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Original Article

Demonstration of the Enhanced Disinfection of *E. coli* Water Contamination by Associated Solar Irradiation with Potassium Persulfate

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Abstract

Background: Tremendous amount of researches have investigated the issue of water photodisnfection. The aim of this research is to illustrate the influences of bacterial density, turbidity, exposure time and potassium persulfate (KPS) dosage on the efficacy of associated solar disinfection (SODIS) with KPS for *E. coli* (ATCC: 25922) eradication as an efficient and inexpensive process.

Methods: Desired bacterial density and turbidity was achieved by spiking of 0.5 Mc Farland (1.5×10^8 cell/ml) and sterile soil slurry in 1 liter of the commercially bottled water.

Results: The highest value of UV_A solar irradiation measured at 13.30 p.m was 5510 μW/Cm². Increase of bacterial density from 1000 to 1500 cell/ml led to an increase in disinfection lapse time, except in 2 mMol/l KPS. Spiking of 0.1 mMol/l of KPS was not effective; however, increase of KPS dosage from 0.1 mMol/l to 0.7, 1.5 and 2 mMol/l led to the enhancement of disinfection time from 4 h to 3 h and 1 h, respectively. For bacterial density of 1000 cell/ml, increasing KPS dosage up to 0.7 mMol/l had no improved effect; however, beyond this dosage the disinfection time decreased to 1 h. Without KPS and up to 150 NTU within 4 h exposure time, *E. coli* disinfection was completed. In 2 mMol/l KPS and 1000 and 1500 cell/ml, the 2 h contact time was sufficient up to 150 and 100 NTU, respectively; moreover, complete disinfection was not achieved at higher turbidity.

Conclusion: Association of KPS with SODIS can lead to decreasing of water disinfection time.

Keywords: Disinfection, Solar irradiation, Potassium persulfate, Water, *E. coli*

Introduction

Access to the safe and reliable drinking water from point of quality and quantity is one of the most important and difficult challenges in the present century (1). Climate changes and intrusion of pollutants from none point sources have enormously complicated the intensity of this problem (2). In recent years, despite comprehensive progress towards the Millennium Development Goals, responsible organizations including United Nations reported that at least 11% of the world's population lacking access to the safe drinking water (3). High incidence of waterborne diseases is a crucial global concern among which diarrhea is the second cause of death of children of less than

five years of age (4, 5). This huge occurrence of mortality especially in developing countries originating from microbial contaminated water shows that inactivation of waterborne pathogens for provision of safe potable water is necessary and must be taken as a priority in health programs (6).
Several procedures such as chlorination, ozonation and UV lamps have been used for bacterial disinfection; however, these traditional methods contain many drawbacks and associated disadvantages. Chlorine reacts with natural organic matters and generates trihalomethanes that are highly carcinogenic (7, 8). Moreover, the UV lamps and ozonation process instruments have their own drawbacks with limited applications, especially in the remote areas (9).
Due to this particular and important barrier, inexpensive and simple disinfection procedures such as solar disinfection (SODIS) that provides safe and reliable drinking water can be used as an appropriate alternative in point-of-use and at the household scale.
SODIS is one of the most cost effective and environmentally prominent techniques for water disinfection, approved by the United Nations Children's Fund (UNICEF), (10). The priority of this technique is to avoid the generation of disinfection by-products (DBPs) that poses serious hazards on the environment and human health (11). In this respect, several advantages of SODIS including ready availability without expensive cost, especially in remote and low-income areas, safety and being environmental friendly, and being independent of electrical, chemical and industrial equipment are noteworthy (1). It is also considered as the promising procedure and several aspects of this process have been investigated by several researchers during the last 30 years (3). Although, SODIS has a number of advantages; but it suffers from several drawbacks including the relatively long disinfection time (from 6 h to two days), and is influenced by the sunlight dose and water turbidity (12, 13).
Moreover, several attempts have been carried out to reduce the limitations and to accelerate the bacterial disinfection by solar photocatalytical disinfection (SPCDIS) process associated with the use of catalysts and is considered as an advanced method (14).
Homogenous and heterogeneous alternatives of catalysts have been used, in which TiO_2 and H_2O_2 have comprehensive applications (15). Although, combination of SODIS with these catalysts addresses the photochemical reaction potential by liberating hydroxyl radicals besides reactive oxygen species such as superoxide radicals $O_2^{\cdot}$ and enhanced SODIS microbial inactivation process, but inner filtration effects in photo-catalysis, separation of slurry catalysts for the provision of safe drinking water at household scale is not feasible (16, 17). Several investigations have solved this problem by coating of catalysts onto the surface of reactors that requires advanced material technology (18). Accordingly, the use of soluble homogeneous catalytical systems appears to be a good alternative.
Potassium persulfate (KPS) availability, with a low cost less than other oxidants, as well as safe handling and its high solubility makes it an excellent oxidant for pollutants purification. Although, applications of this compound lead to product of SO_4^{-2} and increase of total dissolved solids in water body, but this compound is an efficient disinfectant/oxidant, which has been employed for chemical destruction of wide variety of organic contaminants present in aqueous solutions. Redox potential of the main component of KPS [persulfate ion ($S_2O_8^{-2}$)] is 2.05v which implies that this ion is strong oxidant, however, activation of this ion via thermal and UV spectrum leads to the generation of the stronger sulfate radicals ($SO_4^{-\circ}$) with redox potential of 2.6 v that is accompanied with OH° radicals, leading to degradation of contaminants (19). Since disinfection and oxidation is a relevant process, it can be suggested that enhancement of oxidation status can lead to effective microbial water disinfection.
The aim of this study was to develop a cheap and robust water disinfection technique for remote and low-income locations of developing countries with poor access to safe drinking water. Accordingly, the efficacy of homogenous catalytical SODIS associated with KPS at an acceptable level from point of its by-products (SO_4^{-2}, and TDS)

