ISSN: 2186-7631 (SEATUC)
ISBN: 978-1-5386-5092-9 (IEEE)

PROCEEDINGS

SEATUC 2018

SOUTH EAST ASIAN TECHNICAL UNIVERSITY CONSORTIUM

In Conjuction with

InAES 2018

"the 8th International Annual Engineering Seminar"

The 12th SEATUC Symposium

Engineering Education and Research for Sustainable Development

- OS01. Green Energy System
- OS02. Sustainable Building and Infrastructure
- OS03. Information Technology, Smart System and Automation
- OS04. Hazard and Risk Management
- OS05. Earth Science and Geomatics
- OS06. Green and Smart Transportation System
- OS07. Green Advanced Materials
- OS08. Sustainable Industrial Process and Manufacturing System
- OS09. Sustainable Environment
- OS10. Sustainable Urban and Regional Planning & Development
- OS11. Biotechnology and Life Science
- OS12. Engineering Education
- OS13. IEEE

March 12 - 13, 2018
Graduate School Building UGM
(Gedung Pascasarjana)
Yogyakarta, Indonesia

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TEMPERATURE INFLUENCE FOR SOLVENT EXTRACTION TREATMENT PROCESS OF CONTAMINATED SOIL FROM KALIMANTAN

Lely Fitriyani and Edwan Kardena*
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ABSTRACT

Oily contaminated solid always becoming a considerate issue in oil and gas industry. It is very interesting to discern the preeminent method to treat such type of solid waste that also considered as hazardous waste. A beneficiary might be more thoughtful if the oily contaminated solid that has been treated can generate recovered oil while the solid residue has less remaining of hydrocarbon content. There are some methods have been discovered and implemented in big scale project. One of the acquainted method is solvent extraction. In this experiment, temperature effect on solvent extraction process became main interest of the study. Mixing apparatus that has been used was centrifugation with 1000 rpm and 10 minutes duration of treatment process. During the experiments, it was found that by using toluene as solvent, the optimum Total Petroleum Hydrocarbon (TPH) removal obtained at 50°C, while the average of lowest TPH that can be obtained was 1.3%. The study also found that the optimum treatment process has been achieved with the composition of soild to solvent 1:6. It was also found that toulene can be recovered by using distillation process with 85% recovery rate.

Keywords: *contaminated soil, oily sludge, solvent extraction, temperature, centrifugation, sludge treatment, solvent recovery, TPH, solid treatment, hazardous waste, Kalimantan, solid waste, oily contaminated solid waste.*

1. INTRODUCTION

Solvent extraction is a method that has been implemented widely in oil and gas industry. Some solvents reported has been utilized to treat the oil sludge. The solvent extraction process is essentially an adsorption-desorption process of oil between the solid and liquid phases (Liang, J. et. al, 2014). Biceroglu in 1994 has been used intermediate hydrocarbon source to be able to extract oil sludge from refinery storage to become lighter hydrocarbon at several stages of temperature. Temperature that has been selected was from 20°C to 50°C with comparison between solvent and oil sludge is 1:2 respectively and duration of extraction was 1 hour. It was reported that 23-32% hydrocarbon content has been recovered. Solvent and hydrocarbon that has been separated with the solid phase will be fed to crude oil tank for further refinery treatment. Solid phase residue then utilized as alternative energy or being landfilled.

Abouelnasr and Zubaidy in 2008 studied comparative performance of some solvents to extract oil from sludge in room temperature. In the beginning Methyl Ethyl Ketone (MEK) and Liquefied Petroleum Gas Condensate (LPGC) has been utilized with comparison 1:1 until 6:1 between solvent and oil sludge. Solvents has been chosen due to its common availability in every oil and gas refinery plant. LPGC is a product from refinery plant and MEK is chemical that normally used for deasphalting heavy oil process. Additional solvents that has been studied were heptane, hexane, iso-propanol, and iso-butanol. Oil recovery reported varies from 8% for iso-butanol and 39% for MEK. Generally MEK contribute highest efficiency and LPGC contribute efficiency that close to MEK. It was also reported that usage of hexane and alcohol produce synthetic fuel that contain high ash content, carbon resider, and asphaltene.

Gazieu et.al (2005) reported that usage of turpentine as a solvent has been able to extract 13-53% oil from original mass of oil sludge. Zubaidy and Abuelnasr in 2010 made comparative study related to the effect of some organic solvents such as Methyl Ethyl Ketone (MEK) and Liquefied Petroleum Gas Condensate (LPGC). They observed that the most efficient comparison between MEK and Sludge was 4:1. By implementing that, the highest oil recovery that can be reached was 39% for MEK and 32% for LPGC.

