Original Article

Comparative study of ozone treatment and magnetic field treatment in the fractionation of organic matter and hydrocarbons in gray water

Esraa Hashim Ali[1], Amal A. Hussein[1], Natheer Jamal Imran[2]

[1] Department of Applied Sciences, Division of Biotechnology, University of Technology- Iraq.

[2] Environment and Water Directorate, Ministry of Science and Technology, Baghdad, Iraq.

Email: esraahashimali@gmail.com

Abstract

Wastewater treatment processes are very important and economical to improve the quality, and remove the greater part of the contaminants from wastewater and therefore to solve the water crisis, which may provide new sources of water. To conserve water, it must be recycling the gray water (GW). In this study, gray water will be treated using two methods, chemical using ozone and physical using magnetic field. The use of ozone in water treatment is a chemical treatment based on the infusion of ozone into water or wastewater. In this study, the best conditions for treating gray water with ozone were investigated to achieve the best removal of organic matters represented by chemical oxygen demand (COD), Biochemical oxygen demand (BOD_5), Total organic carbon (TOC), Oils and Greases. It was experimentally concluded that the ozone treatment is positively affected by the increase in pH, as well as the ozone concentration and the time of exposure to ozone. The ideal conditions for ozone treatment were determined according to the quality of the resulting water and not according to the removal values of organic materials, and these conditions are pH 8, ozone concentration 40mg/l and ozone exposure time 30 min. Magnetization treatment depends on the strength of the magnetic field and the time of exposure to it, the treatment was tried with four magnetic intensities 5000,6000,7000,8000 gauss and five exposure times 30,60,90,120,150 minutes at pH 8 and normal temperature. It was found that increasing the magnetic intensity leads to a decrease in the removal of organic matter, where the best magnetic intensity to achieve the best removal is 5000 gauss and increasing the time has a positive effect. Therefore, the optimum conditions were determined: 5000 and a time of 30 minutes.

Keywords: Gray water; Ozonation; Magnetization; Water Treatment; COD; THM

Introduction

Water scarcity is one of the major challenges faced by human beings. Drought, conflicting demand for water in most parts of the world and increasing pollution rates in natural water sources 1 have caused intense pressure on water sources. As a result, it has become necessary to rely on waste water as a source of reusable water. Wastewater treatment processes are very important and economical to improve the quality, and remove the greater part of the contaminants from wastewater and therefore to solve the water crisis, which may provide new sources of water 2,3. One method of conserving water, on the local scale, is by recycling gray water (GW).

Gray water is defined as used water that eliminates wastewater from toilets and includes water from baths, hand basins, showers, kitchen sinks and washing machines, in households, schools, office buildings and others 4. GW treatment for reuse is an important strategy towards reducing global water shortage, especially in places where water is scarce, and converting it to a better quality.

Access this article online	
Quick Response Code:	**Website:** www.pnrjournal.com
	DOI: 10.47750/pnr.2022.13.04.002

Address for correspondence: Esraa Hashim Ali, Department of Applied Sciences, Division of Biotechnology, University of Technology- Iraq, Email: esraahashimali@gmail.com

Received date: 11 August 2022 Accepted: 13 September, 2022
Published: 10 October, 2022

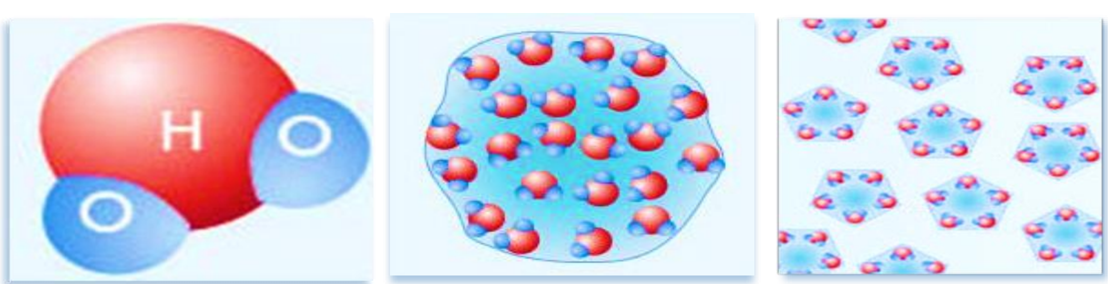
How to cite this article: Ali H E, Hussein A A , Imran N J , Comparative study of ozone treatment and magnetic field treatment in the fractionation of organic matter and hydrocarbons in gray water, J Pharm Negative Results 2022;13(4):10-22

The treated water doesn't have to be drinkable, but can at least be used for various other purposes, such as gardening and agriculture, industrial purposes, steam generation, and others 5,6,7,8. Among the main components of gray water are organic materials, including proteins, carbohydrates and fats, at rates of approximately 50%, 40% and 10%, respectively. Chemical oxygen demand (COD) it is a measure of organic substances and represents the total amount of oxygen wanted to oxidize the organic matter by strong oxidizing chemicals (potassium dichromate) in acidic condition 9. Trihalomethane compounds are the most harmful byproducts to human health, and they are produced from the interaction of organic substances in water with halogen compounds, especially chlorine used to disinfect water, so its presence and concentrations must be investigated 10.

Ozonation (also referred to as ozonisation) is the use of ozone in water treatment as a chemical treatment based on the infusion of ozone into water or wastewater. Ozone (O_3) is a strong oxidant with almost 10 times higher solubility in water than pure oxygen, reacting with organic and inorganic compounds directly, via a hydroxyl radical mechanism and /or by Advanced oxidation processes (AOPs) which are considered a highly efficient technology regarding water treatments for the reduction of organic pollutants classified as bio-recalcitrant and for the inhibition of pathogen microorganisms resistance to conventional techniques 9,11,12.

Ozone, due to the nature of its reactive molecule and its high ability to oxidize substances, has been able to achieve specific objectives if it is used alone in treatment or enhanced by other technology or catalysts. These objectives may include: disinfection, color removal, the degradation of organic micro pollutants and the reduction of chemical oxygen demand (COD) 13. The aim of this study is to installing a wastewater treatment system consisting of an ozone treatment unit, then investigate the ability of this system to treat and minimize organic substances in gray water.

