USING OF MICROWAVE ELECTROMAGNETIC RADIATION FOR TREATMENT OF WASTEWATER AND SLUDGE

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Abstract

The article presents the possibilities of using the microwave electromagnetic radiation to intensify the treatment of municipal sewage and their sediments. Technical and economic parameters and experimental data, indicating the possibility of the use of microwave electromagnetic radiation in technologies of sewage and their sediments treatment, are presented. The experiments confirm the improvement of the sludge properties: decrease of their volume and humidity, improvement of water yielding properties, odor removal and disinfection.

Key words: *method of treatment, wastewater (sewage), sludge (sediments), microwave electromagnetic radiation (radiation of superhigh frequency,* SHF*)*

1. INTRODUCTION

The problem of qualitative sewage treatment and sediments processing with the further utilization is urgent for towns and villages in Russia. Small amounts of oil field construction camps sewage in the Tyumen North, generally, are notable for higher concentrations of organic substances and ammonium nitrogen (table 1).

Table 1. The quality of wastewater undergoing the purification

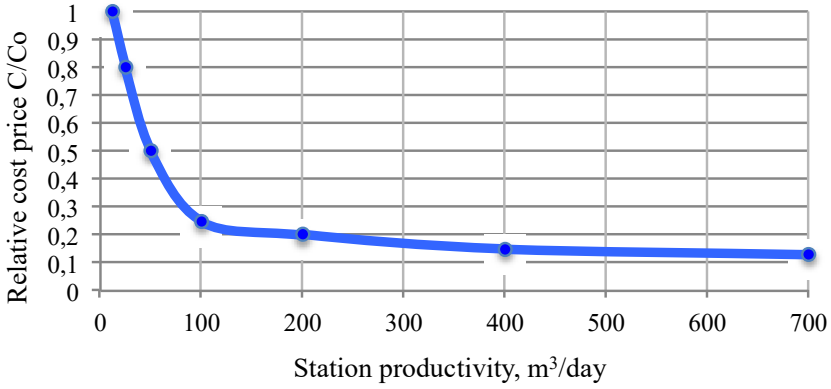
Sewage treatment plants	Productivity, m^3/day	Suspended matters, mg/dm^3	BOD_5, mg/dm^3	COD, mg/dm^3	$N\text{-}NH_4$, mg/dm^3
Septic tanks of construction camp	5	2980	820	5500	140
Construction camp of oil field	200	400	430	750	78
Village of Vagay	400	140	390	500	52
Settlement of Golyshmanovo	1000	150	110	200	35
Town of Yugorsk	7 000	150	120	160	18
Town of Ishim	12 000	300	190	300	53
Town of Tobolsk	40 000	195	250	400	26
City of Tyumen	210 000	305	180	350	34

At sewage treatment plants with low productivity, especially in Arctic conditions, the necessary amount of traditional equipment units of wastewater treatment and sediments processing, the volume of consumables, electric energy costs are gratuitously high. The amount of forming sludge directly depends on station productivity in sewage and its pollution according to main indices, such as suspended matters, BOD, COD (table 2).

Table 2. The amount of forming sediments

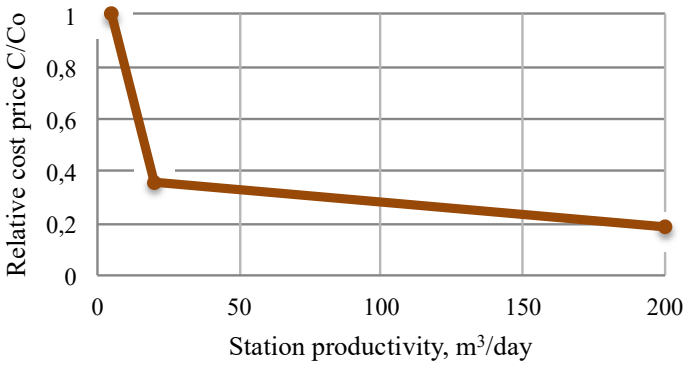
The type of locality	The productivity of sewage treatment plant, m^3/day	The amount of forming sediment, m^3/day	The amount of forming sediment, thousand tons/year
Construction camps with 0.1-0,5 thousand residents	10−250	0.1−1	0.04−0.4
Settlements with 1-5 thousand residents	400−1000	2−10	0,7−3,7
Towns with 40-100 thousand residents	7000−40000	40−250	15−90
Cities with 300-700 thousand residents	100000−220000	600−1800	200−600

It should be noted that cost price of $1m^3$ of water treatment and, correspondingly, of sediments of stations with low (to 5 thousands m^3/day) and average (to 20 thousands m^3/day) productivity is higher than for stations, which productivity is more than 50 thousands m^3/day (fig. 1,2).