and influence of water turbidity, exposure time, bacterial density and KPS dosage, by use of *E. coli* suspended in water model was investigated.

Materials and Methods

Chemicals, Reagents and Instruments

This study was carried out in city of Tehran (Longitude 51° 2' to 51° 36' E and Latitude 35° 34' to 35° 50' N, Sea level 1110 m). The experiments were performed on the roof of a building, adjusted to the UV monitoring instruments and laboratories for bacterial testing, and also the interferences of reflection or shadows casted by the surrounding building was at the minimum level. Intensity of UV light was determined by UVA light meter (UV LIGHT METER UVA-UVB 290 nm-390 nm- Lutron Taiwan). KPS was purchased from Merck Company and used without further purification in 0.1, 0.7, 1.5 and 2 mMol/l and its characteristics are shown in Table 1 and Fig.1. Based on measured UV fluence rate, the water samples were exposed with solar irradiation from 10 a.m. to 16 p.m. (6 h) of local time. Variation of total dissolved solids and sulfate anion concentrations, which is related to KPS addition, was determined by gravimetric and spectrophotometric standard methods (20).

All experiments were conducted in food grade low-density polyethylene containers of 1.5 L volume (Damavand IR.) The container thickness was 45µm in which the *E. coli* spiking and sampling for bacterial culture was performed by screw top plastic with 40 mm diameter.

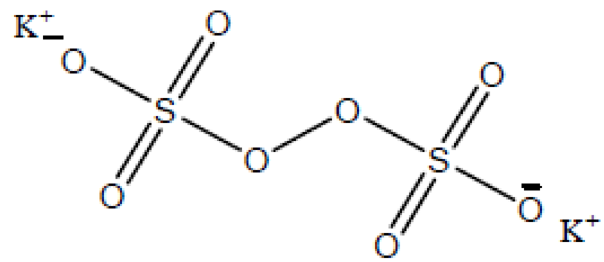

Fig.1: Structural formula of potassium persulfate

Table 1: Physical and chemical properties of potassium persulfate (21)

Property	**Value**
Physical state	Solid
Melting point	Decomposes @ ca. 100 °C
Relative density	2.48 g/cm3 @ 20 °C
Water solubility	60 g/l @ 25 °C
pH	5-8 for 1% solution
Oxidizing properties	Oxidizer

The experiments were carried out on the sunny and non-cloudy days, corresponding to a calendar date from 15 of July to 15 of august, 2012. The SODIS reactor configuration is shown in Fig. 2.

