EFFICIENT HEAT

"Integrated and Cost-Effective Solution to reduce the volume of Pig Slurry, minimize Pollutant Emissions and Process Energy Consumption"

Project summary

The overall objective of EfficientHeat is to offer to the EU pig farmers and external waste management agencies an integrated solution to reduce the pig slurries volume, reduce waste management costs, minimize pollutants emission and optimize total process energy consumption. It is achieving by developing a new evaporation technology and better processes for volume reduction of pig manure during the treatment process. EfficientHeat plant will be a definitive integrated and efficient solution where the abatement of emissions (like N-compounds) will also allow for the reduction of foul odours, one of the main complains from the population near pig farms.

Pig manure is a huge problem and has been identified as a major environmental issue in Europe. The large volume of pig manure and its daily use as fertilizer for agriculture is responsible for causing serious environmental problems. EfficientHeat is aimed at developing an integrated and cost-effective solution to reduce the volume of pig slurry, minimize the pollutant emissions and process energy consumptions.

The main technology to be used here is the special version of the Unicus for evaporation applications. Unicus is a scraped surface heat exchanger for high fouling and viscous fluid applications. During evaporation, the scraping action keeps the heat transfer surface clean and maintains heat transfer high. This allows the evaporator to concentrate to levels where traditional technologies fail. This makes this heat exchanger the ideal solution for concentration of environmental waste where volume reduction is vital.

On this project, the current scraped surface evaporation technology to treat pig manure is being optimized and better ways to increase the performance of the evaporators and make them more economical, are being developed, so the investment for pig farmers can be reduced.

By applying the EfficientHeat technology pig farmers will be able to overcome the current obstacles in the sector by obtaining the following benefits:

- ✓ Recovery of nutrients (nitrogen, magnesium and phosphorous) as fertilizers (valuable by-product).
- ✓ Diminishing ammonia atmospheric emissions and therefore fulfilling EU water and air regulations.
- ✓ Inhibiting fouling and therefore, reducing maintenance cost.
- ✓ As a result, reduction of the total slurry management cost and therefore increasing the profit margin of the end user.

Description of the work performed and main results

The overall objective of the EfficientHeat project is to offer to the EU pig farmers and external waste management agencies an integrated solution to reduce the pig slurries volume, reduce waste management costs, minimize pollutants emission and optimize total process energy consumption.

The final system developed and validated is composed of the following elements or processes:

- ✓ Struvite (Magnesium Ammonium Phosphate – MAP) precipitation system.
- ✓ Innovative heat exchanger with ultrasonic system for fouling abatement.
- ✓ Ion Exchange [IE] treatment for the removal of residual ammonia in the condensate after evaporation.
- ✓ Process control system to monitor and control the EfficientHeat system.

The main goal of the struvite (MAP) precipitation system is to mix the raw slurries with some chemicals in a specific proportion to activate the precipitation of the struvite mineral, which is then extracted from the slurry and recovered as fertilizer for agriculture and soil amendment use. After that, the remaining product is introduced in the advance scrapped surface heat exchanger with the aim of reducing the waste volume by evaporation in order to decrease the costs associated with waste disposal and transport. Finally, the condensate product obtained in the evaporator pass through an Ion Exchange post treatment to recover nitrogen as well as the abatement of emissions (N-compounds) and reducing foul odours. This is the whole Efficientheat system that has been implemented in a pilot plant that has been tested step by step firstly at laboratory level at ITAV (control system) and TUT (MAP and IE processes), then in HRS facilities (HE with control system) and finally on a cow farm in Switzerland with the support of A&P (HE, MAP and IE processes with control system).

Computational fluid dynamics have been studied to understand the behavior of pig slurry inside Scrapped Surface Heat Exchangers. The results of this study have allowed us to better understand in detail the behavior of the slurry inside Scrapped Surface Heat Exchangers, which has been used to generate the appropriate scraper designs, which have been implemented and the final results are according to what was expected.

Optimal conditions for struvite ($MgPO4 \cdot 6H2O$) precipitation in relation to variation in the pig slurry composition have been studied in detail and the results of this study has been used to create an optimal struvite precipitation process, which has finally been put in place by creating the corresponding control system that fits with this optimal process specification. The result of this implementation is a robust process that completely extracts valuable compounds from pig slurry input.

A deep study on adsorption capabilities of the different ion exchange materials for nitrogen removal from the gas evaporated and before compression was also carried out. The result of this study has allowed the Consortium to generate and optimize an ion exchange column that eliminates all possible nitrogen particles in the final evaporated output.

Pig slurry characteristics on the evaporation process efficiency have been studied and this has allowed a proper integration of this optimized efficiency in a process control system by generating the mechanical and physical processes that optimize evaporation.

Several new scraper designs compatible with the formation of a more turbulent flow to avoid the formation of an insulating gas film on the tube walls has been developed, increasing significantly the heat transfer with relation to previous devices. Heat transfer increases of up to 54% (counter spiral new scrapper) have been achieved with the new developed scrapers.

A heat exchanger for pig slurry evaporation with coupling of an ultrasonic system to avoid fouling up to 100% has been developed satisfactorily. No fouling presence has been, directly or indirectly, detected.

