

## *Improvement of Wastewater Coagulation Using Ozone*

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### *Abstract*

A study to evaluate the effect of ozone on solids removal during the coagulation-flocculation of wastewater from Mexico City drainage (including domestic and industrial) was conducted. Results of this study show significant improvements in the effluent quality with small ozone doses. The optimum ozone dosage was found to be  $3.32 \text{ mg L}^{-1} \pm 0.20$ . With this dosage it is possible to reduce the coagulant concentration from  $50 \text{ mg L}^{-1}$  to  $40 \text{ mg L}^{-1}$  without affecting the effluent quality. When coagulant dose is not reduced, an increase in the flocs' settling velocity due to a larger average size (with a decrease in TSS) is observed before and after filtration. In all cases, reductions in turbidity and color levels are seen when polyelectrolytes are used. The best results are achieved using a relation of  $\approx 0.02 \text{ g O}_3/\text{g TOC}$ .

### *Introduction*

A great deal of attention has been given to ozone treatment for potable water supply, but not to its effects on the flocculation process during the physico-chemical treatment of domestic and industrial wastewater. Numerous authors have observed the effects of ozone added to water on particle behavior (Singer et al., 1989), such as a shift in the size distribution of particles toward larger particles, the formation of colloidal particles from otherwise "dissolved" organic matter; and the improved removal of TOC or turbidity during subsequent settling, flotation or filtration. Furthermore, other authors have found that ozonation sometimes leads to a decrease in the coagulant dose necessary to achieve a desired effluent turbidity, TOC and TSS concentration (Edwards et al., 1994). A decrease in floc settling times, extended filter run times as a result of slower head loss buildup and improved removal of trihalomethane precursors also have been observed (Singer et al., 1990; Langlais et al., 1991).

The effect of ozone treatment on particle stability is dependent on the properties of the natural organic matter and particles present in the water and other water quality parameters such as calcium levels. Some proposed mechanisms are (Jekel, 1986; Reckhow et al., 1986; Dowbiggin and Singer 1989; Singer et al., 1990; Edwards and Benjamin, 1991; Jekel et al., 1994):

- Particles are coated to some degree with natural organic matter, and it is well established that specific amounts of adsorbed humic materials stabilize particles in water. The variation of this adsorbed organic coating influences, to a significant degree, the surface properties of the particles, e.g., surface charge and colloidal stability. Ozone causes desorption and particle destabilization via minimization of steric and electrostatic barriers.
- The increase in the concentration of acidic functional groups due to ozonation can cause differences between the modified and non-modified organic material with respect to their interactions with particle surfaces and metal coagulants. Ozonation also can lead to the formation of metastable organics, such as ozonides, organic peroxides and organic free radicals, which may undergo condensation or polymerization reactions. Such reactions at low ozone dosages may lead to the formation of polymers that can assist in the coagulation of particles.
- Ozone produces an increased association of aluminum with ozonated organic matter due to the presence in the organic chains of oxygenated functional groups such as carboxylic acids. It is reasonable to assume that the carboxylic and phenolic functional groups in natural organic matter form complexes with aluminum oxide and clay surfaces.
- Under appropriate conditions, ozone can break up metal-humic complexes (organo-metallic complexes), thereby liberating and oxidizing reduced metal species (e.g., iron and manganese) which may act as metal coagulants.
- Ozone promotes processes to degrade algae, releasing polymeric material into solution where it can bring about aggregation of other particulate material.
- Ozone is effective in inducing coagulation in the presence of calcium. The increase in the degree of calcium complexation (due to an increase in the number of carboxylic acid groups) may cause direct precipitation of organic matter or greater particle destabilization.

Since studies about the effect of ozone on coagulation-flocculation processes in residual waters are scarce, a primary objective of the present work is the systematic evaluation of the effects of ozone on the efficiency of solids removal from residual waters, when these are subjected to a primary chemical treatment.

We have organized the paper as follows: In the first section, results are presented on the optimum location of the ozone application point and ozone dosage in the primary chemical treatment of residual waters, considering filtration and without filtration. In the next section, a description of results when ozone is applied during the chemical treatment is made and several parameters are evaluated: TSS, TOC, pH and color. In the third section, the effect of varying the aluminum sulfate dosage on various parameters (NTU, TSS,

COD, TOC) is analyzed, together with the evaluation of the sedimentation velocity, the fraction of sedimentable solids and size of flocs. Finally, the effect of ozone addition on the optimum amount of chloride necessary to meet the norm of 1000 UFC per 100 mL of water is evaluated in the last section.

