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Ozonation of wastewater in Algeria by dielectric barrier discharge

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ABSTRACT

The oxidation by ozone is considered as being an effective solution and offers irrefutable advantages in wastewater treatment. Ozone is used to treat different types of water due to its effectiveness in water purification and for its oxidation potential. This process of ozonation becomes progressively as an alternative technology and is inscribed in a sustainable development perspective, in particular in Algeria, where other conventional techniques of treatment are used in comparison to the latter, which is often used in Europe. Our work describes this process of treatment using the ozone produced by dielectric barrier discharges (DBD), which are fed by a high voltage of several thousands of volts. So, we conceived and accomplished a new generator of ozone DBD of cylindrical form, which will be used for wastewater treatment (WWTP) of Mascara, west of Algeria. Our experimental results have revealed the effectiveness of this type of treatment on the basis of physico-chemical analysis (pH, turbidity, chemical oxygen demand, biological oxygen demand and oxidable matter) and bacteriological (total coliforms, fecal coliforms, *Escherichia coli* and *Salmonella*) upstream and downstream of the WWTP which presents a very high rate of elimination of all the parameters, particularly for the turbidity and bacteria in a very effective manner.

Keywords: Wastewater; Treatment; Oxidation; High voltage; DBD generator; Ozone

1. Introduction

Wastewater reuse has become an attractive option for protecting the environment and extending available water resources. In the last few years, there has been a significant diversification of water reuse practices such as green space and crop irrigation, recreational impoundment, various urban uses including toilet flushing, industrial applications, and water supply augmentation through groundwater or reservoir recharge [1]. The safe operation of water reuse systems depends on the reliability of wastewater disinfection which is the most important treatment process for public health protection.

Biological treatments are often used in the wastewater treatment plants in Algeria. In such processes, the pollutants are biodegraded or mineralized by the microorganisms. On the one hand, these treatments

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are inexpensive and reliable methods for eliminating pollutants from wastewater, but there are substances with which they are unable to deal. On the other hand, oxidation processes have shown utility for toxic compound elimination and became a viable treatment option for wastewaters. Numerous techniques can complement or substitute biological processes to accomplish a technically efficient treatment. Because of this, the oxidation by electrical methods which rests this work is one of the most possible alternatives [2]. It is very simple to apply and competitive for the wastewater treatment and is made without addition of chemical agents.

Several works demonstrated the possibility of degrading the organic components by electrical discharges directly in water [3,4]. In effect, these produced electrical discharges can generate highly reactive radicalar species *in situ* in the presence of air or oxygen. The ozone production for water treatment is one of their most important applications [5,6]. Ozone is the most efficient chemical oxidant used in water and wastewater treatment due to its many desirable properties. Firstly, it is a powerful oxidant capable of oxidative degradation of many organic compounds and also results in oxidation products which are more biodegradable [7]. Ozone also results in the formation of highly reactive hydroxyl radical in the system which has higher oxidation potential as compared to ozone itself. Ozonation is commonly used for the bacterial disinfection, and oxidation of inorganic and organic compounds, including taste, odor, color, and particle removal [8].

The objective of this research was to study the effectiveness of wastewater treatment by dielectric barrier discharges (DBD) which is considered to be a new technology in Algeria, using a new generator DBD of high voltage (ozone generator), accomplished in our research laboratory. The water collected after electric treatment were subjected to the analysis of different parameters of wastewater characterization. So, a series of analyses was performed on samples taken at the entrance and at the exit of WWTP to show the electric treatment effect on the physicochemical and bacteriological quality of wastewater.

2. Materials and methods

2.1. Sampling

Physicochemical and biological analyses performed on wastewater taken at the entrance of WWTP of Mascara (west of Algeria), in order to quantify their rates of degradation and as a result control the quality of waters treated by ozone. These latters are reused for the irrigation of the perimeters of El Kouayer and the plain of Ghriss, in the region of Mascara. Two levies per week were made and kept at 4˚C in disinfected vials to avoid any outside contamination. Owing to the important number of variables that can influence the quality of water and in front of the impossibility of analysing them all, only widely used parameters were selected. These parameters are, in most cases, pH, turbidity, chemical and biological oxygen demands (COD and BOD_5), oxidable matter (OM), total and fecal coliforms (TC and FC), *E. coli*, and *salmonella*.

2.2. Analysis methods

The standard methods of wastewater analysis are described by Rodier [9] and also in catalogs of the equipment. The pH and turbidity are measured by a pH meter (Hanna type HI 8521) and a turbidimeter (16800 type) of laboratory, respectively. The standardized method (NFT 90-101) is used to measure COD. The organic matters are oxidized with excess of potassium dichromate ($K_2Cr_2O_7$), in acidic medium (H_2SO_4) and in the presence of a catalyst (Ag_2SO_4). After two hours of heating at 150˚C, the COD is determined by volumetric dosing. An OxiTop is used to analyze the BOD_5.

