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*ORIGINAL ARTICLE*

# Application of alternating magnetic field in wastewater treatment at yeast enterprises

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The work is devoted to solving the current scientific and practical problem of increasing the level of environmental safety of yeast production through the use of an alternating magnetic field (AMF) for wastewater treatment and disinfection. The list of industrial effluents' main treatment methods from organic, mineral, and biological pollution is determined. The advantages and disadvantages of these cleaning methods are established. The application of physicochemical technologies of wastewater treatment of yeast production in Ukraine and abroad is considered in detail; the characteristics of their application's physicochemical methods, industry, and conditions are determined. The prospects of using an AMF as a method of purification and disinfection of yeast production wastewater are noted. The physicochemical and microbiological composition of wastewater was studied with the help of physicochemical and microbiological analysis. After exposure to a magnetic field with a magnetic induction intensity of 75 mTl for 10 minutes, there was a decrease in the physicochemical index of chemical oxygen demand by 72 %. The degree of purification by other indicators is in the range of 30 – 50 %, and the degree of disinfection of microorganisms is 87 %. Further development of knowledge on the influence of AMF on the process of wastewater treatment of yeast production depending on its parameters and duration of action. The results of the study can be used to select treatment equipment at yeast plants.
**Keywords:** wastewater; alternating magnetic field; disinfection; total microbial count; magnetic induction

## Introduction

Improving the level of environmental safety through the implementation and development of low-waste energy-efficient environmental protection technologies, highly efficient cleaning equipment, and the creation of closed resource circulation systems is a priority direction for developing the modern Ukrainian economy.

To reduce the negative impact of wastewater on the environment, the improvement of existing and the introduction of new promising technologies of water purification, capable of disinfecting and purifying water regardless of the degree of its chemical or biological contamination, becomes especially urgent. The idea was put forward that it is possible to reduce the negative impact on the environment by improving existing physical and chemical methods and returning purified water to the technological cycle. Water as the main or auxiliary raw materials is used in the vast majority of technological processes of food production. Almost all food production is associated with water consumption from the water supply system and underground aquifers. (Nizhelskaya, Yakunov, 2004). The development of industrial production facilities, in particular the growth of food industry enterprises, increases the volume of water use, which in turn leads to an increase in wastewater that adversely affects the environment. Food industry waste is disposed of mainly by technologies inherent in the disposal of solid household waste of the country's housing and communal services.

Today, most urban wastewater treatment plants work extremely inefficiently due to which causes pollution of natural reservoirs, the processes of their flowering, and overgrowing (State sanitary norms and rules of protection of the population from the influence of electromagnetic radiation, 1996). Industrial enterprises poison reservoirs with wastewater containing a large number of heavy metals, cyanides. Household wastewater and food waste are especially harmful because the oxidation of these substances in reservoirs takes a lot of oxygen (Bezusov, Dotsenko, 2019). Modern water purification technologies (membrane, sorption, catalytic) allow you to purify water from any contamination. However, when using these methods, the cost of purified water increases, and there are no unambiguous consequences. One of the directions that make it possible to organize cleaning processes rationally is implementing modern concepts of synthesis of chemical and technological systems (HTS). Typical wastewater treatment schemes include preliminary cleaning by physical (defending, filtration, flotation), physicochemical (coagulation), and biological (mainly aerobic) methods. (Maylunets', Zatserklyannyy, 2019).

A typical method of cleaning such wastewater is biological. However, the limited areas and locations of enterprises near estates do not allow technical and sanitary views to equip biological wastewater treatment. (Ochkov, 2011). Therefore, the search for alternative means of utilization and effective wastewater treatment is relevant for the entire processing industry. Powerful arguments are the increase in the requirement for the ecological state of enterprises and the need to pay funds for the placement of waste following the current legislation of Ukraine. (Bilyavsky, Butchenko, 2002, Klap, Yaremkevych, Chervetsova, Zayarnyuk, Novikov, 2016, Gamayurova, Krynitskaya, Astrakhantseva, 2004). Currently, yeast-producing enterprises have a problem of wastewater disinfection before they are discharged into the city sewer to reduce the load on organic matter and prevent environmental hazards in possible interactions of wastewater components with total run-off. The safest and most effective technology for non-reagent cleaning methods is physicochemical water treatment. High adaptability to existing technologies, flexibility, and efficiency allows physical technologies both as primary and as an auxiliary, which intensifies wastewater treatment and significantly reduces human-made pollution of the hydrosphere. Thus, the urgent issue is to reduce yeast production's impact on the environment by selecting regimes of physical and chemical methods of wastewater purification.