### *Material and Methods*

Ozone was generated from an EMERY TRAILIGAZ LABO 76 generator with a production rate of 19 g O<sub>3</sub>/h, using oxygen-enriched air as feed gas, supplied by an AIRSEP separator. The air was delivered at 62.1 kPa, -73 °C dew point and with an oxygen purity of 90% ± 5%.

The jar tests, which simulated coagulation-flocculation, were performed using a controlled stirring device PHIPPS & BIRD STIRRER, MOD-7790-400. Optimum conditions of the coagulation-flocculation were established in previous studies (Martinez, 1996). The corresponding test sequence includes a 100 rpm stirring after coagulant addition, followed by polyelectrolyte addition, with further stirring at 70 rpm for 2 min, 55 rpm for another 2 min and 30 rpm for 2 min once again. Finally, 10 min for settling was given. The coagulant used was [Al<sub>2</sub>(SO<sub>4</sub>)<sub>3</sub>·14H<sub>2</sub>O]. The flocculants employed were two polymers: an anionic commercial polyelectrolyte (Prosifloc) of high molecular weight (>1 x 10<sup>6</sup> AMU) and high charge density (80%), and an amphoteric of medium molecular weight (~1 x 10<sup>5</sup> AMU) with low charge density (< 40%) (Orta et al., 1998).

Ozone action in the coagulation process was studied by changing the application point, that is, ozone was added before the coagulation-flocculation, during this treatment (immediately after the aluminum sulfate addition prior to polymer addition), and after the chemical treatment, just before the sedimentation stage (see Figure 1).

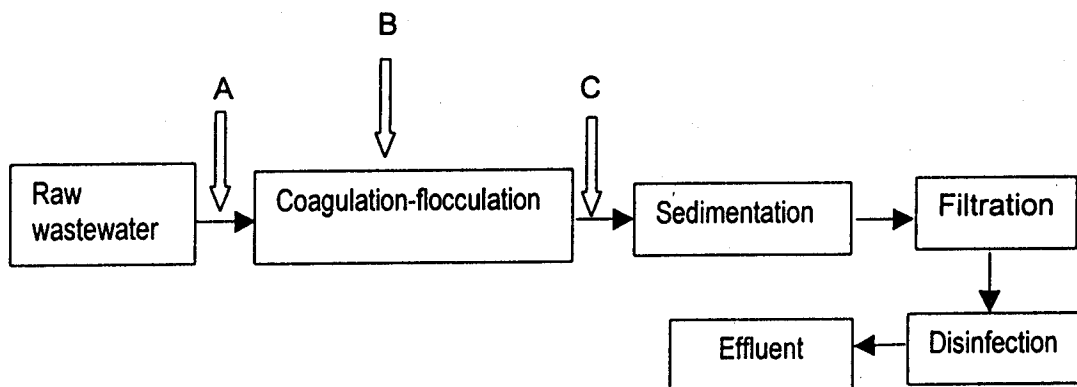


Figure 1. Sequence of chemically-enhanced primary treatment processes wastewater.

For this study an adapted jar test-ozonation system was constructed with hermetically closed dissolution vessels. Every vessel had three 24/40 entrances, each one with a Teflon plug. A stirrer was placed in the central entrance, and ozone was applied through a porous glass diffuser located at the bottom of the vessel. The coagulant and the polymer were fed through the lateral entrances (Figure 2).