The detection of bacteria is determined by the classical methods of culture in medium liquid using most probable number (MPN) technique [10]. The research of TC and FC is made on the liquid medium (BCPL and Schubert Broth), after incubation at an operating temperature range of 37–44˚C for 24–48 h, respectively. The observation of a red coloring after adding Kovacs reagent in the Schubert medium corresponds to a positive reaction for the presence of presumptive *E. coli*. The isolation of *Salmonella* is done on the Hecktoen medium after the enrichment in SFB medium and incubation into petri dish at a temperature of 37˚C during 24 h.

2.3. DBD generator

The ozone generator realized possessing a cylindrical shape which can offer a greater discharge surface as compared to plane shapes and can also generate more ozone [11]. The discharge is obtained between two metal electrodes, one of them is covered by a dielectric material. This generator is composed by an external cylindrical electrode in stainless steel, a glass tube of 77 mm of external diameter, and a second internal cylindrical electrode disposed inside the glass tube (Fig. 1). Two openings are made in the generator, one for input of air and other such as an outlet of

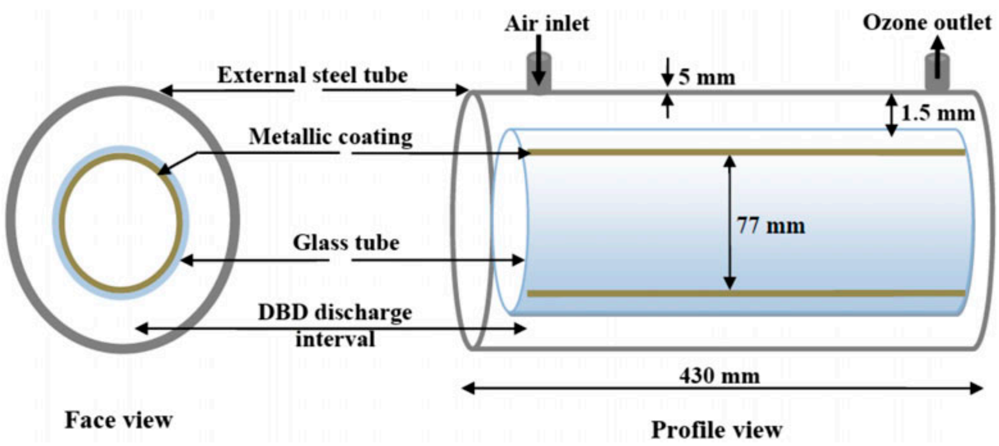

Fig. 1. Schematic diagram of the DBD generator.

ozone. Interval between the glass tube and stainless steel electrode, where the electric discharge occurs, equals 1.5 mm. The length and diameter of the generator are 430 and 90 mm, respectively.

The study of the electric party of the ozone generator is an essential stage to identify the parameters which have an influence on its functioning. An electrostatic voltmeter (7.5 kV) and a digital storage oscilloscope (250 MHz) were used to measure, respectively, the applied high voltage and the intensity of electric current. The high voltage of ozone generator is issued by an AC high-frequency power supply (10 kV max, 30 mA, 20 kHz), applied by an autotransformer (0–220 V). A resistance of 100 Ω is placed in series with the circuit to measure the discharge current. The electric diagram of ozone generator is shown in Fig. 2.

2.4. Experimental setup of the treatment system

A schematic and a photograph of the installation are presented in Figs. 3a and 3b. The ozonation system design of wastewater is composed of a reactor, a high voltage transformer, a DBD generator, and a vacuum pump. Ozone is produced from air using a constant flow rate to about 8 l/min by the application of an intense electric field that initiates an electron avalanche process, leading to the creation of partially ionized plasma. Then, the generated ozone is introduced in the reactor through a Teflon conduct.

Oxidation process was carried out in a glass reactor-shaped balloon with two openings (a central one and a lateral other). The first is used for the introduction of ozone and the second for taking samples using a syringe. After filtration, a volume of 500 ml of

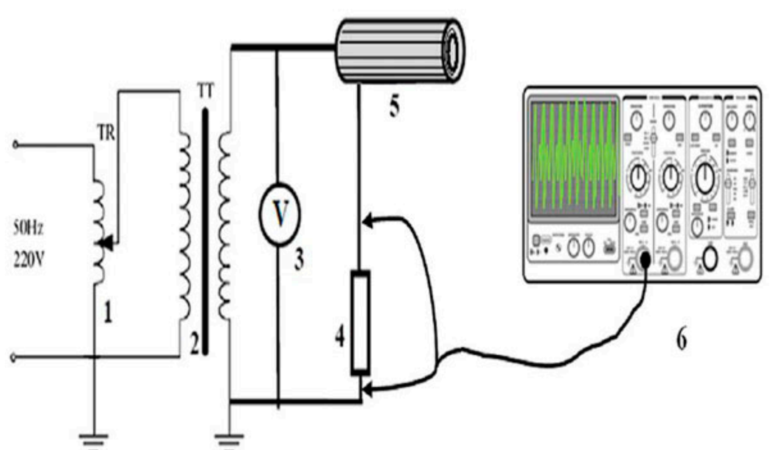

Fig. 2. Electrical circuit of the DBD generator. (1) Auto transformer, (2) HV transformer, (3) electrostatic voltmeter, (4) measurement resistance, (5) DBD generator, and (6) oscilloscope.

