

An Evaluation of the Efficiency of Different Hygienisation Methods

M Zrubková¹

¹ Severomoravské vodovody a kanalizace Ostrava a.s., The Czech Republic

E-mail: marcela.zrubkova@smvak.cz

Abstract. The aim of this study is to evaluate the efficiency of hygienisation by pasteurisation, temperature-phased anaerobic digestion and sludge liming. A summary of the legislation concerning sludge treatment, disposal and recycling is included. The hygienisation methods are compared not only in terms of hygienisation efficiency but a comparison of other criteria is also included.

1. Legislation requirements concerning sludge treatment in The Czech Republic

The new Decree of the Ministry of Environment of the Czech Republic of 19 December 2016 No. 437/2016 Coll., on the conditions for using treated sludge on agricultural land, came into force in January 2017. This new Decree sets stricter microbiological criteria for the use of sludge in agriculture and new requirements such as a hygienisation efficiency assessment. In accordance with the new Decree, the wastewater treatment plant (WWTP) operator is obliged to evaluate the efficiency of the sludge treatment technology (hygienisation) in WWTPs put into operation prior to the effective date of this Decree by 31 December 2019 with the exception of those technologies that have produced sludge “category I” (limits listed in table 1) in the 24 months prior to the date of this Decree coming into force. Sludge treatment technologies in WWTPs put into operation prior to the effective date of this Decree which produce treated sludge and meet the limit values of microorganism indicators for “category II” (limits listed in table 1) will be considered as validated until 31 December 2019. After this date it will not be possible to use sludge classified as “category II” on agriculture land.

Table 1. Microbiological criteria for treated sludge for application to agricultural land during a transitional period (Annex No. 7 to Decree No. 437/2016 Coll.).

Microorganism indicator	Unit	Number of samples tested at each output check	Limit value (result/cfu ^a)	
			Category I.	Category II.
Salmonella spp.	result in 1 g of dry matter	5	negative	
Thermotolerant coliform bacteria	cfu ^a in 1 g of dry matter	5	< 10 ³	10 ³ - 10 ⁶
Enterococci	cfu ^a in 1 g of dry matter	5	< 10 ³	10 ³ - 10 ⁶

^acolony forming unit



Verification of technology efficiency has to be performed by taking 10 input samples and 10 output samples within 30 days, with a minimum of 48 hours between sampling. The difference between sludge contamination before and after treatment must be at least 10^5 cfu per gram of sludge for the microorganism *Escherichia coli* or Enterococci and the output parameters must be in accordance with the set limit values for microorganism indicators listed in table no. 2. Verification has to be performed after each technology change which will influence sludge treatment efficiency.

Table 2. Microbiological criteria for treated sludge for application on agricultural land (Annex No. 4 to Decree No. 437/2016 Coll.).

Microorganism Indicator	Unit	Number of samples tested at each output check	Limit value (result/cfu ^a)
Salmonella spp.	result in 50g	5	negative
<i>Escherichia coli</i> or Enterococci	cfu ^a in 1 g	5	4 < 10 ³ 1 < 5.10 ³

^acolony forming unit

According to the requirements of the new Decree the operator must also take five samples from the beginning of 2017 as part of the control of the output from the technology, as opposed to one sample under the previous Decree.

In connection with the requirements of the new Decree, it is necessary to mention The Sewage Sludge Directive 86/278/EEC which encourages the use of sewage sludge in agriculture and regulates its use. The Directive 86/278/EEC sets limit values for seven heavy metals compared to The Czech Republic that implemented stricter limit values for heavy metals and set requirements for other contaminants (AOX, PCB and PAH). The limit values for microbiological parameters are not included in Directive 86/278/EEC. However, the existing directive can be expected to be tightened in the future, in particular regarding standards for heavy metals, some organic contaminants and pathogens, and requirements for the application, sampling and monitoring of sludge [1].

