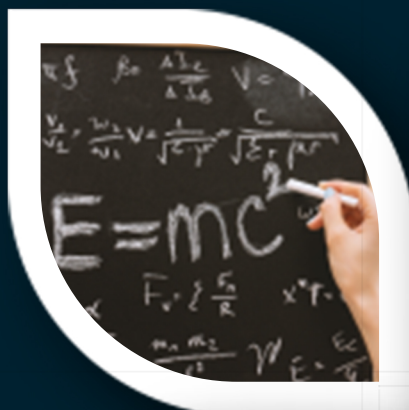


SSSTJ



Suan Sunandha Science and Technology Journal

Volume 6, Number 1, January 2019



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Application of Photocatalytic Oxidation Technology in an Air Purifier for Benzene Removal by Using TiO₂/PLA Film

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Abstract

The objectives of this research were to synthesize a catalyst from TiO₂ embedded on a bio-composite film through photocatalysis application to benzene removal in 785 litre of air through photocatalyzed oxidation process in Air Purifier. And found out the best of benzene volatile organic compound removal condition with Box-Benkhen design's respond surface method. The scope of the study was tested on three polylactic acid biopolymer films with the volume of TiO₂ at 5.0, 10.0 and 15.0%w/w formed by molding film method. The morphology of the film was examined by scanning electron microscope. The chemical structure of the film was scanned by X-Ray diffraction. Light absorbance was detected by UV/VIS Spectrophotometer. After SEM testing, it was found that TiO₂ on the three films were equally distributed and embedded all over the films. The crystal structure of Titanium dioxide was appeared to be an anatase structure. It was found that the energy gap was from 3.14 to 3.22 eV. The result can be confirmed the decrease of benzene compound after photocatalyzed oxidation process on photoreactor consisted of 785 litre of air. The result was shown that the light intensity at 5.24 mW/cm² and TiO₂ at 10.0%w/w can yield the optimum result at 62.28% of benzene compound decrease with initial intensity at 5±0.5 ppm. The most appropriate conditions to remove benzene volatile organic compound with Box-Benkhen design's respond surface method were 5.24 mW/cm² of light intensity, 10.0%w/w of TiO₂, and 5±0.5 ppm of benzene initial intensity. With these conditions, the result revealed that the reaction rate was 58.90% at R² 0.82. Therefore, the concluded that the process of benzene volatile organic compound removal can be further developed in the form of equipment as air purifier with optimum condition.

Keywords: Air purifier, Benzene, Photocatalytic oxidation, Poly lactic acid film, Responsive surface method

1. Introduction

Volatile Organic Chemicals are volatile organic compounds that evaporate into the air at normal temperatures and pressures. Currently found as a compound in many products such as color, cigarette smoke, bleach, solvents in print, scattered in the air. It was found that they have a biological effect and a health hazard (Roschan & Tipayarom, 2014). Office buildings are one area where volatile organic chemicals, benzene, toluene and benzaldehyde are excreted, which, in large doses, pose a risk of disease in people. Photocatalytic oxidation technology is a technology developed to treat both organic and inorganic organic compounds in the water and in the air, called photocatalytic. It is based on ultraviolet wavelength energy combined with semiconductor particle stimulation. However, the process of treating volatile organic chemicals using this

technique has several limitations. For example, controlling the factors that affect the effectiveness of treatment requires advanced techniques, catalysts must be developed to be highly efficient and safe for users and the environment, the application of volatile organic chemicals in the work area requires equipment that controls the condition to be proper. Therefore, the purpose of this study is to apply this technology by using TiO₂/PLA film as a titanium dioxide catalyst in the form of blown film. Benzene treatment in the air. The simulated 785-liter simulated room was designed to be close to the operating area where the spread of VOCs was found and the optimum condition of the experiment with the response surface methodology, Box Benkhen method. (Ray, Lalman, & Biswas, 2009) This research will be a

guideline for further development of the technology for the future design of VOCs removal in air pollution.

2. Research Methodology

2.1 Film synthesis

Film Synthesis: TiO_2 /PLA film production by blow film with Titanium dioxide (TiO_2 , A220) and PLA, 4042D. Preparation of 5.0, 10.0 and 15.0% w/w TiO_2 powder mixed in a maleic anhydride copolymer in a heat-treated at 100-160 °C was then passed through a mixture of twin screw blown film 30 μm thickness (Suwannahong, Liengcharernsit, Sanongraj, & Krueenate, 2012).

2.2 Physical characteristics of catalyst analysis

The morphology of the TiO_2 /PLA films was investigated by scanning electron microscope: SEM (model JXA-840, JEOL), which protected the charge during the test coated with gold, which is used by the metal coating (Shifu, Wei, Sujuan, & Wei, 2009). Examine the structure of TiO_2 embedded crystals distributed in X-Ray film using X-Ray method by the diffraction (TTRAXIII, Rigaku), at a wavelength of 1.5404 $\text{\AA}$ ($\lambda = 1.5404 \text{ \AA}$), at an electrical current of 300 mA and a potential voltage of 50 KV (Ao, Xu, Fu, Shen, & Yuan, 2008)

2.3 Reactor design

Box design, diameter 1.0 m, height 1.0 m, is made from SS 314 corrosion resistant material. Replace the reactor in the Bionaire BAP-625 series air purifier that cleans the pollutants through the annular reactor. Inside is equipped with an air velocity gauge, thermometer, moisture, UV-C and TiO_2 /PLA films. Check the leakage of the pollutant when the machine is running with the method of detecting the joint with bubbles and compressed air with pressure gauge installed on the tank as shown in Figure 1 and Table 1. Examine the effectiveness of benzene treatment that knows the exact concentration, then injected through an air sampling system with gas chromatograph (GC-FID)



Figure 1. Characteristics of modified air purifier and leak detection.

Table 1. Experimental conditions for benzene treatment with 785 liters of laboratory.

Laboratory size	Diameter 1.00 m., Height 1.00 m.
Volume of laboratory	785 liters
Average wind speed within the experimental set	0.380 m/h
Average air velocity in the air purifier room	4.106 m/h
Room size within the air purifier	Width 0.2 m., Length 0.2 m, Height 0.35 m.,
The air flow ratio inside the air purifier unit	0.240 m^3/h (4.7 L/min)
Average laboratory temperature	34.24 °C
Average room humidity	55.79%
Duration	600 mins

2.4 Testing to find the right conditions for benzene removal with respond surface method (RSM)

Testing to find the right conditions for benzene treatment in the test with respond surface method (RSM), Box-Benken Design: BBD model. The results of 3 factors and the level of factors affecting the three levels of experiment were studied with 15 experiments as shown in Table 2 and Table 3.

Table 2. Factors and levels of each factor affecting the experiment.

Factor	Symbol	Level		
		-1	0	1
UV Light intensity (mW/cm ²)	A	1.96	3.59	5.24
TiO ₂ Volume (%w/w)	B	5.00	10.00	15.00
Benzene initial concentration (ppm)	C	5.21	10.02	15.50

Table 3. Data for the optimal conditions of three-factor RSM and three-level test.

Experiment	Light Intensity (mW/cm ²)	TiO ₂ Volume (w/w)	Initial intensity (ppm)
1	1.96	5.00	10.02
2	1.96	10.00	5.21
3	1.96	15.00	10.20
4	1.96	10.00	15.50
5	3.59	5.00	5.21
6	3.59	5.00	15.50
7	3.59	10.00	10.20
8	3.59	10.00	10.20
9	3.59	10.00	10.20
10	3.59	15.00	15.50
11	3.59	15.00	5.21
12	5.24	10.00	5.21
13	5.24	15.00	10.02
14	5.24	10.00	15.50
15	5.24	5.00	10.20

3. Results and Discussion

Physical characteristics of TiO₂/PLA film catalysts, bonding and dispersing of catalysts by scanning scanners were found that the surface of the films are smooth. TiO₂ catalysts were deposited on the film surface of Figure (b)-(d) as shown in Figure 2.

