KEMENTERIAN PENDIDIKAN MALAYSIA

FINAL REPORT
FUNDAMENTAL RESEARCH GRANT SCHEME (FRGS)

Laporan Akhir Skim Geran Penyelidikan Fundamental (FRGS)
Pindaan 1/2015

A

RESEARCH TITLE: Mechanism of Solar Radiation in Retarding the Bioactivity of Pharmaceutical Active Compounds (PhAs)

PHASE & YEAR: 3rd

START DATE: 1 May 2013
END DATE: 30 Apr 2015
EXTENSION PERIOD (DATE): RMC LEVEL: 1 May 2015- 31 Oct 2015 (6 months)
KPM LEVEL:

PROJECT LEADER: Prof. Norli Ismail
I/C / PASSPORT NUMBER: 710925-07-5562

PROJECT MEMBERS: 1. Quaik Shlrene
(including GRA) 2. Adel Ali Saed Abduh

PROJECT ACHIEVEMENT *(Prestasi Projek)*

B

ACHIEVEMENT PERCENTAGE			
Project progress according to milestones achieved up to this period	**0 - 50%**	**51 - 75%**	**76 - 100%**
Percentage (please state #%)			100

RESEARCH OUTPUT		
Number of articles/ manuscripts/ books *(Please attach the First Page of Publication)*	**Indexed Journal**	***Non-Indexed Journal***
	3	1
Conference Proceeding *(Please attach the First Page of Publication)*	**International**	***National***
	1	
Intellectual Property *(Please specify)*		

HUMAN CAPITAL DEVELOPMENT					
Human Capital	**Number**				**Others** (please specify)
	On-going		**Graduated**		
Citizen	Malaysian	Non Malaysian	Malaysian	Non Malaysian	
No. PHD STUDENT	1			1	
Student Fullname: IC / Passport No: Student ID:	QUAIK SHLRENE 860424235592 (Not yet registered)			Adel Ali Saed Abduh	
No. MASTER STUDENT					
Student Fullname: IC / Passport No: Student ID:					
No. UNDERGRADUATE STUDENT			1		
Student Fullname: IC / Passport No: Student ID:			Aisyah Molhit		
Total	1		1	1	

EXPENDITURE *(Perbelanjaan) as Borang K1(RMC)*

C

Budget Approved *(Peruntukan diluluskan)* : **RM 99400.00**
Amount Spent *(Jumlah Perbelanjaan)* : **RM 99279.06**

Balance *(Baki)* : **RM 120.94**
Percentage of Amount Spent *(Peratusan Belanja)* : 99.87 %

ADDITIONAL RESEARCH ACTIVITIES THAT CONTRIBUTE TOWARDS DEVELOPING SOFT AND HARD SKILLS
(Aktiviti Penyelidikan Sampingan yang menyumbang kepada pembangunan kemahiran insaniah)

D

International

Activity	Date (Month, Year)	Organizer
1) 4th ICERT 2015 (International Conference on Environmental Research and Technology, Parkroyal Resort Penang	27-29 May 2015	School of Industrial Technology, Universiti Sains Malaysia
2) BECY Network Meeting 2015 "Strategies for Knowledge-Driven Developments in the Bioeconomy" of the Strategic Network Bio-based Economy (BECY)	29 Sept. – 1 Oct. 2015	University of Hohenheim, Germany,

National

Activity	Date (Month, Year)	Organizer

E	**PROBLEMS / CONSTRAINTS IF ANY** *(Masalah/ Kekangan sekiranya ada)*
F	**RECOMMENDATION** (*Cadangan Penambahbaikan*)
	Various pre-treament may be applied to decrease the turbidity of sample which will further enhance the effectiveness of solar radiation treatment in removal of bacteria. More experiment and treatments should be carried out in investigating the effectiveness of disinactivation and removal of antibiotics via solar disinfection.
G	**RESEARCH ABSTRACT – Not More Than 200 Words** (*Abstrak Penyelidikan – Tidak Melebihi 200 patah perkataan*)
	Solar radiation exhibited positive impact towards removal of total bacteria count (TBC). Our research has indicated that removal of more than 4 $\log_{10}$ colony forming units (CFU)/100 mL for fecal coliforms (FC), Salmonella spp. and S. aureus after 6 hours of SODIS treatment in secondary effluents and lake water. No re-growth was observed for 8 hours of SODIS treatment in these samples. Antibiotic susceptibility test was carried out in reference to disk diffusion test method that stated in Clinical and Laboratory Standards Institute (CLSI) with antibiotics disks of different groups of antibiotics purchased from vendors. Selected antibiotics of interest were ciprofloxacin, gentamicin, erythromycin, tetracycline, penicillin, cephalexin and amoxicillin.Direct colony suspension method was used on Muller Hinton Agar. Isolates from the sample wastewater were all tested in the antibiotic susceptibility test. Isolates from differential and selective agar (EMB and MacConkey) showed resistance towards selected antibiotics. However, removal of the antibiotic resistant bacteria isolates was still promising for treatment of more than 6 hours. Dark and reflective surfaces were also applied during the experiments to study the potential of decresing the exposure time for the same effectiveness. However, more experiment should be carried out in investigating the effectiveness of disinactivation and removal of antibiotics via solar disinfection.
	Date : 1 Februari 2016 *Tarikh* **Project Leader's Signature:** *Tandatangan Ketua Projek*
H	**COMMENTS, IF ANY/ ENDORSEMENT BY RESEARCH MANAGEMENT CENTER (RMC)** *(Komen, sekiranya ada/ Pengesahan oleh Pusat Pengurusan Penyelidikan)*
	.... PROF. DR LEE KEAT TEONG Director Research Creativity & Management Office Universiti Sains Malaysia **Name:** *Nama:* **Signature:** *Tandatangan:* 4/2/16 **Date:** *Tarikh:*

