MILJØDIREKTORATET

REPORT 2 - Consequences of introducing requirements for content of organic pollutants in organic fertilisers based on waste covered by the Norwegian Fertiliser Regulations

COWI

ADDRESS COWI AS
Karvesvingen 2
Postboks 6412 Etterstad
0605 Oslo
Norway
TEL +47 02694
WWW cowi.com

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1 Background

Based on the quality standards for soil suggested in part 1A.

Organic pollutions are present in organic fertiliser based on waste and according to the "Report No. 1 – Limit values for organic pollutants in fertilisers based on organic waste origin" some organic substances are of concern. The authorities look at the consequences of proposing limit values for organic substances in organic fertilisers. Hereunder environment, consequence for the industry, end users and authorities. One consequence may be an increased cost due to other disposal routes and subsequent a result that affect the bio-economy negatively. On the other hand, the effect of introducing limit values may reduce discharges of organic pollutions to the environment and indirectly give acceptance to recycling of organic waste products.

According to the report 1, the organic pollutants that may be of concern regarding concentration in organic fertilisers with respect to soil quality standards are:

- PFAS
- BDE
- DEHP
- Galaxolide/Tonalide
- PCB
- SCCP
- Nonylphenol and ethoxylate

2 Suggested soil quality standards for organic fertilisers

Norway has a yearly production of WWTS of more than 100,000 tonnes TS sludge from municipal wastewater treatment. 95% of this sludge is recycled to both agriculture (around 60%) and application in green areas, road verges and generally as compost (30%). Food waste are not frequently used in agriculture as compost, but more relevant as fertiliser in agriculture when it is digested or co-digested with waste water sludge or manure because of higher nitrogen content in the final product. Sludge from land based fish farms are now up and coming regarding treatment in biogas plants, but has to be combined with less nitrogenous material to make the process work properly.

Treatment of organic waste in order to produce a growing medium requires a low concentration of nutrients in the end product. This means that the treated waste needs to be blended with other materials to lower the nutrient status. Soil quality standards for growing media, the normative value for contaminated soil, example class II may be a suitable approach to control the amount of organic pollutants in the kind of products that are used in parks and landscaping. In products for food production, private gardens or kinder gardens, these soil quality standards are maybe too high.

The suggested quality standards are based on toxicological principles, except for PCB that are based on the principle of getting this substance out of circulation because of its high potential for bioaccumulation and that it is carcinogenic.

The purpose of introducing quality standards for organic fertilisers is to reduce the amount of organic substances introduced into the environment. This purpose has to be combined with a strategical approach in order to enhance and develop an industry in the circular economy. The quality standards should be balanced, as an introduction of quality standards that are too strict may damage the industry. However, if the quality standards are not applicable or too slack, the signal may be undermined regarding controlling emission of environmental hazards.

There are problems with some of the organic substances because of their general appearance in waste water sludge. The majority of the sources are diffuse and it is hard to take the appropriate and correct measures in order to control and stop them locally. The approach may be to reduce targets in order to focus on reduction of these. This approach should be combined with a focus on information on more environmental friendly consumer products to replace the ones currently used, and eventually ban these chemicals in new products. This applies to galaxolide, tonalide, SCCP and PFAS that are currently used legally in consumer products. Some priority substances are used in specific industries, but in this study the concentration levels of these chemicals are not problematic in organic waste.

2.1 Current legislation

The current regulation of application of WWTS is based on the sludge directive and includes limit values for heavy metals. The legislation is dividing the sludge into 4 quality standards depending on the level of heavy metal concentrations, see Table 1 and the allowable amount used.

There is no limit values for organic pollutants, however the waste industry and the end user must show caution and prevent application of fertilisers that may cause damage to health or environment. Furthermore, organic pollutants from the largest WWTPs are screened every 5 years (voluntary scheme for ~15 WWTPs)

Table 1 Quality classes for heavy metals in Norwegian regulation

Quality classes	0	I	II	III For green areas
Maximum application rate	According to nutrient demand	40/ha/10 year	20/ha and 10 year	5 cm and 10 year
	mg/kg DM			
Cadmium (Cd)	0,4	0,8	2	5
Lead (Pb)	40	60	80	200
Mercury (Hg)	0,2	0,6	3	5
Nickle (Ni)	20	30	50	80
Zinc (Zn)	150	400	800	1500
Cobber (Cu)	50	150	650	1000
Chromium (Cr)	50	60	100	150

2.2 Suggestions for quality standards related to organic compounds in organic fertilisers

Based on the first part of this project, quality standards for organic fertilisers are suggested for specific organic pollutants. By assessment of the level of pollutants in the different organic fertilisers, seven organic pollutants are suggested as relevant compounds for regulation. The following compounds are chosen, since they are present in organic waste in concentrations that will cause violation of the normative soil concentrations in soil if applied according to legal procedure for application of organic fertilisers. The abbreviation in brackets are related to type of waste and treated waste that may be problematic. SS = sewage sludge, CH= composted household waste, FW= sorted food fraction of household waste, FO =waste from fish-oil industry

- PFAS Perfluorinated alkylated substances (SS)
- BDE, Brominated flame retardants (SS)
- DEHP, Ftalate (SS)
- Galaxolide/Tonalide, musks (SS)
- PCB, Poly chlorinated biphenyls , (SS, CH, FO, FW)
- SCCP, Short chained chlorinated paraffin(SS)
- NP/E Nonylphenol and ethoxylate (SS, FW)

Other organic compounds has high risk of being present in concentrations close to or higher than the limit where the normative value in soil is exceeded and these are:

- TTB Phenol (SS)
- DBT (SS)

These substances has shown characteristics and concentration, especially in sludge from wwtp, that may reach a concentration that exceed the suggested soil quality standards by NGI if used as fertilizer products in agricultural soil.

