Journal of Multidisciplinary Engineering Science and Technology (JMEST)
ISSN: 2458-9403
Vol. 7 Issue 3, March - 2020

Engineering Problems Of Dehydration Of Sewage Sludge

B.S. Ksenofontov, professor
Department of Ecology and Industrial Safety
Bauman Moscow State Technical University
Moscow, Russia
ksenofontov@bmstu.ru

S.N. Kapitonova, docent
Department of Ecology and Industrial Safety
Bauman Moscow State Technical University
Moscow, Russia
s.n.kapitonova@bmstu.ru

A.A. Zhigalova, student
Bauman Moscow State Technical University
Moscow, Russia
nastia.175@mail.ru

***Abstract*—The engineering problems of processing of sewage sludge in devices of a new type- flotation combine machine are considered. Experimental research of thickening process of activated sludge suspension after secondary tank in the flotation combine machine are conducted. Further dehydration with using of the proposed scheme of drying with the closed circuit heat carrier system is possible. A unit of preparation of the heat carrier, a drying chamber, a device for unloading the finished product, a waste drying agent cleaning system, a waste heat carrier post-treatment unit, a two-circuit system of pneumatic conveying in the scheme are included. An entry of toxic sludge substances into the environment in the offered scheme is excluded.**

Keywords— activated sludge, dehydration, flotation combine machine, sewage sludge.

I. Introduction

The problem of processing of settled sludge particularly the excess activated sludge and its utilization for the last decades has been very relevant, and so far no universal ways of problem solution in this direction have been noticed [1],[5],[7],[8],[11]. Heavytonnage waste products are still disposed marginally, and most of it is stored at landfills [14]. In this regard, new technical solutions are extremely relevant for practical technologies for the processing and utilization of various wastes [4],[10],[13]. The solution of engineering problems concerning to deliquefaction of sewage sludge, including an excess activated sludge has been of a special interest [6], [12], [15].

II. Materials and Method

We have developed a multifunctional flotation combine machine [9] both for sewage cleaning and for deliquefaction of sewage sludge, including an excess activated sludge.

The flotation combine contains a housing on the outside of which there are nozzles for feed water supply, diversion of renovated water and spent slurry letdown and sediment removal, and perforated baffle plates and a purified water device installed inside the housing. At the same time, the flotation combine additionally contains a nozzle of power fluid supply, a flotation sludge thickening unit in the form of an ejector articulated with a hydrocyclone, and a sewage sludge deliquefaction unit consisting of a crimping device, inside of which a bag from synthetic material is placed, and a bottom for collecting the filtrate is located. Moreover, the ejector is made with a pressure drop from 0.05 to 0.5 m, and the synthetic material has cells ranging from 0.001 to 0.1 mm.

Flotation combine (Fig. 1) includes a housing 1, on the outside of which there are nozzles for waste water supply 2 and diversion of purified water 3, a froth-overflow launder 4 with a nozzle 5 for flotation sludge discharge, an ejector 6 with a nozzle 19 for air pressure supply and an outlet nozzle 9, a hydrocyclone 8, a nozzle for concentrated flotation sludge discharge 10, a clarified wastewater nozzle 7 with discharge piping 11, a sludge discharge nozzle 12 and a supply power fluid 21. On the outside of the housing, a sludge deliquefaction unit 13 is additionally installed, consisting of an internal chamber 14 with external control devices 15 and a hose clamp 16. At the same time, a tray for collecting purified liquid 17 is located in the lower part of the flotation combine machine, and perforated baffle plates 20 and a purified water outlet device 18 are installed inside the flotation combine machine.