Fig. 2: SODIS reactor configuration

E. coli growth and working suspension

E. coli (ATCC 25922) was selected as an indicator of faecal contamination and was purchased from Reference Laboratory of Ministry of Health and Medical Education of Iran. The stock and lyophilized form of bacteria was suspended by addition of sterile blood broth as the growth medium. This stock suspension was stored at 4°C (within one week). A distinct colony of *E. coli* was prepared by the inoculation in nutrient agar medium and incubation in 37°C for 24 h. Desired bacterial density was prepared by spiking of colonies in BHI broth (Incubated-shaked in 37 °C for 24±2 h). The suspension was centrifuged in 3000 rpm for 10 min and washed with physiological serum (0.01%). The turbidity of bacterial suspension in serum was determined with spectrophotometer (Cecil-1011) in 625 nm wavelength (22). Based on light absorbance the bacterial density of this suspension was 0.5 Mac Farland (1.5×10^8 cell/ml) which is the desired bacterial density in water (1000 and 1500 cell/ml) prepared by spiking of 6.6 and 10 µl of bacterial suspension onto Damavand LPET bottled water. The detection and viability of non-injured bacterial cells was performed by plating samples onto nutrient agar (Merck). The sterile culture media were poured in plates and stored at 4 °C (no more than 48 h). Serial dilutions of samples were inserted on the plate agar media, followed by incubation for 24±4 h at 37°C and counting of visually identified colonies (5).

Preparation of Turbid Water Samples

Turbid water samples were prepared by addition of disinfected soil on oven (120°C for 2 h) and sterilized slurry (15 min, 121 °C and 1.5 bars). The slurry was shaken for 15 min and then stored for settling for 30 min. The supernatant containing fine component were centrifuged and desired water turbidity (30, 50, 100, 200, 300 NTU) measured with a calibrated turbiditimeter (DRT-15CE) was adjusted by addition of appropriate volume of the slurry.

Results

Effect of KPS on water quality

TDS and SO_4^{-2} are the critical components of water which affect the drinking water acceptability. Furthermore, these components have corrosion effects on plumbing and water distribution systems. Since spiking of KPS may lead to water quality depletion, determination of the chemical water quality from point of TDS and SO_4^{-2} concentrations as KPS by-products is necessary. The characteristics of water used in experiments before and after KPS spiking are shown in Tables 2 and 3. As shown in Table 2, although spiking of KPS in water led to the elevation of TDS and SO_4^{-2} concentrations with a significant variation in treated water, the concentrations of these components were at acceptable levels. So, spiking of KPS was not lead to water quality depletion from point of TDS and $SO4^{-2}$ concentration.

Table 2: Chemical components of water used in experiments

Ca^{++}	**78.5 mg/l**	**$SO4^{-2}$**	**20 mg/l**
Mg^{++}	18.7 mg/l	NO3(N)	1.8 mg/l
Na^{+}	6.2 mg/l	SiO2	13.2 mg/l
K^{+}	0.8 mg/l	F	0.2 mg/l
$HCO3^{-}$	280 mg/l	pH	7.2
Turbidity	1-2 NTU	Temperature	18 °C

Table 3: SO_4^{-2} and total dissolved solids in KPS spiked water

Samples **Constituents**	**Non KPS spiked water**	**0.1 mMol/l KPS**	**0.7 mMol/l KPS**	**1.5 mMol/l KPS**	**2 mMol/l KPS**
TDS	200	200	375	450	600
SO4-2	20	39.17	154	307	403

UV intensity

Figure 3 illustrates the variation of UV fluency rate for the non-cloudy days, corresponding to a calendar date from 15 of July to 15 of august, 2012. The results revealed that the intensity of UV irradiation increased from 7.30 a.m. to 13.30 p.m.; with the highest intensity recorded on 13.30 p.m. as 5265 μW/Cm^2, and later the fluency of UV rate decreased until 16 p.m. as 3650 μW/Cm^2, corresponding to the end point of the experiments. This finding shows that Tehran has an appropriate status for use of SODIS process associated with the technique of KPS for water disinfection and the enhanced active radical formation procedures by solar irradiation which can be applied as innovative techniques for the safe water preservation.

