# UV BASED PROCESS FOR *E.COLI* AND COLIPHAGE IN SECONDARY EFFLUENT FOR WASTEWATER RECLAMATION AND REUSE

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**M. Ab. Wahid[1], I. Kim[2], N. Yamashita[3], H. Tanaka[4] and A. Baki[5]**

*[1]Research Center for Environmental Quality Management, Kyoto University, 1-2 Yumihama, Otsu, Otsu City, Shiga 520-0811, Japan*
*[2]Faculty of Civil Engineering, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia*
*E-mail: [1]ce_marfiah@yahoo.com, [2]jinker123@gmail.com, [3]yamashita@biwa.eqc.kyoto-u.ac.jp, [4]htanaka@biwa.eqc.kyoto-u.ac.jp, [5]aminbaki2@gmail.com*

## *ABSTRACT*

*The persistency and survival of pathogenic contamination related to biological risk has been a public concern when implementing water reclamation and reuse. To secure the public health risk when implementing water reuse, adequate treatment is needed. In this study Ultraviolet (UV), based treatment was studied for the applicability to remove microorganisms from secondary effluent. E.coli, Qβ, T4 and Lambda phages were used as targeted microorganisms during the UV treatment process. The objectives of this study were to investigate the inactivation characteristics of E.coli, Qβ, T4 and Lambda phage to UV treatment process and investigate the effect of combine UV/$H_2O_2$ for E.coli and Qβ phage inactivation. As a result, T4 and Lambda phage from DNA group phage were found more resistant to UV treatment process compared to Qβ phage from FRNA phage group and E.coli from coliform group. Combined process UV/$H_2O_2$ in secondary effluent could increase the inactivation efficiency of E.coli and Qβ. DOC and UV 254 were found strongly affected the disinfection processes. Secondary effluent treated with UV processes was found suitable for wastewater reclamations.*

***Keywords:*** *E.coli; Lambda phage; Qβ; T4; UV; Wastewater*

## 1.0 INTRODUCTION

The concept of converting waste to resource is not a new concept. Waste from wastewater industry has been converted into useful resources [1]. At the source, grey water can be reused for toilet flushing as it is uneconomical to use treated water just to flush toilets [2]. Grey water reuse will reduce the demand for treated water. The reuse of effluent for irrigation purposes has occurred for centuries, and with increasing pressure on potable water supplies, the extent of reuse is increasing [3]. Secondary effluent can also be reused for toilet flushing purposes. Secondary effluent have been used for landscaping and general washing purposes as researchers have found the levels of faecal coliforms are acceptable [4-5]. The utilisation of secondary effluent for reclaimed wastewater also contributes in reducing potential negative impacts of wastewater discharges to receiving waters.

Over the past few years, interest in the existence of pathogens in reclaimed wastewater has rapidly increased with the increased in public awareness on human health and safety. The pathogenic microorganisms in treated wastewater for reclamation purposes pose potential health risks. It was found that apart from faecal coliforms, other pathogens have also been found in effluent, such as *Kliebsela spp.*, *Shigella spp.*, *Enterobacter spp.*, etc. [6]. Therefore, human health risk should be managed related to pathogenic microorganisms contained in the wastewater. In order to reduce biological risk from reclaimed wastewater, a few guidelines were developed.

- California State regulation [7] proposed less than 2 Total Coliform/100ml involved specified multi-steps treatment. Proposed regulation would add $\log_{10}$ microbes reduction levels for bacteria (6-logs) viruses (coliphages) (5-logs) and bacterial spores (*C.perfringens*) as protozoan parasite indicator (4-logs).
- US EPA regulation [8]: Proposed ≤ 200 FC/100ml for less stringent reclaimed water uses and 4-logs reduction of *Cryptosporidium* (22 mJ/cm$^2$), Giardia (22 mJ/cm$^2$) and virus (186 mJ/cm$^2$).
- WHO guidelines [9]: Proposed about 6-7 logs pathogen reduction for unrestricted agricultural uses, 3-4 logs for restricted irrigation and 2-4 logs for drip irrigation purposes.
- Australian Guideline for Water Reuse [10]: This guideline proposed reduction of bacteria (5-logs), virus (6.5-logs), protozoa (5-logs), helminth (5-logs) recommended for Class A+ (dual- reticulation system). Further, reduction of bacteria (8-logs), virus (9.5-logs), protozoa (8-logs), helminth (8-logs) for augmentation of drinking water supplies.
- Malaysian Sewerage Industry Guidelines [11] stipulated that continuous disinfection is required for sewage treatment plants serving more than 20,000 population equivalent (PE) discharging into bathing or recreation waters. For continuous disinfection, Chlorination, UV or Ozone is recommended.

Other sewage treatment plants are to be equipped with dosing tank structure capable of intermittent disinfection facilities and only chlorination is recommended.