Tarikh Cetakan : 02/02/2016

UNIVERSITI SAINS MALAYSIA

JABATAN BENDAHARI

PENYATA PERBELANJAAN SEHINGGA 31 OKTOBER 2015

Projek : MECHANISM OF SOLAR RADIATION IN RETARDING THE BIOACTIVITY OF PHARMACEUTICAL ACTIVE COMPOUNDS (PHACS)
KETUA PENYELIDIK : PROFESOR MADYA NORLI ISMAIL
PENYELIDIK BERSAMA : -
TEMPOH : 01 MEI 2013 HINGGA 30 APRIL 2015 (LANJUTAN SEHINGGA 31 OKTOBER 2015)
PUSAT PENGAJIAN TEKNOLOGI INDUSTRI

No. Akaun : 203.PTEKIND.6711328.

Vot	Nama Vot	Peruntukan Projek	Perbelanjaan Terkumpul Sehingga Thn Lalu	Baki Peruntukan Tahun Lalu	Peruntukan Thn Semasa	Jumlah Peruntukan Thn Semasa	Tanggungan Semasa	Bayaran Thn Semasa	Jum Belanja Thn Semasa	Baki Projek
111	GAJI	28,500.00	0.00	28,500.00	0.00	28,500.00	0.00	0.00	0.00	28,500.00
221	PERJALANAN DAN SARA HIDUP	7,800.00	2,211.60	5,588.40	0.00	5,588.40	0.00	4,817.83	4,817.83	770.57
224	SEWAAN	400.00	105.30	294.70	0.00	294.70	0.00	0.00	0.00	294.70
227	BEKALAN DAN BAHAN LAIN	10,400.00	3,672.40	6,727.60	0.00	6,727.60	7,532.97	8,735.23	16,268.20	-9,540.60
228	PENYELENGGARAN & PEMBAIKAN KECIL	2,000.00	0.00	2,000.00	0.00	2,000.00	0.00	907.17	907.17	1,092.83
229	PERKHIDMATAN IKTISAS & HOSPITALITI	24,300.00	18,433.60	5,866.40	0.00	5,866.40	4,410.00	23,200.00	27,610.00	-21,743.60
335	HARTA MODAL	26,000.00	0.00	26,000.00	0.00	26,000.00	0.00	25,210.00	25,210.00	790.00
552	PERBELANJAAN LAIN	0.00	0.00	0.00	0.00	0.00	0.00	42.96	42.96	-42.96
	Jumlah	**99,400.00**	**24,422.90**	**74,977.10**	**0.00**	**74,977.10**	**11,942.97**	**62,913.19**	**74,856.16**	**120.94**

Elimination of enteric indicators and pathogenic bacteria in secondary effluents and lake water by solar disinfection (SODIS)

Adel A. S. AL-Gheethi, I. Norli and Mohd Omar Ab. Kadir

ABSTRACT

The reduction of enteric indicators (fecal coliforms (FC) and *Enterococcus faecalis*) and elimination of pathogenic bacteria (*Salmonella* spp. and *Staphylococcus aureus*) in the secondary effluents and lake water by solar disinfection (SODIS) was studied in this article. FC, *E. faecalis*, *Salmonella* spp. and *S. aureus* were isolated and enumerated using membrane filtration techniques after SODIS of samples inside transparent polyethylene terephthalate (PET) bottles for 1, 2, 3, 4, 5, 6, 7 and 8 h. The results show that SODIS can reduce numbers of FC, *Salmonella* spp. and *S. aureus* by more than 4 $\log_{10}$ colony forming units (CFU)/100 mL after 6 h. However, regrowth of these bacteria was observed after the incubation of the treated samples at 37 °C for 24 h, whereas SODIS for 8 h would eliminate pathogenic bacteria and no regrowth would be observed in these samples as determined by an absence and presence technique using enrichment medium. *E. faecalis* was not eliminated in the secondary effluents and lake water by SODIS, but this bacterium was reduced to less than detection limits (1 CFU/100 mL) when the treated secondary effluent samples were stored for 16 days at room temperature. The elimination of pathogenic bacteria and reduction of enteric indicators resulted in undetectable levels using SODIS for secondary effluents and lake water.