Legend: Co – maximum cost price, C – cost price at different productivity

Figure 1. Dynamics of water purification cost price reduction with the increase of station productivity



Legend: Co – maximum cost price, C – cost price at different productivity

Figure 2. Dynamics of sewage sediments treatment cost price reduction with the increase of station productivity

The research and development in the sphere of sewage treatment and sediments processing at sewage treatment plants with low productivity allow to obtain high efficiency of the processes. These new methods include the use of technology of wastewater and sludge treatment with microwave electromagnetic radiation (SHF).

2. REVIEW

SHF (superhigh frequency or microwave radiation) is an electromagnetic radiation, which includes decimetric, centimetric and millimetric range of radio waves: wave-length is $1-10^{-3}$ meters, radiation frequency is $3\cdot10^{8}-3\cdot10^{11}$Hz. Electromagnetic waves are able to spread in vacuum and in space, filled with substance. The main characteristics of electromagnetic radiation are considered to be frequency, wave-length and polarization.

Electromagnetic radiation influences mostly heterogeneous water systems or processes, connected with phase transitions (dilution, crystallization and others). These achieved effects are most visible and, naturally, save much time, and in a number of cases they are irreversible.

In the modern world microwaves are widely used in the medicine, industry, household appliances, mobile and internet communication, television, radio-location and other spheres. One of the new directions of microwave energy usage is a treatment of production waste and human biowastes with the aim of their further utilization. Famous Russian developments in the sphere of liquid and solid waste treatment with the usage of electromagnetic fields are shown:

1. Oil-slimes and water and soil oil pollutions treatment. Effectiveness of application of extremely high-frequency (EHF) radiation for the increase of hydrocarbon-oxidizing bacteria Rhodococcus erythropolis E-15 biomass increases. Irradiation of hydrocarbon-oxidizing bacteria's increases the output of bacteria biomass and consumption of hydrocarbons by them on 33 and 31% respectively on average in comparison with unirradiated bacteria (Komarova et al., 2013).
2. Oil emulsion and oil-slimes treatment. New method of dehydration of water-oil emulsions by the use of influence of electromagnetic field, protected by patent, has been worked out. Technology and industrial technological plant of oil slime treatment with the use of SHF energy have been worked out (Minnigalimov, 2010).
3. Biological sewage cleaning. Proposes activation of biological cleaning sewage complex biocoenosis enzymatic system; oxidative capacity of aeratic facilities increases to 40%, the amount of silt index decreases to 45%. Also new method of water disinfection, which is based on usage of perpendicular to the stream constant magnetic field of definite intensity, is worked out (Nikiforova et al., 2002).
4. Sewage disinfection. The way of industrial wastewater disinfection in impact electromagnetic facility with the magnetic intensity 70−80kA/m and frequency 2−10 imp/sec is known (Zhuravlev et al., 1996).
5. Sewage sediments treatment. Investigations of SHF-waves influence on some physical and chemical properties of active silt of food industry plants' treatment facilities were made. It is proved that SHF - treatment of active silt leads to essential increase in the rate of sedimentation and compaction degree (Gaponenkov et al., 2013). It is proved that microwave treatment of sewage sediments allows to provide with effective removal of admixture of heavy metals from sediments with power inputs no more than 0.05kW-hour/kg (Kapustin et al., 2009). Complex way of reagentless treatment of sewage's sediments and briquetting, which includes disinfection of sunken silt briquettes in microwave ovens (Senkus et al., 2011).
6. Solid household waste treatment. Microwave reactor, which is able to process 100 thousand tons of solid household waste (further SHW) in a year, has been worked out. This device is equipped with a special camera, heated through piers with the help of fuel gas and due to microwaves. The application of these two temperature impacts leads to decomposition of substance without oxygen. Substance decomposes into three components: carbonic residuum, gas fraction and different

components, which are compensated after and turn into furnace oil or motor product (S.V. Gunich, E.V. Yanchukovskaya in rambler.news, 2012).

7. Liquid waste disinfection. There is a way of antibacterial treatment of liquid media stream by the use of influence on involute fluid stream using electric fields and creation of ion density gradient. Plant is proposed (Laptev et al., 2006).