The guidelines were developed to ensure the reclaimed water is safe enough and reliable to be used by consumers. In order to attain adequate water quality standard, appropriate treatment is needed. Disinfection process is considered as the last barrier to control pathogenic microorganisms in reclaimed wastewater. However, secondary treatment and chlorination are insufficient to inactivate persistent microorganisms like viruses and protozoa. Therefore, an advanced technology is necessary to consider for achieving high reclaimed water quality.

There are many countries that have even implemented the effluent reuse up to potable water quality. Singapore implemented the production of NEWater (potable quality effluent reuse), initiated in 1998 to supplement Singapore's water resources [12]. United States had implemented the effluent reuse up to potable water quality since 1976 at Water Factory 21, Orange County Water District, Southern California, where high quality water reclaimed from treated used water has been injected into ground water. Similarly, at Upper Occoquan Sewage Authority (UOSA), North Virginia, high quality reclaimed water is discharged into Occuquan Reservoir since 1978 [12]. For both countries, ultrafiltration and reverse osmosis membrane systems were used to treat the secondary effluent and UV was used as the disinfection tool.

UV provides a fast-acting, residual free method of coliform inactivation. UV has been shown to be a potential option for coliform inactivation in stringent wastewater reclamation applications [13]. Previous study by Darby *et al.* [14] had proven that UV disinfection satisfied the requirement for reclaimed wastewater in the State of California at reasonable doses. The advantages of UV treatment include providing microbial inactivation equivalent to chlorine while reducing the formation of known carcinogenic disinfection by-products and the formation of chronic effluent toxicity [15]. The hypothesis was that the addition of $H_2O_2$ to UV process will increase OH radical formation and could increase the inactivation rate of targeted microorganisms. It was also expected that the addition of $H_2O_2$ will reduce the UV dose and thus saving the energy consumption for actual application. UV became an attractive option because of UV effectiveness for inactivation of waterborne pathogens including cysts, oocysts of protozoan and intestinal parasites which are highly resistant to chlorination [16-17].

There are various types of bacteria and viruses in wastewater and it is impossible to analyse all types of these microorganisms. Total coliform, faecal coliform and *E.coli* which have been used as conventional indicators, are insufficient to evaluate the efficacy of the disinfection processes [18]. Studies to find other indicators that may provide a better indication of disinfection performance is important. In some other studies, coliphages were proposed to be used as surrogates to evaluate the efficiency of various water and wastewater treatment processes [20-21]. Evidence suggested that coliphages were more persistent in the environment and had been shown to be good indicators of human enteric viruses in polluted waters [21-22]. Coliphages are often proposed as indicators to identify the origin of faecal pollution [23]. Coliphages are easy to culture compared to actual human viruses and non-pathogenic because they are viruses of *E.coli*. They posses similar structure, morphology, origin, release and tolerance to environmental conditions compared to actual human viruses [19, 24].

In this study, *E.coli* and Qß, T4 and Lambda phage were used as targeted microorganisms. The objective of this study was to evaluate the inactivation characteristics during UV based disinfection processes on secondary effluent for reclaimed wastewater. The effect of secondary effluent constituents have also been investigated by measuring TOC and UV 254 during the inactivation processes.

## 2.0 MATERIAL AND METHODS

### 2.1 Selected Microorganisms

Four microorganisms were selected in this study namely *Escherichia coli* (*E.coli*), Qß phage, Lambda phage and T4 phage. Most of *E.coli* in water environment originates from faeces of human and animals, and their occurrence is, thus, very important in determining the origin of faecal pollution. Typically, *E.coli* account for approximately 11% of the coliforms in human faeces [25].

Qß phage has an icohedral capsid structure and genome consisting of positive-sense linear single-stranded RNA (ss-RNA). Qß phage poses similar size and morphology with enteric viruses and has been used as indicator for water quality assessment and routine monitoring [19, 23, 24]. In this study, Qß phage was selected to represent RNA group viruses in water.

Lambda phage, a virus that infects other bacteria with the ability to transfer genes among them, infects cells of the bacterium *E.coli*, where it can either exist as a quiescent prophage or undergo replication leading to lyses of the host cell and release of new phage particles. T4 phage has a non-segmented genome that contains a single molecule of linear double-stranded DNA (ds-DNA) [26,36]. T4 phage is from the family of *Caudovirales* and sub-family of *Myoviridae*. In nature, T4 phage is non-enveloped double-stranded DNA (ds-DNA). Lambda phage and T4 phage were selected to represent DNA-containing viruses [35].

### 2.2 Preparation of Selected Microorganisms

Qß phage (NBRC20012), Lambda phage (NBRC) and *E.coli* $K12F^+$ (A/λ) (NBRC13965) were obtained from National Institute of Technology and Evaluation Biological Resource Centre of Japan (NBRC). The Department of Urban and Environmental Engineering, Tokyo University provided T4 phage. Qß, T4 and lambda phage cultures were produced by adding the phages stock solution into exponentially growing *E.coli* $K12F^+$ (A/λ) and pure culture growing in the Difco™ LB Broth Lennox at 37ºC.

