**Vol. 4, No. 3, 2019**

# INFLUENCE OF WASTE WATER FROM WASTEPAPER PROCESSING UTILITIES ON THE OXYGEN MODE OF NATURAL AND TECHNICAL WATER OBJECTS

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https://doi.org/10.23939/ep2019.03.130

*Received: 19.07.2019*



**Abstract.** During the experimental investigations the influence of different silicon deaerators, which are added into the pulp to prevent the foam formation, on oxygen saturation of waste waters formed during the paper goods production from wastepaper was estimated. It was shown that deaerators significantly reduce oxygen concentration in waste waters and, consequently, increase its danger for natural water basins. The indicators of performance of the flotation in removing deaerators from waste water were reviewed.

**Key words:** oxygen mode, producing the paper from the wastepaper, waste waters, foam formation, silicon deaerators, aeration, oxygen concentration in waste waters.

## 1. Introduction

The dissolved oxygen is an important component in natural waters, which significantly determines the Dissolved oxygen is an important component in natural waters, which significantly determines the intensity of the processes in hydrobiochemical systems (including self-cleaning), physical and chemical transformations and hydrobiological circulation of substances, etc. Dissolved oxygen reserves are limited because of its low dissolubility. The dissolved oxygen concentration is determined by the ratio of multidirectional physical and chemical, hydrobiological and hydrodynamic processes which occur in the aquatic environment and at the edge of separation between water and atmosphere [1, 2]. The required level of dissolved oxygen in the treated effluent at the biological waste water treatment plants is provided by aeration systems. The dissolved oxygen concentration in systems with active sludge determines the main points of treatment efficiency (the depth and the rate of removing organic particles, nitrogen (nitrification), phosphorous, iron contaminants, etc.) and the level of the ecological safety of treated waste water for natural water basins [3].

Waste water from the paper goods production from wastepaper is one of the most ecologically dangerous effluents. Using wastepaper as the secondary raw material promotes rational nature management (wood saving), reduces cost of production and the load on the environment by the pulp and paper industry. Therefore, there is a steady upward trend in the volumes of processing and consumption of wastepaper in the paper and cardboard production all over the world. Among the most dangerous technological influences of this production on the natural water basins is formation of waste water with high concentration of organic and suspended matter, which is discharged into the natural water basins after mechanical and biological treatment. But the composition of this waste water, its chemical and physic properties extremely complicate the processes of removing and bringing residual concentrations of pollutants to ecologically safe ones [4–6].

The process of production of paper goods from wastepaper is accompanied by the foam formation and oxygen accumulation in the wastepaper mass, which on the one hand slows down the process of production, and on the other hand has a negative influence on the quality of the final product. To solve this problem, chemical (organic and silicon) deaerators are used. They reduce the rate of the foam formation and oxygen accumulation in the secondary fiber [5, 6]. The deaerator includes hydrophobic oils which contain hydrophobic liquid particles. The most widespread is the use of deaerators based on silicon liquids. Silicon deaerators usually are made from polymethylsiloxane liquids which are mixed with hydrophobic silica [7, 8]. The mechanism of the foam destruction by silicon deaerators is based on the action of surfactants (oils which are part of the deaerator), which are quickly distributed at the edge of the "liquid-air" phases separation and hydrophobic particles (part of the deaerator) which constrict the borders of "liquid-air" phases. As a result, the deaerator penetrates through the wall of the foam bubble and breaks it. The phenomenon is conditioned by the action of gravity on the liquid film and Marangoni effect [9–11].

The presence of deaerators in waste water (which are formed after the pulp spin) and their properties can theoretically cause breaking air bubbles which are formed during the aeration of waste water in the biological treatment processes. This phenomenon can cause problems with oxygen saturation of waste water to the required level [12] and providing it to active sludge microorganisms. The result is the inhibition of biological treatment processes in waste water [13, 14] and its extreme danger for natural water basins including the influence on their oxygen mode.

The aim of the work is to determine quantitative characteristics of the silicon deaerators influence on oxygen saturation of waste water formed during wastepaper processing and the efficiency of deaerators removing by flotation.