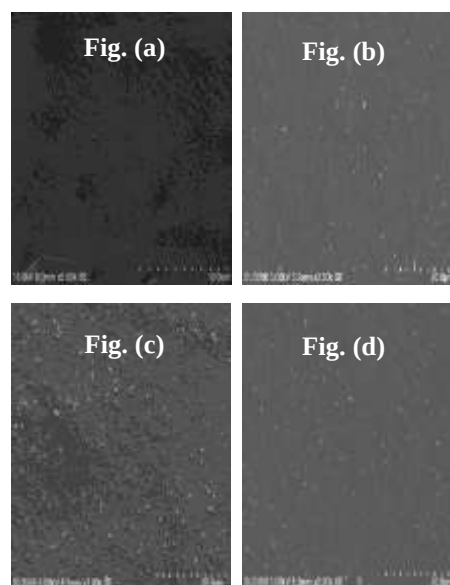


Figure 2. Results of SEM micrographs test (a) PLA film and (b), (c), (d) 5.0, 10.0 and 15.0%w/w of TiO₂/PLA film.

The effect of UV-Vis absorption spectra on all 3 films (5.0, 10.0 and 15.0% w/w) at wavelength range of 200-800 nm showed that the absorption of light spectrum was good at lower 400 nm wavelength. Over 400 nm., as shown in Figure 3. When calculating the power of Eg, it is found that the power in the Eg is at 3.14-3.22 Eg, as shown in Table 4.

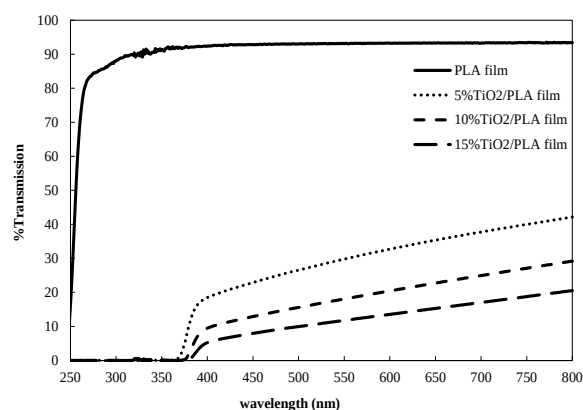
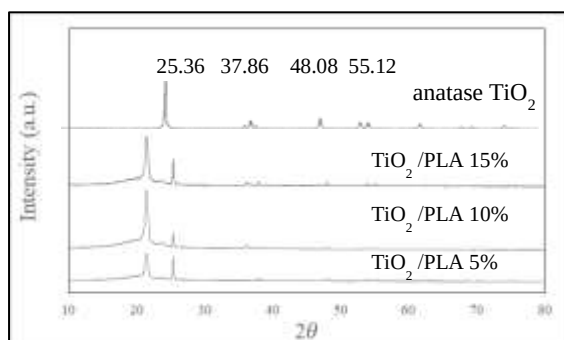


Figure 3. UV absorption test of TiO₂ /PLA film.

Table 4. Results of Eg calculation (TiO₂/PLA film).

Type of film embedded by TiO ₂ (%wt)	Eg (eV)
5.0% nano-TiO ₂ /PLA	3.22
10.0% nano-TiO ₂ /PLA	3.18
15.0% nano-TiO ₂ /PLA	3.14

Figure 3 and Table 4 show that the TiO₂ catalyst in the PLA film, which is close to that the crystalline catalysts with anatase structure (Eg 3.20 eV.) (Zhao & Yang, 2003). The results of the embedded TiO₂ crystalline structure were examined by using X-Ray Diffraction (TTRAXIII, Rigaku) at a wavelength of 1.5404 Å, scanning from 20° to 60°. 5°/min, as shown in Figure 4.

**Figure 4.** Results of X-Ray on crystal structure in films 5.0, 10.0 and 15.0% TiO₂ /PLA film.

From Figure 4, TiO₂ catalysts were found second signal at 2θ in the range of 25.36, 37.86, 48.08 and 55.12 minutes, corresponding to the crystalline structure of the anatase (JCPDS 65-5714) in all 3 ratio.

Test results for benzene removal in air purifier using TiO₂/PLA film by respond surface method. The optimum condition for benzene treatment in 785 liters experimental set found the best response of benzene removal, the linear correlation coefficient at R² was 0.82, at 5.24 mW/cm² light intensity, 10.0% w/w of TiO₂ volume, the initial concentration of benzene volatile 5±0.5 ppm was 58.90%, the mathematical equation for the experimental results and the regression model at the significance level α = 0.05 were obtained as follows.

$$\%C_6H_6 \text{ Removal} = 53.27 + 4.81A + 5.72C - 4.68(A^2) - 4.94(B^2) - 5.85(C^2) \dots\dots(1)$$

When A = Light Intensity (mW/cm²)
B = Volume TiO₂ (w/w)
C = Initial Concentration (ppm)

The results of this study are consistent with the results of Destailats et al. (2012) which found that benzene content suitable for photocatalytic oxidation treatment should be low and consistent with the results of Farhanian, Haghighat, Lee, & Lakdawala (2013). In higher UV intensity, treatment efficiency was higher, consistent with the results of Cao et al. (2000) The catalytic activity was lowest at 10.0%w/w, consistent with the results of Kreetachat, Krueate, & Suwannahong (2013).

4. Conclusion

The film is made from PLA, which is put on the catalyst by the light, throughout TiO₂ distribution, has the chemical structure of anatase TiO₂ crystals, Eg of 3.14-3.22 eV, close to the Eg power of TiO₂ crystals. Therefore, it is suitable for application for the treatment of volatile organic chemicals in the air, and can be applied in benzene treatment with modified air purifier kit at maximum 62.28% and the optimal condition of the experiment by RSM technique with the best response. The TiO₂ content was 10.0%w/w and the initial benzene concentration was 5±0.5 ppm, 5.24 mW/cm² of light intensity, 10.0%w/w of TiO₂, initial concentration of benzene 5±0.5 ppm with a 58.90% response at R² of 0.82. The mathematical model of regression equation (1) at significance level α = 0.05 that can be significantly used to test benzene treatment in air purifier kit was found.

5. Acknowledgements

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Extended-spectrum beta lactamase and carbapenemase-producing *Klebsiella* spp. in urine and fecal samples obtained from hospitals and communities in Lagos, Nigeria

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Abstract

The use of beta-lactams has tremendously increased since the discovery of antibiotics. This has led to the emergence of certain resistant genes such as Extended Spectrum Beta-Lactamase (ESBL) which confer resistance to third generation cephalosporins. The objective of this study was to determine the prevalence of Extended Spectrum Beta Lactamase (ESBL) genes, Carbapenem resistance genes (*bla_{KPC}*, *bla_{OXA}* and IMP) and outer membrane porins genes (OMP-35, OMP-36, and OMP-36N) from different hospitals and laboratories in Ikeja-Lagos, Nigeria. A total of 177 bacterial isolates were collected between May 2017 to July 2017 from patients with urinary tract infections (UTI) and gastroenteritis. They were identified biochemically and investigated for ESBL and Carbapenemase production using phenotypic Double Disk Synergy Test (DDST) and Modified Hodges' Test respectively. Antibiotics susceptibility profile was also investigated. Multiplex PCR was used to detect the genes responsible for the resistant genes. Out of 177 bacterial isolates, 47 (26.6%) were identified as *Klebsiella* spp and 17 (36.1%) were ESBL positive and then 5 (29.4%) were positive for carbapenem resistance. Multiplex PCR revealed that 3 (27.3%) possessed both *bla_{CTX-M}* and *bla_{SHV}* genes, 6 (54.5%) possessed only *bla_{CTX-M}* gene while only 2 (18.2%) possessed only *bla_{SHV}* gene. Also, 13 (76.5%) possessed only *bla_{KPC}* gene. However, *bla_{TEM}* as well as IMP, OXA-48, OMP 35, OMP 36 and OMP 36N genes were not detected. This study revealed that antibiotic resistance is on the rise and preventive measures should be put in place by both government and health care providers to curtail this trend.