In foreign practice there is a well-known microwave reactor for treatment of asbestos-cement waste products (reactor ATON 200), worked out, introduced and patented by the firm ATON-HT SA (Poland). Technology can be applied to any type of asbestos waste products: solid waste (slate) and soft asbestos waste (gyps-asbestos, conduits, cords, pads and others). Reactors ATON-HT S.A. work in France and USA. Company has an experience in utilization of asbestos and sulfuric tar, as well as toxic chemicals and ground, polluted with hydrocarbons. During utilization there is a process material mass reduction on 75−99%.

3. PROBLEM

The great amount of construction camps is situated in the north of Tyumen on the territory of oil-extracting companies' objects far from localities. Septic tanks-accumulators receive sewage from residential and hospital cars, canteen, laundry. The main problem is that effluents contain higher concentrations of the main types of pollutions (table 3), their quality harshly differs from quality of sewage, situated near the stationary sewage treatment plants with low productivity and can not be taken to purification (Vialkova et al., 2012).

Table 3. Concentration of septic tanks-accumulators sewage pollutions

The name of index	Concentration of septic tanks sewage pollutions, mg/dm^3	Permissible concentration at the entry of biological cleaning plant, mg/dm^3
Suspended matters	296−5374	300−500
BOD_5	215−1431	150−500
COD	616−10380	500−800
$N\text{-}NH_4$	83−199	50−70
Phosphate-ion	6.1−27	8−12
pH	6−7.2	6.5−8.5

Thus, accumulated during 1−3 day's effluents are removed to functioning treatment facilities in the nearest town by cesspool cars. As a result of it, transportation and purification at city treatment facilities is rather expensive for plant.

Sewage sediments treatment is also a serious problem. Spatial structure of sewage sediments is a colloidal system, which includes fine-dispersed solid particles. Total negative charge on the surface of colloidal particles cases mutual repulsion, and, as a result, sediments can not be precipitated and filtered.

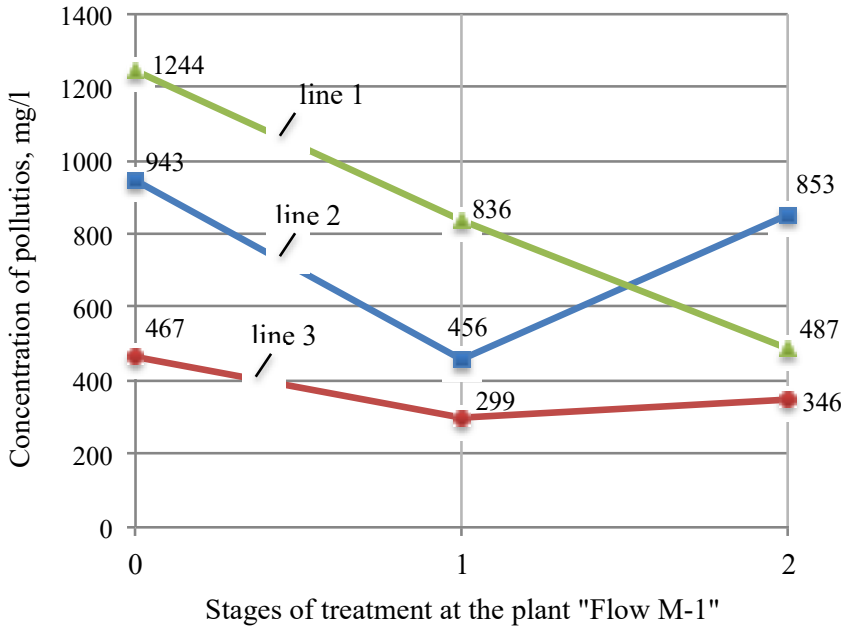
The SHF EMR treatment of urban sewage sediments leads to the formation of dissociated molecules and free radicals, appearance of electrical charges, the conditions of equilibrium shift of colloid systems appear, and, as a result, water yielding properties of sediments improve. Due to the volumetric rise in sediment temperature, moisture evaporation increases, that lead to the reduction of sediment volume. Due to increase of oxygen activity, oxidizing processes, including decomposition of organic substances, become more intense. With that, useful side effect is a destruction of cellulose,

microorganism cell ferments activity reduction, disinfection and destruction of helminth eggs, pathogenic bacteria, that essentially simplifies further utilization of sediments.