Key words | enteric indicator, pathogenic bacteria, regrowth, secondary effluent, solar disinfection, storage period

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INTRODUCTION

The rapid growth of communities and cities during the recent two decades has led to increased amounts of human wastes (domestic, industrial and hospital waste) and the need for these to be managed safely. In most poor communities, the most important pollutant that represents primary concern is human excreta (domestic sewage). It has been reported by the World Health Organization (WHO) that 3.2 million children under the age of five die each year in the developing world due to diarrheal diseases, mainly as a result of poor sanitation and contaminated drinking water (WHO 1992).

Primary and secondary processes of domestic sewage reduce pathogenic bacteria by 95–99%. However, secondary effluents still contain high concentrations of these pathogens in effluents even after sewage treatment (Koivunen & Heinonen-Tanski 2005). Thus, secondary effluents require various kinds of further treatment to reduce the density of pathogenic bacteria to ensure that favorable sanitary effluent quality is achieved. Disinfection emphasizes the reduction of pathogens to less than detectable limits and meets the requirements of environmental or microbiological requirements for effluent reuse.

Many technologies are used for disinfection of secondary effluents and reduction of microorganisms, such as chlorination (Coronel-Olivares *et al.* 2011), filtration

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However, no regrowth was observed of *Salmonella* spp. in samples treated by SODIS for the period of 8 h, and these results were confirmed by enrichment medium as described above under Materials and methods. Bosshard *et al.* (2009) suggest that a relatively small light dose is enough to irreversibly damage the cells of *Salmonella typhimurium* and that storage of bottles after irradiation does not allow regrowth of inactivated bacterial cells.

Regrowth of *S. aureus* in treated samples by solar radiation for 5 and 6 h was observed in up to 96 h incubation periods. The maximum regrowth of *S. aureus* was noted at 96 h incubation of samples at 37 °C, where 2.6 $\log_{10}$ CFU/100 mL was recorded (Figure 4). However, *S. aureus* was undetectable (<1 CFU/100 mL) in samples treated for 8 h of SODIS treatment. The absence of *S. aureus* was confirmed by using enrichment medium. Similar results were noted for *S. aureus* in gray water effluents treated by UV disinfection (Gilboa & Friedler 2008).

CONCLUSIONS

It can be concluded that SODIS of secondary effluents and lake water for 8 h is efficient at eliminating pathogenic bacteria and reduces enteric indicators to less than detection limits (<1 CFU/100 mL).

ACKNOWLEDGEMENTS

This work was supported by the Third World Organization for Academic Science (TWAS) and was funded by Universiti Sains Malaysia (USM). We gratefully thank the Universiti Sains Malaysia for their technical assistance and academic staff supervision.

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School of Industrial Technology