Proposal of limit values based on the findings in fertiliser products may result in different usage and disposal routes. An example, if a limit value of 90% percentile are set, this may cause a 10% reduction of recycled waste products as fertilisers on a national level. However, this is not clear. The different waste producers have a large diversity in size, especially in the wastewater sector. The biggest wwtp are located in the eastern part of Norway and have the largest production. If one or two of the larger wwtp have values in sludge above limit values, the consequence will be larger than for smaller plants. On the other side, if a bigger wwtp have too high concentration in sludge, a larger percentage of the total discharges of pollutions to the environment will be under control.

2.2.1 Suggested limit values

Limit values for organic pollutants in organic fertilisers are based on suggested soil quality standards by NGI (2017), which again are based on the most vulnerable source. The limit value in fertiliser and the concentration that are found in organic fertilisers, mainly sludge, are listed in Table 2.

The main driver for the suggested soil quality standards are secondary poisoning with some exceptions, see Table 3. Human health are the main driver for DEHP and BDE, but the quality standard for BDE are based on detection limit. BDE has a very EQP, probably due to very high log P_{ow}, which indicate a very strong surface sorption to particles. BDE has a high uncertainty factor, AF=50, which means there are limited knowledge behind the QS for BDE. The same AF =50 applies for Galaxolide and Tonalide. For DEHP the uncertainty factor are lower, AF=10, which means some reduced knowledge behind the QS. For PFOS the uncertainty factor are very high, AF=100 which means there is a large knowledge gap behind the QS for PFOS. Limit value for PFAS in this report are based on PFOS. There are no uncertainty factors in the calculation of QS for the other substances, hereunder nonylphenol and ethoxylate, PCB and SCCP.

If all the limit values given for substances in Table 2 should be regarded as cut-off values, this may result in a large impact for the wastewater sector. For other organic waste types, especially waste from fish industry, PCB may be a problem. For food waste and composts there are limited recent analysis, but previous results indicate that NP/E and PCB may be a problem. Since there are limited analytical data from other wastes than sludge, the consequences are hard to quantify until more analysis is performed. The following consequence analysis are therefore mostly based on sludge and the municipal wastewater sector.

Table 2 Concentration in fertiliser products related to sludge (SS). Risk factor is the 90% divided by the suggested limit value in fertiliser based on soil quality standard

Substance	**Unite**	**Mean**	**Median 50%, percentile**	**90% percentile**	**Limit value in fertiliser based on suggested soil quality standards**	**Risk factor**
BDE	mg/kg	0.492	0.316	1.070	0.500	2.1
DEHP	mg/kg	38	33	70	50	1.4
Galaxolide	mg/kg	8.1	6.4	17	0.5	34
NP/E Nonylphenol and ethoxylate	mg/kg	0.0045	0.015	0.036	0.004	9.0
PCB	mg/kg	0.018	0.019	0.030	0.004	7.5
PFAS	mg/kg	0.175	0.030	0.222	0.100 *)	2.2
SCCP	mg/kg	1.036	0.530	2.422	0.900	2.7
Tonalide	mg/kg	1.9	1	2	0.6	3.3

*) Based on toxicity for PFOS

Table 3 Quality levels for different endpoints. Bold values are used as suggested quality standards for soil by NGI.

Substance	**Unite**	**QSsoil (EQP)**	**QSsoil (ecotox.)**	**QSsoil (sec. poisoning)**	**QS_{soil} (human health)**	**Detection limit**
BDE*)	mg/kg	0.00000028	0.19	0.66	0.00017	**0.003**
DEHP	mg/kg	2.1	6.5	-	**0.52**	
Galaxolide	mg/kg	0.38	0.155	**0.01**	228.4	
Nonylphenol and ethoxylate	mg/kg	**0.016**	1.15	0.035	18.4	
PCB	mg/kg	0.01	-	**0.0003**	0.014	
PFAS**)	mg/kg	**0.011**	0.13	-	150	
SCCP	mg/kg	0.8	2.98	**0.091**	9997	
Tonalide	mg/kg	0.5	0.16	**0.011**	1636.8	

*) Suggested normative value for soil are based on quantification limit, however human health is the main driver.

**) PFAS is based on data for PFOS

3 Consequences for waste industry and producers of organic fertilisers

3.1 Requirements for sampling and analytical methods

The current requirements for sampling is based on a risk assessment approach, where the fertilisers are assumed to contain the highest level of pollutants should be sampled with the highest frequency (1-12 samples per year). The relevant authorities are determining the sampling programme. Currently, the analysis include DM, VS, N, P, heavy metals and other nutrients if relevant.

The samples are generally taken after treatment, when the fertiliser is ready for end use, meaning that it can be a mix of different waste streams and after treatment (e.g. composting or anaerobic digestion). To ensure the ability of tracing problematic waste inputs, many treatment plants are taking samples of each input batch, but only analysing the samples if necessary to trace pollutants defined in the fertiliser.

In the following sections the current and suggested future procedures of sampling for each waste stream is briefly described.

3.1.1 Waste water treatment plants

In the present sampling program for WWTPs typical 6-12 yearly samples should be analysed (each sample collected over 1 months) for different parameters (e.g. DM, VS etc.) and heavy metals. The authorities requires an internal control system and a sampling plan for each WWTP which again are based on a risk evaluation or screening on the expected level of pollutants, the size of the plant etc. The industry are taking the actual samples according to this plan and there are no control samples made by the authority.

WWTPs larger than 50,000 PE document levels of organic pollutants in the inlet and outlet water. Sampling frequency for this is 3 times a year.

For the WWTPs it is suggested that the existing sampling program will be extended with requirement for analysis of the chosen organic compounds. Assuming an average of 9 samples per year and approximately 50 larger WWTPs in Norway, this will result in 450 samples per year.

It could be considered to include an approach linked to the size of the WWTP as is the case for sampling of organic pollutants in the water from WWTPs. Depending on the desired level of details the limit could be set to 50,000 PE, 10,000 PE, or even lower (all plants).

