COMMISSIONING NORWAY’S FIRST BIO-FERTILISER FACTORY

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Abstract

IVAR IKS, the regional organisation responsible for the provision of drinking water and wastewater treatment in the Jaeren region of Norway has developed an integrated bio-fertiliser factory at its Stavanger Regional Wastewater Treatment Plant.

In response to significant population growth, wastewater discharge compliance and tightening biosolids recycling regulations, IVAR IKS investigated the potential to utilise thermally dried sludge as an alternative to mineral fertilisers. An extensive 5 year trial and field experiment programme of investigating organic fertiliser products concluded it is possible to produce sludge-based fertilisers similar to those of mineral fertilisers.

Supported by Innovation Norway, IVAR progressed the construction of the bio-fertiliser facility comprising storage silos, dosage and mixing systems for the addition of extra nutrients, pelletiser and a loading unit for packing fertiliser pellets in big bags. The main fertiliser ingredient is thermally dried sludge produced in an existing rotary drying plant. The final products are tailor made MINORGA® organic fertilisers, available in 600 kg big bags.

Optimisation of the waste water treatment facilities focuses on maximising the quality of the biosolids, in particular phosphorus content. This involves the installation of an activated sludge process with an integrated biological phosphorus stage (Bio-P).

The paper describes the initial commissioning of the plant as IVAR prepares for full MINORGA® production in 2015.

Key words

Biosolids recycling, legislation, MINORGA®, organic fertilisers, nutrient recovery, thermal drying and pelletising

Introduction

IVAR IKS is a regional organisation responsible for the provision of drinking water and wastewater treatment in the Jaeren region of Norway. In addition IVAR is responsible for the treatment and disposal of domestic waste in the region. The total population within the region is approximately 330,000.

The Regional Wastewater Treatment Plant of North Jaeren (RWTP), receives and treats wastewater from the densely populated Stavanger region. Following conventional grit and screenings removal, the current wastewater treatment comprises a primary precipitation process using ferric chloride as a coagulant. The existing sludge treatment facility includes anaerobic digestion, centrifuge dewatering, thermal drying and pelletizing of dried sludge. Annual sludge production is approximately 5,000 tonnes of biopellets at 85 % DS (dry solids).
The existing waste water treatment facilities are shown in Figure 1.

![Image of waste water treatment facilities](image-url)

**Figure 1:** Schematic diagram of North Jaeren RWTP

**Frame conditions for the use of biosolids**

The beneficial use of biosolids is carried out under a regulation concerning the use of organically derived fertilisers (Ministry of Agriculture, Ministry of the Environment and the Ministry of Health and Social Welfare, 2003) and is currently being revised. The current approved applications are basically within agriculture, mainly as fertilizer for the production of cereal crops. In addition biosolids are used as nutrient-rich humus in growth media and soil mixtures.

In the last few years the use of phosphate fertilisers on agricultural land has come into national focus due to the considerable increase of the total phosphorous content in the soil; to achieve a reduction in total phosphorous content new fertilising standards have been introduced. Although the phosphorous content of biosolids constitutes an important phosphorous resource it may also represent a potential source of pollution due to relatively large amounts of biosolids currently allowed for land applications.

The current Norwegian limitation for land application of biosolids in Norway is 20 tonnes dry solids per ha. per 10 years. This amount is normally given as a single application, after which the farmer must wait 10 years before the next application. Depending on the type of biosolids, this results in a phosphorous supply ranging between 150-600 kg P/ha which is considerably more than the fertiliser need of the crops. When biosolids are applied to land at such current high application rates the excess phosphorous in the soil represents a significant leakage potential to watercourses.

The new standards for balanced phosphorous fertilisation suggests a maximum phosphorus supply of 160 kg per ha. over a 5 year period. In addition, biosolid applications will not be permitted on land if the plant available phosphorous content in soil (measured as PAL) above a value of 14. This represents significant challenges for the future of recycling of biosolids on agricultural land since the current application rates must be considerably reduced. In some
catchment areas the new standards has already resulted in a ban on the use of biosolids due to the high phosphorous soil content.