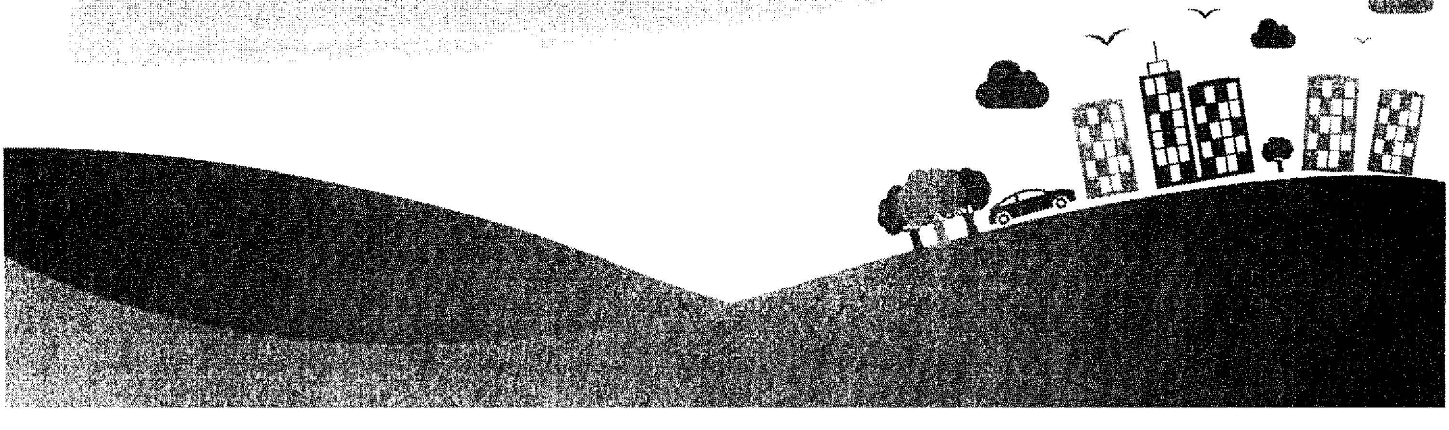
Proceedings of the 4th ICERT 2015

International Conference on Environmental Research and Technology

Exploring the Frontiers in Environmental Science and Technology Research

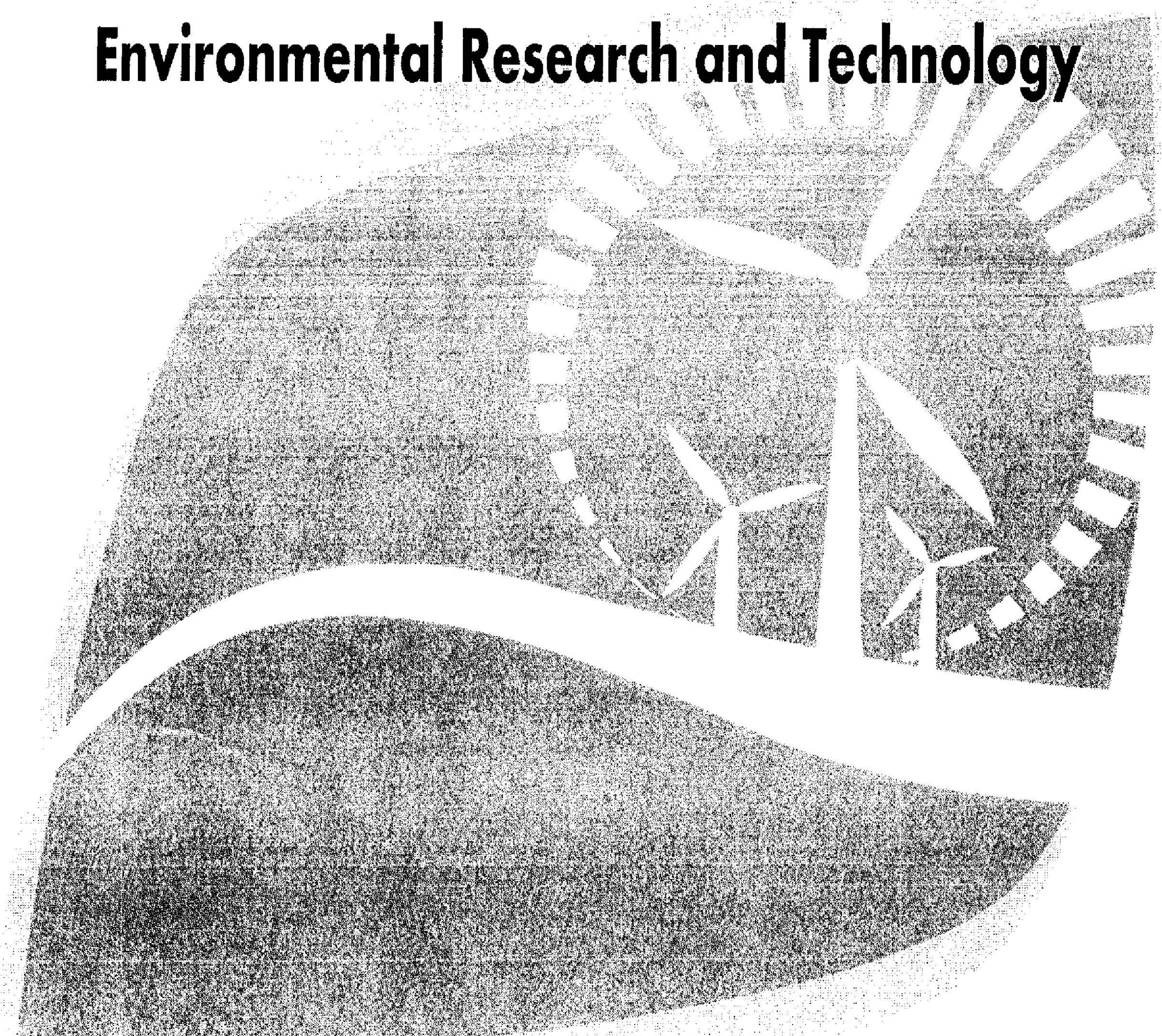
27 - 29 MAY 2015 PARK ROYAL Penang Resort Malaysia

EDITORS: Teng Tjoon Tow
Yusri Yusup
Widad Fadhlullah



4th ICERT 2015

International Conference on Environmental Research and Technology



"Exploring the Frontiers in Environmental Science and Technology Research"

27 - 29 MAY 2015, PARK ROYAL Penang Resort, Penang, Malaysia

KAMI MEMIMPIN

USM UNIVERSITI SAINS MALAYSIA

School of Industrial Technology

PREVALENCE OF ANTIMICROBIAL RESISTANCE BACTERIA IN NON-CLINICAL ENVIRONMENT

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ABSTRACT

The presence of antibiotic resistant bacteria in ambient waters has been documented. Of particular concern are not only that would expose to antibiotics during the humans and animals infections but also that have the ability to spread the resistance genes in among the environmental bacterial populations. The present study investigated the prevalence of antimicrobial resistance among pathogenic bacteria isolated from non-clinical environment included treated sewage effluents and surface water resource in Penang Malaysia. The sensitivity test for ampicillin, amoxicillin, tetracycline, ciprofloxacin and erythromycin was carried out by using the disk diffusion and culture based technique. About 82.13% of *Escherichia coli*, 78.56% of *Klebsiella pneumonia*, 80.94% of *Enterococcus faecalis* and 71.41 % of *Staphylococcus aureus* isolated from treated sewage effluents have multi-resistance for antibiotics including ampicillin, amoxicillin and erythromycin. *E. faecalis* and *S. aureus* isolated from surface water resource occurs some resistance to tetracycline and ciprofloxacin than *E. coli* and *K. pneumonia*. The antimicrobial resistance among bacterial population in treated sewage effluents and surface water resource reflects the availability antibiotics in these environments. The increasing of microbial resistance in the environment occurs as one of the eminent public health concerns and would effect on heath human in the future.