.Magnetization means the use of a magnetic field in water treatment which is a simple and efficient physical method that includes the flow of water through a magnetic field (MF) or the combination of magnetic fields, and this flow will lead to changes in the physical, chemical and biological properties of water and it will be called magnetized water (MW) 14,15. Magnetic treatment of water restructures the water molecules into smaller, uniform clusters easing their travel through the pathways in plant and animal cell membranes. In addition, toxic agents cannot enter the MW structure 16. The strength of MF and the time of exposure to it are factors that affect the properties of MW. This technique of utilizing magnet is clean, simple; with no extra energy used and resulting in scale reduction consider a green technology 17. Although the use of the magnetic field in the treatment of water improves its properties clearly, this technique is still controversial and sometimes conflicting. The water molecule consisting of an oxygen atom and two hydrogen atoms linked together by covalent bonds. Water molecules do not exist singly, but rather in the form of irregular or non-uniform clusters in which water molecules are linked to each other by hydrogen bonds. These irregular clusters allow pollutants and toxins to clump between water molecules. When exposing water to the magnetic field, it will restructure clusters of water molecules in a more regular hexagonal smaller clusters 18 Fig (1), which increases hydration by using less water and makes it difficult for pollutants to settle between its molecules, so the water flow becomes better through the membranes and facilitates its penetration into the plant and animal cell 19.



(b) (c)

Fig.1 (a) water molecule. (b) Ordinary water clusters. (c) Magnetized water clusters.

Materials and Methods

Study Site and Sampling

Treatments and examinations were carried out in Environment and Water Directorate, Ministry of Science and Technology. Gray water samples (hand washing and kitchen sink) were manually collected from the city of Baghdad, Iraq. The sample type is composite; the gray water samples were taken in three stages for the period from November to February 2021-2022. Each stage includes collecting a 100-liter sample of gray water and storing it at 4°C to reduce biodegradation until treatment is done.

Ozone Generator

Ozone used in this study was produced by an ozone generator (The POG-5G Portable Ozone Generator is equipped with a built-in internal air compressor and heavy-duty cooling fan) based on the corona discharge method, Where the electricity passes through a narrow cavity filled with air or oxygen, the oxygen molecules will cleavage into oxygen atoms (O^-) and these atoms combine with other oxygen molecules (O_2) to give ozone (O_3). Below picture (1) showing the ozone generator used in this study.

Pic. (1) The POG-5G Portable Ozone Generator

Magnetic field system

The source of the magnetic field consists of a permanent magnet that generates a constant magnetic field of intensity ranging from 0.1 -1 Tesla (1000 and 10,000 gauss) the required field strength is manually controlled and measured in gauss-meter. Water is pumped by an electric pump from the tank to the permanent magnet through a flexible PVC pipe and then back to the tank, picture (2) shows the system:

Pic (2) Magnetization system.

Chemicals

All solvents and chemicals were at least of analytical purity (> 95%) and bought from several suppliers.

Experimental steps

Initially, GW samples were brought to the laboratory, stored at 4°C, and then analyzed to determine the characteristics of GW in terms of its organic compounds before treatment. GW characterization was done according to steps and working methods described in APHA (the Standard Methods for the Examination of Water and Wastewater) 20. pH of the samples was adjusted using NaOH and H_2SO_4, all experiments were performed at room temperature. pH measured by pH meter (WTW, InoLab), Chemical Oxygen Demand (COD) measured by Open Reflux Method 5220 B. 20, Biochemical oxygen demand (BOD_5) values were determined by measuring oxygen consumption using an oxygen meter (WTW, InoLab) after 5 days of incubation of samples, Total Organic Carbon (TOC) measured by direct method, Oil and Grease measured by Partition-Gravimetric Method 5520 B. 20, and the Turbidity was measured by the turbid meter (Lovibond), for biological examinations for hydrocarbons, gas chromatography (GC) was adopted using the tri-halomethane (THN) standard.

GC condition

All chromatographic analyses were done using a gas chromatograph (GC) model shimadzu – 2010 Japan) equipped with an electron capture detector (ECD) and a split/splitless injector. The column for chromatographic separation was (HP-5, 30 m ´ 0.32 mm ´ 0.25 µm.). Instrumental operation conditions are shown in table (1):

Table 1: Instrumental operation conditions of GC

Injector temperature	250_o C
Detector temperature	280_o C
Column Oven	50_o C –100_o C (10 C / MIN) , 100 – 220_o C (25 C / MIN)
Carrier gas	N2
Sample injection	1 µL
Pressure	100 Kpsi

Experiment design

Treatments was carried out in two stages ozonation and magnetization .Ozonation experiments were conducted to find out the effect of the ozone concentration used in the treatment, the pH and duration of exposure to ozone (Time) on organic content degradation, and thus determine the optimum conditions for degradation. Ozonation was carried out on 5 liters of gray water for each variable, operated in semi-batch mode, for various pH values between 2 and 10, ozone exposure times between 30 and 150 min. and the applied ozone concentrations changed from about 20 to 40 mg O3/L, for the selection of these variables, previous works were taken into consideration. In all experiences, the ozone doses refer to the ozone concentrations in the gas phase. At the end of the treatment under specified conditions, samples of the treated gray water were withdrawn from the reactor to perform the analyses required to determine values of COD, BOD_5, TOC and Oil and Grease after treatment for the estimation of the treatment efficiency. Starting and before performing each treatment, the gray water is examined and the values of each of the following parameters are determined: pH, COD (mg/l), BOD_5 (mg/l), TOC (mg/l) and Oil and grease (mg/l), as shown in Table (2).

In the first stage, the treatment was carried out using five concentrations of ozone, a fixed exposure time of 30 minutes, and pH=8. These conditions gave a degradation of the organic matters represented by COD, BOD_5, TOC and Oil values as shown in table (3).

In the second stage, the treatment was done by changing the pH value and fixing the exposure time and the ozone concentration. These conditions gave a degradation of the organic matters represented by COD, BOD_5, TOC and Oil values, as shown in table (4).

In the third stage, the treatment was done by changing the time of exposure to ozone and stabilizing the ozone concentration and pH value. These conditions gave a degradation of the organic matters represented by COD, Oil and Grease and TOC values, as shown in table (5).

Experimentally, the gray water was retreated at the variables that produced the highest removal of organic matter, pH 10, Ozone concentration 40 mg/l and ozone exposure time 150min., which produced water with a pH of 10, which produces alkaline water of limited use. Therefore, second optimal conditions were chosen with a high degradation, but less than the first conditions and it produces water with a pH of 8 within the values of natural water 16.

Magnetization experiments were conducted to find out the effect of MF intensity used in the treatment, and duration of exposure to MF (Time) on organic content degradation, and thus determine the optimum conditions for degradation. Magnetization was carried out on 5 liters of gray water for each variable, for various MF intensities between 5000 and 8000 gauss and different exposure times between 30 and 150 min. for the selection of these variables, previous works were taken into consideration. At the end of the treatment under specified conditions, samples of the treated gray water were withdrawn from the reactor to perform the analyses required to determine values of COD, BOD_5, TOC, TDS, Turbidity and Oil and Grease after treatment for the estimation of the treatment efficiency. After determining the optimum conditions, the hydrocarbons test (GC) was performed.

