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SEWAGE SLUDGE DECONTAMINATION AND METHODS OF ITS CONTROL

In the article it was considered a problem of urban sewage sludge decontamination and methods of its control. It was estimated the efficiency of sludge decontamination under CaO and microwave treatment on the base of determination a total quantity of coliform, thermotolerant coliform bacteria, mesophilic aerobes and facultative anaerobes, helminth eggs. It was shown that the level of sewage sludge decontamination under microwave treatment at specific energy consumption 0.1 kW·h/kg decreased the amount of sanitary indicative microorganisms, helminth eggs till nominative meanings allowing using non-toxic sewage sludge as fertilizers. It was proposed a biocalorimetric express-method for estimation of sewage sludge decontamination that makes it possible to decrease the labor treatment and time of their safety analysis. Comparative estimation of sludge decontamination efficiency showed that MAFAnM index and cell's heat production are well correlate between each other. It decreases time of sewage sludge safety analysis from 3 days to 20 min.

Key words: wastewater sewage sludge, decontamination, chemical treatment by CaO, microwave treatment, total quantity of microorganisms, coli forms, helminth eggs, biocalorimetry.

Introduction. The use of wastewater sludge (WWS) is actual ecological and biotechnological task. The number of generated and accumulated WWS constantly increasing. This leads to the problems associated with their cost-effective and environmentally safe disposal.

There are three main ways of sludge treatment: dehydration, stabilization, decontamination. The last one is the key processes of WWS treatment, which insure their safety on the sanitary-microbio-logical, parasitological parameters and the possibility of further use as fertilizers [1].

WWS decontamination effect can be obtained by biological, chemical and physical methods, as well as their combinations. The choice of corresponding method of WWS treatment is determined by a number of conditions, the most important of which are the type and quantity of sludge, the efficiency of its decontamination and possibility of further use [1].

Equally important is the control of biological safety of WWS. Existing methods of microbiological and parasitological analysis [2–4] are highly time-and labor consuming and need in improvement.

Main part. The purpose of work is a development of biocalorimetric method of the WWS biosafety control and analysis of the efficiency of WWS chemical and microwave decontamination.

In the work were used WWS from Smorgon wastewater treatment plant.

Sanitary-microbiological and parasitological analyses were carried out in accordance with the МУК 4.2.1884-04 и МУК 4.2.796-99. It was determined the number and viability of helminth eggs (HE) by the method of N. A. Romanenko, total coliform bacteria (CB), thermotolerant coliform bacteria (TCB), MAFAnM by methods of cultivation of microorganisms [2, 3]. Ten-fold dilution of samples were prepared in saline for the microbiological research. In the analysis of CB and TCB obtained dilutions were placed in Kessler medium with floats and stand at (37 ± 1)°C for 24 h. From the samples, where acid and gas formation were noted microorganisms were placed on Endo medium. The samples were incubated at (37 ± 1)°C for 18 h. For identification of microorganisms isolated colonies with Endo medium were examined on Gram stain, oxidase test and culturing cells in Hiss medium with lactose at (37 ± 1) and (44 ± 0,5)°C for 6 h. After identification of coli forms the most probable number of microorganisms TCB and CB were calculated [2].

MAFAnM content in WWS was determined by culturing microorganisms in 2% nutrient agar at 30°C for 3 days, and biocalorimetric method [5].

Decontamination of WWS was carried out by the microwave and chemical treatment with CaO.

For the chemical treatment CaO (10–20%) was added to WWS with humidity 95% and kinetics of heating and cooling of the samples were registered by thermometer in a closed container.

After membrane filtration of supernatant on filters with a pore diameter of 0.45 μm and washing with saline solution, a total amount of alive microorganisms was determined on membrane filters by culturing cells on agar medium [2].

Microwave decontamination of WWS was carried out in a microwave oven Samsung CE935GR at f = 2,450 MHz, p = 300–900 W, t = 0–1 min.

To measure the heat flow of samples microcalorimeter MCM-C was used. Its calibration and preparing for work were made according to [5].

Control sample of WWS received by heating at 100°C, 20 min was placed after cooling in control vessel of MCM-C. The samples of WWS before or after decontamination (m = 1 g) were placed in a working vessel of the MCM-C. Their heat emission (q, µW/g) and total emitted heat (Q, mJ/g) were measured at 30°C for 20 min and used for MAFAnM determination [5].