Keywords: Extended Spectrum Beta-Lactamase, Urinary Tract Infections, Carbapenemase, *Klebsiella* spp,

1. Introduction

ESBL has generally been defined as transmissible β -lactamases that can be inhibited by clavulanic acid, tazobactam or sulbactam, and which are encoded by genes that can be exchanged between bacteria (Paterson & Bonomo, 2005). The most common genetic variant of ESBL is CTX-M (Paterson & Bonomo, 2005; Walsh, 2003). Beta-lactamases are commonly classified according to two general

schemes: the Ambler molecular classification and the Bush–Jacoby–Medeiros functional classification (Ambler, 1980; Anne & Karen, 2007). The Ambler scheme classifies β -lactamases into four classes according to the protein homology of enzymes. Beta-lactamases of class A, C, and D are serine β -lactamase and class B enzymes are metallo- β -lactamases. The Bush–Jacoby–Medeiros functional scheme is based on functional properties

of enzymes. The SHV family of β -lactamases are to be derived from *Klebsiella* spp. The progenitor of the SHV class of enzymes, SHV-1, is universally found in *K. pneumoniae* (Bush, Jacoby, & Medeiros, 1995). The SHV-1 β -lactamase is responsible for up to 20% of the plasmid-mediated ampicillin resistance in *K. pneumoniae* species (Bora et al., 2014).

TEM-1, first reported from an *E. coli* isolate in 1965, has substrate and inhibition profiles similar to those of SHV-1 (Livermore, 1995). TEM-1 is capable of hydrolyzing penicillins and first generation cephalosporins but is unable to attack the oxyimino cephalosporin. The first TEM variant with increased activity against extended spectrum cephalosporins was TEM-3 (Datta & Kontomichalou, 1965; Tzouveleakis & Bonomo, 1999).

TEM-2 the first derivative of TEM-1, had a single amino acid substitution from the original β -lactamase (Soughakoff, Goussard, & Courvalin, 1998). This caused a shift in the isoelectric point from a pH of 5.4–5.6, but it did not change the substrate profile. TEM-3, originally reported in 1989, was the first TEM-type β -lactamase that displayed the ESBL phenotype (Tzouveleakis & Bonomo, 1999). *Klebsiella oxytoca*, harboring a plasmid carrying a gene encoding ceftazidime resistance, was first isolated in Liverpool, England, in 1982. The responsible β -lactamase was what is now called TEM-12. Interestingly, the strain came from a neonatal unit which had been stricken by an outbreak of *K. oxytoca* producing TEM-1. This is a good example of the emergence of ESBLs as a response to the selective pressure induced by extended-spectrum cephalosporins (Datta & Kontomichalou, 1965).

A new family of β -lactamases that preferentially hydrolyzes cefotaxime has arisen. It has been found in isolates of *Salmonella enterica* serovar, Typhimurium, *E. coli* mainly and some other species of Enterobacteriaceae (Soughakoff, Goussard, & Courvalin, 1998; Paterson & Bonomo, 2005). These are not very closely related to TEM or SHV β -lactamases (Bharat et al., 2006). In addition to the rapid hydrolysis of cefotaxime, another unique

feature of these enzymes is that they are better inhibited by the β -lactamase inhibitor tazobactam than by sulbactam and clavulanate (Gazouli et al., 1998). CTX-M β -lactamases are found exclusively in the functional group 2 (Tzouveleakis et al., 2000) and thought to originate from chromosomal ESBL genes found in *Kluyvera* spp., an opportunistic pathogen of the Enterobacteriaceae found in the environment. The first CTX-M proteins were discovered in the late 1980s and today more than 100 variants have been sequenced (Bradford, 2001). Based on their amino acid sequences, they can be divided into five groups (CTX-M group 1, 2, 8, 9, and 25) (Bradford, 2001). The origin of the CTX-M enzymes is different from that of TEM and SHV ESBLs. While SHV-ESBLs and TEM-ESBLs were generated by amino acid substitutions of their parent enzymes, CTX-M ESBLs were acquired by the horizontal gene transfer from other bacteria using genetic apparatuses such as conjugative plasmid or transposon. The gene sequences encoding CTX-M enzymes show a high similarity to those of β -lactamases of *Kluyvera* species (Bush & Jacoby, 2010). In addition, the gene sequences adjacent to the CTX-M genes of Enterobacteriaceae are also similar to those surrounding the β -lactamase genes on the chromosomes of *Kluyvera* species (Bonnet, 2004). Also, *bla_{KPC}* is a gene that codes for carbapenemase production and also OMP 35, OMP 36 and OMP 36N. The OXA-type β -lactamases are so named because of their Oxacillin-hydrolyzing abilities. These β -lactamases are characterized by hydrolysis rates for Cloxacillin and Oxacillin greater than 50% as that for benzyl penicillin (Anne & Karen, 2007). They predominantly occur in *P. aeruginosa* but have been detected in many other Gram-negative bacteria. Extended Spectrum Beta-Lactamase have arisen as a result of different factors of which human related-factors play vital roles. They include overuse of antibiotics, inappropriate prescription, lack of infection control measures in healthcare facilities and the use of sub therapeutic doses of antibiotics for the promotion of animal growth in the agricultural sector. The rise of ESBL producing Enterobacteriaceae has mounted a selective pressure in the usage of Carbapenem as a

drug of last resort for the treatment of infections caused by ESBL. Also the sporadic reports of carbapenem resistant Gram negative organisms is seriously posing a therapeutic issues in the health centres as previously almost abandoned antibiotics which were toxic to humans are now being recruited for treatment of infectious diseases.

The aim of this study was to determine the prevalence and types of Extended Spectrum Beta Lactamase (ESBL) encoding genes and carbapenem resistant encoding genes existing in the hospitals and laboratories in communities in Ikeja, Lagos environs, Nigeria.

2. Materials and Methods

2.1 Clinical Isolates:

A total of 177 bacterial isolates were collected between May 2017 to July 2017 from different private hospitals and laboratories in Ikeja, Lagos, Nigeria after obtaining permission. All 177 bacterial isolates were collected on nutrient agar and incubated at 37°C for 24 hours. The isolates were from samples of patients suffering from different infections such as urinary tract infections (UTI) and gastroenteritis. All bacterial isolates were identified using standard microbiological and biochemical tests (Cheesbrough, 2006).

2.2 Detection of ESBL Producers

The production of ESBL was detected by the double disk synergy test according to CLSI guidelines using a disk of amoxicillin/clavulanic acid along with ceftazidime, ceftriaxone, cefotaxime and aztreonam/cefuroxime (Pitout, Hossain, & Hanson, 2004). A Mueller Hinton agar plate was inoculated with each isolate as described above and labeled properly. Later, an amoxicillin/clavulanic acid disc was placed in the centre of the plate, and ceftazidime, ceftriaxone, cefotaxime, and aztreonam/cefuroxime discs were placed 25 mm (center to center) from the amoxicillin/clavulanic acid disc. After overnight incubation at 37°C, any distortion or increase in the zone of inhibition (i.e., augmentation of inhibition) towards the amoxicillin/clavulanic acid disc was considered a positive result for the ESBL production.