Keywords: Antibiotics, non-clinical environment, pathogenic bacteria, resistance.

INTRODUCTION

The over using of antimicrobial agents in the worldwide has led to occurrence of the antimicrobial resistance [1,2,3,4]. The release of antibiotic agents to the environment other than the excretion from human and animal, come from pharmaceutical industries and the dumping result of unused antibiotics [5,6,7,8]. Consequences of the bacteria resistance present in the aquatic environment will result in the resistance development impact and toxicity to aquatic communities as well as to the public health [7,9,10]. Many of antimicrobial resistant bacteria have isolated from the environment such as sewage effluents [11,12]. Al-Bahry et al. [13] have stated that most bacterial isolates obtained from sewage exhibit resistance to antibiotics. Börjesson [14] has indicated that the sewage treated effluents have high bacterial diversity, which constitutes a basis for the selection and spread of antibiotic resistance. However, the sewage treatment processes period might be not enough to develop the resistance to antibiotics or the transmission process of resistance genes among bacterial population. In surface water, the bacteria are surviving for long time, thus, antibiotics resistance among pathogens would be developed through the process known as natural selection due to the frequent expose of bacteria to the antibiotics. Therefore, the sensitive bacteria to antibiotic could acquire resistance through mutation of a genetic material, which called plasmids [15]. The plasmid is a small DNA molecule, which can replicate independently and contains resistance genes [16]. The Increasing multi-resistant bacteria might be due to transfer of resistance gene between bacterial populations [17-21]. Transmissions of resistance genes are more frequent in the environment that contains high bacteria diversity such as sewage (non-clinical environment). The resistance gene may be specialist to one antibiotic such as ciprofloxacin or group antibiotics such as β-lactams. Therefore, in the bacteria isolated from the environment should be tested for several antibiotics, regardless if some of these antibiotics are clinically using for the treatment of infections caused by these bacteria or not [22]. Besides, the method of antibiotics sensitivity test for pathogenic bacteria from clinical environment might be somewhat different from that obtained from non-clinical environment [23,24]. The present study investigated the prevalence of antimicrobial resistance among *E. coli, K. pneumonia, E. faecalis* and *S. aureus* from non-clinical environment in Penang Malaysia.

MATERIALS AND METHODS

Collection of samples

Treated sewage effluent and surface water samples were collected from different locations in Penang Malaysia as presented in Table 1.

Adel et al., Expert Opin Environ Biol 2015, 4:[illegible]
http://dx.doi.org/10.4172/2325-9[illegible]

Expert Opinion on Environmental Biology

Research Article | A SCITECHNOL JOURNAL

Removal of Cephalexin Antibiotic and Heavy Metals from Pharmaceutical Effluents using *Bacillus subtilis* Strain

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Rec date: Mar 23, 2015 **Acc date:** Apr 29, 2015 **Pub date:** May 03, 2015

Abstract

The rapid development of pharmaceutical industries resulted from producing huge amounts of pharmaceutical effluents. These wastes contain several types of toxins including heavy metals and pharmaceutical compounds, which have high toxicity for human and environment. The traditional technologies are not effective to remove both antibiotic compounds and heavy metals. Besides that, these techniques are associated with toxic by-products. Therefore, this study aimed to investigate the potential of *Bacillus subtilis* strain isolated from sewage effluent for the biodegradation of cephalexin and bioaccumulation of heavy metal ions simultaneously. The efficiency of *B. subtilis* to remove cephalexin and heavy metals was investigated by the inoculation 6 $\log_{10}$ CFU mL^{-1} of this strain into sewage effluents containing cephalexin and different concentrations of heavy metals to simulate the pharmaceutical effluents. The results revealed that *B. subtilis* removed 80% of Ni^{2+} ions, 85% of Cu^{2+} and Zn^{2+} ions, 66% of Pb^{2+} ions and 88% of Cd^{2+} ions as well as exhibited the potential to biodegrade of cephalexin by 27, 22 and 21% at 10 mg L^{-1} of Ni^{2+}, Cu^{2+} and Zn^{2+} ions. It can be concluded that *B. subtilis* strain might be used as an alternative technology for removing heavy metals and antibiotics from pharmaceutical effluents.

