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Intensification of oily waste waters purification by means of liquid atomization

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Abstract. In this research, a possibility of using liquid atomization for improving the efficiency of purification of wastewater by different methods has been studied. By the introduced method and an experimental setup for wastewater purification, saturation rate increases with its purification by means of dissolved air flotation. Liquid atomization under excess pressure allows to gain a large interfacial area between the saturated liquid and air, which may increase the rate of purified liquid saturation almost twice, compared to the existing methods of saturation. Current disadvantages of liquid atomization used for intensification of wastewater purification include high energy cost and secondary emulsion of polluting agents. It is also known that by means of liquid atomization a process of ozonizing can be intensified. Large contact surface between the purified liquid and ozone–air mixture increases the oxidizing efficiency, which allows to diminish ozone discharge. Liquid atomization may be used for purification of wastewaters by ultraviolet radiation. Small drops of liquid will be proportionally treated by ultraviolet, which makes it possible to do purification even of turbid wastewaters. High-speed liquid motion will prevent the pollution of quartz tubes of ultraviolet lamps.

1. Introduction

One of the priority guidelines of Russian Federation development is the rational use of natural resources including research in the field of environmental pollution prevention and liquidation [1]. Ecologists note a tendency of the decrease of wastewater discharge volumes, caused mainly by unstable and ineffective work of waste treatment facilities. Thus, according to the data of Federal agency “Rosgidrometr” (RU) during 2013 surface water bodies of Primorsky krai were polluted with 251 million cubic meters of nontreated wastewaters, and 67 million cubic meters were insufficiently treated [2]. The basic pollutants are oil products of industrial wastewaters of electrical power factories, shipbuilding, chemical and coal industries, machine engineering, metalworking production, and also of commercial, military, fishing, and small boats fleet. In 2012, Sea of Japan was polluted with 47.36 tons of wastewaters containing oil products; it is connected with the fact that most wastewater treatment facilities work on the principles of biological and chemical purification [3]. These methods are not able to provide the required concentration of oil products in wastewaters. At the same time, physicochemical wastewater treatment facilities require high initial and operational expenses. In this regard, intensification of current methods of wastewater purification is a crucial task.

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In this research, a possibility of using liquid atomization for improving the efficiency of different methods of purification, such as dissolved air flotation, ozonizing, and ultraviolet (UV) treatment, was studied.

2. Liquid atomization under dissolved air flotation

Flotation is an accelerated floating of water-repellent contaminative particles adhered to water bubbles. In accordance with the method of bubble supply into the water, flotation can be divided into mechanic, air-driven, pressure, and electrochemical. Among them, the most effective is dissolved air flotation, due to the smallest size of bubbles formed.

Traditional dissolved air flotation process is described below [4].

Oily water solution supersaturated with air is created in a head tank under high pressure. Then the water is supplied into the flotator where the pressure is almost equal to atmospheric pressure. Upon condition of pressure reduction, small bubbles appear and oily particles float to the surface.

For complete dissolving of air, liquid must be in the head tank under excess pressure for at least 5–10 min. This condition increases the dimensions and the mass of the head tank. Head tank volume is assessed as follows:

$$V=Q\cdot t/60, \qquad (1)$$

where V represents the tank volume, m3; Q the saturated liquid loss, m^3/h; and t the time of saturation, min. Solving eqn (1), if the saturated liquid loss is 10 m3/h and time of saturation is 10 min, then the tank volume is 1.6 m^3. Such big volume of the head tank limits the use of dissolved air flotation in constrained environment, for example, in ship waste treatment facility. According to this, one of the dissolved air flotation development tendencies is saturation time reduction with simultaneous raise of concentration of air dissolved in liquid. The existing methods of efficiency improvement of dissolved air flotation were studied in the research by Eskin et al. [5].

