FROM SLUDGE TO BIOSOLIDS TO ORGANIC FERTILISERS – NORWAY’S EXPERIENCES OVER THE PAST 20 YEARS

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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 pioneered innovation and technical development of sludge treatment and subsequent recycling.

As a consequence of the development of the Norwegian oil and gas industry, Stavanger, the population centre of the Jaeren region, has seen unprecedented growth over the past 20 years with both industrial and commercial expansion supporting a significant growth in population.

Although Norway is not part of the EU, full cognisance of EU Directives is taken and stringent environmental regulation is enforced throughout Norway. Against this backdrop of environmental awareness and regulation IVAR IKS developed the first regional wastewater treatment facilities in the 1990’s close to the harbour at Mekjarvik.

Sludge treatment facilities included anaerobic digestion and the first thermal drying process in Norway. Despite a number of operational difficulties with the original pelletising plant IVAR IKS persevered and continue to operate thermal drying plant to this day.

Extensive agronomic trials for the development of a biosolids-based organic fertiliser has resulted in the production of MINORGA® available in big bags for agricultural use in Norway and export to the Far East.

Future regulations are likely to pose further challenges at a time when population growth and expansion of the waste water treatment facilities will generate even more biosolids. The most challenging amendment to the new regulations is related to the phosphorus supply when biosolids are used on agricultural land.

Due to national focus on biogas production, there is an increasing interest in treating wet organic waste in digestion facilities. As a part of this development IVAR was the first company in Norway to offer the receipt of untreated food waste from institutional households and retail stores for the production of biogas.

This has enabled IVAR to increase the biogas production considerably for cost effective use in the adjacent natural gas system. In this context, IVAR was also the first company in Norway to introduce the amine based scrubber technology for this purpose. Purification of biogas to natural gas standards and its distribution through the natural gas systems as fuel for public transport are likely to be the future key market in the Stavanger region.

A second regional co-digestion plant located at Grødaland in the southern part of the region is currently under construction and scheduled for commissioning early 2016. The plant will offer a complete treatment of sludge, source separated food waste from private households, care homes and retail stores. This will ensure treatment capacity and flexibility in accordance with the future development of housing in the region.
The paper looks back to commissioning of the initial thermal drying plant in 1992, traces the development of processes and products and looks to the future regulations and environmental obligations in Norway.

**Introduction**

The Jaeren region of Norway has developed significantly since the humble days of fishing from the relatively small coastal settlement at Stavanger. The innovative spirit flourished with the introduction of mechanised canning systems and the development of highly successful sardine and herring industries.

Since the discovery of the Ekofisk oil field in the North Sea in 1969, the Jaeren region has gone through an extensive industrial and commercial development.

The region has continued to rise to the challenge of innovative development and has seen unprecedented population growth over the last 20 years. The densely populated Stavanger/Sandnes area is Norway’s third largest urban area however it boasts one of the largest single waste water treatment works in Norway.

Due to the pressures of population growth and tightening discharge quality standards, waste water treatment is an important topic for a nation proud of their environmental responsibilities.

**Background to IVAR IKS**

IVAR IKS is the regional organisation responsible for the provision of drinking water and wastewater treatment in the Jaeren region of Norway. The capital of the Jaeren region is Stavanger and IVAR IKS headquarters is located in Stavanger. IVAR IKS operates the sewerage networks and transfer pumping stations that transfer waste water to the treatment facility. Similarly IVAR IKS operate the potable water treatment works, distribution system and booster pump stations that supply the population of the region.

In addition IVAR is responsible for the collection, treatment and disposal of domestic waste in the region. The total population within the region is currently approximately 330,000.

As a municipality organisation IVAR IKS covers 13 separate areas (Communes) and each has a voting position on the IVAR IKS management board.

**Regional WWTP: Initial Installation**

The Regional Wastewater Treatment Plant of North Jaeren (RWTP), receives and treats wastewater from the densely populated Stavanger region.

The original facilities were constructed within a hillside which required blasting and excavation to create the space for the treatment processes. Conventional grit and screenings removal plant is followed by a primary precipitation process using ferric chloride as a chemical coagulant. The treated waste water is discharged to the North Sea via a 1,600 metre long discharge tunnel at a depth of 80 metres below sea level.