Starting and before performing each treatment, the gray water is examined and the values of each of the following parameters were determined: pH, COD (mg/l), BOD_5 (mg/l), TOC (mg/l) and Oil and grease (mg/l), Turbidity (NTU) and TDS (mg/l), as shown in Table (6).

In the first stage, the treatment was carried out using five MF intensities, a fixed exposure time of 30 minutes, and pH=8. These conditions gave a degradation of the organic matters represented by COD, BOD_5, TOC and Oil values as shown in table (7).

In the second stage, the treatment was done by changing the time of exposure to MF and stabilizing the MF intensity and pH value. These conditions gave a degradation of the organic matters represented by COD, Oil and Grease and TOC values, as shown in table (8).

All Treatments at all conditions were re-treated three times and the results were similar. The average was taken and presented in the results tables.

Data Processing

The Removal percentage was calculated according to the formula 22:

Removal % = (Co-C)/Co × 100

Where Co = concentration before treatment.

C = concentration after treatment.

RESULTS

Ozonation

Gray water characteristics

Gray water characteristics are presented in table (2) without treatment. All water samples were considered slightly alkaline since the initial pH (before treatment) was above seven. No pH changes were observed over time during our experiments. The water sample taken was characterized by its yellowish-white color, it has a thicker texture compared to normal water and is soapy misty as a result of containing suspended solids, oils, washing liquids, soaps and kitchen wastes.

Table 2: Parameters values of gray water before treatment

Parameter	Value
pH	8
COD (mg/l)	318
BOD_5(mg/l)	167
TOC (mg/l)	117
Oil (mg/l)	18
Turbidity (NTU)	178

pH, COD, BOD_5, TOC, Oil and Grease and Turbidity values are normal as values of gray wastewater of mixed origin (bathroom, hand wash and kitchen sink) [17]. This information is important to evaluate the efficiency of the treatment or the possibility of reuse.

Impact of ozone concentration

All parameters responded to the ozone treatment and were degraded below the initial value. In the first stage, the treatment was carried out using five concentrations of ozone 20,25,30,35 and 40 mg/l and fixed exposure time of 30 minutes, pH=8. These conditions gave a degradation of the organic matters represented by COD, BOD_5, TOC and Oil and Grease values as shown in table (3). Note: Decimals are neglected in the result.

Table 3: Parameters values of gray water after ozonation at different ozone concentrations.

Parameter	pH = 8 , Time = 30 min.					
	Before treatment	O_3 Conc. = 20mg/l	O_3 Conc. = 25mg/l	O_3 Conc. = 30mg/l	O_3 Conc. = 35mg/l	O_3 Conc. = 40mg/l
COD (mg/l)	318	204	163	147	135	126
BOD_5 (mg/l)	167	131	102	87	66	48
TOC (mg/l)	117	78	66	59	50	41
Oil and Grease (mg/l)	18	15	13	10	8	5

Exposing gray water to ozone concentrations of 20, 25, 30, 35 and 40 mg/l at pH 8 and a time of 30 minutes led to obtaining a removal percentage of COD of 35, 48, 53, 57 and 60%, respectively, and BOD removals of 21, 38, 47, 60 and 71%, respectively, and removal of TOC 33, 43, 49, 57 and 64%, respectively, and oil and grease removal 16, 27, 44, 55 and 72 percent, respectively, as shown in Figure (2):

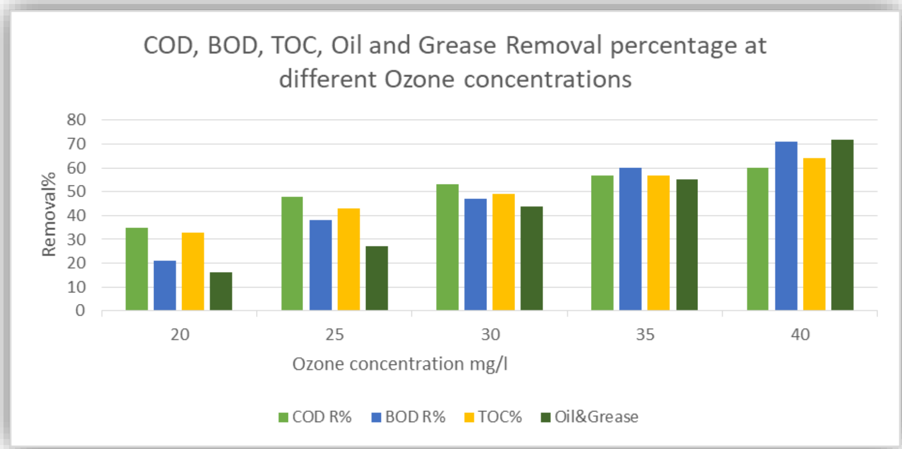


Figure (3) COD, BOD_5, TOC and Oil and Grease Removal at different ozone concentrations.

The above results showed that as the concentration of ozone increases, the concentrations of organic substances decrease, and this corresponds to several studies 21,22,23. The total COD removal was between 35 and 60 %, increasing with the ozone concentration, and also depending on the initial COD content of the sample. Among ozone dosages, after 30 minutes, COD removal at concentration 40 mg/l became significantly higher than at the other four concentrations. The explanation for this is that the increase in ozone concentration means that more ozone available per molecule of organic substances in water. In addition to the concentration of ozone reflects on the production of hydroxyl radical, increasing the concentration of ozone directly leads to the activation of the generation of hydroxyl radicals, which in turn increases the degradation of organic compounds. Although another study was conducted, proved that an increase in the ozone concentration to more than 40mg/l does not lead to an important difference in the rate of COD, TOC removal 24. These results accord well with previous studies 25,26. Another study obtained a result is that higher ozone dosage may adversely affect hydroxyl radicals generation through Eq. (1). In this case, ozone will react with hydroxyl radicals, producing hydroperoxyl radicals, which are less reactive than hydroxyl radicals 27. Then, this reaction might suppress the removals of COD and TOC in ozone treatment.

$$O_3 + HO\bullet \rightarrow O_2 + HO_2\bullet \qquad (1)$$

This study concluded that the best treatment of organic materials at ozone concentration of 40 mg/l which represents the highest concentration used in this study.

The decrease in BOD_5 has been refered to formation of smaller, oxygenated types of organic compounds which is easier for microbes to consume more suitable to microbial attack, and may be to the reduction of bactericidal components, for example, phenolics 28.