## 2. Objects and methods of experimental investigations

The object of the investigation was the pulp with silicon deaerators of different brands. To receive the pulp wastepaper MC-8B (newsprint) was used. The pulp was manufactured using the technique recommended by scientific literature sources [15, 16]. The wastepaper mass was dissolved with formation of the pulp (2 % of dry fiber). To dissolve newsprint, it was filled with water (60 °C) for 10 minutes. Then the soaked paper was disintegrated to receive almost homogeneous suspension using the industrial mixer for 60 minutes at the room temperature. During this process additional reagents were not used. Solid particles were removed from the suspension before conducting the experiment.

During the investigations the deaerator was added into the pulp in the quantity of 0.80–1.0 g/kg, as it was recommended by the manufacturer. The influence of three types of deaerators (WACKER brand) on the pulp was studied: Pulpsil763E, Pulpsil960S, SilfoamSe2. After the pulp separation by filtration we got model waste water and then conducted aeration by the micro-compressor. The volume of model waste water which was aerated was 100 $cm^3$, air expense for aeration and flotation was 4–20 $cm^3/(cm^3 \cdot min)$, aeration intensity during aeration and flotation was 12–60 $m^3/(m^2 \cdot h)$. Oxygen concentration in aqueous media was determined by the portable oxygen meter YSI 55 55/12ft Dissolved Oxygen Meter(USA).

## 3. Results of experimental investigations

### 3.1. Determination of silicon deaerators influence on oxygen concentration in aqueous media of different composition

As the experimental results showed, adding deaerators into the liquid environment reduces the concentration of oxygen in it (Table 1), especially when adding Silfoam Se2. Moreover, raising deaerator concentration causes reducing of oxygen concentration in aqueous media.

*Table 1*

**The effect of deaerators on the oxygen concentration in a distilled water**

| Water environment | Oxygen concentration ($mg/dm^3$) at defoamer concentrations, g/kg pulp | | | |
|---|---|---|---|---|
| | 0 | 1.0 | 2.0 | 4.0 |
| Distilled water | 5.62 | – | – | – |
| Distilled water + Pulpsil 763E | 5.62 | 5.59 | 5.46 | 4.75 |
| Distilled water + Pulpsil 960S | 5.62 | 5.46 | 5.24 | 4.85 |
| Distilled water + Silfoam Se2 | 5.62 | 4.87 | 4.66 | 4.48 |

As theoretical data show [9-11], adding deaerators can cause the main danger for the oxygen mode of water environments by oppression of the process of oxygen saturation from the bubbles during the aeration. Dynamics of oxygen saturation of the pulp and other aqueous media (distilled water and model waste water which was obtained by adding glucose to distilled water with COD of 1000 $mg/dm^3$) during the aeration is presented in Fig. 1. The processed pulp contains a huge quantity of organic particles and refers to concentrated industrial waste water (according to COD). According to our data, COD of the pulp which was obtained in the experiment is 600–900 $mg/dm^3$.

As shown in Fig. 1, all variants of the experiment display the maximum saturation of water environments by oxygen at the $50^{th}$–$60^{th}$ seconds of aeration. Moreover, despite high intensity of the aeration, oxygen concentration in the processed pulp grew slower than compared with other water environments, used in the experiment, especially after the 20th second of processing.

When adding deaerators to the pulp, its oxygen saturation during the aeration slows down even more, which is shown in Table 2. As shown, after 10 seconds of saturation, oxygen concentration in the control variant of the experiment (pulp without deaerators) two and three times exceeded oxygen concentration in the experiment variants, after 20 seconds – 1.8–2 times. Pulpsil 763E deaerator depressed oxygen saturation in waste water most.

The dynamics of the process of oxygen saturation of the pulp which contains different silicon deaerators is shown in Fig. 2. As shown, for 70 seconds of the aeration, the variant of waste water with Pulpsil 763E deaerator shows the most intensive inhibition of oxygen saturation. For first 20 seconds of the aeration, the lowest influence on oxygen saturation was in the variant of waste water with Silfoam Se2 deaerator. But with further aeration, the lowest influence on oxygen saturation was in the variant of waste water with Pulpsil 960S deaerator.