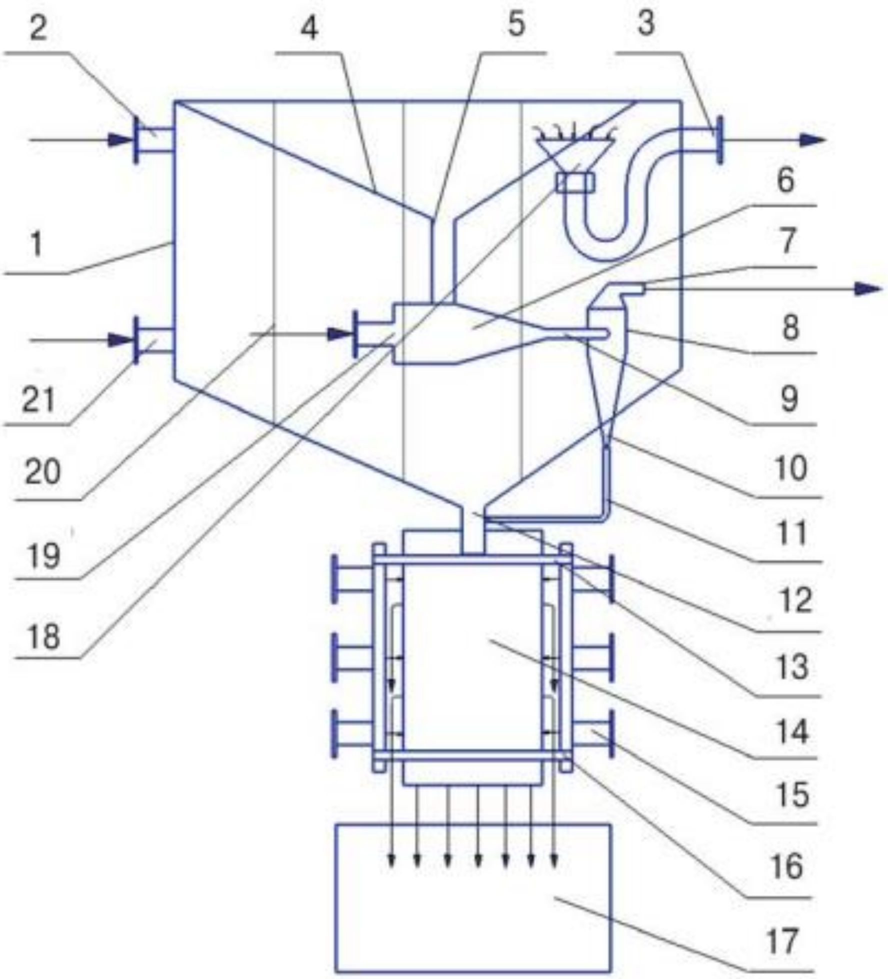

Fig. 1 scheme of flotation combine machine

The principle of operation is as follows. The original feed sewage water supply or mixed liquor through the nozzle 2 enters housing 1 of the flotation combine machine, where it mixes with a working fluid, which enters the nozzle 21. As a result of mixing of these flows, the flotation complexes with a particle of contamination - gas bubbles contained in the power fluid are formed. Formed flotation complexes with big bubbles 1 mm in size and more, surface up to the bubble column fast enough, and flotation complexes with smaller gas bubbles called microflotation complexes, are carried away by the flow of purified liquid, which is then filtrated through perforated baffle plates 20. Microflotation complexes coalesce passing through perforations, uniting into larger flotation complexes, and then surface up to the bubble column, which is gathered in a froth-overflow through launder 4 and quickly discharged through the nozzle 5, and purified fluid through the level control device 18 and then through the nozzle 3 is discharged from the flotation combine machine. The flotation sludge discharged through the nozzle 5 is sucked into the ejector 6, where under the action of forced air supplied through the nozzle 19, it is destroyed and passed into a suspension containing screenings. Thus, the ejector's efficiency is achieved when the required pressure drop ranges from 0.05 - 0.5m. Outside these limits, the necessary positive effect of the destruction of the flotation sludge structure and its following effective thickening is not observed. After the ejector 6, the suspension heads to the hydrocyclone 8, where it is divided into a thickened concentrate water and purified liquid, discharged respectively through nozzles 10 and 7. At the same time, the thickened concentrate water is passed through a pipe-line 11 and then through a pipe-line 12 to the internal space of the dehydration unit 13, where it is situated a bag 14 made of synthetic material with cells ranging in size from 0.001 to 0.1 mm. The necessary effect of thickening the sludge using synthetic fabrics with a cell size outside the specified limit is not observed. Then under the action of external control devices 15 the filled bag is pressed, that leads to the following deliquefaction of the sludge.