The initial waste water treatment facilities are shown in Figure 1.
The original sludge treatment facility included anaerobic digestion, centrifuge dewatering, thermal drying and pelletising of dried biosolids. The design throughput was a biosolids production of approximately 3,500 tonnes at 85% DS (dry solids).

In addition the site receives sludge from minor wastewater treatment plants, untreated food waste from care homes and retail stores and liquid fat from commercial kitchens. This waste is high in readily degradable material and additional biogas was generated in the anaerobic digestion plant.

**Sludge Thermal Drying Plant**

The initial thermal drying plant was installed in 1992 and was the first drying plant in Norway. This plant was a Stord Rotadisc dryer followed by a Sprout Matador pelletising plant. The design intention was to process the complete biosolids generated.

However operational difficulties were experienced with odour, dust generation and wear in the pelletising plant and associated transportation systems. Extensive investigation and trials of the pelletising plant dies over a three year period yielded significant improvements and the process became fully operational in 1995.

**Drying Plant Improvements and Expansion**

Pressure placed on IVAR IKS to recycle more biosolids resulted in a tendering exercise in 2002 for a second rotary disc drying system to operate in tandem with the original thermal drying plant. A key aim of the plant upgrade was to be able to operate the thermal drying plant as unmanned operation overnight.

Fjell Industrier won the drying plant contract with a plant detail similar to the original Stord design. The new plant provided optimum use of steam and ability for the two plants to operate in tandem. The new facilities also included a new CPM pelletising plant and associated cooling system based on the operational experiences of a number of UK and EU plant installations.

As part of phased expansion of the site, and to maximise the energy balance of the thermal drying plant, IVAR assessed the most advantageous use of biogas to be export to the natural gas grid. To meet the quality parameters of the natural gas distribution system, specific gas clean-up technology was supplied by Purac AB in 2009. As a consequence all the biogas produced at the site is upgraded to natural gas standards and distributed in the adjacent natural gas grid and alternatively selling the biogas as a fuel for vehicles. A key aim of IVAR became the maximum conversion of the organic matter in the sludge to methane gas.
New Discharge Requirements: New Regional WWTP

The regional waste water treatment plant was originally designed as a primary precipitation plant with a design capacity of 240,000 population equivalent. Since the implementation of secondary treatment requirements in 2001, the wastewater treatment plant met the requirements for BOD and COD removal as a high fraction of the organic matter available in the form of colloids and SS (~80 %). However due to significant population growth in the region and future discharge quality parameters the ability of the plant performance to meet these quality parameters required detailed investigation.

In 2012 IVAR IKS investigated the possibilities of expanding and upgrading the waste water treatment plant with biological secondary treatment in order to improve the BOD/COD removal. A number of process solutions were assessed and evaluated based on the following key criteria:

- Compliance with the effluent requirements
- Flexibility – in terms of operation and expansion (if new requirements were to be introduced in the future)
- Operational costs, including energy costs and biogas production/climate gas emissions
- Nutrient recovery
- Pre-treatment options
- Sludge quality
- The facilities are to be located within the existing hillside treatment works, with limited scope for expansion

The feasibility study concluded with a recommended future wastewater pretreatment based on rotary band filters to filtrate the wastewater since this allows reduced space for the biological treatment, and reduced energy consumption in the biological treatment. Band filters also provide advantages in the sludge treatment associated with increased biogas production and optimisation of the energy consumption in the thermal drying plant. In addition to enhanced pretreatment, the feasibility study recommended biological treatment based on an activated sludge process with an integrated biological phosphorus treatment stage (Bio-P) to be the best overall solution for the future Regional Wastewater Treatment Plant.

To accommodate the new biological treatment system a phased conversion of the primary precipitation basins was undertaken within the hillside "caverns". Additional space is required for the complete waste water treatment works expansion/conversion and additional rock blasting and excavation. The construction works started early 2014 and is scheduled to be completed in 2016.