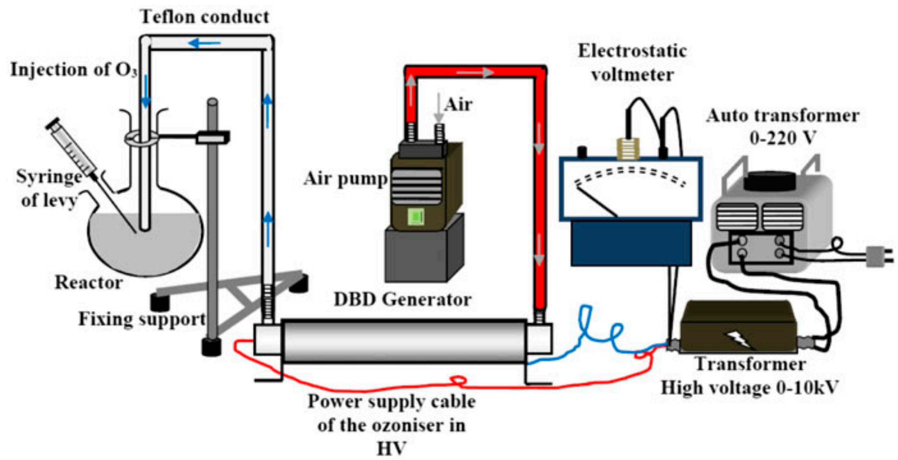

Fig. 3a. Schematic diagram of wastewater treatment by the DBD system.

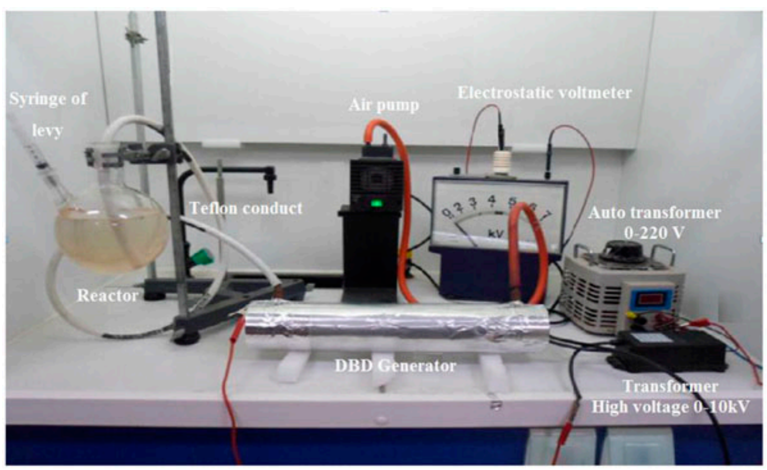

Fig. 3b. Photograph of the experimental montage.

wastewater was introduced in the reactor, representing the testing volume. In parallel, as the filtration progressed, the ozone generator and the ozone detector were started.

3. Results and discussion

Results of this study quantified the responses of wastewater effluent through several key parameters of ozonation. Reductions of those parameters in samples, used for tests to ozone along a 100 min period of time, were determined. To this end, we carried out a series of analyses on the raw and treated waters to evaluate the effect of ozone treatment in order to optimize treatment efficiency and to determine the feasibility of a single-treatment process employing ozone as compared to the aerobic treatment by activated sludge at the WWTP.

The raw wastewaters were filtered to remove the suspended solids and as a result, foster self-purification during treatment. Table 1 shows the characteristics of the raw waters before and after filtration.

3.1. *Physicochemical analyses*

For parameters of the water quality, the data were generated by laboratory analyses. The following parameters were measured every 10 mins during treatment: pH, turbidity, COD, BOD_5 and OM.

Table 1
Characteristics of the raw wastewater

Parameter	Raw wastewater	Raw wastewater after filtration
Temperature (°C)	20	20
pH	7.64	7.86
COD (mg/l)	733	499.9
BOD_5 (mg/l)	376	105
OM (mg/l)	495.1	236.6
Turbidity (NTU)	1,708	64
TC (CFU/100 ml)	140,000	140,000
FC (CFU/100 ml)	7,500	7,500
E. coli (CFU/100 ml)	1,500	1,500

3.1.1. Treatment effect on the pH

The evolution of pH during the ozonation treatment is shown in Fig. 4. The pH increases rapidly in the first 50 min of the treatment and becomes constant at pH 8.43 after this time. In general, the pH values of the effluent (from pH 7.86 to 8.43) tend towards alkalinity, thus respecting the rejection standard delimited between (6.5 and 8.5) [12–14]. However, alkalinity is recommended because it makes it possible to the ozone activity and consequently the degradation rate [15,16]. Alkalinity is mainly due to the carbonates ions and bicarbonates present in water; they constitute excellent traps for the free radicals which slow down the decomposition of ozone. The increase in the pH can be attributed to the accumulation of bicarbonates, as a result of organic matter mineralization with the formation of CO_2 leading to the shifting of the acid–base equilibrium to HCO_3^- [17,18].

