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DISINFECTION OF SECONDARY TREATED WASTEWATER USING UNDER PRESSURE DISSOLVED OXYGEN, COPPER IONS AND HYDROGEN PEROXIDE

R. NABIZADEH[1]
M. ALIMOHAMMADI[1]
R. NEMATI[1,2 *]
K. NADDAFI[1]
S. NASERI[1]
H. ASLANI[1]
S.N. MOUSAVIPOUR[1]

[1]*Department of Environmental Health Engineering*
School of Public Health, Tehran University of Medical Sciences
Tehran University of Medical Sciences, Tehran, Iran
[2]*Current affiliation: Department of Environmental Health Engineering*
School of Public Health and Paramedical
Semnan University of Medical Sciences
Aradan, Semnan, Iran

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*to whom all correspondence should be addressed:
e-mail: reza-nemati@hotmail.com

ABSTRACT

Many studies have been conducted to increase the efficiency of hydrogen peroxide (HP) in wastewater disinfection to make HP disinfection more cost-effective with respect to reduced concentration and detention time. In this study, the effects of HP, copper ions (Cu^{2+}), and 1 atm. pressure-dissolved oxygen (termed O_2 in this study) applied either alone or in a binary or ternary combination to undisinfected secondary treated wastewater (STW) were assessed.

Undisinfected STW in contact (1 h) with various doses of HP (alone), Cu^{2+} (alone), HP/Cu^{2+} (binary) and HP/Cu^{2+} with O_2 (ternary) showed a variable fecal coliforms (FC) removal pattern, ranging from 0.03 to 3.8 logs inactivation. O_2 had the highest synergistic effect when combined with Cu^{2+} and HP. The use of 200 mg L^{-1} HP + 5 mg L^{-1} Cu^{2+} together with O_2 caused a 0.65 log inactivation of FC more than the binary combination (i.e., 200 mg L^{-1} HP + 5 mg L^{-1} Cu^{2+}).

KEYWORDS: Fecal coliforms, Synergistic effect, Wastewater reuse.

1. INTRODUCTION

Secondary treated wastewater (STW) before disinfection may contain pathogenic levels of microorganisms. For example, the infectious dose of *Shigella* spp. is 180 organisms, while levels in STW are about 10^4-10^6 organisms per 100 mL (EPA 2002; U.S. EPA 1992).

Therefore, it is essential that STW is disinfected before it is discharged or reused.

Because of a worldwide water shortage, the reuse of wastewater for various non- potable purposes including agriculture has significantly increased. Related organizations in various countries set different effluent quality guidelines and standards (Andreadakis *et al.,* 2003). According to World Health Organization (WHO) guidelines, fecal coliforms (FC) level, which is one of the environment water quality standards, for unrestricted irrigation water should be less than 1000 organisms/100 mL (Blumenthal *et al.*, 2000). FC levels in raw wastewater are about 10^6–10^8 organisms per 100 mL, and conventional treatments without a disinfection step can reduce these levels by one to three orders of magnitude. However, due to the high initial concentration, this reduction is still inadequate, and effective disinfection is required (George *et al.*, 2002).

Chemical disinfection is considered to be one of the most popular methods for disinfecting STW. Conventional chemical disinfectants such as chlorine gas and hypochlorite have some advantages including rapid oxidation rates, low cost and high biocide potency. However, the mutagenic and carcinogenic by-products produced due to the application of these disinfectants have motivated scientists to seek alternative methods which may be more environmentally friendly (Liberti *et al.,* 2000; Selvakumar *et al.,* 2009).

Although ozone and ultraviolet light do not generate harmful by-products, high capital and operational costs are considered to be limiting factors (Drogui *et al.,* 2000). In addition, other disinfection methods such as TiO2 photocatalysis (Melemeni *et al.,* 2009) are novel and further full scale studies are needed to prove their cost-effectiveness.

Another alternative disinfectant is hydrogen peroxide (HP) which has a low capital cost. However, to achieve a satisfactory level of STW disinfection, high concentrations of HP and a long detention time are required (Ragab-Depre, 1982; Selvakumar *et al.,* 2009; Wagner *et al.,* 2002). Wagner *et al.* (2002) showed that to achieve a 5 log reduction of *E. coli* in STW, more than 700 mg L^{-1} of HP is required for 2 h. Velasquez *et al.* (2008) reduced FC and pathogenic bacteria of advanced primary treatment effluent to acceptable levels according to international legislation, however, this required more than 250 mg L^{-1} of HP and contact times of over 2 h.