2. Sludge treatment and management in SmVaK Ostrava Ltd. (North Moravian water and sewerage company)

Waste water treatment plants operated by SmVaK Ostrava Ltd. produce approximately 34 000 tonnes of sludge per year with an average dry matter of about 25%. The sludge is dewatered at stationary operating machines (centrifuges, belt presses, chamber presses) or mobile centrifuges for WWTPs with less sludge production. The hygienisation process is integrated into existing technology in different ways. In accordance with legislative requirements, the content of nutrients, some organic pollutants, heavy metals and microbiological contamination is analyzed in sewage sludge.

The whole sewage sludge production is currently handed over to a contracted company for reclamation compost production, which is largely used for reclamation of undermined areas. But in the near future it can be assumed that fewer such areas will be available, and it will be necessary to consider how we will handle sewage sludge [2]. The question is also whether it will be permissible to use sewage sludge as an input material for compost and digestate after the revision of The EU Fertilizer Regulation [3].

Based on the legislative changes mentioned above a comparison of different hygienisation methods was made. Three methods are used for the hygienisation of sludge which are described in detail below.

2.1. Sludge liming

This method is used in the majority of WWTPs. Both fixed and mobile liming units are in operation. The dewatered sludge is mixed with lime, which causes the sludge temperature rises up to 55 ° C (due

to exothermic CaO reaction with water) and the dewatered digested sludge undergoes significant alkalization (up to pH = 12).

2.2. Pasteurization

Primary sludge is pumped through a screen separator for removing particles which could cause heat exchanger clogging. The mixture of primary and secondary thickened sludge is continuously pumped through screw spindle pumps from a homogenization tank into the pasteurisation unit (after being mixed in a tank). Pasteurisation consists of two stages of heating the mixed sludge to a final pasteurisation temperature of 72-75 ° C. The sludge is first preheated to 50°C in the recuperation heat exchanger (sludge – sludge) by the heat of pasteurized sludge from the pasteurisation unit. The final temperature is achieved in the heat exchanger (water – sludge) by preheated water. Heating the sludge to the required temperature should not exceed 45 minutes to ensure the hygienisation effect. This heated (the preheated) sludge enters a hygienisation unit. Then the sludge is pumped into a digester after the appropriate retention time which is half an hour. Maintenance is carried out by a small unit every 6 months. This technology is fully automatic and does not require permanent staff.

2.3. Temperature-phased anaerobic digestion (TPAD)

The temperature-phased anaerobic digestion consists of single-stage thermophilic anaerobic digestion followed by single-stage mesophilic anaerobic digestion. The pre-heated mixture of primary and thickened secondary sludge is pumped into the thermophilic digester where the temperature is held constantly at 55 ° C. The retention time in the thermophilic phase is 15 days. The sludge is fed through the macerator and subsequently through a heat recovery exchanger to the second digestion phase which consists of a single-stage mesophilic process formed by three digesters. The retention time in the mesophilic phase is 20 days. The final required temperature for the thermophilic phase is achieved in the heat exchanger (water – sludge) by preheated water. The sludge from digester III overflows into the two smaller mesophilic digesters I and II. The correct sequence of operations must be observed to ensure maximum hygienisation effect. Before feeding the thermophilic digester a sufficient volume for a new batch of preheated mixed sludge must be prepared. Following these steps will prevent leakage of non-hygenized sludge into the mesophilic digesters. This guarantees a minimum period of exposure of pathogens to an inhibitory temperature of 55 ° C, corresponding to the minimum period between individual batches, i.e. approximately 2 hours. However, as stated above, the average retention time in the thermophilic digester is significantly higher at approximately 15 days. A heat exchanger is installed for each mesophilic digester to heat the sludge to the desired temperature but for most of the year only digester I has to be heated.

3. Evaluation

The hygienisation methods are compared in terms of pros and cons regarding hygienisation efficiency, ease of integration into the existing technology, maintenance requirements, consumption of electricity, heat and chemicals and also emissions [2,4].