**The development of organic fertiliser products**

In general, treated biosolids have relatively low fertilising value. The average content of nitrogen (N) and potassium (K) in IVAR biopellets (2013) are 3.4 % and 0.08 % (w/w) respectively. On the other hand, phosphorous (P) content is relatively high at 2.4 % (w/w), which is comparable to mineral fertilisers. Due to a relatively low nutrient value, the product use is recommended as a soil conditioner rather than as a fertiliser. To obtain adequate nitrogen fertilising effects, relatively high application rates have been used in agriculture.

In order to secure future recycling options IVAR started a co-operation with HØST Valuable Waste (HØST) in 2007, to develop organic fertiliser products based on IVAR’s thermally dried biosolids. HØST was chosen as the joint venture partner since the company has achieved a leading position with the sustainable recycling of biosolids in Norway. The co-operation comprises development of production facilities, full scale pelletizing trials, field experiments (including spreading trials), planning and establishment of a fertilising factory, production, marketing and distribution of the final product. The development is based on the concept that standard NPK mineral fertilisers can be developed by balancing the biosolids phosphorous content through the addition of appropriate nitrogen and potassium sources.

The first stage of the development was to clarify the technical aspects associated with the processing of the products. A range of potassium and nitrogen enriched compounds were mixed with the thermally dried sludge. The focus has been on utilising different waste fractions and by-products from other processes and to use a minimum of 50 % thermally dried biosolids (on a weight basis).

Preliminary experiences indicated that it was difficult to obtain a uniform product prior to pelletizing, which is crucial for the production since every single grain of organic fertiliser has to be equal and consistent. Some of the raw materials have turned out to be lumpy, others are hydrophilic and some are delivered as granules. Different equipment such as hammer mill, sieving and mixing systems were tested. As such equipment is regarded a vulnerable part of the process, it has been an objective to simplify the process configuration by utilising the existing equipment as much as possible.

Experiments with different nitrogen sources showed that the addition of a specific UREA product containing a minor fraction of fat, actually simplified the pelletizing process, probably due to beneficial lubrication effects. Use of fat sources supported the production of pellets down to 4 mm diameter. This finding was regarded as an important breakthrough in the development of the product since this enabled IVAR to produce a product very similar to mineral fertilisers with regard to consistent shape, size and physical composition.

An important part of the development was the establishment of a pilot fertiliser plant at the site. The equipment were assembled in a 40 foot ISO container adjacent to the fertiliser factory and included a grinding and pellet mill, vibrating sieve, pellet cooler and dried solids weight/durability tester. The pilot plant has been of significant value to the optimisation of the fertiliser factory and the development of the quality assurance system which is a vital prerequisite for the introduction of MINORGA® into the Norwegian market.
The fertilising effects of organic fertilisers will depend on the hardness and spreadability of the pellets. The hardness of the pellets is important as some experiences indicate that the structure of thermally dried products can be persistent and observed in soil for more than one year (Tornes et al.2005). The hardness will influence the decomposition of organic compounds, release of nitrogen and the ability of plant root systems ability to access the nutrients from the products. Care must also be taken in the spreading of thermally dried products, since this operation may cause dust problems which in turn may lead to a poor spread pattern and most significantly, a loss of confidence in the products.

In order to ensure the physical requirements for the MINORGAR® products the following parameters have been analysed as a matter of standard procedures in the pilot plant.

- **Dry solid content (DS)**: minimum 88 %
- **Hardness**: Acceptance requirement: 2.5 kgf - 5 kgf
- **Durability**: > 92 % - 5 min
- **Particle size/distribution**: standard 4 mm
  - 3.5 mm < 95 % < 4.5 mm
  - Maximum 4 % with particles < 0.1 mm (dust acceptance)

This has been achieved as indicated in the Figure 2.

![MINORGAR® particle size/distribution](image)

**Figure 2:** MINORGAR® particle size/distribution

An important part of the development of the product was also to identify the fire and explosion characteristics of both the raw materials and the final product, in order to ensure a safe production, storage and transportation of the products. The investigations were carried out by GexCon Ltd. in Bergen and it was concluded that the MINORGAR® product is not a product susceptible to spontaneous combustion product according to “Division 4.2” from “UN Recommendation of the transport of dangerous goods - Manual of Test and Criteria. Fifth revised edition (2009)”. This will ensure the packaging of MINORGAR® in 600 kg “big bags” has no particular ADR transportation requirements.