Impact of pH

In the second stage, the treatment was done by changing the pH values and fixing the exposure time and the ozone concentration. These conditions gave a degradation of the organic matters represented by COD, BOD_5, TOC and Oil and Grease values, as shown in table (4)

Table (4) Parameters values of gray water after ozonation at different pH values.

Parameter	Ozone Conc.= 40 (mg/l), Time = 30min. Before treatment	pH = 2	pH = 4	pH = 6	pH = 8	pH = 10
COD (mg/l)	318	233	187	165	121	91
BOD_5(mg/l)	167	142	109	82	55	38
TOC (mg/l)	117	74	70	65	62	56
Oil (mg/l)	18	17	14	11	8	6

Treatment at pH values 2, 4, 6, 8, and 10 produced a removal of COD of 26, 41, 48, 61, and 71%, respectively, a removal of BOD of 14, 34, 50, 67, and 77%, respectively, and of TOC 36, 40, 44, 47, and 52%, respectively, and oil and grease removals of 5, 22, 38, 55 and 66%, respectively, as shown in Figure (4):

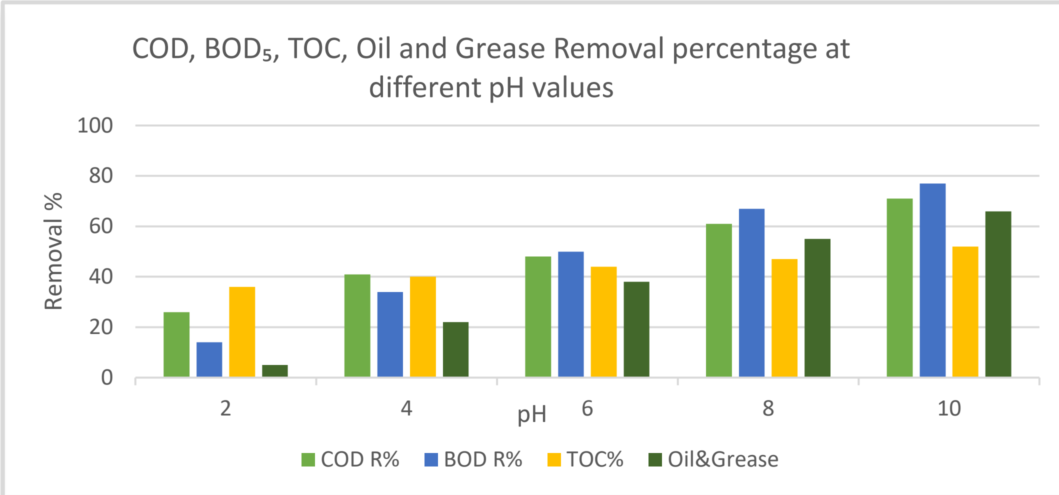


Figure (4) COD, BOD_5, TOC and Oil and Grease Removal at different pH values.

The organic substances removal by ozone is influenced mainly by pH [29]. At the pH within the acidic range (less than 7) direct mechanical prevailed by molecular ozone, at pH values within the basal range, larger amounts of hydroxyl radicals are formed. For pH 10, the decomposition of O_3 into hydroxyl radicals is prompt and this means that the indirect mechanism will prevail (via OH radicals) [12]. The results of the second stage proved that the pH had a major ifluence in the treatment efficiency. At pH 10 the organic matter removal achieved the highest values pointing that a larger quantity of OH radicals were formed and the indirect reaction prevailed, because hydroxyl radicals are less selective and more reactive to degrade organic compounds leading to the increase in organic substances removal. This is not true for some complex chemical substances that disintegrate more and faster at an acidic pH 30. From the foregoing, it can be considered that the pH 8-10 is ideal for the degradation of organic materials in grey water, despite the highest degradation that occurred at pH 10, other studies have found the same result 29,31.

Impact of ozone exposure time

In the third stage, the treatment was done by changing the time of exposure to ozone and stabilizing the ozone concentration and pH value. These conditions gave a degradation of the organic matters represented by COD, Oil and Grease and TOC values, as shown in table (5):

Table (5) Parameters values of gray water after ozonation at different ozone exposure times.

Parameter	pH = 8 , Ozone concentration =40mg/l Before treatment	Time = 30min.	Time = 60min.	Time = 90min.	Time = 120min	Time = 150min.
COD (mg/l)	318	130	126	123	120	115
BOD_5 (mg/l)	167	62	60	54	51	47
TOC (mg/l)	117	64	58	56	54	53
Oil and Grease (mg/l)	18	9	7	5	4	3

These exposure times (30, 60, 90, 120 and 150) produced a removal of COD of 59, 60, 61, 62 and 63%, respectively, a removal of BOD 62, 64, 67, 69, and 71%, respectively, and a removal of TOC 45,50,52,53, and 56% and removal of oils and greases, amounting to 50,61,72,77 and 83%, respectively, as shown in Figure (5):

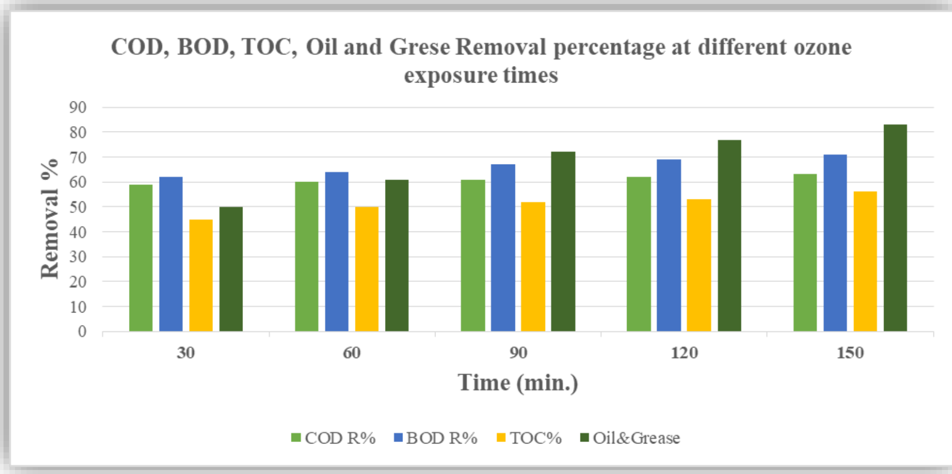


Figure (5) COD, BOD_5, TOC and Oil and Grease Removal at different ozone exposure times.

Increases in ozone exposure time can lead to extensive breakdown of organic compounds (for instance aliphatic and aromatic structures and other electron-rich targets) into lesser molecular weight compounds, thus increasing the amount of biodegradable organic compounds.