It was also reported that the usage of MEK has been also able to separate most of ashes, asphaltene, and some other contaminants. Nevertheless, it was found that high sulphur content presence in the carbon residue of recovered oil. Solvent extraction basically conducted with pouring oil sludge with some solvents in certain proportion to separate water, solids, and extracted solvents. The extracted solvents would then to be sent to distillation unit for separating oil and solvent. (Al-Zahraniet.al, 2013). Further process is required to purify recovered oil to be fuel. El Naggar et. al (2010) studied the usage of some solvents such as naphthalene, kerosene cut, n-heptane, toluene and some other solvents. From several experiments, it was reported that toluene has the highest extraction efficiency, which was 75.94%. Meyer et. al (2006) reported that the usage of oil solvents that has rings such as (naphtalenics and aromatics) for example catalytic cracking oil has highest efficiency in solving asphaltenics compound in oil sludge. Meanwhile, the solvent that has paraffinic content such as diesel paraffinic found effective to extract oil sludge that has high content of paraffinic (high wax). Taiwo and Otolorin (2006) also reported that the usage of Hexane and Xylene can also utilized to extract oil sludge. From the experiment, it was found that 67.5% PHC(s) was able to be extracted.

Guangji Hu. Et.al, in 2013 reported that solvent extraction process has been conducted by mixing solvent and oil sludge in a reactor with certain retention time so that solvent and oil sludge mixed homogenously and then settled for certain time to make sludge residue settled in the bottom. The mixture is then convey to solvent distillation reactor. During this process solvent is evaporated and then to be condensed all the way the piping system toward to returned back to mixing reactor of solvent and oil sludge. The residue of the process periodically will be input to distillation reactor that would also purify solvent that still available at the solvent.

Related with some solvent extraction experiments that has reported before, this study has an intention to explore possibilities of toluene as a solvent that may extract hydrocarbon as much as possible from oily contaminated soil. The experiments would be mainly study about the reduction of TPH content at the soil and observe the efficiency of oil recovery from extracted oil that has been dissolved into the solvent. The guideline of experimental variations has been taken base on some experimental data, result and recommendation that have been studied from the previous research.

2. MATERIAL AND METHOD

2.1 Sample source

Sample has been transported to be treated ex-situ from Kalimantan-Indonesia. It was contaminated soil from one of oil field that containing average 9.6 % TPH. Metal and heavy metal content have been checked to verify its characteristics and its possibility to be categorized as hazardous waste base on applicable regulation in Indonesia. Metal and heavy metal content of soil is listed in table 1.

Table 1. Metal Content of Sample Source

parameter	original sample (ppm)	parameter	original sample (ppm)
Ag	-	Hg	1.165
Al	2831.000	K	799.500
As	38.620	Mg	1289.000
B	9.936	Mn	297.100
Ba	2739.000	Mo	6.876
Be	-	Na	747.100
Ca	11080.000	Ni	6.760
Cd	0.517	Pb	98.660
Co	3.421	Sb	470.400
Cr	3.722	Se	-
Cu	9.678	Ti	7.247
		V	13.87
Fe	13660.000	Zn	130.6

2.2 Preparation of sample

Separate aliquout of 1500 g of contaminated soil, together with a tray. Then dry the sample by using open air for three days to minimize moisture content for further experiments. After drying the solid sample is mix evenly so to ensure the homogenousity. The following table will show the arrangement of sample preparation to be further treated by using solvent extraction method.

Table 2. Sample Preparation Arrangement

Treatment Series	Weight of Soid (gr)	Weight of Solvent (gr)	Soil : Solvent
t-1,t-2,t-3,t-4	10	30	1:3
t-5,t-6,t-7,t-8	5	30	1:6
t-9,t-10, t-11, t-12	7.5	30	1:4

Treatment Series	Weight of Soid (gr)	Weight of Solvent (gr)	Soil : Solvent
t-13,t-14,t-15,t-16	5	25	1:5
t-17,t-18,t-19, t-20	10	30	1:3
t-21,t-22,t-23,t-24	5	30	1:6
t-25,t-26, t-27,t-28	7.5	30	1:4
t-29,t-30-t-31,t-32	5	25	1:5
t-33,t-34,t-35,t-36	10	30	1:3
t-37,t-38,t-39,t-40	5	30	1:6
t-41,t-42,t-43,t-44	7.5	30	1:4
t-45,t-46,t-47,t-48	5	25	1:5

2.3 Solvent extraction process by using centrifugation method.

Solvent extraction method conducted by using centrifugation SETA Oil Test Centrifuge at 1000 rpm with 3 steps of acceleration and 10 minutes duration of extraction. Solvent that has been selected to be used was tolune. Type of toluene that has been used was EMSURE®,Toluene for analysis produced by Merck. It has boiling point 104.6 °C . The comparison between solid that has been choosen as shown in table 2. was 1:3, 1:4, and 1:5, and 1:6. Each four tests represent a formulation of solid to solvent composition and certain temperature that has been chosen to be centrifuged with 1000 rpm speed and 10 minutes extraction duration.

Total Petroleum Hydrocarbon (TPH) has been measured by using USEPA 8440 Method. Each TPH measurement conducted in duplo series while the result is the mean of the duplo series. Heavy metal that contained in the soil also measured by using USEPA 3050 B method.

2.4 Solvent and Oil Recovery Test

Solvent and oil recovery test conducted to know how much oil can be recovered from the mixture of extracted soil and solvent by using IKA RV 10 rotary evaporator under vacuum condition, 35 rpm rotary speed, and 40°C operation temperature. The following tables showed the preparation of the distillation process include resource of extract that has been distilled.