Many methods and methods of improvement and intensification of physicochemical processes are known. The most common methods associated with the use of rational technologically sound schemes, modernization of existing and the development of new structures, the implementation of which is the practice of water purification, is not always possible for technical, economic, or other reasons (for the preparation and dosage of chemical reagents requires special equipment, additional areas, and sometimes additional service personnel). Physical methods related to the water system of external fields (magnetic, electric, ultrasound) are becoming increasingly important to solve this problem. These methods differ from other methods of water purification with versatility, efficiency, and efficiency. Most often, to intensify water purification processes, the method of imposing on water-dispersed systems of the magnetic field is used. For the first time, this method was proposed to prevent the formation of scale. (Trach, 2017). When water passes through the magnetic field created by magnets, under Lorenz's force's influence, water molecules begin to make flexible movements. The resonance caused in this way leads to the separation of water molecules from micro-switchings that can interact. Simultaneously, already in cold water, calcium ions begin to settle on the surface of free impurities - centers of crystallization, forming so-called microcrystals. (Mnykh, Sukhats'kyy, Zin', 2019).

The magnetic field is widely used to intensify wastewater treatment processes from colloidal and other impurities, improve ionic exchange processes. Magnetic treatment allows intensifying the process of wastewater purification without the addition of special reagents, which pollute the environment and prevent the use of closed water supply systems. When exposed to the magnetic field's water, the flotation of suspended substances improves, their deposition and aggregation are accelerated, the structure of the formed sediment changes. The residual concentration of suspended substances decreases by 1.5 times, and the deposition time - 2 times. Dissolved iron is converted into magnetic oxides that are easily extracted from the water in magnetic fields and pollutants adsorbed on them. The advantages of the electromagnetic processing method are the low cost of equipment and low operating costs.

After exposure to the drainage water of the electromagnetic field, the speed of chemical processes and crystallization of dissolved substances increases, adsorption processes intensify, and coagulation of impurities and precipitation improves.

Magnetic processing is sufficient to remove thin suspensions from wastewater that are difficult to predicate (puddling). An essential characteristic of this effect is the ability to accelerate coagulation (sticking and deposition) of particles with large flakes' subsequent formation.

The magnetic field's mechanism of influence on the drain water and its impurities is not sufficiently studied today. Different authors' opinions and hypotheses are based on the magnetic field's polarizing effect on the ions and water molecules. Simultaneously, during the contact of water with the magnetic field, any aqueous solution should have some changes that result in the subsequent release of a solid phase. That is the replacement of concrete deposits with loose ones. At the same time, in the case of magnetic processing of natural water, which is in a state of thermodynamic equilibrium, there is no reason to assume the real possibility of occurrence and significantly prolonged preservation ("magnetic memory") of any changes in water under the influence of weak magnetic fields. In this regard, the magnetic field's effect during water treatment can likely manifest itself only in thermodynamically non-binding systems, that is, systems that are in an unsustainable state. Moreover, the magnetic field's action is strengthened by the presence of ferromagnetic iron oxidation in water. (Shpak, Novikov, 2017).

For clarification and discoloration of water, treatment methods are often used, based on reagents (coagulants), which ensure the transfer of colloidal impurities and contaminants into the sediment. As coagulants often use salts of iron and aluminum, in particular its sulfate. In this method, the magnetic field's use leads to an intensification of the water purification process. The effect of magnetic processing on coagulation is more effective when the magnetic field acts on the solution after the onset formation of conglomerates.

