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# Available UV Killing *Escherichia coli* in oxidation ponds for community wastewater treatment

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**ABSTRACT**

The available ultraviolet radiation (UV) to kill *Escherichia coli* (*E.coli*) was studied in oxidation pond of wastewater treatment system under the Royal Initiated Laem Phak Bia Environmental Research and Development Project (Royal LERD Project), Ban Laem district, Phetchaburi province, Thailand. The available UV radiation were found in 0-750 $W/m^2$ range within 12 hours (06.00-18.00 o'clock). Hydraulic retention time (HRT) as 37 days was found 97.0% *E.coli* reduction efficiency. Amount of *E.coli* was significantly decreased $2.0\times10^3$ to $2.2\times10^2$ CFU/ml from sedimentation pond 1 to oxidation pond 2. On the other hand, there was no significant decreased from oxidation pond 2 to oxidation pond 3. The radiolysis process in term of hydrogen peroxide ($H_2O_2$) concentration were 1.9 and 2.2 µg/L in oxidation pond 2 and 3, respectively. $H_2O_2$ can damage *E. coli* cell membrane and DNA. Therefore, it could be concluded that available UV radiation was the most important factor to reduce *E. coli* in oxidation pond of wastewater treatment.

***Key words :*** *Ultraviolet radiation, E. coli, Oxidation pond, Wastewater treatment*

## Introduction

Community wastewater typically contains *Escherichia coli* (*E.coli*) which presents public health hazard in human. Although the advanced biological wastewater treatment technology such as, activated sludge system (AS), rotating biological contactor system (RBC) and upflow anaerobic sludge blanket (UASB) can remove *E. coli* by chlorine usage at the end of wastewater treatment system. Chlorination is a traditional chemical substance for *E.coli* killing in community wastewater but it's very expensive and difficult to control wastewater treatment system. In fact, most of the local wastewater treatments in Thailand were oxidation pond system, a low cost and easy to operate but high BOD removal efficiency, that *E.coli* was killed by ultraviolet radiation (Hamouri *et al.*, 1994).

Ultraviolet radiation (UV) emitted from the sun, represent in the UV-A (315-400 nm.), UV-B (280-315 nm.) and UV-C (200-280 nm.) bands. The ozone layer in stratosphere can absorb most of UV-C and some of UV-B. So, the radiations that reach the earth's surface are UV-A and some of UV-B. They are important for producers and important for *E. coli* killing in oxidation pond treatment system. UV-A and UV-B play an important role in hydrogen peroxide production. Hydrogen peroxide ($H_2O_2$) *E. coli* cell membrane and DNA damage substance, were produced by water molecule and dissolved oxygen in wastewater via radiolysis process (Davies *et al.*, 1997; Asad *et al.*, 1998). The efficiency of UV killing

depends on many factors such as, available UV radiation, wastewater quality, structure of oxidation pond treatment system and criteria for operation system.

Therefore, it is very important to study on the role of available UV radiation to kill *E.coli* in oxidation pond wastewater treatment system at the Royal Initiated Laem Phak Bia Environmental Research and Development Project (Royal LERD Project) in order to know the relevant factors and mechanism of the *E.coli* reduction.

## Materials and Methods

### Location of the Royal LERD Project Site

H.M. The King's initiative nature by nature process on Laem Phak Bia Environmental Research and Development project (Royal LERD Project) at Laem Phak Bia sub detract, Ban Laem district, Phetchaburi province, Thailand between latitude 130* 02'40" to 130* 03'20'N and longitude 1000* 05'10" to 1000* 05'10"E, or UTM at 1442240 N to 1443480 N and 0617780 to 0619271 E, approximately 122 km. from Bangkok to the south (Fig. 1). Actually, the project site is far from the city of Phetchaburi (Phetchaburi municipal) about 12 km., which is composed of local people 40,000 persons plus tourists and illegal workers about 10,000 persons. The coverage area is about 260 hectares which localizes inside the natural mangrove forest as laid down from Phetchaburi province to Bangkok (Phetchaburi-Bangkok mangrove forest) with about 140 km. length and 2 km. width (seashore to inland side of mangrove forest).