Increasing the time leads to make the water more saturated with ozone, thus allowing a higher rate of oxidation and fragmentation of organic matter.

It was noted that the highest fat removal was done at the longest time used, due to the increase in the period of oxidation of oils and greases, whereas the double bonds in oils and greases can undergo oxidation. This can also be attributed to the hydrogen peroxide H_2O_2 produced by two hydroxyl radicals (OH) are produced from two O_3 molecules which further oxidize and decompose the Oils and Greases 32.

During all three stages of treatment, foam was formed continuously throughout the treatment period and pH value changes slightly and does not affect the treatment.

Ozonation optimum conditions:

Although the most degradation of organic matters represented by COD, BOD_5, TOC and Oil and Grease occurred at PH 10, exposure time of 150 minutes and Ozone concentration of 40mg/l, they cannot be considered optimum conditions, as they are conditions in which the results of the degradation of organic materials are the best possible compared to the other conditions within this study, but they produce water of limited use due to its alkalinity and the length of the treatment period.

Therefore, it is possible to determine less optimum conditions in terms of organic matter degradation, but it produces water of higher quality, especially as it achieves a very good removal of organic matter, and shorter treating time, which makes treatment more practical and these conditions are PH 8, Ozone concentration 40mg/l and exposure time of 30 min.

Magnetization

Gray water characteristics

Gray water characteristics are presented in table (6) without treatment. All water samples were considered slightly alkaline since the initial pH (before treatment) was above seven. No pH changes were observed over time during our experiments. The water sample taken was characterized by its foggy-white color, it has a thicker texture compared to normal water and is soapy misty as a result of containing suspended solids, oils, washing liquids, soaps and kitchen wastes.

Table (6) Parameters values of gray water before treatment

Parameter	Value
pH	8
COD (mg/l)	415
BOD_5(mg/l)	198
TOC (mg/l)	138
Oil (mg/l)	63
TDS (mg/l)	1150
Turbidity (NTU)	288

pH, COD, BOD_5, TOC, Oil and Grease, Turbidity and TDS values are normal as values of gray wastewater of mixed origin (bathroom, hand wash and kitchen sink) 23. This information is important to evaluate the efficiency of the treatment or the possibility of reuse.

Impact of MF intensity

In the first stage, the treatment was carried out using four MF intensities 5000,6000,7000,8000 G and fixed exposure time of 30 minutes, pH=8. Results of this treatment shown in table (7). Note: Decimals are neglected in the result.

Table (7) Parameters values of gray water after magnetization at different magnetic strengths.

Parameter	pH = 8 , Time = 30 min. Before treatment	Magnetic Strength =5000 G.	Magnetic Strength =6000 G.	Magnetic Strength =7000 G.	Magnetic Strength =8000 G.
COD (mg/l)	415	362	412	413	415
BOD_5 (mg/l)	198	174	191	198	198
TOC (mg/l)	138	105	130	134	137
Oil and Grease (mg/l)	63	37	52	58	61

It was experimentally observed that the best treatment was done at a magnetic intensity of 5000G, and that by increasing the intensity, the treatment of pollutants decreased until they became almost non-existent at 8000 G.

The percentages of COD removal achieved at magnetic strengths 5000, 6000, 7000 and 8000 are (12,0.7, 0.4 and 0%), for BOD (12,3,0,0), for TOC (23,5,2,0.7%), and for oils and greases (41,17,7,3%) respectively for each , as shown in Figure (6):

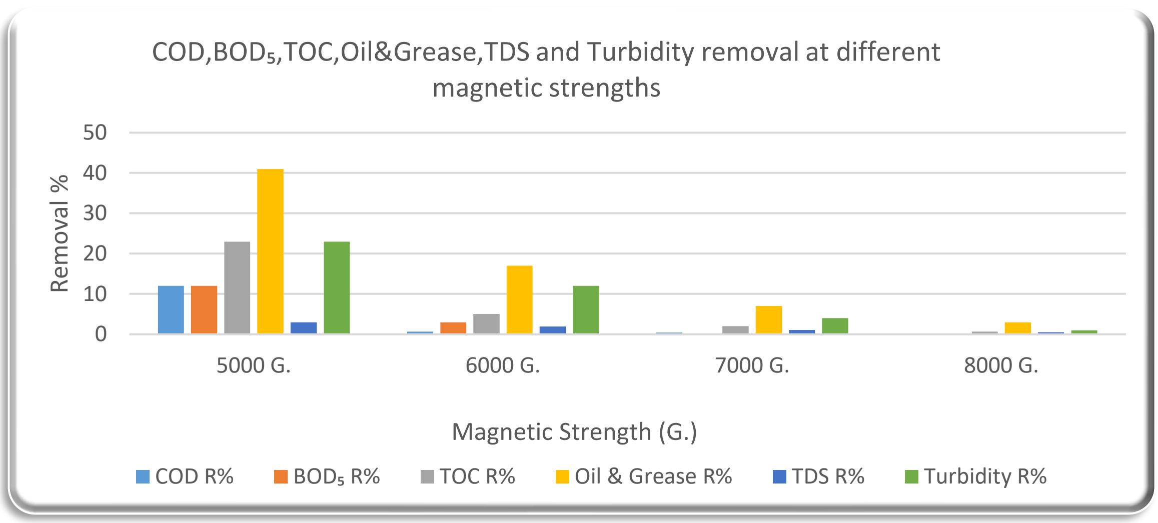


Fig (6) COD, BOD_5, TOC, Oil and Grease, TDS and Turbidity Removal at different magnetic strengths.

Impact of MF exposure time

In the second stage, the treatment was done by changing the time of exposure to MF and stabilizing the MF intensity (5000 G) and pH value (8). These conditions gave a decrease of pollutant concentrations, as shown in table (8):

Table (8) Parameters values of gray water after magnetization at different Magnetic Exposure Times.

