# MINORGA® GOES LIVE!
# PREPARING FOR NORWAY'S FIRST BIO-FERTILISER PRODUCT

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## Abstract

A cooperation between IVAR IKS (IVAR) and HØST Valuable Waste AS (HØST) created an extensive 5-year development programme of investigating organic fertiliser products. Trials and field experiments have demonstrated that it is possible to produce biosolid based organic fertilisers with a consistency, particle size and balanced nutrient composition similar to those of mineral fertilisers. Market name of the biosolid based mineral organic fertilisers is MINORGA®

An important part of the development was the establishment of a pilot fertiliser plant with testing facilities enabling process and product knowledge adequate for operating the full-scale installation. Quality assurance of the product is a vital prerequisite for introduction of MINORGA® into the Norwegian market.

Proper addressing of quality assurance requirements underlie establishing the company MINORGA VEKST AS. This company, owned by IVAR and HØST, undertake marketing, sales and distribution of MINORGA® as cereal fertiliser in Norway. However, there are opportunities for export from the adjacent Mekjarvik harbour, in 650 kg big bags. A range of MINORGA® fertilisers will be tailor-made for different crops and fertilizing strategies.

The paper describes the preparation undertaken for full MINORGA® production in 2015.

## Key Words

Biosolid, Mineral Organic Fertiliser, Fertiliser spreading, Yields, Markets

## Introduction

The Norwegian regulations for organic wastes, among this biosolids, aim at increasing their use as soil amendments and organic fertilisers on land areas. The strategy for achieving this is to secure the supply of only high quality biosolids to agriculture and green areas; the two disposal routes acceptable for land application of biosolids in Norway.

Up to this date, we use most high quality biosolids as organic fertiliser / soil amendments on farmers land. Dosages of 20 – 40 tons DS biosolids per ha. every 10th year depends more or less solely on the content of heavy metals and that the product is proper hygienized and stabilised.

There has been a considerable reduction in heavy metal content of sludge during the last 25 - 30 years, linked with strict control of industrial effluents discharged to the municipal sewerage system and implementation of cleaner technologies within industry (Paulsrud, 1997). Consecutive documentation of the contents of following heavy metals: Cd, Cr, Cu, Hg, Ni, Pb and Zn, is a presumption of any land application of biosolids. When it comes to organic pollutants normally focused in EU, Norwegian regulatory authorities have not imposed the same demands for frequent analysis. However, every 5th year, comprehensive documentation regarding the contents of selected pollutants show low concentrations and a similar decreasing trend as for heavy metals.

Contents of selected indicator organisms documents the hygienic status. Normally, exposure to elevated temperatures and proper validation of treatment methods form a scientific basis for achieving a hygienic safe product. Odour control links with proper stabilization and immediate handling onto and into the soil matrix.

The revision of Norwegian Legislation on the use of organic waste fractions as a fertiliser will focus on phosphorus content, both as a potential pollutant and as a limited source of fertiliser nutrient. Today application of as much as 400 – 1,000 kg of phosphorus per ha. every 10th year is possible[1]. In the future, it must be realised that phosphorus content of biosolids forms an important part of the farmers' fertilising plans and that any use of biosolids reflects this. Consequently, this will result in substantial reductions of future spreading amount of biosolids (tons per ha).

MINORGA® is a precautionary step towards treating high quality biosolids as a resource, aiming to exploit the significant phosphorus content as the key element in a balanced mineral organic fertiliser.

## Results

*Bio solid from IVAR as organic core in a mineral organic fertiliser*

The organic base in the mineral organic fertiliser MINORGA® is a biosolid from IVAR, stabilised through anaerobic digestion and hygienized in a consecutive validated[2] drying step (Tornes, Johnsen and Paulsrud 2008).

Documentation of selected quality parameters ensure a predictable and consistent product, which is well suited for use as an organic N and P source in a balanced fertiliser.

[1] This example is based on variations in total phosphorus in dry biosolids from IVAR
[2] Validation proves the sanitizing effect of a chosen technology, measured as killing chosen indicator organisms

*Organic content and nutritive characteristics*

Figures 1 – 3 document the variability in contents of organic matter (as ignition loss), nitrogen (as Kjeldahl N and ammonium-N) and phosphorus (as total phosphorus and plant available phosphorus) in IVAR biosolids.

As for the organic content, it adds a positive benefit by enrichment of poor soil structures. The application of 1 tonne of MINORGA® per ha. each year, represents slightly above 350 kg organic matter. In the short term, this quantity is insignificant[3], but the organic value of MINORGA® will prove substantial, when used as fertiliser in the longer term.

Since the final biosolid product from IVAR is processed in a thermal drying plant, most of the nitrogen is organic (> 90 % of DS), implying microbial activity as a prerequisite for making nitrogen available for crop uptake. This is a positive key benefit and a biological measure against pollution through nitrogen leakage. However, low temperatures during the spring farming application restricts microbial activity and thereby solubilisation of organic nitrogen. The addition of UREA provides the immediate nitrogen demands for the cereal crops.