The effectiveness of WWS decontamination was evaluated as

$$E_1 = (1 - P_t / P_o) \cdot 100\%, \quad (1)$$

where P_o, P_t – microorganisms content or their power of emitted heat before and after decontamination relatively. Decontamination constant (k_d) was found with dependence of ln (P_t/P_o) from time of treatment.

Efficacy of HE death was determined as percentage alive (N_{zh}) and death (N_n) eggs content:

$$E_2 = N_n / (N_n + N_{zh}) \cdot 100\%. \quad (2)$$

Data obtained were processed by statistic methods, using Microsoft Excel software.

Caustic lime is widely used for decontamination and sludge dewatering [1]. In accordance with the equation

$$CaO + H_2O = Ca(OH)_2 + Q, \quad (3)$$

65 kJ of heat releases when 1 mol CaO is hydrated 1 mol of H_2O, and that allows to calculate the required amount of CaO for treatment.

Fig. 1 shows the kinetics of WWS heating and cooling when they were treated by CaO at 10 and 20%. Maximum heating temperature of the samples ranged to 82°C when processed by 20% CaO.

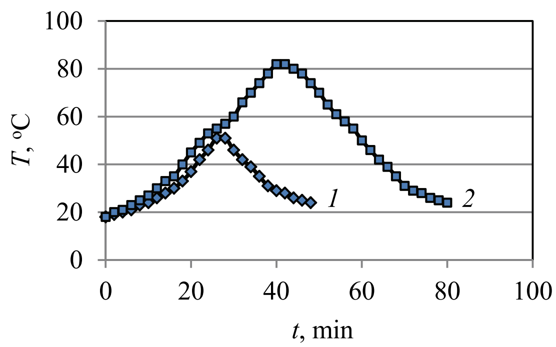

Fig. 1. Kinetics of heating and cooling of WWS in the processing of CaO: *1* – 10%; *2* – 20%

The main objective of the sanitary-microbiological and parasitological research on urban wastewater treatment plants is to check the effectiveness of wastewater cleaning and safety control of WWS before their descent into environment.

In accordance with documentation it were determined such indicators of WWS biosafety as MAFAnM, CB, TCB and HE [2–4]. They characterize the level of fecal pollution of WWS, presence of indicative, pathogenic microorganisms and parasites.

The main criteria for evaluating the efficiency of WWS decontamination are the absence of pathogens, HE, and a low content of CB, TCB [4].

Results of WWS biosafety analysis before and after CaO treatment are given in Table 1.

Table 1

Biosafety analysis of WWS after the CaO treatment

Indicators	CaO			$E_{1,2}$	
	0	15%	20%	15%	20%
CB, CFU/g	7,000 ± ± 900	1,500 ± ± 300	100 ± 20	78.5	98.5
TCB, CFU/g	2,400 ± ± 600	550 ± ± 100	85 ± 20	77.1	96.4
MAFAnM, CFU/g	(2.2 ± ± 0.3) · 10^7	(4.2 ± ± 0.7) · 10^6	(1.5 ± ± 0.3) · 10^6	80.2	93.8
HE, units/kg	12 ± 3	3 ± 1	0	75.0	100

As follows from Table 1, processing with CaO (15%) didn't provide a complete decontamination of WWS both in terms of HE and CB, TCB. Processing WWS by 20% CaO destroys HE, as well as reduces the number of coliform bacteria to standardized values [4].

Among the promising methods of WWS decontamination is the action of microwave. Table 2 shows the efficiency of WWS microwave treatment based on MAFAnM indicator.

Table 2

Efficacy of WWS decontamination after microwave processing determined on MAFAnM indicator

Microwave treatment			MAFAnM, CFU/g · 10^5	E_1, %
P, kW/kg	t, s	T_{max},°C		
0	0	20	220 ± 30	–
3	60	60	60 ± 7	72.7
6	60	72	18 ± 3	91.8
9	60	82	5 ± 1	97.7

As can be seen from Table 2, for effective microwave decontamination of WWS need a specific power consumption P = 6 kW/kg, t = 60 s.

Biosafety control of sewage sludge based on classical methods of microbiological analysis requires a long duration, additional equipment and large materials consumption. To assess safety of WWS in terms of helminth eggs must be 6 h, and with microbiological indicators – 3 days.

In this regard, a search of simple, fast and effective methods of testing microbiological and parasitological parameters of sewage sludge is necessary.

