Upgrading of industrial wastewater technique by pressure flotation

Olga Yantsen, Vladislav Gerasimov and Alexey Storozhev

Moscow State University of Civil Engineering, Yaroslavskoe shosse, 26, Moscow, Russia

Abstract. The aim of the study is to develop a technology for the treatment of industrial wastewater by means of a pressure flotation unit. The modernized unit of pressure flotation with various feed of water-air mixture was designed and constructed on the basis of the review of scientific and technical literature. The tests with different variations in the supply of water-air mixture to the unit were carried out in order to improve the quality of treated wastewater and, as a result, to the reduction of environmental damage. We carried out a comparative analysis of each variant in terms of the quality of treated industrial waste water and we identified the most appropriate variant for various technological treatment schemes. All results of the research considered we offer the automation of this device. The purpose of automation of the pressure flotation unit was to increase the efficiency of the used equipment, to maintain the stability of the unit, to obtain information on all the processes of industrial wastewater treatment, as well as to prevent an emergency situation.

1. Introduction

The problem of conservation of water sources and water supply has become one of the most pressing environmental problems. In the technological processes of many industrial enterprises, a significant amount of water which is taken from natural reservoirs is used. The wastewater contains a large amount of chemicals, suspended particles, and has a high acidity. This water is unsuitable for human exploitation and causes the great harm to water bodies, and therefore requires high-quality treatment.

Industry is a constantly developing sector. The main difficulty in the treatment of industrial wastewater is the variability of the composition and the flow of incoming wastewater. That is why the development of a multifunctional installation that allows to operate in different conditions is one of the pressing issues today.

One of the most common and effective ways to treat industrial wastewater is pressure flotation treatment, which occurs in flotation plants [1]. Flotation processes are widely investigated, new intensification schemes are constantly proposed [2,3]. Therefore, the development of methods to optimize the flotation process seems relevant to the authors.

The operation of the pressure flotation plant consists of many interrelated processes, through which high-quality wastewater treatment and disposal of waste is carried out. In order to bring the best results for all the processes, it is recommended to implement an automation system.

Without the introduction of an automated process control system (APCS), the pressure flotation plant is controlled manually. Under these conditions, the dosage of the reagents used is unbalanced, the probability of
the accidents increases, which leads to unreasonable expenses, as well as to a decrease in water quality after installation, which consequently negatively affects the environment.

The main, defining purpose of management of the equipment, technological and production processes by means of automatic control system is increase of productivity, improvement of quality of production and use of material raw materials and fuel and energy resources.

Advantages of APCS [4]:
1) Increase the efficiency of equipment use.
2) Ability to reduce the costs that were previously required for the operation of remote equipment
3) Stable operation of the equipment
4) Ability to reduce the expenses of maintenance personnel who was required to control the operation of the equipment
5) Obtaining operational information in the event of a malfunction or accident, processing and analysis of the data
6) Prevention of an emergency

2. Methods
During the process of flotation, a few processes occurs in the liquid: dissolution and release of air, adhesion of air bubbles to the particles of suspension and their floating to the surface to form a foam. The conditions of these processes have a significant impact on the effect of water treatment.

Having studied various methods of flotation [5], as well as the design of existing flotators [6-8], the types of formation of water-air mixture, and various types of performance materials from which it is possible to create a flotation plant and its piping - an upgraded model of pressure-reagent flotation was developed [9].

To improve the quality of purified water, the authors performed some tests with different types of water-air mixture supply at the developed pressure flotation unit (Fig. 1).

![Figure 1. Variation of water-air mixture supply](image)

3. Upgrading of pressure flotation technology
In accordance with the proposed methods (Fig. 1), tests were carried out. The test results are presented in the table 1.

| Criteria                      | Types of water-air mixture supply:          |
|-------------------------------|---------------------------------------------|
|                               | I                           | II                          | III                         |
| Indicators                    | Average efficiency of wastewater treatment at the outlet of treatment plants, % |
| Suspended solids              | 75%                         | 85%                         | 97%                         |
| BOD                           | 80%                         | 90%                         | 96%                         |
| COD                           | 80%                         | 90%                         | 96%                         |
| Phosphate ion                 | 85%                         | 88%                         | 94%                         |
| Fats                          | 83%                         | 89%                         | 96%                         |
| Mineral oils                  | 87%                         | 91%                         | 96%                         |
In the first test, the water-air mixture is fed in front of the flotation chamber, after which the wastewater together with the water-air mixture enters the flotation chamber. During this process, the air bubbles are large; no milky mixture is formed. The flotation process is directed only to one point, when the side edges of the flotation chamber are not involved.

The efficiency of water treatment - up to the norms of discharge into the city sewer.

