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COMPLEX TECHNOLOGY FOR PROCESSING SOME ORGANOMINERAL WASTE

Important environmental problems related to the processing of municipal wastewater sludge have been discussed. The proposed technological solution includes the following stages: sludge pretreatment; its thermal decomposition with formation of high-energy gas; production of organo-mineral fertilizers and synthetic soil; obtaining of fuel pellets; recycling of ash residue at the stage of thermal decomposition for obtaining metal oxide mixes, coagulants, construction and decorative materials.

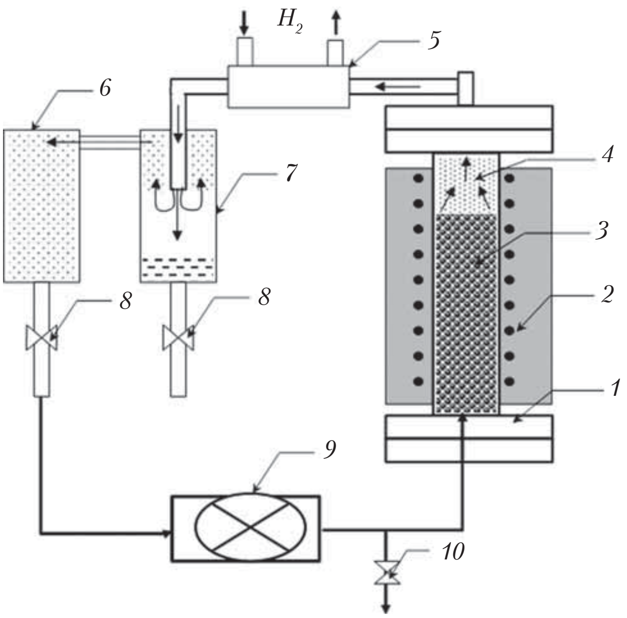
Keywords: housing waste, sludge, recycling, high-energy gas, organo-mineral fertilizers, and high-purity oxides.

The situation in waste management in Ukraine does not comply with the concept of sustainable development, which provides for an inextricable link between its well-balanced economic, environmental, and social components. Huge amount of waste that has accumulated mostly in unsuitable areas and whose number is constantly growing, causes irreparable damage to ecosystems and is one of the factors that call into question the future development of sustainable development conception. Irrespective of our wishes the world is gradually turning into a huge dump [1].

It is clear that only radical measures can significantly change the situation. One of them is deep processing of accumulated waste aimed not only at reducing its volume, but also at utilizing, to maximum extent, their energy and resource potential. The critical state of environment in most parts of the country casts doubt on the prospects for progressive social development. Indeed, fewer and fewer opportunities remain for providing people with high-quality water, clean air, and eco food, with anthropogenic impact on ecosystems continuously growing as a result of outdated and imperfect technology and excessive energy consumption of entire industries.

The situation with waste management in Ukraine mirrors the global problem. According to [2], under current conditions, if the humanity decides to abandon the consumer economy, if it wants to pursue a policy of saving natural resources, where waste is minimized and most resources are used efficiently, it is necessary to take action immediately. As Hugh Thomas, one of well-known experts in the field of recycling puts it, there is no waste in the nature [2]. If in the existing ecological system something dies and becomes unnecessary, it can be successfully used in other ecological system. The humanity can take everything valuable from waste-free production in the nature, but it needs to create new technologies and radically change the way of thinking.

Feasibility of maximum possible use of waste as secondary raw material is almost unchallenged today. Moreover, the benefit of such an approach



Scheme of laboratory plant for high-temperature fast pyrolysis with recirculation of gaseous phase: *1* — reactor; *2* — induction heater; *3* — raw material; *4* — thermal decomposition products; *5* — cooling device; *6* — separator; *7* — gas storage capacity; *8* — valve for gas supply from gas reservoirs to the circulation pump; *9* — circulation pump; *10* — valve for plant vacuuming (at preparation stage) and separation of circulating gases (for analysis)

can be confirmed by many examples when the target recycling has proved itself to be significantly environmentally friendly, more efficient, less energy-intensive and less expensive. Wide-scaled implementation of best practices for waste recycling enables to materially reduce not only the need for raw materials, but also the cost of targeted products and the human impact on the environment [3—13].

An important component of generated and accumulated waste is the organic waste, including: biomass sewage sludge and sediments of treatment facilities; substandard residues of agriculture, municipal sector, food and processing industries; household and industrial organic waste (paper, cardboard, textiles, packaging, plastics, rags, etc.); secondary processed wood (sawdust, shavings, leaves, lignin), peat, river and lake sapropels.