One of the most common oxidizing water treatment methods is the neutralizing of wastewater with chlorine, or its compounds - chlorine dioxide, hypochloride, and chloramine. Sometimes hydrogen peroxide or ozone are used for this purpose. This method removes impurities of biological origin, humus substances, molecular organic substances, and pesticides from the water. Under the influence of the magnetic field, the vast majority of edemic-restorative chemical reactions increase, which leads to the intensification of wastewater treatment by sedimentation.

Magnetic processing also refers to those methods that intensify the process of purifying wastewater without the addition of special reagents, which pollute the environment. It was established that when exposed to the stick water of the magnetic field, the residual concentration of suspended substances decreases by 1.5 times, and the deposition time - 2 times. Dissolved iron is converted into magnetic oxides that are easily removed from the water in magnetic fields and pollutants adsorbed on them. The advantages of the electromagnetic processing method are the low cost of equipment and low operating costs. In particular, electricity costs are 0.05 - 0.2 kW per 1 m3 of water. (Baran B.A. 2006).

According to thermal analysis, as a result of magnetic processing, the thermal conductivity of water increases that gives an additional economic effect when using such water in heaters, refrigerators, and another heat exchanger. The magnetic field significantly affects the kinetics of those physicochemical processes in aqueous solutions, in the mechanism by which hydrogen bonds play a dominant role due to the weakening of hydrogen bonds' energy between water molecules under the influence of the magnetic field structure of aqueous solutions changes. This is one reason for the "magnetic memory" of water, which, depending on the magnetic processing mode, may last several days (Baran, 2006). Magnetization changes not only the physicochemical but also the biological properties of water: increases the permeability of cell membranes (Trincher, Dubrov, 1967), (Trukhin, Pokazeev, Kunitsyn, 2005) affects the activity of enzymes (Tunkov, Zhakun, 2008); reduces cholesterol in the serum (Lisin V.V.); optimizes the action of various drugs used in the form of water systems (Chesnokova L.N., Desnitsaya M.M.), (Novosyolov, Mnykh, Sukhats'kyy, Zin', 2019).

The magnetic field, acting on wastewater containing iron ions, intensifies the appearance of crystallization embryos, which leads to the formation of an sediment (Mnykh, Sukhats'kyy, Zin', 2019). It was found that under the influence of the magnetic field, there is a temporary deformation of the hydrate shells of ions, their distribution in water changes. The role of ions in magnetic water treatment may also be associated with an electric current or pressure pulsation. It is assumed that the magnetic field directly affects the structure of water associations, which can lead to hydrogen bonds' deformation or redistribution of water molecules in temporary associative formations (Mnykh, Sukhats'kyy, Zin', 2019). The magnetic field's direct action affects the electrokinetic potential and aggregation stability of suspended particles and contributes to removing various suspensions from the water, which opens broad prospects for the purification of wastewater in general.

The purpose of the work was to detect the influence of variable magnetic field parameters on yeast wastewater production purification.

## Methods

Wastewater purification by magnetic field was carried out at a laboratory installation, which consisted of magnetic stimulator MS-92M. The frequency setting discreteness was 0.01 Hz. Radiation from the magnetic simulator was applied from below to the flat bottom of a glass bottle of drain water. Drainage water in sterile conditions was poured 100 cm3 into pre-sterilized glass bottles with a volume of 200 cm3 with grated plugs. The research was carried out under the irradiation mode with a frequency of 50 Hz, the value of magnetic induction of 50 mT and 75 mT. The studied sample of flow water was installed between the lower and upper inductors of the magnetic stimulator. At the end of irradiation, the sample under study was removed from the inductor. The control sample of water was not processed.

To study the process of purification and disinfection of general wastewater under magnetic field influence, the frequency of magnetic pulses of 50 Hz, the induction intensity - 50 mT, and 75 mT. The activity of this range is experimentally confirmed in work (D'omkyn, 2000). The exposure was 4, 7, 10, and 13 minutes, optimal for inactivating microorganisms (Sabliy, 2011). The water temperature was 19.85 °C. The total number of microorganisms in the control sample was 1.2•106 AMC/cm3.