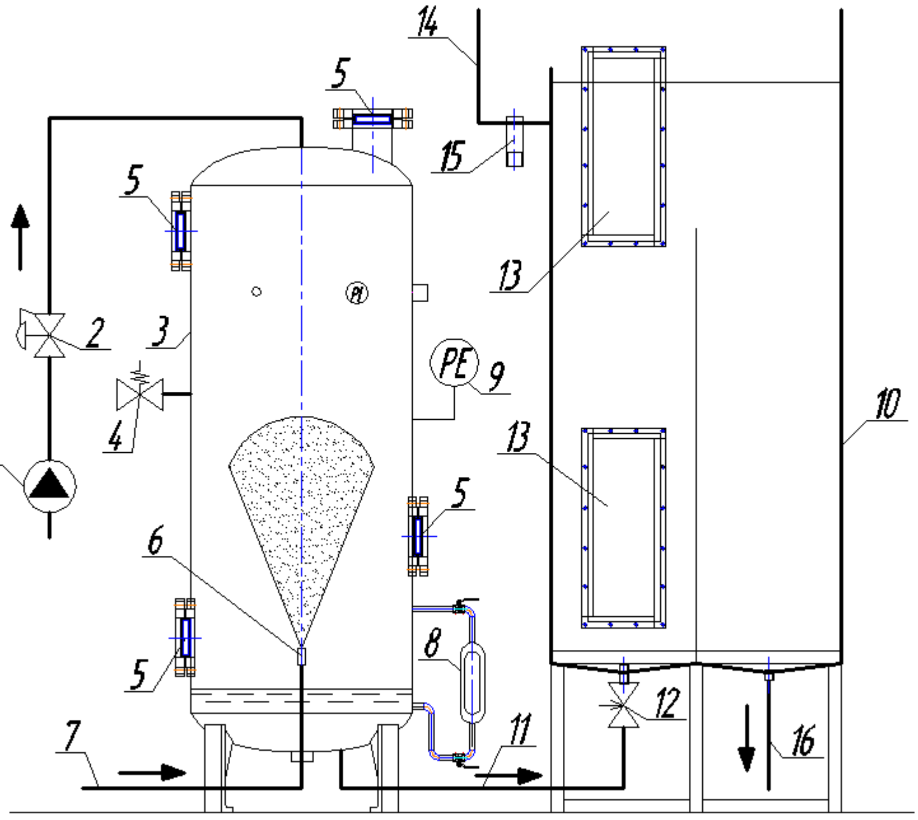

Figure 1. Dissolved air flotation experimental plant.

The researchers of the Department of Buildings and Constructions Engineering Systems at Far Eastern Federal University introduced a method and an experimental setup (Fig. 1) to intensify the process of liquid saturation with air [6]. In the head tank (3), the air pump (1) work creates excess air pressure, the rate of which is controlled by means of pressure sensor (9) and maintained by a permanent pressure controller (2). Purified liquid is supplied over the pipeline (7) under pressure to a pressure-operated atomizer (6). After flowing through the atomizer, the liquid is atomized in the form of flare, and the drops formed have an extra small diameter (less than 1 mm); thus, there is a large contact surface between liquid and gas phases from where liquid gets saturated with air almost in a moment. To protect head tank from pressure exceeding the maximum permissible level (8 bar), a safety relief valve is installed (4). For a visual observation of spray form and degree of dispersion, observation windows are provided (5), and the liquid level in the tank is controlled by means of level gauge (8). Saturated liquid over a pipeline (11) flows through a throttling valve (12) to the bottom part of the flotation tank (10). Under saturated liquid supply to a flotation cell its pressure abruptly reduces, and as a result, bubbling occurs with a subsequent formation of flotation complexes, which float on the surface due to low specific weight and a foam layer is formed. Flotation tank has a viewing window (13) with which you can control the speed of ascent and the size of the bubbles. Floated product is supplied to a collecting unit (14) and flowed out through a nozzle (15). Purified water flows out through a nozzle (16). The scheme of the experimental plant is shown in Fig. 1.

The use of this method allows to diminish the time of saturation and to increase the productivity of flotation plant, saving mass-dimensional measures. It is especially important in terms of using the plant in organic space. However, such a method may have a range of disadvantages.

The first possible disadvantage is secondary emulsification of oily particles. In the spray cone, an active turbulent liquid motion occurs, which may cause oil products' original drops to split into smaller drops. On the other hand, dissolved air flotation is predominantly used for preliminary purification of wastewaters after mechanical purification, with oily particles diameter ranging from 2 to 8 μm. It is possible that with such a small particle diameter, flow energy is not enough for a secondary emulsification of original oil products.

The second disadvantage of the introduced method is high energy costs in comparison with a traditional method of saturation. Atomizers have a significant pressure resistance, which requires using the pumps of high capacity with rather low coefficient of efficiency. However, liquid atomization has its advantages. First, it has a high speed with increase in the rate of liquid saturation, which may be a determining factor in terms of definite requirements to the conditions and speed of purification. Water saturation with air in a pulverizing absorber takes 75–95% of full theoretical one, while for a pressure tank of airlift type this measure is within the range of 16–35% [7]. Besides, energy costs for finely divided spray cone may be compensated by means of using other methods of purification such as ozonizing and UV treatment simultaneously with liquid saturation. These methods are discussed in detail in relevant sections of this work.

