J. T. K. L.
JURNAL TEKNIK KIMIA DAN LINGKUNGAN

J. Tek. Kim. Ling. 2023, 7 (2), 92-103
p-ISSN : 2579-8537, e-ISSN : 2579-9746
http://jurnal.polinema.ac.id/index.php/jtkl
DOI: http://dx.doi.org/10.33795/jtkl.v7i2.3851

Evaluation and Management of B3 Waste Sludge via the Sludge Oil Recovery (SOR) Program at PT. X Plaju

Widya Reza Nurdiasna[1], Iva Yenis Septiariva[2], I Wayan Koko Suryawan[1,*], Mega Mutiara Sari[1], Nova Ulhasanah[1]

[1]Department of Environmental Engineering, Faculty of Infrastructure Planning, Universitas Pertamina, Komplek Universitas Pertamina, Jakarta Selatan, Jakarta 12220, Indonesia
[2]Study Program of Civil Engineering, Faculty of Engineering, Universitas Sebelas Maret, Jalan Ir Sutami 36A Surakarta, Jawa Tengah 57126, Indonesia

ABSTRACT

With the ever-increasing need for waste management solutions, PT. X Plaju is one of the entities that contribute to B3 waste production, a waste type characterized by its explosive, flammable, reactive, corrosive, and toxic properties. This research centers on the evaluation and management of B3 waste sludge, particularly at PT. X Plaju. The institution implements two licensed B3 waste control programs: the Sludge Oil Recovery (SOR) and used lubricant utilization programs. The SOR program, which focuses on recovering components from oil deposits or sludge, operates under the recovery principle. This study showcases the importance of the oil component in the oil sludge, emphasizing that it must constitute more than 20% of the total volume to be deemed suitable for refinery production. Our findings highlighted a water content of 28.32% within the waste oil sludge. Additionally, the ultimate analysis showcased carbon, hydrogen, and nitrogen compositions of 85.99%, 13.42%, and 0.21%, respectively, while the density was measured at 0.85 gr/cc. This research offers insights into the waste management practices of PT. X Plaju, emphasizing the potential of the SOR program in managing B3 waste effectively.

Keywords**:** B3 waste, sludge, sludge oil recovery, waste management, refinery production.

1. INTRODUCTION

Population growth that continues to increase yearly results in the need for energy to support human life, which can increase over time [1,2]. Indonesia, one of the countries with the largest population globally, will require an ample supply of energy [3]. One industry that plays a role in supporting energy supply is the oil and gas industry. PT. X Plaju-Sungai Gerong is one of the processing units. Its main business activity is processing crude oil into fuel and non-fuel products. Both during production and non-production, petroleum processing activities will produce emission waste, non-B3 solid waste liquid waste, and hazardous and toxic waste (B3) [4].

One of the wastes produced by PT. X Plaju, whose management is regulated explicitly by regulations, is B3 waste. B3 waste produced by PT. X Plaju has five characteristics: explosive, flammable, reactive, corrosive, and toxic. The dominant waste comes from cleaning tank activities in the form of sludge. Sludge oil is categorized as B3 waste with flammable characteristics, and the source category is a specific source. Therefore, it is necessary to analyze the characteristics of sludge oil, which will be treated specifically with the Sludge Oil Recovery (SOR) method. Two B3 waste control programs at PT. X Plaju have a permit: the SOR program and the used lubricant utilization program. Based on the permit of the Ministry of Environment through the Decree of the Minister of Environment of the Republic of Indonesia No. 201 of 2012 concerning the access for B3 waste utilization, PT X has succeeded in

*Corresponding author: I Wayan Koko Suryawan
Department of Environmental Engineering, Universitas Pertamina
Komplek Universitas Pertamina, Jakarta 12220, Indonesia
E-mail: i.suryawan@universitaspertamina.ac.id

Received : August 14, 2023
Accepted : October 4, 2023

carrying out a 3R program for non-dominant waste, namely used lubricant by recovering 100% of the waste generated. Meanwhile, the SOR program has a permit from the Ministry of Environment with the Decree of the Minister of Environment of the Republic of Indonesia No. 369 of 2013 concerning hazardous and toxic waste of PT. X Plaju. The principle applied to the SOR program is recovery which aims to recover components from oil deposits or oil sludge. The SOR is recovering components from oil deposits or oil sludge [5–7]. Oil recovery from sludge oil is an environmentally friendly option because it can handle sludge oil being reused for reprocessing and reformulation or energy recovery. In addition, oil recovery can reduce the volume of B3 waste disposal outside industrial areas and prevent the spread of contamination. There are various methods used to obtain oil recovery. This study aims to determine the management of B3 waste sludge at PT. X Plaju. This study aims to assess the management of B3 waste sludge at PT. X Plaju.