Almost all these types of waste are a serious environmental problem. In this regard, the biomass sewerage sludge and sediments of treatment facilities would seem to present few difficulties because of their relative stability, predictability, and concentration in certain places. However, this is not the case. Firstly, their processing using the existing technological solutions is extremely energy-intensive, inefficient, and unprofitable. Secondly, because of constant increase in the volume of arriving wastes that is comparable to that of processed ones, the area under deposits continues to steadily expand, which requires land acquisition at the expense of lands for other purposes, including the agricultural lands.

Given the contamination with pathogens that accompany activity of microorganisms containing in the sludge ponds and are released to the environment, this simple, at first glance, waste becomes much more harmful.

The waste distribution by utilization methods varies significantly among the countries. In the United States, it is distributed as follows: fertilizers (36%); incineration (16%); field waste deposits (10%); waste ponds (38%). Distribution in Western Europe is as follows: fertilizers (33%, with an upward tendency); waste deposits (15—20%, with subsequent reduction in the share due to banned waste storage and disposal); incineration (4—11%, with an expected significant growth in the future by as a result of closing the landfills); landscape reclamation (about 10%); and composting (1—3%). Apparently, there is no single approach and it is hardly anticipated, whereas, in our opinion, the waste management system must be based exclusively on the «turn waste into profit» principle.

The aim is to develop effective approaches to processing organo-mineral waste (municipal waste water sludge) with low- or zero waste scheme for their implementation.

Given this, the scheme for processing organo-mineral waste has been proposed in this work. It is based on the following phases: waste pretreatment that may use one or more process lines, depending on the ultimate goal; obtaining of organo-mineral soil or fertilizer; thermal recycling of waste using advanced technological solutions to obtain high-energy gas; production of mixed briquetted fuels; fractionation of ash residues of organo-mineral waste thermal processing; manufacture of building materials for use in residential and non-residential construction; creation of reagents with coagulating properties for treatment of wastewater of different nature and origin. At first glance, the presented scheme is simplified, but, as one can see below, its elements specify the most important issues to be addressed to make this scheme low- or zero-waste and the resulting products marketable with good prospects for further use.

OBTAINING OF ORGANIC SOILS OR ORGANO-MINERAL FERTILIZERS

One of the promising ways of using municipal sludge is production of organo-mineral fertilizers or artificial soil [14—17]. This way has many various benefits. On the one hand, it reduces huge volume of accumulated sediments. On the other hand, there is no need to use scarce and expensive fertilizers to enrich and to increase the organic component in soil using natural regenerative substances. In addition, the soil is enriched with macro- and micronutrients, nitrogen, phosphorus, magnesium, calcium, zinc, copper, molybdenum, manganese, cobalt, and other elements from the sludge.

The main obstacle is a risk of contaminating the areas where the sludge is stored and processed with heavy metals and pathogens. It entails the need for developing the necessary guidelines, legislative framework and standards. The environmental problems that may occur after the use of sludge have been studied in many research centers around the world.

It should be noted that in recent decades, the share of humus in the soil fell drastically. For example, as of 2005, the area of degraded and unproductive arable land in Ukraine exceeded 5 million ha or 12.2% of the total agricultural land. Such a pace of «progress» in this area cannot but raise serious concerns. The amount of humus accumulated in soils for many hundred thousand years has decreased from 14 to 7% for the black soil in last 50 years and from 8 to 4%, on average, in the fertile soils of Ukraine. It should be kept in mind that if its content in the soil is below 1.5% the land is deemed to loss ability to self-recovery.

The way out of this difficult situation, in addition to total rejection of consumer attitude to the land, is reclamation of topsoil using biomass as problematic waste. Not focusing on the known facts it should be noted that wastewater sludge (WWS) recycling for its use as fertilizer (or organic soils) shall not be carried out unless the content of heavy metals and pathogens in sludge and the composition of soil to which sludge is planned to be added are strictly monitored and the maximum permissible concentration (MPC) of heavy metals is elaborated and justified.

Taking into account the above mentioned risks, the possibility of use of WWS from Kaniv treatment plants where the first stage of the process is anaerobic digestion in psychrophilic conditions has been studied [18]. Samples were collected at wastewater treatment plant (WWTP) facilities in four locations of sludge bed where the sediments have been stored within one year after formation. The selected samples were ground to a smooth consistency and stirred to get a bulk composition. Moisture content was measured by weight loss after 3-hour drying at 105 °C: Sample 1 and Sample 2 had a moisture of 24.26% and 25.10%, respectively. Organic to inorganic ratio was determined by thermal decomposition in air in a muffle furnace, at 600 and 900 °C. The results are presented in Table 1.