A more delicate question concerns the use of ferric chloride as the chosen coagulant for trapping phosphorus in the wastewater treatment plant. Results from far-reaching research projects prove limited plant availability of ferric- and alumina phosphorus salts in Norwegian biosolid qualities (Falk-Øgaard, 2013). Our tests so far supports MINORGA® as an adequate phosphorus fertiliser. However, it is difficult to conclude whether the reason for this is elevated concentrations of available phosphorus already present in the soil, partly as a consequence of long lasting P-fertilization (Tunney and Liebhardt, 2014) or if microbial activity actually manages to solubilize phosphorus from the precipitated Fe-salts (Sharma et al., 2013). In the original composition meat and bone meal (MBM) was a key ingredient to "guarantee" sufficient plant available phosphorus in the MINORGA® product. However, due to ever-increasing costs and some reluctance against including an additional organic regulated fraction in our fertiliser, biosolid from IVAR remained the only organic fraction in MINORGA®. For the time being IVAR is converting the existing WWTP from a chemical precipitation system into a fully biological system, in which selection of bacteria aiming at the luxury uptake of phosphorus replace the chemical coagulant (Tornes and Whipps, 2014). This treatment change will affect phosphorus availability in a positive way and result in a biosolid in which iron does not play a dominating role.

[3] Hard to detect as an increase of organic matter in soil samples

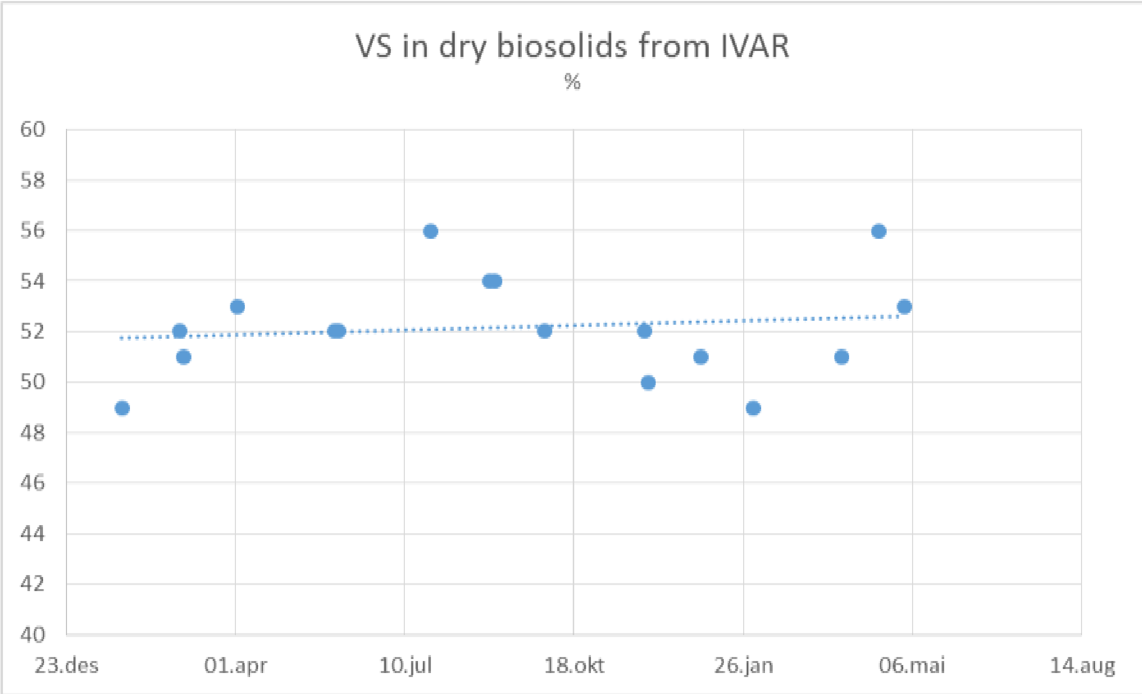



**Figure 1:** **Volatile Solids (VS) in dry biosolids from IVAR (figures from 2013)**

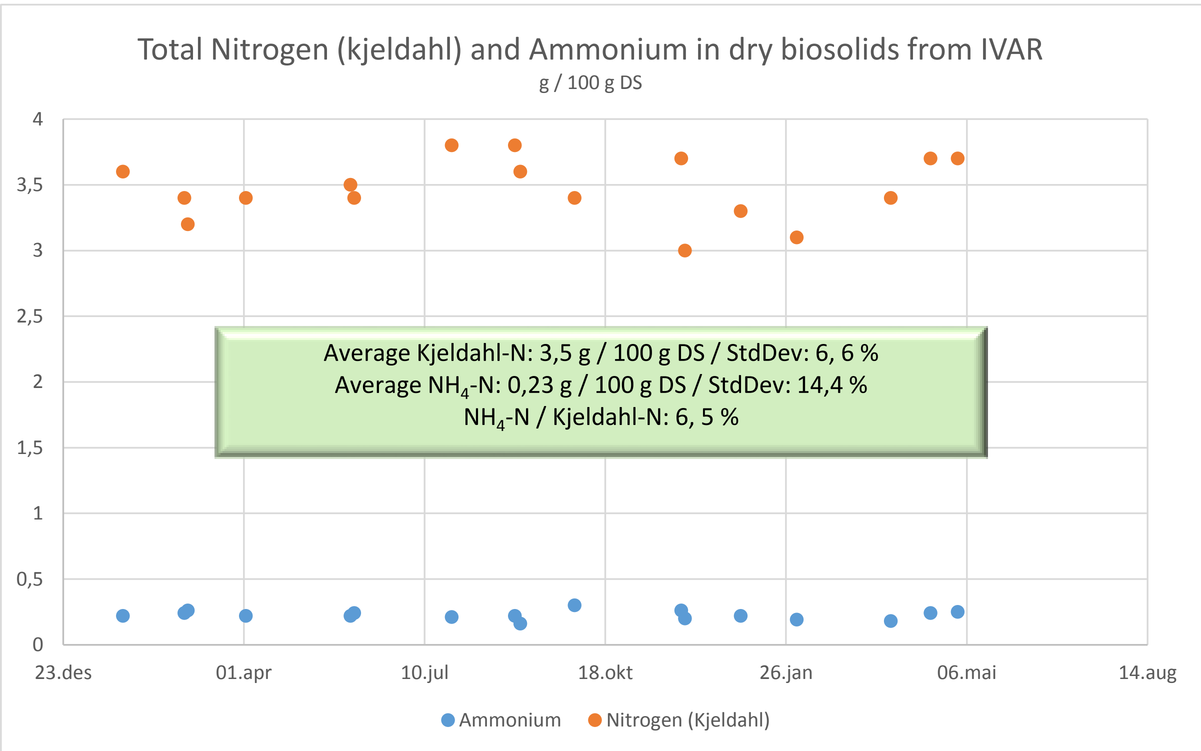



**Figure 2:** **Total Nitrogen (as Kjeldahl - N) and ammonium in biosolids from IVAR (figures from 2013). In green frame average values, standard deviations and mineral fraction of total-N (in %).**

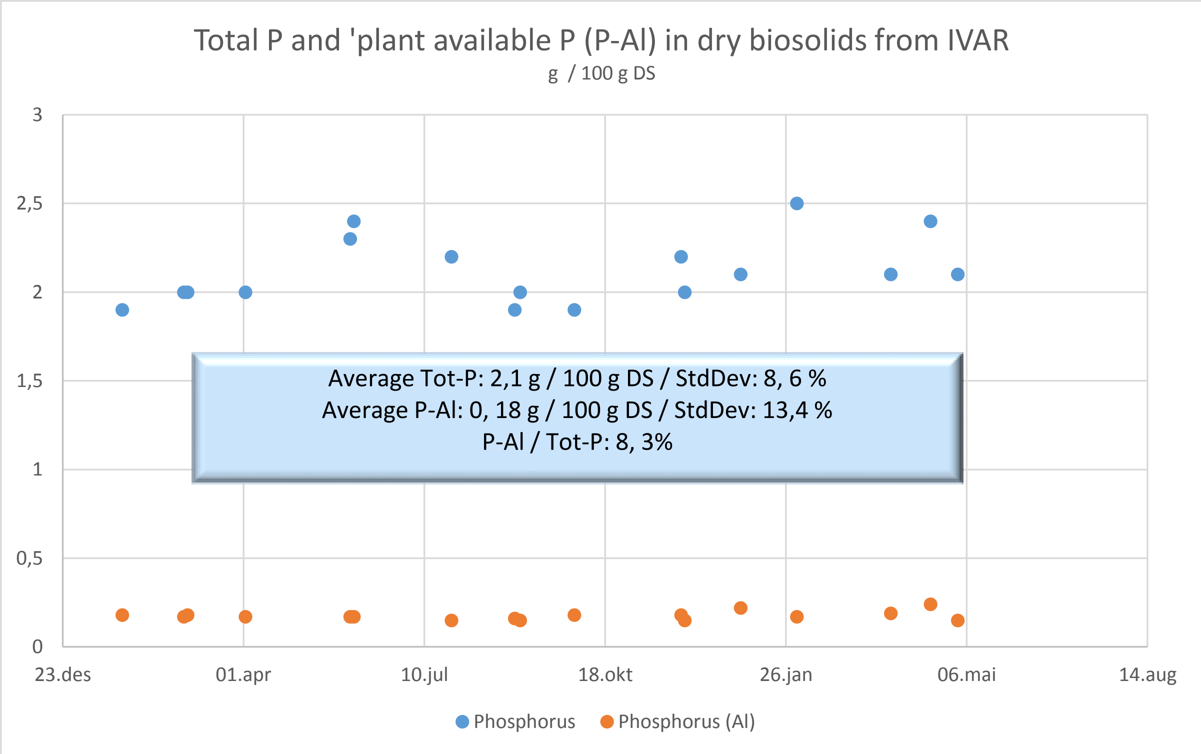



**Figure 3:** **Total phosphorus (Tot-P) and plant available phosphorus (P-Al) in biosolids from IVAR (figures from 2013). In blue frame average values, standard deviations and P-Al fraction of total-P (in %).**

*Heavy metals in biosolids from IVAR*

The heavy metal contents in biosolid from IVAR vary marginally over the year. This is demonstrated in Figure 4A, B and C

A)