4. DESCRIPTION OF STUDIES

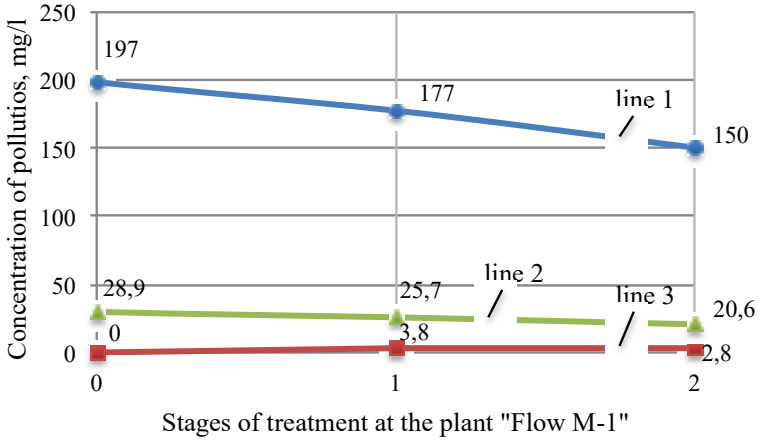
At Industrial University of Tyumen at the chair of "Water supply and sanitation" test investigations of SHR-radiation influence on the quality of highly concentrated municipal sewage, taken from accumulators of construction camp, situated on the north of Tyumen on the territory of oil-extracting companies' objects, were carried out.

Sewage of septic tanks-accumulators with the initial high concentrations is processed on the flowing SHF-plant "Flow EM-1" during 10 minutes, at the laboratory of the university. In the process of double-stage treatment effluents heated to the temperature 80˚C and higher. At the output the range of indices were measured according to the standard methodology. The results of the quality change on every stage are shown on the figures 3,4 and 5.



Legend: COD (line 1), suspended matters (line 2), BOD_5 (line 3)

Figure 3. The change of pollution concentration in the process of SHF sewage treatment



Legend: ammonium –ion (line 1), phosphate –ion (line 2), nitrate –ion (line 3)

Figure 4. The change of pollution concentration in the process of SHF sewage treatment

In the process of SHF treatment the amount of COD significantly decreases: more than in 2.5 times. Suspended matters and BOD_5 after first stage of treatment decrease in 1.5-2 times, but after second stage there is some increase of concentrations, maybe because of the COD destruction and formation of new compounds.

Concentration of ammonium nitrogen decreases on 23-25% on average, concentration of phosphates – on 28-30%. Concentration of nitrate-ion, as figure 4 demonstrates, increases, that confirms the transition from ammonium nitrogen to nitrate –ion. Also, there is an increase of pH, it also confirms the change of medium composition (figure 5).

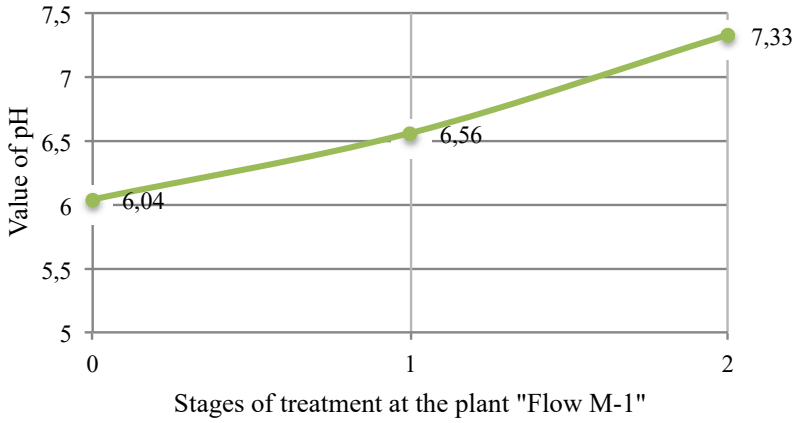


Figure 5. The change of index of medium pH activity in the process of SHF sewage treatment

Thus, the quality of sewage under the influence of electromagnetic radiation significantly changes. The resulting patterns are subject to more detailed study.

