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Adsorption of Lead (Pb) Ions from Workshop Wastewater Using a Combined Filter of Coconut Shell Charcoal, Pumice, and Hair Waste

Marlinang Isabella Silalahi[1]✉, Ermi Girsang[2], Agung Abadi Kiswandono[3], Hartono[4], Putranto Manalu[5]

[1]Program Studi Kesehatan Masyarakat, Fakultas Kedokteran, Kedokteran Gigi dan Ilmu Kesehatan, Universitas Prima Indonesia, Medan, Indonesia
[2]Program Studi Kesehatan Masyarakat, Fakultas Kedokteran, Kedokteran Gigi dan Ilmu Kesehatan, Universitas Prima Indonesia, Medan, Indonesia
[3]Jurusan Kimia, Fakultas Matematika dan Ilmu Pengetahuan Alam, Universitas Lampung, Indonesia
[4]Program Studi Kesehatan Masyarakat, Fakultas Kedokteran, Universitas Adiwangsa, Jambi, Indonesia
[5]Program Studi Kesehatan Masyarakat, Fakultas Kedokteran, Kedokteran Gigi dan Ilmu Kesehatan, Universitas Prima Indonesia, Medan, Indonesia

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Abstract

The abundance of natural materials has attracted the attention of numerous researchers, who are now developing them into effective adsorbents for waste treatment applications. The waste stream in question includes laundry liquid waste from workshops, which is discharged directly into the environment via soil or drainage channels without any form of pretreatment. The lead content (Pb) in workshop laundry liquid waste is hazardous if discharged into the environment because it is difficult to degrade. This study investigates a filtration media composed of a combination of natural adsorbents—coconut shell charcoal, pumice stone, and hair waste—as an option for treating workshop laundry liquid waste. This research was conducted in January 2021 and focuses specifically on its effectiveness in reducing Pb levels. Adsorbents are arranged in a 60 cm diameter barrel with a height of 40 cm for each adsorbent. Laboratory analysis for the lead test method according to SNI 6989.8.2009 with Atomic Absorption Spectrophotometry (SSA) shows a decrease in Pb levels starting from the control to the first repetition, second repetition, and third repetition, where the final results show that Pb levels are safe to be discharged into the environment because they are below the environmental quality standards based on the Regulation of the Minister of Environment of the Republic of Indonesia Number 5 of 2014 concerning Wastewater Quality Standards, which is a maximum of 0.03 mg/L. Filtration A showed a Pb level of 0.021 (50% decrease), and Filtration B showed a Pb level of 0.106 (80% decrease)

Introduction

Workshop activities generate wastewater that can harm the environment if not treated before being discharged directly into water bodies or the environment. Every workshop activity, regardless of its scale, generates wastewater with unique characteristics and loads, which are determined by the specific processes involved. The accumulation of pollutants in wastewater from workshop activities can surpass the self-purification capacity of water bodies, thereby leading to their pollution (Dinas Lingkungan Hidup Kota Surabaya, 2019). The management of

✉ Correspondence Address:
Program Studi Kesehatan Masyarakat, Fakultas Kedokteran, Kedokteran Gigi dan Ilmu Kesehatan, Universitas Prima Indonesia, Medan, Indonesia
Email: marlinangsilalahi@yahoo.com

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hazardous waste from motorcycle workshops in Banjarbaru City, which includes used oil, oil filters, contaminated rags, and packaging bottles, is inconsistent with applicable government regulations, namely Government Regulation No. 22 of 2021. The substantial waste generation, combined with a lack of adherence to proper management protocols, underscores the imperative for immediate improvements to mitigate environmental risks. Oil used by motor vehicles will be exposed in the workshop. Mineral oil is a byproduct of crude petroleum, whereas synthetic oil is engineered from highly refined petroleum. Petroleum contains toxic compounds, including benzene, toluene, xylene, and ethylene dibromide. A study investigated the environmental impact of activities at the Tunas Sanjaya Motor Workshop in Sungai Belidak Village, Sungai Kakap Subdistrict, Kubu Raya Regency. Used oil waste from the workshop was directly disposed of into the environment, leading to significant soil and water pollution in the surrounding area. Liquid waste can consist of both organic and inorganic materials. If the waste seeps into the ground, it can damage the soil's fertility and contaminate the underground water sources (Widiyanto *et al*., 2015).

Workshop wastewater consists of oil, grease, solvents, and detergents. Analysis also shows that this wastewater has significant concentrations of COD (Chemical Oxygen Demand) and BOD (Biochemical Oxygen Demand), which are strong indicators of contamination (Wijayanti & Purnomo, 2023). Although the concentration of oil and grease is highest in the effluent, the presence of heavy metals is also crucial to consider, given the difficulty of their degradation in the environment. Lubricant waste oil is classified as hazardous waste. It is produced during engine friction processes and contains impurities, rendering it unsuitable for reuse without further treatment. Used lubricating oil contains heavy metal contaminants, including lead. Lead in used lubricating oil is toxic and can pollute the environment (Yehezkiel *et al*., 2023). Meanwhile, the processing of waste lubricants or used oil into liquid fuels with constant heat treatment has not been able to provide maximum results. Although the resulting fuel meets physical standards, it still has a high shortcomings, such as high viscosity and water content (Azharuddin *et al*., 2020). There is a strong correlation between the concentration of lead (Pb) in the air and its concentration in the blood, as well as with hemoglobin levels. The higher the concentration of Pb in the air, the higher the concentration of Pb in the blood, and the lower the hemoglobin levels (Khotijah *et al*., 2017).