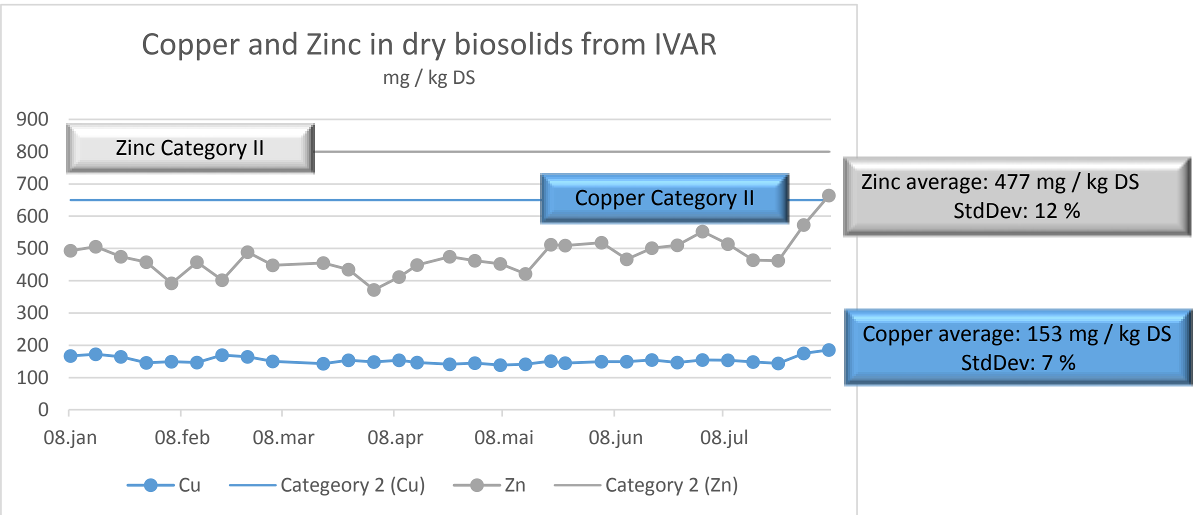
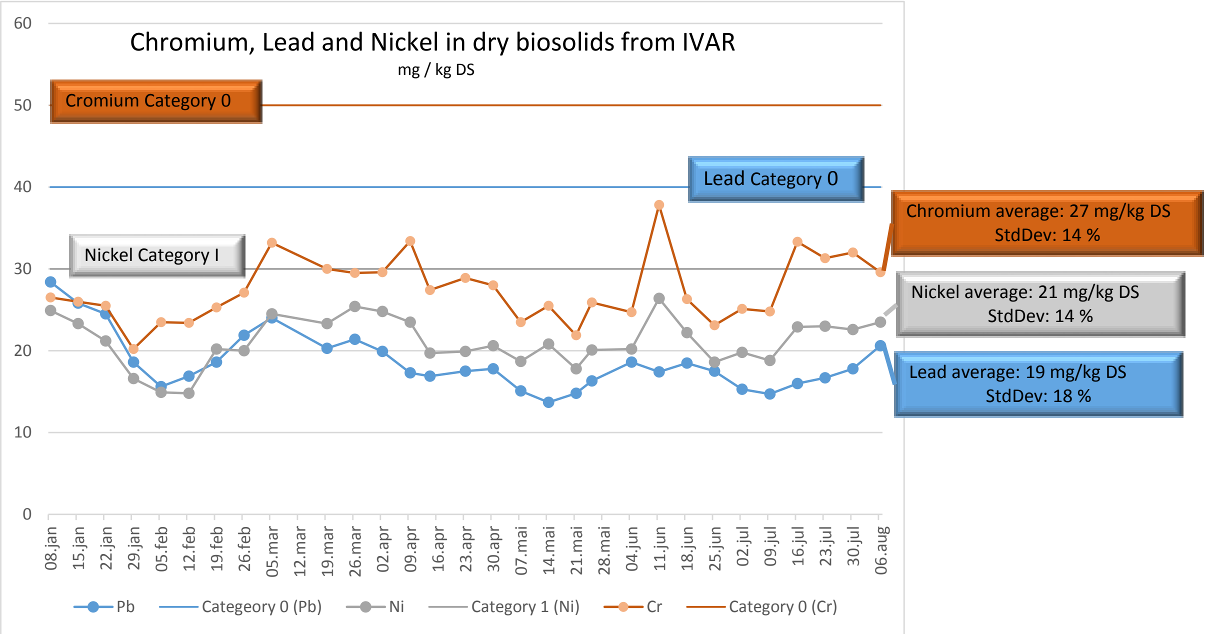



**Figure 4A:** **Copper and Zinc content in biosolids from IVAR (figures from 2014)**

B)




C)

**Figure 4B:** **Chromium, Lead and Nickel content in biosolids from IVAR (figures from 2014)**

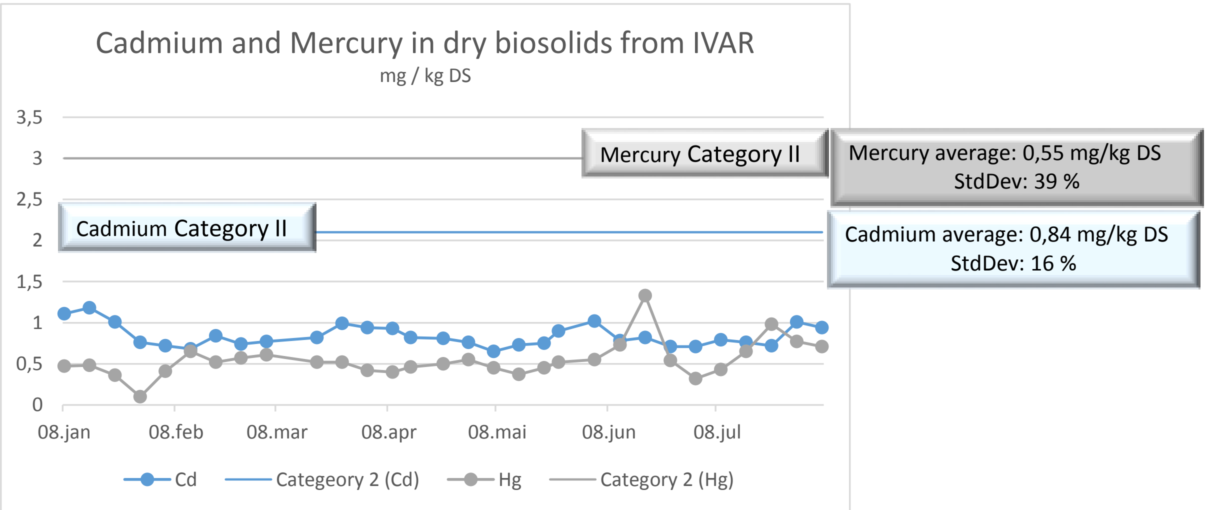



**Figure 4C:** **Cadmium and Mercury content in biosolids from IVAR (figures from 2014)**

In the three versions of Figure 4, heavy metals in biosolids, contain frames to the right average values and standard deviations. The straight lines with corresponding colours show the upper limits for relevant quality categories as given in the Norwegian legislations[4]. Use of biosolids is restricted to cereal crops.