Suspended phages were collected by centrifugation (10000rpm, 20 min, 4ºC) and filtration through 0.45µm membrane filter (Milipore) to remove the cell lysate and to remove any other bacteria that may present. The stock phages suspensions were diluted 10-fold with phosphate-buffer solution (PBS, pH 7.2) to prepare the working phage suspension, essentially to avoid UV absorption by any proteins carried over from cell culture growth medium. The phage stock solutions were preserved at 4ºC for further experiment.

*E.coli* $K12F^+$ (A/λ) (NBRC13965) stock solutions were cultured in DifcoTM LB Broth Lennox at 37ºC shaking for 4 hours. The stock *E.coli* $K12F^+$ (A/λ) suspensions were diluted 10-fold with phosphate-buffer solution (PBS, pH 7.2) to prepare the working *E.coli* $K12F^+$ (A/λ) suspension. The stock solutions were also used as a host cell for plaque assay of all the phages.

## 2.3 Inactivation Experiment

In these experiments, the temperature of tested water was maintained at 20°C by circulating water into a water jacket outside the reactor using a water circulator. The low-pressure mercury UV lamp was manufactured by Iwasaki Electric Co., Ltd, Japan. Applied UV lamp was stabilised for 5 min before each experiment. In order to simulate the actual condition, a laboratory scale reactor (as shown in Figure 1) was used. Experimental conditions are shown in Table 1.

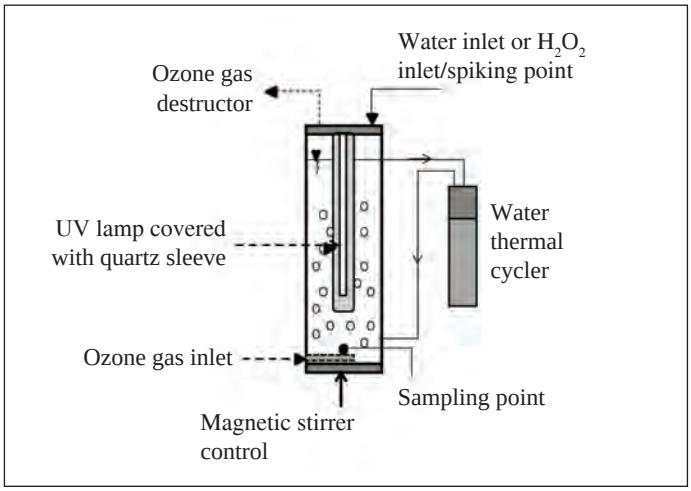


***Figure 1: Schematic Diagram of Lab-Scale UV Reactor***

***Table 1: Experimental Condition***

| | | | | |
|---|---|---|---|---|
| Microorganism | *E.coli*, Lambda , Qβ, T4 | | | |
| Tested water | Secondary effluent | | | |
| Effective volume (L) | 1.7 | | | |
| UV wavelength (nm) | 254 | | | |
| UV intensity(mW/cm$^2$) | | | | |
| Time contact (min) | 0-10 | | | |
| UV dose (mJ/cm$^2$) | 0, 38.4, 76.8, 153.6, 230.4, 384 | | | |
| Process | UV | UV/ $H_2O_2$ | UV/ $H_2O_2$ | UV/ $H_2O_2$ |
| $H_2O_2$ concentration (mg/L) for *E.coli* and Qβ phage | 0 | 2 | 4 | 6 |

## 2.4 UV Dose Measurements

UV is a physical disinfectant and the measurement of UV system performance occurred within the reactor. UV dose (mJ/cm$^2$ or mW-sec/cm$^2$) is expressed by multiplying the UV intensity (typically expressed in mW/cm$^2$) and contact time with the UV source (sec or min). UV intensity was determined from biodosimetry test.

## 2.5 The Inactivation Quantification by UV Based Experiment

The inactivation of targeted microorganisms were calculated by the basic model relationship log (N/No) = -Kt, where No is the coliphages or *E.coli* count at the initial time (time = zero), N is the coliphage count at contact time t, and K is the inactivation rate (slope function). The logarithm of the average inactivation coliphage or *E.coli* ratios were plotted against UV dose (UV intensity x contact time) and was computed as a linear or pseudo-first order kinetic reaction.

## 2.6 Detection Method

The indicator microorganisms were treated with UV and UV/ $H_2O_2$, and then 30 ml of tested water was collected from 0 to 10 minutes contact time. Contact time of 10 min was chosen based on a previous study [27]. It was shown that the most significant microbial reductions typically occur during the first 10-15 min of contact time. The samples were concentrated and purified with membrane filtration procedure [28]. In brief, 1M $MgCl_2.H_2O$ was added to final concentration of 0.05M and 1M HCl was added to final pH of 3.5. Membrane filtration method using cellulose acetate membrane filter with 0.45µm of pore size was adapted to recover the phages. After membrane filtration, phages recovered on the filter were eluted by 3% beef extract with pH 9.0.