2.3 Detection of Carbapenemase Producers

Carbapenemase production was tested using the Modified Hodge Test according to CLSI guidelines (2012). A 0.5 McFarland suspension of each isolate in 5 mL of sterile saline was prepared. A 1:10 dilution was prepared by adding 0.5mL of the 0.5 McFarland suspension to 4.5mL sterile saline, this was then used as inoculum for an MH agar plate. The plate was dried for 5mins and a disk of meropenem (10µg), was placed in the center of the agar plate. The colonies of the test organism were selected and streaked in a straight line, from the edge of the disk, up to the edge of the plate. After overnight incubation at 37°C, Carbapenemase production was identified by observing a clover leaf-like indentation of *Escherichia coli* 25922 (susceptible strain) growing along the test organism growth streak within the disk diffusion zone.

2.4 Antibiotic Susceptibility Testing

Susceptibility was determined by Kirby Bauer disc diffusion method as described by Clinical and Laboratory Standard Institute (CLSI) (2012). All Isolates were grown on nutrient broth for 18 hours at 37°C. The suspension was visually adjusted with normal saline to equal that of 0.5 McFarland turbidity standard. The inoculum was swabbed across the entire surface of Muller Hinton agar plate using sterile swab stick and the plate was rotated approximately 60°C between streaking to ensure an even distribution.

The inoculated plates were left to stand for 5 minutes before the discs were applied. Commercial antibiotics discs (Oxoid) used contained ceftazidime (30µg), cefotaxime gentamicin (10µg), ciprofloxacin (5µg), amoxicillin clavulanic acid (30µg), ceftriazone (30µg) and meropenem (10µg). The plates were incubated within 15 minutes before the application of the discs at 37°C and subsequently incubate at the same temperature for 18 hours after discs' application. The inhibition zone diameter around the disc was measured and interpreted according to the CLSI guidelines. Isolates were considered as multidrug resistance when it showed resistance to ≥ 3 antimicrobial agents.

2.5 DNA Extraction (By Boiling)

Cells were harvested into 1000µl of sterile water. They were vortexed until it was completely dissolved. It was centrifuged for 5 minutes at 10,000rpm. The supernatant was then discarded and 1000µl of sterile water was added. It was vortexed and centrifuged, the supernatant was decanted and then 200µl of sterile water was then added and vortexed till it was thoroughly mixed. It was heated for 10 minutes at 100°C and cool immediately on ice and vortexed. It was centrifuged for 5 minutes at 10,000 rpm and the supernatant was transferred into another Eppendorf tube and the pellet was discarded.

2.6 Multiplex PCR amplification of ESBL and Carbapenemase genes

A multiplex PCR reaction was carried out using the Solis Biodyne 5X HOT FIREPol Blend Master mix. PCR was performed in 20 µl of a reaction mixture, and the reaction concentration was brought down from 5x concentration to 1X concentration containing 1X Blend Master mix buffer (Solis Biodyne), 2.0mM MgCl₂, 200µM of each deoxynucleoside triphosphates (dNTP) (Solis Biodyne), 20pmol of each primer (Jena Bioscience, Germany), 2 unit of Hot FIREPol DNA polymerase (Solis Biodyne), 5µl of the extracted DNA, and sterile distilled water was used to make up the reaction mixture.

Thermal cycling was conducted in a Pielter Thermal Cycler PTC 100 (MJ Research Series) for an initial denaturation of 95°C for 5 minutes followed by 35 amplification cycles of 30 seconds at 95°C; 1 minute at 59°C and 62°C and then 1 minute 30 Seconds at 72°C. This was followed by a final extension step of 10 minutes at 72°C. The amplification product was separated on a 1.5% agarose gel and electrophoresis was carried out at 80V for 1 hour 30 minutes. After electrophoresis, DNA bands were visualized by Ethidium bromide staining. 100bp DNA ladder was used as DNA molecular weight standard. Table 1 shows the list of primers used.

Table 1. list of primers for Multiplex PCR amplification of ESBL and Carbapenemase genes

Primers	Product size (bp)	Reference
SHV-F ATGCGTTATATTCGCCTGT	753	Sharma <i>et al.</i> , 2010
SHV-R TGCTTTGTTATTCGGGCCAA		
CTX-M-F TTTGCGATGTGCAGTACCAGTAA	543	Edelstein <i>et al.</i> , 2003
CTX-M-R CGATATCGTTGGTGGTGCCATA		
TEM-F AAACGCTGGTGAAAGTA	822	Nasehi <i>et al.</i> , 2010
TEM-R AGCGATCTGTCTAT		
OXA-48 F TGTCTTTGGTGGCATCGAT	177	Monteiro <i>et al.</i> , 2012
OXA-48 R GTAAMRATGCTTGGTTCGC		
IMP-F GAGTGGCTTAATTCTCRATC	120	Mendes <i>et al.</i> , 2007
IMP-R ACCTAYCCAARATCCAATATRTAAC		
KPC-F GATACCACATTCCGTCTGG	246	Anne and Karen, 2007
KPC-R GCAGGTTCCGGTTTGTCTC		

Data analysis: Data was analyzed using simple percentage.

3. Results

Out of 177 bacterial isolates, 47 bacterial isolates were biochemically identified as spp and 17 out of the 47 bacterial isolates were ESBL producers. The biochemical patterns of the 17 ESBL producers are shown in table 2.

Table 2. Biochemical patterns of the ESBL producers

s/n	Butt	Slope	H ₂ S	Gas	Indole Test	Citrate Test	Lactose	Glucose	Organism
1	Y	Y	-	-	+	+	+	+	<i>Klebsiella oxytoca</i>
2	Y	Y	-	+	-	+	+	+	<i>Klebsiella pneumoniae</i>
3	Y	Y	-	-	+	+	+	+	<i>Klebsiella oxytoca</i>
4	Y	Y	-	-	+	+	+	+	<i>Klebsiella oxytoca</i>
5	Y	Y	-	-	+	+	+	+	<i>Klebsiella oxytoca</i>
6	Y	Y	-	-	+	+	+	+	<i>Klebsiella oxytoca</i>
7	Y	Y	-	-	+	+	+	+	<i>Klebsiella oxytoca</i>
8	Y	Y	-	-	+	+	+	+	<i>Klebsiella oxytoca</i>
9	Y	Y	-	-	+	+	+	+	<i>Klebsiella oxytoca</i>
10	Y	Y	-	-	+	+	+	+	<i>Klebsiella oxytoca</i>
11	Y	Y	-	-	+	+	+	+	<i>Klebsiella oxytoca</i>
12	Y	Y	-	-	-	+	+	+	<i>Klebsiella ozaenae</i>
13	Y	Y	-	-	+	+	+	+	<i>Klebsiella oxytoca</i>
14	Y	Y	-	-	-	+	+	+	<i>Klebsiella ozaenae</i>
15	Y	Y	-	-	+	+	+	+	<i>Klebsiella oxytoca</i>
16	Y	Y	-	-	+	+	+	+	<i>Klebsiella oxytoca</i>
17	Y	Y	-	+	-	+	+	+	<i>Klebsiella pneumoniae</i>

KEY: Y=Yellow

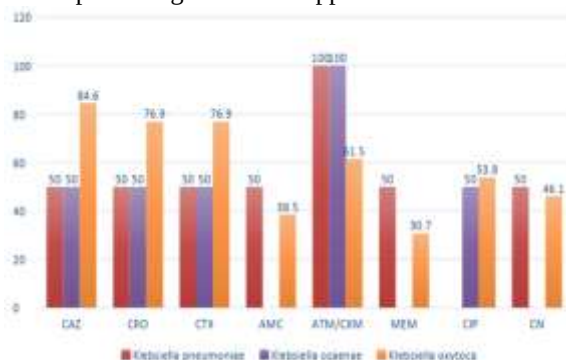
Each of the organisms showed varying zones of inhibition to the various antibiotics used as shown in Table 3.