Algorithms for interaction with sensors and have been developed, configured and optimized. The direct consequence of this development is the achievement of a total extraction of valuable compounds from pig slurry and an important increase in heat transfer in heat exchangers.

pH control to favour the formation of struvite before evaporation and to avoid formation of struvite during evaporation has been designed, implemented and optimized. An exhaustive control on pH levels provides an optimized valuable compound extraction. The removal efficiency for ammonia has reached 100% in certain slurry types, while simultaneous N & P removal was > 85- 90 % even in matrix with 1.5-2% solids.

Precise case studies, same for initial prototyping tests as for the final industrial plant have been elaborated. This will ensure a smoother step to convert the developed concept into a real market product.


Heat exchanger and struvite precipitation system of EfficientHeat pilot plant

Final results

The EfficientHeat solution contributes to achieve an Integrated and Cost-Effective solution to pig waste management by significantly reducing the volume of pig slurries using an innovative technology designed to:

- ✓ Reduction of ammonia emissions by 95%.
- ✓ Recovery of phosphorus (up to 100%) and nitrogen (up to 15%) for use as fertilizer.
- ✓ Decrease treatment costs up to 40% by:
  - Increasing of the heat transfer by 20%.
  - Achieving a slurry concentration up to 60%.

In order to reach these objectives, EfficientHeat project has developed a next generation scraped surface evaporation technology with increased heat transfer capacity and reduced investment costs. This technology consists of an evaporation unit with two treatments process for nutrients recovery and abatement.

The following units are part of EfficientHeat solution:

STRUVITE TREATMENT UNIT: recovering of nitrogen, phosphorus and magnesium in a high quality fertilizer (struvite). The MAP recovery system was resulting very innovative and we demonstrated for the 1st time simultaneous N & P recovery from complex matrices such as animal slurry. The removal efficiency with mechanical stirring was > 90 % translating into an average mean of 35 kg struvite per m3 of slurry. Our system also removes Ca from the slurry liquid bulk and thus limits or eliminates fouling in the EfficientHeat downstream processes that can translate into large cost saving and thus improves the economics of the integrated process. The MAP recovery system as a whole is economical and sustainable.

SLURRY CONCENTRATION UNIT: By using a newly developed scraped surface evaporator for slurry concentration including a novel system to prevent the formation of fouling inside the tubes (anti-fouling system). The new Scrapped Surface Heat Exchanger heat transfer has been clearly improved by moving away from the standard HRS scrapers and using more optimum designs. Heat transfer rates were increased

up to as much as 54%. The increase in heat transfer is inversely proportional to heat transfer area needed for a given needed evaporation capacity. So the development of these new scrapers allows us to design more efficient evaporator models for the future.

Moving away from the HRS scraper to the more complex scrapper design gives higher pressure drop values with the exception one new scraper: at high fluid velocities (0,85 m/s) this scraper types shows increases in heat transfer up to 29% but with less pressure drop: 18% less. This result makes this spiral scraper type potentially the most interesting of all. Better heat transfer results are obtained with decreased pumping cost. This means savings can be made on both capital expenditure and operational expenditure when this scraper type is applied in evaporators.

ION-EXCHANGE TREATMENT UNIT: using an ion exchange material for residual ammonia abatement. Regarding the IE tests, no clean condensate was generated from the runs with cow slurries and AD digestate due to foaming in the evaporator. However, the evaporation of the pig slurry took place after the MAP precipitation and recovery, which removed ammonium from the slurry 100% (< 0.35 NH_4-N mg/l). The MAP pretreatment of this particular type of slurry obviated the need for treating the condensate with IE. The condensate had no ammonia emission problem. Nevertheless, the specific zeolite we were using in the IE trial tests was proved at TUT to be suitable for recovering ammonia from different true raw slurries tested under wide range of operating conditions.

PROCESS CONTROL: adapting the process to the specific slurry characteristics, controlling the anti-fouling system coupled to the evaporator and dosing the substances of the chemical treatments.

In conclusion, we can confirm that the performance of the entire EfficientHeat system developed on this project is very high and fulfill the scientific and technological objectives of the project, meeting them satisfactorily.

EfficientHeat pilot plant design

Potential impact and use

The need for heat ejection and transfer in all industrial processes continue to drive the demand for heat exchangers in the European market. Improved economic conditions from end of 2013, as well as investment in key end-user industries are expected to drive revenues, which are estimated to reach € 5,2 billon by 2015.

There are currently 1200-1500 large-scale pigs farms operating in Europe, facilities that needs to install waste management treatment in order to cope with EU regulations. EfficientHeat Consortium is aware of the importance that the cost-efficiency of the proposed solution will play in its broad implementation. Therefore, a cost analysis of the product and a profitability assessment has been carried out to ensure that the investment cost will have an attractive return of investment and that the sector will rapidly accept and implement this technology across Europe.

The Consortium has carried out a sales forecast (European and Worldwide) of economic benefits for the SMEs of the sector considering a market penetration on the EU market of 10% in the fifth year after the completion of the project and 20% in the tenth year. The initial commercialization strategy will be focused on the EU market, given the strong presence of the members of the EfficientHeat Consortium. The EfficientHeat heat exchanger solution will be also marketable in environmental industry in general, biogas and food industry, wherever product are found with high viscosities and fouling problems.

Consortium members

Partner	Short name	Country
HRS HEAT EXCHANGERS	HRS	Spain
ARNOLD & PARTNERS	A&P	Switzerland
SINAPTEC	SIN	France
TALLERES MARTINEZ LORENTE	TLM	Spain
TECNOLOGIAS AVANZADAS INSPIRALIA S.L.	ITAV	Spain
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