3.1.2 Composting and anaerobic digestion of food waste

For composting and anaerobic digestions plants treating food waste there is the same requirement for internal control system and risk evaluation however there has not been conducted systematic screening of organic pollutants in food waste treatment pants. The plants are deciding the sampling frequency and the common samplings scheme for heavy metals and nutrients are one or two sample per year representing the whole volume treated.

For composting and anaerobic digestion plants it is suggested that all plants should take samples at least once a year (organic compounds) and at least one sample per 10,000 tons food waste (ww input). As Norwegian composting plants treating food waste is typically treating in the magnitude of 15,000 tonnes food waste/year (ww), this will result in 1-2 samples per year for an average composting plant. For large biogas plants (typically treating <60,000 tonnes food waste/year (ww)), the corresponding number of samples will be 6 samples per year or one sample every second month. Since the total amount of food waste for treatment is estimated to 240,000 tonnes/year (ww), the total number of samples will be in the magnitude of 24 samples per year.

3.1.3 Sludge from fish farms

Sludge from fish farms should currently be sampled at least once a year. The number of fish farms is assumed to be approximately 200-250 and rapidly increasing. The amount of sludge is estimated to 551,000 tons (ww)/year. The average fish farm therefore produce around 2,500 tonnes sludge (ww)/year (however big differences in the size of the plants).

For sludge from fish farms it is suggested to require sampling at least once a year and possibly one sample per 3,000 tonnes of sludge (ww). These requirements will result in approximately 200 samples per year. Today no samples are taken.

3.1.4 Manure

Manure should only be analysed if applied outside the farm of origin. Since most manure is applied on own farms land, current sampling of manure is limited.

For manure it is suggested that all producers of manure placed on the marked should take samples at least once a year documenting the level of heavy metals and organic compounds: In this report we have suggested that around 50 farms supply the marked with manure. Today no samples or analyses are performed.

3.1.5 Ash

Mono incineration plants producing ash fit to use at fertiliser should take samples at least once a year documenting the level of heavy metals and relevant organic compounds.

3.1.6 Costs of sampling

The consequents if four organic compounds are included in the regulation are calculated for the following substances:

- PFAS
- BDE
- DEHP
- Galaxolide/Tonalide
- PCB
- SCCP
- Nonylphenol and ethoxylate

The costs related to the addition of organic compounds to the existing sampling programme are shown in Table 4. The prices for analysis are based on input from Norwegian laboratories (fall 2018). The prices do not include any discount or package prices, which may result in the price being lower

Table 4 Costs of analysis of the organic compounds (based on prices from Norwegian laboratories, spring 2018.

Organic compound	NOK/analysis
PFAS (12 different)	4590
BDE	7300
DEHP	1680
Galaxolide and Tonalide	3550
PCB	1580
SCCP	2160
Nonylphenol and ethoxylate	3250
Total (package)	**24110**

The table below shows the estimated number of yearly samples for each waste fraction and the corresponding costs.

Table 5 Estimated costs of analysis of the suggested organic compounds (NOK/yr for Norway)

Organic compound	Requirement (no of samples/yr)	No of samples	Costs (NOK/yr)
WWTP	6-12/yr	450	10,849,500
Composting and AD of food waste	>1/yr >1/ 10,000 t food waste (ww)	24	578,640
Fish farms	>1/yr >1/ 3,000 t sludge (ww)	200	4,822,000
Manure	>1/yr	50	1,205,500
Total			**17.5 mio.**

3.2 Altered waste treatment and recycling

The circular economy includes products, infrastructure, equipment and services, and applies to every industry sector. It includes 'technical' resources (metals, minerals, fossil resources) and 'biological' resources (food, fibres, timber, fertiliser etc). It includes discussion of the role of money and finance as part of the wider debate. Organic waste suitable for treatment and recycling as a fertiliser product is a perfect example of circular economy. Circular economy include focuses on the recycling critical raw material and turning one industry's by-product into another industry's raw material. Organic waste may be a link between urban and rural areas.

The value of fertilisers based on organic waste for farmer and users of soil products for landscaping and gardening are different. The value for farmers are primarily nutrients, especially nitrogen but also secondary and micronutrients. Phosphorus in organic fertilisers is a resource too, however applied in to high doses will give environmental impacts as eutrophication in nearby water bodies. The second value is to enhance the soil condition effect due to content of organic material. In areas with extensive grain production, the soil organic matter has shown depletion. However, the amount of waste based fertiliser product that are allowed, do not improve this significantly. Some sludge are added lime as a part of the sludge treatment technology. This is a benefit for farmers directly and can reduces direct costs for farmers.

The benefits regarding use of organic fertiliser for use as landscaping and gardening is based on the quality of the product. However, this has to be compared with the alternative, which normally are based on peat or local soil. By replacing peat with products based on organic waste the CO_2 emission due to drenching and decomposing of stored CO_2 in marshlands will be reduced.

The demand of high product quality is higher for this group of users than for the farmers and demands higher production costs for the waste industry. However, there is a potential to get a higher price covering the costs rather than using the fertiliser product in the agriculture sector.

Implementation of limit values for organic contaminants may reduce the access and potential to store organic carbon in soil. However, nutrients like nitrogen and phosphorus can be recovered by using different recovery technology. The cost of these recovery techniques has proven to be too expensive compared with the marked prise of these nutrients, especially for the typical size of a Norwegian wwtp (Blytt et al 2017).

If limit values of organic contaminants are implemented this may stop the recycling of organic waste for selected wwtp or some periods of production. Whether this occur will depend on the substance that stops recycling and if there are applicable measures to stop it to enter the waste water stream.