Table 3. Representation of organisms and their zones of inhibition (mm) (ESBL)

S/N	Specimen	Age	Gender	CAZ	CRO	CTX	AMC	ATM/CXM	MEN	CIP	CN	Organism
1	Urine	40	F	15	17	15	25	17	23	21	15	<i>K. oxytoca</i>
2	Stool	5	F	18	29	18	15	20	29	23	18	<i>K. pneumoniae</i>
3	Urine	71	F	23	24	24	18	17	33	25	20	<i>K. oxytoca</i>
4	Urine	33	M	17	22	20	15	30	14	16	16	<i>K. oxytoca</i>
5	Stool	40	M	13	13	15	18	24	30	15	22	<i>K. oxytoca</i>
6	Stool	49	F	20	26	30	18	11	18	20	4	<i>K. oxytoca</i>
7	Stool	36	F	15	8	8	12	0	15	23	23	<i>K. oxytoca</i>
8	Urine	31	F	18	17	29	28	13	25	27	12	<i>K. oxytoca</i>
9	Urine	70	F	18	9	9	10	0	24	18	13	<i>K. oxytoca</i>
10	Urine	65	F	11	20	25	18	24	0	25	14	<i>K. oxytoca</i>
11	Stool	75	M	12	28	27	17	18	28	17	17	<i>K. oxytoca</i>
12	Urine	45	F	21	26	18	19	23	32	24	19	<i>K. ozaenae</i>
13	Stool	30	F	15	30	23	22	20	35	27	21	<i>K. oxytoca</i>
14	Urine	60	M	20	25	28	18	18	37	15	18	<i>K. ozaenae</i>
15	Urine	77	M	26	14	24	23	10	19	10	13	<i>K. oxytoca</i>
16	Urine	38	M	16	24	14	21	29	26	30	0	<i>K. oxytoca</i>
17	Urine	70	M	27	12	26	27	3	22	0	0	<i>K. pneumoniae</i>

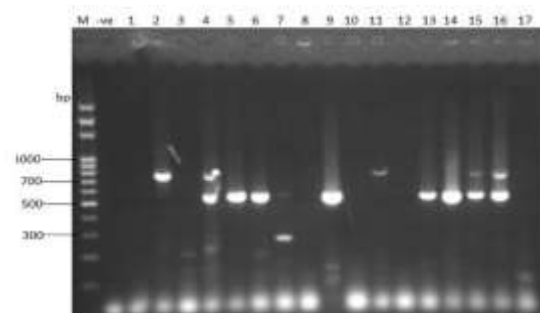
Key: CAZ (Ceftazidime; R, I, S= $\leq 17, 18-20, \geq 21$), CRO (Ceftriaxone; R, I, S= $\leq 22, 23-25, \geq 26$), CTX (Cefotaxime; R, I, S= $\leq 22, 23-25, \geq 26$), AMC (Amoxicillin-Clavulanic acid; R, I, S= $\leq 13, 14-17, \geq 18$), ATM/ CXM (Aztreonam/ Cefuroxime; R, I, S= $\leq 17, 18-20, \geq 21$), MEM (Meropenem; R, I, S= $\leq 19, 20-22, \geq 23$), CIP (Ciprofloxacin); R, I, S= $\leq 15, 16-20, \geq 21$, CN (Gentamicin; R, I, S= $\leq 10, 13-14, \geq 15$). R=Resistant; I=Intermediate; S=Sensitive.

In the case of carbapenemase production, 5 (29.4%) out of 17 (36.1%) isolates were positive. They were 1 (5.9%) *Klebsiella pneumoniae* and 4 (23.5%) *Klebsiella oxytoca*. The antibiotic susceptibility profile of the organisms showed varying degrees of Multidrug Resistance among the isolates as shown in Figure 1. *Klebsiella pneumoniae* showed complete resistance to aztreonam/ cefuroxime (100%) and it was absolutely susceptible to ciprofloxacin (0%). *Klebsiella pneumoniae* was resistant to ceftazidime (50%), ceftriaxone (50%), cefotaxime (50%), meropenem (50%), amoxicillin-clavulanic acid (50%) and gentamicin (50%). *Klebsiella ozaenae* was absolutely resistant to aztreonam/cefuroxime (100%) and absolutely susceptible to amoxicillin-clavulanic acid (0%), meropenem (0%) and gentamicin (0%). *Klebsiella ozaenae* was also resistant to ceftriaxone (50%), ceftazidime (50%), cefotaxime (50%) and ciprofloxacin (50%). *Klebsiella oxytoca* showed high level of resistance to ceftazidime (84.6%) and it was susceptible to meropenem (30.7%). It was also resistant to ceftriaxone (76.9%), cefotaxime (76.9%), aztreonam/cefuroxime (61.5%), amoxicillin-clavulanate (38.5%), ciprofloxacin (53.8%) and gentamicin (46.1%).

Figure 1. Antibiotic susceptibility profile of the ESBL producing *Klebsiella* spp.


Key: CAZ = Cefotaxime, CRO = Ceftriaxone, CTX = Cefotaxime, ATM/CXM = Aztreonam/ Cefuroxime, MEM = Meropenem, CIP = Ciprofloxacin, CN = Gentamicin.

Genotypic characterization of the isolates was performed by Multiplex PCR and specific primers such as: SHV, TEM and CTX-M were used to detect the genes responsible for ESBL resistance. Figure 1 shows CTX-M gene distribution among ESBL producing isolates. Multiple genes were detected in 3 (27.3%) of the isolates which possessed both *bla*_{CTX-M} and *bla*_{SHV}. However, 6 (54.5%) possessed only *bla*_{CTX-M}. Two (18.2%) possessed only *bla*_{SHV} consisting of 1 (50%) *K. pneumoniae* and 1 (50%) *K. oxytoca* as shown in Table 2. However, no TEM gene was displayed by any of the isolates in this study.

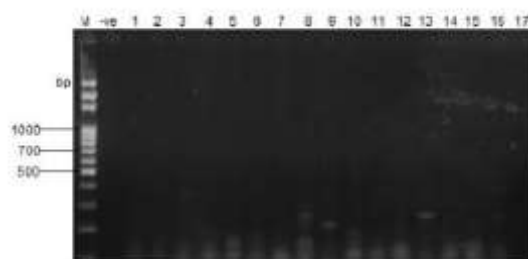
Figure 2. Gene Distribution among ESBL producing isolates.


Lane M: DNA Marker (100bp), Lane -VE: Negative Control, Lane 1-17: Test organisms, Lane 5, 6, 7, 9, 13, 14: CTX-M positive, Lane 2 and 11: SHV positive, Lane 4, 15 and 16: CTX-M and SHV positive.

Table 2. Genotypic characterization of ESBL and Carbapenemase genes

S/N	Organisms	ESBL genes	KPC & OMP
1	<i>Klebsiella pneumoniae</i>	-VE	-VE
2	<i>Klebsiella pneumoniae</i>	-VE	+VE (KPC)
3	<i>Klebsiella pneumoniae</i>	-VE	+VE (KPC)
4	<i>Klebsiella pneumoniae</i>	-VE	+VE (KPC)
5	<i>Klebsiella pneumoniae</i>	-VE	+VE (KPC)
6	<i>Klebsiella pneumoniae</i>	-VE	+VE (KPC)
7	<i>Klebsiella pneumoniae</i>	-VE	-VE
8	<i>Klebsiella pneumoniae</i>	-VE	+VE (KPC)
9	<i>Klebsiella pneumoniae</i>	-VE	+VE (KPC)
10	<i>Klebsiella pneumoniae</i>	-VE	-VE
11	<i>Klebsiella pneumoniae</i>	-VE	+VE (KPC)
12	<i>Klebsiella pneumoniae</i>	-VE	+VE (KPC)
13	<i>Klebsiella pneumoniae</i>	-VE	+VE (KPC)
14	<i>Klebsiella pneumoniae</i>	-VE	+VE (KPC)
15	<i>Klebsiella pneumoniae</i>	-VE	+VE (KPC)
16	<i>Klebsiella pneumoniae</i>	-VE	+VE (KPC)
17	<i>Klebsiella pneumoniae</i>	-VE	-VE

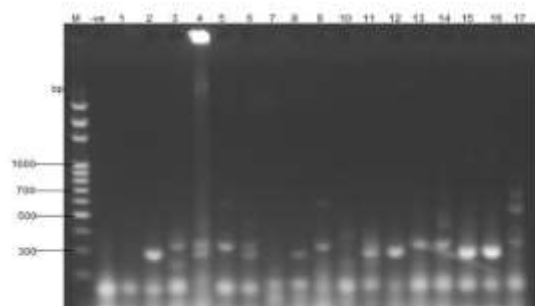
Also using Multiplex PCR the genes responsible for Carbapenem resistance was also determined using primers such as OXA-48 and IMP. However, no gene was detected for these primers (Figure 3.0. Plate 2).