In fact, the study areas are not only the Royal LERD project site at Laem Phak Bia but also included the whole area of Phetchaburi municipal as point sources of community wastewater which produced approximately 7,000 cu.m./day. However, the modification of sewage drainage system in town was taken care for holding back wastewater instead of direct flowing to Phetchaburi River but turning back by lifting up the pipe ends to the collection culverts to the four sub pumping stations then pumping them to the main collection pumping station at Klongyang village. For implementation, Phetchaburi municipal wastewater at Klongyang collection wastewater station had to pump continuously through 18.5 km HPDE pipe to the Royal LERD project site about 3,600 cu.m./day to treat at the first pond (sedimentation pond 1), to the second pond (oxidation pond 2), the third pond (oxidation pond 3), the fourth pond (oxidation pond 4) and the fifth pond (oxidation pond 5) for community wastewater treatment as illustrated in Figure 2. In addition, all 5 wastewater treatment ponds was laid down in the open air without interruption of sunshine and blow in wind in order to promote algae photosynthesis and pond evaporation. Free oxygen was added up in wastewater by thermo siphon and thermo osmosis processes for bacterial organic digestion.

### Solar Radiation Measurement

The 40 m. height micrometeorological tower has been settled down at the east corner of the Royal LERD Project site (Figure 1) for measuring the net radiation (Rn), ultraviolet radiation spectrum (VIBGYOR) and near infrared. Data collection would be daily analyzed to serve needs of any experiment that concerning with H.M. the King's initiative nature by nature process on community wastewater treatment and garbage disposal.

### Wastewater Quality Sampling

To investigate the influences of available UV (in term of net radiation) to the quantity of DO and $H_2O_2$ in wastewater, the blue sky day (19 May 2011) would be selected as the representative. In the same manner, the sampling points had been fixed at the middle side of the wastewater treatment ponds. Water samples were daily collected by following the wastewater hydraulic retention time (HRT) ineach pond (day 1-6: in sedimentation pond 1, day 7-21: in oxidation pond 2 and day 22-37: in oxidation pond 3). The samples were taken at 30 cm. depth with PE bottles at 11:00 o'clock.

### Wastewater Quality Analysis

The applications of APHA AWWA and WPCF (1995) were conducted to determine wastewater quality. In addition, $H_2O_2$ concentration was determined by titration method (Solvay, 2004). The wastewater properties analysis were thermometer for water temperature, pH meter for pH, azide modification for DO, azide modification 5 day 20 $^oC$ for BOD and dilution plate count technique for total bacteria, total coliform bacteria and *E. coli*.