Among the roster of wastes produced by PT. X Plaju, B3 waste, governed meticulously by a slew of regulations, stands out for its potential environmental ramifications. Characterized by its explosive, flammable, reactive, corrosive, and toxic nature, B3 waste from PT. X Plaju predominantly arises from tank cleaning activities, manifesting primarily as sludge. This sludge oil, owing to its flammability, is categorized under B3 waste. Notably, its origin stems from a very specific source, thereby necessitating a targeted treatment approach. It is here that the SOR method plays a pivotal role.

Two B3 waste management programs have been sanctioned at PT. X Plaju: the SOR program and the program for used lubricant utilization. As an affirmation of its commitment to sustainable practices, PT. X Plaju has been successful in implementing a 3R (Reduce, Reuse, Recycle) approach for its non-predominant waste, especially used lubricants, achieving an impressive 100% recovery rate as per the directive of the Ministry of Environment [3]. In parallel, the SOR program also operates under the aegis of the Ministry of Environment, adhering to stipulated guidelines and aiming to recover components from oil deposits or oil sludge.

The importance of the SOR cannot be understated. It is more than just a waste management technique; it is an emblem of environmental stewardship. This process reclaims components from oil deposits or oil sludge, presenting an eco-friendly avenue to handle sludge oil either through reprocessing, reformulation, or energy recovery [4-6]. The twofold benefits are evident: a significant reduction in the volume of B3 waste earmarked for disposal outside industrial precincts, and a check on the spread of contamination. However, the domain of oil recovery is not monolithic; various methods exist to achieve the desired results. Each comes with its own set of advantages, challenges, and implications. With this backdrop, the present study endeavors to undertake a comprehensive examination of the management strategies deployed for B3 waste sludge at PT. X Plaju. The core objective is to not only discern the methodologies at play but also to critically assess their efficacy, challenges, and potential for further optimization.

While numerous studies have delved into the broader realm of waste management in the oil and gas sector, there remains a conspicuous lacuna in literature specific to the strategies and challenges associated with B3 waste sludge at PT. X Plaju. This study seeks to bridge this gap by offering a granular insight into the waste management protocols at PT. X Plaju, especially in the context of the SOR method. Furthermore, the novelty lies in juxtaposing the theoretical underpinnings of B3 waste management with the on-ground realities at PT. X Plaju, thereby providing a pragmatic perspective to stakeholders in the industry.

2. RESEARCH METHODS

The approach to this research was underpinned by an offline survey technique, a method chosen for its propensity to yield direct insights from participants. However, like all methodologies, this too came with its share of limitations. A conspicuous constraint was the inability to directly experience and engage with the operative systems and modalities at PT. X Plaju. To ensure a comprehensive understanding of the processes and dynamics at PT. X Plaju, the research methodology was bifurcated into two main segments: provisioning of materials and data collation.

In the first segment of material provisioning, it became evident that a foundational understanding of Health, Safety, and Environment (HSE) protocols was imperative. This foundational knowledge would set the stage for the exploration of more intricate environmental management activities at PT. X Plaju. The decision to prioritize the introduction to HSE was driven by the recognition of its pivotal role in ensuring the safety and well-being of employees, as well as its broader implications for environmental and operational sustainability.

The environmental management material was meticulously structured, dividing the vast area into three distinct categories: control of emission waste, liquid waste management, and solid waste oversight. The rationale behind this structured dissemination was to ensure clarity and to mitigate the possibility of overwhelming the participants with information overload. The narrative began with a focus on emission waste control, elucidating the methods and technologies adopted by PT. X Plaju to minimize harmful emissions. The narrative then transitioned to the domain of liquid waste control, shedding light on the mechanisms and systems in place to manage and treat wastewater and other liquid effluents. The final portion of the material revolved around solid waste control, which delved into the methodologies and best practices employed by PT. X Plaju to manage, recycle, and dispose of solid waste in an environmentally responsible manner.

To foster a deeper engagement with the provided materials, an interactive phase was integrated post dissemination. Participants were encouraged to draft questions, queries, or areas of ambiguity they encountered in relation to the HSE materials and the broader environmental management strategies. This step was vital, not just for the participants' comprehension but also to identify potential gaps or oversights in the material itself. Any queries or doubts raised were systematically addressed by the supervisory team, ensuring a robust understanding before progressing to the subsequent phase of the research.