According to [19, 20], the sludge used for fertilizers must have at least, 4.0%, 1.0%, and 0.6% portion of organic matter, nitrogen, and phosphorus, respectively. The content of heavy metals in the samples prepared in accordance with GOST 215600-82 requirements was determined by atomic absorption method using Quant-Z. ЭТА.-T spectrometer. The results of tests of three

Table 1

Content of Organic and Inorganic Components and Biogenic Elements in Sludge Digested in Anaerobic Psychrophilic Conditions, %

Samples	Thermal decomposition at 600 °C		Thermal decomposition at 900 °C		Biogenic element content	
	Organic component	Inorganic component	Organic component	Inorganic component	Nitrogen	Phosphorus
1	43.1	58.7	42.4	57.6	2.1	1.8
2	42.0	58.1	42.9	57.1	2.1	1.8

Table 2

Heavy Metals Content in the Sludge (mg/kg of dry matter)

Method	Cr	Mn	Ni	Pb	Cd	Sr	Fe	Zn	Co	Al	Ag
1	78	92	99	30	1,8	69	19 292	390	4,2	4809	17
2	88	103	94	29	1,6	76	20 474	346	5,2	5719	16
3	86	108	91	29	2,4	73	15 141	417	6,2	6703	18
*	750	2000	200	750	30	300	25 000	2500	100		
**	5000	7000	900	2000	250	600	45 000	9000	300		

* — permissible toxicological indices of fertilizers suitable for the use in agriculture [19];** — permissible toxicological indices of fertilizers suitable for the use in forestry, green construction, and land reclamation [19].

samples taken in various points of Kaniv WWTP sludge pond perimeter are given in Table 2.

Some discrepancies in the content of heavy metals for the samples 1-3 can be explained, mainly, by the fact that the sludge was brought to the pond at different times and obtained from treatment of waste waters having various level of contamination. At the same time, all samples have a heavy metal content within the permissible range (Table 2), which enables to consider such sludge as material for organic soil (or organo-mineral fertilizers).

Given maximum permissible concentration (MPC) of heavy metals for local type of soil and their existing background content sludge hygienic load has been estimated by formula:

$$H_{hyg.} = (MPC - C) \times 3 \times 10^{3}/C,$$

where $H_{hyg.}$ is permissible sludge hygienic load on soil; MPC is maximum permissible concentration of metals in soil, mg/kg; C is metal content in sludge, mg/kg of dry matter; 3×10^{3} is conversion factor.

Comparing the results with standard values gives reason to refer the studied sludge to a group of fertilizers to be used for growing grain, fodder, and industrial crops at a dose of 4—5 t/ha (dry matter) annually, or more than 15 t/ha every three years. The content of heavy metals is also suitable for the use of these fertilizers in forestry, green construction, and land reclamation at doses equivalent to the conventional fertilizers.

To detect the presence and viability of pathogens in the sludge stored or deposited at the pond during a year under atmospheric conditions, the sample 1 and sample 2 were prepared by heat drying at a temperature of 105 °C and without heat treatment, respectively. The sanitary and microbiological studies were carried out in microbiological laboratories of Boryspil Interdistrict Department for Laboratory Research. No helminth eggs were found in the sample 1, while the sample 2 contained viable eggs of *Ascaris lumbricoides*.

Since the majority of wastewater treatment plants in Ukraine does not foresee any sludge decontamination that is mandatory for the use of sludge as an organic fertilizer or soil, the ultimate goal cannot be achieved unless it is implemented. Among the known decontamination methods, thermal and chemical methods, as well as long deposition and composting are noteworthy.

In our view, the most rational way is organic sludge composting with different fillings. On the one hand, this method gives a valuable product and, on the other hand, it is a purification that makes municipal sludge safe for environment. Waste biodegradation ensures physical and chemical transformations of organic substrate to form manure, a stable humified final product that is a valuable organic fertilizer and a means of improving the soil structure. Necessary input data for the design and creation of appropriate composting systems at WWTPs have been collected. In general, research activities in this direction are relevant, important, and necessary. This is likely the only way to restore the potential of different soils through balancing content of biogenic elements, microelements, and organic component.

To develop the use of municipal sludge as organic soil or components of organomineral fertilizers, field research of organo-mineral fertilizer based on Bortnychi WWTP sludge that had been proved highly effective for growing potatoes was designed and carried out. The samples were taken from different maps located within a chain of previously selected sludge pond and thoroughly stirred up until homogeneous. Then, metal content was determined in (mg/kg of dry matter) as Cr (348), Mn (260), Ni (34), Pb (370), Cd (20), Sr (98), Fe (13500), and Zn (760).

The studied sludge mix has been found to meet permissible toxicological indicators of fertilizers suitable for the use in agriculture [20]. Table 3 shows the composition of produced organo-mineral fertilizer used for planting *Spartan* potato in gray sandy soil. The yield of the reference section was 130 kg/ha, while that of the trial section was 220 kg/ha, i.e. it increased by 69.2%. In addition, the quality of potato grown in the trial section differs from that grown in the reference one. Table 4 shows the comparative characteristics of potatoes grown in the trial and reference sections.