Many studies have been conducted to increase the disinfection efficiency of HP in order to make HP disinfection more cost-effective with regard to reduced concentration and detention time (Orta De Velasquez *et al.,* 2008; Ragab-Depre, 1982; Wagner *et al.,* 2002). Studies have indicated that the addition of various transition metal ions to HP (Fenton reagents) can enhance the biocide activity of HP. In the Fenton reaction, reduced metal ions react with HP and produce hydroxyl radicals ($OH^{\cdot}$). Hydroxyl radicals are highly reactive and are responsible for biological damage to microbial cells (Cross *et al.,* 2003; Ragab-Depre, 1982; Selvakumar *et al.*, 2009; Shapiro *et al.,* 2004). Further studies on this phenomenon showed that modification of the Fenton reagent by Cu^{2+}, aqueous dissolved oxygen and ascorbic acid formulation have biocide potency and can destroy spores of *Bacillus* which are unaffected by environmental stresses such as heat radiation and toxic chemicals (Cross *et al.,* 2003; Shapiro *et al.,* 2004). Cross et al investigated the potency of the combination of dissolved oxygen, Cu^{2+} and ascorbic acid on the inactivation of *Bacillus* spores. They reported that dissolved oxygen increased the inactivation rate. They proposed that the simultaneous presence of Cu^{2+}, ascorbic acid and dissolved oxygen led to the formation of hydroxyl radicals which, as noted, are responsible for cell damage (Cross *et al.,* 2003).

In some studies, it was observed that dissolved oxygen had no effect on HP or Cu^{2+} biocidal potency, however, these studies did not involve the STW disinfection process (Samuni *et al.*, 1983). In addition, it was not determined whether under pressure dissolved oxygen had the same effect or had a synergistic effect on Cu^{2+} and/or HP disinfection efficiency.

In this study, the effects of under pressure (1 atm) dissolved oxygen (termed O_2 in this study) on STW disinfection together with HP and/or Cu^{2+} were studied.

2. MATERIALS AND METHODS

2.1. Sampling

Undisinfected samples were taken from a secondary sedimentation tank (before chlorination) at the Zargandeh wastewater treatment plant north east of Tehran, Iran. This wastewater treatment plant purifies municipal wastewater by a contact stabilization- extended aeration activated sludge process. The plant is designed to treat average flow of 190 cubic meter per hour which covers a polulatin of 12000 people. Samples were collected in non-reactive precleaned 10 l containers and transported to the laboratory. All samples were examined within 5 h.

2.2. Materials

Copper (II) chloride dihydrate (Merck product number 102733) was used as the Cu^{2+} source. All other chemicals including hydrogen peroxide (30% w/w) (product number 1085972500), EDTA disodium salt (product number 324503), sodium thiosulfate pentahydrate (product number 106513), A-1 medium (product number 1004150500) and sodium chloride (product number 1064041000) were purchased from Merck Chemical Company (Germany). A standard oxygen cylinder of 244 ft^3 at 2200 psi and 70°F (6.5 m^3 at 15200 kPa at 20°C) was used and O_2 of 99.9% purity was used as the oxygen source. In all stock solutions and other water preparations double distilled water was used. The exact concentration of HP was determined by the permanganate titration method (Huckaba and Keyes, 1948).

2.3. Pilot set up

Two steel containers (reactors) were set up to determine the effect of under pressure dissolved oxygen on HP and Cu^{2+} biocide activity. Both containers were cylindrical and were made of stainless steel and had a volume of 6 l. One of the containers did not have any appurtenance and was used for the disinfection experiments where O_2 injection was not performed. The other container did have appurtenance which is shown schematically in Figure 1. This container was connected to a cylinder which was filled with pure oxygen (99.9% pure) by a plastic pipe.

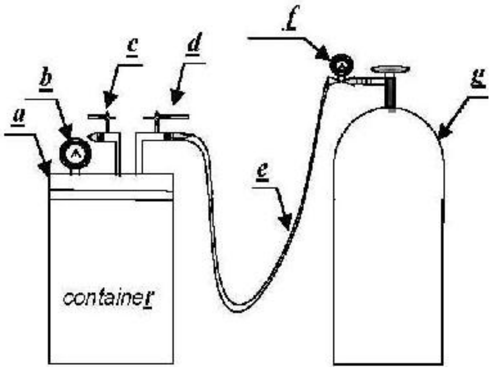


Figure 1. Schematic representation of the under pressure container. (a) Screw cap, (b) Pressure gauge, (c) Ball valve for gas pressure regulation, (d) Ball valve for oxygen gas entrance, (e) Connector hose, (f) Pressure reducing Valve, (g) Oxygen cylinder

After the addition of 1l of undisinfected STW to both containers and the application of appropriate doses of HP and/or Cu^{2+} ions to the containers, the containers were sealed immediately by closing the screw cap. The oxygen gas entrance valve (marked d in Figure 1) was then opened until the pressure gauge displayed 1 atm. pressure. An increase in pressure to more than 1 atm. was adjusted manually by opening the gas pressure regulator valve (c in Figure 1).