3.1.2. Treatment effect on the turbidity

Turbidity describes the degree of process water clarity, quantifying the interference with passage of light by soluble colored organic compounds and suspended solids [19]. It informs indirectly about the presence of microorganisms; the higher the content of particles of water is, the more it is probable to find microorganisms [9]. Among the water quality parameters measured in this study in conjunction with the effect of ozonation, turbidity showed the greatest reduction in Fig. 5. Starting from initial values between 1708-64 NTU, ozonation removed between 37.5 and 95.5% of turbidity.

Turbidity removal was very active at the beginning of the tests, more than half of its reduction occurring in the first 40 min of treatment about of 92.9%. This high decrease is due to the rapid reaction of turbidity along with molecular ozone. After this time, turbidity declines slightly to reach equilibrium at a reduction varies from 93.6 to 95.9%. Slower rate of turbidity reduction after 40 min may be due to the destruction of the large organic molecules difficultly degradable by ozone and their transformation into smaller organic molecules that are readily biodegradable. Taking our results into consideration, the value obtained at the end of treatment of 2.6 NTU remains much lower than the Algerian standard of rejection 50 NTU [12].

3.1.3. Treatment effect on the COD

The COD is a good indicator on quantity of chemically oxidable organic substances present in the water [20]. In this study, the COD concentration was one parameter used to assess the removal of ozone-reacting pollutants from the wastewater. Previous studies showed the strong reduction of the COD during ozonation [21]. Fig. 6 demonstrates the evolution of COD reduction with contact time. The COD removal was fast during the first 70 min, and then slows with a reduction of 33.3–86.6% at the end of treatment.

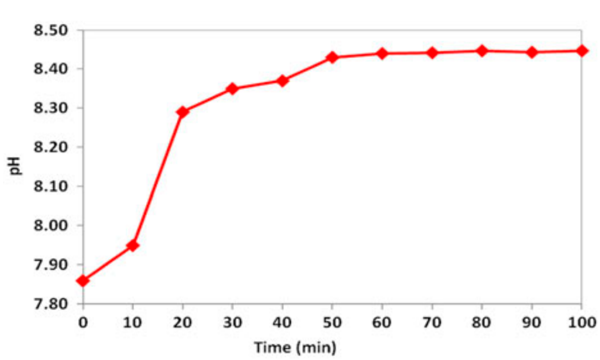

Fig. 4. Evolution of pH during DBD treatment.

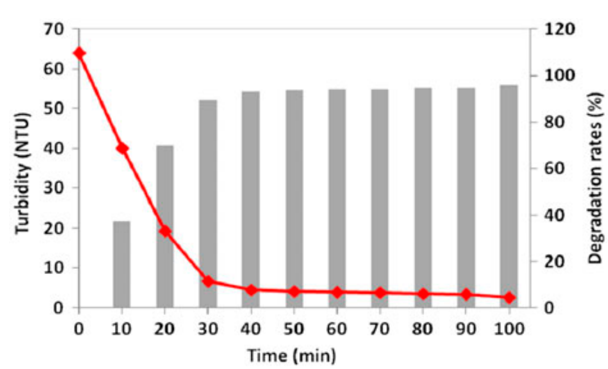

Fig. 5. The effect of DBD treatment on turbidity.

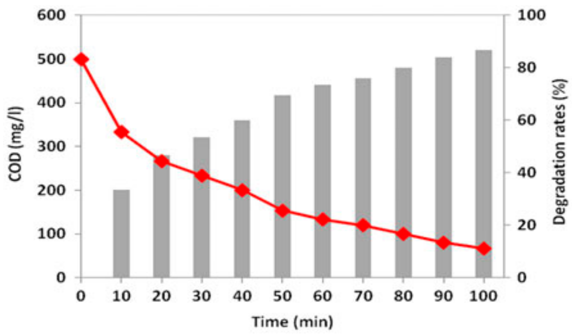

Fig. 6. The effect of DBD treatment on COD.

At the beginning, the fast increase in the COD reduction is due to the degradation of the cyclic compounds. Then, the reduction increases slowly because of the degradation of the aliphatic compounds which require more energy compared to the cyclic ones. The COD reduction in the effluent finds its explanation in the good performance of the treatment technique. In addition, the value of COD after ozonation (66.6 mg/l) remains very low compared to that after biological treatment (333.3 mg/l). We also note that the COD obtained, after ozonation, remains lower than the Algerian standard of rejections (120 mg/l) [12], thus, to the WHO standard (90 mg/l) [14] and is slightly higher than that of the water intended for the irrigation (90 mg/l) [13]. A rate of elimination of 86.6% at the end of treatment satisfies the European standards with abatement of 75% [22].

3.1.4. *Treatment effect on the* BOD_5

The BOD_5 is the dissolved oxygen concentration, consumed by microorganisms to oxidize the organic, dissolved substances or in suspension [9]. In this study, BOD_5 was measured to quantify biodegradable organic pollutants. Concentration values of the BOD_5 vary from 105 to 56 mg/l after 100 min of ozonation. As shown in Fig. 7, the oxidation of organic matter by ozone was effected in two stages. The reduction of BOD_5 increased by 40.5% after the first 70 min, and then varied little during the remaining testing time. Biodegradability improvement induced by ozonation also has been reported in numerous studies involving various wastewaters [23,24]. In the first stage of ozonation, the improvement in biodegradability has been attributed to formation of smaller, oxygenated species more suitable to microbial attack, and possibly to the reduction of compounds with bactericidal proprieties [25]. During the second stage, the profile of BOD_5 started to reach a plateau, since the remaining organic matters in the wastewater were difficult to oxidize at a concentration of 56 mg/l and a reduction of 46.6%.