[4] Biosolid qualities group in one of four categories (0, I, II and III) dependent on concentrations of heavy metals. The category selects where to use a specific biosolid quality and in which doses.

Category 0 opens for use as an ordinary fertiliser, Category I opens for use of 4 tons DM every 10th year. Category II opens for 2 tons DM every 10th year.

The quality of biosolids from IVAR is representative for a typical Category II product.

## MINORGA® variations and physical demands

After the exclusion of MBM, HØST developed MINORGA® fertilisers with variations of mixtures of biosolids from IVAR, mineral N and mineral K sources. The standard MINORGA® 10-1-5 represents the 50 % version of the typical spring fertiliser for use in the sowing machine.

Use of MINORGA® 5-1-9 in the sowing machine combined with MINORGA® 12-1-0 after corn germination, represents an alternative fertiliser strategy. The project will test-out more types, dependent of fertilising strategies and cultures. However, up to now, MINORGA® products have relied on UREA as a rich nitrogen source and potassium chloride (KCl) as the supplier of potassium.

The success in achieving regular pellets of 4 * 4 mm with a smooth surface, compatible with deliveries from combined spreaders (sowing machines), and appropriate hard consistency, compatible with lowest possible deterioration, relies on lubricating and hardening qualities of the raw materials mentioned above. Several combinations tested in the pilot-scale fertiliser line, prove it possible to meet our specification demands (Tornes and Whipps, 2014) without any additions of lubricators or curing compounds. The photo in Figure 5 gives an impression of typical pellets from MINORGA® 10 – 1 - 5, which is our standard fertiliser for use in spring applications in the sowing machine and MINORGA® 10-3-14 a fertiliser tailor made for coffee production.

It seems possible to maintain high quality pellets with substantial variations of mineral organic mixes.


**Figure 5:** **Photos of A) Pilot pelletizer, B) MINORGA® 10 – 1 – 5, C) MINORGA® 10 – 3 - 14**[5]

*Spreading tests*

Compatibility with conventional spreading equipment is extremely important to achieve success in the fertiliser market. Pellet quality must neither complicate even distribution nor clog the combined systems delivering fertiliser together with seeds. Several tests show even distribution from *centrifugal spreaders*, although at lower concentrations (kg / area), compared to mineral fertilisers, when the spreading picture adjusts for the latter (Figure 6). This is most probably due to the lower densities of MINORGA® fertilisers, compared to mineral fertilisers. Cooperating farmers do not consider this to be a severe hindrance, as simple adjustments of the spreading equipment will solve the problem.

Tests in *combined* systems (sowing machines) identify a possible challenge associated with the lower spreading rates. Upper limits of 600 – 650 kg MINORGA® per ha. might require the delivery of fertilisers over several applications.

[5] Taylor made Fertilizer for Coffee. Phosphorus and Potassium given as $P_2O_5$ and $K_2O$ respectively.