As the research transitioned into the data collection phase, the lens of inquiry narrowed, centering on the specialized theme of B3 waste management at PT. X Plaju. This theme was not chosen arbitrarily; B3 waste, with its potential hazards, is of paramount significance, and its effective management is critical for environmental sustainability and human health. Within PT. X Plaju's portfolio of B3 waste management strategies, the SOR program, facilitated through a SOR equipment rental system, emerged as a focal point.

Before diving deep into data collection related to the SOR theme, it was imperative for the participants to have a nuanced understanding of the domain. Thus, supplementary material, tailored to this theme, was provided. This material encompassed the scientific, operational, and environmental dimensions of SOR, detailing the processes, technologies, and the environmental implications of the SOR system.

Following this comprehensive preparation, the research entered its final phase: the literature review. Data was meticulously gathered from a plethora of sources, including scientific journals, industry reports, case studies, and white papers, to paint a holistic picture of B3 waste management and the specific nuances of the SOR system within PT. X Plaju's operational context.

3. RESULTS AND DISCUSSION

The waste generated is identified by comparing the characteristics of the waste, the source of the waste, and the source category based on PP no. 101 of 2014. For example, in Table 1, the following are the types of B3 waste at the PT. X Plaju refinery. Based on PP 101 of 2014 concerning management of hazardous and toxic waste, hazardous and toxic materials from now on abbreviated as B3 are substances, energy, or other components due to their nature, concentration, or amount, either directly or indirectly pollute the environment. Meanwhile, waste is a business or activity [8,9]. So that, hazardous and toxic material waste is the residue or a business or activity that contains B3.

The refinery at PT. X Plaju generates several kinds of B3 waste, each coming from different units and exhibiting distinct hazardous characteristics. For example, sludge oil or tank bottom residue, whether it is SOR, co-processing, or cake SOR, primarily originates from the production units involved in cleaning tanks and is recognized for its flammable nature. Similarly, sludge from WWTP is produced in CD&GP units and is also flammable.

Used catalysts like FCC, ceramic ball, mole sieve, and P205, derived from FCCU and polymerization units, are known to be toxic and corrosive. Likewise, used activated carbon from utility units and used filters from utility and workshop units are categorized as toxic, with the latter also being flammable. Used batteries coming from the workshop, F&I, and utility units are identified as corrosive, while laboratory waste containing B3 is recognized as corrosive, reactive, and toxic. In contrast, B3 contaminated waste, which includes materials contaminated with oil, tube gas detector, and spent DEA from production maintenance, OH-HSE, and polypropylene units, are known to be flammable. Substances like sodium hydroxide and sulfuric acid, originating from laval treater and alkylation units, respectively, are marked as corrosive, and used B3 packaging materials, including drums, jerry cans, sacks, jumbo bags, IBC tanks, and ink toner from various units like PP, HVU, FCCU, Lab, and IT, are labeled as toxic.

Ink waste packaging from office activities is deemed poisonous, and used lubricants from FCCU, workshop, and utility units, along with residual and used stabilizer like additive fluff from polypropylene units, and used refractories from maintenance units, are all flammable. Meanwhile, resin waste from utility units and TL lamps from maintenance units are identified as toxic, and used rags and the like are also deemed flammable. The various categorizations of waste underline the diverse range of hazardous materials generated at the refinery, each demanding a unique approach to management and disposal, conforming to environmental safety and regulatory norms.

For corrosive, reactive, or toxic waste, correct identification and segregation are paramount, ensuring that such wastes are kept separate from other waste types to avoid dangerous reactions [10–12]. These types of waste must be stored in containers that are resistant to corrosion and leakage, typically made of plastic or glass, to prevent any spillage or contamination. Proper labeling of containers with appropriate hazard symbols is equally crucial to avoid mishandling or accidental mixing of incompatible wastes. To provide an added layer of safety, secondary containment structures should be employed, and any spills or leaks should be immediately contained and cleaned. Proper disposal of these hazardous wastes is essential, and licensed hazardous waste disposal companies must be engaged to ensure waste is treated and disposed of in accordance with local, state, and federal regulations.

Table 1. Types of hazardous waste at the PT. X Plaju.