The expanded waste water treatment facilities are shown in Figure 2.
Sludge Quality Challenges

The introduction of biological treatment in the upgraded Regional Wastewater Treatment Plant will have significant impact on the sludge treatment and sludge quality and includes the following elements:

- Sludge and biogas production
- Dewatering and thermal drying properties
- Dewatering liquor load to the wastewater treatment
- Polymer consumption
- Fire and explosion characteristics of dried sludge
- Sludge quality and NPK content of the final product

Following anaerobic digestion the sludge is dewatered in centrifuge plant from about 3.5 % DS to 32 – 33 % DS. The sludge is then thermally dried to about 85 – 90 % DS before pelletising. Conventional dewatering of secondary biological sludges achieves a lower DS content in centrifuges compared to primary sludge. A lower dried solids content will result in more water to be evaporated in the drying plant, with consequential more energy required. However, an increasing portion of primary sludge will reduce the energy required for evaporation in the dryer. Is is expected that the new biological sludge will achieve a minimum of 25 % DS and on that basis, the amount of required evaporation increases by nearly 40 %.

It will therefore be of vital importance to achieve a DS content close to current operational conditions to maintain stable and cost effective drying. However, this must be balanced with a sludge recovery ratio in the centrifuges which in turn will affect the thermal dryers. In that respect, there are also uncertainties related to how the evaporation capacity will be affected when introducing a biological sludge to the thermal dryers. Specifically this includes the power consumption of the rotor, recycling ratio, capacity and configuration of screw conveyors etc. It is also expected that the dewatering liquor will represent a significant additional load on the wastewater treatment which might justify the installation of P recovery plant by Struvite precipitation.
As a consequence of the wastewater treatment expansion IVAR included investment for upgrading of the sludge treatment comprising:

- Upgrading of the biogas plant with a new digester and associated gas systems, High Voltage distribution and electrical installations integrated with the existing biogas plant.
- Upgrading of the dewatering and thermal drying plant integrated with the existing plant.

The agronomic consequences for the sludge quality are expected to have positive effects on the sludge quality and are mainly related to:

- Increased plant availability of phosphorous
- Increased plant availability of organic nitrogen
- Enriched content of micronutrients based on the assumption that the activated sludge process in the wastewater treatment effectively accumulate these compounds from the wastewater.
- Lower fibre content in dried sludge that may simplify the pelletising process.

**From Sludge to Organic Fertilisers**

To accommodate the compositional changes anticipated with the new biological sludge and tightening standards with respect to recycling biosolids to agriculture, IVAR undertook extensive investigation of potential to create organic fertilisers from the thermally dried biosolids.

IVAR IKS entered into a cooperation agreement with the HØST Valuable Waste company to assess the practicality of developing organic fertilisers to secure recycling options. A range of field trials were undertaken using “fertilisers” created in a laboratory scale mixing/blending plant at the site. The field trials were set up to assess effective spreading rates and plant growth/uptake for a range of fertiliser compilations.

The field trials indicated positive cereal yields compared to the control application and losses of nitrogen from the application of the organic “fertiliser” were lower than compound fertilisers.

Following these positive field trials and commercial evaluation of developing a full scale fertiliser factory, IVAR IKS decided to invest in the facility adjacent to the existing thermal drying facilities. To secure an identity in the fertiliser market IVAR IKS named the organic fertiliser brand as MINORGA®.

The construction of the fertiliser factory works started in February 2013 with installation of the machinery commencing in September 2013. The process commissioning was initiated in June 2014 and was officially opened by the Environment Secretary in June 2015. The construction of the fertiliser factory also included the upgrading of the thermal drying facilities. This involved the replacement of the original Stord Rotadisc with a new thermal drying plant of similar design to that installed by Fjell Industrier. The design allowed for full integration between the existing and new thermal drying plant.

The project has been progressed as expected apart from minor problems associated with condensation and bridge formation in the main buffer silo and the pelletiser feed hopper.

The problems in the main buffer silo has been solved partially by a larger outlet valve, an additional pressure relieving plate in the bottom section of the silo, and an additional air purging and a vibration generator system. Some problems with bridge formation in the buffer silo remain, however, these do not prevent the scheduled production of MINORGA® but require greater maintenance than expected. Similar problems apply with the bridge formation within the pelletiser feed hopper.