The development of the product to date has produced a fertiliser product mixture of 70 % biosolids and 30 % urea and potassium chloride on a weight to weight basis. The product has been registered with the brand name MINORGAR®.
The influence on the future wastewater treatment strategy

The regional waste water treatment plant was originally designed as a primary precipitation plant with a design capacity of 240,000 person equivalents. Since the implementation of the secondary treatment requirements in 2001, the wastewater treatment plant has for most of the time met the requirements for BOD and COD removal as a high fraction of the organic matter is in the form of colloids and SS (~80 %). However the safety range between the requirements and plant performance is becoming tighter due to the significant population growth in the region. This has led to an increasing concern for the future ability to comply with the discharge permission. This concern has been further fortified by the increasing replacement of old combined sewers with separate sewers resulting in higher concentrations of organic matter, including dissolved organic matter which is not removed by simple precipitation.

In 2012 IVAR IKS therefore decided to investigate the possibilities of expanding and upgrading the plant with biological secondary treatment in order to improve the BOD/COD removal. Different process solutions were assessed and evaluated based on the following criteria:

- Compliance with the effluent requirements
- Flexibility – in terms of operation and expansion (if new requirements)
- Operation costs, including energy costs and biogas production/ climate gas emissions
- Nutrient recovery
- Pretreatment options

The introduction of biological treatment will have significant impact on the sludge treatment as well as the new fertiliser factory. The evaluation of the biological treatment stage considered the impact on the dewatering/thermal drying plant as well as the sludge quality.

The existing wastewater treatment facilities are located in rock caverns within the mountain whilst the sludge treatment, administration and workshop buildings are located outside the mountain. Since there is limited space available for new biological treatment facilities within the mountain it was therefore important to consider both space and energy saving process solutions.

The introduction of biological treatment will have significant impact on the sludge treatment as well as the new fertiliser factory. As a consequence the evaluation of the biological treatment stage considered the impact on the dewatering/thermal drying plant as well as the sludge quality.

Suspended solids (SS) in wastewater consists mainly of energy-rich organic compounds and is a valuable energy source. A high level of SS removal is positive for the energy budget of the plant, unless the method of SS removal is very energy consuming. High SS removal as pretreatment has a number of advantages:

- Substrate for methane gas production via digestion
- Lower aeration costs in the biological treatment stage
- Lower volume requirements for biological treatment
All the biogas produced at the site is upgraded to natural gas standards and distributed in the adjacent natural gas grid, selling as a fuel for vehicles. It was therefore a key aim to maximise conversion of the organic matter in the sludge to methane gas.

After anaerobic digestion the sludge is dewatered in centrifuges from about 3.5 % DS to 32 – 33 % DS. The sludge is then finally dried to about 85 – 90 % DS before pelletizing. Normally dewatering secondary biological sludge gives a lower DS content in centrifuges compared to primary sludge. Lower dried solids content means that more water must be evaporated in the drying plant, which requires more energy. However, an increasing portion of primary sludge will reduce the energy required for evaporation in the dryer. An example of this relationship is illustrated in Figure 3 below.

![Figure 3: Mass of water to be evaporated as a function of sludge composition.](image)

The future wastewater pretreatment was therefore arranged to include a rotary band filter to filtrate the wastewater since this allows reduced space for the biological treatment, and reduced energy consumption in the secondary treatment. This will also provide advantages in the sludge treatment in the form of increased biogas production and optimisation of the energy consumption in the thermal drying plant.

In order to improve the sludge quality and recycling of nutrients in the dewatering liquors, it was also an aim to avoid the use of metal salts in the wastewater treatment. Increased content of plant-available phosphorous will reduce the need of extra phosphorous compounds.

The recycling of nutrients (N, P and K) will have large impacts on the operational costs of the fertiliser factory associated with reduced purchase of extra nutrients.
The most apparent methods for P recovery from the dewatering liquors is by struvite precipitation. This method is also interesting since it captures ammonia (NH₄⁺). This can further be increased by the use of a heating process to strip the ammonia from the precipitated struvite and recycling the heat-treated struvite as a precipitate. Another option for plants with BOD/COD removal could be to nitrify the ammonia in the dewatering liquors and use the nitrate for BOD/COD removal in the wastewater plant. These aspects played an important role in the final evaluation of alternative secondary treatment processes.

