Nutrient Recycling from Sewage Sludge using the Seaborne Process

J. A. Müller *, L. Günther **, T. Dockhorn **, N. Dichtl **, L.-C. Phan ***, I. Urban ***, D. Weichgrebe ***, K.-H. Rosenwinkel ***, N. Bayerle ****

* PFI Consulting Engineers, Karl-Imhoff-Weg 4, 30165 Hannover, Germany
(Email: Mueller@pfi.de)

** Institute of Sanitary and Environmental Engineering, Technical University of Braunschweig, Pockelsstrasse 2a, 38106 Braunschweig, Germany,

*** Institute of Waste Quality and Waste Management, Welfengarten 1, 30167 Hannover, Germany

**** ASG Stadt Gifhorn, Winkeler Str. 4a, 38518 Gifhorn, Germany

Abstract: In the Seaborne process, nutrients are separated from the sewage sludge and processed to a fertilizer containing no heavy metals or organic pollutants. A first large scale pilot plant was built between 2005 and 2006 at the wastewater treatment plant Gifhorn, (50,000 PE) in lower Saxony (Germany). In the first process step, heavy metals and nutrients are remobilised by decreasing the ph-value with sulphuric acid. The solids are separated from the flow by using a centrifuge and a filter system and are then dried and incinerated. In the next treatment step, the digester gas, high in hydrogen sulphide, is used to precipitate the heavy metals from the process flow. The desulphurised biogas is then utilised in a co-generation plant. The nutrients are recycled in the following process step. After the addition of sodium hydroxide, to adjust a basic pH-value, and magnesium oxide as precipitant, the crystalisation of magnesium, ammonium and phosphorus to MAP (struvite) is achieved. Finally the surplus nitrogen is separated as ammonium sulphate in a stripping plant. The treated process stream flows back to the influent of the WWTP. The products of the Seaborne process, MAP and ammonium sulphate, can be agriculturally reused.

Keywords: Heavy Metals; Incineration; Nutrients; Recycling; Struvite

INTRODUCTION

Since 2000 a pilot plant for the Seaborne Process has been in operation in Owschlag, Germany (Schulz, 2003). Now the first large-scale installation was established in 2005 on the wastewater treatment plant of Gifhorn in the northern part of Germany. It has a capacity of approx. 1,000 tons of dry solids per year.

The technical and scientific monitoring of the Seaborne process application is carried out by PFI Consulting Engineers in cooperation with the Institute of Sanitary and Environmental Engineering at the Technical University of Braunschweig and the Institute of Waste Quality and Waste Management at the University of Hanover.

In the following, the different components of the entire process are presented in detail and described. Only the process set-up for the treatment of (predominantly) sewage sludge as biomass is considered.

PROCESS LAYOUT

The process consists of several individual modules, which are linked with one another via the material flow. Apart from the recycling of phosphorus and nitrogen in the form of mineral fertilizers, a removal of heavy metals as well as a digester gas cleaning are to take place. This requires a complex process, which is presented in Figure 1.

The digested sludge is treated with acid, whereby a part of the heavy metals, the phosphorus and the organic substance go into solution. The organic solids are separated and can be burned for example. Ash can be fed back into the process. In a next process step, the heavy metals must be precipitated and separated from the phosphorus containing flow. The precipitation can take place if necessary via supply of H_2S containing digester gas. Thereby the digester gas is desulphurised simultaneously.

From the heavy-metal-free liquid phase nitrogen and phosphorus are precipitated as struvite after increasing the pH by adding magnesium hydroxide. The excess ammonia is fed to a stripping column and can by separated as ammonium sulphate.