Table 3

Composition of Produced Organo-Mineral Fertilizer

No	Components	Component content	
		Weight content	%
1	Sludge from Bortnychi Aeration Station	201.7	40.7
2	Urea	48.0	9.7
3	Potassium sulfate	70.0	14.1
4	Phosphoric flour	59.2	11.9
5	Clinoptilolite	100.8	20.3
6	Ammonium nitrate	15.8	3.2

Table 4

Quality Indices of Potato Grown at Trial and Reference Sections

Quality indices	Reference samples	Trial samples
Starch content, %	12.6	14.8
Yield, hwt/ha	130	220
Content of microelements, mg/kg of dry matter		
Cu	1.4	1.7
Mg	3.0	6.0
Fe	33.3	43.5
Zn	18.4	19.5

Proceeding from the analysis of data in Table 4, the application of produced organo-mineral fertilizer to the section for growing potato leads to a significant increase in its yield and in the content of starch and microelements in potato. The obtained results are important both from the standpoint of effective use of municipal waste and in the view of creating a stock of effective organo-mineral fertilizers. The importance of this direction lies in the fact that the abuse of artificial (or mineral fertilizers) whose production is accompanied by huge raw and power consumption is very harmful for land and water resources and pollutes air.

OBTAINING OF HIGH-ENERGY GASES

Thermal treatment is the most widespread (after deposition) method for municipal waste treatment, although it is quite expensive, especially, for getting the samples with required moisture content. The most widespread method of sludge disposal is incineration (combustion). There are numerous proposals concerning the organization of this process, with diversified equipment for combustion in fixed bed, dynamic and fluidized bed furnaces designed. Despite its relative simplicity, the prospects for widespread use of simple combustion, when the resulting heat is not always utilized, are questionable. More effective methods are pyrolysis and gasification, and among them, in our opinion, the most interesting is thermal decomposition under rapid heating when the desired temperature is reached for 0.5—1 minutes. Fast pyrolysis enables to organize continuous closed production process without gum formation and to reduce energy costs by, at least, 30%, i.e. to significantly cheapen the final product.

The possibility of fast pyrolysis by thermal decomposition of various organic materials: sludge from biological WWTP (Ukraine, Kyiv, BSA) and (Bursa, Turkey): switchgrass *Panicum virgatum* L., pine sawdust, rubber crumb, and polyethylene terephthalate (PET) waste. The samples were heated by induction heater KX-5188A25. Reactor temperature (1100 °C) was set by induction currents based on the experimental conditions. Varying inductor's power enables to adjust the intensity of heating for 10—25 seconds i.e. to take into account the heating rate and time factor of material stay in the reactor. The raw material is downloaded 5 hours. Before run, the plant is purged with nitrogen in order to ensure a slowdown in oxidation processes that lead to the formation of undesired carbon dioxide when generating high-energy gas. For the circulation of gases generated, the process scheme foresees a circulation pump with a capacity of 30 l/h.

The Figure shows the scheme of laboratory plant for high-temperature fast pyrolysis. Table 5 contains the results obtained for thermal decomposition of organic waste of different origin. It can be seen that the amount of hydrogen gas as a component of energy varies from 15 to 50%, depending on the type of material. For PET, hydrogen yield is the lowest because of its negligible content in the material. Pyrolysis of pine sawdust and switchgrass yields hydrogen and carbon monoxide at concentrations that are relevant to the content of these components in rubber crumb. Carbon monoxide yield is fixed at 42% for PET that contains a lot of oxygen in its structure. A comparison of the municipal sludge has showed that Kaniv WWTP sludge is the most mineral-

Table 5

Chemical Content of Gaseous Phase Obtained by Thermal Decomposition of Organic Waste in Fast Heating Mode

Gas component	Content in gaseous phase, % (vol.)						
	Sludge of BAS, Ukraine	PET	Rubber crumb	Switchgrass	Sludge of Kaniv WWTP	Sludge (Bursa, Turkey)	Pine sawdust
H_2	49.2 /53.3	15.5/17.2	31.5/34.5	36.5/43.8	26.1/33.2	30.5/43.3	32.5/44.1
N_2	5.5/4.0	4.6/4.2	1.0/3.5	2.6/3.2	3.8/5.1	3.9/5.0	4.3/5.8
CO	23.7/30.8	41.8/45.9	35.3/37.0	31.8/37.8	29.4/32.6	34.3/31.6	33.0/49.0
CH_4	4.8/3.6	8.4/6.4	7.1/6.1	6.4/5.3	5.1/3.9	6.9/5.7	6.7/5.6
Hydrocarbons $C_2 - C_7$	0.9/0.5	1.2/0.8	1.0/0.8	0.9/0.2	1.1/0.4	1.0/0.5	1.0/0.2
CO_2	16.1/7.9	28.5/25.5	24.1/18.1	21.7/9.7	34.7/24.8	23.4/14.0	22.5/5.4

ized [21]. High mineralization is reported also for sludge from Bursa WWTP, where the effluents are treated with lime. Finally, BAS sludge has the highest content of organic matter, which determines its highest effectiveness in terms of flammable components (Table 6).