No.	Type/Name of B3 Waste	Waste Source	Characteristics	Source Category
1	Sludge oil/ tank bottom residue (SOR)	Production (cleaning tanks)	Flammable	Specific source
2	Sludge oil/ tank bottom residue (co-processing)	Production (cleaning tanks)	Flammable	Specific source
3	Sludge oil/ tank bottom residue (cake SOR)	SOR (Env)	Flammable	Specific source
4	Sludge (WWTP)	Production (CD&GP)	Flammable	Specific source
5	Used catalyst (FCC, ceramic ball, mole sieve, P205)	FCCU, polymerization	Toxic/ corrosive	Specific source
6	Used activated carbon	Utilities (UTL)	Toxic	Specific source
7	Used filters	UTL, workshop	Toxic/flammable	Non-specific source
8	Used battery/battery	Workshop, F&I, UTL	Corrosive	Non-specific source
9	Laboratory waste containing B3	Laboratory	Corrosive/ reactive/ toxic	Non-specific source
10	B3 contaminated waste (material contaminated with oil, tube gas detector, spent DEA)	Production maintenance, OH-HSE, polypropylene	Flammable up	Non-specific source
11	Sodium hydroxide (base)	Laval treater	Corrosive	Non-specific source
12	Sulfuric acid (acid)	Alkylation	Corrosive	Non-specific source
13	Used B3 packaging (drums, jerry cans, sacks, jumbo bags, IBC tanks, ink toner, etc.)	PP, HVU, FCCU, Lab, IT	Toxic	Non-specific source
14	Ink waste packaging (ink toner)	Office activities	Poisonous	Specific source
15	Used lubricants	FCCU, workshop, UTL	Flammable up	Non-specific source
16	Resin waste	UTL	Toxic	Non-specific source
17	TL lamp	Maintenance	Toxic	Non-specific source
18	Used rags and the like	Used cloth (used rags)	Flammable up	Non-specific source
19	Residual and used stabilizer (additive fluff)	Polypropylene	Flammable	Specific source
20	Used refractories	Maintenance	Toxic	Special specific source

Flammable waste requires careful handling and storage in approved containers that are designed to prevent leaks and spills [10,13]. It's critical to isolate these wastes from any potential ignition sources, including open flames and sparks. Proper ventilation of storage areas is necessary to avoid the accumulation of flammable vapors, and well-designed facilities are needed for controlled incineration or other approved disposal methods of flammable waste. Employees must be trained in the safe handling, storage, and emergency response procedures specific to flammable waste to avoid accidents.

Toxic waste management necessitates meticulous identification, labeling, and secure storage. This waste should be stored in secure, leak-proof containers to avoid exposure and environmental contamination and should be kept separate from non-toxic and incompatible substances [14,15]. Specialized disposal by licensed waste disposal entities specializing in toxic waste management is mandatory to ensure adherence to disposal standards and prevent environmental harm. Adequate protective measures, including the use of Personal Protective Equipment (PPE), must be in place for workers handling toxic waste, and regular monitoring and reporting of the storage areas and disposal are vital to maintain transparency and compliance with waste management regulations.

Beyond these specific measures, the implementation of waste reduction strategies and recycling and recovery programs are essential to minimize the environmental impact of waste generation [2]. Regular environmental audits should be conducted to ensure ongoing compliance and to identify areas for improvement in waste management practices. Emergency response plans should be well-formulated and implemented to address any accidental spills or leaks promptly. Finally, maintaining open lines of communication with the local community and other stakeholders is critical to address any concerns and ensure transparency and trust in waste management practices.

There are two B3 waste control programs at PT. X Plaju with a license, namely the SOR program and the used lubricant utilization program. The principle applied to the SOR program is recovery which aims to recover components from oil deposits or oil sludge. In implementing the SOR process, tools are needed that can support the operation.

A boiler is a tool used to make steam with a steam boiler capacity used in the SOR process with 2000 liters/hour. The mixing tank is the entry point for sludge oil from the sludge pond to the decanter. Mixing tanks are used to make the slurry oil more mixed and help accelerate the recovery of solid oil in the form of sand and other impurities mixed in the slurry oil gathered under the mixing tank. The decanter centrifuge is a high-speed device that rotates to produce a strong centrifugal force to separate components with different densities [16]. Content with a greater mass will be removed through the outlet.

Meanwhile, the lighter mass (oil and water) will be removed from the settling tank. The settling tank can accommodate the separation of oil liquids and improve the quality of the oil by settling. In addition, the jumbo bag serves to accommodate cake that has been separated from the decanter with a jumbo bag capacity of 1 m^3.

The vacuum tank transfers the recovered oil to the tank, which will later be reused as CDU feed. The first process carried out is making steam with a boiler. Next, steam is used for the SOR process by flowing into all SOR processes, starting from heating the sludge oil in the sludge pond until it becomes slurry oil. The stage of changing from sludge oil to slurry oil is the first stage in the SOR process. After these changes, the slurry oil is flowed by the pump to the mixing tank in a hot state. At the mixing tank stage, the process of stirring the slurry oil and settling and separating the liquid and solid or impurities from the slurry oil for the first time. Next, the slurry oil has flowed to the decanter centrifuge process. In the decanter centrifuge, the slurry oil begins to be separated between the liquid and solid phases. The liquid phase then flowed to the oil-settling tank for further separation of oil and water.