Figure 3. Plate 2.0: Gene distribution among Carbapenemase producing isolates


Lane M: Marker (100bp), Lane -VE: Negative control, Lane 1-17: Test organisms (All negative)

Additionally, KPC primers were used to determine the other causes of Carbapenem resistance. Plate 3 revealed that out of 17 (36.1%) isolates, only 13 (76.5%) exhibited the KPC gene which were 1 (7.69%) *Klebsiella pneumoniae*, 2 (15.4%) *Klebsiella ozaenae* and 10 (76.9%) *Klebsiella oxytoca*.

Figure 4. Gene distribution among KPC (*Klebsiella pneumoniae* carbapenemase) producing isolates



Lane M: Marker (100bp), Lane –VE: Negative control, Lane 1-17: Test organism, Lane 2, 3, 4, 5, 6, 8, 9, 11, 12, 13, 14, 15, 16: KPC +ve

4. Discussion

The types of Extended Spectrum Beta-Lactamase (ESBL) in Ikeja, Lagos community is now recognized. ESBL are plasmid mediated bacterial enzymes typically found in enteric Gram negative important pathogens involved in nosocomial infections. They are able to hydrolyse a wide range of beta-lactam antibiotics including third and fourth generation cephalosporins (Rahal, 2000). The widespread use of broad spectrum beta-lactam antibiotics has led to a marked increase in the incidence of ESBL producing Gram negative microbe especially *Klebsiella* spp. (Shakil et al., 2010). This study was carried out to determine the presence and prevalence of these enzymes among isolates obtained from Ikeja, Lagos community. From the result obtained in this study, greater part of the organisms were least resistant to meropenem. *Klebsiella pneumoniae*, *Klebsiella oxytoca* and *Klebsiella ozaenae* showed 5.9%, 23.5%, and 0% resistance to meropenem respectively. This result obtained from *K. pneumoniae* is consistent with the findings of Abdullah and colleagues (Abdullah et al., 2015) which had a resistance of 4% while the result obtained from *K. oxytoca* is similar to the report by Shakti and associates (Shakti et al., 2014) which had a prevalence of 23% against meropenem. The reason of low rate of resistance to meropenem could be that the drug has not been used extensively in this community. This study also revealed that most of the isolates were resistant to ceftazidime and this agrees with the study of Rabindra and colleagues (Rabindra & Sibnarayan, 2014) which reported ceftazidime resistance rates of 59% in *Klebsiella pneumoniae*, 48% in *Klebsiella ozaenae* and 76% in *Klebsiella oxytoca* from a community in

India. In previous years, no ceftazidime resistance was detected in isolates of *K. pneumoniae*, *K. ozaenae* and *K. oxytoca* isolated from a Chicago hospital, however, in recent times, 27% of these isolates were resistant to ceftazidime (Shakti et al., 2014). The result from this study showed high carriage of CTX-M gene (54.5%) in *K. pneumoniae*, *K. oxytoca* and *K. ozaenae*. This is contrary to the findings of Maninder and Aruna (Maninder & Aruna, 2013) which had a prevalence of 25% of CTX-M among ESBL positive *Klebsiella* spp. From this study, CTX-M and SHV genes were observed in 27.3% of all the isolates obtained. This is contrary to that reported by Maninder and Aruna (Maninder & Aruna, 2013) that showed a prevalence of 12.5% among their isolates. This shows the continued increase and high dissemination of genes responsible for resistance in the community. Also, this study revealed a prevalence of 76.5% of *bla*_{KPC} gene in *K. pneumoniae*, *K. ozaenae*, *K. oxytoca* and this contradicts the findings of Masoume and colleagues (Masoume, 2015) that recorded no presence of *bla*_{KPC} in any of their isolates. Interestingly, this study recorded no presence of the TEM gene in any of the isolates.

5. Conclusion

The results obtained from this study shows that ESBL resistance is on the rise not only among *Klebsiella* species. Their genes which are plasmid borne are easily transferred through horizontal gene transfer and could pose serious threats to global health. Therefore, the identification and treatment of patients infected with these organisms is of prime necessity.

6. Acknowledgement

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Load Profiles in Grid-Connected Residential Buildings: Experimental Studies with Rooftop PV and Battery Systems

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Abstract

The number of photovoltaic (PV) installation in many countries has increased in the past decades. The advantages of energy from PV consists of reduction of CO₂ emission, low maintenance cost, low operation cost, etc. On the other hand, the main problems of this technology consist of: (1) electrical power is relatively fluctuated and (2) the excessive energy from PV generating cannot be stored for any use in another necessary time. One of the solving solution is the integration of the PV systems with battery systems to keep the system stability. Moreover, the reduction of battery price leads the electricity users interest in the installation of battery systems with rooftop PV on their buildings. In the past, a number of works studied on PV systems with integrated batteries as the off-grid systems and evaluated by simulation programs. In this work, the load profiles of buildings in different categories (i.e. households, small offices, and home offices) of residential section are discussed. The characteristics of load profiles in residential buildings installed with a grid-connected rooftop PV system with batteries are analyzed by physical experimentations. It was found that battery systems were significantly affected the load profiles of the residential buildings. Household was found to be the highest proportion (21.68%) of excessive electricity. The ratio of PV met to load (29.15%) was smaller than the ratio of battery charging (50.17%). In addition, the excessive electricity in small office was the lowest proportion (10.39%), while the ratio of PV met to load (57.83%) was higher than the battery charging (31.78%).

Keywords: Load profile, Residential building, Rooftop PV, Battery system

1. Introduction

Nowadays, the world needs more energy to supply the increase of energy demand due to the activities of users. Renewable energy is important for reducing the proportion of electricity generated from fossil fuel sources (Shah, Mithulananthan, Bansal, & Ramachandaramurthy, 2015). The progress of global installed photovoltaic (PV) capacity had been increased significantly from 2000 to 2014 (Haque & Wolfs, 2016). Moreover, according to the strategies plan of renewable energy, Thailand will have a total energy from renewable sources of 19,684 MW in 2036 (20.11% of the total energy). PV will be installed in Thailand for 6,000 MW (30.5% of the total

renewable energy sources) (Department of Renewable Energy Development and Energy Efficiency, 2015).

Nonetheless, one of the limitations of solar source was the fluctuation of the energy generation because solar arrays produce electricity depending on many factors, i.e. solar radiation, shading, temperature, etc. In case of many countries, the system with rooftop PV was connected with utility grid making electricity can be exchanged between household and utility grid. In Thailand, according to the rules of connection rooftop PV to utility grid between customers and Metropolitan Electricity Authority (MEA) or Provincial Electricity Authority (PEA), the household that equipped with

rooftop PV were forced to installed the protection relay (reverse power relay) to check the direction of electrical power. For this reason, they can receive the electricity from the grid only. They cannot feed the excessive electricity to the grid due to the stability issue of MEA or PEA systems. One of the solutions to solve this problem is installation of battery systems for electrical storage (Watson et al., 2016). Price reduction of battery systems was significant impact for installation in buildings (Posada et al., 2017). According to a fact sheet of energy storage market in Germany, the cost of battery system was reduced every year from 2011 to 2018, that was opposite from the trend of electricity tariff. For this reason, residential buildings installed with rooftop PV and battery systems are chosen to criticize and analyze about the influence of load profiles in this work.

