JEE Journal of Ecological Engineering

Journal of Ecological Engineering 2023, 24(10), 315–323
https://doi.org/10.12911/22998993/169960
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Received: 2023.06.27
Accepted: 2023.07.24
Published: 2023.08.24

Utilization of Tar Waste from the Gasification Process of Landfill Waste as a Disinfectant

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ABSTRACT

Gasification is a combustion process that can converts waste into electricity. Tar waste is liquid waste from the gasification process that has not been managed and utilized. Tar waste contains toxic compounds that can pollute the environment if they enter it. Tar waste has the potential to be used as a raw material for disinfectants because it contains phenol and polycyclic aromatic hydrocarbon (PAH) compounds This study aims to determine the potential of tar waste as a disinfectant based on antibacterial activity tests and phenol coefficient tests with *Salmonella typhimurium* bacteria. Tar waste was tested for its antibacterial activity to determine the effective concentration between with concentrations of 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% and 100% that has the potential to be an active ingredient in disinfectants. The effectiveness of the disinfectant was measured by the coefficient value of tar waste compared to 5% phenol against the *Salmonella typhimurium* test bacteria. If the coefficient value is equal to or greater than 1, it is said that tar waste is effectively used as a disinfectant. The results showed that the effective concentration of tar waste as a raw material for disinfectant through the antibacterial activity test was 100% with an inhibition zone diameter of 0.275556 mm in the weak category. The phenol coefficient value of 100% tar waste is 0.05. The conclusion of this study is that tar waste with a concentration of 100% is not yet effective as a raw material for disinfectant according to SNI 1842:2019.

Keywords: tar, disinfectant, antibacterial, phenol coefficient.

INTRODUCTION

The gasification process is a solution for the dumping of garbage with the consept of waste into energy (Nurfadhilah et al., 2022). The system for processing waste into electrical energy uses several methods, one of which is processing waste into electricity using gasification technology (Faruq, 2016). Gasification is a thermochemical method of converting solid fuel into syngas gas fuel in a gasifier container by supplying gasification agents such as hot steam, air, and others (Suhendi et al., 2016). Gasification generally consists of four processes, namely drying, pyrolysis, oxidation, and reduction (Vidian, 2008). The gasification process produces products in the form of syngas (gas phase), char (solid phase), and tar (liquid phase). Syngas is used to turn the generator's turbines, and the char is used as fuel for power plants. While tar waste has not been utilized, every process always produces tar. Tar waste produced has not been used yet, so it is only handled in a holding tank because it cannot be utilized and cannot be disposed of directly into the environment. The amount of tar waste will continue to increase along with the increasing intensity of the operation of the gasification installation, so efforts are needed to deal with the presence of tar waste so that it is managed and becomes a product that has use value. The tar waste generated from the gasification process accounts for as much as 10–15% of the energy in all gasification products (Zeng et al. 2020). The composition of the gasified tar contains phenolic compounds, aromatic compounds, aldehydes, ketone furans, and acids (Siagian, 2016). The composition of phenolic compounds in tar at a temperature of

400 °C is 6.72%, while at a temperature of 600°C it is 8.99% (Siagian, 2016). Tar waste contains phenols, which produce secondary pollution, and benzene compounds, which are carcinogenic, so they can endanger health and cause environmental pollution if disposed of directly into the environment (Zeng et al., 2020). Tar waste also contains mild aromatic compounds, especially benzene and toluene, with a content of 70% (Prando et al., 2016). Therefore, it is necessary to treat tar waste so that it does not pollute the environment.

Utilization that can be done on tar waste is to make it a raw material for disinfectants because the composition of the tar contains phenol compounds. Phenol compounds function as strong antibacterial and antioxidant active compounds (Tambun et al., 2016). Phenol is set as a standard in testing the effectiveness of disinfectants because of its proven ability to kill microorganisms (Khaira, 2016). During a pandemic and when viruses are spreading in the environment, disinfectants are products that can be useful for the community because they can protect the environment from the dangers of infectious diseases caused by microorganisms. Utilization of tar waste as a disinfectant can also be beneficial for the environment because, by utilizing this tar waste, it will not be disposed of directly into the environment, thereby reducing soil, water, and air pollution due to the adverse effects of the tar content in the waste. Disinfecting tar waste is not only a solution for the environment; it can also be of economic value. Utilization on a household and industrial scale can be carried out to develop disinfectant products based on tar waste and can create new jobs. The whole series of gasification processes will further minimize the existence of unused waste products and increase their economic value. Based on the problems above, researchers want to conduct research with the aim of knowing the potential of tar waste as a disinfectant.

