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Original Articles

Evaluating of the Disinfection and Water Quality Effects on UV Application in the Primary Stage of Water Treatment

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Abstract

Background: Irradiation of water by UV has been considered as an attractive alternative for disinfection because its low-impact, pathogen killing capacity shows tremendous promise for meeting today's drinking water regulatory requirements. This study has been performed with the objective of utilizing medium pressure lamp in the preliminary stage of municipal water treatment, namely prior to water clarification and filtration.

Methods: Raw water samples were irradiated for 30 s in a lab-scale closed reactor. Disinfection results showed nearly 2 log reduction in HPC for all the samples without formation of nitrite in excess of its MCL. As in a few previous works the formation of nitrite as an objectionable DBP had been reported, this study was extended by preparing synthetic water samples having different amounts of nitrate and turbidities.

Results: As far as the initial nitrate concentration dose not exceed 10 mg/L N-NO3, there would be no risk of nitrite increasing in excess of the MCL.

Conclusion: Meeting the goal of at least 90 % disinfection for water samples with turbidity levels of as high as 750 NTU is possible by utilizing medium- pressure UV lamp.

Keywords: *Disinfection, Drinking, Water, Pressure, Nitrites*

Introduction

In the face of ever-increasing new regulations and standards for potable water, lots of managers of water treatment plants are moving towards new treatment processes (1). In Europe, most countries do not want to deal with chemicals and look at the use of ultraviolet (UV) to tackle pathogens in the drinking water supply and combining the technology as part of a multi-barrier approach (2, 3). The same trend also is considered in US and Canada (4, 5) and the world's largest potable water treatment plant in N.Y. city will use the largest UV disinfecting unit ever built for unfiltered water. This 2 bgd plant is scheduled to be completed in 2009 (6). Like US, China is also turning increasingly to UV light as a mean of water and wastewater disinfection (7). In contrast to chlorine which is ineffective to tackle pathogenic protozoa such as *Cryptosporidium* and *Giardia* in the permissible doses, recent data show that both pathogens are very easily inactivated by UV light, even with much lower UV dose rates than typically used for bacteria inactivation (8). As a consequence, the USEPA has classified UV disinfection as a "critical com-pliance technology" in the treatment of drinking water to protect the public against all important pathogens. In fact , the use of UV is becoming more common as surface water treatment plants are upgraded to comply with new rules of stage 2D/DBPs (disinfectant/ disinfection-by-products) and LT2ESWT (long term enhanced surface water treatment) (9, 10). But by use of conventional UV lamps (low-

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pressure), acceptable results are obtained only when turbidity of water is insignificant. Just in the last decade, the second generation lamps namely medium pressure (MP) has emerged. The germicidal light produced by this lamp type is polychromatic from 200 to 320 nm and it is claimed that this is the only technology that can face the problem of disinfection when the turbidity of water is high (11). Thus, MP lamp is now the type favored for use in a number of countries (12, 5).

D/DBPs rule also has established limits for ozonation because this practice can lead to the formation of undesirable compounds such as bromate and formaldehyde. Thus, preozonation is not recommended for all water sources (1). Whereas, UV disinfection performance even by LP lamps is predicted to be successful for water with transmittance value of more than 65% (10).

This study has been performed with the objective of utilizing this new lamp in the preliminary stage of water treatment. This stage has been considered to be very substantial for providing safe desirable water, but to date, no research about using UV at this stage has been recorded or considered .However, such researches are expected to accomplish and take effect until the end of this decade for meeting the requirements of the mentioned new rules.

Materials and Methods

UV Equipment The UV system source was a medium pressure mercury lamp. The lamp's characteristics are presented in Table1. In contrast to the low- pressure lamps which can be precisely monitored with a calibrated photodetctor, the irradiance of the MP lamps cannot easily determined by similar available apparatus. This being the case, the data was confined to the determination made by the lamp manufacturer which was reported to be 90 μW/cm2 UV irradiance in 1 meter distance from the new lamp. For running the experiments by this lamp, a lab-scale UV submerged system was arranged with 3 liters effective volume and 10 cm ID. This single- lamp reactor was adjusted to operate at the flows of 18 and 6 L/min in the equivalent contact times of 10 and 30 s. Fig. 1 shows the used UV reactor. The MP lamp was enclosed within a quartz jacket in order to prevent the direct contact of lamp with water. As shown in Fig. 2 this jacket is quite transparent for wavelengths more than 250 nanometer.