If the limit value are based on the 90% percentile or the suggested limit values based on soil quality standard this will change the consequences dramatically. With a limit value based on the 90% percentile there is a possibility that 10,000 tons DM of sewage sludge has to be disposed of as waste to incineration plants to ash or by pyrolysis to bio-char followed by carbon storage. If the suggested limit values are implemented almost all sewage sludge has to be disposed. Secondary treatment as composting after digestion is not considered as an alternative.

The suggested organic pollutants are primarily found in WWTS and inclusion of the compounds in the regulation will therefore primarily affect the recycling of this waste stream. Recycling of the other types of organic fertilisers included in this project will probably not be significantly affected by the changes in the regulation. However, the data set are restricted so there are some uncertainties.

According to today's practice of sludge disposal on agricultural soil, maximum load are 2 tons DM/ha due to concentration of heavy metals. The suggested limit values are based on 4 tons DM/ha. New regulations demand a lower load of phosphorus, especially if the phosphorus are plant available. This means that the "risk factor" described in Table 2 will be lower and closer to one if the normal use of 2 tons DM /ha are used except for PCB, Nonylphenol and ethoxylate and Galaxolide. The concentration of PCB in sludge are uncertain due to limited analysis the last years and has declined substantially the last 20 years. The same decline has been shown for nonylphenol and ethoxylate. Galaxolide will still be present in wastewater and sludge in high concentration because it is not yet prohibited.

3.2.1 Distribution of fertilisers from WWTS

Based on the measured concentrations of the selected organic compounds the suggested values for fertilisers based on normative values in soil may result in a large fraction of the WWTS not being suitable for agricultural application, because the mean value are above the suggested limit value. The figures below illustrates the results of the different studies (assuming normal distribution) compared to a cut off value based on 90% percentile for all samples taken the last years for any compound, the last 10% cannot be disposed as fertiliser. How this distribution apply for specific wwtp is not known.

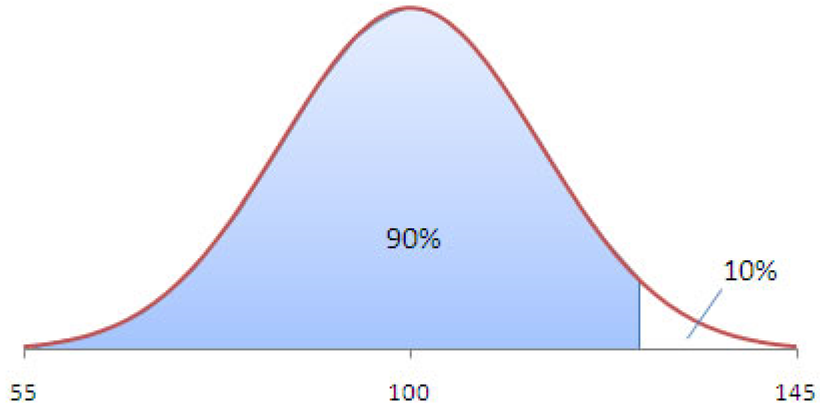


Figure 1 Example of a distribution of analyses result of fertilisers based on organic waste.

It is possible that the concentration of some of the organic compounds could be reduced by composting of the digested sludge. However, composting may increase the level of heavy metals in the sludge due to dry matter reduction during the process but this depends on the amount and type for structure material. Composting may be relevant as post-treatment technology for sludge with relatively low level of heavy metals.

3.2.2 Cut-off values

The suggested limit values for PFAS, BDE, DEHP, Galaxolide/Tonalide, PCB, SCCP and Nonylphenol and ethoxylate in fertiliser based on suggested normative values from NGI 2016 in soil, are lower than the 90% percentile found in sludge from wwtp. With the maximum fertiliser load of 4 tons DM/ha the concentratinos will exceed the suggested limits and pose a risk to the environment. I practice the normally applied load is closer to 2 tons DM/ha most of the investigated substances will have a risk factor closer to 1 (Table 2). The exceptions are PCB, Galaxolide and Nonylphenol/ Ethoxylatem where the concentrations are too high even with the lower fertiliser load. The major concern when introducing a cut-off limit is Galaxolide where the average concentration in sludge exceed the normative values, and if a cut-off limit is introduced for Galaxolide then most of the sludge will need to be disposed of in alternative ways. This will result in major consequences for the industry because 100,000 tons of DM sludge has to be disposed of as waste.

3.2.3 Alternative treatment

If the WWTS cannot be applied digested sludge to agricultural soil it will most probably need to be incinerated. Use of sludge for landscaping and road slide requires low nutrient concentration and structure and composted sludge are the better product. Landfilling of organic material (including sludge) is generally not permitted and can only be allowed in special situations. However, it could be relevant for very small WWTPs in very remote areas, where the sludge would have to be transported very long distances to final waste treatment.

WWTS can possibly be incinerated at waste incineration plants mixed with other waste streams. Norwegian waste incineration plants generally handle maximum 15% sludge (weight). However, the spare capacity of the waste incineration plants in Norway is limited, the calorific value of WWTS is low and the structure of the WWTS limits the fraction of the material that the plants can handle. The waste incineration plants in Norway can therefore only handle a small amount of sludge.

If a large share of WWTS must be transferred from agricultural application to incineration, it will be necessary to construct dedicated incineration plants for WWTS. Until now, no dedicated incineration plants for mono incineration of sludge has been constructed in Norway, primarily due to high costs, long transport distances and relatively small amounts of sludge to justify this investment. The investment costs of such dedicated plants is in the area of 100-400 MNOK depending on the required size of the plant. Due to large transport distances, the required number of incineration plants for WWTS in Norway will be 10-20.

Up-stream works to reduce contaminants are the better approach to reduce concentration of contaminants of sludge. This approach is best suited if the source can be identified and stopped. If the contaminates has origin from consumer products up-stream work are not as efficient. These kind of substances has to be limited by other regulations and generally better access and use of environmental friendly products. One approach is to have better control of septic deliveries to ensure that no hazardous waste are mixed into the sewage. Another approach is to be sure the industry have control of the discharges and a better follow-up on discharge permits.