## Results and Discussion

### Quantitative of available UV

The results of available UV radiation measurement

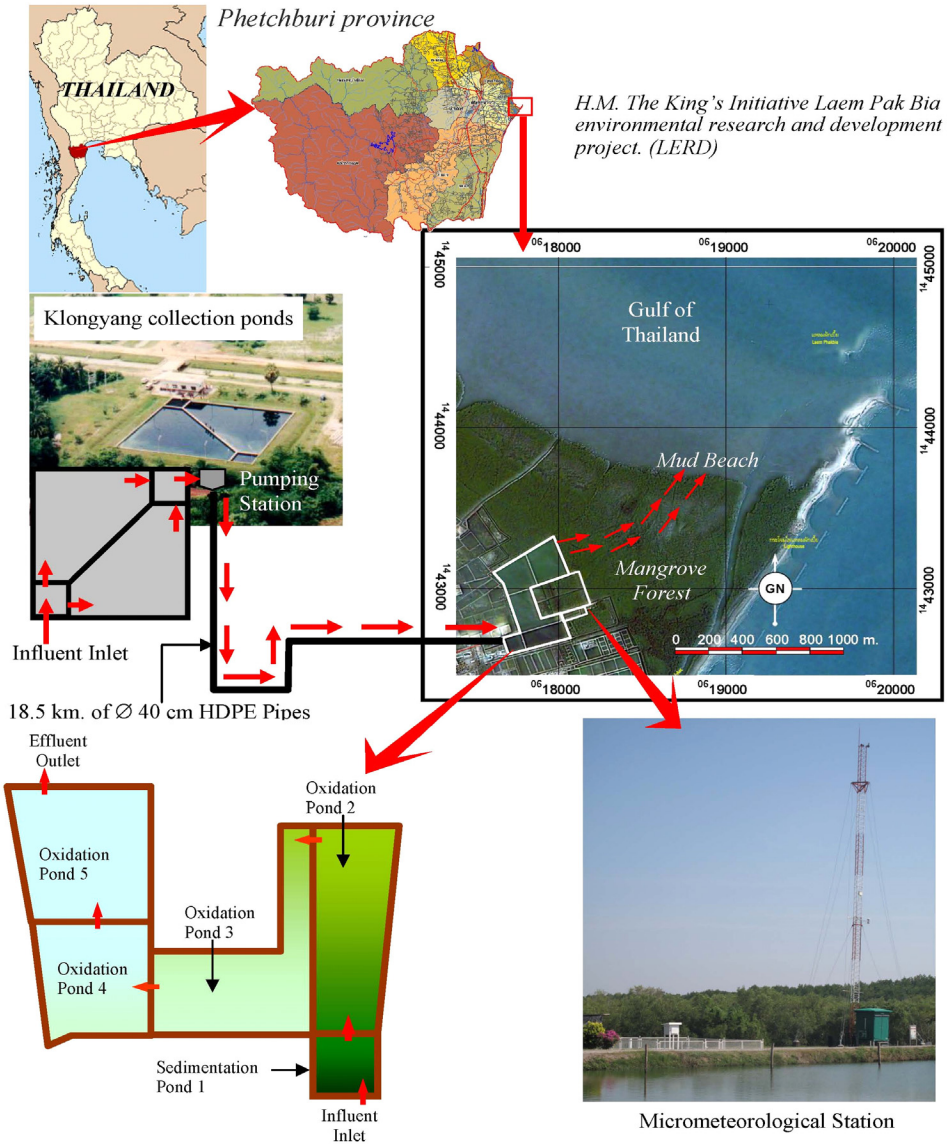


**Fig. 1.** Location of the Royal LERD project site at Laem Phak Bia sub district, Ban Laem district, Phetchaburi province, including Phetchaburi municipal wastewater, Klongyang collection pond, pumping station, 18.5 km. HPDE pipe, five ponds for wastewater treatment and micrometeorological tower.

by micrometeorological station were found in 0-750 $W/m^2$ range within 12 hours (06.00-18.00 o'clock) (Figure 2). Results showed that the available UV began to shine after 06:00 o'clock and maximized about 12.00 o'clock. In the same behavior, the heat energy is gradually increased to the peak, and then decreasing down to about 19:00 o'clock. In turn to the increasing of heat, this was enough to affect to the DO and $H_2O_2$ increment which influenced to the bacterial organic digestion processes.

However, all above statements play a significant role in the death of *E.coli* after wastewater flowing over the weir crest of sedimentation pond 1, oxidation pond 2 and oxidation pond 3. It is a matter of fact, the Royal LERD Project area is located on the open uniform site therefore the effects of blockage due to surrounding trees and buildings can be ignored for consideration on solar energy.

For making a clear understanding, the polynomial correlation was studied on the relationship between available UV and DO of sedimentation pond1

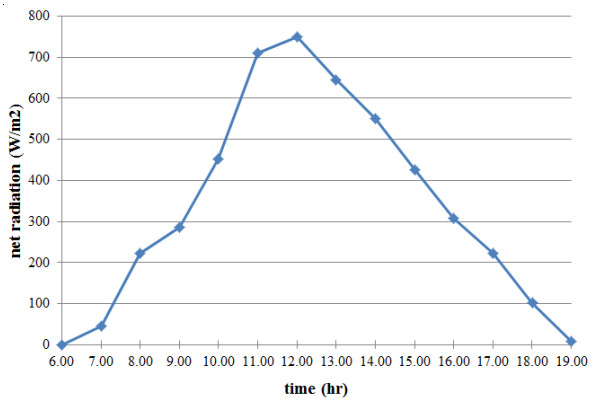


**Fig. 2.** Net radiation of the Royal LERD Project site in Phetchaburi province

for two periods in the morning (06.00-12.00 o'clock) and in the afternoon (13.00-19.00 o'clock). The results of the correlation coefficient ($R^2$) of sedimentation pond1 in the morning were 0.944 and in the afternoon was 0.934. (Figure 3a and b).

In addition, the polynomial correlation between available UV and $H_2O_2$were studied. It was found that the correlation coefficient of sedimentation pond1 in the morning and in the afternoon were 0.944 and 0.986, respectively (Figure 4a and b).