The concentrated viruses were diluted 10-fold with Difco™ LB Broth Lennox and assayed in double agar layer with Difco™ Agar and plated out with *E.coli* K12F$^+$ (A/λ) (NBRC13965) as the host cells. All samples were prepared in duplicated petri dishes and incubated invertedly at 37˚C for 18 hours. The clear spot appeared in *E.coli* lawn represented dead cell of *E.coli* and known as plaque. The plaques were counted as Plaque Forming Unit per ml (PFU/ml).

*E.coli* was recovered using membrane filtration with 0.45µm of pore size after 10-fold dilution series [29]. The membrane filter containing filtered *E.coli* was laid on XM Nissui Agar to perform a blue colony after incubation at 37ºC when the *E.coli* enzyme reacted with the agar. The colonies were counted as Colony Forming Unit per ml (CFU/ml). All samples were prepared in duplicated dishes.

Each selected microorganism was spiked separately into the secondary effluent before treatment experiments to the final concentration of $10^6$ PFU/mL.

## 2.7 TOC and $UV_{254}$ Analysis

UV absorbance ($UV_{254}$) was measured by spectrometer (UV-16000, Shimadzu). The absorbance at 254nm ($UV_{254}$) was measured and indicates amount of unsaturated bonds in compounds in tested water. TOC concentration measured with Total organic carbon analyzer (TOC-5000A, Shimadzu). TOC is a measurement of organic compound in tested water.

# 3.0 RESULTS AND DISCUSSIONS

## 3.1 Inactivation Characteristics of Qβ, T4, Lambda phage and *E.coli* with UV Alone Process

The observed inactivation rates are shown in Figure 2. In comparison with coliphage Qβ under the same condition, coliphage T4 and Lambda demonstrated slower inactivation kinetics. *E.coli* was very sensitive to UV and displayed the fastest inactivation rates compared to the others.

The UV doses needed for 1-log to 4-logs inactivation for *E.coli*, coliphage Qβ, T4 and Lambda were calculated for comparison. The doses required for the 1-log and 4-logs inactivation, were calculated based on the regression analysis of each experiment. The doses of 46.9, 44.6, 32.1 and 27.8 mJ/cm$^2$ were needed to inactivate Lambda, T4, Qβ and *E.coli* respectively, by 1-log. The inactivation increased with UV doses. In order to achieve more than 4-logs inactivation, 128.2 mJ/cm$^2$ was needed for Qβ, whereas 178-188 mJ/cm$^2$ were required for T4 and Lambda.

Lambda phage was found to be the most resistant to UV treatment process in secondary effluent, followed by T4, Qβ and *E.coli*. Different UV doses were observed to achieve the same log inactivation of *E.coli*, Qβ, T4 and Lambda. Among all coliphage, Qβ was more susceptible to UV inactivation compared to T4 and Lambda.

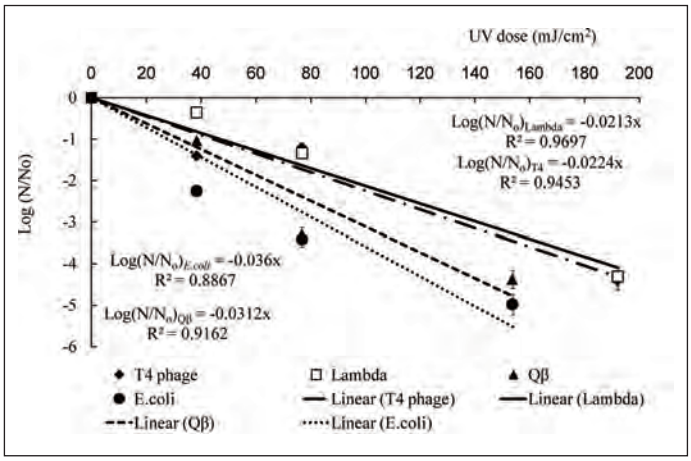


***Figure 2: UV Inactivation of Targeted Microorganism (The error bars show maximum and minimum value for each duplicate dishes)***

Previous study found that MS2, rotavirus, poliovirus and hepatitis A virus needed 64-93 mJ/cm$^2$, 50 mJ/cm$^2$, 23-29 mJ/cm$^2$ and 6-15 mJ/cm$^2$ respectively with UV process for natural waters to achieve 4-logs inactivation [30]. Based on the condition in this study, high dosage is required to achieve the same inactivation indicated the effect of the quality of tested water.

The significant differences in viral susceptibility to UV irradiation that of the cytosine content, or the complexity of the viral capsid and organisation of amino acids, carbohydrate and lipid composition of the protein capsid [17, 31]. Based on the characteristics of targeted microorganisms it could be suggested that protein coat (capsid) of T4 and Lambda may act as a partial shield against UV penetration to the genetic material. Capsid structure, as well as nucleic acid size, render ds-DNA virus less susceptible to UV inactivation [32].