Keywords: Biodegradation; Bioaccumulation; Heavy metals; Pharmaceutical wastes; *Bacillus subtilis*

Introduction

The increasing pharmaceutical industries and chemotherapy treatments since 1950s has given raise to the discharge a huge amount of pharmaceutical wastes into the environment [1]. Pharmaceutical wastes contain organic compounds, total solids, pharmaceutical active compounds (PACs), heavy metals and other solvents [2-5]. Antibiotics and heavy metals are the most important due to ability of these pollutants to increase the antibiotics resistance among bacterial population in the environment [6-9]. Many of antibiotics resistant bacteria have been isolated from the environment [10,11]. Current treatment processes of effluents are insufficient to totally removing heavy metals and antibiotics [12-16]. The studies indicated that pharmaceutical effluents have contained wide range of antibiotic concentrations ranged from 14 mgL^{-1} of ciprofloxacin to 44 mg L^{-1} of Penicillin G [17,18] and in some cases has reached to 1065 mg L^{-1} of oxytetracycline [19]. According to Lin et al. [20] and Guo et al. [21] cephalexin has detected with high concentrations in the effluents. It was due to its resistance to degradation during the primary and secondary treatment processes. Ozonation [22] and UV irradiation [23] as advanced treatment are effective for degradation of antibiotics in the effluents. However, one of the main disadvantages of ozonation is the potential to produce by-products forms and their toxicity [24-27]. On the other hand, UV irradiation is less effective in effluents due to presence high particles that prevent the penetration of UV light through the effluents [28].

The pharmaceutical effluents also contains different types of heavy metals such as mercury, cadmium and zinc [2], Lokhande et al. [3] have revealed that pharmaceutical industries effluents have contained 35.8 and 33.6 mg L^{-1} of Cd^{+2} and Ni^{2+} respectively. However, these concentrations are less than that can be removed by adsorption and ion exchange processes, because these techniques are ineffective to remove heavy metals concentration in the range between 1 and 100 mg L^{-1} [29,30].

By all accounts, the ideal treatment process should comprise a simple treatment system that will not contain toxic by-products, fewer requirements of chemical additives, economical and has the ability to remove a wide range of the challenging contaminants only within one stage treatment process [31]. Therefore, the application of bio-augmentation processes as an alternative technology to remove heavy metals and antibiotics, are merited the study and research. Bio-augmentation process is defined as the utilization of microorganism for treatment of complex ecosystem. Some bacteria have the ability to adapt and live under the severe environment conditions such as presence of toxic heavy metals and antibiotics and might be used for the treatment process. Moreover, the choice of organisms is particularly important because of differences in their ability for growth, survival under extreme conditions and affinity for pollutants [32].

The pharmaceutical effluents may appear as a source of bacterial strains, which have high resistance for heavy metals and antibiotics. However, these bacteria are unsuitable to be used in the bio-augmentation process because the bacterial load in pharmaceutical effluents are those used during the biological activity tests conducted for pharmaceutical products, which are usually pathogenic in origin. Therefore, sewage effluents consider the appropriate source due to high diversity of non-pathogenic bacteria in these wastes, which might be used for bio-augmentation process without negative effects. Sewage effluents are also contains toxic metal ions [33] and antibiotics [34] that have excreted with humans faces and urine into sewage [35]. These pollutants may present in low concentration but it is enough to induce bacterial cells to acquire resistance against heavy metals and antibiotics. Various heavy metal and antibiotic resistant bacteria have been isolated from sewage effluents [36,37].

Bacterial cells have the ability to remove heavy metals by biosorption and bioaccumulation processes as well as have the potential to biodegrade antibiotics using β-lactamase. Therefore, these processes would be useful to remove both heavy metals and antibiotics in one stage. In the previous work [36,37] *B. subtilis* strain exhibited high efficiency to biosorption of heavy metals and biodegradation of antibiotics but each process was conducted separately. The novelty of appropriate to reuse for agricultural purpose. However, in this study, the biodegradation of cephalexin using *B. subtilis* was determined as a function of enzymatic biodegradation by β-lactamase. The results noted that the biodegradation was high at low concentrations of heavy metals indicating the ability *B. subtilis* to produce β-lactamase at heavy metal concentrations more than that remaining in the final effluents. The maximum biodegradation of cephalexin was in average 21%, which means that the final effluents still contains cephalexin with low concentrations of heavy metals. These characteristics are suitable to reuse these effluents for production of biogas and β-lactamase. The screening process conducted in previous work [36] revealed that *B. subtilis* strain exhibited the ability to use cephalexin as sole carbon source and produced detectable amounts of the enzyme in sewage effluents without nutrients. Therefore, the biomass yield during the previous treatment could be removed by filtration process and the supernatant would be reused as a production medium for biogas and β-lactamase production. β-lactamase has many of applications for instance, destruction of residual penicillins/ cephalosporin in body fluids, treatment of penicillin sensitivity reactions, penicillin electrodes and for drug design and the applications in antibody-directed enzyme pro-drug therapy [56].

Many investigators have reported the utilization of effluents as production medium for enzymes. Barros et al. [57] reused cassava wastewater as production medium for amylase, protease and lipase by *B. subtilis* strains. Al-Gheethi [58] recycled sewage sludge contaminated with nickel ions as production medium for the production of cellulase by *B. megaterium* strains. Both studies indicated that the bacteria produce detectable amounts of the enzymes in the comparison to the synthetic liquid medium. Regarding of biomass yield that contains bio-accumulated heavy metals, these biomass could be regenerated and reused again for the removal of heavy metals [37,59].