The previous works studied on PV systems with energy storage in the parts of optimization in the energy storage systems (Lorenzi & Silva, 2016; Opiyo, 2016; Quoilin, Kavvadias, Mercier, Pappone, & Zucker, 2016; Shen, 2009), modelling the idealized load profiles (Beck, Kondziella, Huard, & Bruckner, 2016; Treado, 2015) and creating a simulation in software (Ogunjuyigbe, Ayodele, & Oladimeji, 2016). For examples; Quoilin et al. (2016) evaluated the level of self-consumption for buildings with rooftop PV and battery systems. They created a database of profiles from monitoring data and generated the household profiles. They reported that: (1) self-consumption is a non-linear function between rooftop PV and battery system size and (2) the situation of high penetration of rooftop PV may lead to unfair distribution of network charges and taxes which consumers do not have to pay.

In this work, residential buildings equipped with rooftop PV and battery systems in a grid-connected mode was studied. The physical experimentations at King Mongkut's University of Technology Thonburi (KMUTT), Bangkhuntien campus, was installed and investigated. Three different characteristics of residential sections were focused. The differences of this study from the previous works are: (1) other works focused on other groups of electricity users (e.g. Quoilin et al. (2016) investigated and criticized on the load profiles of medium general service); (2) other works studied and analyzed by the simulation data, not actual recording data from experimental site (Quoilin

et al., 2016; Treado, 2015; Ogunjuyigbe et al., 2016); and (3) the strategies related with time of use (TOU) rate were analyzed on residential section equipped with rooftop PV and battery systems in this work.

2. Methodology

2.1 The experimental site

A terrace of a building of Faculty of Media Art located at KMUTT, Bangkhuntien campus (13.5773° N, 100.4414° E), was used for creating the experimental site for the investigation. The terrace of this building was approximately 25 m in height from the ground floor. Figure 1 illustrates the area of terrace of building. It was equipped with 2.4-kW rooftop PV systems. The specification of PV arrays was Solartron rooftop PV panels (SP130E, 130-Watt) with a Leonics hybrid inverter (S-219C ia, 5,000-Watt). Figure 2 shows a diagram of the rooftop PV electrification system in the modelled building. This system was connected to the utility grid, that means this building can exchange electricity from the grid. The significance of the study in this building is the proportion of the electricity distributed to or received from the utility grid.

According to load profiles of the residential building provided by Thailand Provincial Electricity Authority (PEA), the peak of electrical power is approximately 1.7 kW, whereas rooftop PV can generate electrical power of about 1.5-2 kW due to the density of solar radiation. All remaining electricity cannot be sold to the utility grid due to the regulation of the utility authority. If this system is equipped with the battery storage system, it will back up electricity for uses in nighttime. According to TOU time table, customers must pay the monthly bill in two different rates: a peak time (09:00 a.m.-10:00 p.m. on Monday-Friday) and an off peak time (10:00 p.m.-09:00 a.m. on Monday-Friday and 24 hours on Saturday-Sunday) as shown in Table 1. In this work, the strategies to allocate the load profiles were created and related to the structure of electricity tariff in TOU rate. At daytime, rooftop PV can produce the electricity to charge the battery and feed to load for reducing the electricity proportion from grid. However, small office and home office may consume the electricity from grid due to more activities in daytime (peak rate). At nighttime

(07.00 p.m.-10.00 p.m.), battery systems were discharged by electrical load because this time was peak rate and the high consumption in household and home office.

Table 1. The electricity tariff in TOU rate.

Consumption/voltage	Energy charge (THB/kWh)		Service charge (THB/month)
	Peak	Off peak	
At voltage level lower than 22 kV	5.7982	2.6369	38.22



Figure 1. Terrace of the experimental building at KMUTT, Bangkhuntien campus.

A hybrid inverter (grid-connected type, 5 kW) and lead (Pb) acid deep-cycle batteries (125 Ah, 48 V) were equipped to the existing rooftop PV arrays (2.4 kW) on the terrace of building. All devices were connected to the utility grid and household loads. Three main characteristics of residential buildings, *i.e.* households, small offices, and home offices were studied by recording the data every minutes.

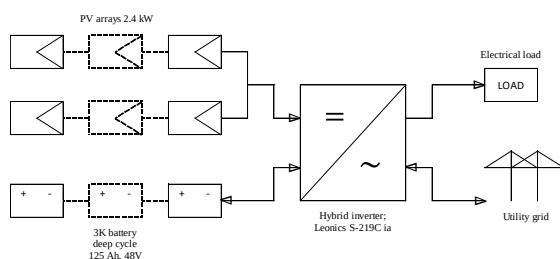
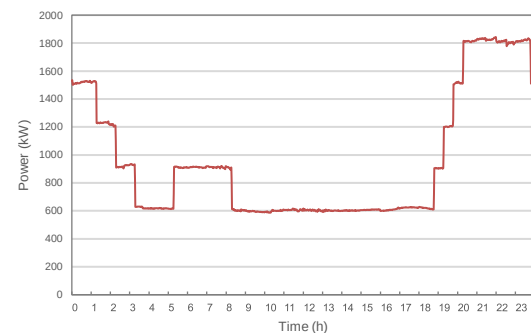


Figure 2. Schematic diagram for installations of experimental equipment.

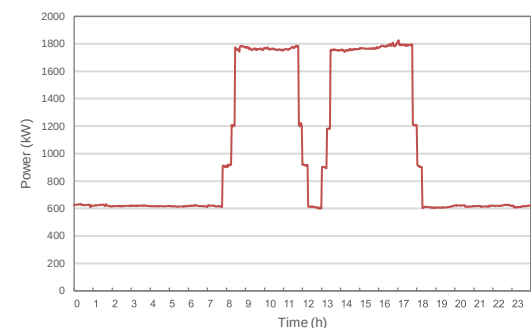
2.2 Differences of load profiles in residential buildings

Different sections of electricity uses have different characteristics, depending on the activities of electricity customers. The cases of residential

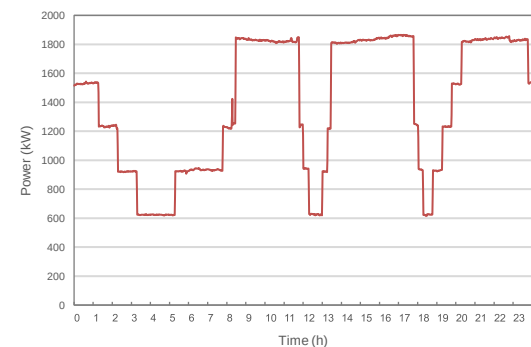
section of Thailand were used in this works. In this work, load profiles of the residential buildings were focused. Residential buildings mean households and other dwelling places, monasteries, houses of priest, and religion places of worship through a single watt-hour (Wh) meter. Figure 3 illustrates load profiles of residential buildings, including (1) households, (2) small offices, and (3) home offices. Households are the residential buildings that are used for stays only. Some residential buildings are used as small offices (for works only), while some buildings are used as home offices (for works and stays). The load profiles were produced based on the data of PEA, Thailand (Provincial Electricity Authority, 2015).



(a)



(b)



(c)

Figure 3. Load characteristics of residential buildings: (a) household, (b) small office, and (c) home office.