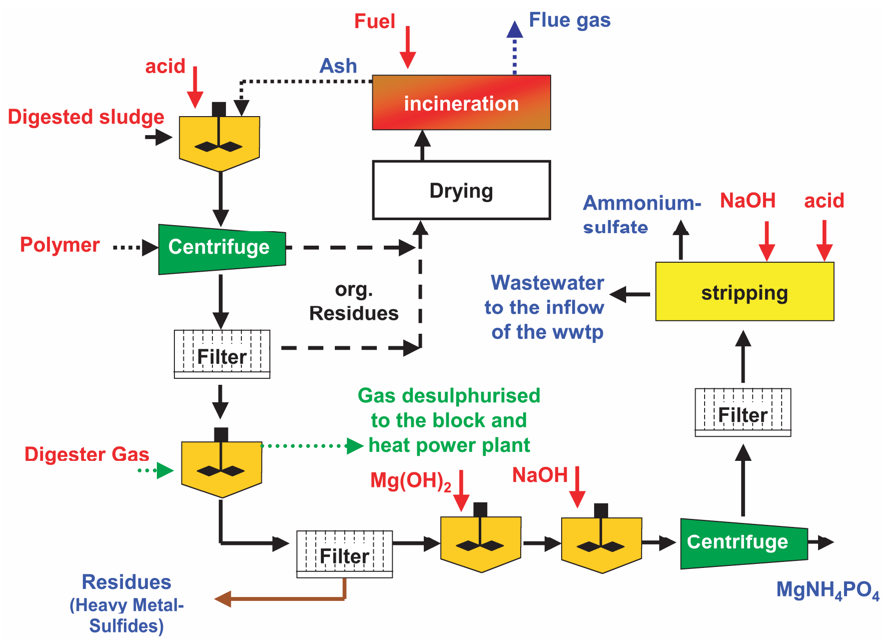

Figure 1 Process flow sheet of the Seaborne process at the WWTP Gifhorn

PROJECT HISTORY

The construction of the Seaborne plant in Gifhorn (Germany) began at the end of 2003. In 2004 the civil engineering works were completed and the installation of the machine technology started in early 2005. The first test runs for individual parts of the plant commenced in early 2006 and from mid of 2006 first test runs were undertaken for the complete process. Figure 2 shows a picture of the installation.

The technical and scientific monitoring of the Seaborne process application started in the middle of 2004 with a first data collection and a basic mass balancing. In a next step, the operational changes on the WWTP due to the revision of the sludge treatment process were determined. During a second measuring programme directly before the start up of the seaborne plant, all processes on the WWTP were recorded in order to be able to close all mass balances.

All material flows were analysed for carbon, nitrogen and phosphorous. Furthermore, selected parameters of sludge characteristics (particle size distribution, zetapotential, polymer demand), the concentrations of inorganic and organic pollutants in each flow were determined and a microscopic analysis of waste activated sludge and anaerobic sludge were carried out. All this was combined to a “finger print” of the whole WWTP to allow a comparison to upcoming operational conditions.

Figure 2 Partial view of Seaborne plant with centrifuges and stripping column

CONCEPTUAL CHANGES IN PROCESS LAYOUT

The process layout realized on the WWTP in Gifhorn differs from the original concept of the Seaborne company (see Figure 3). Besides economic reasons, a revised calculation of heat requirement led to these changes.

The biogas cleaning by addition of CO_2 during the production of sodium hydrogen carbonate proved to be unprofitable, because the by-product calcium chloride needs to be dried in order to achieve a high market value. The investment for the drying as well as the heat requirements were to high. A disposal of liquid calcium chloride was also not cost-covering.

For the reuse of magnesium hydrogen phosphate in a closed cycle, initially a drying/degassing process was intended. This process step will remain an option, because of economic and thermotechnical reasons and will be investigated in experimental operation only. The discharge of nitrogen and phosphorous is realized as magnesium ammonium phosphate (struvite) as well as di-ammonium sulphate (DAS). Struvite is generated as a precipitate after the addition of magnesium hydroxide and a pH-adjustment using sodium hydroxide and is separated by a centrifuge from the liquid phase. The centrate is supplied to an air stripping column, were ammonia is stripped to the gas phase and separated as DAS using sulphuric acid. By using the stripping column, a high degree of nitrogen removal can be achieved without the necessity of adding higher amounts of phosphorus to achieve a stoichiometric struvite precipitation.

The essential process steps, the removal of heavy metals and the nutrient recycling thus are preserved in the new process layout as well.

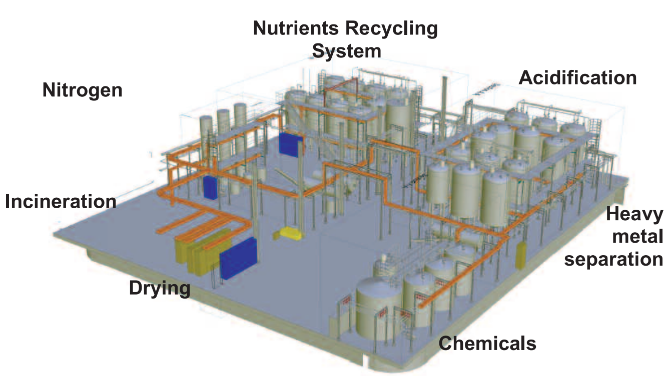

Figure 3 3D-Process Layout of Seaborne plant

PROBLEMS DURING START UP OF THE PROCESS

During the start up phase, a number of mechanical as well as procedural problems occurred. The stirrers in several vessels were torn off for example and base bearings had to be added. This technical problem alone caused a delay of several weeks because liabilities and cost coverage had to be settled.

Another problem occurred with the solid-liquid separation of the acidified sludge. None of the proposed polymeric flocculants lead to a satisfying result in the range of pH 2. After test runs of different manufacturers, finally a product was detected which achieved a good separation.