MATERIALS AND METHODS

Materials

The sample of the waste studied comes from the gasifier that is in the processing ino electrical energy (Surakarta, Indonesia). The waste used for making *feedstock* and raw materials consists of two types of waste, namely *new waste* and *old waste. New waste* is new waste that comes from the waste depositor, while *old waste* is waste that has been piling up for a long time at the landfill garbage. The two types of waste are mixed and then dried until the water content is less than 20%. All types of waste can enter the gasification installation, but iron-type waste and soil mixtures are avoided, namely because they are separated by magnetic and sieving technology.

Antibacterial activity

Antibacterial test using agar diffusion method. Antibacterial activity of tar waste with concentrations of 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% and 100% compared to the positive control disinfectant solution of 1.5% *Benzalkonium chloride* and pine oil 3.5% and positive control aquadest 100%. *Salmonella thypimurium* bacteria were inoculated on nutrient agar (NA) media. then incubated for 24 hours. Dissolving the bacteria using a 0.8% NaCl solution and adjusting the turbidity with a 0.5 M Farland standard solution. Then streak the bacteria on the MHA media which has thickened in a petri dish aseptically. Sterile paper discs with a diameter of 5.43 mm were immersed in the test solution for 10 minutes. Place the paperdisk in the petri dish that already contains the bacteria. Cover the petri dish with plastic wrap and incubate for 24 hours at 37 °C. Observe the inhibition zone that forms around the paper disc. The test was carried out three times. The diameter of the cold zone is measured by calculating the horizontal, vertical, and inclined diameters divided by 3. The concentration of tar wastes with the largest barrier zone is the most effective concentration for disinfection, and advanced testing of phenol coefficients is carried out on the samples.

Phenol coefficient

The killing power of the test solution was compared with the killing power of phenol. In the test of phenol coefficients used one sample of tar waste with effective concentrations obtained through previous test of antibacterial activity. A waste test solution of tar waste and 5% phenol was diluted with dilutions of 1:20, 1:30, 1:40, 1:50, 1:60, 1:70, 1:80, 1:90, 1:100, 1:110, 1:150, 1:200, and 1:250. Dilutions were carried out in test tubes for each solution and dilution level. Test bacteria (*Salmonella typhimurium*) were inoculated on NA medium, diluted with NaCl 0.8%, and adjusted for turbidity with 0.5% McFarland's solution. Bacteria were homogenized with the test solution at contact times of 5 minutes, 10 minutes, and 15 minutes. Then incubated for 24 hours at 37 °C. The presence of bacterial growth is indicated by the media becoming cloudy, and the absence of bacterial growth is indicated by the media remaining clear.