Load profile of household has high volume of electricity consumption in morning and evening (Figure 3(a)). Peaks of consumption rises around 20:00-23:00. According to Table 2, household load profiles has the proportion of night-time load (62.45%) more over than day-time load (37.55%). The characteristic of small office load profile looks like an actual office, i.e. high concentration of electricity consumption occurs in two periods, 08:00-12:00 and 13:00-17:00 (Figure 3(b)). In this group, the proportion of day-time load (74.90%) is higher than night-time load (25.10%) around 50%. Anyway, small offices have lower electricity consumption than the actual offices due to the ratio of quantity of electrical devices and people. Nonetheless, the characteristic of home office load profile is the combination between the load profiles of household and small office. There are two behaviors of electrical loads, (1) day-time loads from the activities that are same as the small office load profile and (2) night-time loads that are same as the household load profile (Figure 3(c)). Moreover, home office has the proportion of day-time load (64.87%) more than night-time load (35.13%) as shown in Table 2.

Table 2. The proportion of power consumption in three categories of residential buildings.

Parameter	Proportion (%)		
	Household	Small office	Home office
Day-time load	37.55	74.90	64.87
Night-time load	62.45	25.10	35.13

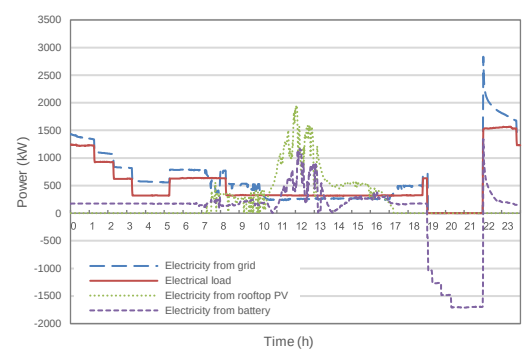
3. Results and Discussion

According to the recent situation of some countries, including Thailand, (1) the trend of installation of rooftop PV has increased rapidly and (2) rooftop PV with battery system was not allowed to equipped in grid connected mode for exchanging electricity with the authorities [PEA or Metropolitan Electricity Authority (MEA) in case of Thailand] due to the regulations of electrical utilities. This work was carried out to create a mini grid to investigate the influence of the installation of rooftop PV with battery systems.

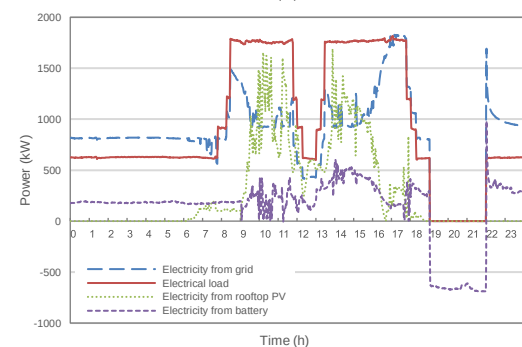
Treado (2015) studied various models of PV equipped with or without battery storage system. The differences between the previous work and this work consist of: (1) day-time and night-time loads were created by constant values of load profiles for simulation in a software in the previous work,

while the physical experimentations of rooftop PV equipped with battery systems were carried out and the actual data from measurement was investigated in this work; and (2) the parameters in the previous report focused on times of electrical loads and various PV efficiencies, while the changes of load profiles were realized in this work, because the specific parameters affected to the characteristic of the load profiles.

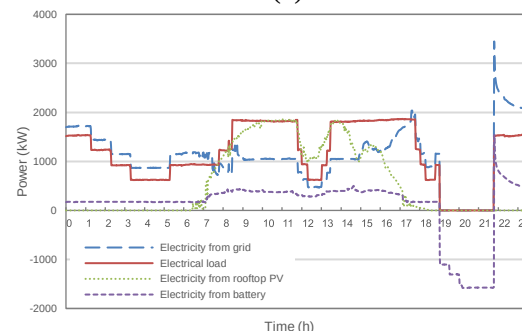
In Figure 4, the behaviors of load profiles installed with rooftop PV and battery systems are illustrated in term of the electrical power flow.



(a)



(b)



(c)

Figure 4. Electrical load profiles in residential buildings installed with rooftop PV and battery systems in (a) households, (b) small offices, and (c) home-offices.

Load profiles of three categories of residential buildings (—) were generated from the actual data based on PEA load profiles; i.e. household (Figure 4(a)), small office (Figure 4(b)), and home office (Figure 4(c)). The electricity generated from rooftop PV (.....) slightly increased due to solar radiation around 07:00 and met to load around 10:00. The excessive electricity was found in afternoon with the proportion of electrical consumption in each category. The fluctuation of the electricity generation of rooftop PV occurred around afternoon and directly affected the battery charging. The electrical power that consumed from the utility grid (—) slightly increased and varied by each type of residential buildings. Moreover, the surplus of electricity from the utility grid occurred due to the proportion of battery charging at night time. In day time, the battery charging (---) depended on the power generation from rooftop PV around 08:00-16:00 and the proportion of electricity from the utility grid decreased from night time. Besides, household has the highest proportion of battery charging compared with small office and home office, because of the number of day-time load. The excessive electricity had the inverse ratio with electricity charging to battery. The electricity from battery systems was discharged at 19:00-22:00. This proportion was fed to electrical load at 22:00 because of the reduction of the number of peak load to help the utility grid. Afterwards, the majority part of electricity to feed load came from the utility grid till morning time.

The power consumptions in three types of residential buildings are shown in Table 3. The excessive electricity in households was the highest proportion (21.68%) due to the ratio of day-time load. Furthermore, the ratio of PV generated to load (29.15%) was smaller than the ratio of battery charging (50.17%). Household utilized the battery systems with high efficiency because of the characteristic of load profiles in this category. In addition, the total electrical power can be calculated from Equation (1):

$$P_{Load}(t) = P_{PV}(t) + P_{Battery}(t) + P_{Grid}(t) \quad (1).$$

Table 3. The proportion of power consumptions in three types of residential buildings.

Parameter	Proportion (%)		
	Household	Small office	Home office
PV to load	29.15	57.83	51.09
PV to battery	50.17	31.78	29.23
Excessive electricity	20.68	10.39	19.68

In small office, the excessive electricity in this category was the lowest proportion (10.39%) because of a lot of day-time load. On the other hand, the ratio of PV generated to load (57.83%) was more proportion than the battery charging (31.78%). In this sense, the battery system in small office was less significant compared with household and home office.

According to TOU rate, the net savings with this strategy can be calculated by System Advisor Model (SAM). Net savings with strategy are the differences between costs without strategy (using battery for emergency only) and with strategy. Household and home office gain more net savings than small office as shown in Table 4 because the proportions of electrical consumption in two sections are higher than small office at 07:00 p.m.-10.00 p.m. that matched with the battery discharge to reduce the load profiles in each section.

Table 4. Net saving with strategy.

Sections	H	SO	HO
Net savings with strategy (THB)	4,938	4,211	4,986

*H is household, SO is small office, and HO is home office.

4. Conclusion

One of the solution to solve power fluctuation in PV rooftop system is the installation of a battery system. This solution will stabilize the energy and quality of the electrical power. This work aims to allocate the highest efficiency of energy consumption. The characteristics of load profiles of the residential buildings (i.e. household, small office, and home office) equipped with rooftop PV with battery systems are focused. Household showed the highest proportion of surplus electricity (20.68%) and the largest battery charging from PV (50.17%) due to the number of day-time load. In this sense, battery systems in household are significant more than that in small office and home office. The day-time load in the small office (74.90%) and the home office (64.87%) is more than household (37.55%), so

the proportion of PV feeding to load is higher than household. Moreover, net savings with strategy in household and home office show the interesting point of this strategy. In the future, the technologies of battery systems will be researched and developed. An installation of battery systems on buildings equipped rooftop PV will be more interesting, because of stability and sustainability of the systems.

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