Parameter	pH = 8, Magnetic Strength = 5000 G. Before treatment	Exposure Time = 30 min.	Exposure Time = 60 min.	Exposure Time = 90 min.	Exposure Time = 120 min.	Exposure Time = 150 min.
COD (mg/l)	415	362	340	310	275	242
BOD_5 (mg/l)	198	174	166	152	143	130
TOC (mg/l)	138	105	100	96	91	85
Oil and Grease (mg/l)	63	37	35	33	30	27

The percentages of COD removal achieved at magnetic strength 5000 and pH 8 for several exposure times 30, 60, 90, 120 and 150 were 12, 18, 25, 33, 41%, respectively, and for BOD 12, 16, 23, 27, 34% for TOC 23, 27, 30, 34,38%, for oils and greases 41, 44, 47, 52, 57%, for TDS 3, 3, 4, 4, 5%, and for turbidity 23, 27, 29, 32, 36%, respectively for each of them, as shown in fig (7)

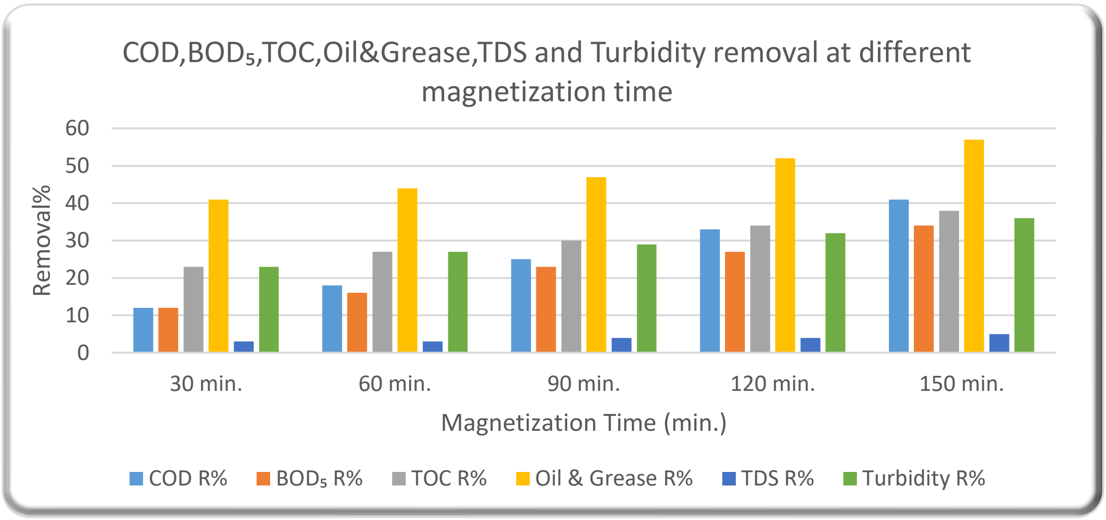


Fig (3) COD, BOD_5, TOC, Oil and Grease, TDS and Turbidity Removal at different exposure times

The results obtained can be attributed to more than one factor, the first of which is the changes caused by the magnetic field in the structure of the water molecules, increasing the hydrogen bonds between them and the reduction of the electrokinetic potential lead to the rapid coagulation of the particles in the water 33,34

The second factor is the Lorentz forces, the force that affects and redirects moving charges in a magnetic field, which enhance the efficiency of wastewater treatment processes by affecting the direction of movement of charged particles and increasing the possibility of collision among them, which consequently leads to their deposition 35,36.

This matches the results of another study that found that the use of a magnetic field of intensity 0.4-0.6 leads to the sedimentation of activated sludge in a shorter time and a better coagulation rate, in addition to a decrease in the electro-kinetic potential of the water 37. The reason for the decrease in the concentrations of organic and inorganic pollutants in waste water is the increase in the number of hydrogen bonds between water molecules by up to 34%, this restructure the water molecules and makes its stick more cohesive and more difficult to penetrate by pollutant particles 38.

Increasing the time of exposure to the magnetic field allows for an increase in the organization and arrangement of water molecules, and thus the sedimentation and coagulation processes of pollutants occur more widely.

Magnetization optimum conditions

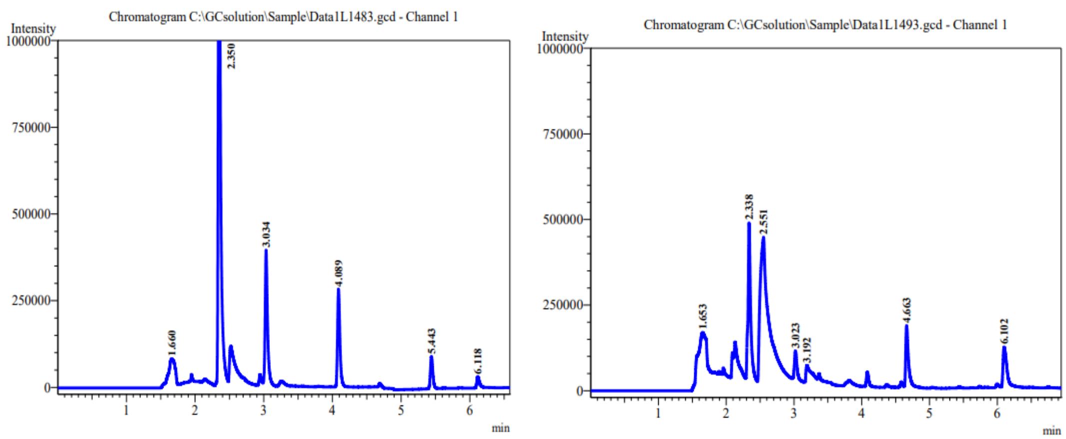
It can be considered that the best magnetic field strength is 5000, and the time can be determined according to the application. As time increases, the percentage of removal of organic and inorganic pollutants increases.

Hydrocarbones

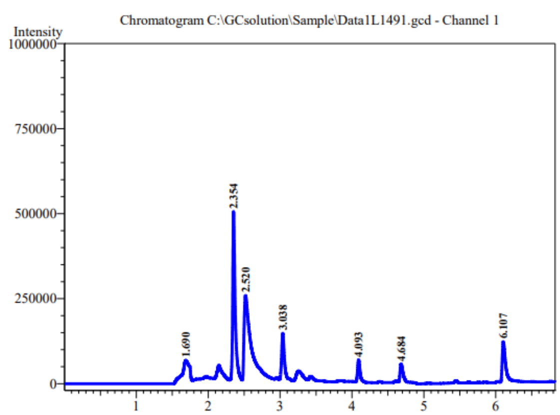
Gas chromatography was conducted for each ideal condition to determine its ability to remove hydrocarbons. The presence of THM compounds is a by-product of the interactions of organic substances in water with halogen compounds that are carcinogenic, so it is necessary to investigate their presence and concentrations. The results of the hydrocarbons examination by GC using the tri-halomethane standard showed the presence of each of the hydrocarbons (Chloroform, Bromo di-chloromethane, Di-bromo chloromethane, Bromoform) in the non-treated GW , ozonized and magnetized GW at the concentrations shown in the table (5) and fig (4) the chromatogram before and after treatment.