One of the basic problems in the operation of the plant, is the application of the precipitation agents used in the WWTP for he phosphorus removal. To maintain effluent quality, the dosing of precipitants cannot be abandoned especially during winter time, when enhanced biological phosphorus removal is limited. Redissolution of heavy metals, however, is hindered by the presence of metals from the precipitants (ferric salts).

Serious problems were caused by the precipitation of calcium carbonate in the top part of the stripping column, where the pH is increased in order to strip off nitrogen as ammonia. In parallel precipitation of calcium carbonate occurs, which requires a periodic cleaning of the column head. Currently the source of the high amount of calcium carbonate is investigated and a possibility to reduce the input is looked at. In parallel, a possible removal prior to entering the column will be investigated.

At present, the most severe problem is the separation of the precipitated heavy metal sulphides. An originally installed fine filter was retrofitted by a belt filter, treating the washing water of the fine filter. But it turned out that the heavy metal sulphides are of colloidal size, making it impossible to achieve an acceptable degree of separation. The colloids are displaced into the following process steps where they cause considerable operational problems. Investigations will have to show whether a separation by centrifugation is possible.

RELIABLE OPERATION WITH LIMITED FUNCTIONALITY OF THE SEABORNE-PROCESS

At the moment, the Seaborne plant is operated with altered parameters. In particular the acidification is operated at pH 4 instead of pH 2 as originally planed. Thus the dissolution of the nutrients nitrogen and phosphorus is still guaranteed but the redissolution of heavy metals is limited. Therefore they cannot be separated and remain in the sludge. This prevents the above mentioned problems with the separation of heavy metal sulphides, but incineration of the dried sludge is not possible, because the heavy metals would then partially be emitted to the atmosphere.

By applying the above mentioned operational changes a reliable operation of the Seaborne plant was achieved. This was above all necessary to allow a processing of the daily produced sludge in the WWTP. Before, only the operation of a mobile sludge dewatering centrifuge guaranteed a proper sludge disposal.

FUTURE PROJECT PROGRESS

At present, analytics are underway to determine the degree of dissolution of nutrients at the current mode of operation and to determine the fate of the heavy metals. The analysis of the products is supposed to define their concentration of valuable components as well as pollutants, which will be of great influence on the market price that can be achieved.

Starting April 2007, the complete dissolution of nutrients and heavy metals will be tested by reducing the pH during acidification. In the first place, the problem of heavy metals sulphide separation has to be solved. For this purpose, the operation of a centrifuge in a side stream shall be carried out. Furthermore the influence of a reduction of precipitation agents in the WWTP will be investigated.

The objective is to achieve a reliable operation of the Seaborne plant with a complete nutrient recycling and separation of heavy metals by summer 2007. As soon as this is achieved, the scientific monitoring will determine a complete set of all plant parameters.

CONCLUSIONS

The Seaborne process is a combination of newly developed and well-known process steps linked with one another to a complex process. In principle, it allows the recycling of nitrogen and phosphorus from sewage sludge and other organic wastes. At the end of the process, synthetic fertilizer, digester gas, a heavy metal-rich residual and waste water will remain.

Thus the Seaborne procedure represents an interesting and innovative process for the recycling of nitrogen and phosphorus from sewage sludge with subsequent fertilizer production. The interaction of the individual components of the complex plant had not been tested on an industrial scale yet.

During the start up of the plant a number of mechanical as well as procedural problems occurred. Most of the problems have been solved in the meantime. Currently the plant is operated using altered operational parameters. It is planned to achieve a reliable operation of the Seaborne plant with complete recycling of nutrients and heavy metals by summer 2007.

REFRENCES

J. A. Müller, M. Reinhardt, L. Günther, T. Dockhorn, N. Dichtl, I. Urban, D. Weichgrebe, K.H. Rosenwinkel, N. Bayerle, N.O. Vesterager (2005), Fundamentals and Feasibility of Nutrient Recycling using the Seaborne Process, IWA Conference "Management of resudues emanating from water and wastewater treatment, Johannesburg August 2005.

Schulz, M., Schulze, N., Simon, H. (2000), Die Seaborne-Anlagentechnik zur Aufbereitung organischer Reststoffe, Wasser und Abfall 9, 36-40.

PFI (2003), Machbarkeitsstudie zum Seaborne Verfahren, PFI Planungsgemeinschaft Hannover und Technische Universität Braunschweig im Auftrag des Niedersächsischen Umweltministeriums, Feb. 2003

Balmer, P. (2003), Phosphorous recovery, an overview of potentials and possiblities, Wastewater Sludge as a Resource, Proceedings, 257-270.

ATV (2003), Phosphorrückgewinnung, Bericht der Arbeitsgruppe AK 1.1, KA-Abwasser, Abfall Vol. 50, No. 6, 805-814.

ACKNOWLEDGEMENT

The authors appreciate the substantial funding of the project by the Ministry of the Environment of the Federal State of Lower Saxony.