Holding the bag 14 in an unchanged position, is carried out by a hose clamp 16. The squeezed from the sludge liquid is collected in the tray 17. After squeezing the liquid out of the sludge, the bag 14 is removed from the dehydration unit 13 and sent for disposal. As a result of usage of new additional units in the flotation combine, the fast bleed-off of screenings from the inner space and their subsequent thickening, which ultimately leads to an increase efficiency of cleaning due to a rapid decline in the rate of particles falling out of the bubble column and to the achievement of the thickened sludge in a single device - flotation combine machine, are improved.

III. Results and Discussion

The determination of the optimal operating mode for activated sludge was carried out at various ratios of the initial suspension of activated sludge and power fluid, and also by varying the processing time of the separated mixture. The experimental results are presented in the table 1.

The analysis of the data presented in the table shows that the best results were achieved when there is processing activated sludge in a flotation combine machine with a ratio of the initial suspension of activated sludge and power fluid is 2:1 and a treatment time during 20 minutes. Using this operating mode, a concentration of activated sludge biomass of more than 6% ADS is achieved, which makes such a sludge transportable, and also, if necessary, suitable for feeding to ceramic drying, which, is appropriate during processing precipitation in individual cases, when called upon by a number of developers [2],[3].

In this case, it is better to use drying with a closed circuit system with a heat-transport medium to prevent the ingress of toxic matter from the sludge into the environment, which is extremely important, as many plants dry or burn sludge without such kind of detoxifying system.

Figure 2 shows a principle diagram of a drying process with a 100% closed circuit system with a heat-transport medium. The sludge deliquefaction facility includes a heat-transport medium preparation unit 1 (drying agent heater), a heat-exchange unit 5, a chamber drier 7 containing a spraying mechanism 6, gas approach 8 and exhaust gas flue 9 of the drying agent, a device for unloading the finished product, including a cyclone separator for output the finished product from small to large circuit pneumatic conveying system, a waste drying agent cleaning system in view of a group of cyclone separators 10, a Venturi scrubber 13 with a droplet separator 14, a condenser 10, a waste heat-transport medium post-treatment unit 15, a two-circuit system of pneumatic conveying 23 of the finished product, including the unloading cyclone separator 19 with an additional feed into it of the flow from the unloading cyclone separator 20 to the silo tower 18 and the separation device of the cross form 24. The gas flows are circulated by fans 2,3,4,11,12,21,22.

Table 1 separation efficiency of activated sludge suspension dependency on operation mode in flotation combine machine.

The flotation process mode		Concentration of biomass, % ADS (absolutely dry substance)		
The ratio between initial suspension and working fluid	Period of separation, min	In the initial suspension	In the sludge	In the purified water
5.0:1.0	5	0.81	3.50	0.24
4.5:1.0	7.5	0.81	3.76	0.18
4.0:1.0	10	0.81	3.98	0.17
3.5:1.0	12.5	0.81	4.47	0.15
3.0:1.0	15	0.81	5.66	0.14
2.5:1.0	17.5	0.81	6.14	0.13
2.0:1.0	20	0.81	6.30	0.11
1.5:1.0	22.5	0.81	5.97	0.17
1.0:1.0	25	0.81	3.86	0.25
0.5:1.0	27.5	0.81	1.90	0.36

