Experience in industrial wastewater treatment of woodworking enterprise system

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Abstract. The paper presents the results of the experience of industrial wastewater reuse after cleaning from formaldehyde-containing compounds in the water supply system at a woodworking enterprise. The drains after the main stage of mechanical cleaning, cascade precipitators, were additionally settled with the addition of chemical reagents: 5% aluminium sulphate solution, 6% polyacrylamide solution and 10% sodium solution. In this case, the maximum cleaning effect was achieved by 7% higher without the use of reagents. A detailed analysis of the dry residue showed that during the processes of settling up to 28% of the dissolved resins are transferred to the solid phase, and the additional treatment with chemical reagents no longer contributes to the transition of the dissolved resins to a dispersed state. As a modification of the technological scheme of industrial wastewater treatment, two options were proposed that differ in the preliminary preparation of the effluent before evaporation.

1. Introduction
At the enterprises of the woodworking industry, engaged in the synthesis of urea-formaldehyde resins (UFR) and the production of chipboard (chipboard, laminated chipboard) based on them, a significant amount of industrial effluents polluted with formaldehyde, UFR and a number of organic and inorganic compounds are formed annually [1-3]. To improve the efficiency of the raw materials used at the enterprise, a system of closed or circulating water supply can be introduced, however, manufacturers face the problem of cleaning industrial effluents and further utilizing the resulting sediments (sludge) [3, 4]. The solution of such problems is of interest not only from a scientific and practical point of view, but also from a technical, economic and technological aspect.

Currently known complex methods of industrial wastewater treatment contaminated with formaldehyde, UFR, organic and inorganic compounds, including formaldehyde and FSC are reduced to the sorption of each impurity separately, or to thermal combustion, or biochemical destruction of all impurities together, or to their transformation into other, not less harmful substances [2-5].

Due to the structural features, UFR is extremely difficult to destructive disposal, therefore, in the cleaning process, they remain in the drains, which leads to an excess of chemical oxygen demand (COD) in wastewater [3-8]. Thus, at present, in the process of cleaning industrial wastewater at woodworking enterprises, tons of frothy products (formaldehyde and CFS) are being destroyed while spending considerable amounts of money on cleaning industrial wastewater from these contaminants [2-8].
2. Problem statement
The analysis of formaldehyde and CFS content in industrial effluents and the development of a modified production line to reduce the concentration of these pollutants and to reuse water was carried out at one of the woodworking enterprises of the region.

3. Theoretical part
According to the production line, formaldehyde-containing drains are formed after washing the impregnation lines. The average volume of wastewater is $4 \text{ m}^3/\text{day} \approx 1,500 \text{ m}^3/\text{year}$. The chemical composition of the effluent is presented in table 1.

| The name                     | Unit of measurement | Value   |
|------------------------------|---------------------|---------|
| Dry residue                  | mg/l                | 3500 30000 |
| Ammonia and ammonium salts  | mg/l                | 280 1800 |
| Petroleum products and fats  | mg/l                | 0.95 9.7 |
| Formaldehyde                 | mg/l                | 1000 11400 |
| Rigidity                     | mg-equiv/l          | 3 6 |
| Common iron                  | mg/l                | 0.3 |
| ASAS                         | mg/l                | 1.39 |
| pH                           |                     | 5 8 |

The main pollutants of industrial effluents are amino formaldehyde resins in colloidal form and in the form of suspensions, as well as free formaldehyde. After going through the treatment at the existing wastewater treatment plants of the woodworking enterprise, the circulating (process) water enters the plant for the production of resins and additives. Previously, the method of physical sedimentation on cascade precipitators was used to purify water from contamination.

In 2017, the company, in addition to the production of resins, began to produce additives. Due to the change in the processing line, the requirements for the quality of recycled water have become higher. The company has two sites designed for the treatment of industrial waste. Wastewater treatment takes place on cascade precipitators, which are five communicating baths installed according to the cascade principle. When wastewater enters the treatment in the first bath, wastewater overflows over the edge into the second bath, etc. (figure 1).

![Figure 1. The process of deposition of particles on the cascade precipitators.](image)

As a result of cleaning, the concentration of hardened resin particles on cascade precipitators decreases, however, mechanical impurities are not completely removed. There is dissolved resin in the
industrial effluent, which continues to polymerize and forms a suspension. In addition, small particles remain in suspension due to thermal movement of water molecules. For their deposition, the effluent from the last bath is subjected to additional purification with the help of chemical reagents in the shop for the preparation of resins and additives.