As shown in Fig. 3, based on Tehran local time and UV fluency and the calendar time rate from July to august, it can be concluded that the local time of 10 a.m. to 16 p.m. (6 h exposure) is the best time for application of SODIS with UV irradiation for water disinfection. Based on these results, it can be claimed that Iran's geographical latitude (25° 3' to 35° 47' N and 44° 5' to 63° 18' S) provided the appropriate status for development and application of SODIS technique as a simple method for safe water provision, especially in remote and low income areas.

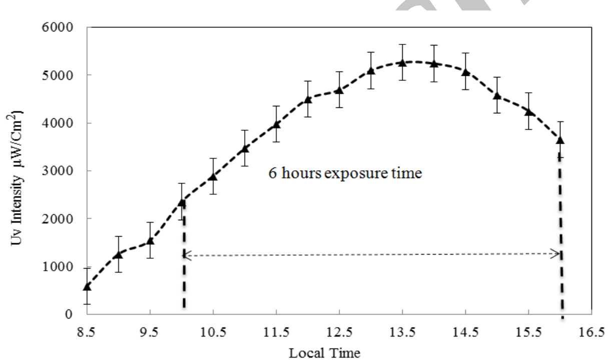

Fig. 3: Graphic presentation of UVA-B irradiation registered during the experiments

Effect of Bacteria density and KPS dosage

Figure 4 shows the effect of bacterial density on *E. coli* inactivation with SODIS without KPS.

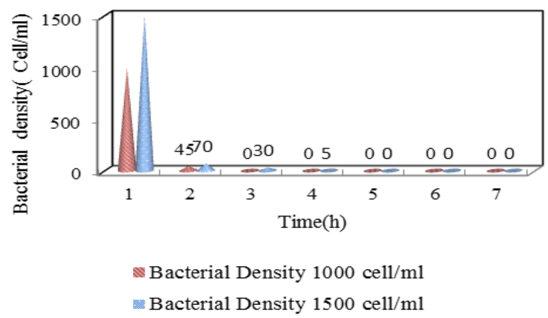

Fig. 4: Effect of bacterial density on disinfection time without KPS

It illustrates the decreased rate of bacteria with SODIS and reveals that the increase of bacterial density could lead to increase of disinfection time. Thus, at 1000 cell/ml and 1500 cell/ml, complete disinfection was achieved after 2 h and 4 h, respectively. Several earlier researches reported that 6 h was required for water disinfection by SODIS which implies that the result of this research differs from the earlier reports presented by others. This is an additional support in favor of our finding that Iran has an appropriate geographical location for SODIS application for water disinfection. Figure 5 illustrates the effects of KPS dosage as a catalyst for bacteria disinfection time. The data implies that increase of KPS dosage leads to decrease in disinfection time. As demonstrated in Fig. 5, increase of KPS concentration up to 0.7 mMol/l did not have enhancing effects on disinfection time in 1000 cell/ml of bacteria density.

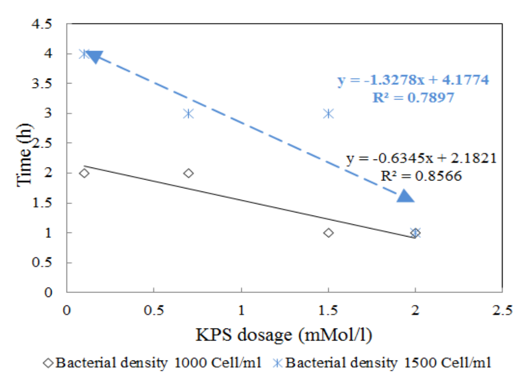

Fig.5: Disinfection time v/s KPS dosage

Moreover, higher point and the increasing of KPS concentration to 1.5 and 2 mMol/l led to the decrease of disinfection time from 2 h to 1 h. Hence, the doses of 1.5 and 2 mMol/l showed the same results. At bacterial density of 1500 cell/ml, increase of KPS from 0.1 mMol/l to 0.7 mMol/l decreased disinfection time from 4 h to 3 h. Notice that the doses of 0.7 and 1.5 mMol/l showed the same result, then excessive addition (2 mMol/l) led to the decrease of disinfection time up to 1 h. Based on this experimental study, it may be concluded that for 1000 and 1500 cell/ml, 1.5 and 2 mMol/l of KPS respectively is suitable for the concentration of attributed radicals (OH^{o} and $SO^{0}_{4}{}^{-}$) that are generated by photo-thermal splitting of $K_2S_2O_8$ and is sufficient for disinfection process and accelerates the *E. coli* disinfection.