Table 3. Preparation of Solvent and Oil Recovery Test

source of liquid	distillation process
t1+t2+t3+t4	dist1
t5+t6+t7+t8	dist2
t9+t10+t11+12	dist3
t13+t14+t15+t16	dist4
t17+t18+t19+t20	dist5
t21+t22+t23+24	dist6
t25+t26+t27+t28	dist7
t29+t30+t31+t32	dist8
t33+t34+t35+t36	dist9
t37+t38+t39+t40	dist10
t41+t42+t43+t44	dist11
t45+t46+t47+t48	dist12

3. RESULT AND DISCUSSION

3.1 Optimum Dosage

As shown in figure 1,2,3, and 4, the efficiency of TPH reduction is varies depend on composition of solid to solvent. A linear correlation shown regarding with the amount of solvent in the extraction process and TPH reduction. The higher volume of solvent to solid, the higher TPH reduction that can be obtained. Base on the experiment that has been conducted for contaminated soil from Kalimantan, it showed that the optimum dosage of soild to solvent is 1:6.

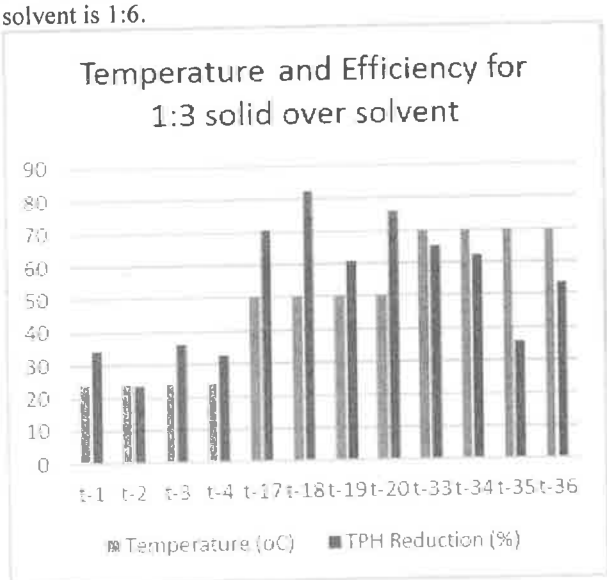

Figure 1. Temperature and Efficiency for 1:3 solid over solvent

Figure 1 indicating that the TPH reduction for solvent extraction process by using solvent to solid composition 1:3 have higher efficiency at higher temperature. Temperature 50°C shown the highest TPH reduction compare to other temperature treatment condition. The indication occurred the same for the other three different temperatures. The highest efficiency also obtained by solid to solvent composition 1:4, 1:5, and 1:6 at 50°C.