The liquid phase-separated into oil (recovered oil) is pumped into a vacuum truck and then transported to the R28/29 tank to be mixed into the Crude Distillation Unit (CDU) process. Furthermore, the separation in water will flow into the OC-8 channel. Meanwhile, solids or what is commonly called cake/solid waste will be put and packed into jumbo bags. Then, it is stored in the B3 waste TPS before being handed over to a third party who has a permit. Figure 1 showed process flow assumes a linear progression from the creation of steam to the disposal of solid waste, with the details as described in the text. Creating a visual representation with a tool like Microsoft Visio or any other graphic design software would be more illustrative and can better represent parallel processes or loops if they exist in the actual workflow.

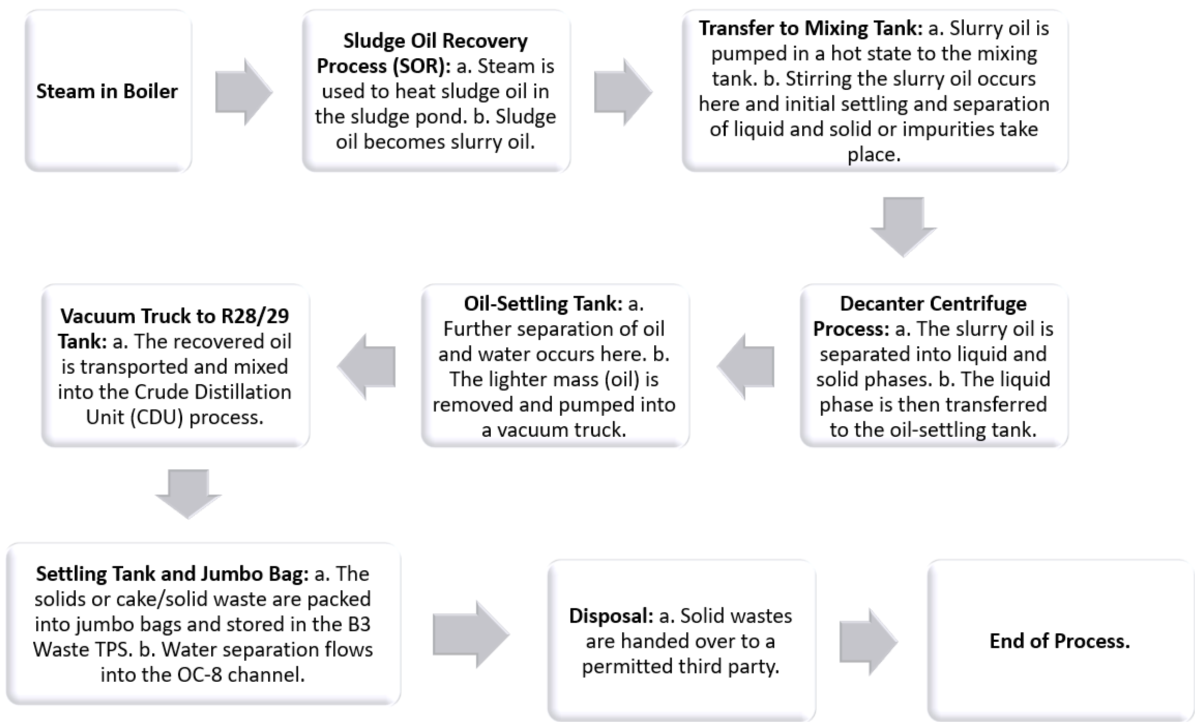

Figure 1. Flow Process.

B3 sludge oil waste is a waste generated from petroleum refining and activities [17]. B3 sludge oil waste contained in PT. X Plaju is obtained from cleaning tank activity. There are three main components possessed by sludge oil [17], namely:

1. Water: 20–95%
2. Oil: 5–70%
3. Solids: 5–10% (in the form of wax, mud, iron rust, tar, resin, biological material, metal, and others)

Sludge oil, given its nature and composition, has distinct properties and applications that are pivotal to its utility, especially in the context of refinery production. Our study seeks to provide a comprehensive understanding of these characteristics, especially considering the evolving demands and standards of the petroleum industry.

A critical criterion for sludge oil's application in refinery production is the content of the oil component. For it to qualify as a viable raw material for refining, the oil component within the sludge must constitute more than 20% of the sludge oil's total volume. If the oil content falls short of this threshold, standing at less than 20%, then the sludge oil has to be handed over for external processing. It is imperative that this external entity possess the requisite permit for the treatment of B3 waste, ensuring that the handling aligns with environmental and safety regulations. However, sludge oil's composition is not limited to the triad of oil, water, and solids. A more detailed dissection of its content reveals the presence of other materials, which might be considered impurities or by-products from the storage tanks and the refining process. These include components like tank rust, sand, ash, and other residual materials. Among these constituents, petroleum hydrocarbon stands out as the most integral element, primarily due to its role in determining the quality and utility of the sludge oil.