In the second test of the supply water-air mixture goes to flotator on the inlet of the flotation cell, at 25 cm from the bottom is along the width of the skimmer tubing with small holes along its length, is pumped through the water-air mixture. Unlike the first technique, the flotation process is directed to the entire width of the flotation chamber. During this process it was noticed that liquid that looks like milk is formed, but not the foam. Also, the flotation unit plays the role of the primary settling tank.

The efficiency of wastewater treatment is higher than in the first case, but discharge is still permissible only in the city sewer [10].

During the third test the mixed supply of water-air mixture also the water-air mixture is supplied to 2 points: both in front of the flotation chamber and in the flotation chamber. During this process, it was noticed that the air bubbles have the necessary size for the formation of «milky mixture», and also, together with this process, foam is formed. The flotation process is directed to the entire width of the flotation chamber. Also, the flotation unit plays the role of the primary settling tank.

Achieving a high quality of wastewater treatment according to the indicators presented in table 1, together with the subsequent purification on biofilters will allow to discharge wastewater into the reservoir.

The ability to use different variations of the water-air mixture allows the use of this unit in a variety of technological schemes. The introduction of the APCS system in this pressure flotation device will allow it to adapt to abrupt changes in the volumes and compositions of wastewater coming from industrial enterprises [11, 13].

4. Improving the efficiency of the pressure flotation device

After designing and constructing the pressure flotation unit and conducting tests on it with different variations of the water-air mixture, it has become necessary to fine-tune all parameters.

As it was mentioned earlier, the effluents from industrial enterprises can seriously change not only in the composition of incoming wastewater but also in volumes. Since the equipment is configured for certain settings, the operating personnel will have to configure the installation from the beginning, which will take a large amount of time. Negligence in setting up the pressure flotation device will result in the decommissioning of this equipment, which will subsequently disrupt the entire wastewater treatment chain.

To prevent this problem and improve the efficiency of the equipment, ensure the stability of its operation, as well as reduce maintenance and operation costs, it is necessary to automate the process of the pressure flotation unit and install sensors to control the parameters of this unit [12, 14]. Process automation must meet the following requirements, it is necessary to:

1) to control the filling of the container E1 on 4 levels. Provide regulation of submersible pumps: dry running, on, off, accident. Alarm (light, sound).

2) to provide control of supply of drains in the flotation device

3) to control the acidity of the flow in the flotator, thereby regulating the flow of reagents into the tube flocculator.

4) to automate the process of switching on and off the circulation pump supplying clarified water to the tube saturator. In case of an accident, provide emergency shutdown of all equipment.

5) to automate the process of switching on and off the compressor unit, which supplies air to the tube saturator. In case of an accident, provide emergency shutdown of all equipment.

6) to provide different variation of the water-air mixture in the flotation device, at different cleaning modes.

7) to automate the process of switching on and off the scraper mechanism for removing foam. In case of an accident, provide emergency shutdown of all equipment.

8) After stopping the flow of averaged wastewater to the flotator, the circulation pump, compressor unit and scraper mechanism should continue their work for complete purification of the drain and collection of the resulting foam within 30 minutes. To provide possibility of regulation of time of work of all equipment.

9) to automate the supply of purified water by means of a circulation pump to the nozzles. Water supply should occur periodically for 2 minutes, with a break of 3 minutes.
10) to provide for periodic removal of sediment from the bottom of the cone of the flotation plant. Removal of sediment should occur periodically for 5 minutes every two days.

11) to control the filling of the flotation tank. The control should be carried out both on the lower and on the upper level. If the water level in the flotator becomes insufficient, all equipment must stop working. If the water level exceeds the maximum, the water is drained from the flotator to the required level, as well as a temporary shutdown of all equipment. Alarm (light, sound).

12) to provide possibility of emptying of all system.

5. Description of the functional scheme of automation and algorithm of the installation

Table 2 shows a table of sensor designations.

| Designation | Name              |
|-------------|-------------------|
| LS          | Level switch      |
| PS          | Pressure switch   |
| PET         | The pressure controller |
| FET         | Flowmeter         |
| TET         | Temperature sensor |
| PI          | Pressure gauge    |
| QET         | PH sensor         |
| EMV         | Electromagnetic valve |

Figure 2 shows the flocculator.

Capacity E1 is installed on the line. In the capacity of E1 has 4 level sensors LS1.1 – LS1.4. 2 submersible pumps P1.1 and P1.2 (both working) are installed in the tank E1. The pumps are switched on alternately (Each pump works one cycle-30 min, the first cycle starts the pump P1.1). The pumps can operate in both automatic and manual mode. In automatic mode the pump flow is controlled by level sensors:

1. LS1. 1-dry running sensor, when LS1.1 is activated, the submersible pumps are switched off.
2. LS1. 2-pump shutdown
3. LS1. 3-switching on the first pump
4. LS1. 4-sensor accident. When it is switched on, both pumps come into operation.