Additionally, Fig. 5 shows the effect of bacteria density and implies that the increase of bacterial density from 1000 cell/ml to 1500 cell /ml led to elevation of disinfection time from 2 h to 4 and 3 h for 0.1 and 0.7 mMol/l of KPS, respectively. In 1.5 mMol/l of KPS dosage, disinfection time increased from 1 h to 3 h, upon bacterial density increase from 1000 to 1500cell/ml.

The effect of turbidity

Turbidity is one of the main parameters, which can affect water disinfection processes performance including chlorination, UV and SODIS. Table 4 and 5 demonstrate the simultaneous effects of turbidity and bacterial density on SODIS alone and SODIS combined with KPS, respectively.

Table 4: Effect of turbidity and bacterial density (SODIS without KPS and 4 h contact time)

Bac. Den. (CFU/ml)	UV Intensity(μW/Cm²)	Turbidity (NTU)				
		30	50	100	150	200
1000	3198±713.7	0	0	0	0	5±7.07
1500	3198±713.7	0	0	0	0	5±7.07

Table 5: Effect of turbidity and bacterial density (SODIS with 2 mMol/l KPS and 2 h contact time)

Bac. Den. (CFU/ml)	UV Intensity(μW/Cm²)	Turbidity (NTU)				
		30	50	100	150	200
1000	3198±713.7	0	0	0	0	5±7.07
1500	3198±713.7	0	0	0	10	15±7.07

As shown in Table 4, SODIS alone can overcome 150 NTU water turbidity with 4 h contact time and 1000 and 1500 cell/ml bacterial density without KPS and can provide safe drinking water. However, beyond this range of turbidity, this process cannot completely disinfect *E.coli;* so, based on WHO recommendation the bacterial quality of water and its safety was depleted from safe rank to low risk rank. Table 5 implied that SODIS with 2mMol/l KPS disinfected 1000 cell/ml and 1500 cell/ml, turbidity 150 and 100 NTU in 2 h, respectively; however, beyond these ranges of turbidity, the processes cannot completely disinfect *E. coli*. As shown in 1000 cell/ml, increasing of turbidity over than 150 NTU led to decrease of water safety from safe rank to low risk rank, hence, in 1500 cell/ml this elevation led to medium risk rank. In 2 mMol/l KPS and 1000 and 1500 cell/ml, the 2 h contact time was sufficient enough up to 150 and 100 NTU, respectively; however, complete disinfection was not achieved at higher turbidity.

Discussion

Diarrhea and its relevant deaths is one of the most legitimated health concerns which can be prevented by safe drinking water supply, including quality, quantity, treatment and safe storage of household water, and promotion of community-wide sanitation systems. Although, water treatment methods, including boiling, chlorination, filtration and etc., are being used widely in the world, but microbiological quality of drinking water poses several health risks and drinking water replication needs to be better understood by using of simple water sanitation in household scales. Although, several trials have revealed that use of the SODIS technique to treat drinking water may lead to a significant improvement in drinking water quality and diarrheal disease risks, but this technique has suffered from some drawbacks which requires further technical enhancements (4). A present, application of catalytically agents with SODIS is considered important in which homogenous catalysts are very attractive. Although, several catalysts including lemon and vinegar have been associated with SODIS, but they have some drawbacks such as taste and odor problems and activity on acidic pH (~3) which is a requirement for water stabilization (23). So, application of compound with low side effects on human health and water quality is of importance.