2.4. Experiments
Parameters such as TSS, BOD_5, COD, pH, and FC values were tested after mixing the samples. STW characteristics (average) are presented in Table 1.
As in the pilot set up, 1 L of the well-mixed effluent was placed in each of the two sterile steel containers. Specified amounts of HP, Cu^{2+} and the combined HP/Cu^{2+} solutions were added to each container (Table 2). Contact time in all disinfection experiments was 1 h and started immediately after adjusting the pressure of oxygen to 1 atm. In all experiments the sample volume was 1 L.
As FC are a reliable indicator of microbial contamination in aquatic environments, these were selected as disinfection indicator microorganisms in this study (Niemi and Niemi, 1991).

Table 1. Physicochemical and microbiological characteristics of undisinfected STW

Parameter	Range		Mean	Standard Deviation
	Minimum	Maximum		
Temperature	17.4	18.2	17.88	0.32
pH	6.87	7.81	7.476	0.40
BOD5 (mg L^{-1})	4.56	39.3	18.492	14.20
COD (mg L^{-1})	6.4	86.4	36.12	148
TS (mg L^{-1})	280	640	492	31.94
TDS (mg L^{-1})	276	605	469.1	134.88
Fecal coliforms (MPN/100 mL)	3.5×10^5	7.0×10^5	4.9×10^5	--

Fecal coliforms (FC) concentrations were determined by using the multiple-tube fermentation direct test (APHA (American Public Health Association) 2005). Quantitative measurements of FC were performed before and after disinfection. All experiments were carried out at laboratory temperature (22-26°C) by adding various doses of disinfectants. After completion of the disinfection detention time, HP and Cu^{2+} were neutralized by a stoichiometric ratio injection of sodium thiosulfate and disodium EDTA, respectively (Samuni *et al.,* 1983; Luna-Pabello, 2009).

Table 2. Applied disinfectant doses (mg L^{-1})

HP	Cu^{2+}	combination	
		HP	Cu^{2+}
0 (blank)	0 (blank)	0 (blank)	0 (blank)
10	0.01	10	0.01
20	0.1	20	0.1
50	0.5	50	0.5
100	1	100	1
150	3	150	3
200	5	200	5
300	-	-	-
600	-	-	-

3. RESULTS

3.1. HP and HP/O_2 disinfection

The efficiencies of HP and HP/O_2 on FC inactivation in undisinfected STW are shown in Figure 2. It can be seen from this figure that O_2 alone (HP = 0 mg L^{-1}) did not eliminate a significant number of FC. Moreover, neither increasing the HP dose up to 50 mg L^{-1} alone or the combination of HP and O_2 (i.e., HP/O_2) had a significant effect on FC levels. Considerable FC inactivation occurred at HP doses higher than 50 mg L^{-1}. With increasing HP concentration up to 200 mg L^{-1}, the FC inactivation efficiencies of both HP and HP/O_2 increased sharply. In the range of 50-200 mg L^{-1}, FC log inactivation by HP and HP/O_2 increased from 0.03 and 0.1 logs at 50 mg L^{-1} HP to 1.18 and 1.37 logs at 200 mg L^{-1}, respectively. For HP doses higher than 200 mg L^{-1}, the increase was slower; at an HP dose of 600 mg L^{-1}, FC log inactivation by HP and HP/O_2 was 1.46 and 1.94, respectively. However, despite the high doses of HP, neither HP nor HP/O_2 satisfied the microbial requirements set by WHO.