In manual mode, the pump flow is not controlled by level sensors, except for the dry run sensor.
The supply line is equipped with a pressure sensor PET1, which measures the pressure on the drain supply line, as well as monitors the operation of submersible pumps. Also in this line there is a temperature sensor TET1, to control the temperature of the supply drain. The signal from the sensors is fed into the local control cabinet (LCC).

The averaged wastewater is fed through the fet1 ultrasonic flowmeter to the flotation device. The signal from the ultrasonic flowmeter is fed to the LCC by the flotation device. There is also a pressure gauge PI1 installed on the supply line for manual monitoring of the network pressure and EMV1 (Normally Open (NO)) for monitoring the flow of the drain.

A tube flocculator is installed in front of the pressure flotation device, which is used to mix the averaged wastewater with reagents using static mixers.

At the end of the pipe flocculator line, a pH controller QET1 is installed, which serves to control the acidity of the flow in the flotator and regulate the flow of reagents into the pipe flocculator. The signal from the pH controller goes to the LCC of the flotator, and then from this LCC cell the signal goes to the reagents preparation and supply station, where the dose of reagents is adjusted.

Figure 3 shows an upgraded pressure flotation plant.
Figure 3. Streamline the installation of pressure head flotation

The signal from the ultrasonic flowmeter FET1, at the passage of the average flow $> 0$, sends a signal to the LCC of the flotator, to turn on the circulation pump P2, the compressor unit P3 and the scraper mechanism. When the averaged flow passes through the ultrasonic flowmeter FET1 = 0, a signal is sent to the LCC of the flotator including a timer for all equipment. After stopping the flow of the average flow to the flotation device, the circulation pump P2, compressor unit P3 and scraper mechanism continue their work for complete purification of the drain and collection of the resulting flotation foam for 30 minutes, after which a signal is received from the LCC to turn them off. The shutdown time of all equipment can be adjusted in LCC.

When the average flow is fed to the flotation device, a signal is received from the local control cabinet to turn on the circulation pump P2, which pumps the purified flow in the flotation process to the pipe saturator. On the line of the circulation pump P2 installed: pressure sensor PET2, which monitors the pump and in the event of an accident sends a signal to shut off the circulation pump in the local control cabinet (at critical pressure), and the pressure gauge sensor PI2 to monitor the pressure in manual mode. At the end of the pipe...
saturator line, a pressure gauge sensor PI4 is installed to monitor the pressure in manual mode and a pressure sensor PET4 to monitor the pressure on the supply line after the pipe saturator, supplying a signal to the local control cabinet. In the event of an accident (at the critical pressure) switch to turn off all equipment. The alarm is deactivated manually using the SB1 button.

When the average flow is fed to the flotation device, the control cabinet sends an activation signal to the compressor unit P3, which supplies compressed air to the pipe saturator. The signal is also applied to the electromagnetic valve EMV2, to regulate the air supply to the tube saturator. A pressure switch PS3 is installed on the compressor unit line to monitor the emergency shut-off of the compressor unit at overpressure, PET3 which sends a shut-off signal of the compressor unit to the LCC at critical pressure, and a pressure gauge sensor PI3 for manual pressure control.

After switching on the compressor unit P3, a signal is sent from the LCC to the scraper mechanism for collecting flotation foam. The scraper mechanism can also operate in manual mode, with the SB3 on / off button. The floating mass is continuously removed by mechanisms for raking the flotation foam into the sludge storage.

To quickly settle the foam to the bottom of the sludge chamber, the foam is moistened by spraying purified water through nozzles. A signal is sent from the LCC to the EMV6 solenoid valve. There is a periodic supply of purified, after the flotation process, waste water circulation pump P2 to the nozzles for 2 minutes, with a break of 3 minutes. The on and off time of the solenoid valve can be adjusted in LCC.

The flotator has 2 level sensors LS2. 1-LS2.2 the LS2. 1 Sensor is used to control the lower limit of the water level in the flotator. If the water level in the flotation device becomes lower than this sensor, it sends a signal to the local control cabinet, and from it a signal to turn off all equipment and turn on the alarm signal. The alarm is deactivated manually using the SB1 button. The LS2.2 sensor is used to monitor the upper limit of the water level in the flotation device. If the water level in the skimmer is above this sensor, it sends the signal to the local control cabinet, and from it a signal on the emergency discharge of water from the flotation cell, turning on the emergency signal and shutdown of all equipment (pump, compressor unit, scraper mechanism). The alarm is deactivated manually using the SB1 button.

The supply of the water-air mixture is controlled by means of electromagnetic valves EMV3 (Normally close (NCL)) and EMV4 (NCL). Due to the various variations in the inclusion of these valves, it is possible to control the degree of wastewater treatment to different indicators. The signal on EMV3 (NCL) and EMV4 (NCL) comes from the control cabinet. The valves can operate in different modes. In the case of deep treatment, both valves are opened together with the inclusion of the pump P2 and the compressor P3. In the case of not deep treatment (before discharge into the sewer), only 1 of the valves opens. Operation mode selection is set manually.