Water samples Two types of water were examined: natural surface samples from the entrances of Tehran Water Treatment Plants No.3 as well as No.4 and synthetic ones prepared by addition of insoluble solids, nitrate and microbic pollutants to Tehran tap water. Sampling of raw water (totally 12) was performed in the spring and summer of 2004, and preparing synthetic samples with turbidity range of 1-750 NTU had been done by adding definite mixtures of clay and soil from Jajrood river banks. Besides, nitrate concentrations were brought about in the desired range by adding sodium nitrate (Na NO3).

Disinfection tests Comparison of disinfection results of various water samples at different conditions has been performed by determination of heterotrophic plate count (HPC) before and after irradiation by MP lamp. HPC in an accepted indicator for total heterotrophic bacteria for drinking water and the test has been done according to the procedure described in Standard Method (13). Results of the test which has been performed by plate count agar in 35 °C and 48 h incubation time are reported as CFU/ mL. For this study, HPC values of synthetic water samples had been adjusted to be in the range of 650-2500 cfu/mL. For natural samples the maximum and minimum valves before irradiation were determined to be 850 and 75 cfu/ml.

Nitrate and nitrite determination The classical spectrophotometric methods for NO3 and NO2 determination are well known and widely used. Methods of analyses as described in Standard Methods are based on UV spec-trophotometry (in 220 nm) for NO3 and Griess diazotization for nitrite (visual spectrophotometry, in 543 nm). Concentrations of nitrate in synthetic water samples had been adjusted in the range of 1.5 to 31 mg/L N/NO3.

Table 1: The UV lamp specifications*

Lamp Type	L (mm)	D (mm)	Arc Length (mm)	Voltage (V)	Current (Amp)	Life time (h)
MP MV 400	125.5	20	72	130 + 15	3.25	10000

*Technical information report from the lamp manufacturer (Arda Inc. France – 1995).