Another important question for the research is the emulsifying property of the pumps. In traditional method of water saturation, pumps with high emulsifying property are used [8]. For the purpose of creating pressure sufficient for liquid atomization under excess air pressure, it is required to use pumps with a strong thrust, for example, rotary-laminated pumps. These pumps are of extensional impact and it is supposed that their emulsifying abilities are lower than the abilities of rotary ones.

Purification of oily wastewater with liquid atomization by means of dissolved air flotation is a new method and it requires handling different theoretical and experimental researches.

Currently, an experimental plant has been prepared for operation, and it is planned to conduct experimental research for defining a quantity of absorbed air, emulsifying ability of liquid-operated atomizer and rotary-laminated pump through the use of this plant.

3. Liquid atomization under ozonizing

Ozonizing is one of the effective methods of purification of wastewaters of different origin [9, 10]. Ozone is the strongest oxidant and is able to annihilate bacteria, spores, and viruses. Water purification mechanism in terms of ozonizing method is based on ozone ability to block the activity of complex organic materials of protein nature present in living forms and plant bodies. Ozone dipole molecule fixates on charged particles and breaks double bonds with the formation of oxides.

One of the disadvantages of ozonizing method is its high cost. It is connected with high power costs for ozone production. Thus, for extraction of 1 kg of ozone, 28–30 kW of electrical energy is required. According to this, the reduction of ozone loss is an important task. Nowadays, liquid ozonizing reactors of airlift type with porous diffusors gain widespread application [11]. In these applications, ozone–air mixture is supplied to a vertical column through the porous diffusor, forming a large volume of drops (3 mm in diameter). The main disadvantage of this method is less space of contact surface between liquid and gas phases, and consequently, high cost of ozone and long-term water presence in the reactor.

Process of ozonizing may be intensified by means of its combination with dissolved air flotation, whose saturation is based on liquid atomization under excess pressure (Fig. 1). Instead of air, ozone–air mixture may be supplied to a pressure tank. While the liquid is saturated with air, pollution agents are oxidized. Due to large contact area between the phases, ozone, comparing with traditional methods of ozonizing, will interact with polluters dissolved in liquid more effectively. Due to this, purification efficiency rate increases and at the same time the ozone loss reduces. Saturated and ozonized liquid is supplied to a flotation tank. Bubbles formed under reduced pressure allow to derive insoluble products of oxidation and not oxide polluting matters from water.

4. Atomization under ultra-violet purification

Another effective method of purification is the use of UV radiation [12]. In recent years, this method attracted much attention in connection with ecologists concern about purified waters' residual chlorine impacting on the environment. UV radiation has a strong property and effective ability to destroy microorganism. When comparing with other methods of purification, UV radiation does not change the chemical composition of water. Water purification under UV radiation occurs due to UV rays' ability to destroy cellular membrane and nucleic acids: DNA and RNA. DNA destruction is possible due to rays' intake and consequent process of two thymine molecule combination. This process causes microorganism propagation deceleration and consequent extinction.

In the practice of water purification, wastewaters are radiated by UV with a definite wavelength and a definite intensity during the time stated. Treatment efficiency depends on three factors: (1) UV radiation intensity; (2) contact time; and (3) quality of waste flows (turbidity).

The main factor limiting the usage of UV radiation for purification is wastewater turbidity. If the quality of wastewater is bad, suspended matter prevents UV radiation penetration into wastewaters and the process efficiency decreases. Current requirements in the Russian Federation limit the usage of UV radiation for wastewater purification with suspended matter concentration over 10 mg/l. A low penetrating ability of UV radiation compels to increase its power, the number of lamps, and the time of liquid presence in the contact tank.

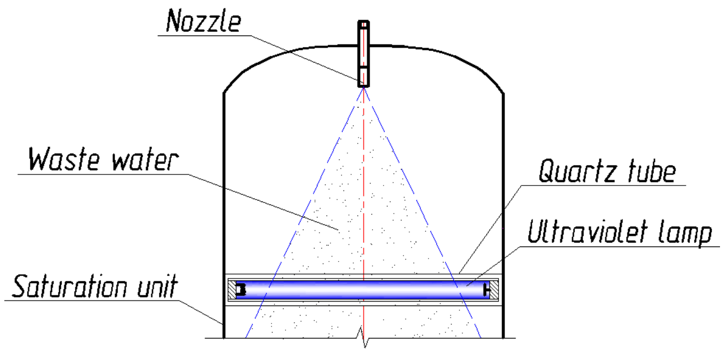

Figure 2. Atomized liquid ultraviolet treatment

Another disadvantage of UV radiation treatment is the need for periodical purification of quartz tubes (with UV lamps inside) from the pollution formed.