The efficiency of hygienisation is assessed by the number of enterococci and Salmonella (table 3). Samples of primary and secondary sludge, pasteurized sludge, digested sludge, dewatered sludge and storage sludge were taken to evaluate the effectiveness of hygienisation.

The results (table 3) show that only the liming process meets the conditions given by the new Decree, i.e. results below 10^1 , and achieves up to 10^6 reduction of pathogens. Methods such as temperature-phased anaerobic digestion or pasteurisation do not meet these conditions. The results of microbiological indicators in most cases in digested or pasteurised sludge are lower than that of dewatered sludge which can be caused by the regrowth of microorganisms in subsequent technological equipment. A comparison of other criteria is seen in table 4.

Table 3. Hygienisation efficiency.

Hygienisation method	Microorganism indicator	Primary sludge (result/ cfu ^a)	Secondary sludge (result/ cfu ^a)	Digested/ pasteurised sludge (result/ cfu ^a)	Dewatered sludge (result/ cfu ^a)
liming	enterococci Salmonella	7x10 ⁵ negative	5,6x10 ⁶ negative	2,9x10 ⁴ negative	<5x10 ¹ negative
pasteurisation	enterococci Salmonella	2,1x10 ⁵ negative	4x10 ⁶ negative	5x10 ¹ negative	6,8x10 ³ negative
temperature-phased anaerobic digestion	enterococci Salmonella	2,6x10 ⁵ negative	6,2x10 ⁵ negative	<5x10 ¹ negative	2x10 ⁵ negative

^acolony forming unit

Table 4. Advantages and disadvantages of different hygienisation methods.

Hygienisation method	Advantages	Disadvantages
Liming	<ul style="list-style-type: none"> – easy to integrate into existing technology – no need to modify existing equipment – lower investment costs – can be made mobile for multiple locations – no extra heat requirements – easy to take offline 	<ul style="list-style-type: none"> – high maintenance demands (Personal Protective Equipment, dust, odour) – sludge mixture hardens during downtime – problematic transport of mobile plant, especially in winter – more complicated dosing of lime into hopper in mobile plant – higher chemical consumption resulting in higher dry matter production – requires air filtration due to ammonia emissions – reduction in the nitrogen concentration
Pasteurisation	<ul style="list-style-type: none"> – higher degree of organic matter degradation leading to higher biogas production – no emissions – no chemicals required for operation – environmentally friendly 	<ul style="list-style-type: none"> – more time consuming in preparation, implementation and optimisation – necessity of assessing capacity of existing heat management - boiler output, cogeneration unit and hot water storage tank capacity before integration – higher electricity and heat demands in early operational stages – higher investment costs

		– higher flocculant consumption for sludge dewatering
Temperature phased anaerobic digestion	– higher degree of organic matter degradation leading to higher biogas production	– time-consuming, especially if the existing digester cannot be used
	– no emissions	– necessity of assessing effect of higher temperatures on construction of existing digesters, including existing sludge pumps
	– no chemicals required for operation	– higher investment costs especially if a new digester is required
	– environmentally friendly	– sensitive to operational conditions
		– higher flocculant consumption for sludge dewatering

4. Conclusion

It can be seen from the above results that after 2020 it will be very difficult to meet the requirements of the legislation. From the performed assessment of the hygienisation effect of different hygienisation methods the following conclusions were made. The only method which meets the stricter requirements is sludge liming. The liming process stabilizes sludge with no risk of pathogen regrowth. On the other hand, emissions of ammonia and odors arising from liming must be eliminated, both for the purpose of ensuring the working environment in compliance with the legislation and with regard to the reduction of emissions into the air. In addition, there is a reduction in the nitrogen concentration in the sludge with the release of ammonia into the atmosphere. Based on the above evaluation it is obvious that the agricultural use of sludge in The Czech Republic will be more challenging in the near future and the operators will have to improve sludge hygienisation efficiency.

However before the integration of the hygienisation method into the existing technology, all impacts on the environment should be considered, rather than assessing technology based on one single parameter.

References:

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