Operating experiences so far have shown that the physical quality of the pellets with regard to hardness and durability depends on the die used in the pelletiser. This supports the importance of the die design and links with initial operational experience of the thermal drying plant. In that respect it
should be mentioned that the existing pelletising plant has been operated with an average die life of nearly 1,000 hours due to focus on die design and refurbishment of rollers.

The operating experiences with the fertiliser factory so far have shown that the quality of urea is of importance for the pelletising process. Although the more expensive and refined urea tends to have better pelletising properties than cheaper products on the market it is still remains necessary to develop a die design which will ensure an acceptable hardness value for the product. This will in particularly apply to the stringent quality requirements for the domestic market (Norway) but is of less importance for the products dedicated for export (e.g. Vietnam).

The biosolids-based mineral organic fertiliser, currently marketed under the name MINORGA® has been launched into the commercial market under the direction of Minorga Vekst AS. It is the aim to produce 1,000 – 1500 tonnes of MINORGA® during 2015. The estimated production for the next twelve months (2016) is approximately 6,000 tonnes of which 4,000 tonnes is dedicated to sales in Vietnam.

A schematic presentation of the new fertiliser factory is shown in Figure 3.

**Figure 3. Schematic flow diagram of Fertiliser Factory**

**Current Experiences and Legislation**

Norway has extensive experience of a good dialogue with the stakeholders in biosolids recycling involving agricultural advisory and experimental societies and local authorities.

Local growth trials with biosolids have traditionally served two main purposes; to demonstrate and document the benefits of biosolids and increase user’s practical experiences and knowledge of recycling biosolids. These trials have served to demystify the fertilising and soil improving effects of treated biosolids. It is interesting to observe that farmers hosting field trials often appear to be the leading farmers in their localities which undoubtedly has contributed to positive view and acknowledgement of the benefits of biosolids recycling in Norway.
Norway has been among the leading countries in the world with regard to both quantity and quality of biosolids recycled to agriculture. Although the application of biosolids to agricultural land has been considered a safe and sustainable option in the past, the debate on biosolids recycling over the last 10 years has shown that it cannot be taken for granted that agricultural outlets will continue to be the main recycling route in Norway in the future.

In order to meet this challenge Norwegian Water (Norsk Vann BA) developed a communication strategy with the aim to promote public acceptance and confidence with the utilitarian value of recycled biosolids. The strategy was developed in 2004 with a provisional 3 year programme period and comprised the establishment of a national forum for the use of biosolids within agriculture and green amenity areas respectively.

The communication programme revealed the need for national guidelines for long term quality control and a quality service system to enhance mutual confidence and information transfer between stakeholders. It is important that those involved in regulation, treatment and recycling of biosolids need to ensure that minimum standards are consistently achieved and that best practices are applied across the country.

Different approaches were considered based on experiences in Sweden, UK and USA. There was a general scepticism towards the introduction of a certification system for biosolids since it was believed that this could impose large costs on municipalities and for the smaller municipalities difficult to implement. Norway is made up of 428 municipalities and many of these have less than 5,000 inhabitants. In addition, Norway has comprehensive and stringent legislation relating to sludge and all sludge treatment plants are under regular supervision by the Norwegian Food Safety Authority. Alternative approaches involving forming partnerships were also considered but discounted as the major stakeholders would not wish to bind themselves to such commitments.

As a result of this process, Norwegian Water developed national guidelines for the beneficial use of biosolids. The guidelines are based on a joint policy document and comprise recommended quality assurance systems and codes of good practice for biosolids recycling. The implementation stage requires all involved with sludge treatment and biosolids recycling to commit to specific electronic training courses, review recommended guidelines and sign a “declaration of conformity”. The declaration will give access to a brand image issued by the Norwegian Water which verifies that the facility has a consistent and holistic quality assurance system so that partners and customers can have confidence with the quality of the product.

The guidelines have met with approval from the Norwegian Food Safety Authority and it is believed that this voluntary approach could act as an alternative to the more costly certification systems applied in other countries. The guidelines or norm has been implemented at 6 large wastewater treatment works and 4 other sites are at the implementation stage. It is anticipated a major proportion of the biosolids recycling in Norway will be covered by the norm by 2018.