These results enabled us to show the increase in the biodegradability of organic matter, whereas the residual concentration in DBO_5 (56 mg/l) remains higher than the Algerian standards of rejection (35 mg/l) [12], like to the standards of WHO (30 mg/l) [14], and to the extreme standards limited to water of irrigation (30 mg/l) [13]. The load of biodegradable organic matter after ozonation (56 mg/l) and biological treatment (83 mg/l) is due to the abundance of the bacterial population responsible for this elimination as indicated thereafter and to the decrease in the oxygen content due to its consumption by micro-organisms [20].

Variations in the wastewater biodegradability were measured by the BOD_5/COD ratio. The value of BOD_5/COD ratio for raw wastewater is 0.51 and decreased in a proportion of less than two-fold to 0.21 after filtration. Fig. 8 shows the ratio variation of BOD_5/DOC with time. The ratios found during treatment increased in the range of 0.21–0.84 in the final

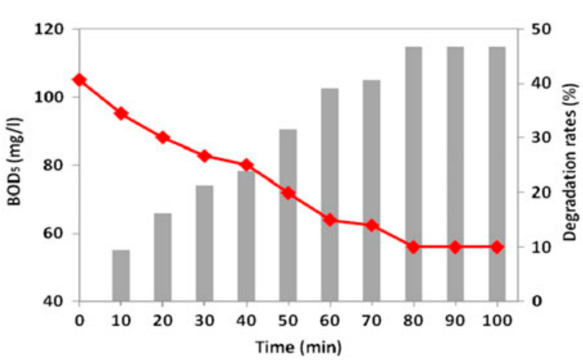

Fig. 7. The effect of DBD treatment on BOD_5.

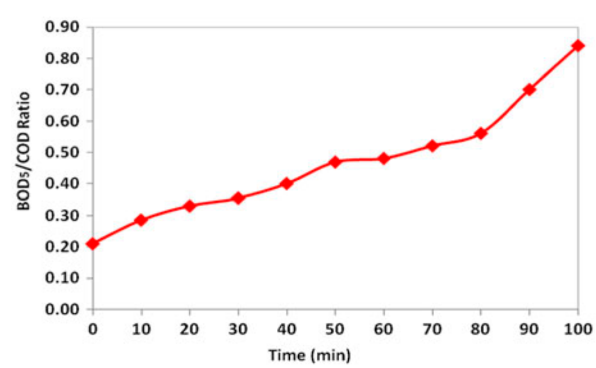

Fig. 8. The effect of DBD treatment on BOD_5/COD ratio.

sample, indicating that the organics had a significantly higher degree of oxidation after ozonation.

3.1.5. Treatment effect on the OM

The OM is, for the most part, composed of organic matter developed by the discharges of sewage plants. Their degradation consumes the oxygen dissolved in the water, sometimes up to total depletion in case of excessive overload, leading to the loss of living organisms. It is therefore a state parameter of the essential environment to follow. The OM is a parameter used by water agencies to characterize their organic pollution. It is defined from COD and BOD_5 [9,26] as:

$$OM = \frac{COD + 2\,BOD_5}{3} \quad (1)$$

The initial oxidizable material in the raw water, in the order of 236.6 mg/l after treatment, reduces to a value of 59.5 mg/l. From Fig. 9, it can be seen a rapid increase in reduction at the beginning of the treatment and slows thereafter. In the first 60 min, a reduction of more than half about to 63.2% was obtained. Then, the change in levels of the OM becomes low of 81.6–59.5 mg/l by a maximum reduction of 74.8%. According to these results, this elimination shows the effect of ozone on the oxidation of the organic matter throughout the treatment.

The degradation rates were compared with that of the control, which was subjected to aerobic oxidation in the WWTP. Fig. 10 shows the effect of ozonation as compared to that of control. From this figure, it can be seen that ozonation led to substantial increase in the rate of different parameters of the effluent as compared to the aerobic oxidation. Aerobic oxidation of treated effluent yielded approximately 54.5% of COD reduction, and 90.9% for the same parameter in the case of ozone treatment was obtained at the end of 100 min. Moreover, ozonation treatment presents authorized values for the majority of parameters as compared to those of biological oxidation.

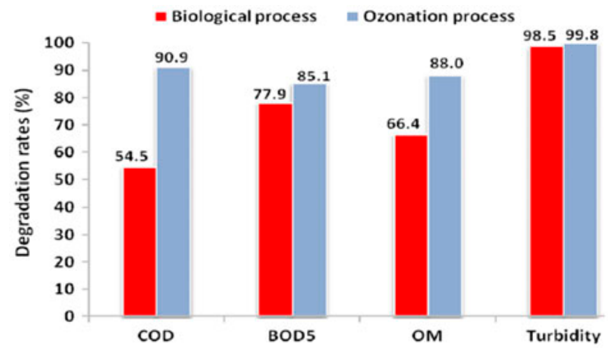

Fig. 10. Elimination rate of physicochemical parameters.