Some contaminants may leach form surfaces and sediments of old sewer systems connected to industry and landfills. A good clean-up of old pipes may reduce the source of contaminates in waste water and sludge, however the spills from the clean-up has to be treated separately to ensure it is not released into the environment.

In general, the industry has permits to release their wastewater to municipal waste water system if this controlled and they show low consequences for the environment. This evaluation are in generally evaluated for the discharges to the waterbodies. This is again justified by cost of the alternatives. Implementing cut-off /limit values for contaminants in sludge may change the cost-evaluation behind the discharge permit for the industry.

Specific treatment methods for contaminated sludge has been evaluated (Paulsrud, 1992) and in general, contaminants can be reduced by four methods: Biological reduction, Chemical fixation, Thermal treatment and Radiation. Even though this is an old study, the results shows that only thermal treatment gave significantly reduction of organic contaminants, which will treat the sludge to a product that no longer can be considered as a fertiliser. Aerobic treatment may reduce nonylphenol. Chemical fixation has shown reduction of PCB and immobilisation of heavy metals.

3.2.4 Treatment costs

The costs of incineration of sludge in waste incineration plants has been estimated to approximately 1,000 NOK/ton ww (Paulsrud and Blytt, 2011).

If sludge incineration at the waste incineration plants should be performed as the primary treatment of wwtp some investments will be required at the waste incineration plants. E.g. none of the plants now have facilities for temporary storage of the sludge and smell issues must be handled at the plants. Furthermore, waste incineration plants in Norway generally do not have the necessary permission to receive WWTS and only have the capacity to receive limited amounts of WWTS.

Table 6 Estimated costs for treatment of WWTS (Paulsrud and Blytt, 2011). The costs for Norway is estimated based on the assumption that 10% of the WWTS must be incinerated instead of applied to agricultural land due to the organic compounds added to the regulation.

	Agricultural application of sludge	Incineration at waste incineration plants	Incineration at mono incineration plants
Estimated costs per ton	420 NOK/t ww	1,000 NOK/t ww	1,000 NOK/t
Estimated costs per year (Norway)	21 MNOK	50 MNOK	5O MNOK

The increased cost of incineration will most likely affect the different WWTPs differently. It can be assumed that for some of the WWTPs more than 10% of the sludge will have a concentration of organic pollutants higher than the new limits. For a smaller plant where a large amount of the sludge is unfit for use as organic fertiliser, the increased cost of incineration can be difficult to handle. With the estimated costs in Table 6, incineration leads to an increased treatment expense of almost 140% per ton.

Note that the estimated yearly costs in the table above only covers the assumed 10% of the sludge deemed unfit for use as fertiliser. By incinerating these 10% the increased cost for the industry will amount to about 29MNOK.

It can be assumed that wwtps will affected differently by the implementation of the limit values. Some plants where a large amount of sludge might contain concentrations outside the acceptable limit values can experience that operational costs increase significantly, and other plants might not be affected at all beyond the possible increased sampling frequency.

3.3 Transportation

Waste incineration plants in Norway are situated in and around the larger cities like Oslo, Bergen, Trondheim, Ålesund, Fredrikstad, Kristiansand and Tromsø. This means that transport distances for sludge for incineration in the southern Norway is reasonable, while the distances for sludge produced at WWTPs in the northern part of the country will be very long. However, since the amount of sludge produced is linked to the population, the largest amount of sludge will be produced in the southern part of the country.

The transportation costs are closely linked to the transport distance. The costs of transportation of sludge is assumed to be 500-1000 kr/ton for a distance of up to 300 km.

While the volumes of sludge to be transported will remain unchanged (other than increased amounts due to increased population), the proper unloading location may change depending on the concentration of pollutants in the WWTS. This may lead to longer transport distances and increased transport costs for the WWTPs handling the sludge. Increased transportation costs may be indifferent for plants located close to a suitable combustion plant, but for those plants where the distance increases significantly the effect can be substantial.

3.4 Administrative costs - reporting

In the current administrative system, all plants producing organic fertilisers (e.g. WWTPs, composting plants, biogas plants and fish farms) must be register into an electronic database. The database contains the plant responsible for treatment and marketing/disposal of the fertiliser (and not e.g. fish farms delivering sludge to biogas treatment or WWTPs delivering sludge to other treatment plants).

The authorities use the database as a basis for supervision. The frequency of supervision is not directly stated in the legislation, but is decided by the local authority (Food safety Authorities with approximately 50 local offices).

Each supervision visit has a duration of approximately half a day. The number of supervision visits will probably not be changed by incorporation of the organic compounds in the legislation.

The administrative costs of reporting for the plants is mainly depending on the sampling programme, thus the number of samples per year/treated volume.

The extension of the sampling programme will cause only limited extra administrative costs for the WWTPs. Four more analysis should be ordered for each sampling process (6-12 times per year per plant) and the results should be reported to relevant authority. However, since this can be done in the same working process, the extra time consumption is assumed limited.

For the composting and anaerobic digestion plants treating food waste and fish farms the average number of samples will not change considerably. However, the required number of samples will increase for larger plants due to the additional requirement of sampling per volume (xx ton of food waste treated or xx ton of sludge produced from fish farming respectively).

For farmers the administrative costs will increase since most farmers do not sample manure today, since the manure is applied to own farmland. The requirement of one sample per year will require extra time for sampling, ordering of analysis and reporting to relevant authority one time per year.

4 Consequences for the end users

4.1 Supply of organic material and nutrients

WWTS is often used as fertiliser in agriculture due to the content of nutrients and organic material. In Norway WWTS is primarily applied to clayey soil where depletion of carbon is a general problem due to continuous grain production. By intensive culturing of the agricultural land, the carbon content can fall drastically, if not maintained by application of organic fertilisers, causing a lower yield for the specific field. Studies have shown that a carbon content below 2% is critical for agricultural culturing, with increasing yields up to 6%.