Table (9) Hydrocarbons in gray water before and after treatment by ozone and magnetic field

Name	Before Treatment (ppm)	pH=8, Ozone Conc.=40 (mg/l), Time=30 min (ppm)	pH=8, Magnetic Field=5000 G Time=30 min (ppm)
Chloroform	10.25	6.89	7.14
Bromodichloromethane	7.89	5.18	5.22
Dibromochloromethane	5.44	UDL	1.58
Bromoform	3.89	UDL	UDL



(b)



(c)

Fig (4) (a) Non-treated GW chromatogram, (b) Magnetized GW chromatogram, (c) Ozonized GW chromatogram.

Both treatment methods showed efficiency in fractionating and removal of the four compounds. Ozone achieved removal for Chloroform, Bromodichloromethane, Dibromochloromethane and Bromoform of 32, 34, 99 and 99%, respectively, the removal of them by magnetization was 30, 33, 70 and 99%, respectively. It is noted that ozone is more efficient in the process of removing from the magnetic field, although both showed efficiency in the fractionation of hydrocarbons.

Conclusion

Ozone treatment is more effective in reducing and removing organic and hydrocarbon materials. Gray water treatment with ozone exhibited high efficiency in organic substances and Hydrocarbones removal. At pH 10, ozone concentration 40 mg/L, and ozone exposure time of 150 minutes, the highest removal of organic matter occurred, but it is not considered optimum conditions because it produces alkaline water that is not suitable for use in most fields. Therefore, the optimum conditions were considered as pH 8, ozone concentration 40 and treatment time 30. The reactivity of ozone with organic substances is great and promises a great development within the applications of treating and reusing wastewater, especially gray ones. Ozone breaks down organic materials at acidic and basic conditions, although the efficiency of the treatment increases with increasing pH. This may enable us to produce potable water if a second treatment with ozone is used to get rid of salts and inorganic materials. Ozone treats the wastewater without the formation of any sludge or other solid waste thus there will be no residue left after the treatment and this reduces waste disposal costs.

Grey water treatment with MF exhibited efficiency in organic substances and Hydrocarbones removal. The highest removal obtained at magnetic intensity 5000 gauss and time of 150 minutes. 30 minutes achieved a satisfactory removal so it can be considered an ideal time for gray water. Magnetization of water is a very simple, effective, economical and hygienic method as it does not generate by-products, so it can be considered as an environmentally friendly technology. It is recommended to enact a law to separate gray water from black water in sewage networks to facilitate its treatment and utilization.

It is recommended to enact a law to separate gray water from black water in sewage networks to facilitate its treatment and utilization.

Compliance with Ethical Standards statements

Ethical approval: University of Technology- Iraq/ certifies the ethical approval, Funding details (In case of Funding): I am responsible for paying the financing, Conflict of interest: There is no conflict of interest, Informed Consent: Department of Research and Studies, University of Technology- Iraq \ Agreed

References

A. A. Hussein, Monthly changes of some physicochemical parameters for Tigris river- Baghdad between2002-2003. Engineering and Technology Journal, 27(2009), 64-70.

Z. He, Z. Lyu, Q. Gu, L. Zhang, and Wang, J., Ceramic-based Membranes for Water and Wastewater Treatment. Journal of Colloids and Surfaces A: Physicochemical and Engineering Aspects, 578, (2019). https://doi.org/10.1016/j.colsurfa.2019.05.074.

N. Ait-Mouheb, A. Bahri, B.B. Thayer, B. Benyahia, G. Bourrié, B. Cherki, N. Condom, R. Declercq, A. Gunes, M. Héran, N. Kitir, B. Molle, D. Patureau, A. Pollice, A. Rapaport, P. Renault, K. Riahi, B. Romagny, T. Sari, C. Sinfort, J.P. Steyer, S. Talozi, B. Topcuoglu, M. Turan, N. Wéry, E. Yıldırım, J. Harmand, The reuse of reclaimed water for irrigation around the Mediterranean Rim: a step towards a more virtuous cycle? Journal of Regional Environmental Change, 18, (2018), 693–705. https://doi.org/10.1007/s10113-018-1292-z.

A. A. Ali, The Reuse of Greywater for irrigation in suburban area. Thesis. (2013) Building and Construction Engineering Department, University of Technology-Iraq.

E. Eriksson, K. Auffarth, M. Henze, and A. Ledin, Characteristics of grey wastewater. Journal of Urban Water 4 (2002), 85–104. http://dx.doi.org/10.1016/S1462-0758(01)00064-4.

R. Etchepare, J. Peter, and V. Der Hoek, Health risk assessment of organic micropollutants in graywater for potable reuse. Journal of Water Researches, 72 (2014), 186–198. https://doi.org/10.1016/j.watres.2014.10.048.

M. Khalil, and Y. Liu, Greywater biodegradability and biological treatment technologies: A critical review. International Biodeterioration & Biodegradation, 161(2021). https://doi.org/10.1016/j.ibiod.2021.105211.

I. Shaikh, and M. Ahammed, Quantity and quality characteristics of greywater: A review. Journal of Environmental Management, 261 (2020, 110266. https://doi.org/10.1016/j.jenvman.2020.110266.

S. R. Qasim, and G. Zhu, Wastewater Treatment and Reuse Theory and Design Examples Volume 1: Principles and Basic Treatment. Taylor & Francis Group.Taylor & Francis Group, London, UK, 2018.

B. Durmishi, A. Reka, T. Hellon, M. Ismaili, M. Srbinovsk, and A. Shaban, Disinfection of Drinking Water and Trihalomethanes: A Review. 2 (2015), 45-56.

D. G. Rao, R. Senthilkumar, J. A. Byrne, and S. Feroz, Wastewater Treatment Advanced Processes and Technologies.IWA publishing London, UK, 2013.

J. Cardenas, B. García, A. Agüera, J. Pérez, and F. Agugliaro, Wastewater Treatment by Advanced Oxidation Process and Their Worldwide Research Trends. International Journal of Environmental Research and Public Health, 17(2019), 170. https://doi:10.3390/ijerph17010170.

P. Paraskeva, and N. Graham, Ozonation of Municipal Wastewater Effluents. Journal of the Water Environment Federation, 74(2002), 569-581. https://doi.org/10.2175/106143002X140387.

Y. Qin, B. Dong, and W. Li, Experimental study of the frosting characteristic of water on a cold surface in the magnetic field. Journal of Experimental Thermal and Fluid Science. 114(2020), 110094. https://doi.org/10.1016/j.expthermflusci.2020.110044.

A. A. Hussein, and S. H. Nasher, Effect of magnetic field on the growth of Escherichia coli and Staphylococcus aureus. Journal of Engineering and Technology, 26(2008), 311-314.