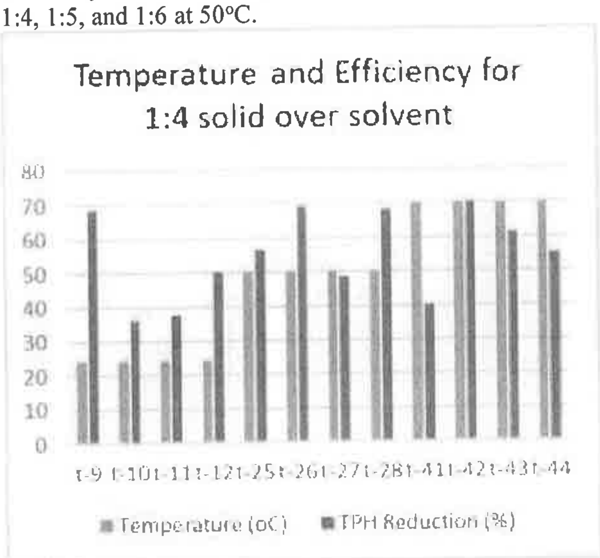

Figure 2. Temperature and Efficiency for 1:4 solid over solvent

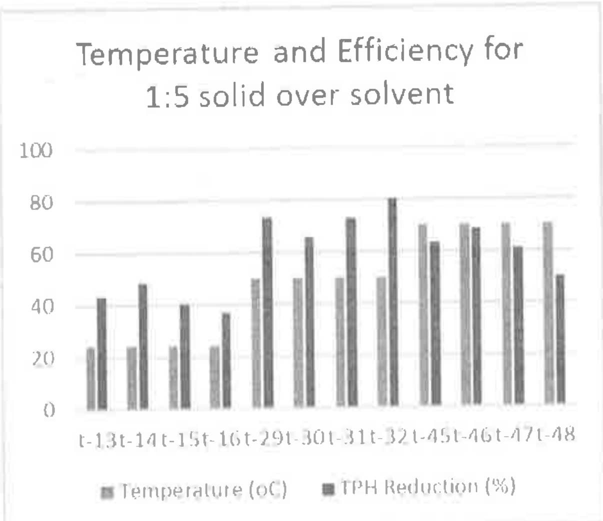

Figure 3. Temperature and Efficiency for 1:5 solid over solvent

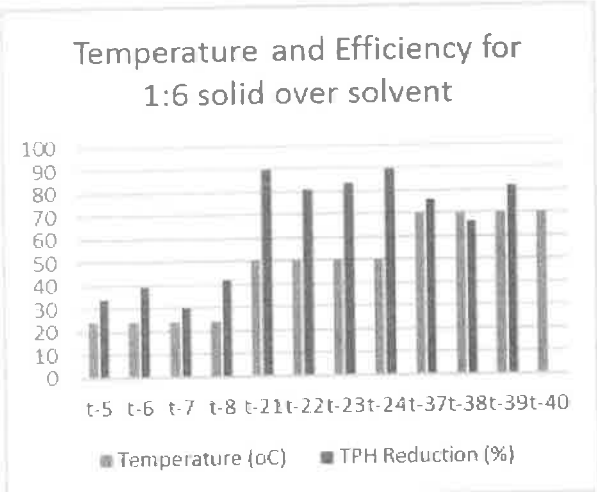

Figure 4. Temperature and Efficiency for 1:4 solid over solvent

3.2 Temperature Effect

Temperature shown to be an important factor affecting demulsification of water/oil (W/O) emulsions. Nii.et al. in 2009 reported that increasing temperature in oily solid waste will reduces viscosity and accelerates the settling of water droplets in oily sludge, thus promoting the separation of water and oil. Contaminated solid which became object of this study have 9.6% moisture would require the increasing of temperature to settle the water droplet to increase its oil extraction process. Nii, et. al (2009) experiments shown proportional correlation with this current experiment. The increasing of temperature gave better TPH reduction after treatment by using solvent extraction process.

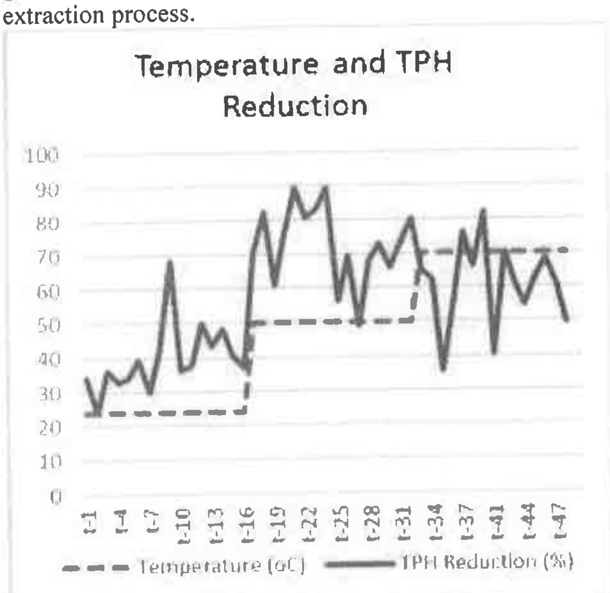

Figure 5. Temperature and TPH Reduction

As shown in figure 5, it was observed that toluene working the most optimum at 50°C. It gave a surprising result due to most studies mentioned that solvent extraction process would be optimum working at 70°C of treatment process operation. El Naggar et. al in 2010 reported that generally the oil recovery increases as a function of temperature till reached to the maximum value then, there is no increase in recovery with any increase of temperature. The temperature 70°C was reported giving best performance for all solvents that has been used during the study which are Methyl Ethyl Ketone (MEK), toluene, n-heptane and petroleum cuts using solid and semi solid sludge giving the maximum oil recovery for each solvent. Toluene was also studied during the experiment, however it was not using 50°C as parameter and centrifugation method as this study implemented.

3.3 Metal Analysis pre-and post treatment

Metal content of the solid also tested to the soil as consideration for the solid to be justified as hazardous waste base on the metal and heavy metal content prior and post- treatment. From the preparation stage it has ben known that other that its TPH content the metal and heavy metal content was not parameters that exceed threshold limit value in Indonesia. In figure 6 below, post-experimental test that conducted showed that mostly metals reduced during the extraction process. Only few that has increment of value eventhough they are still not exceed the threshold limit value base on PP 101 year 2014 that applied as regulatory guideline for hazardous waste in Indonesia