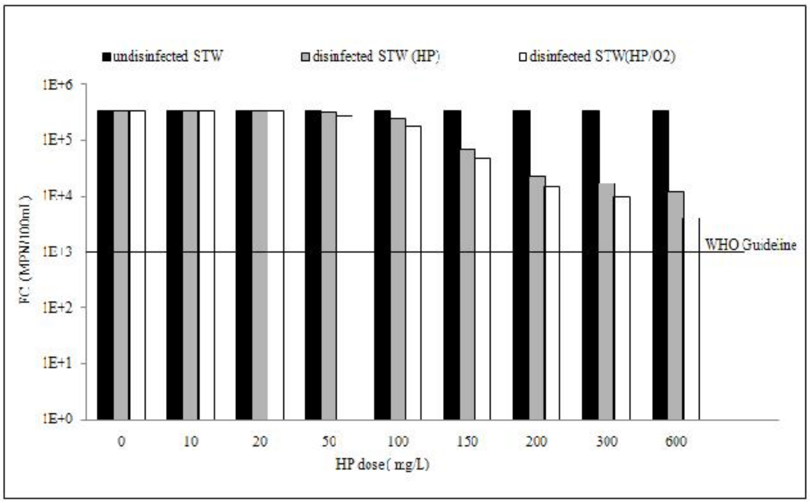
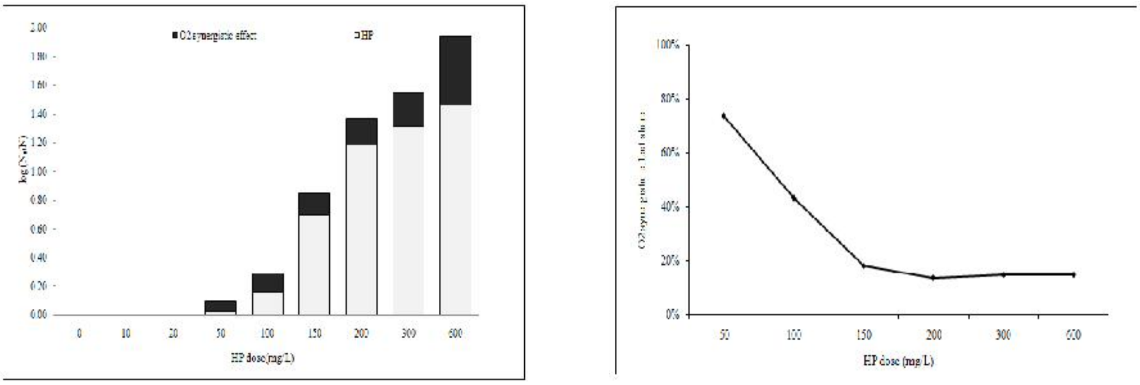


Figure 2. FC levels in STW before and after disinfection using various doses of HP alone and together with O_2 (contact time = 1 h)

The synergistic effect of O_2 on HP disinfection is shown in Figure 3a. The synergistic effect was obtained by subtracting the log inactivation value of an individual disinfection agent from the log inactivation value of their combination. It can be seen that the O_2 synergistic effect at low doses of HP had a significant role in disinfection efficiency and its quantities gradually increased. In contrast, its role at moderate doses varied slightly and with increasing HP dose its proportional share decreased. Although at the highest doses this value increased.



(a) (b)

Figure 3. Proportional share of HP and synergistic effect of O_2 in FC inactivation using various doses of HP together with O_2 (a) and O_2 synergism effect share variations in STW disinfection using various doses of HP together with O_2 (b)

When the total disinfection efficiency of HP/O_2 was considered, the proportional share of the O_2 synergistic effect was still low. From Figure 3a it can be seen that the proportional share of the O_2 synergic effect on HP disinfection efficiency ranged from 0.07 logs at an HP dose of 50 mg L^{-1} to 0.48 logs at an HP dose of 600 mg L^{-1} which was considered a low synergistic effect. Figure 3b displays the proportional share of the O_2 synergistic action variations on HP disinfection efficiency. It can be seen that the O_2 proportional share was significantly decreased from around 74% at an HP dose of 50 mg L^{-1} to 18% at 150 mg L^{-1} HP + O_2. At higher doses, this value continued to decrease, but its slope was very slow and at higher doses it was almost constant. The value at the highest dose (i.e. 600 mg L^{-1} HP) was about 15%.

3.2. Cu^{2+} and Cu^{2+}/O_2 disinfection

As illustrated in Figure 4, disinfection of secondary effluent with Cu^{2+} or Cu^{2+}/O_2 reduced FC. The disinfecting effect of Cu^{2+} and Cu^{2+}/O_2 was observed at doses higher than 0.1 mg L^{-1}. As an overall trend, it is clear that increasing concentrations of Cu^{2+} caused a corresponding increase in the FC inactivation rate due to Cu^{2+} and Cu^{2+} / O_2.