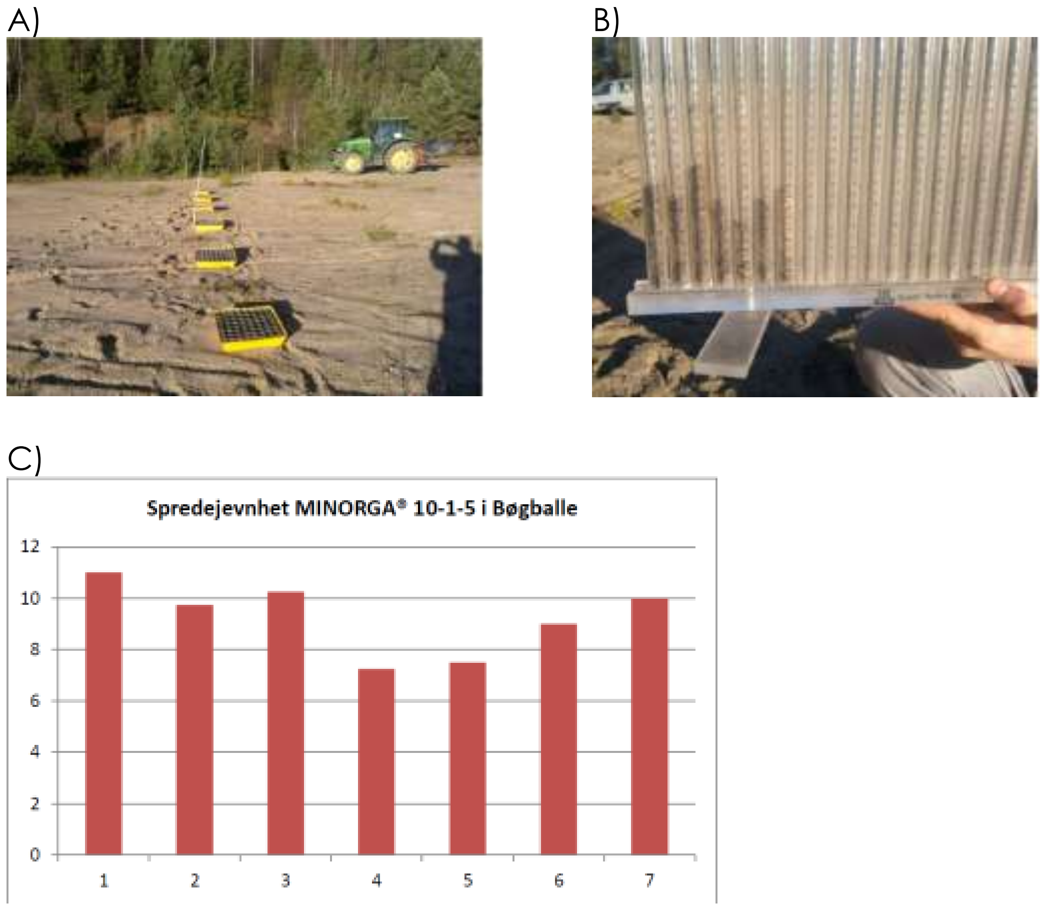



**Figure 6.** **A) Spreading of fertiliser with Bøgballe centrifugal spreader, B) Height in cm's of MINORGA® 10-1-5 collected from each of 7 vessels (see A), C) results as cm for each vessel, presented as column diagram.**

## Results From Field Tests

Results from tests of MINORGA® as an alternative to conventional mineral fertilisers, shown below, prove its adequacy.

With adequate irrigation and mixing into soil, MINORGA® yields and quality are at least comparable with those from conventional mineral fertilisers (Table 1). Figure 7 indicates increased nitrogen uptake from MINORGA® 10-1-5 later in season. This quality could be due to increased availability of organic N.

However, there are some challenges connected to application on surfaces during dry conditions. Table 2 and Figure 8 indicate a sensitivity connected to low water activity and potential loss of nitrogen as $NH_3$ (from UREA) upon surface spreading. Under these circumstances, there were indications of P-limitation.
Since surface spreading is not the normal situation during spring farming, we conclude that this circumstance represents a minor problem in using MINORGA®.

Table 3 and Figure 9 document MINORGA® as an adequate fertiliser for the production of Rye grass (feedstock).

The results shown in Table 4 suggest MINORGA® as a maintenance fertiliser for delivery after germination of the cereals, approximately 4 - 6 weeks after sowing. Although lack of statistical relevance, the results are indicating somewhat higher yields from fields of MINORGA® fertiliser, this might indicate that heavy rain has washed out the nitrogen (as $NO_3$) from the mineral fertiliser.

**Table 1: Effects of rate and type of fertiliser on nitrogen uptake (YNT-values), yields and % crude protein in dry matter of wheat (corn and straw). Mineral fertiliser (YARA 20-3-10)**

| | Chlorophyll readings (YNT) | | Grain (Yields) | Straw (Yields) | Cereal Protein |
|---|---|---|---|---|---|
| | Early | Late | kg / ha | kg / ha | % of DM |
| NO fertilizer | 493 | 333 | 2870 | 2340 | 10,2 |
| Mineral fertilizer (50 kgN * $ha^{-1}$) | 575 | 462 | 4220 | 3410 | 10,7 |
| MINORGA 10-1-5 (50 kg N * $ha^{-1}$) | 618 | 521 | 4300 | 3560 | 11,4 |
| Mineral fertilizer (100 kgN * $ha^{-1}$) | 603 | 578 | 4750 | 4190 | 12,2 |
| MINORGA 10-1-5 (100 kg N * $ha^{-1}$) | 591 | 601 | 4830 | 4130 | 12,8 |
| Mineral fertilizer ((100 kgN + 10 kg P) * $ha^{-1}$) | 618 | 578 | 4940 | 4170 | |
| MINORGA 10-1-5 ((100 kg N+ 10 kg P) * $ha^{-1}$) | 634 | 610 | 4980 | 3960 | |
| Mineral fertilizer (150 kgN * $ha^{-1}$) | 640 | 632 | 5330 | 4750 | 13,4 |
| MINORGA 10-1-5 (150 kg N * $ha^{-1}$) | 604 | 650 | 5240 | 4810 | 13,9 |

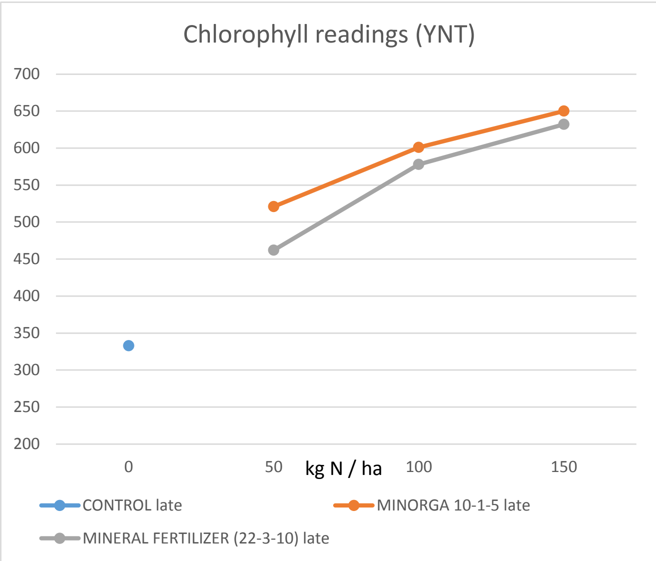



**Figure 7. Late season YNT[6] figures (nitrogen) as function of fertiliser and nitrogen applications.**

[6] Yara Nitrogen Tester (YNT) is a hand-held device measuring nitrogen status of a crop from the chlorophyll content of its leaves.