A 5% solution of aluminium sulphate, which acts as a coagulant, and a solution of polyacrylamide, which acts as a flocculent, were used as chemical reagents at the plant.

To determine the effectiveness of wastewater treatment at the cascade precipitator, samples were taken from the first bath. The results of the chemical analysis are presented in table 2.

**Table 2. The quality of wastewater before and after cleaning.**

| Quality indicator       | Unit of measurement | Wastewater before treatment at the cascade precipitator | Wastewater after the cascade precipitator | Wastewater after cascade precipitator and chemical precipitation |
|-------------------------|---------------------|--------------------------------------------------------|------------------------------------------|---------------------------------------------------------------|
| pH                      | units pH            | 5.96                                                   | 6.07                                     | 8.61                                                          |
| Suspended substances    | mg/dm³              | 731                                                    | 348                                      | 301                                                           |
| Dry residue             | mg/dm³              | 14500                                                  | 10400                                    | 10600                                                         |

Each sample was further divided into two equal parts. The first part of the samples was settled for 7 hours, followed by chemical analysis using the same parameters. The second part of the samples after settling, was separated from the precipitate by decanting, treated with chemical reagents (4 ml of 5% aqueous solution of aluminium sulphate, 1 ml of 6% polyacrylamide solution and 1 ml of 10% sodium solution per 1 l of waste water) and again defended for 1 hour (figure 2).

Analysis of the concentration of suspended solids before and after cleaning showed that more than half (52%) of suspended particles in solution are deposited on the cascade precipitator, and the use of additional treatment of distilled water with chemical precipitators is ineffective, since the maximum cleaning effect is only 7%.

A detailed analysis of the dry residue in samples of waste water showed that during the processes of settling up to 28% of the dissolved resins go into the solid phase, and the additional treatment with chemical reagents no longer contributes to the transition of the dissolved resins to a dispersed state.

4. Practical recommendations
As a modification of the technological scheme for the treatment of industrial effluents, two options were proposed (figures 3 and 4), which differ in the preliminary preparation of the effluent before evaporation. When implementing the first variant of the technological scheme, industrial effluents, which are formed immediately after washing the impregnation lines, are sent to a vacuum evaporator.

4.1. 1-st option (without cascade precipitator)
After the impregnation line (1) is stopped, the impregnating solutions from the bath, the pallet and the storage tanks are pumped into special vat containers (11). Residues of tar and other impurities of the impregnation line are removed by means of a high-pressure apparatus with hot water. The resulting wastewater through special drainage channels is collected in the pit (2). In the storage tank (7) the wastewater from the pit is pumped by a diaphragm pump (3) or delivered by an exhaust truck (5). Evaporation of water and volatile substances occurs in a vacuum evaporator (9) in automatic mode. The discharged wastewater is supplied by a pump (8) from the storage tank (7) to the evaporator (9) in batches. Also, a portion-in-built pump unloads the concentrated residue from the vacuum evaporator (9). Unloading is carried out automatically according to indications of the built-in densimeter or by timer. The concentrated residue is pumped by the pump (10) into a container for curing (11), where it is mixed with the recipe. With the joint polymerization of the filler and the recipe, solid industrial waste (12) of the polymerized mixture of amino-formaldehyde resins is formed. The distillate containing impurities of formaldehyde is collected in a storage tank (13) and, as necessary, is pumped into the reactor for the production of UF-resin (14).

Figure 3. Process flow diagram of formaldehyde-containing waste disposal. Option I: 1 - impregnation line, 2 - transfer pump, 5 - exhaust truck, 7 - tank for collecting wastewater, 8 - pump for pumping wastewater to a vacuum evaporator, 9 - vacuum evaporator, 10 - a pump for pumping concentrated residue, 11 - bottom container without top for curing, 12 - solid polymerized waste, 13 - distillate, 14 - reactor produced by UF-resin.