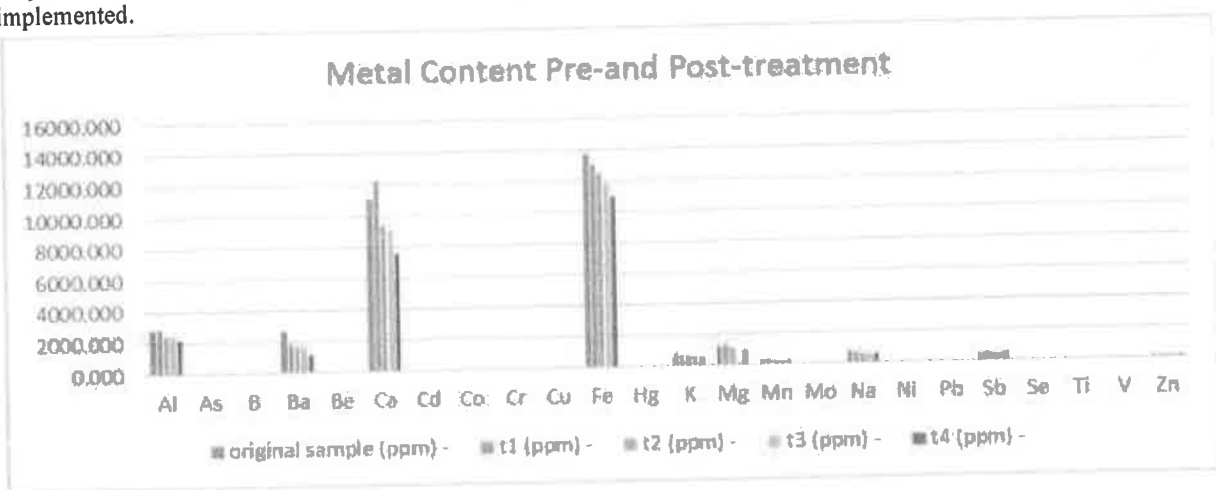

Figure 6. Metal Content Pre- and Post- treatment

3.4 Solvent and Oil Recovery

Solvent and Oil Recovery test showed that the solvent recovery obtained in average 92.61%. Recovered oil that could be separated from distillation process could be obtained around 1-3 grams, which is in average 1.99% from total extracted liquid.

Table 4. Solvent Recovery

distillation series	Mass of liquid extract (gr)	Recovered Toluene (gr))	Solvent Recovery Rate (%)
1	101.6	96.3	94.78
2	102.1	96.4	94.42
3	99.4	94.4	94.97
4	93.1	88.2	94.74
5	95.5	88.1	92.25
6	96.5	91.2	94.51

distillation series	Mass of liquid extract (gr)	Recovered Toluene (gr))	Solvent Recovery Rate (%)
7	100.2	94	93.81
8	85.7	78.9	92.07
9	97.5	88.8	91.08
10	86	76.3	88.72
11	92.8	86	92.67
12	81.2	70.9	87.32
	Average		92.61

Table 5. Oil Recovery

distillation series	Mass of liquid extract	Recovered oil (gr)	Oil Recovery Rate (%)
1	101.6	0.7	0.69
2	102.1	0.9	0.88
3	99.4	1.2	1.21
4	93.1	1.4	1.50
5	95.5	3	3.14
6	96.5	1.7	1.76
7	100.2	2.1	2.10
8	85.7	3.5	4.08
9	97.5	2.3	2.38
10	86	1.4	1.63
11	92.8	2.2	2.37
12	81.2	1.7	2.09
	Average		1.99

4. CONCLUSION AND RECOMMENDATION

This study shown some selected optimum operation condition by using toluene at solvent extraction method the optimum temperature process is occurred at 50°C with 1000 rpm centrifugation mixing in 10 minutes duration, while solid to solvent composition is 1:6. It is recommended to conduct further experiments for additional solvent varians include some additional additive that may increase TPH reduction such as biosurfactants, surfactants or the variation of speed and soil to solvent composition.

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PHOTOS AND INFORMATION

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Molecular imprinted hydrogel polymer (MIHP) as microbial immobilization media in artificial produced water treatment

To cite this article: E Kardena *et al* 2018 *IOP Conf. Ser.: Earth Environ. Sci.* **106** 012088

Molecular imprinted hydrogel polymer (MIHP) as microbial immobilization media in artificial produced water treatment

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Abstract. Produced water generated during oil and gas exploration and drilling, consists of many chemicals which used in drilling process. The production of produced water is over three fold of the oil production. The water-cut has increased over time and continues to do so because the fraction of oil in the reservoir decreases and it is more difficult to get the oil out from an old oil-field. It therefore requires more sea water to be injected in order to force the oil out; hence more produced water is generated. Produced water can pollute the environment if it is not treated properly. In this research, produced water will be treated biologically using bacterial consortium which is isolated from petroleum processing facility with Molecular Imprinted Hydrogel Polymer (MIHP) for microbial immobilization media. Microbial growth rate is determined by measuring the MLVSS and hydrogel mass, also by SEM-EDS analysis. SEM-EDS analysis is an analysis to evidence the presence of microbe trapped in hydrogel, and also to determine the types and weight of the molecules of hydrogel. From this research, suspended microbial growth rate was found at 0.1532/days and attached microbial growth rate was 0.3322/days. Furthermore, based on SEM analysis, microbe is entrapped inside the hydrogel. Effectiveness of microbial degradation activity was determined by measuring organic materials as COD. Based on COD measurement, degradation rate of organic materials in wastewater is 0.3089/days, with maximum COD removal efficiency of 76.67%.
Keywords: COD, hydrogel, MIHP, produced water, SEM-EDS

1. Introduction

Saline wastes are generated in significant quantities in petrochemical industries such as oil and gas production. These generated wastes contain organic compounds and high concentrations of salt (>1.5%). Generated wastewater is considered as salty water trapped in the reservoir rock and brought up along with oil or gas during production. It subsists under high pressures and temperatures, and usually contains hydrocarbons and metals. Therefore, it must be treated before being discharged to the environment. The discharge of such wastewater containing at the same time of high salinity and high organic content without prior treatment is known to adversely affect the aquatic life, water potability and agriculture [1]. In spite of the detrimental effect of salty produced water on microbial activity, moderate acclimation of activated sludge to high salinity is possible. Acclimation implies the exposure of non-salt-adapted micro-organisms to increasing salt concentrations in order to permit the obtention of satisfactory effluent treatment performance at a given salt concentration. The success of such adaptation depends on several factors, such as the type and growth phase of micro-organisms, as well as the rapid or gradual increase of salt concentration during acclimation [1], [2].