UV disinfection could cause damage to the nucleic acid is well described in previous study [33]. But the knowledge of the ability to repair UV-induced effect or photo-reactivation to different microorganisms is still unclear. This ability could reduce the UV disinfection efficiency.

In order to ensure minimal biological risks, UV has the capability to establish as a primary disinfection for water reclamation facility. The susceptibility of selected microorganisms differed with the microorganism's characteristic. In this study, dsDNA bacteriophages T4 and Lambda demonstrated greater resistant compared with Qβ and *E.coli*. This finding is consistent with previous studies [29, 37].

## 3.2 Effect of H2O2 Addition on the Inactivation of Qβ phage and *E.coli* during UV Treatment

In order to reduce the energy consumption during treatment of high resistance virus and to control the photoreactivation of microorganisms, combination of UV with $H_2O_2$ is necessary and should be considered for actual wastewater reclamation facility.

The effects of $H_2O_2$ addition on the inactivation of Qβ and *E.coli* during UV treatment are illustrated in Figure 3 and Figure 4. These experiments were performed under three different initial $H_2O_2$ concentrations in order to compare the effects of $H_2O_2$ addition during UV treatment.

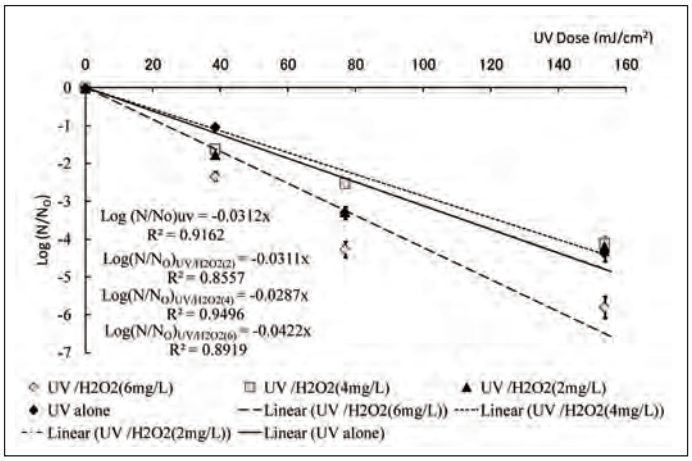


***Figure 3: The Effect of UV/$H_2O_2$ Treatment Processes to Qβ Inactivation Rate (Error bars represent maximum and minimum value for duplicate experiments)***

Figure 3 shows 3-logs inactivation occurs at 96 mJ/cm$^2$ for UV alone process. On the other hand, additional of 6 mg/L $H_2O_2$ reduced UV dosage to 71mJ/cm$^2$. By increasing the UV dosage to 160 mJ/cm$^2$, 5-logs inactivation could be achieved by UV alone process. UV combined with 2 mg/L $H_2O_2$ and 4 mg/L $H_2O_2$ did not significantly increased the inactivation rate. However, the combination with 6 mg/L of $H_2O_2$ yielded higher inactivation rate with lower UV dose at 118mJ/cm$^2$. It was calculated that combination of UV/$H_2O_2$ enable approximately 26% reduction in UV dosage to achieve the same log inactivation compared to UV process alone.

For the combined process, during coliphage Qβ inactivation in secondary effluent, the combination of UV and $H_2O_2$ promoted the production of hydroxyl radical and OH° radical formation increased the inactivation rate.

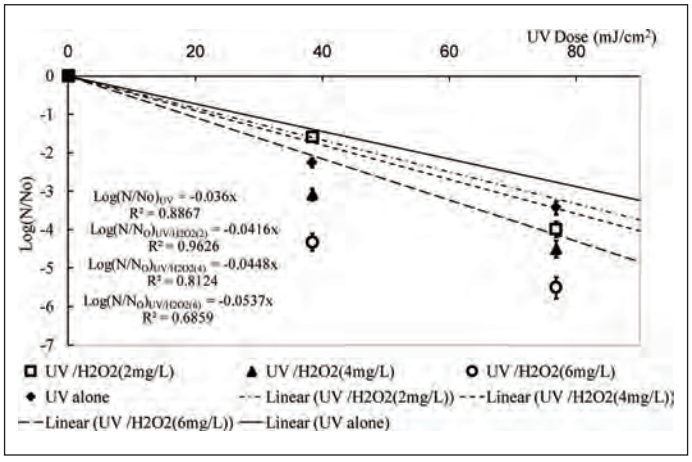


***Figure 4: The Effect of UV/$H_2O_2$ Treatment Processes to E.coli Inactivation Rate (Error bars represent maximum and minimum value for duplicate experiments)***

The combined processes of UV/$H_2O_2$ were tested for *E.coli*. The results showed that the addition of $H_2O_2$ significantly increased the inactivation of *E.coli* (Figure 4). The inactivation of *E.coli* gradually increased with additional of $H_2O_2$. For *E.coli*, 3-logs inactivation were achieved with 72, 67 and 55 mJ/cm$^2$

UV doses with addition of 2, 4 and 6 mg/L $H_2O_2$ respectively. The rates of inactivations of 5-logs were reached with 120, 112 and 93 mJ/cm$^2$ with 2, 4 and 6 mg/L $H_2O_2$, respectively. The combined processes were able to achieve approximately 32% reduction of UV dosage with 6 mg/L $H_2O_2$ compared to UV process alone.