*Table 2*

**The dependence of oxygen saturation of wastewater on the presence of various deaerators in their concentration 1,0 g/kg pulp**

| Saturation time, s | Increasing the concentration of oxygen in the waste water compared to the original | | | |
|---|---|---|---|---|
| | without adding deaerators | with added deaerators | | |
| | | Pulpsil 763E | Pulpsil 960S | Silfoam Se2 |
| 10 | 1.8 | 0.56 | 0.56 | 0.84 |
| 20 | 3.37 | 1.69 | 1.84 | 1.89 |

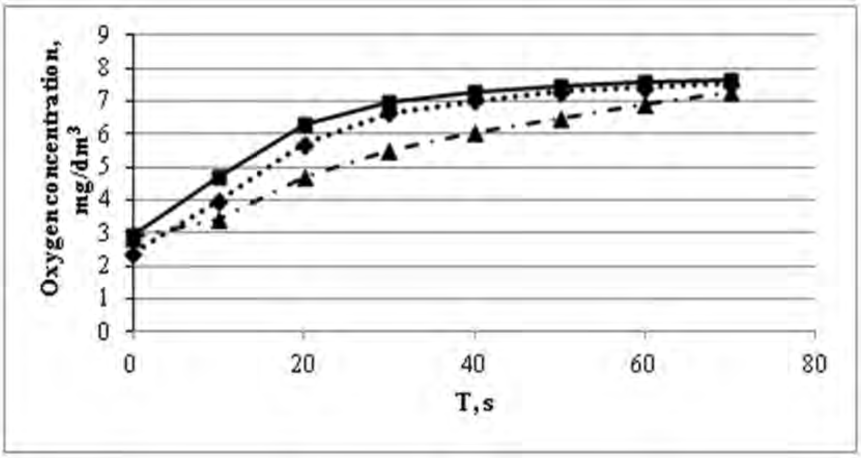


**Fig. 1.** Dynamics of oxygen concentration in aqueous media of different composition during aeration
( ■ distilled water,···¨ ··· model wastewater with COD 1000 mg/dm$^3$, ▲· pulp)

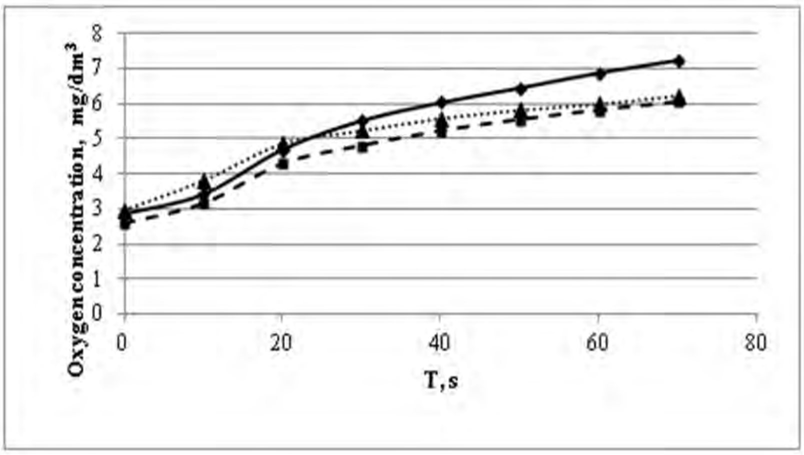


**Fig. 2.** Influence on the dynamics of pulp oxygen saturation with various silicone defoamers (in concentration 1,0 g/kg pulp) with aeration
(– ■ – pulp + Pulpsil 763E, –¨ – pulp + Pulpsil 960S, ···▲··· pulp + Silfoam Se2)

The impact of the deaerators concentration on the level of inhibition of oxygen saturation in waste water during the aeration has been reviewed (table 3). As we can see, when the concentration of deaerators Pulpsil 763E and Silfoam Se2 raises, oxygen saturation in the pulp is steadily inhibited. In the pulp with Pulpsil 960S deaerator such dependence can be traced only at the start of the aeration. In general, at the 60$^{th}$ second of the aeration, raising of the deaerators concentration two times (from 0.1 to 2.0 g/kg of the pulp) caused 11 %, reduction of oxygen concentration in variant pulp+Silfoam Se2 approximately in variant pulp+Pulpsil 960S –14 % and in variant pulp+Pulpsil 763E –23 %. Adding the aerators (concentration of 2.0 g/(kg·pulp) at the 60$^{th}$ second of the aeration reduced oxygen concentration up to 5.5 % (Pulpsil 960S), 60 % (Pulpsil 763E), 68 % (Silfoam Se2) compared with the pulp without aerators. So, according to the absolute concentration of the dissolved oxygen the most negative influence on the content of experimental industrial waste water was created by adding Silfoam Se2 deaereator into the pulp, and the lowest – by adding Pulpsil 960S deaerator.