Many studies reported that operation of activated sludge process at salt contents higher than 20 g/L is characterized by poor flocculation, high effluent solids, and a severe decrease in substrate utilization rate [2]. Researcher [3] reported that the nature of pollutants and the high salinity (about 29 g/L) of oil-field generated water has an unfavorable effect on the activated sludge process. High hydraulic loadings (above 2.5 m^3 /m^3.day) increased the wash-out of the activated sludge from the reactor. The addition of Powdered Activated Carbon improved the sludge volume index and increased the rate of biodegradation. This is due to the ability of biofilm formation on the activated carbon surface. The low settleability of sludge is caused by the salt content in produced water that reduces the population of protozoa, resulting in low settle-ability. Salt content in produced water increases the buoyancy forces, causing low sedimentation efficiencies.

Cell immobilization is an efficient strategy to form an artificial biofilm on a substrate. Biofilm formation in a media/substrate will overcome the buoyancy forces of the biomass in a salty environment and avoid the wash-out of the activated sludge from the treatment plant. The advantages of immobilized technique include easy separation of the cells from the carrier material, greater productivity due to high cell concentrations achieved and the protection of cells against harsh environmental conditions [4], [5], [6]. Studies have shown that polymer types play a dominant role in determining the properties of the microspheres. Examples of synthetic gels include poly(carbamoyl) sulphonate, polyhydroxyethylmethacrylate (polyHEMA) and polyacrylamideand polyvinyl alcohol (PVA). Microspheres are almost exclusively produced using water-soluble polymers which provide a high degree of permeability for nutrient sand metabolites with a low molecular weight, thus providing optimal conditions for the functioning of immobilized microbial cells [6], [7].

This study investigated the applicability of an immobilisation technique based on cell entrapment in a Molecular Imprinted Hydrogel Polymer (MIHP), a strategy to increase the ecological competence of degrading microorganisms in treating salty produced water.

2. Research Method

2.1. Bacterial and growth condition

Mixed culture of degrading bacteria wasobtained from culture collection of Environmental Laboratory, Bioscience and Biotechnology Research Center, Institut Teknologi Bandung, Indonesia. All culture were previously isolated from petroleum-contaminated soils by an enrichment culture technique using crude oil as the sole source of carbon and energy. The culture was maintained at 4° C on crude oil basal medium.

The syntheticoilfield-produced water was used throughout the study to determinethe capability of strains of bacteria to degrade organic compounds.The synthetic oilfield-produced water was prepared by mixing crudeoil (1.5 mL/L) and salt water (sea water and tap water), as described in the literature [8]. The C/N/P ratio of the medium was adjusted to approximately 100/5/1 by adding appropriate concentrations of $(NH_4)_2SO_4$ and KH_2PO_4 to the synthetic oilfield-produced water. This synthetic oilfield-produced water was used throughout our study to determine the capability of immobilized cell ofbacteria to degrade organic compounds. The characteristics of the realand synthetic oilfield-produced water samples are listed in Table 1.

2.2. Molecular Imprinted Hydrogel Polymer (MIHP) Synthesis
Reagent used in MIHP synthesis are bis-acrylamide, N-N'methylenbisacrylamide, NaOH 4N, potassium persulfate, tetramethyletilendiamine (TEMED), and buffer pH 6. All chemical are obtained from Merck, Sigma-Aldrich and JT Baker. MIHP produced in the form of dry gel Bis-acrylamide and N-N'methylenbisacrylamide used to synthesize acrylamide-bis 40%, which functions as crosslinker.MIHP synthesized by adding a buffer solution of pH 6 into acrylamide-bis 40%. After homogenized, add potassium persulfate (as initiator) and TEMED (as catalyst) to speed up the polymerization process. The solution was left overnight until a hydrogel is formed. Hydrogel formed are washed by demineralized water until it reaches neutral pH, then dried in the oven with temperature of 110°C. The hydrogel are used as immobilized media and attached media for microbes growth throughout the experiment in the synthetic oilfield-produced water treatment. SEM-EDS analysis was used to determine the hydrogel structure and microbial attachment both in outer and inner of the hydrogel.

2.3. Produced water biodegradation by immobilized cells
In order to assess the biodegradation potential of oilfield-produced water by the immobilized degrader, the bacteria were acclimated first to the intended environment. Acclimation implies the exposure of non-salt-adapted microorganisms to increasing salt concentrations substrate until it reached the desired performance. The degradation potential was based on the growth rate (μ) and chemical oxygen demand (COD) removal efficiency. The microbial growth was obtained by measured the MLVSS over the observation time (t). The initial and final CODs were measured using standard methods (DR-2800, Hach Company). Reactor-1 arrangement (PW+Cell) is produced water + immobilized cell, while reactor-2 (PW-Cell) is a control reactor contains produced water without immobilized cell addition.