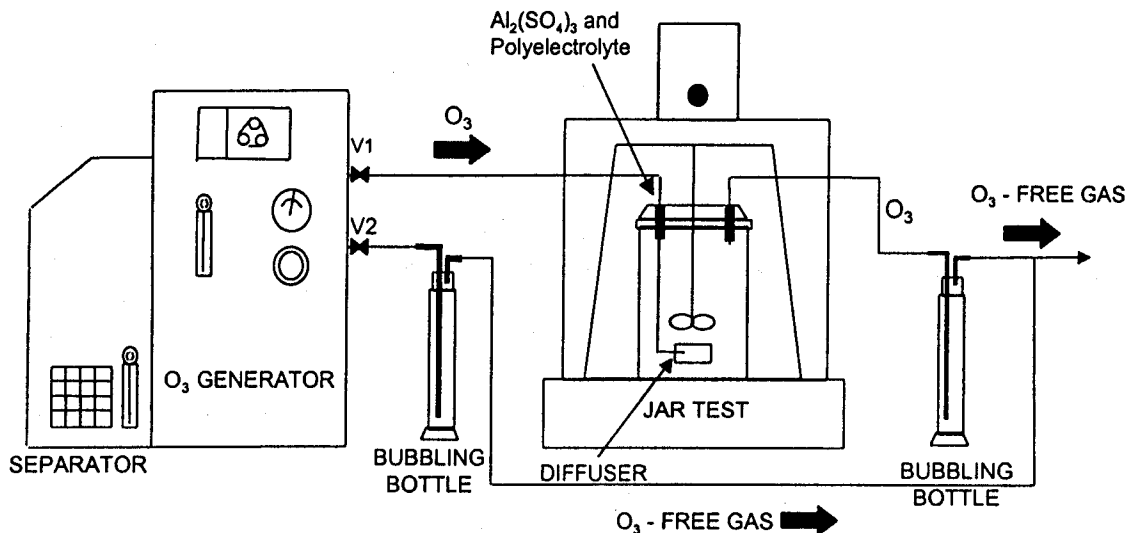


Figure 2. Ozonation system.

Ozone content in the gas phase was measured using the iodometric method (Birdsall et al., 1952) employing two 500 mL gas bubbling bottles joined to a PRECISION SCIENTIFIC MOD. 63115 wet-test meter (Figure 1). The residual ozone content in the aqueous phase was determined by the indigo colorimetric method (Bader and Hoigné, 1981).

Physico-chemical parameters such as pH, turbidity, color, conductivity, suspended solids and COD were determined in accordance with the standard methods (APHA, 1992). The sedimentable solids fraction was determined using the Imhoff cone volumetric test expressed as mL.L<sup>-1</sup> with respect to a characteristic volume (APHA, 1992). TOC was determined using a BECKMAN INDUSTRIAL MOD. 915-B CARBON ANALYZER, following the standard Combustion-Infrared method 5310-B (APHA, 1992). Floc size characterization was carried out in a WILD LEITZ MOD. LEITZ LABORLUXS microscope. Fecal coliform determination was made using the membrane filter technique according to the standard methods (APHA, 1992). Settling velocity was measured according to *Standard Methods for the Examination of Water and Wastewater* (number 2710 E) of the APHA-AWWA-WPCF manual. Measurements were made in an interval of one min with a time test of 15 minutes.

### Results and Discussion

#### DETERMINATION OF THE OPTIMAL OZONE FEED LOCATION IN THE CHEMICALLY-ENHANCED PRIMARY TREATMENT

Ozonation of wastewater was carried out before, during and after the coagulation-flocculation stage to determine the most suitable ozone application point. Conditions were 28% of the maximum output voltage, 0.6 ampere and a total ozone gas flow of 0.65 - 0.70 L/min. Ozone was applied in a range from 4.6 to 27.8 mg.L<sup>-1</sup> considering three different ozonation times (10, 30 and 60 sec). The commercial anionic polymer was added into samples at a concentration of 0.4 mg.L<sup>-1</sup> after metallic coagulant addition [ $\text{Al}_2(\text{SO}_4)_3 \cdot 14\text{H}_2\text{O}$  at a concentration of 50 mg.L<sup>-1</sup>] and after ozonation, to avoid any rupture or flotation of flocs. Subsequently, a settling time of 10 minutes and vacuum filtration (on Whatman #

40 filters) separated the supernatants and solids, allowing the determination of TSS content. Results are shown in Table I.