Generated gas recirculation through the heating area with carbon ensures increase in the quantity of hydrogen and carbon monoxide, with that of carbon dioxide and methane decreasing for all samples studied. This means the generated gas recirculation through the heating area ensures carbon dioxide conversion and methane decomposition.

Above 1000 °C, there is carbon dioxide disproportionation as a result of contacting carbon ($CO_2 + [C] \rightarrow 2CO$): here, this coal releases as a result of high-temperature pyrolysis of carbon-containing materials.

Above 1000 °C, methane transforms according to the reaction scheme $CH_4 \rightarrow [C] + 2H_2$, with formation of hydrogen and graphitic carbon. Hence, generated gas circulation lead to the creation of additional hydrogen and carbon monoxide. For more complete carbon conversion at high-temperature pyrolysis, water gas reaction, namely, dosed feed of water or steam to heat-up carbon (1000—1300 °C): $[C] + H_2O \rightarrow CO + H_2$ can be used.

Hence, thermal decomposition with generated gas recirculation through the reaction zone enables to obtain high-calorific product, to control and to change proportion of its components, and to ensure full conversion of carbon residue into gaseous phase, if necessary.

Table 6

Content of Organic and Nonorganic Components in Municipal Waste of Different Origin (Thermal Decomposition at 900 °C), %

Raw	Inorganic part	Organic part
BAS sludge	32.4	67.7
WWTP sludge (Bursa, Turkey)	52.7	47.4
Kaniv WWTP sludge	57.4	42.6

Table 7 shows high and low combustion heat of obtained gases and calorific capacity factors estimated for both stationary conditions of thermal decomposition and for the case of generated gas recirculation.

USE OF SLUDGE FOR OBTAINING PRESSED MIX FUELS

The idea to use sludge for producing mixed fuel there has existed for a long time. Typically, a mix consists of low-grade coal (mostly coal dust) or peat, sewage sludge and other components. Criterion of «right to exist» for the mixed fuel is its calorific value and ash content. In terms of utilizing fuel that has no use (coal dust) or limited use (peat, brown coal) and sewage sludge as energy source the feasibility of mixed fuel production is undeniable.

Table 7

Estimated High and Low Combustion Heat of Obtained Gases and Their Calorific Capacity Factor

Combustion heat Q, kJ/kg*	Sludge of BAS, Ukraine	PET	Rubber crumb	Switchgrass	Sludge of Kaniv WWTP	Sludge (Bursa, Turkey)	Pine sawdust
Q_{high}	11 800/ 12 500**	11 500/ 11 100	12 000/ 12 100	11 900/ 12 700	9800/ 10 200	11 700/ 12 200	11 700/ 14 300
Q_{low}	10 600/ 11 300	10 700/ 10 400	11 000/ 11 100	11 100/ 11 600	9000/ 9400	10 700/ 11 000	10 700/ 13 100
Calorific capacity factor**	0.3614/ 0.3853	0.3648/ 0.3546	0.3750/ 0.3785	0.3785/ 0.3955	0.3069/ 0.3205	0.3648/ 0.3750	0.3648/ 0.4466

* — estimated according to [22]; ** — low heat to high heat ratio of conventional fuel (29330 kJ/kg).

Table 8

Content of Oxide Components in Inorganic Part of Municipal Sludge, %

Components of inorganic part of sludge	Component content		
	BAS sludge	Bursa WWTP sludge (Turkey)	Kaniv WWTP sludge
Al_2O_3	12.9	11.3	13.6
CaO	11.7	19.0	9.7
Fe_2O_3	6.6	13.0	15.5
SiO_2	59.1	42.8	44.3
SO_2	1.2	5.1	6.9
P_2O_5	4.2	3.1	6.1
K_2O	2.0	2.7	3.9
Cr_2O_3	0.3	0.1	–
CuO	0.2	0.1	–
MnO_2	0.2	0.2	–
Ni_2O_3	–	0.1	–
TiO_2	0.8	1.9	–
ZnO	0.5	0.5	–
PbO	0.1	–	–
Other oxides	0.1	0.1	0.1

Several options for the production of pressed fuel (coal dust-oil slim-sludge; peat-sludge-oil slim; coal dust-lignin-sludge-oil slim; and fiber waste-sludge-coal tar) have been proposed. Irrespective of composition, the manufacturing process is almost identical: grinding, stirring to form a homogeneous mass, drying (if necessary), and pressing. The mix is formed by pressing without/or with the addition of binder. Changing the nature of components in the mixture enables to obtain a material with calorific value of, at least, 14650–25100 kJ/kg, with the component ratio selected in such a way as the ash content in the final product does not exceed 15% of initial volume.