3. Results and Discussion

3.1. Cell immobilization
This research focuses on the synthesis of molecular imprinted hydrogel polymer as microbial immobilization medium. The polymer used is non-template polymer, the cavity formed in hydrogel is a cavity of water molecules that evaporate due to heating process. Polyacrylamide is synthesized from bis-acrylamide 40%, which contains a monomer of acrylamide and bis-acrylamide as crosslinker. To initiate polymerization, an initiator is required. The initiator is a material that can immediately turn into free radicals when heated or irradiated by electromagnetic radiation. Initiator and catalyst used in MIHP polymerization is 10% potassium persulfate and tetraethylmethylendiamine (TEMED). Excessive or too low concentrations of ammonium persulfate will not produce MIHP, whereas TEMED has an effect on polymerization time. The ratio between bis-acrylamide 40%, buffer pH 6, initiator, and catalyst must be precise, otherwise polymerization will be difficult and hydrogel is hard to form. The hydrogel structure can be seen in Figure 1.

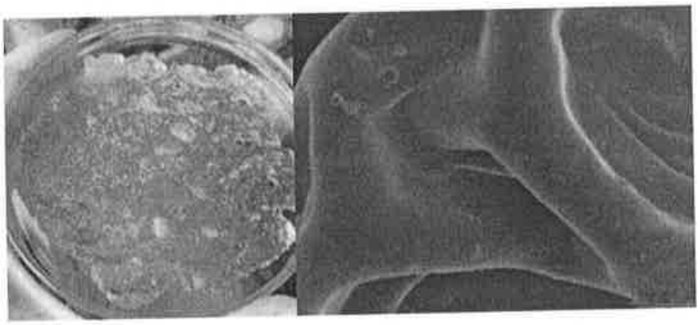

Figure 1. Wet hydrogel structure (left), and SEM image with 1000x magnification (right).

Immobilized cells have advantages of higher activity, higher cell density and longer stability than free cells. Hence, the immobilized cells have the potential to degrade toxic chemicals at higher concentration as compared to the suspended cells. Requirement for an effective and safecarrier for resting a microorganisms should be nontoxic and non-polluting, consistent in quality, have a long shelf life, allow sufficient cell activity and cell density [6], [9]. MIHP hydrogel was introduced to the microbial culture suspension in order to imbedded the cell into the hydrogel structure by using a shrink/swell procedure. The cell suspension will enter and entrapped into the hydrogel pore, also attached on the surface of the hydrogel structure (Figure 2).

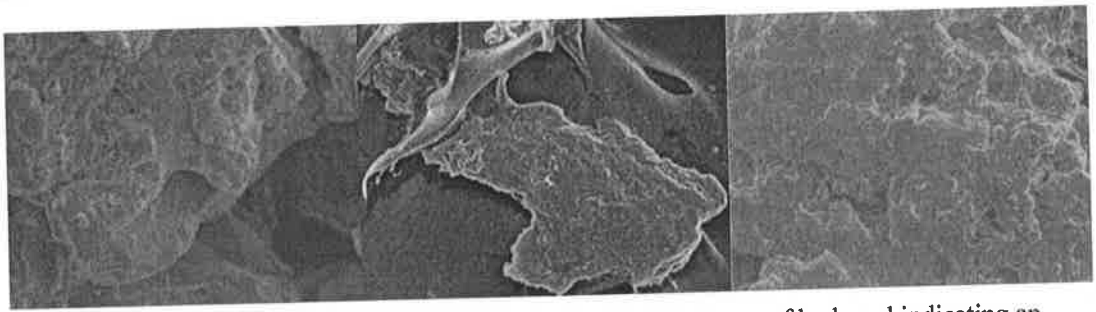

Figure 2. Apparent structure of hydrogel: (left) internal structure of hydrogel indicating an immobilized cells; (middle) cells attached on the surface of hydrogel after 3 days incubation; (right) cells attached on the surface after 5 days incubation.

3.2. Biodegradation of oilfield-produced water by immobilized cells

Performance of immobilized cell in the biodegradation of synthetic oilfield-produced water was studied in the 2L reactor volume that contain initial concentration of 868 mg/L MLVSS degrader microbe. The growth and performance of the immobilized cell in the treatment of oilfield-produced water can be seen in Figure 3. Characteristics of the synthetic oilfield-produced water used in this study and its comparison with typical produced water is described in Table 1.

Table 1. Characteristics of produced water (PW).

No.	Parameter	Synthetic PW	Typical PW*
1	COD, mg/L	1,200	100-4000
2	Oil&Grease, mg/L	-	2-500
3	TSS, mg/L	-	10-200
4	pH	6.89	4-10
5	Conductivity, μS/cm	13,080	4,000-58,000
6	Salinity, %	0.73	0-2.5
7	Phenols, mg/L	0.472	0-23

*adapted from [8], [10], [11]

The growth of degrader microbe in the reactor (PW+Cell) tends to grow and reach the exponential phase without showing any lag phase. This indicates that the strains of bacteria can consume organic compounds in the oilfield-produced water as a carbon source as soon as they come into contact with the wastewater. The specific growth rate (μ) and COD removal of the strains of bacteria tended to increase over time showing the efficacy of the degrader microbe. As observed in Figure 3, the COD removal rate was increased significantly after 2 days of incubation time. On the other side, the control reactor (PW-Cell) where there is no augmented degrader bacteria that added in the system shows a considerable increase in COD removal for up to 33.3% efficiency after 5 days of incubation time. Even without addition of degrader microbe, degradation process will occurred because of the oxidation from aeration process in the reactor.