The differences in disinfection efficiencies of UV and $H_2O_2$ could be explained by differences in mechanisms or susceptibility of indicator microorganisms to disinfectants. The main target of UV treatment are the nucleic acids, meanwhile the chemical $H_2O_2$ probably attacked the membrane walls, capsid or protein function for infectivity. The combination of UV/$H_2O_2$ produced OH˚ radical during the reaction to increase the inactivation rate of *E.coli* and Qβ. OH˚ radical is a strong oxidant and produced during advance oxidation processes such as UV/$H_2O_2$ and UV/$O_3$ treatment processes. Based on the results, the efficacy of combined UV/$H_2O_2$ depended on the ratio of UV dosage to $H_2O_2$ concentration. OH˚ radical is non-selective oxidant and react very fast in water. The combination of UV/$H_2O_2$ has been proposed as a measure to control photo-reactivation of microorganisms [38].

This study had shown that the secondary effluent treated with UV based processes had high potential to be used as reclaimed wastewater. Reduction of 1-log,3-logs,4-logs to 5-logs during UV based processes for *E.coli* and coliphages suggested that secondary effluent treated with UV based processes were suitable for restricted and non-restricted usage. Examples of potential usage include irrigation purposes and for receiving water being used for recreational activities with body contact [8, 9]. However, for more resistant viruses or for augmentation of drinking water supplies and dual reticulation in the building [10], higher quality is needed. The approach in producing NEWater by Singapore can then be considered, where microfiltration and reverse osmosis with UV disinfection were used to produce reclaimed wastewater for potable reuse [12]. This study was also found that the doses required for *E.coli* and coliphages were reasonable compared to USEPA requirement [39].

## 3.3 The Effect of Secondary Effluent Constituents

The significant effect of secondary constituents on coliphage Qβ and *E.coli* inactivation were examined. The required doses for 3 to 5-logs inactivation as determined from the experiment were correlated to the measured value of TOC and UV absorbance (UV254). The effect of dissolved organic compound (DOC) and UV absorbance are shown in Figures 5 – 8.

Most organic compounds absorbed UV energy, thus it can be expected that a correlation between DOC and inactivation would exist. DOC demonstrated strong correlations as seen in Figures 5 and 6 during Qβ phage and *E.coli* inactivation. The combined processes by addition of $H_2O_2$ during UV exposure produced OH° radical. OH° radical is highly reactive and can oxidize almost all contaminant in wastewater. However, organic compound in wastewater will undergo oxidative degradation and increased the competition of OH° radical consumption during the inactivation of microorganism.

UV absorbance reflects the quantity of UV energy absorbed by the medium (secondary effluent). Increased absorbencies mean that less UV energy is available for disinfection. In secondary effluent might contain many water matrixes showed strong correlation between $UV_{254}$ and inactivation for indicator microorganisms as shown in Figures 7 and 8.