However, there is a need to develop the guidelines towards a recognised quality assurance system ensuring a good, environmentally friendly and cost-effective production and recycling of biosolids. At present the guidelines are not sufficiently implemented in the industry's quality assurance systems. There is also a lack of preferred measures and organisation of future work under the direction of Norwegian Water. In addition the communication and marketing strategy remains weak with no appropriate meeting places for the stakeholders. The proposed future work will therefore include the development of clear aims and strategies to improve and strengthen communication and marketing strategies.

**Future Trends and Regulation**

At the start of the 1990’s sewage sludge was often referred to as “sludge – from a problem to a resource”. The attitude of authorities to sludge has changed so that sludge is to be considered as a resource and treated as a resource and not a waste for disposal. The use of the term “biosolids” in place of sludge has played an important part in changing perception.
Biosolids has mostly been produced near the densely populated areas in the eastern and western part of Norway. However, the areas in the eastern parts are dominated by small livestock, poor humus soil condition and high cereal production; in comparison the southwest part of Norway has significant production of manure from local livestock and lack of available land to meet the future demand of expanding productivity.

The need to supply organic material to cereal growing areas has been favourable for the marketing potential for biosolids. The main benefits of biosolids recycling to agriculture has focused on the high organic matter content and the positive effects on soil structure and consequential reduction of soil erosion. This is emphasis is also reflected in current legislation and the maximum allowable quantity applied to land. The fertilising benefits of nitrogen and phosphorous has therefore been considered as secondary effect.

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 main change in this revision process is that the authorities’ attitude to biosolids is changing a simple soil conditioner to a complex fertilising product.

The main reason for the change of emphasis is the need to reduce the run-off and leaching of nutrients (in particular phosphorous) from agricultural land. From an agricultural perspective there has also been a change from previous principle of a “stock based fertilisation”; this principle assumed that the soil can be supplied with more phosphorous than the crop/plants are able to take up in a normal crop cycle, and the crop/plants can utilise the remaining fertiliser at a later date. This principle has now been abandoned and replaced by the balanced fertilising principle; this approach requires the supply of phosphorous that the crop/plants normally requires for healthy growth. This will of course also apply to biosolids recycling.

The increasing interest in the responsible use of phosphorous within the EU has also affected the debate in Norway. The new standards for balanced phosphorous fertilisation suggests a maximum phosphorus supply of 160 kg per ha. over a 5 year period. In addition, biosolids 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 a significant challenge for the future of biosolids recycling to agriculture since the current application rates must be considerably reduced. In some catchment areas the new standards have already resulted in a ban on the use of biosolids due to the high phosphorous soil content. It is also interesting to observe that new wastewater discharge permits are seeking phosphorus recovery in dewatering liquors.

Conclusion

IVAR IKS have demonstrated a responsible approach to balancing their obligations to their customers in the Jaeren region of Norway whilst pioneering innovation and technical development of sludge treatment technology.

From the initial installation of anaerobic sludge digestion and the first Norwegian thermal drying system, IVAR IKS have continued to learn from their extensive operational experiences and investigate options to optimise existing facilities.

Faced with the challenge of supplying biosolids to a small and tightly controlled agricultural outlet, IVAR IKS have objectively assessed the increase of biosolids generation linked to population growth and the additional biological treatment system required to serve that population and revised discharge consent standards.

Investment in additional sludge treatment and thermal drying capacity with biogas upgrading facilities mean that IVAR IKS can maximise the value of the biogas utilised in eth local natural gas network.

Earlier agronomic trials and fertiliser formulations demonstrated the feasibility of developing a biosolids-based organic fertiliser and IVAR IKS invested in the construction of a fertiliser factory at the site of the Regional Wastewater Treatment Plant. In conjunction with a joint venture with the HØST
Valuable Waste company IVAR IKS have launched the MINORGA® product on the fertiliser market and have secured significant sales in Vietnam where the soil conditioning and nutrient/fertiliser properties are in great demand.

MINORGA® combines the positive properties from both mineral and organic fertilisers and the product will ensure a safe and sustainable recovery of nutrients. Moreover, the launching of MINORGA® can also stimulate increased competition, technology development and cost reduction. It is considered this may form the basis for a better resource exploitation of phosphorus and market conditions for both biogas and fertiliser products.

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