**Table 2:** **Effects of type of fertiliser and extra phosphorus on yields in dry matter of wheat, grown on sandy soil and clay soil**

| Regime | Light soil (Sand) | Heavy soil (clay) | Average | Relative | difference |
|---|---|---|---|---|---|
| (N + P - kg / ha$^{-1}$) | kg / ha | kg / ha | kg / ha | (%) | $\frac{(MINERAL - MINORGA)}{MINORGA}$ |
| No Fertilizer | 1220 | 3190 | 2205 | 100 % | |
| MINORGA (50+0) | 3210 | 4420 | 3815 | 173 % | |
| MINORGA (100+0) | 4360 | 5660 | 5010 | 227 % | |
| MINORGA (100+30) | 5230 | 6360 | 5795 | 263 % | |
| MINORGA (150+0) | 4100 | 6450 | 5275 | 239 % | |
| MINERAL (50 + 0) | 3520 | 5100 | 4310 | 195 % | 13 % |
| MINERAL (100 + 0) | 5320 | 6540 | 5930 | 269 % | 18 % |
| MINERAL (100 + 30) | 4930 | 7210 | 6070 | 275 % | 5 % |
| MINERAL (150 + 0) | 4930 | 6820 | 5875 | 266 % | 11 % |

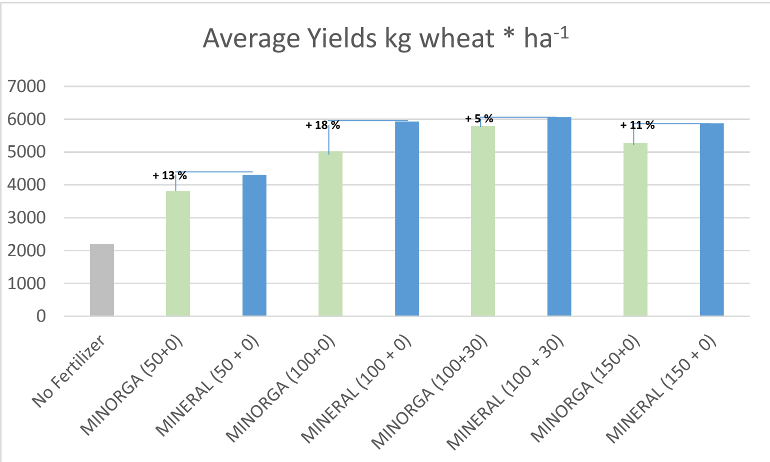



**Figure 8:** **Effects of fertiliser regimes on average yields of spring wheat grown on sandy and clayish soil.**

**Table 3:** **Effects of fertiliser on yields of rye grass (2 harvests)**

| Fertilizer | 1st Hay harvest | 2nd Hay Harvest | Sum 1st - 2nd | Relative Yield | Differense |
|---|---|---|---|---|---|
| (N - kg / ha) | kg / ha | kg / ha | kg / ha | % | $\frac{(MINORGA - MINERAL)}{MINERAL}$ |
| NO FERTILIZER (Controle) | 530 | 140 | 670 | 100 % | |
| MINORGA (50) | 1480 | 180 | 1660 | 248 % | 6 % |
| MINORGA (100) | 2760 | 340 | 3100 | 463 % | 27 % |
| MINORGA (150) | 3370 | 340 | 3710 | 554 % | 5 % |
| MINERAL (50) | 1350 | 210 | 1560 | 233 % | |
| MINERAL (100) | 2210 | 230 | 2440 | 364 % | |
| MINERAL (150) | 3160 | 360 | 3520 | 525 % | |

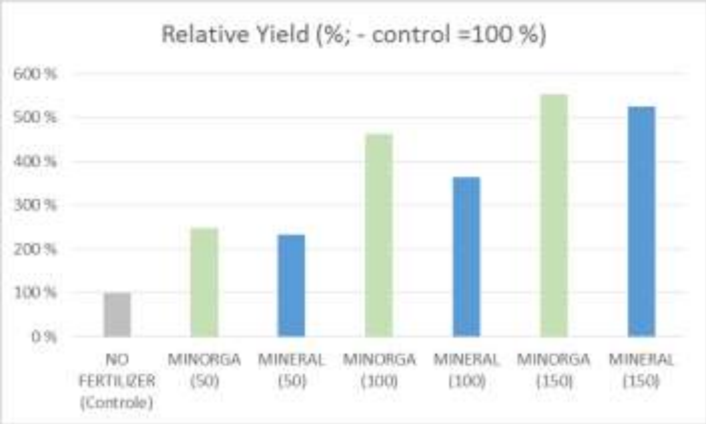



**Figure 9:** **Relative yields from two harvests of rye grass as a function of fertiliser**

In Table 4, MINORGA® 10-1-5 proves a satisfactory effect when used as a maintenance fertiliser applied 4 – 6 weeks after sowing. The marginally higher density with corresponding lower fall number as well as higher protein content indicate positive quality differences as well.