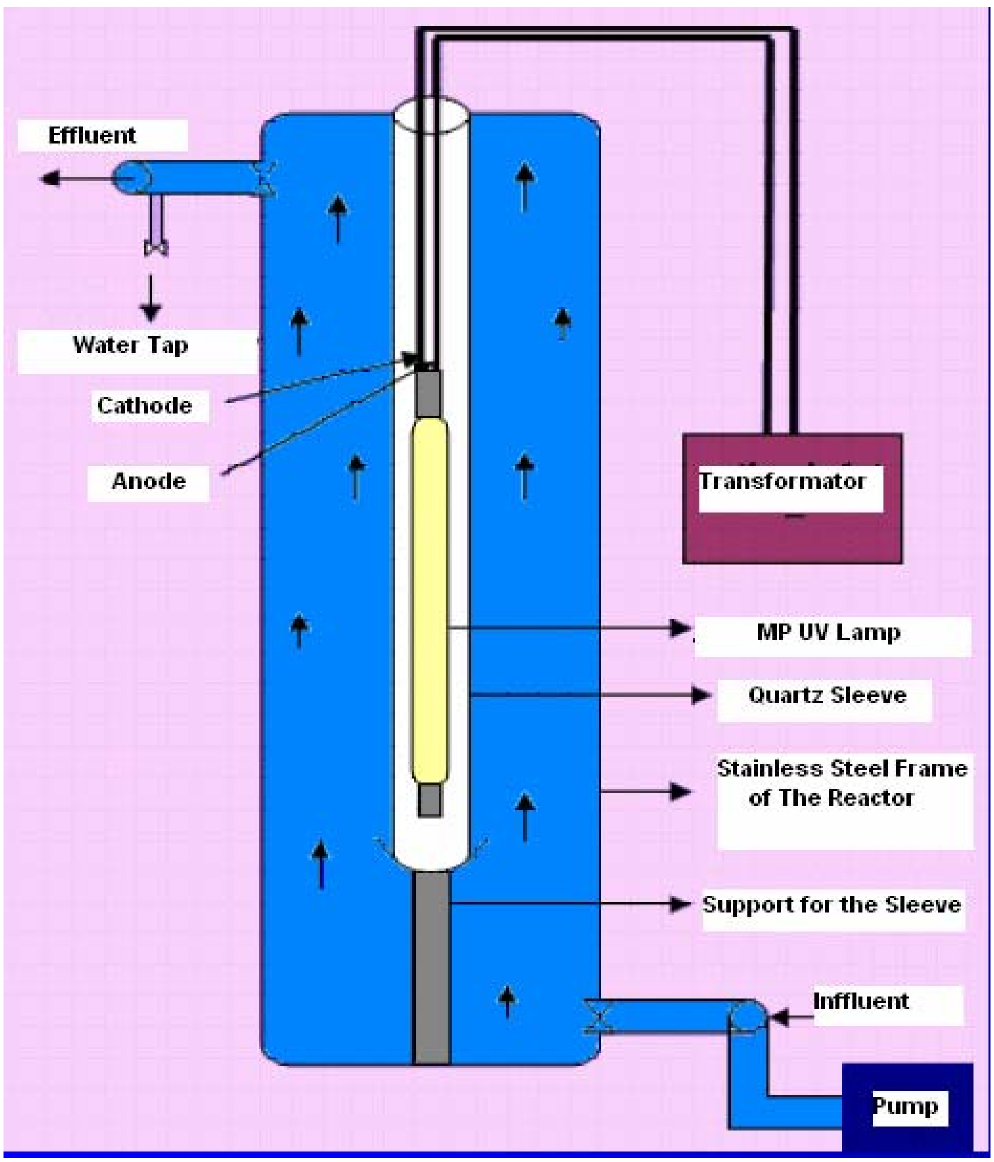

Fig. 1: Medium pressure UV reactor for water disinfection

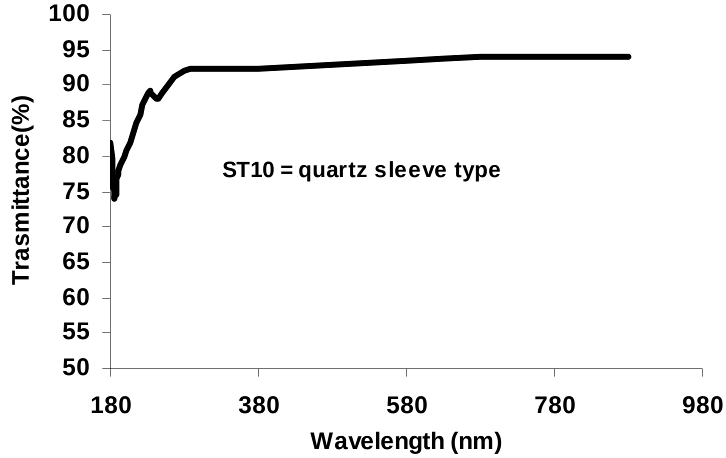

Fig. 2: Characteristics of the quartz sleeve

Results

For determining the effects of water turbidity and nitrate as the major pollutants of raw water on the disinfection process, two series of experiments were performed by irradiation of synthetic water samples having specified concentrations of HPC and different amounts of the mentioned pollutants. Results of these experiments are shown in Fig. 3 and 4. In the second phase of the study, water samples from the entrances of Tehran water treatment plants had irradiated in the UV- reactor for 30 s. Results obtained for disinfection of natural water samples can be considered in Fig. 5 and 6.

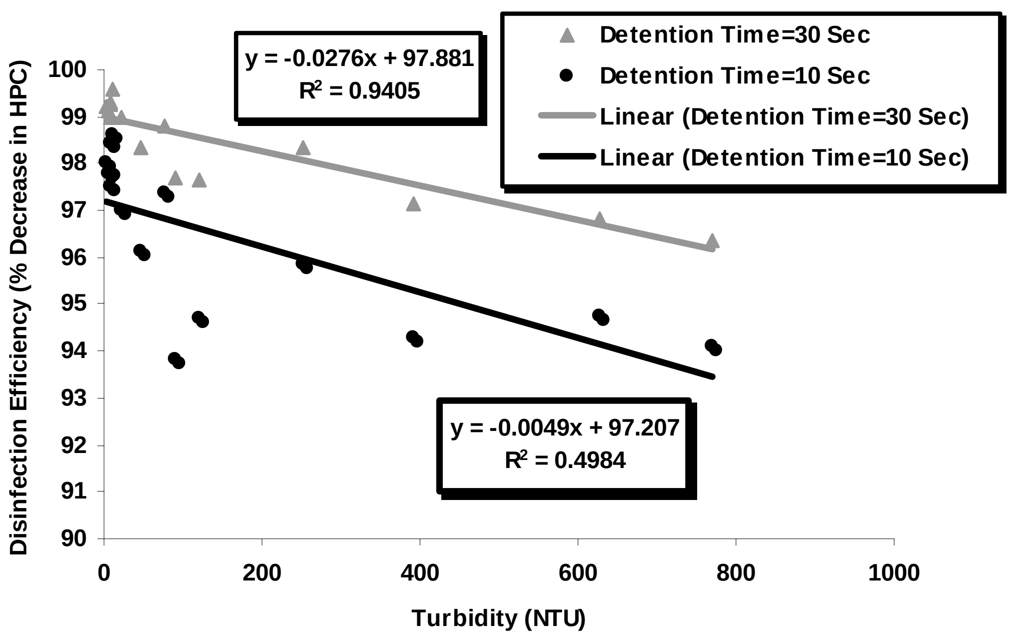

Fig. 3: Comparison of results in two contact times of 10 and 30 seconds for disinfection of synthetic water samples