## Wastewater Quality

The measurement of wastewater quality indicators were collected by hydraulic retention time once a day in sedimentation pond as the first day (19 May 2011) and collected in oxidation pond3 as a final day (HRT=37 day)

The BOD, TKN and TP were significantly decreased that showed the treatment efficiencies as 52.9, 63.0 and 46.1%, respectively. However, the system was not decreased TDS, because the oxidation pond was biological wastewater treatment by aerobic bacteria. The aerobic bacteria were degraded organic substance to inorganic substance that dissolved to the wastewater and make TDS content increased up.

An important wastewater quality in the *E.coli* killing (especially DO and $H_2O_2$) was shown in Table 1. They showed significantly increased from sedimentation pond 1 to oxidation pond 3. DO was continuously increased from 0.7, 5.2 and 8.1 mg/L in sedimentation pond 1, oxidation pond 2 and oxidation pond 3, respectively. That was a function of phytoplankton to employ inorganic substance as the nutrient for photosynthesis. On one hand, $H_2O_2$ was

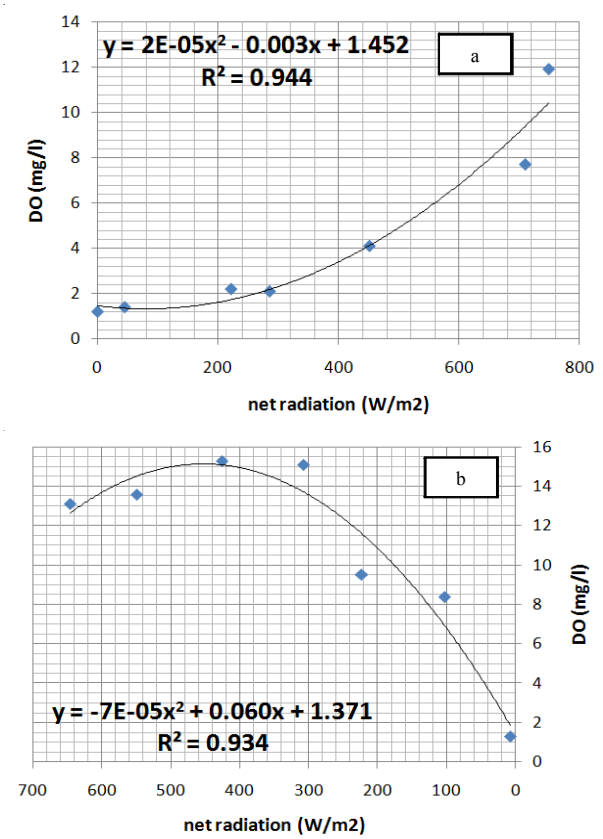


**Fig. 3.** Relationship between available UV and DO of sedimentation pond1 for two periods. (3a) in the morning (06.00-12.00 o'clock) and (3b) in the afternoon (13.00-19.00 o'clock)

increased from non-detectable, 1.9 and 2.2 µg/L. These increment results indicated the reaction between available UV, DO and water molecule to produce $H_2O_2$ in radiolysis process.

The amount of total bacteria, total coliform bacteria and *E.coli* were significantly decreased that the treatment efficiencies were 99.9, 99.8 and 97.0%, respectively, the results as shown in Table 1.

Relationship between $H_2O_2$, total bacteria, total coliform bacteria and *E.coli* in oxidation pond wastewater treatment system

From the studied, $H_2O_2$ showed significantly increased but amount of total bacteria, total coliform bacteria and *E.coli* were significantly decreased (Figure 5a). The polynomial correlation was studied on the relationship between $H_2O_2$, total bacteria total coliform bacteria and *E. coli* that the negative correlation coefficients were 1.00, 1.00 and 1.00, respectively (Figure 5b, c and d).These indicated an inversed