**Table 4:** **Effects of component fertiliser[7] on yields, density, fall number and % CP in spring wheat.**

| | Yield (15 % water) | Fall number | Density | Protein |
|---|---|---|---|---|
| Fertilizer | kg / ha | (sek) | kg / 100 l | % DM |
| 420 kg 22-3-10 / ha + 370 kg MINORGA (37 kg N / ha) | 7150 | 391 | 78,4 | 11,3 |
| 421 kg 22-3-10 / ha + 250 kg $Ca(NO_3)_2$ (39 kg N / ha) | 6960 | 430 | 78 | 11 |
| Differences | 2,7 % | | | 2,7 % |

## Is There a Market for Biosolid Based Fertilisers?

In Norway, corn farmers are the main market for use of quality assured biosolids as fertilisers. Normally farmers receive the solids free of charge, and spread it in connection with sowing in the spring. A minor compensation for spreading might be the case, but in general, the handling of biosolids represents a substantial cost for the producer. So, why should farmers in Norway want to pay for a new mineral organic fertiliser on as much as 50 – 70 % biosolids? In a marketing survey, IVAR asked 400 farmers (5 counties) about their interest in buying a new mineral organic fertiliser as an alternative to conventional mineral products (figure 10).

A majority (68 %) were willing to test and pay a price reflecting its contents of Nitrogen, Phosphorus and Potassium. Knowing that biosolids were the organic source, only 33 % maintained positive. When the 34 % responding negative to a biosolid based MINORGA® were 'offered' lower prices as a stimulus for buying, 76 % turned positive. Only a very small number remained negative to the use of the product (3 %).

[7] Spread 4 – 6 weeks after germination

We believe there are markets for MINORGA® if quality and fertiliser effect is equal to the conventional mineral fertiliser.

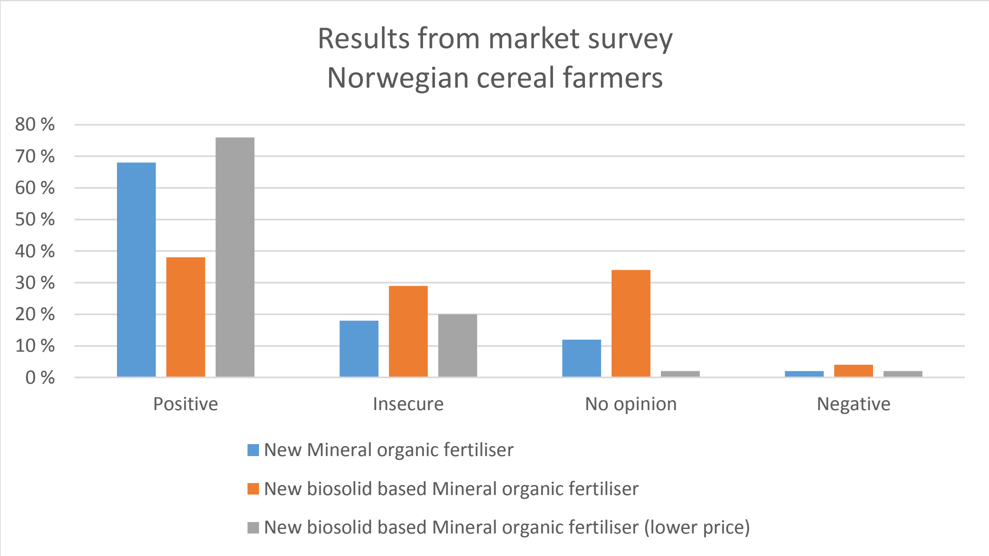



**Figure 10: Results from a market survey introducing MINORGA® as a biosolid based alternative to conventional mineral (compound) fertilisers**

## Conclusion

The use of fertilisers based on biosolids is currently restricted to cereals crops.

Since MINORGA® is a fertilising system building its qualities around the phosphorus content in biosolids, it represents an important 100 % alternative to mineral commodities. We hope that MINORGA® receives a permanent authorisation for use as a standard fertiliser. If so, there will be no requirement to report the application nor to bury the pellets down in the soil matrix after surface spreading as required by the Norwegian legislations.

During the last 5 years, we have documented MINORGA®'s potential as a credible alternative cereal fertiliser. We intend to develop more products, aiming to exploit alternative waste-based nutrient sources as well as optimising qualities for use in different seasons or moderate physical / mechanical characteristics to suit a range of spreading systems.

The quality of biosolids reflects the quality of the different sources as well as the sewers, WWTP and methods of sludge stabilisation and hygienization. We believe that focusing on documentation and quality assurance will lead to predictable and consistent biosolids of high quality suitable as raw material for combined fertilisers.

In a world committed to depleting its soil resources there will be an urgent need for organic alternatives to current mineral fertilisers.

## References

Falk Øgaard, A. 2013. Plant available phosphorus in biosolids – testing analytical methods for demonstration of availabilities of phosphorus. Bioforsk report vol. 8, no. 34, 2013. ISBN 978-82-17-01063-0.

Paulsrud, B. and Nedland, K. T. 1997. Strategy for land application of sewage sludge in Norway. Water Science and Technology. Vol. 36, Issue 11, pages 283 – 290.

Sharma, S. B., Sayyed, R. Z., Trived, M. H. and Gobi, T. A. 2013. Review: Phosphate solubilizing microbes: sustainable approach for managing phosphorus deficiency in agricultural soils. http://www.springerplus.com/content/2/1/587

Tornes, O. and Whipps, A. 2014. Commissioning Norway's first bio-fertiliser factory. 19th. European Biosolids and Organic Resources Conference, Leeds, 15th – 17th, November 2014

Tornes, O., Johnsen, G. and Paulsrud, B. 2008. Validation of the IVAR thermal drying plant in Stavanger, Norway. 13th European Biosolids and Organic Resources Conference, Manchester 10th -13th November, 2008

Tunney, H. and Liebhardt, W. C. 2014. World phosphorus resources and their use. A vision for sustainable phosphorus use in tomorrow's world. http://www.phosphorusplatform.eu/images/download/SCOPE%20Vision%20texts%20received%205-2014.pdf