For several years authors of this article have been carrying out experiments, concerning the SHF-radiation treatment of active silt and the mixture of damp sediment and active silt (in ratio 1:2), taken from municipal treatment facilities of sewerage of Tyumen (Western Siberia, Russia). The purpose of

these experiments is investigation of SHF influence of electromagnetic treatment (further – SHF EMT) on the properties of sludge and intensification of their treatment process; establishment of the main laws. As a result of investigation of different properties of statically processed sediments in laboratory conditions following conclusions were drawn:

1. SHF EMT positively influences the degree and speed of compression of sediments mixture, active silt compresses intensively on 33%, diluted sediments mixture compresses on 18%, the volume of sediments' sample decreases on 37.5%;
2. EMT of sediments mixture improves water yielding capacity: at sediments EMT with the capacity 0.8 kW during 5 minutes the time of capillary suction of sediments reduces by 1.2 times on average (in comparison with unprocessed EMT sediment); specific resistance of filtration (r) significantly decreases: (r) of initial sediments is $37.5 \cdot 10^{10} g/cm^3$, (r) of sediments after SHF EMT is $6.93 \cdot 10^{10} g/cm^3$;
3. At treatment of sediments mixture with EMT humidity (W) reduces on 3.7% on average; ash content (3) increases in 6.1%;
4. Processes of influence of capacity and time of SHF- treatment of sludge on degree and speed of their compression, on humidity, ash content are quite adequately described by polynomial models of first and second orders;
5. SHF EMT of sludge significantly reduces the adhesion to the surface, there is no putrescibility of sediments during two days after treatment, there is a disinfection of sediments, the output of admixtures of heavy metals in clarified water increases.

Thus, at the first stage the possibility of usage of reagentless way of treatment and neutralization of urban sewage sediments with the help of SHF EMT was scientifically substantiated and experimentally confirmed, as a result, the main laws of sediments properties changes during SHF EMT were established and equations of influence of treatment parameters (capacity and duration of EMT) on properties of sewage sediments (compression degree, humidity, ash content), that reflect these laws, were obtained.

At the next stage the flowing plant of SHF-treatment of sewage sediments "Flow EM-1", which allows carrying out the sediments treatment directly on pipeline of sediments supply, was designed by Zemlianova M. V. and Vialkova E.I.(2014, 2015), that significantly simplifies the exploitation and reduces the price of technological treatment.

Kinetic characteristics of process of compression of SHF-processed sediments were defined, and optimum parameters (capacity and duration) of EMT sediments were proposed on experimental-industrial plant of flowing type "Flow EM-1". The comparison of different variants of sediments treatment discovered that effectiveness of compression of SHF -processed on plant "Flow EM-1" sediments is 7.6% higher in comparison with sediments, processed with flocculant "Zetag 8165", and is 25% better, than treatment with burnt lime. Optimum time of compression after EMT is two hours, that is 1.5 times lower, than it is necessary for compression of unprocessed sediment.

At dissertation of Zemlianova M. V. (2015) the possibility of use of experimental-industrial plant "Flow EM-1" in technological schemes of sewage treatment plants with the aim of EMT of urban sewage sediments was confirmed. Three variants of reagentless technological schemes of urban sewage sediments treatment with the use of plants "Flow EM-1" (at the stations with sediment productivity – no more than 4-5 m^3/day) and more improved modifications, depending on water and sediment productivity of stations, were proposed. Practical value is that offered way of treatment and plant "Flow EM-1" can be used at designing new technological schemes of sediments treatment and reconstruction of existent ones.

The results of technological and economic comparison of two variants of treatment and utilization of sewage sediments, both existent today on treatment facilities of Tyumen and offered method SHF EMT of sludge, showed that introduction of EMT method is an effective nature conservation measure

and is economically the most profitable. The comparison of costs of sediments treatment is presented in table 4.

Table 4. The comparison of costs of sewage sediment treatment

Productivity of sewage treatment plant, m^3/day (sludge)	The cost of sewage sediment treatment with the use of SHF EMT, euro/year	The cost of sewage sediment treatment with the use of flocculant "Zetag 8165", euro/year
5	13482	23885
20	26527	30771
200	210332	134995
1000	906185	513053

At the same time aborted ecological damage is 2.72 thousand euro, cost price of treatment and utilization of 1 m^3 of sediments is 7-3 euro, that is 1.77-1.16 times less than at existent scheme of sediment treatment with flocculants an average. Introduction of SHF EMT sediments method allows reducing the costs of treatment and utilization of sewage sediments by 1.3 times an average. Offered way of sewage sediments treatment is considered to be a variant of import substitution of expensive chemical reagents.

4. CONCLUSION

SHF treatment contributes to the processes of sewage treatment from organic pollutions, positively influences sediments mixture compression speed and degree, improves water yielding capacity. Moreover, a disinfection of sediments occurs, the output of admixtures of heavy metals in clarified water increases. Introduction of SHF EMT sediments method allows reducing the costs of treatment and utilization of sewage sediments.

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