TREATMENT OF ASH RESIDUE FROM THERMAL DECOMPOSITION OF MUNICIPAL SLUDGE

The fast heating thermolysis reactor generates two products: the high-energy gas that can be used at the place of its generation or after additional purification can be supplied to other customers and the mineral part (ash) which content is showed in Table 8. Obviously, the storage of sludge in open ponds, where there is a risk of direct contact between heavy metals and ground waters, is very undesirable, insofar as some metal compounds can form when contacting water, which entails their migration into soils and water resources. No need to focus attention on the fact that the majority of heavy metals and their compounds is highly toxic and accumulates in tissues of living organisms with adverse consequences. This is a reasonable ground for raising a problem of managing both sludge itself and ash residue from, for example, thermal decomposition of sludge.

The developed approaches are reduced to processing of ash residue with obtaining metal oxide mixes and separate silicon dioxide. Irrespective of sludge origin, silicon dioxide extraction accounts for 96–97.5% at a purity of 99.98%, 99.87% and 99.97% for BAS, Bursa WWTP and Kaniv WWTP, respectively. The received dioxide is amorphous that essentially simplifies further purification from impurities for getting solar-grade silicon. It is obvious that extraction of more than 95% silicon dioxide means enrichment of obtained residue with oxides contain in it. Working with such systems it is necessary to pay attention to the presence of phosphorus in them, inasmuch as obtained residue can be further used as source of phosphorus.

One more promising application for the obtained ash is its use as raw material for inorganic coagulants. It is advisable to analyze the results obtained in the course of developing coagulants based on Mykolaiv alumina refinery sludge (hereinafter, the sludge) [23]. The sludge was treated with mineral acids of various concentrations, with obtained solutions used for river water (Table 9) and wastewater (Table 10) purification.

The reagents obtained from sludge treatment with 5% acid solution are seen to be quite effective for purification of river water and as good as known reagents and to exceed them by activity either.

Comparison of composition of sludge and ash residue after silicon dioxide extraction (Table 11)

Table 9

Coagulant Effect on the Desna River Water Purification

Coagulant	Oxide content, % wt.		Color index, deg	Turbidity, mg/l	Alkalinity, mEq/l
	Al_2O_3	Fe_2O_3			
Aluminum sulfate	15.4	—	21	4.4	4.5
Sludge + 5% HCl	2.2	1.6	19	4.5	4.3
Sludge + 5% HCl	4.3	3.2	14	3.2	3.6
Sludge + 5% HCl	6.5	4.8	11	2.6	3.0
Sludge + 5% H_2SO_4	5.2	0.5	14	3.2	3.1
Sludge + 5% H_2SO_4	10.5	1.0	8	1.4	1.7
Sludge + 5% H_2SO_4	15.7	1.4	5	2.0	0.2

Note. Initial water: temperature 2 °C; color index 26 degrees; turbidity 4.5 mg/l; alkalinity 4.6 mEq/l. Quality was determined after water precipitation for 30 min.

Table 10

Coagulant Effect on Household Wastewater

Coagulant	Dose by Al_2O_3, mg/100 ml	Dose by Fe_2O_3, mg/100 ml	Weighted substances, mg/l	Phosphates, mg/l
Sizol-2500	0.77; 3.85	—	25.2; 6.35	3.07; 3.00
Polvak	3.2; 16.0	—	4.41; 3.90	1.80; 1.40
Aluminum sulfate	0.385; 7.7	—	9.80; 9.35	0.28; 0.11
Sludge + 5% HCl	1.09	0.80	5.45	0.53
Sludge + 5% HCl	2.17	1.59	2.50	0.14
Sludge + 5% H_2SO_4	2.62	0.24	14.80	0.47
Sludge + 5% H_2SO_4	5.24	0.48	10.40	0.33

* Content at the inlet of WTP: weighted substances 140.0 mg/l; phosphates 14.8 mg/l.