KPS is one of these homogenous catalysts which has oxidation potential and can be associated with SODIS for water disinfection but, its application may arise some drawbacks from point of its toxicity and water quality. The toxic kinetics studies show that the LC_{50} of the KPS is 1130mg/kg body weight in rats, implying that this material is safe from the systemic poisoning standpoint (21). Therefore, it can be used as a catalyst with SODIS for water disinfection. Due to high solubility (60 g/l at 25°C), the dissociation and dissolution of KPS onto aqueous solution leads to the generation of active radicals and increase of $SO4^{-2}$ as the final product in water as summarized in the following equations (19, 24):

$$S_2O_8^{2-} + hv \rightarrow 2SO_4^{\circ} \qquad [1]$$

$$SO_4^{\circ -} + H_2O \rightarrow SO_4^{2-} + OH^{\circ} + H^+ \qquad [2]$$

$$SO_4^{\circ -} + OH^- \rightarrow SO_4^{2-} + OH^{\circ} \qquad [3]$$

$$S_2O_8^{2-} + H^+ \rightarrow HS_2O_8^- \qquad [4]$$

$$HS_2O_8^- \rightarrow SO_4^{\circ -} + SO_4^{2-} + H^+ \qquad [5]$$

It can be concluded that the KPS associated solar photodisinfection of water has no drawbacks from the point of the TDS and $SO4^{-2}$ concentration elevation, and on the other hand, due to the dissociation of KPS into $SO4^{-2}$ and $2K^+$, spiking of this oxidizer material for enhancement and catalyzing of *E. coli* disinfection has no meaningful drawback, especially for its application in the remote areas, emergency situations and short time applications.

Although, the KPS is inherently an oxidizer compound, but its addition in the aqueous solutions leads to the production of high potential radicals (sulfate and hydroxyl) leading to the degradation and removal of several contaminants, especially the organic pollutants from aqueous solutions. Since the dominant components of bacterial cell wall are organic in nature, the radicals attack to these compounds and lead to the perturbation of bacterial cell wall function by the oxidation and bacterial injuries.

Review of disinfection process and disinfectants characteristics shows that all of these agents are inherently oxidizers and oxidation is the predominant phenomenon in water disinfection. So, application of the KPS associated with solar UV radiation enhances the production of $SO4^{\circ}$ and OH° oxidants and can be elaborated based on the above-mentioned reactions. Although, previous studies reported that TiO_2 can be used as an appropriate catalyst for SODIS performance acceleration, but comparison of the generated radicals potential revealed that KPS can be more effective than TiO_2. Therefore, irradiation of TiO_2 with solar UV leads to production of OH^0, but KPS irradiation produces simultaneous highly effective radicals (sulfate and hydroxyl). Additionally, TiO_2 is a heterogeneous catalyst that needs stabilization on an appropriate surface and requires high performance separation system (5). Saien and et al. compared the efficacy of KPS and H_2O_2 and reported that the first agent has a better performance. The higher efficacy of KPS may be relevant to species and oxidation potential of generated radical (19).

UV intensity is another factor that should be considered in SODIS process. Although, the effect of geographic factors such as latitude, altitude, and solar elevation on disinfection potential has not been systematically documented, but the microbicidal properties of natural sunlight are well documented, (25) and several studies show that in areas, where the latitudes are between 15 to 35 N/S and areas which are located between equator and 15 N/S are the most favorable regions for SODIS that usually have more than 3000 and 2500 hours sunshine annually, respectively and have the best potential for using the natural sunlight for various goals such as SODIS (26).

Majority of the developing countries are located between latitudes 35°N and 35°S. Therefore, the population living in these countries has an opportunity to use solar radiation as an energy source for solar disinfection of drinking water naturally (27).

The highest value for UV irradiation in latitude 37° 5' 54" N was 38.4 w/cm^2, considered higher than the higher irradiation (5265 $\mu w/cm^2$) which was recorded in this study (4). Since the latitude is one of the most effective factors in UV irradiation, the differences of UV fluency of these studies can be attributed to the differences of latitudes of the experimental areas as an effective factor (4). Although, in the present study the recorded UV radiation is lower than the previous studies but, experimental trials revealed that these range of UV irradiation is sufficient for SODIS application. Based on these geographical conditions, it can be concluded that the different cities in Iran have the suitable potential for use of natural solar irradiation for safe water preservation which can be applied in remote areas from the point of view of the control of the water- borne diseases and health promotion.