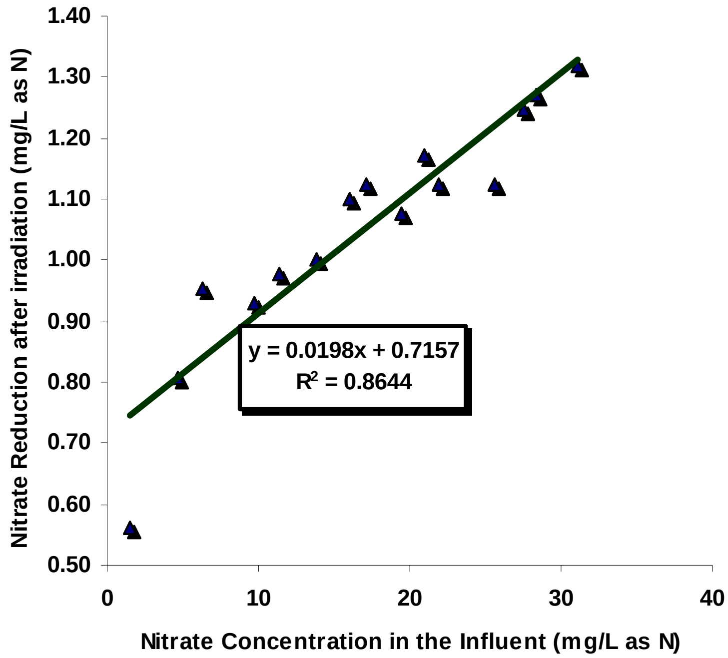

Fig. 4: Nitrate reduction values vs. initial nitrate concentrations for synthetic water samples (30 seconds contact tim)

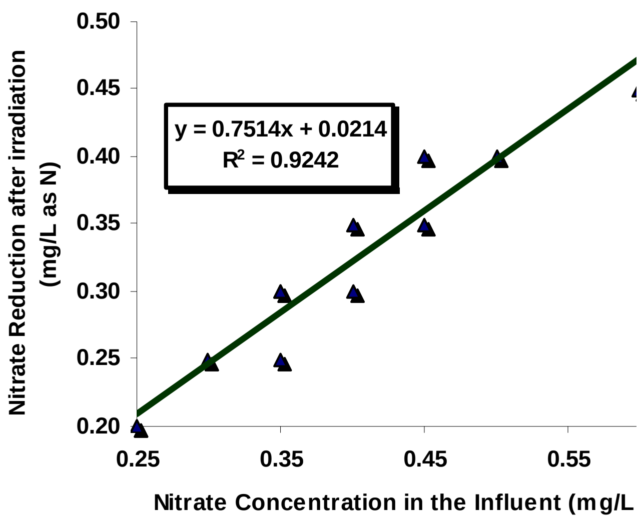

Fig. 5: nitrate reduction values vs. initial nitrate concentrations for natural water samples (30 seconds Contact Time)

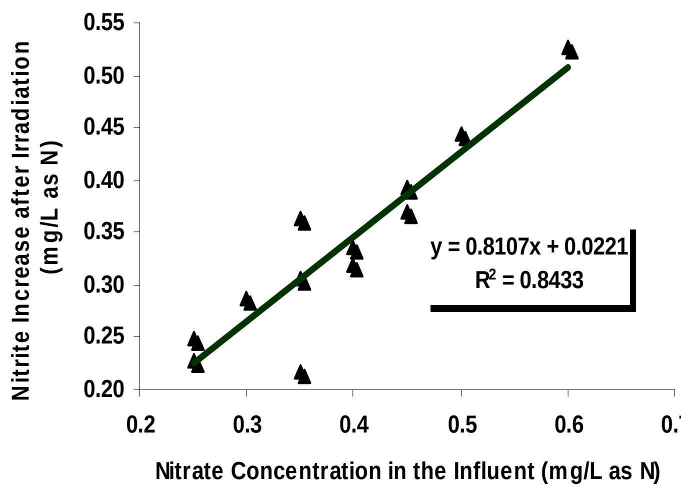

Fig. 6: Relationship between initial nitrate concentrations and produced nitrites after irradiation of natural water samples (30 Seconds Contact Time)