TABLE I. OZONATION EFFECT ON TSS REMOVAL BEFORE, DURING AND AFTER COAGULATION-FLOCCULATION. TSS ( $\text{mg L}^{-1}$ )

Sample	TSS ( $\text{mg L}^{-1}$ )					
	Without filtering			After filtering		
Raw water	110			---		
Coagulation-flocculation	19			12		
Ozonation $\text{O}_3$	10 s	30 s	60 s	10 s	30 s	60 s
Before	15	12	12	11	9	9
During	16	9	12	6	3	5
After	17	12	12	8	6	7

Ozone ( $\text{O}_3$ ) is applied during, before and after coagulation-flocculation

As observed in Table I, a more effective ozonation is provided when ozone is applied during and after the coagulation-flocculation, as measured by the removal obtained after filtration. To check such results, a randomized-block statistical arrangement was designed (Montgomery, 1991) keeping the optimum ozonation time (30 s), reactive concentration and operating conditions fixed.

Results indicate that significant differences exist among each of the procedures, and the worst data is obtained when ozone is applied before chemicals addition. It is also important to point out that flotation and floc breakage is observed when ozone is applied after the chemical treatment. As a conclusion, it was decided to apply ozone during the chemical addition stage in the forthcoming experiments.

According to studies performed by Langlais et al. (1992), ozone favors complexation and ligand generation in reactions between organic matter and aluminum, due to the formation of oxygenated compounds. On the other hand, this is a complex water with high ionic content (as measured by electric conductivity data, i.e.,  $2.7 \text{ mS.cm}^{-1}$ ), and therefore, application of ozone during the chemicals addition will promote interactions between generated oxygenated compounds, polymers and aluminum sulfate.

#### *Ozone Dose in Chemically-Enhanced Primary Treatment*

Dosage and ozone consumption were determined for the three ozonation lines (10 s, 30 s and 60 s) using the following relations:

**Ozone Dose**

$$D[O_3] = \frac{[O_3]_{g,i} \cdot V'g \cdot t}{V_r} \quad [1]$$

$D[O_3]$  = ozone dose ( $\text{mg L}^{-1}$ )

$[O_3]_{g,i}$  = ozone concentration in the gas phase of the reactor feed ( $39.7 \text{ mg.L}^{-1}$ )

$V'g$  = gas flow ( $0.7 \text{ L.min}^{-1}$ )

$V_r$  = reactor volume (1 L)

$t$  = ozonation time 10, 30 and 60 s, respectively)

**Ozone Consumption**

$$C[O_3] = \frac{([O_3]_{g,i} - [O_3]_{g,e}) \cdot V'g \cdot t}{V_r} - [O_3]_{L,r} \quad [2]$$

$C[O_3]$  = ozone consumption

$[O_3]_{L,r}$  = liquid phase residual ozone concentration

Ozone doses for each ozonation time are  $4.63 \text{ mg.L}^{-1}$ ,  $13.90 \text{ mg.L}^{-1}$  and  $27.80 \text{ mg.L}^{-1}$ , respectively. Considering the ozone residual concentration, consumption is  $0.48 \text{ mg.L}^{-1}$ ,  $3.32 \text{ mg.L}^{-1}$  and  $5.0 \text{ mg.L}^{-1}$  for each ozonation period.

**COAGULATING EFFECTS OF THE OZONATION PROCESS**

To properly account for the coagulation effects of ozone, the following parameters were evaluated in jar tests supernatants and filtrates: TSS, TDS, TOC, COD, settleable solids, turbidity, conductivity, pH and color. Jar tests simulated the chemical treatment, using  $\text{Al}_2(\text{SO}_4)_3 \cdot 14\text{H}_2\text{O}$  ( $50 \text{ mg.L}^{-1}$ ) as a primary coagulant. Alternatively, two flocculants were considered for a comparative study between a commercial, high charge density anionic polyelectrolyte ( $> 1 \times 10^6$  AMU) and a non-commercial, low charge density, amphoteric polyelectrolyte ( $\approx 1 \times 10^5$  AMU). The optimum concentration of polyelectrolyte ( $0.4 \text{ mg.L}^{-1}$  for the anionic and  $0.1 \text{ mg.L}^{-1}$  for the amphoteric) was determined in previous studies (Martinez, 1996). Average results are shown in Table II.

Conductivity ( $2.7 \text{ mS.cm}^{-1}$ ) is not affected during treatment processes. COD shows modest removals because oxidation reactions were not significant. Color has a considerable decrease in all cases due to rupture of chromophore groups by ozone. In addition, better removals in suspended materials, dissolved solids, turbidity and TOC with ozone doses of  $3.2 \text{ mg.L}^{-1}$  (ozonation time is 30s), are reflected in a small increase in the sludge production (settleable solids) as seen in Figure 3. Properties of the raw water and that treated are shown in Table III.