Draining the sediment from the cone part is performed using the electromagnetic valve EMV5 (NCL). Removal of sediment occurs periodically for 5 minutes every two days. In the event of an emergency (with a signal from the LS2.2 sensor), all equipment (Circulation pump, compressor unit, scraper mechanism) is switched off. EMV5 is triggered and emptying occurs before the sensor is switched off. Sound and light signals are triggered. The alarm is deactivated manually using the SB1 button.

To empty the entire system, all mechanisms are switched off (Circulation pump, compressor unit, scraper mechanism), EMV5 is triggered and complete emptying occurs. To drain the system in manual mode, the SB2 button is provided.

When an alarm is triggered on the unit, the alarm signal A1 (light, sound) is triggered. The alarm is deactivated manually using the SB1 button.

Figure 4 shows a table with sensor signal designations.
6. Conclusions

1. The proposed flotation device expands the range of supply of water-air mixture, in comparison to the classical flotators, which in turn increases the efficiency of wastewater treatment.

2. Due to the modernization of this flotation plant, it is possible to use it in various technological schemes.

3. A modular water treatment system is proposed, which can be easily adjusted to the changed composition of incoming wastewater, depending on the specified parameters.

4. The automation of the pressure flotation device operation process has been developed which reduces the risks of emergency situations and also allows to achieve optimal results in the quality of treated water.

5. Automation of the flotation device will reduce the time to set it up with a sharp change in the options of incoming wastewater.

6. With the introduction of APCS, it will be easier for staff to control the operation of this plant, to monitor the changes in the parameters of incoming wastewater, as well as to make quick and right decisions.

Reference

[1] Alekseev D, Nikolaev N and Laptev A 2005 Integrated treatment of sewer systems at industrial enterprises using the jet flotation method. – Kazan: Kazan state technological University. 156 p

[2] Mao Y, Xia W, Peng Y and Xie G 2019 Ultrasonic-assisted flotation of fine coal: A review. Fuel Processing Technology, 195

[3] Faustino L, Braga A, Sacchi G, Whitaker W, Reali M, Leal Filho L and Daniel L 2019 Removal of iron ore slimes from a highly turbid water by DAF. Environmental Technology (United Kingdom), 40 (26), 3444-3455

[4] Samandarly S and Voronin I 2016 Advantages of introduction of automated control systems of technological processes at the enterprise and organization. Economic environment. 2 (16), 57-59

[5] Alekseev E 2009 Fundamentals of wastewater treatment technology by flotation: Monograph, scientific publication. - Moscow: publishing house DIA, 136 p., II

[6] Eskin A, Tkach N, Tsygankova K and Zakharov G 2014 Pressure flotation Method. Experiences of efficient use of energy resources of the Far East. Publishing house “Mountain book”, 135 - 140 p
[7] Vilavski E, Mazakaeva S and Baymukhambetova M 2016 Intensification of flotation treatment of industrial wastewater from petroleum products. Universum: technical Sciences

[8] Shevchenko T and Shevchenko A 2016 Intensification of the flotation plant in wastewater treatment of dairy enterprises. Eastern European journal of advanced technology. Izd-vo Technology centre (Kharkov), 1, 6 (79), 4-12 p

[9] Matsnev A 1976 Wastewater Treatment by flotation. Kiev. «BUDIVELNIK » publishing house, 132 p

[10] Yantsen O, Gerasimov V and Storozhev A 2016 Modern technological solutions at reconstruction of treatment plants of food production. Bulletin of Civil Engineers. 3 (74)

[11] Volkov A, Sedov A, Chelyshkov P, Pavlov A and Kievskiy L 2016 Promising energy and ecological modeling in computer-aided design. International journal of applied engineering research. 11, 3

[12] Volkov A, Chelyshkov P and Lysenko D 2016 Information management in the application of bim in construction. The roles and functions of the participants of the construction process. Procedia engineering. 153, 828-832

[13] Volkov A, Chelyshkov P and Lysenko D 2016 Information management in the application of bim in construction. stages of construction. Procedia engineering. 153, 833-837

[14] Volkov A, Sedov A, Chelyshkov P, Titarenko B, Malyha G and Krylov E 2016 The theory of probabilities methods in the scenario simulation of buildings and construction operation. Research journal of pharmaceutical, biological and chemical sciences. 7, 3, 2416-2420

Acknowledgement
This research was carried out under the BECK (Integrating education with consumer behaviour relevant to energy efficiency and climate change at the Universities of Russia, Sri Lanka and Bangladesh) project funded with support from the European Commission. The findings and opinions reported in this paper reflect the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained in it.