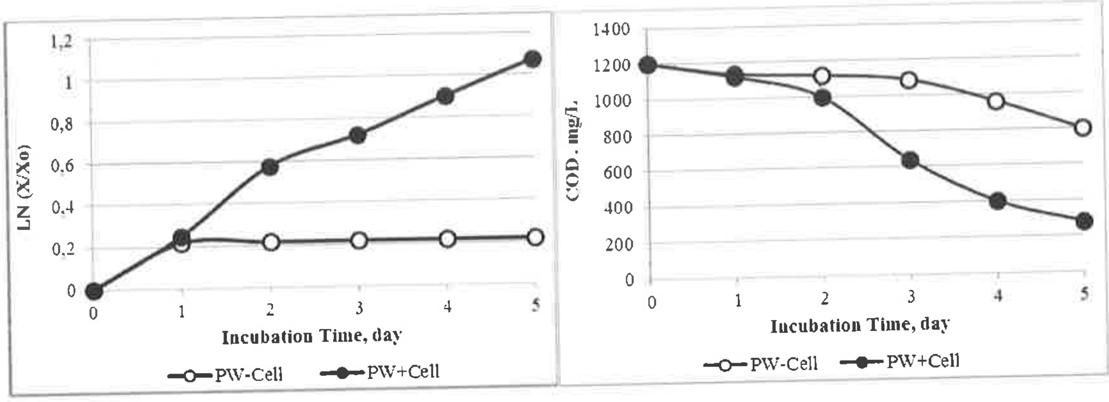

Figure 3. Profile of microbial growth (MLVSS) and COD removal of the syntetic oilfield-produced water in the reactor with addition of immobilized cell (–•–); and control reactor without addition of immobilized cell (–○–).

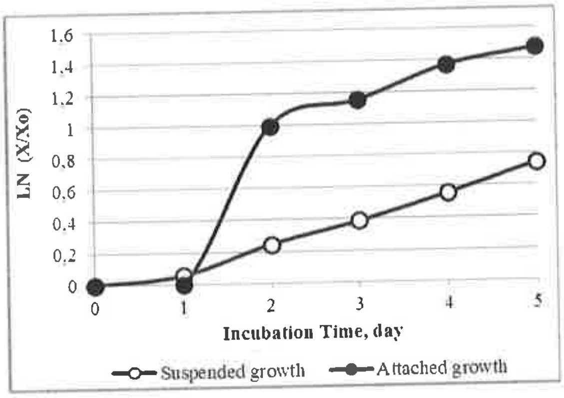

Figure 4. Growth rate of degrader microbe in the PW+Cell reactor, (–○–) suspended growth; and attached growth in the hydrogel (–•–).

The performance of the activated sludge in the treatment period can be seen in Figure 3. It was observed that, from the beginning of lag phase, the concentration of MLVSS increased. However, reactor without addition of microbial starter (PW-Cell) reached a steady-state condition after day 1, while reactor with addition of microbial starter (PW+Cell) continue to increase and became more adapted to the new environment as a function of time. In the fifth days of incubation period, the highest MLVSS concentration was observed in PW+Cell reactor (2.532 mg/L), while the lowest concentration was found in PW-Cell reactor (385 mg/L). COD removal efficiency in the PW+Cell compared to PW-Cell reactor within 5 days incubation time was 76.6% to 33.3%, respectively. As can be seen in Figure 4, attached growth rate is higher than in suspended state in the PW+Cell reactor, indicating that microbe able to attached in the hydrogel and utilized it as a growth support media.

4. Conclusion

The produced water discharged from both onshore and offshore platforms is typically treated by use of chemical and physical systems due to its simple operations. These conventional technologies, however, does not remove the organics such as suspended oil particles and other dissolved compounds. Some chemical treatment technologies also produce hazardous sludge and the cost of those operational processes can be significant. Biological treatment of produced water can be a cost-effective and environmental friendly method, but could be a problem on offshore installation due to the space limitations on the installations. To overcome the space limitation, a compact biological process is needed such as microbial entrapment or immobilization methods can be used. High concentration of microbe/MLVSS can be achieved in a compact reactor compare to conventional suspended activated sludge units that require larger space to achieve the same cell density. Molecular Imprinted Hydrogel Polymer (MIHP) from Polyacrylamide can be used as a support medium for microbial immobilization. This indicated by the SEM analysis, which shows that on the fifth days of incubation, the internal surface of the hydrogel is covered by microbes. The rate of microbial growth in wastewater suspension is 0.1532/day and the rate of microbial growth in hydrogel is 0.3322/day. The rate of microbial growth in hydrogels is higher than in suspended state. This shows that microbes are able to utilized hydrogel as an attached growth media. The advantage of this method is the amount of biomass required in the synthetic oilfield-produced water treatment process fulfilled rapidly, because the microbe grows faster with hydrogel supporting media.

Acknowledgement
The study was performed within the Indonesian Ministry of Research, Technology and Higher Education (Ristek-Dikti) Research Grant fiscal year 2017, also facilitated by Environmental Laboratory of Bioscience and Biotechnology Research Center, Institut Teknologi Bandung.

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