A small increase in the overall solution acidity upon ozonation is present, probably due to formation of new compounds with acidic properties (carboxylic acid production). Improvements in other parameters were not significant.

TABLE II. OZONATION EFFECTS ON SOME PHYSICOCHEMICAL PARAMETERS DURING COAGULATION-FLOCCULATION

Sample	pH	TDS (mg.L <sup>-1</sup> )	COD (mg.L <sup>-1</sup> )	Color (U Co-Pt)
Raw wastewater	8.4	1649	408(303)	350(330)
Coagulation-flocculation (anionic polymer)	8.5	1639	297(288)	200(180)
O <sub>3</sub> 10 s	8.3	1632	293(283)	190(150)
O <sub>3</sub> 30 s	8.3	1605	280(273)	170(130)
O <sub>3</sub> 60 s	8.3	1625	286(284)	140(100)
Coagulation-flocculation (amphoteric polymer)	8.4	1645	302(292)	205(180)
O <sub>3</sub> 10 s	8.3	1618	298(284)	193(150)
O <sub>3</sub> 30 s	8.3	1601	283(278)	170(135)
O <sub>3</sub> 60 s	8.3	1632	285(281)	135(100)

( ) samples after filtering; s: ozonation time in seconds; O<sub>3</sub>: ozone dose, 10 s (0.48 mg.L<sup>-1</sup>), 30 s (3.32 mg.L<sup>-1</sup>), 60 s ( 5.0 mg.L<sup>-1</sup>).

TABLE III. PHYSICOCHEMICAL PROPERTIES OF THE RAW WASTEWATER AND COAGULATION-FLOCCULATION EFFLUENT

Parameter	Raw wastewater	Coagulation-flocculation
Turbidity (NTU)	217	93-124
TOC (mg.L <sup>-1</sup> )	144	94-110
TSS (mg.L <sup>-1</sup> )	152	15-22
Settleable solids (mg.L <sup>-1</sup> )	0.5	8.8-8.9

**EFFECTS OF VARIATION OF COAGULANT DOSAGE**

Additional consideration was given to the reduction in the amount of metallic coagulants in the ozonation process. Gradual decreases in the amount of coagulant were tested keeping the ozone dose (3.32 mg.L<sup>-1</sup>) and polymer concentration constant. Results showed that with a reduction of 20% in coagulant dose (from 50 to 40 mg.L<sup>-1</sup>), similar removals are obtained with respect to those without ozone addition (Tables IV, V). Advantages are a considerable decrease in color (from 15 to 17% before and ≈ 35% after filtration) and settleable solids production (30%).