The main reasoning behind application of WWTS in Norway is therefore maintenance of the carbon content in the soil. However, the value of the sludge is very depending on the state of the specific soil with respect to soil type, culturing pattern, current carbon content, access to other carbon sources etc. If the carbon content is reasonable and there is access to other organic fertiliser, removal of sludge may not affect the agricultural yield of the field. However, if the carbon content is already low and there is no obvious access to other carbon sources, the removal of sludge may be critical.

4.2 Procurement of new equipment

Organic fertilisers may be applied directly as liquid fertiliser or in dried form as pellets. Norway has one producer of pellets based in WWTS mixed with other compounds. This product is on the market competing other fertilisers, including chemical fertilisers.

The equipment for spreading of the fertilisers is different for liquid fertilisers (tubes) and pellets ("normal" agricultural equipment). The need for new equipment is thus depending on the currently applied fertiliser at the farms.

Production of liquid fertilisers, especial digestate based on food waste, manure ect. require storage facility between the periods for spreading fertiliser. A general rule is to have storage for at least one year of production. Storage facility for liquid fertiliser will include additional costs.

If there will be requirements for controlled storage of dewatered organic fertiliser (25-30 %) it may give additional cost.

4.3 Fertilisation methods

The suggested limit value for organic pollutants in the organic fertilisers is based on assumptions of yearly application. This is in contrast to the current application, where a larger amount of fertiliser is applied every e.g. 5 or 10 year. When applying the fertiliser every year, the concentration of organic pollutants can be higher than by application of a larger amount every 5 or 10 years.

The yearly application means that the organic fertilisers must be distributed to more farmers or fields, thus requiring more logistics, local storage etc.

5 Consequences for the authorities

5.1 Surveillance of organic fertilisers

5.1.1 Experiences from Denmark

Overview

Regulation

Agricultural application of organic fertilisers in Denmark is regulated by the Slambekendtgørelsen (Order No. 1650 of 13th of December 2006 regarding agricultural application of waste). This Order is administered by the Danish Environmental Protection Agency and is currently under revision (new version expected ultimo 2018).

The Danish regulation (Slambekendtgørelsen) covers treated sludge from wastewater treatment plants, organic household waste and a range of other specified organic waste products. Only waste products listed in the regulations Appendix 1 can be applied according to this regulation. Agricultural application of other waste products require specific permission (§19 in the Miljøbeskyttelseslov) from the municipality, where the waste product should be applied (including specific assessment of the waste product and the area for application).

Slambekendtgørelsen includes limit values for heavy metals and organic compounds as shown in Table 7. Furthermore, Slambekendtgørelsen regulates the maximum yearly load of nutrients (N and P) applied per hectar and defines hygienic restrictions for the application of the specific waste products.

Table 7 Limit values in the Danish Slambekendgørelsen.

	mg/kg DM
LAS	1,300
PAH	3
DEHP	50
NPE	10
PCB (vejledende)	0.4

When the treatment includes mixing of different waste products (e.g. more inputs to one biogasplant), each waste product must comply with the limit values before mixing with other sources to prevent dilution as a disposal strategy for polluted waste streams.

General sampling frequencies for the different waste streams is shown in Table 8.

Table 8 General sampling frequencies for different waste streams according to the Slambekendtgørelsen. The supervision authorities (municipality) can decide to increase or decrease the frequency for "other waste streams".

	Heavy metals	Organic compounds
WWTS	1-18 samples/yr*	>1 sample/yr
Organic household waste	>1 sample/2,000 m³	>1 sample/yr
Other waste streams (listed in Appendix 1)	>3 sample/yr	>1 sample/yr

*Depending on the volume of the waste stream and the expected level of heavy metals.

Revision of the regulation

The Danish EPA is currently in a revision process of the Order and is (among other things) evaluating the organic compounds included in the current legislation. In this process, the Danish EPA has investigated the regulation according to this in the neighbouring countries. This investigation showed that Sweden and Germany have chosen different compounds than Denmark. For the single compound appearing in all regulations (PBC) the limit, value is in the same magnitude (0.2-0.4 mg/kg DM).

Table 9 Limit values for organic compounds in WWTS in Denmark, Sweden and Germany (ref: Nabotjek rapport fra MST). Values in brackets are suggested future limit values.

	Denmark	**Sweden**	**Germany**
LAS	1300		
Sum PAH	3	3 (indicative)	
DEHP	50	-	
NPE	10		
PCB	0.4 (indicative)	0.4 (indicative)	0.2
PCDD/PCDF			100
Dioxine		(20)	(30)
AOX			500
Silver		(5)	
PFOS		(0.07)	(0.1)
Klorparaffiner		(4)	
BDE-200		(0.7)	

In this process, Denmark is considering whether there should be changes in the list of organic compounds in the Danish regulation. The original choice of compounds and limit values are based on screening of Danish WWTS to identify relevant compounds (heavy metals and organic compounds). The chosen compounds and limit values are not directly related to soil quality criteria.

Some of the chosen compounds may be less relevant today. One example is LAS, which have to some extend been phased out of products (primarily washing powder). In relation with the revision of the order, the Danish EPA has performed a screening of PFOS and musk compounds in WWTS for agricultural application. PFOS was found to be near the recommended concentration (EU) and it is therefore considered to include PFOS in the regulation. At the same time, the Danish EPA is considering to permanently include PCB at the list (not just as indicative value) and to revise some of the limit values for heavy metals (MST interview, November 2017).