*Table 3*

**Influence of deaereators on oxygen concentration in the pulp**

| Pulp composition | Initial concentration $O_2$, mg/dm$^3$ | Concentration $O_2$ through 60s aeration, mg/dm$^3$ | Increased concentration $O_2$ compared to baseline, mg/dm$^3$ | Increased concentration $O_2$ compared to baseline, % |
|---|---|---|---|---|
| Pulp without deaereator | 2.9 | 7.55 | 4.65 | 160.34 |
| Pulp + Pulpsil 763E | | | | |
| 1.0 g/kg pulp | 2.67 | 5.81 | 3.21 | 123.46 |
| 2.0 g/kg pulp | 2.60 | 5.04 | 2.27 | 100.00 |
| Pulp + Pulpsil 960S | | | | |
| 1.0 g/kg pulp | 2.86 | 6.89 | 4.03 | 140.90 |
| 2.0 g/kg pulp | 2.71 | 6.89 | 4.18 | 154.24 |
| Pulp + Silfoam Se2 | | | | |
| 1.0 g/kg pulp | 2.99 | 6.01 | 3.02 | 101.00 |
| 2.0 g/kg pulp | 2.52 | 4.53 | 2.33 | 92.46 |

### 3.2. Determining the prospects of implementation of flotation for removing silicone deaerators from the processed pulp

As evidence shows, the investigated deaerators can cause very negative influence on the composition of waste water, especially their properties in the environments of waste water disposal facilities [17], biological treatment of waste water and in natural water basins. Waste water treatment of the enterprises which produce paper goods from wastepaper mass requires biological treatment. Such action can reliably protect natural water basins from getting deaereators into them, however, only if effective cleaning is organized, which becomes very problematic with the revealed characteristics of waste pulp with deaerators. Therefore, there is an urgent demand to discharge such industrial wastewater to biological treatment plants only if they are purified from deaerators.

Due to the fact that deaerators contain surfactants, the experimental studies have determined the effectiveness of their removal from sewage by flotation method. This solution avoids the use of additional chemical reagents which can make waste water treatment more complicated. In experimental investigations the achievement of oxygen saturation in aerated waste waters of the same value as in the pulp without deaerators and the value of equilibrium concentration of oxygen after finishing the aeration (table 4) was used as an indicator of deaerator removal from wastewater. The intensity of the aeration reached the recommended value [11, 15, 16] – 40–50 m$^3$/(m$^2$·h).

As evidence shows, Pulpsil 960S deaerator has been removed effectively (controlled both by oxygen saturation in the environment and its equilibrium concentration) even during the low intensity of the aeration – 12–27 m$^3$/(m$^2$·h)). But only at the concentration of this deaerator of 1.0 g/kg·pulp. In the pulp which contained 1.0 g/kg·of pulp both Pulpsil 763E and Silfoam Se2 deaerators, oxygen saturation of ~7 mg/dm$^3$ (as in the control version) was achieved only with maximuuum intensity of the air input (60 m$^3$/(m$^2$·h)) for 5 minutes. But equilibrium concentration of oxygen after finishing the aeration was essentially lower than in the control version. When the concentration of all deaerators was 2.0 g/kg of pulp, none of the flotation modes allowed to reach the control level of oxygen concentration in the pulp.

