge contains a minor amount of organic matter which will contribute to gas production.

Utilization of ferric sludge at biogas plants can potentially improve the plant's economy and thus an opportunity to increase capacity and hence gas production. Biogas replaces the use of fossil fuels and hence reduces greenhouse gas emissions, that is why greater utilization of ferric sludge for this purpose is desirable.

Content of arsenic in ferric sludge from Danish waterworks has been measured in the range of 18-3,200 mg/kg of dry matter content, but it is usually around 25-300 mg/kg of dry matter content. If arsenic values are above 1,000 mg/kg of dry matter content, the ferric sludge, according to “The Danish Waste Order”, is classified as hazardous waste, due to the element's carcinogenic properties. If a company generates hazardous waste, it should be reported to the local council, which decides how to treat the fraction. It is previously estimated that approx. 20% of the ferric sludge produced in Denmark exceeds this limit value. Typically, in this case, the ferric sludge must be deposited.

In Denmark, when using ferric sludge at wastewater treatment and biogas plants, the municipal council often sets a limit value for arsenic content. This value varies. There are examples of limit values of both 1000 mg/kg of dry matter content related to “The Waste Order”, and 20 mg/kg of dry matter content related to the limit value for the quality requirement for land.

BARRIERS

In the following section, there are examples of barriers to the previously described utilizations for ferric sludge. The section is not comprehensive. There are also other barriers which can require technical or legal clarifications before symbiosis can be realized and financially attractive for the participating companies.

In the case of ferric sludge, there will often be a focus on the content of arsenic, since heavy metals and environmentally harmful substances are usually not considered problematic.

The content of arsenic in groundwater varies considerably geographically.. By regular water treatment at a waterworks, the content of arsenic in drinking water is reduced, so that it meets the accepted limit. Arsenic accumulates especially in ferric sludge during the reaction with active surfaces of iron.

When sand filters are washed before precipitation of ferric sludge, the amount of sand, which is a part of the ferric sludge, has to be minimized. Sand is not desirable in neither biogas nor wastewater treatment plants where it can result in wear and tear and accumulation.

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