The magnetic pulse frequency (MP) was chosen so that the magnetic field's limit frequency was 50 Hz (Kovalsky, Ocheretny, Postolatiy, 2019, Doroguntsov, 1999). With a low frequency of the electromagnetic wave, electrons and ions of matter have time to react to changes in electrical and magnetic fields' intensity. With a high frequency of electrons and ions, substances do not have time to shift during the field oscillation in the wave, and therefore the polarization and magnetization of the environment are much smaller (Magnetic water treatment. Principle, facts, opinions, 2008,Sabliy, 2011). The effects of MP on microorganisms of general discharge wastewater were evaluated according to the microbiological indicator – the total microbial number (LMF).

The content of chlorides was determined by the method [State Standard of Ukraine. DSTU ISO 9297: 2007 Water quality. Determination of chloride. Titration of silver nitrate with chromate indicator (Mora method)], total nitrogen content [State standard of Ukraine. DSTU ISO 5663: 2007 Water quality], suspended substances [State standard of Ukraine. DSTU EN 872: 2013 Water quality], sulfates [State Standard of Ukraine. GOST 31940-2012. Drinking water. Methods for determining the content of sulfates], chemical oxygen consumption [State standard of Ukraine. DSTU ISO 6060: 2003. Water quality. Determination of chemical oxygen need (ISO 6060: 1989, IDT)]. The pH values of water were measured by the potentiometric method [Derzhstandard of Ukraine. DSTU 4077-2001. Water quality. pH determination (ISO10523: 1994, MOD)]. The total number of microorganisms was determined by the method [ISO 6222: 1999 Water quality]. Laboratory tests were carried out in three replications.

## Results

The dependence of the magnetic field's influence on the disinfection of public wastewater from the processing and magnetic induction duration on the LWP was obtained (Figure 1).

In the processing for 4–10 minutes, the magnetic induction value of 50–75 mT achieves the smallest value of the LWP indicator. The least effective was the use of MP with an magnetic induction intensity of 50 mT and a treatment duration of 13 minutes. , in which the index of SMC is WMD = 8.4·106 AMC/cm$^3$). The magnetic field with the intensity of magnetic induction of 50 mT for 4–13 minutes on the drain water showed the degree of destruction of yeast cells within 30- 65%. Simultaneously, a slight influence of the magnetic field with the induction intensity of 50 mT had a sample of flow water, which was treated within 13 minutes, and the greatest impact had a magnetic field of the same intensity for 4 minutes. In this case, with an increase in the time of wastewater treatment by the magnetic field, the process of activation of microorganisms is observed.