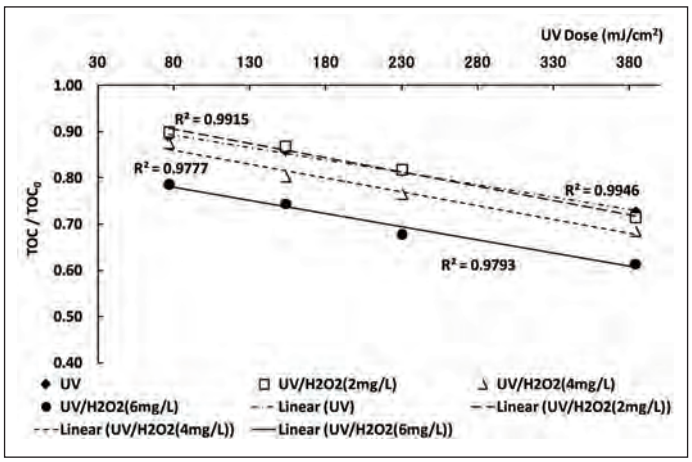


***Figure 5: Correlation between UV Dose during Qβ Inactivation and DOC Reduction***

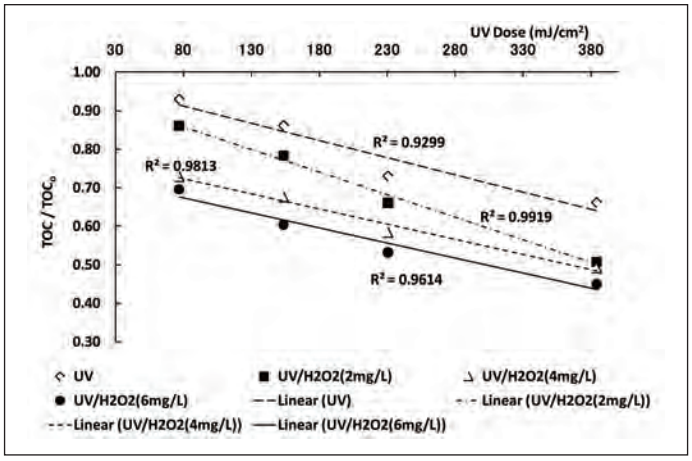


***Figure 6: Correlation between UV Dose during E.coli Inactivation and DOC Reduction***

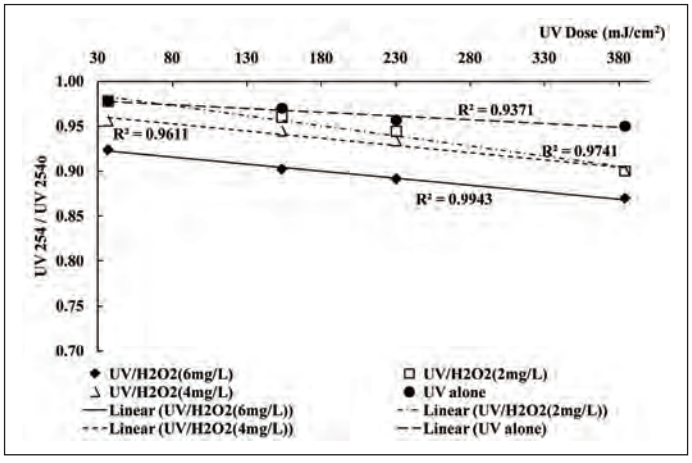


***Figure 7: Correlation between UV dose during Qβ Inactivation and UV Absorbance***

Other study has also found that constituents of secondary effluent will have significant impacts on reclaimed water quality [40]. Microfiltration and reversed osmosis membrane systems were used to treat secondary effluent from sewage treatment plant in Malaysia. The reclaimed water quality complied with all parameters set by WHO Guidelines for Drinking Water [41], except for Ammoniacal Nitrogen and total plate count [40]. The non-compliance of Ammoniacal Nitrogen was because the sewage treatment plant was not designed with nutrient removal

facilities. Thus, secondary effluent contained high Ammoniacal Nitrogen, which affects the reclaimed water quality. The total plate count did not comply because no disinfection facilities were provided. Therefore, the secondary effluent quality is expected to affect the reclaimed water quality in terms of chemical properties.

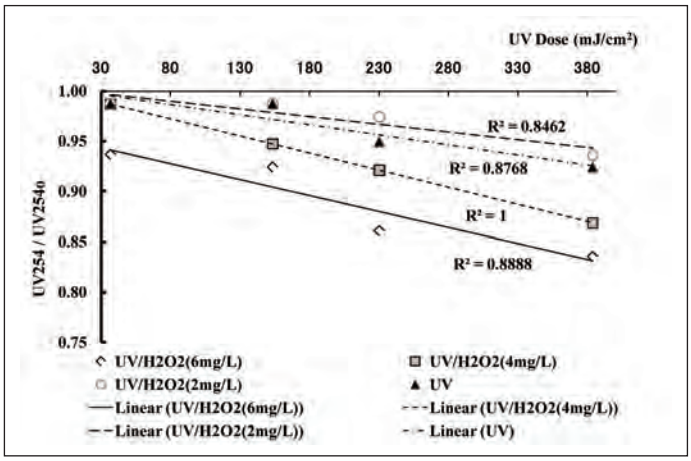


***Figure 8: Correlation between UV Dose during E.coli Inactivation and UV Absorbance***

## 4.0 CONCLUSION

This study emphasised on UV based processes for disinfection of selected microorganisms from secondary effluent. Secondary effluent was recognised as having a potential to be an alternative water resources as reclaimed wastewater. Nevertheless, the biological risks to end users should be considered. In order to reduce the biological risks of secondary effluent as reclaimed wastewater, proper disinfection is needed.

The results from this study provide information on the effectiveness of low-pressure UV treatment of *E.coli* and coliphage in secondary effluent using lab scale reactor. UV treatment process has efficiently inactivated *E.coli* and coliphage with effectiveness ranging from 1-log to 5-logs. The inactivation characteristics of each microorganism were differed due to their structure and characteristics. From this study, it can be concluded that Qβ phage from RNA group was more sensitive to UV process in comparison with T4 phage and Lambda phage from DNA group. More than 4-logs inactivation could be attained with 128.2 mJ/cm$^2$, 178 mJ/cm$^2$ and 188 mJ/cm$^2$ were required for Qβ, T4 and Lambda, respectively.

The combined processes of UV/$H_2O_2$ significantly increased the inactivation of *E.coli* and Qβ phage. This study indicated that the ratio of additional $H_2O_2$ played an important role for disinfection efficiency and could reduce the UV dosage.