3.2. Microbiological analyses

The bacteria are commonly sought in water mainly as witnesses of fecal contamination [27]. The research of pathogenic organisms in a specific manner is very costly and random; hence, the interest to the concentrations of the germs witnesses (total coliforms (TC), Fecal coliforms (FC), *E. coli*, and *Salmonella*) is able to estimate the pathogens population. FC and *E. coli* were chosen as standard fecal indicators in this study, because they are usually regulated for wastewater discharge or reuse. *E. coli* is the species most represented in this group by 50–90% [28].

3.2.1. Treatment effect on the TC, FC, and E. coli

The inactivation efficiencies are presented in Fig. 11. It should be noted that the initial concentration of

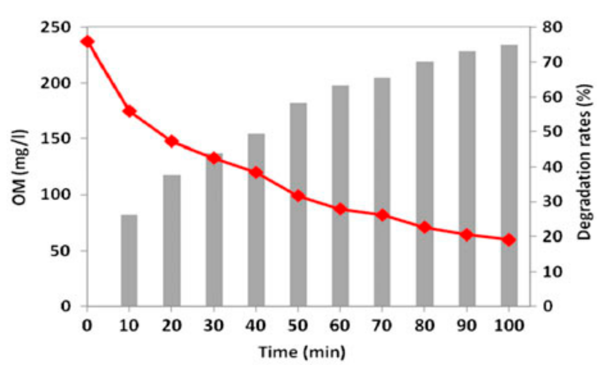

Fig. 9. The effect of DBD treatment on OM.

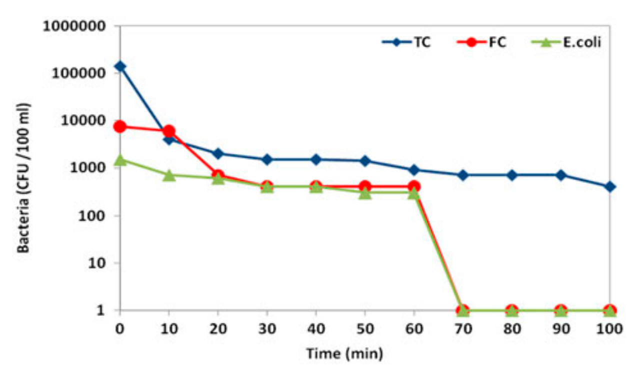

Fig. 11. The effect of DBD treatment on bacteria.

microorganisms limited the maximum inactivation values that could be reached. Estimation of TC after treatment using the presumptive test shows that 10 min allow to minimize the maximum of TC from 1.4×10^5 to 4×10^3 CFU/100 ml. Beyond, the reduction becomes slow with an inactivation of 4×10^2 CFU/100 ml at the end of the experiment. For FC, an inactivation of 99.8% was achieved between 60 and 70 min of 4×10^2 to 1 CFU/100 ml as compared to the initial concentration of 7.5×10^3 CFU/100 ml. Thus, according to Xu et al. [29], the elimination of FC by ozone under certain conditions can achieve low concentrations in the effluents of the order of 14 CFU/100 ml; as compared to our results, optimal efficiency of treatment shows a total elimination of these germs in 70 min. Indeed, the levels in fecal coliform in the ozonated water become very consistent with the Algerian standards of rejection and of WHO used for agricultural reuse (<1,000 CFU/100 ml) [13,30].

As shown in Fig. 11, the inactivation of FC and *E. coli* during ozonation was similar in agreement with previous results [31]. We note a strong reduction of *E. coli* during the first 10 min, more than half of the initial concentration of 53.3%, and reached 99.7% between 60 and 70 min. The effectiveness of the *E. coli* inactivation becomes important in the presence of ozone [31], which complies with the inactivation of this bacterium in this treatment by the direct reaction. However, studies have shown damages in the cell membrane and to the constituents of nucleic acids (DNA) during its inactivation, which can occur only at very high concentrations of ozone [32].

3.2.2. *Treatment effect on the* salmonella

Salmonella's research revealed the absence of colonies of color blue gray with a black center in the raw water, which proves the absence of this germ. However, the macroscopic observation of petri dishes of raw water (1), indicated us the salmon colonies which characterize the presence of other bacteria namely *citrobacter*, *klebsiella*, *enterobacter*, *serratia,* and *yersinia*. After treatment, the population declined significantly to half after 10 min (2) and has totally disappeared after 20 min (3) (see Fig. 12). The same observation is demonstrated by the petri dish N°4; these bacteria have totally disappeared in the biologically treated water, but after several processing steps.

The effectiveness of the disinfection depends on the BOD_5, turbidity, the number, and type of microorganisms present in the effluent [33,34]. Our results show that this good inactivation of bacteria is due to high rates of reduction of these various parameters and particularly the turbidity, which can increase the rate of disinfection. The process contributes to a total reduction of these bacteria and therefore, becomes unable to develop their immunity in the presence of ozone.