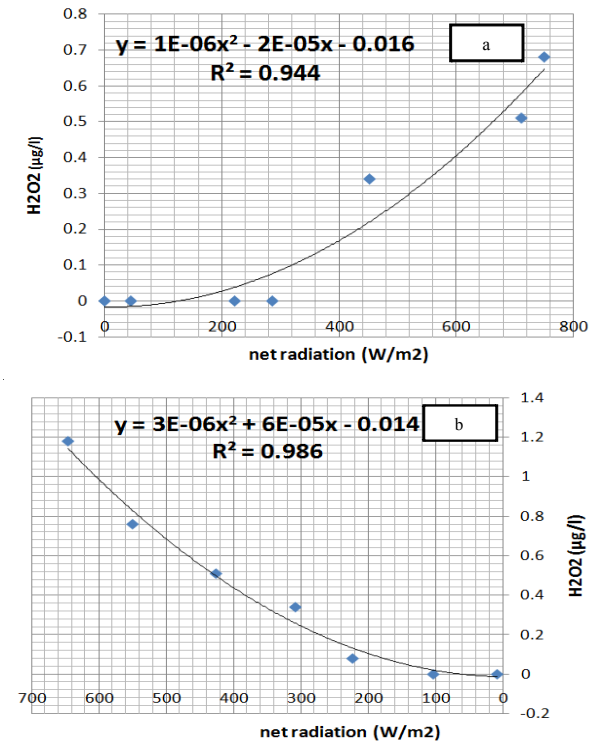


**Fig. 4**. Relationship between available UV and$H_2O_2$of sedimentation pond1 for two periods. (4a) in the morning (06.00-12.00 o'clock) and (4b) in the afternoon (13.00-19.00 o'clock)

relationship of $H_2O_2$ and wastewater bacterial amount. $H_2O_2$ was highly oxidizing agent that can damage cell membrane or DNA of bacteria (Davies *et al.*, 1997; Asad *et al.*, 1998). In addition, it react with fatty acid layer at bacterial outer membrane of gram-negative bacteria such as coliform bacteria and *E.coli*, called lipid peroxidation (Chamberlain and Moss, 1987; Biplab *et al.*, 1989; Peng *et al.*, 2010), which cause leakage of cytoplasm, dysfunction both of DNA in cytoplasm and DNA in nucleus and loss of viability.

## Conclusion

The available UV radiation was the most important factor to killing *E.coli* in oxidation pond of wastewater treatment at Royal LERD project, Thailand.The reaction of UV radiation, DO and water molecules to produce $H_2O_2$, called radiolysis. From this studied found the significantly decreased of total coliform and *E.coli* in the treatment system while $H_2O_2$ found significantly increased. Therefore, it makes sure that the available UV was an important role for produce $H_2O_2$ to kill total bacteria, total coliform bacteria and *E. coli* in oxidation pond wastewater treatment system at Royal LERD project, Thailand.

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**Table 1.** Wastewater quality in oxidation pond wastewater treatment systemat Royal LERD project, Thailand

| Parameter | Wastewater quality | | | Standard | Efficiency |
|---|---|---|---|---|---|
| | Sedimentation pond1 (HRT 6 day) | Oxidation pond2 (HRT 14 day) | Oxidation pond3 (HRT 17 day) | | |
| Temp.($^{\delta}$C) | 26.0$^{a}$ | 26.4$^{b}$ | 27.4$^{b}$ | - | - |
| pH (-) | 7.7$^{a}$ | 7.7$^{a}$ | 8.1$^{b}$ | 5.5-9.0 | - |
| TDS (mg/L) | 484.3$^{a}$ | 503.4$^{b}$ | 551.8$^{c}$ | - | - |
| TKN (mg/L) | 14.6$^{a}$ | 8.8$^{b}$ | 5.4$^{c}$ | 20.0 | 63.0 |
| TP (mg/L) | 3.9$^{a}$ | 2.7$^{b}$ | 2.1$^{b}$ | 2.0 | 46.1 |
| BOD (mg/L) | 37.8$^{a}$ | 27.1$^{b}$ | 17.8$^{c}$ | 20.0 | 52.9 |
| DO (mg/L) | 0.7$^{a}$ | 5.2$^{b}$ | 8.1$^{c}$ | - | - |
| $H_2O_2$ (µg/L) | ND$^{a}$ | 1.9$^{b}$ | 2.2$^{b}$ | - | - |
| TB (CFU/mL) | $1.1\times10^{8}$ $^{a}$ | $5.2\times10^{4b}$ | $2.4\times10^{4b}$ | - | 99.9 |
| TCB (CFU/mL) | $1.9\times10^{5a}$ | $7.1\times10^{2b}$ | $3.8\times10^{2b}$ | - | 99.8 |
| *E.coli* (CFU/mL) | $2.0\times10^{3a}$ | $2.2\times10^{2b}$ | 60 $^{b}$ | - | 97.0 |