DOC and UV absorbance strongly affected the UV based process. The competition between the organic compound in secondary effluent and inactivation of indicator microorganisms were observed for UV process and the combined processes.

Secondary effluent from the biological treatment after treating with UV based processes was found suitable for reclaimed wastewater. Disinfection processes using adequate UV dosage, will pose minimal biological risks and applicable for irrigations and many other purposes.

## ACKNOWLEDGEMENT

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# PROFILES

**DR MARFIAH BINTI AB. WAHID** graduated from Faculty of Civil Engineering, UiTM in 1999, received Master in Environmental Engineering from UKM in 2005 and PhD from Kyoto University, Japan in 2011. She is currently a lecturer at Faculty of Civil Engineering, UiTM, Shah Alam. Her specialisation lies in the field of Water and Environment. Her major research interests are detection and control of pathogenic microorganism, water and wastewater treatment including filtration, chlorination, ozone, UV and AOPs, water reclamation and reuse, climate change, antibiotic-resistant bacteria and energy saving. She is also registered with Board of Engineers Malaysia.

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**DR NAOYUKI YAMASHITA** received BS of Civil Engineering from Okayama University and MS of Environmental Science from Tsukuba University, Japan. Then, he received PhD of Sanitary & Environmental Engineering from Kyoto University, Japan. He had worked for Reseach Center for Environmental Quality Control, Kyoto University as a doctoral researcher for 1 year and for Public Works Research Institute as a researcher for 3 years. In 2005, Dr Naoyuki Yamashita moved to Kyoto University as a lecturer of Reseach Center for Environmental Quality Management and then has worked for Kyoto University for 7 years. His current research includes fate of emerging contaminants including pharmaceuticals and personal care products, ecotoxicological evaluation of the emerging contaminants and removal of pathogenic microorganisms by membrane technology and oxidation process. And his research is also related to wastewater reclamation and reuse towards establishment of water circulation system in urban area.

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**IR. ASSOC. PROF. DR AMINUDDIN BIN MOHD. BAKI** graduated with B.E.(Hons)/B.Com (in Civil Engineering and Management Studies) and PhD in Civil Engineering from the University of Wollongong, Australia. He is a professional engineer registered with the Board of Engineers Malaysia and a Fellow of the Institution of Engineers Malaysia (IEM). He is registered as ASEAN Engineer, APEC Engineer, an International PE with EMF Register, and a Member of the Institution of Engineers Australia. He has worked in the industry for about 12 years in various fields including construction, contract, design and sewerage management. He also has academic experiences for about 12 years, 7 of which at Universiti Teknologi MARA (his current position). He is actively involved in IEM. He was formerly the chairman of Water Resources Technical Division of IEM, former IEM Journal Editor, former committee member of the Environmental Engineering Technical Division of IEM and former IEM Admission sub-committee member.

**DR ILHO KIM** is an Associate Professor at University of Science & Technology, Korea and as a Senior researcher at Korea Institute of Construction Technology. Dr Ilho KIM received his PhD in Urban and Environmental Engineering from Kyoto University, Japan in 2008. His specialisation lies in the field of analysis and control of micro pollutants in water. He received Master of Environmental Engineering and Bachelor of Environmental Engineering from University of Seoul, Korea in 2000 and 1998 respectively. His research interest are analysis and control of micro pollutant, detection and control of pathogenic microorganism, application of ozone, UV and AOPs, wastewater reclamation, energy saving technologies in water and sewage facilities and smart water grid. He is also a registered professional engineer of Water Pollution Environmental, Water Supply Sewage, Korea, Korea Society of Environmental Engineers and The Korean Environmental Science Society.

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**PROFESSOR HIROAKI TANAKA** received his BS, MS, PhD of Sanitary & Environmental Engineering from Kyoto University, Japan and MS of Civil & Environmental Engineering from The University of California, Davis. He had worked for Ministry of Construction in charge of sewage works for six years and for Public Works Research Institute as research engineer, senior research engineer and Section Chief (Water Quality Section) from 1986 to 2003. In 2003, Hiroaki TANAKA moved to Kyoto University as a professor of Graduate School of Engineering. He is a registered Professional Engineer (Construction Environment, Water Supply and Sewerage, Comprehensive Technical Management). He is also Director of Kyoto University-Tsinghua University Cooperative Research and Education Center for Environmental Technology. His current studies include the planning and regulatory aspects of water resources development and water reuse; emerging contaminants including pharmaceuticals and personal care products; wastewater reclamation and reuse, advanced water and wastewater treatment. Hiroaki Tanaka was awarded Research Achievement Award in 2012 and Paper Award in 2011 by Japan Society of Civil Engineering. He was also awarded by many organisations including IWA Fellow 2010 by International Water Association in 2010, National Land Development Engineering Award by Ministry of Land Infrastructure and Transport, Japan in 2003, Jack Edward McKee Medal by Water Environmental Federation in 1999 etc.