Table 3

WWS decontamination after microwave treatment

Indicators	Average values			
	Control	After microwave treatment, W · h/kg		k_d.
		0.05	0.1	
q, μW/g	783 ± 14	232 ± 19	64 ± 2	1.02
MAFAnM, CFU/g ·10^5	220 ± 30	60 ± 7	18 ± 3	1.00
CB, CFU/g · 10^3/g	7.0 ± 0.9	1.8 ± 0.3	0.09 ± 0.03	1.78
TCB, CFU/g · 10^3/g	2.4 ± 0.6	0.7 ± 0.2	0.04 ± 0.02	1.66
HE, ind./kg	12 ± 3	4 ± 1	0	0.88

One of the promising methods for safety analysis of WWS is biocalorimetry. From the energy point of view, a measure of viability of any organisms may be the average power of their heat release, which reflects the intensity of metabolic processes occurring in the cells [5].

To confirm the possibility of using biocalorimetry for monitoring of WWS decontamination it was studied heat release of the samples after micro-wave action (Fig. 2).

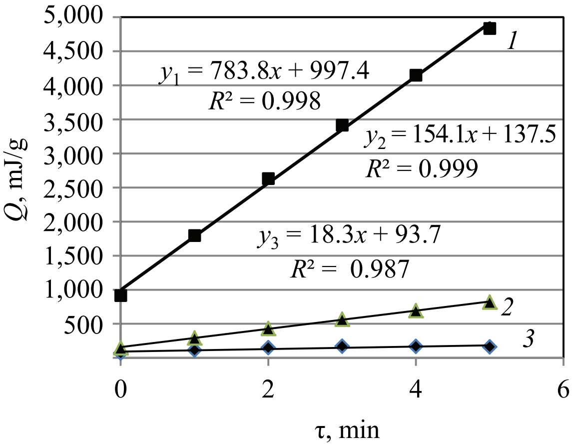

Fig. 2. Kinetics of heat release of microorganisms at WWS: *1* – without treatment; *2*, *3* – after microwave treatment, P = 9 kW/kg, t = 30 and 60 s

The decrease a level of heat release was observed after microwave treatment, that was connected with death of microorganisms.

A comparison analysis of WWS decontamination was studied on kinetics of heat release by microorganisms after chemical and microwave processing (Fig. 3).

As Fig. 3 shows, a level of heat release of microorganisms at WWS after CaO treatment is higher than after microwave action. The effectiveness of WWS decontamination by 15% CaO was (82.8 ± 3.0)%, and microwave (6 kW/kg, 1 min) – (91.8 ± 2.4)%.

In the Table 3 are presented the results of WWS microwave treatment. Only dose 0.1 W · h/kg was enough for effective WWS decontamination.

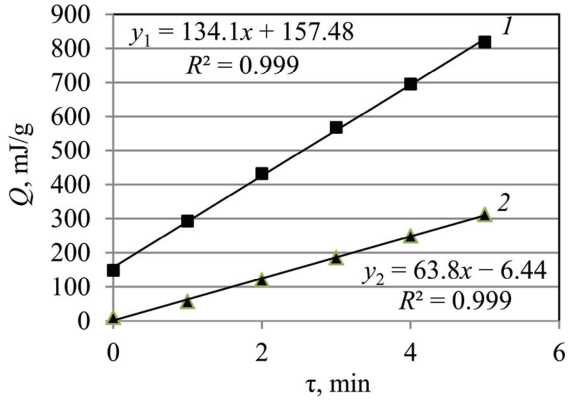

Fig. 3. Kinetics of heat release by microorganisms at WWS: *1* – decontamination with CaO (15%); *2* – microwave decontamination, P = 6 kW/kg, t = 1 min

There is a strong correlation between the indexes of q and MAFAnM. If value k_d for MAFAnM taken as 1.0, it may be noted that the greatest resistance to the microwave treatment showed the HE indicator, the lowest – CB (Table 3).

All results indicate that biocalorimetry is a fast, accurate method suitable for biosafety analysis and evaluation of the efficiency of WWS decontamination.

Conclusion. In the paper it was analyzed efficiency of WWS decontamination by CaO and microwave treatment made on the base of determining MAFAnM, CB, TS and HE indicators. It was found that microwave treatment of WWS at 0.1 kW · h/kg corresponds to their chemical processing with 20% CaO. We proposed biocalorimetric method for assessing the degree of WWS decontamination based on the strong correlation between MAFAnM and their heat production. This reduces the labor intensity and duration of WWS biosafety analysis from 3 days to 20 min.

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