**Note-** Water quality standard from the pollution control department of Thailand; ND = non detect

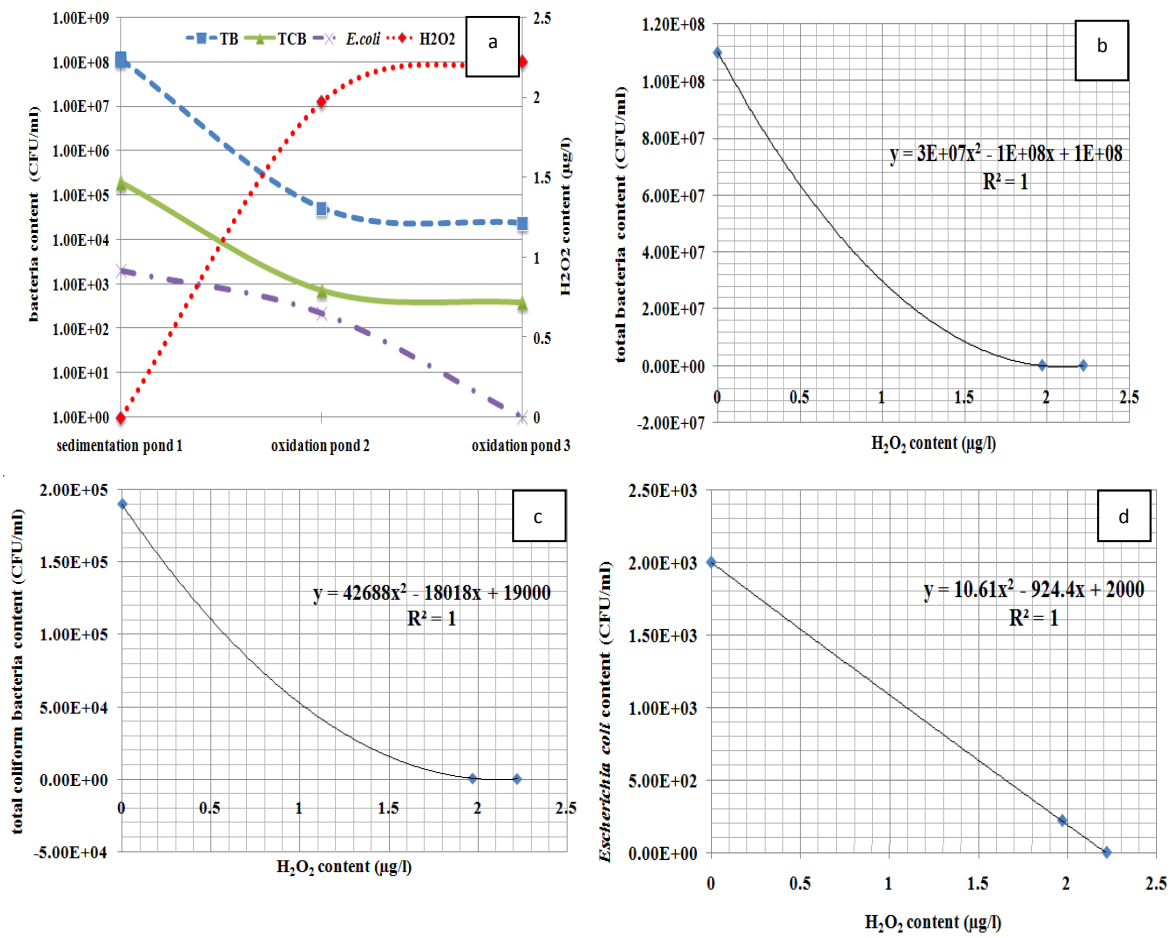


**Fig. 5.** Relationship between $H_2O_2$ and bacteria; (a) $H_2O_2$ and all bacteria (b) total bacteria, (c) total coliform bacteria and (d) *E.coli* in oxidation pond wastewater treatment systemat Royal LERD project, Thailand

**Conflict of Interest:** The authors declare that they have no conflict of interest.

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