RESULTS AND DISCUSSION

Disinfectants are chemicals contained in antimicrobial products and used in disinfection activities. Disinfectant products need to be tested to see the effectiveness of the ingredients used in disinfectants. (Hazefa, 2021). Samples of tar waste have been studied for their potential as disinfectant raw materials. In this study, testing the effectiveness of tar waste disinfectant was carried out through bacterial activity tests and phenol coefficient tests. Based on the physical observations carried out, the tar waste sample has the characteristics of a liquid, concentrated brown colour and a striking smell that is typical of combustion smoke. The chemical content of tar waste resulting from waste gasification was obtained through a literature study. According to Chan *et al*. (2020), the content of tar waste from the gasification of municipal solid waste is dried to a moisture content of 25% of the total waste weight, then sorted into a waste composition consisting of plastic (35%), paper (25%), textiles (7, 7%), wood (6.9%), food waste (16%), and horticultural waste (11.4%) can be seen on Table 1. Based on Table 1, tar waste contains aromatic hydrocarbons, and some of them are included in polycyclic aromatic hydrocarbon compounds (PAHs). Aromatic hydrocarbon compounds in tar waste with dominating levels are toluene, styrene, ethylbenzene, and xylene. The chemical components of tar waste that are classified as aromatic hydrocarbon compounds are Naphthalene , Anthracene, flouranthene, pyrene, Indeno, and benzo, which are included in the main PAH compounds (Hasan, 2020). Another chemical component of tar waste is phenol, which is included in the disinfectant class. Phenol in tar waste has a low concentration (1–5%). P-cresol is also a compound derived from phenol, which is contained in tar waste at a concentration of <1%.. The presence of phenol content in a material will indicate the potential activity of the material as an antibacterial (Agustina et al., 2017). Based on the chemical components in tar waste, what contributes to being an active disinfectant are phenolic compounds and their derivatives. The low content of phenolic compounds and their derivatives in the tar waste from gasification of waste is because the raw material for the waste used in the gasification process is a mixture of old waste and new waste where the process of decomposition of organic materials has not occurred optimally and the waste is pretreated before entering the gasification process. The process

Table 1. Content in the result tar gasification rubbish

Content	Amount in gathered tar
Toluene	++++
Ethylbenzene	++
p- xylene	++
Styrene	++++
0-xylene	++
Phenol	++
p- cresol	+
Naphthalene	+++++
Naphthalene-2-methyl	++
Naphthalene-1-methyl	++
Biphenyl	++
Naphthalene-2-ethyl	+
Naphtakene-1-ethyl	+
Naphthalene-2,3-dimethyl	+
Naphthalene-1,3-dimethyl	+
Acenaphtilene	++
Naphthalene-1,2-dimethyl	+
Biphenylene	+
Acanaftena	+
Flourena	++
Phenanthrene	++
Anthracena	++
Phenylnaphthalene	+
Flouranthena	++
Pyrenees	++
Benzo (a) anthracene	+
Krisena	+
Benzo (b) fluoranthena	+
Benzo (k) flourantine	+
Benzo (a) pyrene	+
Indeno (1,2,3-cd) pyrene	+
Dibenzo (a,b) anthracene	+
Benzo (g,h,i) perylene	+

Note: ++++ (>10% of measured tar content), +++ (5–10%), ++ (1–5%), and + (<1%) (Chan et al., 2020).

of decomposing waste or organic matter can produce phenolic compounds. As stated by Arbain et al. (2009), the decomposition of organic waste containing toxic synthetic organic matter will produce high levels of phenol. According to Haji et al. (2006), the chemical content of gasification products is influenced by the chemical content of the raw materials and the temperature during the pyrolysis process. High phenol levels are also caused by the decay of organic materials such as wood, animal feed residues, and organic fertilizers (Yogafanny, 2015). Phenol content is also influenced by the amount of lignin contained in the raw material because phenol comes from the decomposition of lignin (Agustina et al., 2017).

Antibacterial activity of tar waste

Antibacterial activity test was conducted to determine the ability of tar waste to inhibit bacterial growth as an active antibacterial ingredient in disinfectants. The bacteria used in this study, *S.typhiimurium* , was chosen because it is a gram-negative facultative anaerobic bacterium and is the standard for testing bacteria in SNI 1842:2019. *S.typhiimurium* is a representative bacteria used in this study. Based on Table 2 and Figure 1, it can be seen that the antibacterial results of tar waste against *S. typhimuriu*m with a solution concentration of 10–80% have no zone of inhibition. The inhibition zone was formed