Finally, the bioaccumulation and biodegradation processes in a continuous-operating reactor may keep the bacterial growth at the highest stage of β-lactamase production and biomass yield. Thus, more heavy metals and antibiotics would be removed and the pharmaceutical effluents might meet the standards limits required for the disposal process. However, in the current study, the treatment of pharmaceutical effluents by using *B. subtilis* was conducted in the batch scale and the continuous-operating reactor will be conducted in the possible future work.

Conclusions

It can be concluded that, *B. subtilis* has the potential to remove cephalexin and heavy metals from sewage treated effluents in one stage. *B. subtilis* has also other advantages such as not expensive, eco-friendly, non-pathogenic, does not produce toxic by-products. Therefore, can be used as alternative advanced technology for sewage effluents before the land application or disposal.

Acknowledgements

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REVIEW

Removal of heavy metals and antibiotics from treated sewage effluent by bacteria

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Abstract The increased loads of antibiotics and heavy metals in sewage lead to bacterial cells acquiring resistance to both heavy metals and antibiotics. Therefore, these bacteria can play an important role for removal of pollutants from sewage. The utilization of the microbial processes such as biosorption and enzymatic biodegradation processes has increased during the recent years. These processes are significantly inexpensive and eco-friendly. Enzymatic techniques known as white biotechnology have the ability to degrade complex compounds. Hence, these can be applied to industrial processes. In the current review, the removal of heavy metals and antibiotics from treated sewage effluents by heavy metal/antibiotic-resistant bacteria will be discussed.

Keywords Heavy metals · β-Lactam antibiotics · Removal · Bacteria · Sewage effluents

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Introduction

A treated sewage effluent is the sewage generated from sewage treatment plant (STP). Sewage can be classified into three classes. These include domestic sewage that is identified as complex mixture containing organic and inorganic constituents and large numbers of bacteria (U.S. EPA 2003). Second, hospital sewage generated from the hospitals includes sewage and wastewater resulting from the cleaning of healthcare facilities. The hospital sewage consists of antibiotics and antibiotic-resistant bacteria (Pauwels and Verstraete 2006; Jury et al. 2010). Industrial wastewaters are identified as the third class, which include wastewaters associated with high concentrations of heavy metals and other constituents (Rao et al. 2012).

Sewage effluents are seriously contaminated with toxic metal ions., The most common are Zn^{2+}, Ni^{2+}, Cu^{2+}, Cd^{2+}, and Pb^{2+} (McLaren and Smith 1996). Ni^{2+} can cause stomach cancer, prostate, cavity and kidney diseases (Habib-ur-Rehman et al. 2006). Zn^{2+} is a toxic element with high-to-moderate importance as a trace element, and Cu^{2+} is not only an important metal for many organisms as cofactor, but is also very dangerous at high concentrations (Nies 1999). Cd^{2+} and Pb^{2+} are both classified as toxic metals (Nasrazadani et al. 2011).

Most antibiotics and their metabolites excreted by humans after administration, find their way into the sewage. However, more than 90 % of non- metabolized β-lactams are excreted through faeces and urine into sewage (Avisar et al. 2009). The sewage-treatment processes are insufficient to remove antibiotics. Many antibiotics have been detected in large quantities in sewage-treated effluents and activated sludge (Spongberg and Witter 2008). Cephalexin presents in sewage effluents in high concentrations due to its resistance to biodegradation (Lin et al. 2009; Guo et al. 2010).

Ragsdale (1998) described four nickel-containing enzymes; superoxide dismutase, carbon monoxide dehydrogenase, methyl-coenzyme-M reductase and acetyl-coenzyme A synthase. These enzymes were produced from *Streptomyces* species, *R. rubrum*, methanogenic bacteria and methogenic bacteria, respectively. Al-Gheethi (2014) investigated the enzymatic biodegradation of cephalexin in sewage effluents by *B. subtilis* 1556WTNC. The sewage effluents were contaminated with different concentrations of heavy-metal ions (Ni^{2+}, Cu^{2+}, Zn^{2+}, Cd^{2+} and Pb^{2+}). The results indicated that *B. subtilis* 1556WTNC exhibited the potential to biodegrade cephalexin by 27, 22 and 21 % at 10 mg L^{-1} of Ni^{2+}, Cu^{2+} and Zn^{2+} ions, respectively. *B. subtilis* 1556WTNC also removed 80 % of Ni^{2+} ions, 85 % of Cu^{2+} and Zn^{2+} ions, 66 % of Pb^{2+} ions and 88 % of Cd^{2+} ions. He concluded that *B. subtilis* 1556WTNC isolated from the sewage effluents possess an important potential to remove heavy metals and β-lactam antibiotics.