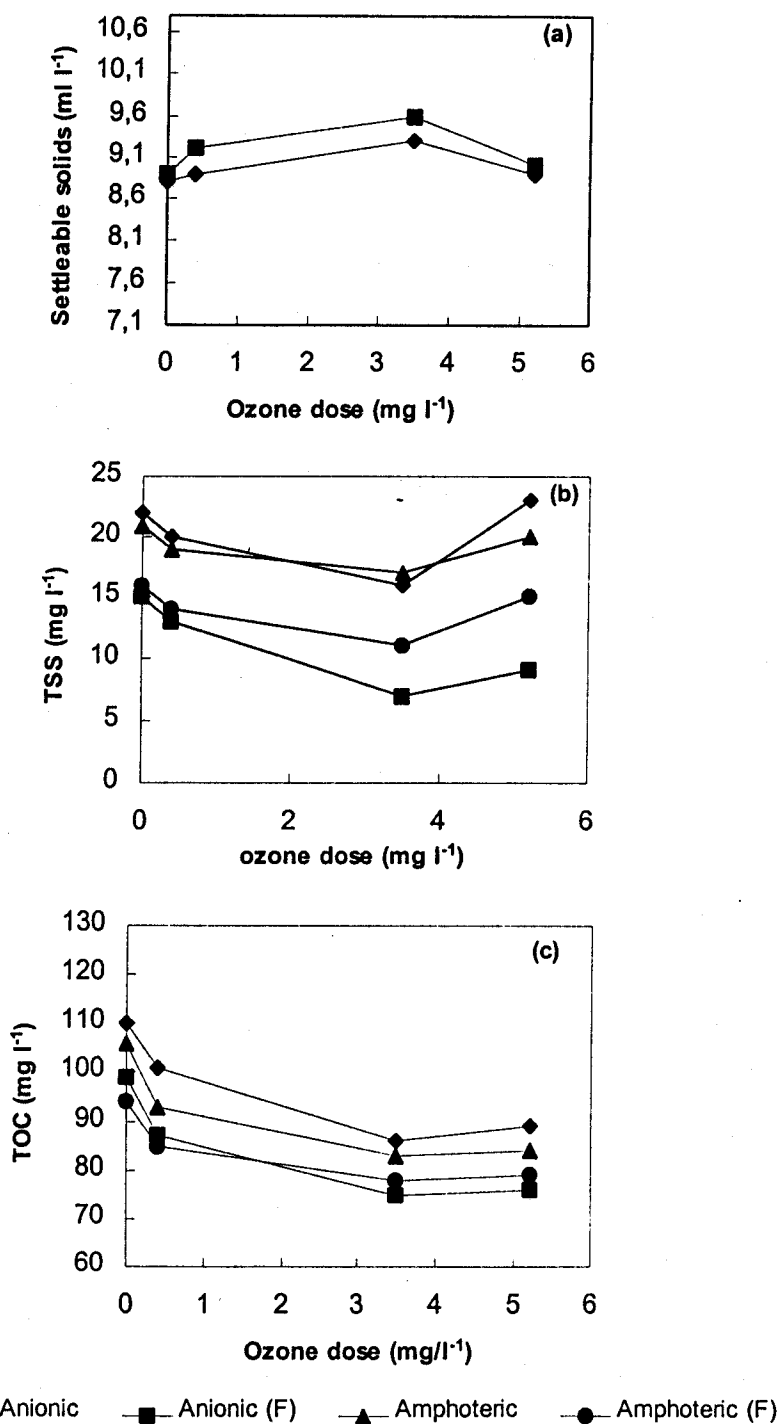


Figure 3. Coagulating effects of ozone on some physicochemical parameters.

It is important to remark that when a 50 mg.L<sup>-1</sup> of aluminum sulfate plus polymer is maintained because of the 3.32 mg.L<sup>-1</sup> ozone dose, the amount of settleable solids rises. (see Table V).



TABLE IV. EFFECTS OF COAGULANT DOSE REDUCTION ON SOME PHYSICO-CHEMICAL PARAMETERS

Sample	Turbidity (NTU)	TSS (mg.L <sup>-1</sup> )	TOC (mg.L <sup>-1</sup> )	COD (mg.L <sup>-1</sup> )
Raw wastewater	209 (152)	68 (20)	192 (164)	480 (296)
<b>Coagulation-flocculation (anionic polymer)</b>				
1. Al <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub> 50 mg.L <sup>-1</sup> + polymer	128(120)	22(18)	148(130)	359(345)
2. Al <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub> 50 mg.L <sup>-1</sup> + O <sub>3</sub> + polymer	120(116)	13(11)	78(70)	356(340)
3. Al <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub> 40 mg.L <sup>-1</sup> + O <sub>3</sub> + polymer	127(121)	18(16)	140(98)	365(360)
<b>Coagulation-flocculation (amphoteric polymer)</b>				
1. Al <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub> 50 mg.L <sup>-1</sup> + polymer	129(125)	22(20)	151(126)	365(349)
2. Al <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub> 50 mg.L <sup>-1</sup> + O <sub>3</sub> + polymer	124(117)	13(12)	89(78)	355(343)
3. Al <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub> 40 mg.L <sup>-1</sup> + O <sub>3</sub> + polymer	128(121)	17(14)	144(124)	363(348)
(:) samples after filtering; O <sub>3</sub> : ozone dose (3.32 mg.L <sup>-1</sup> ), polymers: anionic (0.4 mg.L <sup>-1</sup> ) and amphoteric (0.1 mg.L <sup>-1</sup> )				