Table 11

Chemical Composition of Sludge and Ash Residue from Thermal Decomposition of Municipal Sludge after SiO_2 Extraction

Components, % wt.	Sludge		Ash residue from thermal decomposition of municipal sludge after SiO_2 extraction *		
	[23]	[24]	BAS sludge	Bursa WWTP sludge	Kaniv WWTP sludge
Fe_2O_3	67.4	40—55	15.4	22.3	27.2
Al_2O_3	11.4	14—18	30.2	19.2	23.7
CaO	3.4	5—10	27.3	32.4	16.9
SiO_2	6.1	5—10	4.5	2.4	2.5
TiO_2	2.9	4—6	1.9	3.6	—
Na_2O	0.4	2—4	—	—	—

* — Estimate of average degree of silicon dioxide extraction is 96.75%.

has showed that the ash residue in terms of content of iron and aluminum as key components of coagulant is suitable as source of raw material for its obtaining. The use of various mineral acids not only significantly expands the capabilities of the proposed method, but also enables to produce reagents for specific tasks of water system purification. The instrumental component of process scheme is based on simple chemically stable capacitive equipment with a mixer and affordable chemically stable pump system. The residue after treatment with acid is expected to be used as filler for construction mixes, road construction, and building materials.

CONCLUSIONS

The proposed scheme foresees an integrated approach to municipal sludge treatment. The common stage — sludge preparation — can include a line for pretreatment of working material and its dewatering until required moisture content. The next stages are defined by several factors and can include the following lines: production of organic soil or organo-mineral fertilizer; production of fuel composites; thermal treatment by fast pyrolysis (mandatory or desired).

Thermal decomposition must be added with a line for ash reside processing. This line can be oriented towards fractioning this residue to obtain metal oxides, construction materials and other marketable products (for instance, coagulants).

REFERENCES

1. Artem'iev S.S., Hajdabuka V.Ye.. Zberihannia ta utylizatsiia vidkhodiv. Shliakhy vyrishennia problemy. *Vestnyk NTU "KhPY" (Bulletin of the National Technical University KhPI)*. 2009. No. 22. P. 40—48 [in Ukrainian].
2. Falck F.Y., Ricci A.J. *5000 day for rescue of planet*. CUTU. Wolff, 1992.
3. Smetanin V.I. *Zashhita okruzhajushhej sredy ot proizvodstvennyh i bytovyh othodov*. Moskwa: Kolos, 2000 [in Russian].
4. Lifshic A.B. Sovremennaja praktika upravlenija tverdymi bytovymi othodami. *Chistyj gorod (Clean city)*. 1999. 1(5): 2—10 [in Russian].
5. Zhuhovickij V.B., Meller V.Ja., Tugov A.N. *Utilizacija tverdyh bytovyh othodov. Dnepropetrovsk*, 2011 [in Russian].
6. Grinin A.S., Novikov V.N. *Promyshlennye i bytovye othody: khranenie, utilizacija, pererabotka*. Moskwa, 2002 [in Russian].
7. Jeskin N.B., Tugov A.N., Izjumov M.A. Razrabotka i analiz razlichnyh tehnologij szhiganija bytovyh othodov. *Razvitie tehnologij podgotovki i szhiganija topliva na jelektrostancijah*: sb. nauch. st. Moskwa, 1996. P. 77—84 [in Russian].
8. Pal'gunov P.P., Sumarohov M.V. *Utilizacija bytovyh othodov*. Moskwa, 1990 [in Russian].
9. Fedotova O.G. Analiz podhodov k pererabotke tverdyh promyshlennyh i bytovyh othodov. *Nauchnye trudy Doneckogo nacional'nogo tehnicheskogo universiteta. Serija: jekonomicheskaja (Scientific works of Donetsk National Technical University. Series: Economic)*. 2003. No. 68: 135—141[in Russian].
10. Parfenjuk A.S. Krupnomasshtabnaja kompleksnaja pererabotka tverdyh uglerodistyh promyshlennyh i bytovyh othodov. *Koks i himija (Coke and Chemistry)*. 2001. No. 5: 41—46 [in Russian].
11. Prokip A.V. *Ekoloho-ekonomichna otsinka zamischennia nevidnovliuvanykh enerhoresursiv biolohichno vidnovliuvanymy: monohr*. Lviv, 2010 [in Ukrainian].
12. Schokin A.R., Kolesnyk Yu.V. Perspektyvy vyrobnytstva i zastosuvannia biopalyva v Ukraini [Elektronnyj resurs]. *Elektronnyj zhurnal enerhoservysnoj kompanyy «Ekolohycheskye systemy» (Electronic magazine of an energy service company «Ecological systems»)*. 2003. URL: http://www.esco.co.ua/journal/2003_5/art79.htm [in Ukrainian]. (Last accessed: 20.11.2016)
13. Lotosh V.E. *Pererabotka othodov prirodopol'zovanija*. Ekaterinburg, 2007 [in Russian].
14. Turovskij I.S. *Obrabotka osadkov stochnyh vod*. Moskwa, 1988 [in Russian].
15. Evilevich A.Z., Evilevich M.A. *Utilizacija osadkov stochnyh vod*. Leningrad, 1988 [in Russian].
16. Gol'dfarb L.L., Turovskij I.S., Beljaeva S.D. *Opyt utilizacii osadkov gorodskih stochnyh vod v kachestve udobrenija*. Moskwa, 1983 [in Russian].
17. Baliuk S.A., Lisovyj M.V. *Kontseptsiia ahrokhimichnoho zabezpechennia zemlerobstva Ukrainy na period do 2015 roku*. Kharkiv, 2009 [in Ukrainian].
18. Evdokimenko A.N., Kashkovskij V.I., Pisanko N.V., Bublyk V.A., Evdokimenko A.N. Kombinirovannye ochistnye sooruzhenija dlja nebol'shih gorodov i naselennyh punktov Ukrainy. *Voda: tehnologija i jekologija (Water: chemistry and ecology)*. 2010. No. 2: 55—70 [in Russian].
19. SOU ZhKH 03.09-014:2010 Pobutovi vidkhody. Tekhnolohiia pereroblennia orhanichnoi rechovyny, scho ie u skladi pobutovykh vidkhodiv. 2010. URL: http://www.dnop.com.ua/dnaop/act18300.htm [in Ukrainian]. (Last accessed: 20.11.2016).
20. Tekhnolohichni ta ahroekolohichni normatyvy vykorystannia osadiv stichnykh vod mis'kykh ochysnykh sporud u sil's'komu hospodarstvi. KND 33-3.3-02-99. Vydannia ofitsijne. Kyiv, 2000 [in Ukrainian].