Descriptively, sludge oil manifests as a semi-solid substance with a dark or blackish hue. It carries a distinctive smell, reminiscent of hydrocarbons, an aroma familiar to those in the petroleum industry. Furthermore, sludge oil is characterized by its extremely low solubility in water, emphasizing the importance of segregation processes in its management. To fathom the intricate details of sludge oil's characteristics, several tests and analytical processes are employed. A proximate analysis offers insights into the moisture, volatile matter, ash, and fixed carbon content, providing a fundamental understanding of its immediate components. Meanwhile, an ultimate analysis sheds light on the elemental composition, revealing the percentages of carbon, hydrogen, nitrogen, sulfur, and oxygen. The density test and pH level determination present the physical and chemical properties, respectively. Additionally, the Atomic Absorption Spectroscopy (AAS) test further scrutinizes the metal content in the sludge oil, underlining any potential contaminants or elements of concern. Proximate analysis of solid fuels is used to determine the characteristics and quality concerning the use of the coal, namely to determine the relative amount of moisture content, volatile matter (VM), ash, and tethered carbon (FC) contained [18–20]. This proximate analysis is the most basic test in determining the quality of solid fuels [20–22]. Based on the data in Table 2, the moisture content is 28.32%; this the amount of water content contained in the sludge oil waste. The ash content contained in sludge oil is 0.033%. The volatile content of 71.11% means the organic part in the oil sludge evaporates when heated at a temperature of 950°C, and 0.53% fixed carbon indicates the amount of carbon contained in the residual material after the volatile matter is removed.

Fixed carbon was determined to determine the carbon content after the carbonization and activation process. The ultimate analysis determines the number of the elements carbon, hydrogen, and nitrogen obtained 85.99, 13.42, and 0.21%, respectively. The density of sludge oil based on the above data is 0.85 gr/cc. At the same time, the pH of sludge oil has a value of 7.9 which means that sludge oil has a neutral pH (6-9) [17].

Table 2. Data analysis of proximate, ultimate, density and pH of sludge oil [17].

Proximate analysis (%)				Ultimate Analysis (%)			Density (gr/cc)	pH
Moisture	Ash	Volatile	Fixed Carbon	C	H	N		
28.32	0.033	71.11	0.53	85.99	13.42	0.21	0.85	7.9

Our exploration primarily revolves around the data derived from the SOR process. When dissected, the data reveals some intriguing patterns and trends. In reference to Table 3, the year 2016 displayed a total inflow of sludge measuring up to 1,355.154 barrels (bbls). Post-processing, the breakdown of this sludge revealed different components: solid, oil, water, and emulsion. Delving deeper into these numbers, the components amounted to 111 bbls for solid, 475 bbls for water, 798 bbls for emulsion, and a notably lower 70 bbls for oil. The data presents two striking insights. Firstly, the emulsion component had the highest volume among all other constituents, making it the most dominant aspect of the sludge for that year. Conversely, the oil content was the least, with its volume accounting for a mere 70 bbls. When this is viewed in proportion to the total sludge inflow, the oil component constitutes only about 5% of the entire incoming sludge in 2016.

Transitioning to the year 2017, a shift in the composition is noticeable. There was an upsurge in the water component, reaching a volume of 1,611.667 bbls. The oil content, on the other hand, registered at 131.667 bbls. When these numbers are contextualized, it's evident that the oil only made up approximately 7% of the total incoming sludge for the year 2017, as inferred from Table 3. While this percentage denotes a slight increase from the previous year, the content of oil in the incoming sludge remains relatively low. This continuous low proportion of oil, as deduced from the two years of data, beckons further investigation to ascertain its underlying causes and potential implications for the efficiency of the SOR process at PT. X Plaju. It is essential to probe whether this is a pattern unique to these years or a more extended trend, as it may have significant ramifications for the overall profitability and sustainability of the operation.

One approach to mitigate the oil increase is by refining the sludge separation process to enhance the extraction of oil effectively and efficiently. Enhancing the operational parameters, optimizing the separation process, and regular maintenance of the equipment involved in the sludge oil recovery can potentially aid in the reduction of oil levels in the SOR process. Moreover, the development and implementation of more advanced and precise oil extraction technologies can also contribute to resolving this issue.