Conclusion

The developments of advanced treatment processes have recently attracted great interest. The advanced treatment processes should be a simple procedure, yield no toxic by-product, do not require chemical additives and economical. The microbial processes may play an important role in waste management. The utilization of the microbial process tools is rare, but the development of this biotechnology may be desirable from environmental and economic aspects. However, problems faced with the use of inoculated microorganisms in sewage-treated effluents are the insufficiency of substrate, competition between the introduced species and the indigenous biomass. Hence, the choice of organisms is particularly important because of differences in their abilities for growth and survival under extreme conditions and affinities for pollutants.

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Solar disinfection and lime stabilization processes for reduction of pathogenic bacteria in sewage effluents and biosolids for agricultural purposes in Yemen

Adel A. S. Al-Gheethi, Norli Ismail, A. N. Efaq, J. D. Bala and Ramzy M. A. Al-Amery

ABSTRACT

Yemen is the least advanced country among Middle Eastern countries in sewage reuse and safety control. The current sewage effluent quality in Yemen is generally poor as none of the existing sewage treatment plants produces effluents that comply with the effluent quality regulations. There is no plan to build tertiary treatment systems. However, the oxidation and stabilization ponds are considered most appropriate for the warm climate conditions in the country. Sewage effluents and biosolids generated from these ponds are used extensively for agricultural purposes. This review discusses the potential use of solar disinfection (SODIS) and lime treatment for the reduction of pathogens in sewage effluents and biosolids before reuse. SODIS and lime treatment are natural processes, simple, easily implemented, produce non-toxic by-products and are low cost. The merits of these processes are enormous, and they are suitable for application in developing countries such as Yemen.

Key words | biosolids, lime treatment, pathogenic bacteria, sewage effluents, solar disinfection, Yemen

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INTRODUCTION

Sewage effluent is the treated liquid that comes out of a treatment plant after completion of the treatment processes, while biosolids are the solid and semi-solid residues generated during the sewage treatment processes (US EPA 2009). Sewage treatment is a multistage process that ranges from a main process for the treatment of raw sewage to advance processes for removing pollutants that remain in secondary effluents (Gupta *et al.* 2000; Heritage *et al.* 2003).

In Yemen, oxidation and stabilization ponds are considered the most appropriate treatment system (UN 2012). There are 32 oxidation/stabilization ponds, 16 septic tanks, 5 Imhoff tanks, and only 2 sewage treatment plants (STPs) have activated sludge systems in the country (Figure 1). ACWUA (2010) and Al-Nozaily *et al.* (2012) have reported that the loading of these plants is greater than the designed capacity and hence the current sewage effluent quality in Yemen is generally poor as none of the existing STPs produces effluents that comply with the effluent quality regulations (UN 2012). The characteristics of the main STPs in Yemen are presented in Table 1.

The direct disposal of industrial wastewater to sewerage systems in Yemen leads to weak efficiency of STPs, due to increased concentrations of heavy metals and organic contaminants (UN 2012). Almost 164 factories in Sana'a, Yemen discharged untreated wastewater to STPs (IRIN 2009). Many STPs cannot eliminate heavy metals (ACWUA 2010). Also, wastewaters from hospitals, medical laboratories, and pharmaceutical factories in Yemen are discharged into the sewerage system (IRIN 2011). In Sana'a there are 75 hospitals, 34 clinical centers, and 7 pharmaceutical factories (National Information Centre 2011). The

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CONCLUSION

SODIS and lime stabilization are natural processes. These treatments are more suitable for application in developing countries, such as Yemen, with semi-arid to arid climates and that do not have the capacity for high-efficiency sewage treatment. Both treatments could reduce pathogens in sewage-treated effluents and biosolids generated from STPs effectively. SODIS and lime treatment are simple, easy implementable, produce no toxic by-products, and are cost-effective.

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Invitation Letter

Dear Colleagues,

On behalf of the University of Hohenheim, I would like to invite a delegation from the Science University Malaysia (USM), Malaysia, for the BECY Network Meeting 2015 "Strategies for Knowledge-Driven Developments in the Bioeconomy" of the Strategic Network Bio-based Economy (BECY) held at the University of Hohenheim, Germany, from September 29 – October 01, 2015.

The Strategic Network Bio-based Economy (BECY) co-ordinated by the University of Hohenheim, is a strategic network of six leading universities in the emerging research field of bio-based economy and related disciplines. The project is funded by the German Academic Exchange service (DAAD) with support from the German Federal Ministry of Education and Research.

Purpose of this visit is to present current research activities, strengthen our collaboration, and talk about future collaboration activities for mutual benefit.

The list of delegation members is as follows:

1) Norli Ismail (PhD)
   Professor and Deputy Dean of Research, Environmental Technology Division

2) Fazilah Ariffin (PhD)
   Associate Professor and Acting Deputy Dean of Academic, Food Technology Division

The University of Hohenheim will provide assistance for hotel arrangements if needed. It is our understanding that all expenses (e.g. international and local transport, accommodation) will be borne by the delegation members themselves or by their institution. Travel insurance for the delegation should be arranged before arrival.

With kind regards

Dr. Gabriele Erhardt
Coordinator Strategic Network Bio-based Economy (BECY)