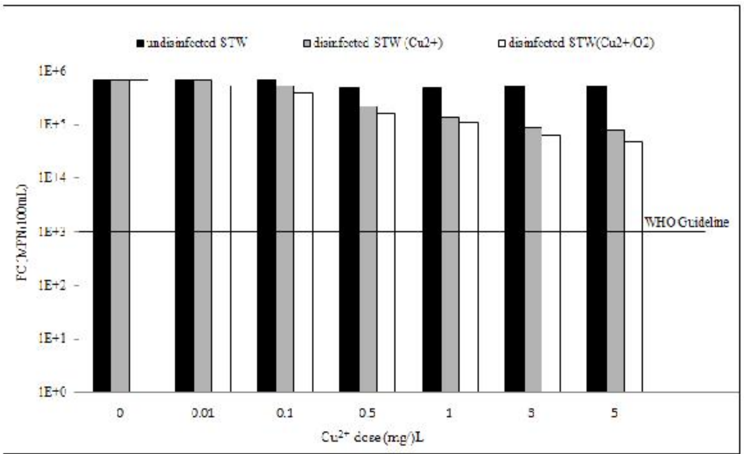
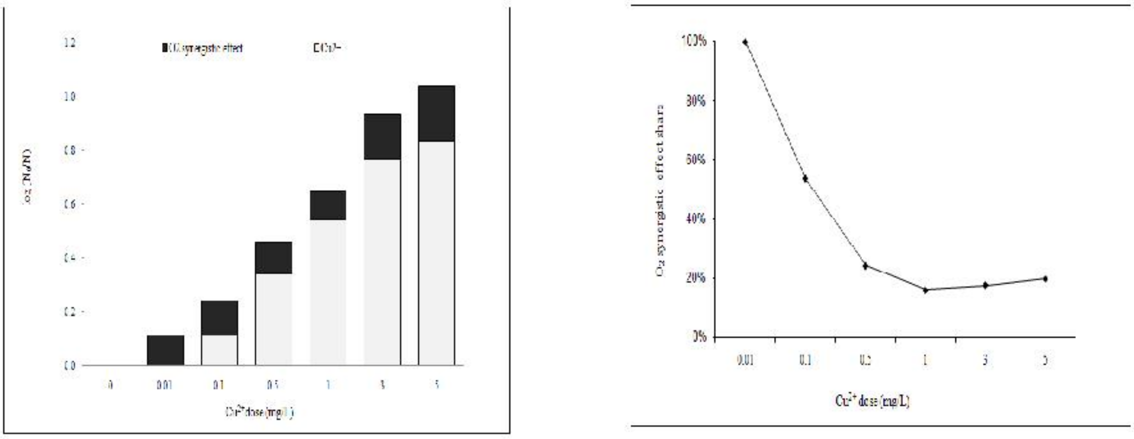


Figure 4. FC levels in STW before and after disinfection using various doses of Cu^{2+} alone and together with O_2 (contact time = 1 h)

Death rates of FC increased gradually up to 1 mg L^{-1} Cu^{2+} and continued to increase slowly at higher doses. The application of Cu^{2+} (alone) at doses of 0.1, 1, and 5 mg L^{-1} caused a 0.1, 0.5, and 0.83 log reduction, respectively; the corresponding log reductions for the Cu^{2+}/O_2 combination were 0.2, 0.6, and 1, respectively. Therefore, the efficiency of disinfection with Cu^{2+} or Cu^{2+}/O_2 was not sufficient to meet the WHO criteria for wastewater re-use.

The relative share of the O_2 synergistic action in the disinfection efficiency of Cu^{2+} is shown ın Figure 5a. It can be seen that this value increased as the Cu^{2+} dose increased. Since the increased disinfection rate due to Cu^{2+} was significantly higher than the O_2 synergistic effect increase, the O_2

(synergistic effect) proportional share rapidly decreased. The variation in the O_2 synergistic effect vs. Cu^{2+} doses is shown in Figure 5b. It can be seen that at low Cu^{2+} doses, the O_2 synergistic effect was very important in the disinfection efficiency. This value decreased from about 100% at the lowest dose (0.01 Cu^{2+}) to about 20% at the highest dose. Although, the synergistic effect of O_2 on the disinfection of STW with Cu^{2+} increased due to the application of higher doses of Cu^{+2}, the effect (about 0.2 log reductions) was not considered practically significant.



(a) (b)

Figure 5. Proportional share of Cu^{2+} and the synergistic effect of O_2 on FC inactivation using various doses of Cu^{2+} together with O_2 (a) and the O_2 synergism effect share variations on STW disinfection using various doses of Cu^{2+} together with O_2 (b)

3.3. Cu^{2+}/HP and Cu^{2+}/HP/O_2 disinfection

The effects of the binary combination of HP/Cu^{2+} and the ternary combination of HP/ Cu^{2+}/O_2 on FC levels in undisinfected STW are presented in Figure 6. It can be seen that the FC inactivation rate in the binary (i.e., Cu^{2+}/HP) and ternary (i.e., Cu^{2+}/HP/O_2) combinations rapidly increased as Cu^{2+} and HP increased. As illustrated in Figure 6, the combination of Cu^{2+}/HP at the highest dose (i.e., 200 mg L^{-1} HP + 5 mg L^{-1} Cu^{2+}) led to a significant drop in FC level to 450 MPN/100 mL complying with the WHO effluent standard (FC 1000 MPN/100 mL). The addition of O_2 to the HP/ Cu^{2+} combinations catalyzed the FC inactivation rate so that this combination was capable of achieving the WHO standard level at a lower dose (150 mg L^{-1} HP + 3 mg L^{-1} Cu^{2+} + O_2). The ternary combination at the highest applied dose (200 mg L^{-1} HP + 5 mg L^{-1} Cu^{2+} + O_2) in this study decreased FC concentration to 100 MPN/100 mL and when the initial FC concentration was considered, this was equivalent to a 3.7 log reduction. A comparison of the binary and ternary disinfection efficiency revealed that O_2 had a significant synergistic effect on HP/Cu^{2+} disinfection.