21. Kashkovs'kyj V.I., Yevdokymenko V.O. Vprovadzhennia resursozberihaiuchoi tekhnolohii ochyschennia komunal'nykh stokiv iz zastosuvanniam anaerobnykh psykhrofil'nykh reaktoriv. *Materialy vtoroj Mezhdunarodnoj nauchno-prakticheskoj konferencii «Sovremennye resursosberegajushhie tehnologii. Problemy i perspektivy»*. Odessa. 2012. 161—167 [in Ukrainian].
22. Nauchno-metodicheskie materialy dlja opredelenija teploty sgoranija uglevodorodov sostava $C_XH_YO_Z$. URL: http://servis-teplo.ru/sgoranija-uglevodorodov [in Russian]. (Last accessed: 20.11.2016).
23. *Patent Ukrainy No. 77315*. Kashkovs'kyj V.I., Vojnovskyj V.V., Matiash L.P., Zubenko O.V., Matvijchuk D.A.; Sposib oderzhannia koahuliantu (Process for coagulant producing). Priorytet vid 15.11.2006 [in Ukrainian].
24. Hubina V.H., Kadoshnikov V.M. Chervonyj shlam Mykolaivs'koho hlynozemnoho zavodu — tsinna tekhnohenna syrovyna. *Heoloho-mineralohichnyj visnyk. (Geology and Mineralogy Bulletin of the Kryvyi Rih National University)*. 2005. No. 2: 122—126 [in Ukrainian].

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КОМПЛЕКСНА ТЕХНОЛОГІЯ ПЕРЕРОБКИ ДЕЯКИХ ОРГАНОМІНЕРАЛЬНИХ ВІДХОДІВ

Роботу присвячено вирішенню важливої екологічної проблеми – переробці осадів комунальних стічних вод. Запропоноване технологічне рішення включає наступні стадії: попередня підготовка вихідного матеріалу; його термічний розклад з отриманням високоенергетичного газу; виготовлення органомінеральних добрив та штучного ґрунту; одержання паливних пелет; переробка зольного залишку стадії терморозкладання осаду з метою утворення сумішей оксидів металів, ефективних коагулянтів, будівельних і декоративних матеріалів.

Ключові слова: осади комунальних стічних вод, переробка, високоенергетичний газ, органомінеральні добрива, суміші чистих оксидів металів.

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КОМПЛЕКСНАЯ ТЕХНОЛОГИЯ ПЕРЕРАБОТКИ НЕКОТОРЫХ ОРГАНОМИНЕРАЛЬНЫХ ОТХОДОВ

Работа посвящена решению важной экологической проблемы — переработке осадков коммунальных сточных вод. Предложенное технологическое решение включает следующие стадии: предварительная подготовка исходного материала; его термическое разложение с получением высокоэнергетического газа; изготовление органоминеральных удобрений и искусственного грунта; получение топливных пеллет; переработка зольного остатка стадии термического разложения осадков с целью получения смеси оксидов металлов, эффективных коагулянтов, строительных и декоративных материалов.

Ключевые слова: осадки коммунальных сточных вод, переработка, высокоэнергетичный газ, органоминеральные удобрения, смеси чистых оксидов металлов.