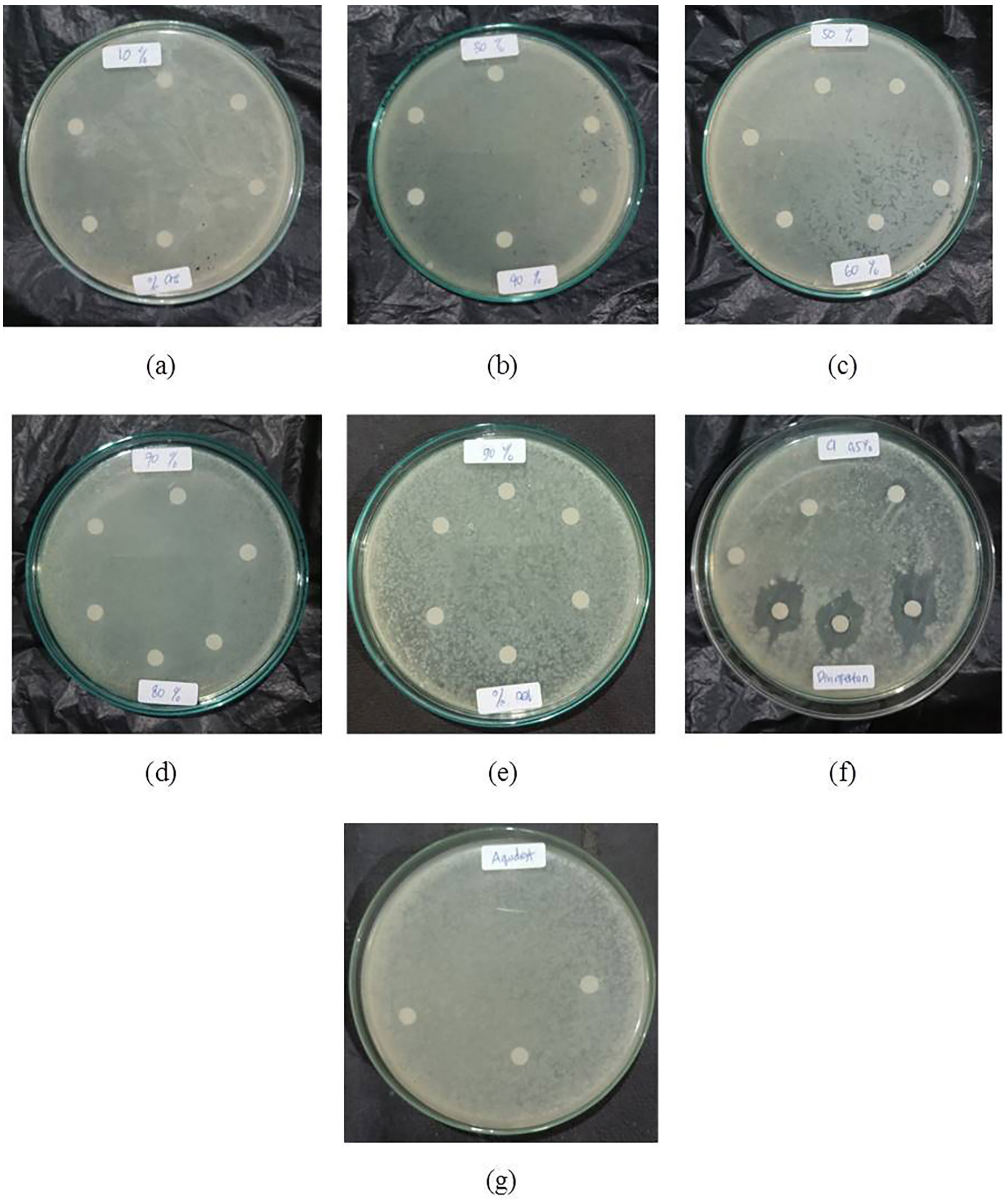

Figure 1. Inhibition zone diameter of tar waste at concentrations: (a) 10% and 20%; (b) 30% and 40%; (c) 50% and 60%; (d) 70% and 80%; (e) 90% and 100%; (f) control (+); (g) control (-)