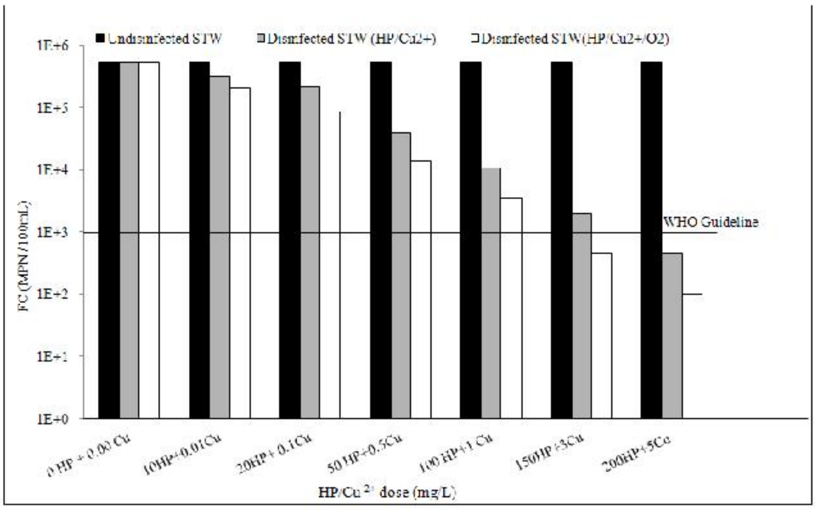
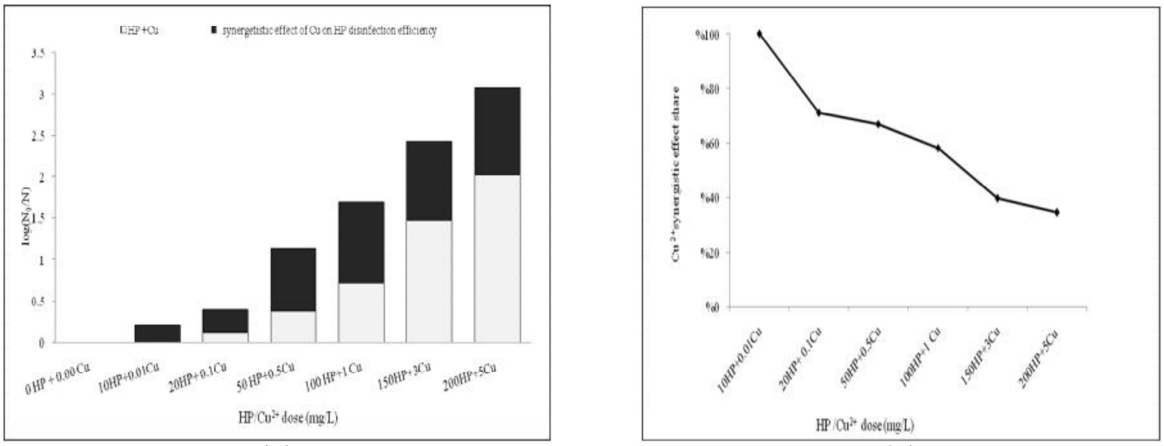


Figure 6. FC levels in STW before and after disinfection using various doses of HP alone and together with O_2 (contact time = 1 h)