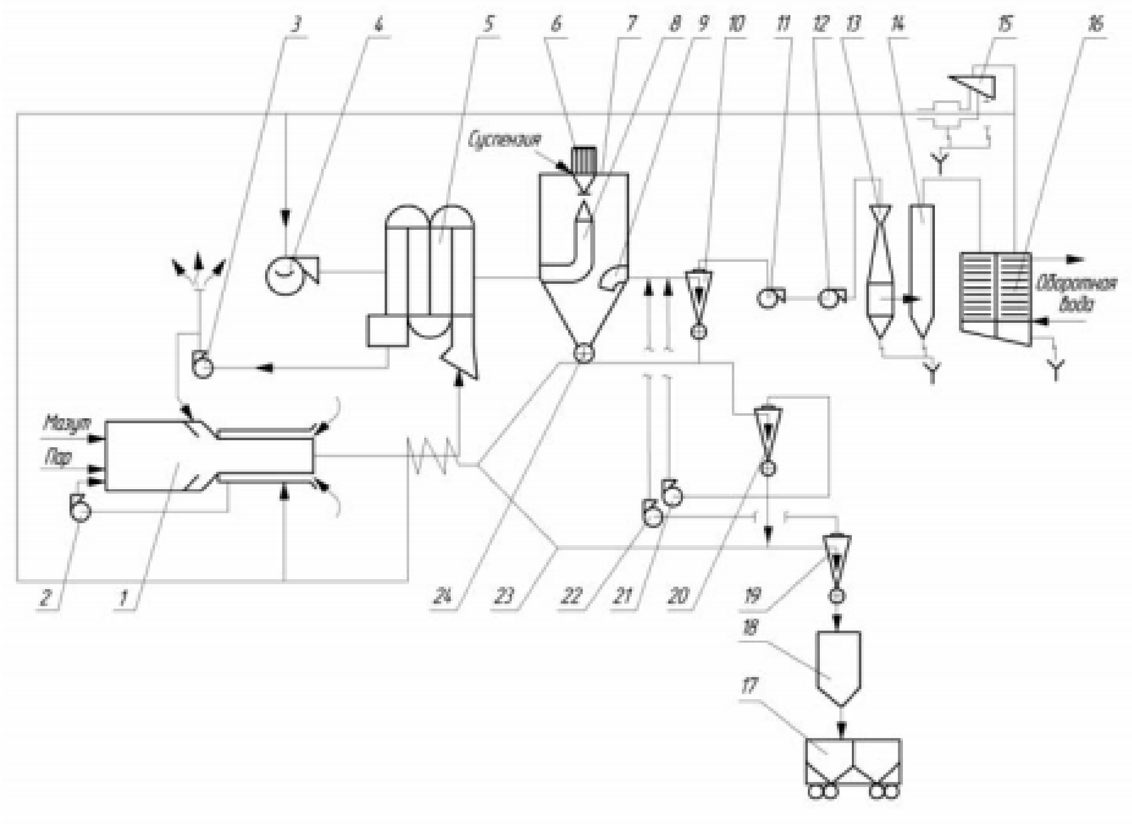

Fig. 2 the principle drying process scheme with 100% closed circuit heat carrier

Installation works as follows.

The dryable suspension is fed by a spraying mechanism 6 into the chamber drier 7, where the suspension sprayed to the smallest particles is dehydrated for a short period of time. The dried product through the unloading cyclone separator 19 enters the silo tower 18 and then into the intake tank 17. The waste drying agent with a temperature of 100-120 °C through exhaust gas flue 9 is cleaned in a group of cyclone separators10 and in a Venturi scrubber 13 with a droplet separator 14. Then the waste drying agent with a temperature 65-85 °C enters the condenser 16, where its temperature is decreased to 45-55 °C due-to a contact with in zigzag order arranged pipes through which the liquid refrigerating agent circulates.

As a result of decreasing the temperature of the drying agent (in the condenser 16), there occurs partial condensation of the moisture contained in it, which is removed from the condenser in liquid form. Then, the waste drying agent with a temperature of 45-44 °C entering the waste heat-transport medium post-treatment unit 15 passes through the gas pipe into the drying agent heater, and part of it goes to the a two-circuit system of pneumatic conveying system of the product and then to the silo tower 18. In this case, the waste heat-transport medium is fully (100%) used repeatedly without emission into the atmosphere. The usage of a condenser 16 and a unit 15 for the post-treatment of the waste heat-transport medium allows to achieve a high degree of purification of the waste heat-transport medium, which makes it possible to carry out its 100% return to the drying stage.

IV. Conclusion

As a result of the drying process with a 100% closed circuit system in the device receives a product with a moisture content of not more than 10%. At the same time, the drying process is environmentally friendly, without emission of gas into the atmosphere, and moisture from the waste the liquid refrigerating agent is removed in liquid form.