TABLE V. EFFECTS OF COAGULANT DOSE REDUCTION ON SETTLING VELOCITY, SUSPENDED SOLIDS, SLUDGE PRODUCTION, TOTAL DISSOLVED SOLIDS AND COLOR

Sample	Vsed. (m/min)	TSS (mg.L <sup>-1</sup> )	Settle-able solids (mg.L <sup>-1</sup> )	TDS (mg.L <sup>-1</sup> )	Color (U Co-Pt)
Raw wastewater	---	95(65)	0.4	1098	345
<b>Coagulation-flocculation (anionic polymer)</b>					
1. Al <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub> 50 mg.L <sup>-1</sup> + polymer	0.10	24(19)	10.5	1016	190
2. Al <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub> 50 mg.L <sup>-1</sup> + O <sub>3</sub> + polymer	0.15	14(11)	11.0	979	165
3. Al <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub> 40 mg.L <sup>-1</sup> + O <sub>3</sub> + polymer	0.11	20(18)	7.25	996	165
<b>Coagulation-flocculation (amphoteric polymer)</b>					
1. Al <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub> 50 mg.L <sup>-1</sup> + polymer	0.05	24(20)	11	994	195
2. Al <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub> 50 mg.L <sup>-1</sup> + O <sub>3</sub> + polymer	0.06	15(13)	12	956	165
3. Al <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub> 40 mg.L <sup>-1</sup> + O <sub>3</sub> + polymer	0.05	19(16)	8.7	977	165
(:) samples after filtering; O <sub>3</sub> : ozone dose (3.32 mg.L <sup>-1</sup> ), polymers: anionic (0.4 mg.L <sup>-1</sup> ) and amphoteric (0.1 mg.L <sup>-1</sup> ).					

To verify that the increase in sedimentation velocity or the increase in floc size is due to ozonation, micrographs of the flocs resulting from the chemical treatment were taken. In this, the anionic and amphoteric polymers were used, giving a floc size of 840-1120  $\mu\text{m}$  and 420-700  $\mu\text{m}$ , respectively. Considering the best case (anionic polyelectrolyte) and applying the optimum ozone dose ( $3.32 \text{ mg.L}^{-1}$ ), the mean size increases to 980-1260  $\mu\text{m}$ . When the coagulant dose of  $\text{Al}_2(\text{SO}_4)_3 \cdot 14\text{H}_2\text{O}$  is reduced to  $40 \text{ mg.L}^{-1}$  in the presence of ozone, the same mean floc size is obtained compared to that resulting from the simple primary chemical treatment.

### ***EFFECTS OF OZONATION ON THE DISINFECTANT DOSE***

Savings in sodium hypochlorite consumption monitored as active chlorine were determined in the final effluent after filtration. A bifactorial statistical design (Montgomery, 1991) was carried out to evaluate the overall effect on disinfection considering two factors (active chlorine dose and ozone dose) and their mutual interactions. An active chlorine dose of  $20 \text{ mg.L}^{-1}$  was determined in a previous study for this water (Orta, 1995). Such study was carried out to meet an irrigation water standard of 1000 CFU/100 mL. Results showed that the required chlorine dose for reaching irrigation water standards, in conjunction with 30 seconds ozonation time, ranges from 15 to  $20 \text{ mg.L}^{-1}$  of  $\text{Cl}_2$ . Subsequently, to estimate chlorine savings using ozone, the active chlorine dose was limited to 15, 17 and  $20 \text{ mg.L}^{-1}$ . It is important to mention that fecal coliforms vary throughout the year between  $10^5$  and  $10^7$  CFU/100 mL for this wastewater (Table VI).

TABLE VI. REMAINING FECAL COLIFORM CONCENTRATION (RAW WASTEWATER WITH  $1.8 \times 10^7$  CFU/100 mL.)

	$15 \text{ mg.L}^{-1} \text{ Cl}_2$	$17 \text{ mg.L}^{-1} \text{ Cl}_2$	$20 \text{ mg.L}^{-1} \text{ Cl}_2$
Without ozone	$4 \times 10^5$	$1.3 \times 10^5$	0
10 s ozonation	$3 \times 10^5$	$1.2 \times 10^5$	0
30 s ozonation	$2 \times 10^4$	$1.5 \times 10^3$	0
60 s ozonation	500	0	0

Although results are somewhat similar, note that with  $17 \text{ mg.L}^{-1}$  of active chlorine and 30 s of ozonation time (with a dose of  $\sim 3.4 \text{ mg.L}^{-1}$ ) an adequate approximation to water irrigation standards is met.