In addition, conducting thorough and regular analyses of incoming sludge can also facilitate the identification of anomalies in oil content, enabling timely interventions. This approach ensures that any discrepancies in oil levels are promptly detected and rectified, preventing any potential escalation in oil content within the SOR process. Lastly, efficient water and solid removal processes should also be optimized and enhanced to ensure that the rise in oil levels is addressed comprehensively, ensuring the sustenance of environmental equilibrium and operational efficiency. Regular monitoring, combined with continual improvements in the processes and technology employed in SOR, can play a crucial role in maintaining and potentially reducing the oil levels in the SOR process, fostering a more sustainable and efficient operational environment.

Table 3. Data Processing SOR [23].

No.	Parameters	2016	2017
1.	Incoming sludge	1,355.154 bbls	1,974.857 bbls
2.	Solid	111.000 bbls	46.933 bbls
3.	Oil	70.000 bbls	131.667 bbls
4.	Water	475.000 bbls	1,611.667 bbls
5.	Emulsion	798.000 bbls	406.233 bbls

4. CONCLUSION

Regarding the innate attributes of the sludge oil being processed. This information is crucial to evaluate the oil’s quality, the efficacy of the recovery method, and the environmental impact of the process. A preliminary proximate analysis from existing literature discloses that the oil has a considerable moisture content of 28.32%. This high moisture content underscores the need for effective dehydration or segregation procedures to optimize recovery efficiency. The ash content is minor, measured at 0.033%, indicating a minimal presence of inorganic residues and contaminants. It is also noted that a significant 71.11% of the sludge oil is volatile, meaning that a majority of the oil’s components can evaporate when subjected to high temperatures, a significant point for processes like distillation or refining. Meanwhile, the fixed carbon content is 0.53%, denoting the remaining non-volatile carbon after the volatile components have evaporated. In addressing anomalies in oil content and maintaining operational efficiency, conducting meticulous and regular analyses of incoming sludge is essential. This proactive approach ensures the immediate identification and rectification of any discrepancies in oil levels, preventing potential escalations within the SOR process. Ensuring the optimization of water and solid removal processes is also crucial in managing increases in oil levels, reinforcing environmental balance and operational efficiency. Persistent monitoring and continual enhancements in the technologies and methodologies deployed in the SOR are critical. Such advancements can significantly aid in sustaining and potentially reducing oil levels in the SOR process, promoting an operationally efficient and environmentally sustainable framework.

REFERENCES

[1] A. Shahsavari, M. Akbari, Potential of solar energy in developing countries for reducing energy-related emissions, *Renew. Sustain. Energy Rev.*, vol. 90, pp. 275–291, 2018.

[2] I. W. K. Suryawan, C.-H. Lee, Citizens' willingness to pay for adaptive municipal solid waste management services in Jakarta, Indonesia, *Sustain. Cities Soc.*, vol. 97, pp.104765, 2023.

[3] M. H. Hasan, T. M. I. Mahlia, H. Nur, A review on energy scenario and sustainable energy in Indonesia, *Renew. Sustain. Energy Rev.*, vol. 16, no. 4, pp. 2316–2328, 2012.

[4] Q. Helmy, E. Kardena, Petroleum Oil and Gas Industry Waste Treatment; Common Practice in Indonesia, *J. Pet. Environ. Biotechnol.*, Vol. 6, No. 5, pp. 1000241, 2015.

[5] E. A. Taiwo, J. A. Otolorin, Oil Recovery from Petroleum Sludge by Solvent Extraction, *Pet. Sci. Technol.*, vol. 27, no. 8, pp. 836–844, 2009.

[6] P. Yan, M. Lu, Q. Yang, H.-L. Zhang, Z.-Z. Zhang, R. Chen, Oil recovery from refinery oily sludge using a rhamnolipid biosurfactant-producing *Pseudomonas*, *Bioresour. Technol.*, vol. 116, pp. 24–28, 2012.

[7] Q. Huang, X. Han, F. Mao, Y. Chi, J. Yan, Effect of the Particle Surface on Oil Recovery from Petroleum Sludge, *Energy & Fuels*, vol. 28, no. 7, pp. 4480–4485, 2014.

[8] N. Ardiana, I. W. K. Suryawan, B. Ridhosari, M. M. Sari, Hazardous Waste Generation and Composition from Electric Train Activities, *Indonesian Journal of Chemical Analysis*, vol. 5, no. 1, pp. 62–67, 2022.

[9] N. L. Pangestu, N. L. Zahra, A. Sarwono, I. W. K. Suryawan, Produced Water Treatment Planning Using Corrugated Plate Interceptor and Ultra Filtration for Water Recycling, *J. Serambi Eng.*, vol. 6, no. 4, pp. 2286–2293, 2021.