The comparison is also made on the inactivation rates of bacteria for the ozonated water and the treated water in the WWTP. The most significant inactivation is obtained by the process of ozonation as shown in Fig. 13. It is necessary to point out that the effluent is still heavily loaded in pathogens after its treatment in the WWTP, of 2.5×10^4 CFU/100 ml for TC, 1.5×10^4 CFU/100 ml for FC, and 7×10^2 CFU/100 ml for *E. coli*. The proportions of inactivation observed in this study show that the treatment process used creates a certain effectiveness in the bacterial disinfection in relation to the one the WWTP, particularly for *E. coli*.

4. Kinetics of elimination

The extent of degradation for each treatment strategy is quantified in terms of the change in the values of physicochemical and bacteriological parameters. The degradation process was found to be first order with respect to the residual concentration and the kinetic of elimination was determined for each parameter by plotting a graph of logarithmic decrease against time of the treatment.

4.1. *Model of the pseudo-first order*

The model of the first order is applied to check the kinetics of elimination of organic and inorganic compounds:

$$\ln(C/C_0) = -k\,t \tag{2}$$

where C_0 represents initial concentration of pollutants, C is concentration of pollutants after treatment, k is first-order kinetic constant, and t is contact time.

The plot of $\ln(C/C_0)$ vs. time shows that each curve yields a straight line, whose slope is equal to the kinetic rate constant of the model assumed in Eq. (2) (graph shown in Fig. 14). According to Fig. 14, the line of turbidity shows well an exponential variation particularly in the first 40 min of treatment (see Figs. 8 and 14). The other result is clearly seen on the right of the turbidity which presents two slopes and therefore two stages of reduction. This change in slope may be due to the presence of dissolved solids in suspension non-degradable. For the estimation of the kinetic rate constant, the R^2 values were about 0.94–0.97 which indicated good fitting of the reduction data by the kinetic model first order. This kinetic rate constant was used to estimate treatment effectiveness.

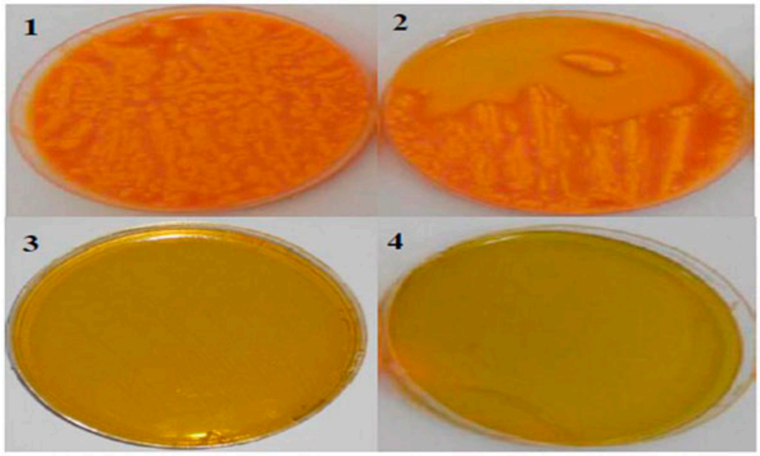

Fig. 12. Research macroscopic of *salmonella*. (1) Raw water, (2) ozonated water (after 10 min), (3) ozonated water (after 20 min), and (4) outlet water in the WWTP.

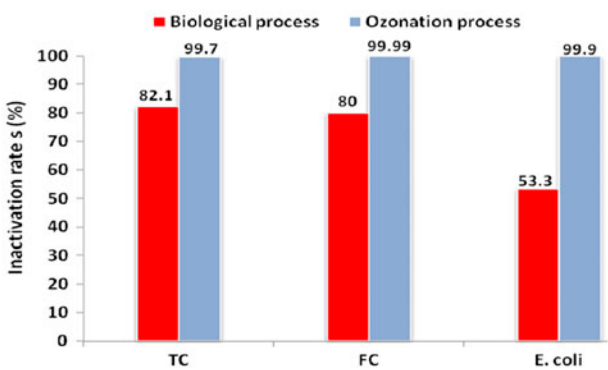

Fig. 13. Inactivation rate of bacteria.

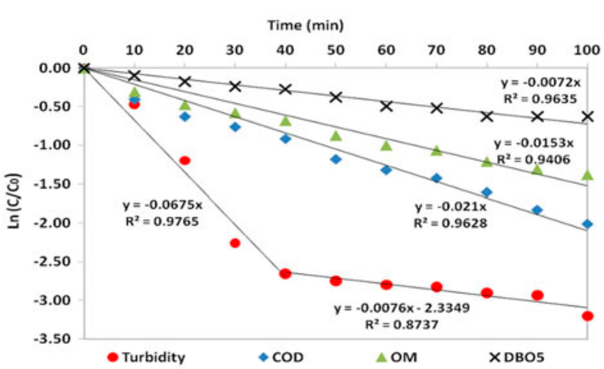

Fig. 14. Degradation kinetics of physicochemical parameters by ozone.

The greater value of the kinetic rate constant obtained from this plot on the line of turbidity is 0.0675 min^{-1}, as compared to the other parameters in the range of 0.0072–0.021 min^{-1}, respectively. It is also important to note the kinetic rate constant of the COD in this study of 0.021 min^{-1} was 15 times higher than that found by Pandit et al. [18] after 40 h of ozone treatment of 0.0015 min^{-1}.