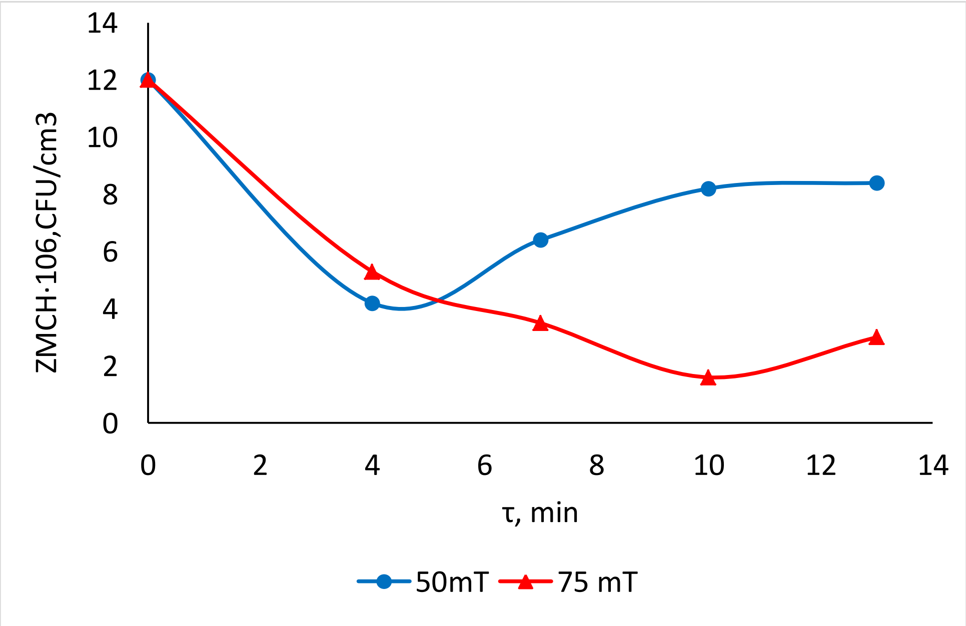


**Figure 1.** Dependence of processing duration (τ) and magnetic induction on LMF wastewater of general discharge.

In samples of flow water treated by a magnetic field, the induction intensity of 75 mT during 4, 7, 10, and 13 minutes, the degree of destruction of yeast cells is 55.83%, 70.83%, 86.67%, and 75%, respectively with an increase in the time of action of the magnetic field, the inactivation of microorganisms increases. We registered the highest degree of microorganisms destruction (86.67%) under the induction intensity of 75 mT within 10 minutes under the magnetic field's action.

Treatment of wastewater by a general discharge by a magnetic field leads to improved physical and chemical parameters (Table 1).

**Table 1.** Physical and chemical composition of wastewater after the magnetic field action (P = 0.95, ± δ, %).

| Indicators | Value |
|---|---|
| pH | 6.0 ± 0.05 |
| Chlorides, $mg/dm^3$ | 405 ± 1.0 |
| Nitrogen, $mg/dm^3$ | 4 ± 1.5 |
| Suspended substances, $mg/dm^3$ | 1600 ± 1.0 |
| Broken residue, $mg/dm^3$ | 800 ± 0.9 |
| Sulfats, $mg/dm^3$ | 1152 ± 0.7 |
| HSK, $mgO_2/dm^3$ | 5107 ± 1.0 |

The data indicate that after the magnetic field's action, a significant decrease in HSC is achieved by 72%, chlorides - 70%, available nitrogen - 66%, suspended substances and a permeable residue - 50%, sulfates - 67%.

## Discussion

During the purification of wastewater by a magnetic field, the rate of chemical processes and crystallization of dissolved substances increases, adsorption processes are intensified, and coagulation of impurities and precipitation is improved. In water, after magnetic treatment, the concentration of dissolved oxygen increases, which improves the bactericidal effect of magnetic treatment of flow water.

It is known that magnetic processing of aqueous systems leads to the following physical and chemical changes: the rate of dissolution of inorganic salts increases tenfold (for $MgSO_4$ - 120 times), in water after magnetic treatment, the concentration of dissolved oxygen increases. There is also data that indicate the bactericidal effect of magnetic water treatment. Magnetically treated wastewater does not acquire any side, harmful properties and does not change its salt composition.

Magnetic water treatment also affects the electrokinetic potential and aggregation stability of suspended particles, the reasoning that accelerates their deposition; it contributes to the extraction of various suspensions from the water. The magnetic field's direct effect on impurities ions contributes to the activation of adsorption processes and opens broad prospects for water treatment in general (Mnykh, Sukhats'kyy, Zin', 2019).

## Conclusions

The optimal parameters of electromagnetic wastewater treatment have been confirmed, namely T = 293 K at a magnetic induction of 75 mT lasting 10 minutes, which allows achieving the degree of wastewater treatment according to physicochemical and microbiological indicators by 30 – 72% and 86.67%, respectively.

Thus, the use of physical and chemical methods of wastewater purification makes it possible to obtain a high antimicrobial effect and a significant reduction in pollutants, which leads to an improvement in sanitary and epidemiological indicators of the quality of wastewater. The results can be used to select cleaning equipment at yeast enterprises.

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