[10] M. Qasim, Z. Shareefdeen, Advances in Waste Collection, Storage, Transportation, and Disposal, in *Hazardous Waste Management: Advances in Chemical and Industrial Waste Treatment and Technologies*, Z. Shareefdeen, Ed. New York: Springer Cham, 2022, pp. 135–166.

[11] D. A. Vallero, An introduction to hazardous waste engineering, in *Hazardous Waste Management: An Overview of Advanced and Cost-Effective Solutions*, D. Yadav, P.

Kumar, P. Singh, D. A. Vallero, Ed. Amsterdam: Elsevier, 2022, pp. 217–273.

[12] A. Dhawande, S. Moon, V. Kale, A. M. Pethe, N. A. Raut, Pharmaceutical waste: an emerging threat to the ecosystem, in *360-Degree Waste Management: Biomedical, Pharmaceutical, Industrial Waste, and Remediation*, vol. 2, N. A. Raut, D. M. Kokare, B. A. Bhanvase, K. R. Randive, and S. J. Dhoble, Ed. Amsterdam: Elsevier, 2023, pp. 3–37.

[13] X. Liu, J. Li, X. Li, Study of dynamic risk management system for flammable and explosive dangerous chemicals storage area, *J. Loss Prev. Process Ind.*, vol. 49, pp. 983–988, 2017.

[14] A. D. R. Atthar, M. M. Sari, I. W. K. Suryawan, I. Y. Septiariva, S. Suhardono, I. M. J. Sianipar, Repercussions of the COVID-19 Pandemic on the Generation and Composition of Medical Waste at Hospital X City of Jakarta, Indonesia, *Int. J. Public Heal. Sci.*, vol. 11, no. 3, 949–956, 2022.

[15] M. M. Sari, M. Yosafaat, A. K. Nastiti, I. Y. Septiariva, R. T. B. Aryanto, Y. E. Priutama, I. W. K. Suryawan, S. Suhardono, Planning of Single-Used Mask Waste Containers as Personal Protective Equipment: A Case Study of Jakarta City Station, *Int. J. Public Heal. Sci.*, vol. 11, no. 3, pp. 927–934, 2022.

[16] G. Hu, Development of novel oil recovery methods for petroleum refinery oily sludge treatment, Ph.D. dissertation, University of Northern British Columbia, Canada, 2016.

[17] M. Silalahi, Pengolahan limbah lumpur minyak (*oil sludge*) menjadi bahan bakar gas alternatif, 2015.

[18] E. Nursanto, A. Ilcham, Characteristic of low rank coal from Warukin Formation, South Kalimantan and their implication for coal liquefaction, *IOP Conf. Ser.: Earth Environ. Sci.*, vol. 212, pp. 012027, 2018.

[19] S. A. Opatokun, T. Kan, A. Al Shoaibi, C. Srinivasakannan, V. Strezov, Characterization of Food Waste and Its Digestate as Feedstock for Thermochemical Processing, *Energy & Fuels*, vol. 30, no. 3, pp. 1589–1597, 2016.

[20] I. W. K. Suryawan, I. Y. Septiariva, E. N. Fauziah, B. S. Ramadan, F. D. Qonitan, N. L. Zahra, A. Sarwono, M. M. Sari, K. K. Ummatin, L. J. Wei, Municipal Solid Waste to Energy : Palletization of Paper and Garden Waste into Refuse Derived Fuel, *J. Ecol. Eng.*, vol. 23, no. 4, pp. 64–74, 2022.

[21] A. K. Majumder, R. Jain, P. Banerjee, J. P. Barnwal, Development of a new proximate analysis based correlation to predict calorific value of coal, *Fuel*, vol. 87, no. 13–14, pp. 3077–3081, 2008.

[22] I. W. K. Suryawan, J.-W. Lim, B. S. Ramadan, I. Y. Septiariva, N. K. Sari, M. M. Sari, N. L. Zahra, F. D. Qonitan, A. Sarwono, Effect of sludge sewage quality on heating value: case study in Jakarta, Indonesia, *Desalin. Water Treat.*, vol. 249, pp. 183–190, 2022.

[23] A. M. Cahyani, M. Busyairi, J. Nurdiana, Identifikasi Timbulan Limbah *Sludge Oil* dari Kegiatan Eksploitasi Dan Produksi Minyak dan Gas Bumi PT. AMC, *Prosiding Seminar Nasional XII "Rekayasa Teknologi Industri dan Informasi" Sekolah Tinggi Teknologi Nasional*

Yogyakarta, pp. 282–287, 2017.