Table 2. Tar waste antibacterial test results against Salmonella typhimurium

Concentration	Inhibition zone diameter (mm)			Average (mm)
	I	II	III	
Control (-)	0	0	0	0
10%	0	0	0	0
20%	0	0	0	0
30%	0	0	0	0
40%	0	0	0	0
50%	0	0	0	0
60%	0	0	0	0
70%	0	0	0	0
80%	0	0	0	0
90%	0.283	0.213	0..047	0.181111
100%	0.207	0.297	0.323	0.275556
Control (+)	13.163	9.903	10.94	11.33556

at a solution concentration of between 90% and 100%. Both of these concentrations formed a weak inhibition zone, which was larger than the negative control but still small compared to the positive control disinfectant containing 3.5% pine oil and 0.75% BKC. The largest inhibition zone was found at a 100% solution concentration with an inhibition zone diameter of 0.275556 mm, and the smallest inhibition zone was at a 90% solution concentration with an inhibition zone diameter of 0.181111 mm, but they were still very far away when compared to the inhibition zone in positive controls using disinfectants containing 3.5% pine oil and 0.75% BKC with an inhibition zone diameter of 11.33556 mm. The increase in the diameter of the inhibition zone at concentrations of 90% and 100% indicates that the greater the concentration used, the greater the inhibition zone formed. This is in line with the research of Suryani et al. (2019), which showed that the increasing concentration of n-hexane extract of E. elatior stems provided a larger inhibition zone because the many nonpolar compounds extracted could inhibit the growth of *S. mutans* bacteria.

According to the inhibition zone category by Paudel et al. (2014) in Table 3, there are four categories of antibacterial activity: very strong (inhibition zone >20 mm), strong (inhibition zone 15-20 mm), moderate (inhibition zone 10-15 mm), and weak (inhibition zone 10). Based

Table 3. Category of antibacterial activity (Paudel et al., 2014)

Inhibition zone diameter (mm)	Category
<10	Weak
10–15	Moderat
15–20	Strong
>20	Very strong

on the category of antibacterial power strength in Table 4 above, the tar waste with a concentration of 90% and 100% and a diameter of the inhibition zone of, respectively, 0.18111 mm and 0.275556 mm is included in the weak category, while the positive control used a disinfectant containing pine 3.5% oil and 0.75% BKC of 11.33556 mm showed a moderate category as an antibacterial in inhibiting the growth of *S. typhimurium* bacteria and a negative control of 0 mm.

Negative control of the aquadest solution does not show antibacterial properties. This suggests that the solvent does not affect the antibacterial activity of the test solution against *S. typhimurium*, so the presence of antibacteric activity is caused by the trial solution. Test solutions with concentrations of 10%, 20%, 30%, 40%, 50%, 60%, 70%, and 80% are not able to inhibit the growth of *S. typhimurum* bacteria. The absence of inhibition of bacterial growth may be related to the structure within the cell walls of the

Table 4. Result Phenol coefficient of tar waste for Salmonella typhimurium

Parameter	Result	Minimal	Standard
Phenol coefficient	0.05	1	SNI 1842:2019

complex gram-negative bacteria and the concentration of the active ingredients contained in the test solution. According to Nuri (2009), most of the Gram-negative bacteria have lipopolysaccharide complexes on the cell walls. Gram-negative bacteria are also protected by the outer membranes becomes an effective barrier regulating the passage of large molecules such as antibacterial agents into cells (Dewanto, 2021). The characteristic of the test bacteria is the inhibitory factor of the compounds in tar waste to diffuse on the bacterial cells. Test solutions with concentrations of 10%, 20%, 30%, 40%, 50%, 60%, 70%, and 80% have different concentration of the active substance, the smaller the concentration, the lower the content of the effective substance. This is in line with Hazefa (2021), which states that the antibacterial performance on each ingredient is different because the concentration of the ingredients and active substances used as antibacteria can affect the antibacterial activity.