As discussed in earlier studies, the dosage of catalysts such as TiO_2 and H_2O_2 affects the overall photo-catalysis reactions efficacy (5). Hence, experimental analysis of the effect of oxidant/catalysts concentration is essential to enhance the efficiency of the catalytical/oxidation systems and to make the process cost effective. Moreover, increasing of catalyst dosage over the required mass can lead to disruptive effects via radical scavenger process (28). It is generally assumed that increase of catalyst may lead to increase of reaction rate; however, optimization of catalyst concentration should be considered from the point of economic and operational drawbacks such as inner filtration effects of suspended catalysts (19). The results of this research revealed that the increase of KPS dosage is effective in certain range and increase of its concentration beyond specific range can lead to several drawbacks such as increase of SO_4 and TDS concentration and interferences in photo-catalysis reaction by the scavenging effects of OH^o and $SO4^{o-}$, in which excessive amount of $S_2O_8^{-2}$ reacts with $SO4^{o-}$ and forms $SO4^{-2}$. Similar results were reported for chemical contaminants degradation in which increase of KPS dosage from 0.14 g/l to 0.81 g/l led to the increase of COD removal efficiency from 54% to 68.6%. Consequently, further increase of $K_2S_2O_8$ to 1.62 g/l did not have significant effect (28). Similar result was reported for Triton X-100 degradation by UV/TiO2/KPS system (19). Although the present study did not imply the disruptive effects of excessive amount of KPS on bacterial disinfection, but optimizing of catalyst dosage is necessary from points of economic, operation aspects and treated water quality assurance.

Although, several interventional-epidemiological studies had proven effectiveness of SODIS for water-borne diseases and related incidences of diarrhea, especially in tropical areas in developing countries, nevertheless this technique suffers from several drawbacks, such as water turbidity and is limited to low turbid waters(<30NTU) (27, 29). Dunlop et al. studied *E. coli* water disinfection with TiO_2 associated SODIS and reported that increasing of water turbidity up to 50 NTU led to increasing of required exposure time for complete disinfection (5). This result implied that KPS performance is better than TiO_2 as a catalyst for SODIS efficacy enhancement. So, KPS associated SODIS can overcome up to 100 and 150 NTU for 1500 and 1000 cell/ml with 2 h contact time. This

phenomenon may attribute to limitations through a combination of reduced.
light intensity, induced turbidity and inner filtration effects of TiO_2 powder and limited dissolved oxygen in sealed systems; so, increasing of TiO_2 up to 0.5 g/l led to elevation of water turbidity (over than 1000 NTU) which was not occurred for KPS associated SODIS (5).
Performance and types of the generated free radicals and their oxidation-reduction potential have important role. Hence, in TiO_2 associated SODIS, OH^0 is the predominant generated radical but, in KPS associated system SO_4^0 and OH^0 radicals are simultaneously generated in which $SO4^0$ has a higher potential than OH^0 (19).
Since water turbidity causes limitation for the *E. coli* disinfection beyond 150 NTU, it can be concluded that turbidity may affect the efficiency of the process by inner filtration, in which the UV light penetration is limited and bacterial inactivation is caused by pasteurization and it requires the temperature of at least 50 °C, which is not provided in many countries. Therefore, there is a need for crucial requirement for the reduction of turbidity effects by low-cost and practical methods, such as association of SODIS with KPS, which would allow faster water disinfection and may appreciably increase the number of people who can use SODIS as a means of point-of- use technique for a safer water use and health promotion. Although, further investigations is needed for declaring coagulation potential and turbidity decreasing effects of KPS, but it can be claimed that KPS has K^+ in its structure which can affect water turbidity and enhance water disinfection by limitation of inner filtration effects which are attributable for heterogeneous catalysts. Although, the addition of NaCl can lead to decrease of water turbidity and enhance the SODIS performance, but this technique may suffer from several drawbacks from point of economic and water quality depletion due to the increase of water salinity (30).

Conclusion

Association of SODIS by KPS can be used as an innovative technique in which disinfection time was approximately 50% less, when SODIS was used alone. Simultaneous use of SODIS with KPS has an enhancing effect on SODIS efficiency that can appreciably increase the number of people who can use it as a ready and simple point-of-use technique for access to the safe water.

Ethical considerations

All of ethical issues including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc. have been completely observed by the authors.

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