In addition to enhanced pretreatment, the feasibility study recommended a secondary treatment in the form of an activated sludge process with an integrated biological phosphorus stage (Bio-P) as the best overall solution for the future Regional Wastewater Treatment Plant. The construction works started early 2014 and is scheduled to be completed within 2016.

**The fertiliser factory**

The existing thermal drying and pelletizing plant facilitate the integration of the new fertilising factory at the site. A schematic presentation of the new fertiliser factory is shown in Figure 4 below.

*Figure 4: Schematic flow diagram of Fertiliser Factory*

Thermally dried biosolids is fed to a buffersilo (50 m³) by a dense phase pneumatic conveyance system. The purpose of this silo is to buffer the continuous production of dried biosolids to the fertiliser factory which will be operated daytime between the hours 08:00 and 15:00. The extra nutrients are added via 3 storage silos (10 m³ each) mainly utilising urea and potassium chloride (or other mineral salts or high quality organic by-products). The additives and biosolids are crushed and mixed in a hammer mill to ensure a homogeneous mixture before being fed into the pelletizer feed hopper. A 4 mm diameter pellet product is cooled to room temperature and then directed to a big bag loading and package system. The final product will be packed in big bags containing 600 kg of MINORG®.
The fertiliser factory is located in a new 600 m² building adjacent to the thermal drying building; this makes it possible to produce both biosolids and MINORGA® depending on the demand for the product. This provides efficient use of equipment, energy and manning of the factory. The equipment is installed on 3 levels with a total height of 16 m. The design capacity is 6 tonnes per hour based on a production of at least 10,000 tonnes of MINORGA® per year. The fertiliser factory is configured for a future expansion to 20,000 tonnes of MINORGA® per year.

**Commissioning the Fertiliser Factory**

The construction works started in February 2013 with installation of the machinery works commencing in September 2013. The process commissioning was initiated in June 2014, and has progressed as expected apart from minor problems associated with condensation and bridge formation in the main buffer silo and the pelletizer feed hopper. The problems in the main buffer silo has been solved by an additional pressure relieving plate in the bottom section of the silo, supported with an air purging and a vibration generator system.

In order to solve the problems with bridge formation within the pelletizer feed hopper, an air purging system was installed. However, experiences gained so far indicate that this is not sufficient and will probably be replaced with a flat bottom section and screw conveyors.

In addition the commissioning stage has also shown that the pneumatic dense phase transportation system from the drying plant has been sensitive to moisture and condensation forming within the feed hopper. Efforts have been made to ensure proper cooling in the cooling screws (approximately 35 °C) to avoid moisture entering the dense phase feed hopper; to date this has proven to work satisfactory.

Preliminary full scale trials with other mixtures have shown that the physical quality of the pellets with regard to hardness and durability can be difficult to achieve without altering the die in the pelletizer. This supports the importance of the die design and links with initial operational experience of the thermal drying plant (Tornes 1997). Further investigation will be undertaken in the pilot plant.

The commissioning will be completed as part of the final performance tests which include demonstration of guaranteed capacities and the following requirements for the final product:

- **Dry solid content (DS)**: 85-90 %
- **Pellet size**: 4 mm
- **Pellet length**: 4-6 mm
- **Hardness**: 4-8 kgf
- **Durability**: 95 – 98 %

Most of these requirements have been demonstrated however there are some minor adjustments required to optimise the durability parameters and pellet length

Full plant taking over is scheduled for December 2014.
Conclusion

As a result of the promising results, IVAR and HØST decided to establish a joint venture company “Minorga Vekst” to be responsible for the sale of MINORGA® purchasing of raw materials and marketing systems while IVAR IKS will be responsible for the production of the MINORGA® products. IVAR and Høst Valuable Waste are equal partners in the joint venture company.

The feasibility study undertaken in 2009 concluded that a fertilising factory might provide economical benefits for IVAR. The feasibility study concluded that the total operating costs will balance the expected income from sales of MINORGA® within 3 - 5 years of operation. At best the calculation even suggested a potential profit depending on the market prices for nitrogen.

The biosolids-based mineral organic fertiliser is currently marketed under the name MINORGA® and will be launched into the commercial marked in 2015 under the direction of Minorga Vekst AS. It is the aim to produce 2,000 tonnes of MINORGA® within March/April 2015 and the sales campaign has already started.

References