Both disadvantages described above may be eliminated upon definite conditions by means of liquid atomization. If the purifying method introduced (Fig. 1) includes UV lamps (Fig. 2), it will allow one to intensify the process of liquid purification.

It is supposed that liquid under atomization will be equally treated by UV radiation due to the small size of drops and a wide space between them. Besides, high-speed liquid motion after flowing out of the atomizer nozzle will prevent pollution on the surface of quartz tube.

5. Conclusion

Liquid atomization may be used for wastewater purification by different methods: dissolved air flotation, ozonizing, and UV treatment.

Traditionally, dissolved air flotation liquid saturation occurs in pressure tanks of airlift type. If saturation in pressure tanks is conducted using liquid atomization, the rate of saturation may be increased more than twice. In spite of the fact that liquid atomization requires using pumps of high capacities and high energy costs, this method may be used when the speed of liquid saturation and small dimensions of pressure tank are the most important factors.

By means of purified liquid atomization, ozonizing efficiency may be increased. Due to the large space of contact surface between small drops of liquid and ozone– air mixture, the oxidation process will be more intensive, and it will allow one to reduce ozone loss.

Liquid atomization may be used under purification of wastewater using UV radiation. Small drops of liquid will be equally treated by UV, which allows conducting purification even of turbid wastewaters. High-speed liquid motion will prevent the pollution of quartz tubes of UV lamps.

A possibility of using liquid atomization for wastewater purification must be estimated based on the required conditions of the technologic process. It is necessary to compare the positive effect of liquid atomization with high energy costs.

Energy costs for liquid atomization may be compensated by combining several methods of purification; the efficiency of which improves with purified liquid surface space enlargement, dissolved air flotation, and ozonizing, for instance. It is possible to implement atomized water saturation with air and its ozone treatment in one pressure tank, which allows one to raise the efficiency of each method with reduction of the dimensions of the installation.

Hence, it is necessary to conduct theoretical and experimental researches that may allow estimating the efficiency of liquid atomization under different methods of purification. First, it is important to estimate the effect of strong turbulent water flow in atomizer on dispersion of polluters and to estimate liquid atomization energy costs.

6. Acknowledgments

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References

[1] RF Presidential Edict No. 899 of 07.07.2011 "On approval of the priority directions of development of science, technology and engineering in the Russian Federation and of the list of critical technologies of the Russian Federation"

[2] Izrael Y A 2013 *Environmental pollution in Russian Federation at the beginning of the XXI century: status and tendencies. Issue 2* (Moscow: Rosgidromet)

[3] Korshenko A N 2014 *Sea waters qualities at hydro-chemical rate. Annual. 2013* (Moscow: Nauka)

[4] Patent CN № 2633859 2004 High efficiency air float machine

[5] Eskin A A, Zakharov G A, Tkach N S and Tsygankova K V 2015 Intensification dissolved air flotation treatment of oil-containing wastewater *Modern Applied Sciense* **9(5)** 114-124

[6] Patent RU №2474538 2013 Oily waste waters purification device

[7] Stahov E A 1983 *Purification of oily wastewater of enterprises of fuel oil storage and transportation* (Leningrad: Nedra)
[8] Istomin V I 2004 *Shipping oily waste waters integrated treatment* (Sevastopol': SevNTU)
[9] Hong A and Xiao T 2013 Treatment of oil spill water by ozonation and sand filtration *Chemosphere* **91(5)** 641–647
[10] Oh K S, Poh P E, Chong M N, Gouwanda D, Lam W H and Chee C Y Optimizing the in-line ozone injection and delivery strategy in a multistage pilot-scale greywater treatment system: System validation and cost-benefit analysis J*ournal of Environmental Chemical Engineering* **3(2)** 1146–51
[11] Andriamiado L (ed) 2007 *Water Treatment Handbook 2 Volume set, 7th ed.* (Edited by Degremont: Rueil-Malmaison, France)
[12] Spellman F R 2009 *Handbook of Water and Wastewater treatment plant operations* (Boca Raton: CRC Press)