Discussion

The performance of a UV system can be affected by turbidity and some dissolved solids such as hardness and nitrate. As such, bench- scale and pilot testing will help to ensure that disinfection with UV is adequate and determine site- specific needs based on the characteristics of the specific water to be treated. Water that absorbs a significant amount of UV light (i.e. high UV absorbance or low percent transmittance) will need a longer lamp exposure time to achieve the same level of disinfection as water with lower UV absorbance. Accordingly, it is an accepted fact that application of UV lamps after the unit processes that reduce the mentioned pollutants is important. This is the reason why all the reported works were about UV systems with this traditional configuration.

To achieve an efficient disinfection in the preliminary stage of surface water treatment the disinfectant used should be strong enough to tackle pathogens under the worst-case conditions. Most chemicals such as chlorine can do the proper disinfection only at high concentrations but this is not advisable because the chemical quality of water will degrade. Results of determining the bacteria- killing capacity of UV under the worst-conditions of raw- water quality i.e. at very high turbidity levels (as is described in Fig. 3) reveal that more than one log decrease (>90% kill) in HPC is always achievable at turbidity levels of 750 NTU (the maximum turbidity level tested) or less. Tripling the contact time has not a significant effect and in other words disinfection efficiency may not improve more than about 2% by prolonging the treatment. Fig. 3 which has been drawn for showing disinfection results of natural water samples in-dicates that nearly 2 log decrease ($\simeq$ 99% kill) in HPC is achievable at turbidity levels of less that 25 NTU. This killing is considered sufficient for initial disinfection of surface waters. However, for achieving a better disinfection it is obvious that increasing the number of lamps or decreasing the depth of flowing water over each lamp would be necessary.

The only problem reported by treatment plants using UV is the probable conversion of nitrate to nitrite if the irradiation time is expended. By absorption of UV light, the NO3 ion may be converted to NO2 (11):

$NO3^{-} + h\upsilon = (NO3^{-}) \quad (NO3^{-}) = NO2^{-} + (O)$

NO3 and NO2 are both contaminants but the MCL set for NO2 in drinking water is much less (0.9 mg/L N-NO2 compared to 11 mg/L NNO3) so this conversion may be considered quite critical. Results of 30 s irradiation of 15 synthetic water samples as shown in Fig. 4 have demonstrated that as far as the initial NO3 concentration dose not exceed 10 mg/L N- NO3, no risk of much nitrite increase would be caused because the amount of nitrate converted to nitrite is less than the critical value (0.9 mg/L). As this concentration of NO3 (10 mg/L) is near its MCL (11 mg/L) it can be concluded that UV irradiation of water is a safe action for water samples with permissible amounts of NO3.

Other effective factors are the irradiation time and the type of quartz sleeve. Much of the UV disinfection data are about the utilities that apply UV doses of about 40 mJ/cm2 with contact times as low as 10 s. Perhaps this may not be the same for the preliminary stage of water disinfection which is the subject of this study, but in any case increasing the exposure time to more than 30 s cannot be recommended unless it would be possible to decrease the nitrate concentration of raw water to less than 10 mg/L N- NO3.

As Fig. 2 indicates, the quality of the quartz sleeve used in our study was not ideal as it had transmitted the short UV wavelengths (less than 220 nm) capable of converting NO3 to NO2. Now, some manufacturers have produced quartz systems which are characterized as “non- ozone producing” (14). Sleeves made of the quartz which act as optical filters can also prevent the formation of nitrite in water.

Fig. 5 and 6 which represent the relationships between the initial nitrate concentrations in Tehran raw water with NO3 reduction values and produced nitrites indicate that converting NO3 to NO2 after 30 s irradiation has not created a problem for the quality of final potable water because the NO3 content of raw water was below its MCL during the period of the study.

The data from the studies performed by others (15, 16) provide evidence that as many microorganisms are sensitive to wavelengths other than that is produced by LP lamp, so polychromatic lamps like MP can accomplish a better water disinfection. This is an important reason why we have better disinfection results compared with similar works performed by use of LP lamps.

Our final conclusion is that better quality water can be expected if the primary disinfection may be accomplished by UV irradiation.

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