The mechanism of inhibition of bacterial growth in the test solution with a concentration of 90% and 100% can occur due to inhibition of bacterial cell membrane synthesis. Damage to the cell membrane prevents important materials from entering the cell and causes nucleotides and amino acids to leave the cell (Suhara et al., 2020). The existence of antibacterial activity in tar waste is because tar waste contains phenolic compounds. The mechanism of phenol as an antibacterial agent which is toxic in protoplasm can damage and penetrate the cell wall, then precipitate bacterial cell proteins (Harman, 2013). Antibacterial agents are substances used to control the growth of pathogenic bacteria (Dewanto et al., 2021). In line with research conducted by Ajizah (2004), the inhibition of *S. typhimurium* is influenced by concentration factors active substances dissolved in *Psidium guajava* and types of antimicrobial ingredients. In his research *Psidium guajava leaves* showed antibacterial properties against *S. typhimurium.* The chemical compounds contained in *Psidium guajava leaves* are tannins, essential oils, and flavonoids which have antibacterial properties (Ajizah, 2004). Phenol compounds are the content of tar waste in low levels (1–5%). The results of the study showed that the antibacterial activity of tar waste was in the weak category, indicating that even though a small concentration of phenol still had an antibacterial effect. As stated by Mayachiew and Devahastin (2008) minor components can act as factors that contribute to antibacterial activity, because it is possible that there is a synergistic effect between the various forming components.

The addition of an inhibition zone at a concentration of 100% compared to a concentration of 90% indicates that tar waste has antibacterial effectiveness, and the higher the concentration, the greater the resulting inhibition zone. A tar waste concentration of 100% is the concentration with the best antibacterial effectiveness. This is because the higher the concentration, the more active ingredients it contains (Manarisip et al., 2019). Because the higher the active ingredient and the higher the sample concentration, the greater the antibacterial activity produced (Kurnia, 2020). According to Irianto (2007), the antimicrobial properties of a compound are said to have high activity against bacteria if the lowest bacterial inhibition concentration is small but has a large inhibition diameter. The most effective concentration to be used as a disinfectant is a 100% solution concentration where the inhibition zone value is 0.275556 mm.

Phenol coefficent of tar waste

The determination of the phenol coefficient was carried out by comparing the lethality of tar waste against a standard 5% phenol solution using the test bacteria *Salmonella typhimurium.* The standard phenol coefficient value has been determined according to SNI 1842 of 2019. The standard phenol coefficient value has been determined according to SNI 1842 of 2019. In testing the phenol coefficient, a sample with an effective concentration obtained based on the previously carried-out antibacterial activity test was used. namely tar waste with a concentration of 100%. The concentration of 100% is the concentration with the highest antibacterial properties, so it has the most potential as a raw material for disinfectants. Based on Table 4, the phenol coefficient of tar waste against *S. typhimurium* is 0.05. The results of this calculation indicate that tar waste is less effective in killing *S. typhimurium*. According to Budiarti et al. (2021), the type of bacteria being inhibited, the structure of the bacterial cell wall, and the penetration and bonding of antibacterial compounds can affect the activity of antibacterial substances based on variations in the efficiency values of the phenols obtained. Gram-negative bacteria have an outer membrane that has low permeability so that it functions as a barrier, limiting the entry of antibacterial agents into the membrane (Khaira, 2016). In the outer membrane of negative bacteria, the formation of phospholipids (inner layer) and non-polar lipopolysaccharides (outer layer) can also occur, which makes it more difficult for compounds to enter gram-negative bacteria cells so that their antibacterial activity is less strong than that of gram-positive bacteria (Budiarti et al., 2021). Previous research showing the ineffectiveness of test disinfectants was done by Khaira (2016); the phenol coefficient value of 1.5% *Benzalkonium chloride* against *Pseudomonas aeruginosa* was 0.72. This value indicates that BKC 1.5% is less effective in killing *Pseudomonas aeruginosa*. This ineffectiveness is due to the characteristics of the *Pseudomonas aeruginosa* bacteria, which are resistant to antibacterial agents such as BKC, benzethonium, cetrimide, hexachlorophene, diamidin, triclosan, and others because of their physical ability to withstand the effects of interactions with these materials (Khaira, 2016).