J. Tolgyessy, Chemistry and biology of water, air and soil environmental aspects, Elsevier, (1993).

E. Eriksson, K. Auffarth, M. Henze, and A. Ledin, Characteristics of grey wastewater. Journal of Urban Water, 4(2002) 85–104. http://dx.doi.org/10.1016/S1462-0758

Y. Ali, R. Samaneh, R, Zohreh, and J. Mostafa, Magnetic Water Treatment in Environmental Management A Review of the Recent Advances and Future Perspectives. Jouranal of Current World Environment. 9(2014), 1008-1016. http://dx.doi.org/10.12944/CWE.9.3.56.

M. Florez, M. Carbonell, and E. Martinez, Exposure of maize seeds to stationary magnetic fields: Effects on germination and early growth.

Journal of Environmental and Experimental Botany. 59(2007), 68–75.
https://doi.org/10.1016/j.envexpbot.2005.10.006.

Standard Methods for the Examination of Water and Wastewater, 20th ed. APHA, AWWA, WPCF: Washington DC, (1998).

W. Chu, N. Gao, D. Yin, Y. Deng, and M. R. Templeton, Ozone–biological activated carbon integrated treatment for removal of precursors of halogenated nitrogenous disinfection by-products. Journal of Chemosphere, 86(2012), 1087-1091. https://doi.org/10.1016/j.chemosphere.2011.11.070.

D. Gerrity, A.N. Pisarenko, E. Marti, R. A. Trenholm, F. Gerringer, J. Reungoat, and E. Dickenson, Nitrosamines in pilot-scale and full-scale wastewater treatment plants with ozonation. Journal of Water Research, 72(2015), 251-261. https://doi.org/10.1016/j.watres.2014.06.025.

M. J. Reaume, R. Seth, K. N. McPhedran, E. F. da Silva, and L. A. Porter, Effect of media on biofilter performance following ozonation of secondary treated municipal wastewater effluent: Sand vs. GAC. Journal of Ozone-Science & Engineering, 37(2015), 143-153. https://doi.org/10.1080/01919512.2014.939741.

J. Barzegar, J. Wu, and F.Ghanbari, Enhanced treatment of greywater using electrocoagulation/ozonation: Investigation of process parameters. Journal of Process Safety and Environment Protection, 121(2018), 125-132. https://doi.org/10.1016/j.psep.2018.10.013.

M. Ekblad, P. Falas, H. El-taliawy, F. Nilsson, K. Bester, M. Hagman, and M. Cimbritz, Is dissolved COD a suitable design parameter for ozone oxidation of organic micropollutants in wastewater? Journal of Science of the Total Environment, 658(2019), 449–456. https://doi.org/10.1016/j.scitotenv.2018.12.085.

J. Altmann, A. S. Ruhl, F. Zietzschmann, and M. Jekel, M., Direct comparison of ozonation and adsorption onto powdered activated carbon for micropollutant removal in advanced wastewater treatment. Journal of Water Research 55(2014), 185–193. https://doi.org/10.1016/j.watres.2014.02.025.

S. Song, Z. He, J. Qiu, L. Xu, J. Chen, Ozone assisted electrocoagulation for decolorization of C.I. Reactive Black 5 in aqueous solution: An investigation of the effect of operational parameters. Journal of Separation and Purification Technology, 55(2007), 238-245. https://doi.org/10.1016/j.seppur.2006.12.013.

J. Rivas, F. Beltran, B. Acedo, and O. Gimeno, Two-step wastewater treatment: sequential ozonation – aerobic biodegradation. Journal of Ozone Science and Engineering, 22(2000), 617 – 636. https://doi.org/10.1080/01919510009408803.

M. Pereira, A. Borges, F. Heleno, L. Faroni, and J. Silva, Experimental Design Optimization of Dairy Wastewater Ozonation Treatment. Journal of Water, Air, & Soil Pollution, 229(2018), 1–11. https://doi.org/10.1007/s11270-018-3737-x.

V. Urbano, M. Maniero, M. Moya, and J. Guimarães, Influence of pH and ozone dose on sulfaquinoxaline ozonation. Journal of Environmental Management, 195(2017), 224-231. http://dx.doi.org/10.1016/j.jenvman.2016.08.019.

S. Malik, P. Ghosh, A. Vaidya, and S. Mudliar, Hybrid ozonation process for industrial wastewater treatment: Principles and applications: A review. Journal of Water Process Engineering, 35(2020), 101193. https://doi.org/10.1016/j.jwpe.2020.101193.

N. Kishimoto, M. Hatanaka, and Y. Kinoshita, Applicability of ozonized water treatment for controlling fat, oil, and grease deposition onto a drainpipe. Journal of Applied Research in Water and Wastewater, 10(2018), 417-420. https://dx.doi.org/10.22126/arww.2018.974.

Y. Wang, X. Gu, J. Quan, G. Xing, L. Yang, C. Zhao, P. Wu, F. Zhao, B. Hu, and Y. Hu, Application of magnetic fields to wastewater treatment and its mechanisms: A review. Journal of Science of the Total Environment, 773(2021), 145476. https://doi.org/10.1016/j.scitotenv.2021.145476.

N. Gokon, A. Shimada, H. Kaneko, Y. Tamaura, K. Ito, T. Ohara, Magnetic coagulation and reaction rate for the aqueous ferrite formation reaction. Journal of Magnetic Materials 238(2002), 47–55. https://doi.org/10.1016/S0304-8853.

X. L. Hao, H. Liu, G. S. Zhang, H. Zou, Y. B. Zhang, M. M. Zhou, Y. C. Gu, Magnetic field assisted adsorption of methylblue onto organo-bentonite. Journal of Applied Clay Science. 55(2012), 177–180. https://doi.org/10.1016/j.clay.2011.11.019.

J. Ma, Y. Ma, F. Yu, X. H. Dai, Rotating magnetic field-assisted adsorption mechanim of pollutants on mechanically strong sodium alginate/graphene/L-cysteine beads in batch and fixed-bed column systems. Environment Science and Technology. 52(2018), 13925–13934. https://doi.org/10.1021/acs.est.8b05409.

M. Krzemieniewski, M. Debowski, W. Janczukowicz, J. Pesta, Effect of the constant magnetic field on the composition of dairy wastewater and wastewater and domestic sewage. Polish Journal of Environmental Studies 13(2004), 45–53. https://www.researchgate.net/publication/.

K. T. Chang, C. I. Weng, The effect of an external magnetic field on the structure of liquid water using molecular dynamics simulation. Journal of Physics 100(2006), 043917. https://www.doi.org/10.1063/1.2335971.