### ***Conclusions***

Ozone has a positive influence in the coagulation-flocculation process when applied in small quantities, such as those reported in the literature for drinking and surface water. Excessive dosages lead to a deterioration and subsequent coagulation.

Ozonation presents positive effects in the coagulation-flocculation process, as far as the inorganic coagulant dose is diminished and a better removal of solids and improvement of physicochemical parameters. These results coincide with those of Edwards et al. (1994) on the natural organic matter content (NOM) using a similar treatment.

Due to the complex wastewater composition, it is difficult to elucidate the mechanisms implied in the process. A relevant result found is the determination of the most suitable ozone application point in terms of desired benefits, which shows that ozone must be applied immediately after coagulant addition and mixing. A short time lag between ozonation and coagulation will result in a better availability of ozone for reactions during molecular contacts.

With respect to the optimum coagulation ozone dose for this residual water, an improvement in organic matter and suspended particles removals was found at low dosages ( $\approx 0.02$  g O<sub>3</sub>/g TOC).

Additional benefits of low ozone dosages include reduction in turbidity and color for all cases considered, diminution in sludge production as a consequence of reductions in coagulant dose, larger floc sedimentation velocity and possible extended filter run times when coagulant dose is maintained constant, and a reduction in chlorine disinfection dose. A greater efficiency in the action of the amphoteric polymer also was found, reflected in a similar removal with only a fourth of the required concentration of the traditional treatment. However, floc size was smaller than that of the commercial polymer and, therefore, more susceptible to resuspension in a continuous process.

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### *Key Words*

Ozone; Municipal Wastewater; Coagulation-Flocculation; Chemically-Enhanced Primary Treatment;

### *Résumé*

Une étude a été réalisée pour évaluer les effets de l'ozone sur l'élimination des matières en suspension au cours de la coagulation-flocculation des eaux résiduaires des égouts de Mexico (incluant les rejets domestiques et industriels). Les résultats de cette étude montrent une amélioration significative de la qualité de l'effluent avec de faibles doses d'ozone. La dose d'ozone optimale a été trouvée égale à  $3,32 \text{ mg/L} \pm 0,20$ . Avec cette dose, il est possible de réduire le taux de coagulant de  $50 \text{ mg/L}$  à  $40 \text{ mg/L}$  sans affecter la qualité de l'effluent si l'on ne diminue pas la dose de coagulant, on observe une augmentation de la vitesse de décantation de la vitesse de décantation de floc, due à une taille moyenne plus grande des particules, et une diminution des TSS avant et après filtration. Dans tous les cas, on observe réduction de la couleur et de la turbidité lorsque l'on utilise des polyélectrolytes. Les meilleurs résultats sont obtenus si l'on utilise un rapport de  $0,02 \text{ g}$  d'ozone par  $\text{g}$  de COT.

### *Zusammenfassung*

Eine Studie untersuchte den Einfluß von Ozon auf die Feststoffentfernung bei der Flockung eines Abwassers von Mexiko-Stadt (häusliches und industrielles Abwasser). Kleine Ozondosen verbesserten die Partikelentfernung. Die optimale Ozondosis lag bei  $3,32 \text{ mg}$  Ozon pro Liter  $\pm 0,2$ . Durch diese Dosis gelang es, die Flockungsmittelmenge von  $50 \text{ mg/L}$  auf  $40 \text{ mg/L}$  zu verringern, ohne dass sich die Ablaufqualität verschlechterte. Wenn die Flockungsmittelmenge bei der Ozonung nicht vermindert wird, so ergibt sich eine verbesserte Absetzgeschwindigkeit durch grössere Flocken und ebenfalls eine verringerte Trockensubstanzmenge. In allen Fällen zeigt sich beim Einsatz von Polyelektrolyten eine Verminderung der Trübung und Farbe. Die besten Ergebnisse werden beim Einsatz von  $0,02 \text{ g}$  Ozon pro Gramm TOC erreicht.