4.2. 2-nd option (with regular cascade precipitator)
After the impregnation line (1) is stopped, the impregnating solutions (recipes) from the bath, the pan and the storage tanks are pumped to the bottom of the containers (11). Wastewater generated during the washing of the impregnation line is collected in a pit (2) through special drainage channels. In the first bath of the cascade precipitator (4) the wastewater from the pit is pumped by a diaphragm pump (3). After removing suspended particles by settling, the wastewater from the last bath of the cascade precipitator is transported to the storage tank (7) of the vacuum evaporator by a pump (6) in the old workshop or by an auto-truck (5) from the new workshop. Evaporation of water and volatile substances occurs in a vacuum evaporator (9) in automatic mode. The placement of the vacuum evaporator is assumed in the old workshop. The discharged wastewater is supplied by a pump (8) from the storage tank (7) to the evaporator (9) in batches. Also, a portion-in-built pump unloads the concentrated residue from the vacuum evaporator (9). Unloading is carried out automatically according to indications of the built-in densimeter or by timer. The concentrated residue as a filler for the recipe is pumped by the pump (10) into the container for curing (11) and mixed with the recipe. With the joint polymerization of the filler and the recipe, solid industrial waste (12) of the polymerized
mixture of amino-formaldehyde resins is formed. The distillate containing impurities of formaldehyde is collected in a storage tank (13) and, as necessary, is pumped into the reactor for the production of UF-resin (14).

Figure 4. Process flow diagram of formaldehyde-containing waste disposal. Option II: 1 - impregnation line (a - old workshop, b - new workshop), 2 - sump for collecting waste water, 3 - transfer pump, 4 - cascade precipitator, 5 - exhaust truck, 6 - pump for pumping separated sewage, 7 - tank for collecting effluent, 8 - pump for pumping effluent to a vacuum evaporator, 9 - vacuum evaporator, 10 - pump for pumping the concentrated residue, 11 - bottom container without top, 12 - solid polymerized waste, 13 - distillate, 14 - reactor production UF-resin.

5. Conclusion
For a given technological line, the separation of formaldehyde and solutes by chemical and mechanical purification methods cannot fully satisfy the requirements for purifying process water. As a solution, a cleaning line for industrial effluents with a vacuum evaporator was proposed, allowing formaldehyde and further use of water in the technological cycle to be removed from the effluent. The next step in the evaluation of the proposed process lines is a practical test in production.

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References
[1] Man Y, Han Y, Wang Y, Li J, Chen L, Qian Y and Hong M 2018 Woods to goods: Water consumption analysis for papermaking industry in China Journal of Cleaner Production 195 1377-88 doi: https://doi.org/10.1016/j.jclepro.2018.06.026
[2] Maa L, Chena Z, Xud C, Lie F et al 2018 Water Meta-cycle model and indicators for industrial processes- the pulp &paper case in China Resources, Conservation and Recycling 139 228-36
[3] Morrissey A 2018 Treatment and Recycling of Domestic and Industrial Wastewater Reference Module in Materials Science and Materials Engineering doi: https://doi.org/10.1016/B978-0-12-803581-8.11082-3
[4] Semakina A S and Dyagilev M Yu 2017 Modernization of treatment facilities of a woodworking enterprise in order to improve the quality of cleaning Ecology and safety to technosphere: modern problems and ways of solution Proceedings of the All-Russian scientific-practical conference of young scientists, graduate students and students. Yurginsky
Institute of Technology pp 105-10

[5] Kaczala F, Marques M and Hogland W 2010 Biotreatability of wastewater generated during machinery washing in a wood-based industry: COD, formaldehyde and nitrogen removal Bioresource Technology 101(23) 8975-83 doi: https://doi.org/10.1016/j.biortech.2010.06.122

[6] Badve M, Gogate P, Pandit A and Csoka L 2013 Hydrodynamic cavitation as a novel approach for wastewater treatment in wood finishing industry Separation and Purification Technology 106 15-21 doi: https://doi.org/10.1016/j.seppur.2012.12.029

[7] Fulazzaky M A, Talaiekhozani A and Majid M Z A Formaldehyde removal mechanisms in a biotrickling filter reactor Ecological Engineering 90 77-81 doi: https://doi.org/10.1016/j.ecoleng.2016.01.064

[8] Gong Y, Zhou X, Ma X and Chen J 2018 Sustainable removal of formaldehyde using controllable water hyacinth Journal of Cleaner Production 181 1-7 doi: https://doi.org/10.1016/j.jclepro.2018.01.220