The presented drying scheme guarantees the impossibility of transfer extremely hazardous substances of the sludge into the environment, that is very important when drying various liquid sludges containing toxic substances. The importance of the presented technical solutions for heat treatment of waste should be highlighted, as the people living near such plants consider, that gas-treating plants are ineffective. In our case, atmospheric pollutant emission is guaranteed to be excluded.

References

[1] Antonova, E. (2019) Determination of parameters of the water-air mixture generated by an ejection aeration system with a dispersing agent. IOP Conference Series: Materials Science and Engineering. Vol. 492., No. 1. IOP Publishing.

[2] Barber, W. P. (2009) Influence of anaerobic digestion on the carbon footprint of various sewage sludge treatment options. Water and Environment Journal, 23(3), pp. 170-179.

[3] Barjenbruch M., Berbig C., Ilian J., Bergmann M. (2011) Sewage sludge dewatering without flocculant aid (Schlammentwdsserung ohne Flockungshilfsmittel), WWT-online.de

[4] Cieślik, B. M., Namieśnik, J., Konieczka, P. (2015) Review of sewage sludge management: standards, regulations and analytical methods. Journal of Cleaner Production, 90, pp. 1-15.

[5] Gron' V.A., Korostovenko V.V., Shakhrai S.G., Kaplichenko N.M., Galaiko A.V. (2013) The Problem of oil slurries formation, upgrading and utilization (Проблема образования, переработки и утилизации нефтефламов.). Successes of modern natural sciences (Успехи современного естествознания), № 9, pp. 159-162.

[6] He, D. Q., Luo, H. W., Huang, B. C., Qian, C., Yu, H. Q. (2016) Enhanced dewatering of excess activated sludge through decomposing its extracellular polymeric substances by a Fe2O3-based composite conditioner. Bioresource technology, 218, pp. 526-532.

[7] Ksenofontov B.S. (1992) Sewage water treatment: flotation and thickening sludges (Очистка сточных вод: флотация и сгущение осадков). M. Khimiya, p. 144.

[8] Ksenofontov B.S. (2011) Water systems flotation treatment. Wastewater and soil flotation treatment. Saarbrucken , LAP LAMBERT Acad. Publ., p.189.

[9] Ksenofontov B.S. reg 18.04.2017 Pat. RF of useful device model «Flotation combine machine for sewage water treatment» (Патент Российской Федерации на полезную модель «Флотокомбайн для очистки сточных вод»). №170182, patent bulletin № 11.

[10] Ledakowicz, S., Stolarek, P., Malinowski, A., Lepez, O. (2019) Thermochemical treatment of sewage sludge by integration of drying and pyrolysis/autogasification. Renewable and Sustainable Energy Reviews, 104, pp. 319-327.

[11] Neumann, P., Pesante, S., Venegas, M., Vidal, G. (2016) Developments in pre-treatment methods to improve anaerobic digestion of sewage sludge. Reviews in Environmental Science and Bio/Technology, 15(2), pp. 173-211.

[12] Raheem, A., Sikarwar, V. S., He, J., Dastyar, W., Dionysiou, D. D., Wang, W., Zhao, M. (2018) Opportunities and challenges in sustainable treatment and resource reuse of sewage sludge: a review. Chemical Engineering Journal, 337, pp. 616-641.

[13] Turunen, V., Sorvari, J., Mikola, A. (2018) A decision support tool for selecting the optimal sewage sludge treatment. Chemosphere, 193, pp. 521-529.

[14] Zhang, X. P., Zhang, C., Li, X., Yu, S. H., Tan, P., Fang, Q. Y., Chen, G. (2018) A two-step process for sewage sludge treatment: Hydrothermal treatment of sludge and catalytic hydrothermal gasification of its derived liquid. Fuel processing technology, 180, pp. 67-74.

[15] Zhu, X., Yuan, W., Wu, Z., Wang, X., Zhang, X. (2017) New insight into sludge digestion mechanism for simultaneous sludge thickening and reduction using flat-sheet membrane-coupled aerobic digesters. Chemical Engineering Journal, 309, pp. 41-48.