4.2. Model of Chick-Watson

The classical first-order model of Chick-Watson defines the rate of inactivation of some bacteria by ozone, particularly *E. coli* [32]:

$$\log (N/N_0) = -\, k' C t \tag{3}$$

where N_0 represents initial number of microorganisms, N is the number of microorganisms after treatment, k′ is rate constant for the inactivation of a particular micro-organism, and C is concentration of a disinfectant.

The degradation kinetics of bacteria is studied using this model of the first order which can estimate the levels of deactivation often in log reduction. The term of log reduction or log inactivation, instead of percent reduction, is used in regulations for ease in disinfection reporting. The logarithmic decrease was determined by plotting a graph of log (N/N_0) against time of the treatment as shown in Fig. 15. TC and *E. coli* levels were reduced to 2.54 log (99.71%) and 3.2 log (99.93%), respectively. FC levels were reduced by greater than 3.5 log (99.99%) within 70 min. Xu et al. [29] have shown a reduction in FC in the order of 2.48 log to a concentration of ozone transferred from 15.2 mg/l and that can exceed 3 log even before reaching the demand of ozone [5,29]. The three types of bacteria have a very important order of reduction and superior to that found by these

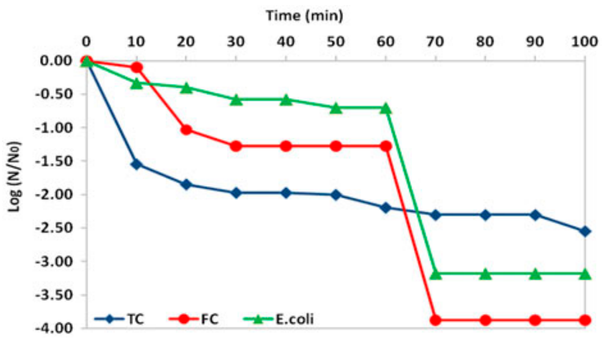

Fig. 15. Inactivation kinetics of bacteria by ozone.

studies which certainly shows the presence of ozone in high concentrations and their rapid bactericidal action.

According to this figure, the inactivation of bacteria does not really follow the Chick-Watson model of exponential decay. In fact, inactivation curves of the FC and *E. coli* clearly follow a shoulder type (shoulder curve), indicating a lag phase during early period of inactivation. According to Carlson [35], the shoulder curves are observed when the bacteria are agglutinated, while Finch [36] attributes this phenomenon to the lysis effect of organisms following the action of the oxidant. The most common explanation is that of Haas and Joffe [37], for which this period represents the time required by the disinfectant to disseminate across the cell membrane.

The total coliform follows the opposite phenomenon; after a period of rapid inactivation, the rate of inactivation slows down (phenomenon of tailing-off). This latency period would be due to the disparities of resistance within a same population, while Finch [38] mentioned several factors including heterogeneity of the population, formation of aggregates, as well as the physiological state of the organisms.

5. Conclusion

The implementation of a treatment system by ozone produced by DBD allowed us to study its effect on the degradation of organic matter, inorganic, and micro-organisms that might be found in wastewater from the WWTP of Mascara. This ozone generator is effective for wastewater treatment and disinfection.

The treated wastewater showed significant oxidative action of ozone which is characterized by important degradation rates especially for bacteria. Bacteriological analysis demonstrates a total elimination of FC and *E. coli* in an optimum time of 70 min. This allows to achieve better rates of degradation for a short duration of treatment with low energy consumption. However, this significant inactivation shows the efficiency of degradation of physicochemical parameters and especially for turbidity which has helped to further the rate of disinfection.

Indeed, ozone treatment have significant elimination values as compared to the biological treatment, which shows a deterioration of half of the COD levels and *E. coli* in the WWTP. The degradation kinetics of physicochemical parameters well follows first-order model with a significant kinetic rate particularly for turbidity. The reductions in bacteria by ozone vary 2.5 log to more than 3 log depending its type.

While the treated wastewater by aerobic oxidation in the Mascara WWTP are very loaded in bacteria, the treated effluent did not meet the WHO recommendations and Algerian standards when reuse in irrigation. This study has shown the effectiveness of our treatment processing which allowed us to consider it as an alternative or a complement to that used in the WWTP, to better minimize microbiological hazards, and ensure sanitary quality of irrigation water.

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Symbols

AC	—	alternating current
BCPL	—	bromcresol purple lactose broth
BOD	—	biochemical oxygen demand, mg/l
COD	—	chemical oxygen demand, mg/l
CFU	—	colony-forming unit
DBD	—	dielectric barrier discharges
E. coli	—	*Escherichia coli*, CFU/100 ml
FC	—	fecal coliforms, CFU/100 ml
MPN	—	most probable number
NTU	—	nephelometric turbidity unit
OM	—	oxidable matter, mg/l
pH	—	potential hydrogen
SFB	—	selenite broth sodium acid
TC	—	total coliforms, CFU/100 ml
WHO	—	World Health Organization
WWTP	—	wastewater treatment plant
C	—	concentration, mg/l
t	—	time, min

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