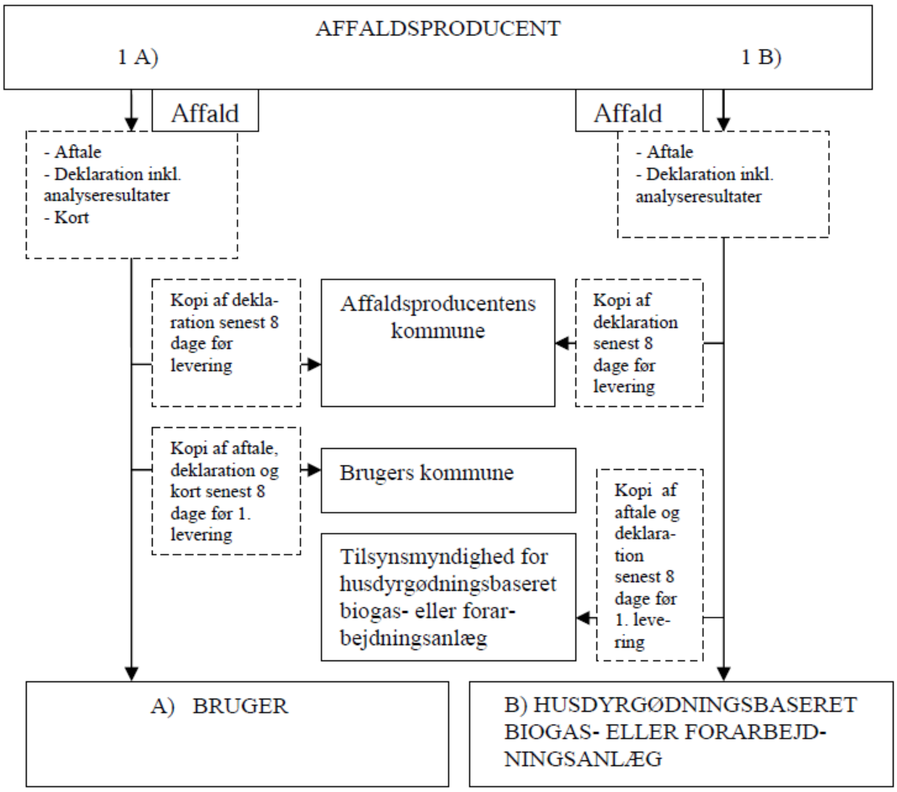
The new version of the Order is expected to be ready in the Fall 2018 (MST interview, November 2017).

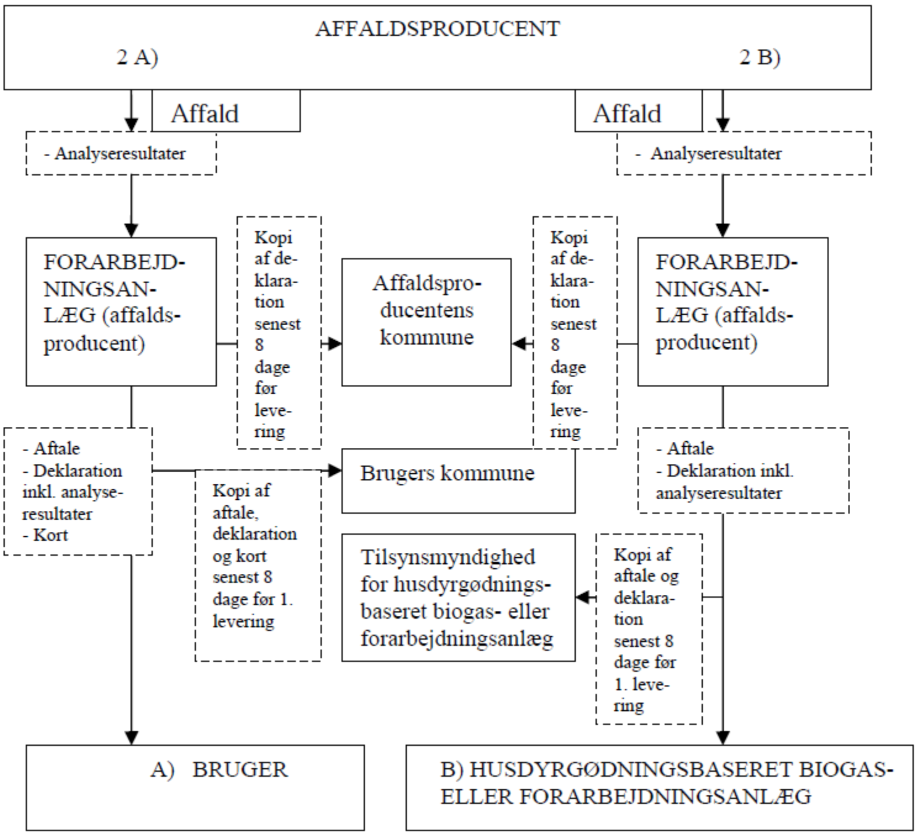
Treatment of WWTS

Currently, approximately 70% of the Danish WWTS is biologically treated and applied to agricultural land or similar. The remaining 30% is incinerated in dedicated waste incinerators for WWTS (Affaldsstatistik 2015). Incineration is mostly used in the larger cities, where the sludge is often too polluted to comply with the regulation of (limit values for heavy metals and organic compounds).

Responsibilities

The administrative process related to treatment and agricultural application of organic fertilisers in Denmark is illustrated in the figures below (fra Vejledning til Slambekendtgørelsen).





The responsibilities of the different stakeholders according to the Danish Slambekendtgørelsen are listed below:

<u>The waste producer</u> (the WWTP, the municipality or the company):

- Analysis of the waste product according to the requirements in the Slambekendtgørelsen. The analysis should be performed by accredited laboratories.
- Preparation and distribution of the declaration of the waste product.
- Registering of the amount of waste for agricultural application the previous year to the municipality at the latest the 1st of March.