The potential of tar waste

Tar waste generated from the gasification process is a source of aromatic hydrocarbon compounds for the environment. PAHs such as Benzo(a) Anthracene, Benzo(a) pyrene, Benzo[b] fluorantene, Dibenzo(a,h) anthracene, and Benzo[g,h,i] perylen are included in the group of compounds that are carcinogens, mutagens, and toxic, both to humans and aquatic organisms (Alawi et al., 2016). According to Ahmad (2012), PAH compounds that settle on the bottom of the waters are very toxic to aquatic organisms (shellfish types) which will accumulate in the bodies of aquatic organisms and then be eaten by humans so that humans will also accumulate PAH compounds in the body which can cause health problems. Tar waste also contains compounds belonging to the aromatic hydrocarbon group, namely the BTEX group (benzene, toluene, ethylbenzene, and xylene). Benzene can contaminate the soil, surface water, sediment, and groundwater environments and interfere with human health if it is contaminated with drinking water (Fahruddin, 2010). According to Rachmawani et al. (2016), the BTEX group is one of the causes of degradation of mangrove ecosystems, and at high concentrations, it can cause mass death of mangroves by disrupting the mechanism of nutrient and mineral exchange in roots and leaves. Tar waste that is stored and there is no good and correct management of this waste will contaminate water, air, and land, with the severity of the pollution depending on how severe the condition of the waste is left in an open environment without proper handling (Yana and Badaruddin, 2017). This pollution can originate from leaks in underground oil storage tanks and from industrial waste (Fahruddin, 2010).

Tar waste can be optimized for use as a disinfectant by purifying it of PAHs and adding other disinfectant active ingredients. Utilization of tar waste can be done by purifying it first because it contains carcinogenic PAH compounds. According to Wardayanie & Sitorus (2012), purification of PAH compounds needs to be done, especially for benzo(a)pyrena, which is a PAH compound that has the most dangerous carcinogenic effect, so that it can be used without causing side effects. According to Yulianti and Susanto (2011), an adsorbent that can be used in the treatment of industrial waste containing PAH compounds is active rice husk charcoal. The decomposition of benzene compounds can also be carried out by biological processes. Types of microbes that can degrade benzene are *Pseudomonas, Acinobacter, Bacillus, Alcaligenes, and Nocardia* (Fahruddin, 2010). The addition of active ingredients can be done by adding disinfectant products from household cleaners such as carbolic acid (which contains *benzalkonium chloride*) and floor cleaning liquid (which contains *pine oil*). As in the research of Musafira et al. (2020), disinfectant liquid can be made from household cleaning products, namely bleach, which contains *sodium hypochlorite* as a disinfectant in efforts to prevent the spread and transmission of the COVID-19 virus. Research by Hidayati and Syafitri (2021) used bleach, carbolic acid, floor cleaning liquid (containing *pine oil*), and vinegar ingredients as spray disinfectants. The addition of citronella essential oil can also be done to give an aroma and remove the smell of tar waste. Citronella essential oil contains ingredients that are efficacious apart from giving a distinctive aroma and, most importantly, as an antibacterial (Siregar, 2020).

The gasifier can produce tar waste of 0.5 tons per hour for each unit it operates and this figure will continue to increase in line with the increasing intensity of gasifier operations. With the quantity of tar waste produced, utilization is carried out, which can be a solution to management problems and increase the use value of tar waste. Tar waste can be optimized to be used as a disinfectant, but there are obstacles and challenges to applying it. The obstacle to implementing solutions to optimize tar waste into disinfectants is that the process requires additional time and materials. Tar waste from waste gasification must first go through the purification process of PAH and BTEX compounds, so it is necessary to procure and prepare a series of tools to carry out the process. Tar waste that has been purified from PAH and BTEX compounds is then formulated to determine the correct concentration for adding the active disinfectant ingredient. The formulation must be researched first. The correct formulation obtained can then be applied to optimize tar waste as a disinfectant.

CONCLUSIONS

Tar waste has antibacterial ability at concentrations of 90% and 100%, with sequential inhibition zones of 0.181111 mm and 0.275556 mm. The most effective concentration of an antibacterial active ingredient in disinfectant raw materials is 100% because it has the largest inhibition zone. Based on the phenol coefficient test, tar waste has a value of 0.05, which indicates that the disinfectant made from tar waste does not meet the minimum standards for disinfectants according to SNI 1842: 2019.

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