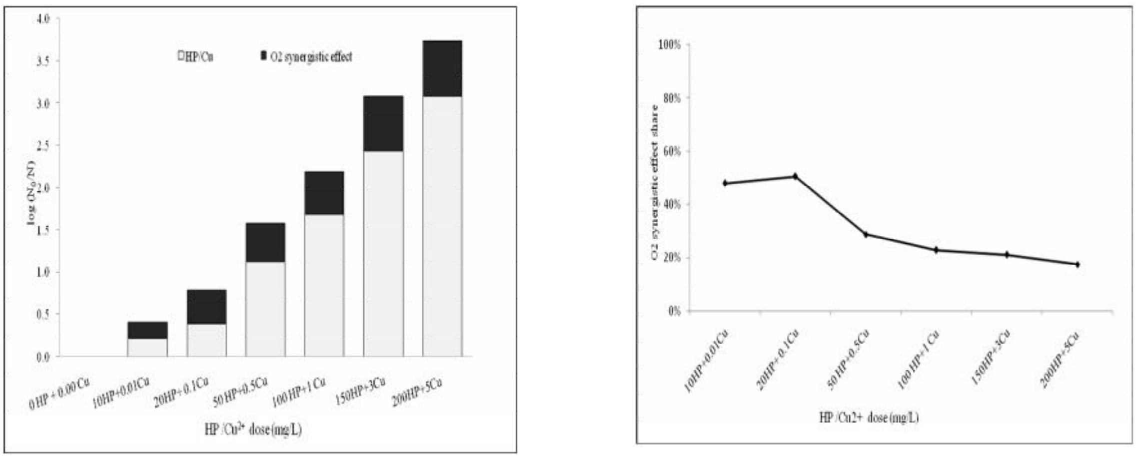
The synergistic influence of Cu^{2+} on HP is shown in Figure 7a. It can be seen that at lower doses, synergism plays the main role in FC inactivation. In addition, this figure shows that the synergistic effect of Cu^{2+} at lower doses was considerably increased, but at higher doses the value remained almost constant. The synergistic share of the lowest applied dose (10 mg L^{-1} HP + 0.01 mg L^{-1} Cu^{2+}) was 0.21 log. When the combinations of 100 mg L^{-1} HP + 1 mg L^{-1} Cu^{2+} and 200 mg L^{-1} HP + 5 Cu^{2+} mg L^{-1} were used this value was enhanced to 0.96 log and 1.06 log, respectively. Figure 7b demonstrates the portion of the Cu^{2+} synergistic effect in the disinfection process. It can be seen that with increasing doses this portion quickly declined. At the lowest employed dose (i.e. 10 mg L^{-1} HP + 0.01 mg L^{-1} Cu^{2+}) nearly all of the disinfection efficiency was related to synergistic action, however, this value at the highest employed dose (200 mg L^{-1} HP + 5 mg L^{-1} Cu^{2+}) reduced to about 34%.



(a) (b)

Figure 7. Proportional share of HP + Cu^{2+} and the synergistic effect of Cu^{2+} on FC inactivation using various doses of HP/Cu^{2+} (a) and the Cu^{2+} synergism effect share variations on STW disinfection using various doses of HP and Cu^{2+} combinations (b)

Figure 8a shows the O_2 synergistic effect on HP/Cu^{2+} disinfection efficiency. At lower doses the synergistic effect of O_2 gradually increased, but at higher doses this effect remained stable. This value increased from 0.2 log inactivation at 10 mg L^{-1} HP + 0.1 mg L^{-1} Cu^{2+} combination to 0.5 and 0.65 log inactivation at 100 mg L^{-1} HP + 1 mg L^{-1} Cu^{2+} and 200 mg L^{-1} HP + 5 mg L^{-1} Cu^{2+} combinations, respectively. Figure 8b demonstrates the proportional share of the O_2 synergistic action in the ternary combination (HP/Cu^{2+}/O_2). It is obvious that the synergistic share of O_2 at lower doses was higher and at the lowest applied dose it was about 50%. This value decreased sharply to 29% at the 50 mg L^{-1} HP + 0.5 mg L^{-1} Cu^{2+} combination and continued to decrease but with a gentle slope to around 20% at the highest dose (200 mg L^{-1} HP + 5 mg L^{-1} Cu^{2+}).



(a) (b)

Figure 8. Proportional share of HP/Cu^{2+} and the synergistic effect of O_2 on FC inactivation using various doses of HP/Cu^{2+} together with O_2 (a) and the O_2 synergistic effect share variations on STW disinfection using various doses of HP together with O_2 (b)

4. DISCUSSION

Similar to many previous studies (Orta De Velasquez, 2008; Wagner *et al.,* 2002), the application of HP (alone) on STW disinfection in our study was unsuccessful. The application of 600 mg L^{-1} with a contact time of I h (C.T= 36000 mg.min l^{-1}) was not effective in reducing the FC level below the WHO standard level for agricultural use (≤1000 MPN/100 mL). Velasquez *et al.* (Orta De Velasquez, 2008) reported that to achieve acceptable FC and pathogenic levels in advanced primary treatment effluents using HP, the required dose should be more than 250 mg L^{-1}; and the contact time should be longer than 120 minutes (C.T>30000).

Although adding Cu^{2+} to HP can increase the disinfection efficiency, it should be noted that Cu is a bioaccumulative environmental toxin, which can disrupt the balance of soil and aquatic life (Luna-Pabello *et al.*, 2009).

Agricultural-based guideline values for Cu in irrigation water are variable. For example, the Iranian Environmental Protection Organization (Iran EPO, 1995), the U.S. Environmental Protection Agency (EPA), (EPA 2004), the Australian/New Zealand Environment Conservation Council (ANZECC), (ANZECC, 2000) and the Food and Agriculture Organization of the United Nations (FAO), (FAO 1992) set an effluent limit of 0.2 mg L^{-1} for Cu^{2+}, while this limit in Saudi Arabia and Oman is 0.4 and 1 mg L^{-1}, respectively (CEHA, 2006).