<u>The treatment plant</u> (e.g. pre-treatment plant for organic household waste)

- See waste producer

<u>The municipality of the waste producer</u>

- Supervision of the paper work documenting the waste product. This includes the written agreement between the waste producer and the treatment plant and the declaration of the waste product, containing information on dry matter content, VS, nutrients, heavy metals, organic compounds etc.

- Supervision of the storage of the waste products at the waste producers.

- Register the amount of organic waste for agricultural application the previous year to the Danish EPA at the latest 1st of July. These amounts covers from amounts from waste producers situated in the municipality as well as WWTS and organic household waste from the municipality.

The municipality of the end user (where the organic waste is spread)

- Supervision of the paperwork between the waste producer and the treatment plant/end user (including declaration).

- Supervision of the storage, handling and spreading of the waste product, including the restrictions regarding maximum loads of nutrient on agricultural land.

- In case of organic waste products not included in the Appendix 1 in the Slambekendtgørelsen: Preparation of permission for agricultural application of the specific waste product according to §19 in the environmental protection law (Miljøbeskyttelsesloven).

The Danish EPA:

- Administering the Order, e.g. approving exemptions.

Landbrugsstyrelsen:

- The overall supervision obligation regarding WWTS (anaerobic digestion plants for WWTS) and organic household waste (pre-treatment plants) for agricultural application.

- Supervision of the relation between domestic animals and nutrients for each farm (harmonikravet).

Work load, DK

The Danish EPA assess the work load for the different stakeholders according to supervision and administration related to the Slambekendtgørelsen to be in the order of 0.5 man year for the EPA and less for the Plantedirektoratet (0.25 man year, whereof the main part is performed by a student) (MST interview, November 2017).

The work load for the municipalities is largely depending on the number of waste producers and waste users in each municipality. The EPA assesses, that larger Danish municipalities will have a work load of 0.5-1 man year related to supervision and administration related to the Slambekendtgørelsen (MST interview, November 2017).

5.1.2 Experiences from Sweden

Sweden produces about 200,000 tons WWTS per year where 25% is used for agricultural applications, 29% to soil production and 24% to securing landfills.

To offer guidelines and to motivate producers to lower concentrations of pollutants in the sludge, the Swedish waste management association has created a quality symbol that producers can label their product with if they are within the limits. The certification rules for digestate from biodegradable waste (SPCR120) focuses on heavy metals and offers a guideline for organic substances. SPCR152-'Certification rules for compost from biowaste' contains the quality requirements for certified re-use of compost from biodegradable waste. REVAQ – the Swedish certification system for sludge application to land can be used as a complemental guideline to these. REVAQ is a voluntary certification system used to regulate the application of wastewater sludge on agricultural soil in Sweden. The system aims to ensure that nutrients from the wastewater can be sustainably reintroduced to the land in accordance to the Swedish environmental regulations and goals. The SPCR120 has a positive list on proven additives for dewatering and chemical precipitation/flocculation in wwtp. There are no limit values regarding content of organic contaminants.

Compliance with these specific certification rules are voluntary, but in practice the producers need this quality stamp in order to be able to dispose of the product in the market.

Treatment plants that want to achieve the quality symbol awarded by the Swedish authorities need to establish acceptable programs concerning continuous quality control of the product. The control is performed mainly by the manufacturer, but controls and procedures are controlled by the authorities through audits.

In order for a treatment facility to be certified and achieve the mentioned quality labels the products treated must be considered 'clean'. Note that sludge from waste water treatment plants is not considered 'clean' waste.

Table 10: Examples of clean waste that qualify plants to get the quality certification.

Source	**Example**
Parks, gardens and other green areas	Leafs, grass, fruit, flowers, bushes etc. Manure from zoo
Greenhouses, industrial gardens etc.	Flowers, plants, etc.
Households, restaurants etc.	Fruit and vegetables, coffee, and other food waste
Food industry (inc. slaughterhouses), grocery stores etc.	Fruit, vegetables, dairy products, paper, meat, bread, bone, fish, candy etc.

Agriculture	Manure from farm animals, hay, crops, harvest residue, etc.
Biodiesel production	Glycerol from FAME production,
Fodder industry	Residue from fodder production
Other, originating in animal feed or food chain	

Sampling intervals

SPCR120 offers guidelines for testing intervals where it is suggested to take out and analyze one sample from the sludge every week.

Proposed new arrangement

It is proposed to introduce limit values for heavy metals in wastewater sludge that gets continuously tighter. This means that no matter how low the concentration of heavy metals is, the plants must search for methods to improve even more. This has yet to be implemented.

6 Recommendations

The suggested limit values for PFAS, BDE, DEHP, Galaxolide/Tonalide, PCB, SCCP and Nonylphenol and ethoxylate in fertiliser based on suggested normative values from NGI 2016 in soil, are lower than the 90% percentile found in sludge from wwtp. This means that there is a risk for the environment if used in maximum load of 4 tons DM /ha. The concentration in food waste, fish waste and manure his has not been shown to be of any risk regarding increasing organic contaminants when used in soil. Sludge are normally spread using 2 tons DM/ha, this means that especially PCB, Galaxolide and Nonylphenol/ Ethoxylate may exceed the suggested normative values in soil when used. The Galaxolide is the major concern because the average concentration in sludge also exceed the normative values.

In an implementation of a cut off value for Galaxolide are implemented in a regulation this will give major consequences for the industry because 100,000 tons of DM sludge has to be disposed as waste.

If a 90% percentile of concentration are implemented as a cut off value for fertiliser based on waste (based on the concentration in sludge) this could lead to an increased yearly analytical cost for the waste sector in general of 17.5 MNOK and 29 MNOK if sludge from wwtp has to be incinerated.

As a first step, the regulation could require analysis of organic pollutants that are of concern so that the industry may take measures to stop sources that enters the waste stream. Guideline values for necessary measures may be implemented rather than strict cut off values. This will lead to improved quality of fertiliser regarding organic pollution and enhance circular economy.

7 References

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