*Table 4*

**Wastewater flotation rates for deaereators removal**

| Deaereator | The concentration of deaereator, g/kg pulp | Aeration rate, $m^3/(m^2 \cdot h)$ | Saturation concentration of $O_2$, mg/dm$^3$ | The duration of aeration to saturation, s | Equilibrium concentration of $O_2$, mg/dm$^3$ | Duration of exposure to achieve equilibrium concentration of $O_2$, s |
|---|---|---|---|---|---|---|
| Pulp without defoamer | – | 12 | 7.2–7.3 | 60–105 | 6.0 | 210 |
| Pulpsil 763E | 1.0 | 12 | 5.7 | 70 | 4.37 | 210 |
| | 1.0 | 27 | 6.6 | 225 | 4.37 | 210 |
| | 1.0 | 60 | 7.1 | 300 | 4.37 | 600 |
| | 2.0 | 12 | 4.85 | 70 | 3.81 | 160 |
| Pulpsil 960S | 1.0 | 12 | 7.0 | 70 | 6.3 | 180 |
| | 1.0 | 27 | 7.22 | 120 | 6.12 | 600 |
| | 2.0 | 12 | 6.73 | 70 | 5.0 | undefined |
| Silfoam Se2 | 1.0 | 12 | 6.04 | 80 | undefined | undefined |
| | 1.0 | 60 | 7.1 | 300 | 4.73 | 630 |
| | 2.0 | 12 | 4.33 | 70 | 3.05 | 140 |

## Conclusions

During the discharge of waste water containing deaerators into the sewerage system, they will interfere with its oxygen saturation from the air and intensify anaerobic processes. During the discharge of deaerators into the waste water treatment plants they will block oxygen saturation of processed waste water, and therefore aerobic microbiological processes of pollutants destruction. This will essentially reduce the efficiency of waste water treatment and increase the level of their danger to natural water reservoirs.

Waste waters formed during the processing of wastepaper, before the discharge into the sewerage system must be treated from deaerators. The use of flotation for removing the deaerator from the processed pulp (where its concentration does not exceed 1.0 g/kg of pulp) allows effective removing of Pulpsil 960S with the aeration intensity of 12–27 $m^3/(m^2 \cdot h)$. For removing other aerators it is necessary to use other technologies of flotation.

## References

[1] Osadchy V. I., Osadcha N. M.: Sci.pr. UkrNDGMI, 2006, 256, 265. (in Ukrainian)

[2] Golovaneva A. E.: Vestnik VSU, series: Geography. Geoecology, 2017, 2, 74. (in Russian)

[3] Kovalchuk V. A.: Ochystka stichnykh vod. Rivne, 2002. (in Ukrainian)

[4] Yurchenko V. O., Ivanin P. S.: Naukovyy visnyk budivnytstva, 2018, 1(91), 206. (in Ukrainian)

[5] Denkov, N. D. Langmuir, 2004, 20, 9463.

[6] Smook, G. A. Handbook for Pulp and Paper Technologist, Angus Wilde Publications: Vancouver Bellingham. 1992. P. 74–83.

[7] Garrett, P. R. The Mode of Action of Antifoams. In Defoaming Theory and Industrial applications, Garrett, P. R., Ed., Marcel Dekker: New York. 1993. P. 66–82.

[8] McGee, J. Silicones: The Environmentally Friendly Drainage Aids for Brown stock Washing, APPITA Conference; Melbourne, Australia, May 2, 1991.

[9] Abdolahi F., Moosavian M ., Vatani A.: Journal of Applied Sciences, 2005, 5, 1122.

[10] Marinova K. G., Tcholakova S., Denkov N. D., Roussev S., Deruelle M.: Langmuir, 2003, 19 (7), 3084.

[11] Drelich J., Pletka J., Boyd P., Raber E., Herron D., Luhtaet E. el.: SME Annual Meeting, 2001, 1.

[12] Virk A. P, Puri M., Gupta V., Capalash N., Sharma P.: PLOS ONE, 2013, 8(8). Access mode: https://doi.org/10.1371/journal.pone.0072346. (lastaccess: 06.02.2019).

[13] Mahshewari R., Rani B., Saxeno A., Prasad M., Singht U.: Journal of Advanced Scientific Reserch, 2012, 3 (1), 82.

[14] Bellebia S., Kacha S., Bouyakoub A. Z., Derriche Z.: Environ. Prog. Sustain. Energy, 2012, 31 (3), 361.

[15] Viesturs U., Leite M., Eisimonte M., Eremeeva T., Treimanis A.: Bioresource Technology, 1999, 67, P. 255.

[16] Pala H., Mota M., Gama F. M.: Journal of Biotechnology, 2004, 108, 79.

[17] Iurchenko V., Lebedeva E.: Environmental Problems, 2016, 1(2), 155. (in Ukrainian)