In some guidelines for irrigation water quality, the limitations of effluent components are set according to the duration of effluent loading. These guidelines introduced the long-term use value (the maximum concentration of contaminant in the irrigation water which can be tolerated assuming 100 years) and the short-term use value (maximum concentration of contaminant in the irrigation water which can be tolerated for a shorter time period of 20 years) (ANZECC, 2000). According to U.S. EPA and ANZECC guidelines for irrigation water quality, the maximum allowable concentration of Cu in irrigation water for long-term use and short-term use is 0.2 and 5 mg L^{-1}, respectively (ANZECC, 2000; EPA, 2004). Therefore, using binary combinations of HP/Cu^{2+} and ternary combinations of HP/Cu^{2+}/O_2 (containing less than 5 mg L^{-1} Cu^{2+}) for STW disinfection are acceptable for short-term use. For long-term application, effluent dilution with other water sources seems to be the only way of meeting the standard value which is not practically feasible in many cases, especially where disinfected effluents are the only sources for irrigation.

It should be noted that some reputed organizations such as WHO did not set limitations for Cu^{2+} and other metals in treated effluents used for irrigation. However, WHO and other agencies are more focused on monitoring these constituents in soil rather than setting rigid limitations for Cu^{2+} and other metals in effluent. As previously mentioned Cu reacts with organic matter in effluents (e.g. proteins) and is converted to highly stable compounds which have lower toxicity (Luna-Pabello 2009).

As observed, O_2 had a synergistic effect on disinfection with HP, Cu^{2+} and the combination of HP/Cu^{2+}. Since the O_2 synergistic effect on HP or $Cu2^+$ was not enough to meet the microbial quality requirements in conventional doses, it seems that using HP or Cu^{2+} together with O_2 is not applicable. As seen in Figure 6, the binary combination of HP/Cu^{2+} at the highest dose (i.e. 200 mg L^{-1} HP + 5 mg L^{-1} Cu^{2+}) and the ternary combination at the two highest doses caused FC levels to drop below the WHO guideline level for unrestricted irrigation.

Khazaie M. *et al.* (2007) studied the efficiency of hydrogen peroxide-silver ion complex in removing total coli forms from samples taken from Qom wastewater. In the concentration of 80 and 480 mg L^{-1}, logarithmic removal value of total coli forms was 1.9 and 4.5 respectively. In CT value 8600 mg L^{-1}.min and more, the total coli forms effluent standard for surface water discharge and agriculture irrigation was achieved. It was concluded that the use of hydrogen peroxide-silver ion complex as a water and wastewater disinfectant, has some benefits such as elimination of hazardous by products, and measurable residual amount. However its application in wastewater effluent is more costly than other usual disinfectants so it is not economically advisable (Khazaie *et al.,* 2007). It is remarkable that ternary combinations at lower doses of HP/Cu^{2+} (i.e., at 150 mg L^{-1} HP + 3 mg L^{-1} Cu^{2+}) rather than the binary combination of HP/Cu^{2+} (i.e., at 200 mg L^{-1} + 5 mg L^{-1} Cu^{2+}) meet the WHO guideline FC levels for unrestricted irrigation. Dissolved Air Flotation (DAF), the process of removing suspended solids, oils and other contaminants via the use of air bubble, was extensively used in the field of wastewater treatment. Application of under pressure dissolved oxygen in disinfection would be simpler and technically practical. Oxygen is dissolved into wastestream (in a pressure vessel tank) which comes from the secondary sedimentation tank of a activated sludge system and is released from solution at the end of contact time. The higher microbial effectiveness and better effluent quality may be compensating factors for the high O_2 costs.

5. CONCLUSION

Our study showed that O_2 has a noticeable synergistic effect on the disinfection efficiency of HP, Cu^{2+} and the combination of HP/Cu^{2+}. The greatest synergistic effects were seen when the combination of HP/Cu^{2+} was used which met the international legislation on microbial quality for STW. Previous research revealed that for achieving a satisfactory level of STW disinfection, high concentrations of HP and a long detention time are required (Ragab-Depre, 1982; Selvakumar *et al.,* 2009; Wagner *et al*., 2002). Wagner *et al.* (2002) showed that to achieve a 5 log reduction of *E. coli* in STW, more than 700 mg L^{-1} of HP is required for 2 h. We could reduce the amount of required hydrogen peroxide using hydrogen peroxide-silver ion complex in our previous study. In this study, it was concluded that using 200 mg L^{-1} HP + 5 mg L^{-1} Cu^{2+} and under pressure dissolved oxygen caused FC levels to drop below the WHO guideline level for unrestricted irrigation. According to the objective of present study, it is concluded that using under pressure dissolved oxygen could be considered as an interventional combination process to reduce the amount of required hydrogen peroxide. But, the HP dose is still high and more research should be performed to reduce the disinfectant concentrations to an economically feasible level.

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