The concentration and distribution of heavy metals in groundwater at selected auto repair shops in Ozoro metropolis, Nigeria, showed that they were unevenly distributed across the study area. The pollution index revealed that groundwater from the sampled sites was contaminated with heavy metals, including Cd, Ni, Cu, Mn, and Pb at moderate levels. Although the International Monitoring Agency mentioned that the groundwater in the area was within the approved limits for drinking water, there was evidence of slight contamination due to auto-repair activities (Owamah *et al*., 2023). Plumbum (Pb) is one type of heavy metal found in workshop laundry wastewater. The concentration of heavy metal Pb in groundwater samples as a result of workshop activities based on research conducted in Alphonso Zone, Ibadan (Nigeria) was 10.5 mg/L, which exceeds the WHO permissible limit (Maddusa *et al*., 2023). Research in Indonesia also revealed that the highest lead (Pb) content in groundwater was found in Keparakan Village. Most of the research sites had an RQ value more than 1, indicating a serious health risk. Therefore, the public needs to limit their consumption of well water, treat water according to health standards, and reduce lead exposure in their daily lives (Musfirah & Rangkuti, 2019). Health complaints influenced by lead levels in the blood are hematological disorders and kidney disorders in workers at a paint shop (Muliyadi *et al*., 2015).

To mitigate environmental Pb exposure, one effective method is to utilize various natural materials as adsorbents. This process involves the adsorption of Pb onto the material's surface, thereby reducing the concentration in the wastewater. The natural adsorbents focused on in this study are hair waste, pumice, and coconut shell charcoal. These three types of

adsorbents are then arranged into a filtration system to filter out polluting components from workshop laundry waste. Previous research has proven that the use of the three adsorbents in a combined filtration media proved to be quite effective in absorbing BOD, COD, TSS, phosphate, and oil levels (Silalahi *et al*., 2023). For this reason, the study wanted to determine the effectiveness of this type of filtration in reducing Pb levels from workshop laundry waste.

Hair possesses a significant ability to absorb substances, with numerous studies confirming its high absorption capacity. Research on the utilization of human hair and carbide waste as a ceiling substitute revealed that hair possesses a significant absorption capacity. Water absorption tests on GRC ceilings using human hair waste fibers show that the more hair fibers used, the higher the water absorption ability (Ramadhani *et al*., 2023). Research has proven that human hair can be a material for removing hexavalent chromium from aqueous solutions (Mondal & Basu, 2019). In a comparative analysis of different adsorbents, human hair demonstrated a higher maximum adsorption capacity than organoclay, rice husk, reed grass, treated sludge, modified palm leaves, peat moss, and activated carbon. Therefore, human hair can be modified into booms to clean up oil spills (Mondal & Basu, 2019).

Pumice has adsorbing properties, whereby it can bind molecules from a liquid to its surface. This capacity stems from the physical characteristics of pumice, which has a large surface area, high porosity, and active properties, as well as chemical stability that prevents it from reacting with the adsorbed substances (Sholehah *et al*., 2023). Pumice has a high silica content (70.90% SiO2). Silica provides durability to the material, making it very suitable as an adsorbent. Adsorption of Pb by pumice samples from the Mount Ararat region (Turkey) achieved a removal efficiency of up to 84.30 mg/L under optimal conditions, specifically at a pH of 5.75 and a temperature of 41.11°C (Şahan & Öztürk, 2014). Pumice, a silicate-rich volcanic glass rock, is characterised by its porous structure and extensive fine capillary network. These characteristics make it an economical yet highly effective alternative adsorbent. Its adsorbent potential has been tested, for example, in studies showing its ability to remove arsenic from drinking water and remove copper and chromium metals from liquid effluents. The maximum adsorption capacity of lead by powdered pumice from Lombok and Kediri resulted in more than 80% lead removal efficiency. Therefore, it is evident that both pumice stones have the potential to be utilized as raw materials for new natural cationic adsorbents (Hasanah *et al*., 2019).

Coconut shell charcoal is a reliable adsorbent for heavy metals, including Pb. Activated carbon derived from coconut shells is effective for a range of applications. It has been successfully used for organic chemical adsorption, wastewater treatment, and energy storage. Additionally, it serves as an ideal resource for advancements in green synthesis and solar vapor generation. Coconut shells are suitable for producing activated carbon. It has excellent natural structure and low ash content (Basha *et al*., 2023). Experimental studies proved that coconut shell charcoal can effectively treat industrial wastewater as an adsorbent. The study revealed that the removal of phosphate and zinc with the same removal efficiency pattern of removing 90% phosphate and 97% zinc for a particle size of 150 μm (Packialakshmi *et al*., 2021). The rainwater treatment process by shell sand filtration and coconut shell-activated carbon adsorption is highly effective in reducing the lead (Pb) content and turbidity of rainwater. The effectiveness was 99.47% and 71.65%. Statistical analysis shows that the Pb content and turbidity of the rainwater after treatment were significantly lower than before the process (p=0.000) (Khayan *et al*., 2017). CO can also be absorbed by charcoal, and a study shows the decline percentage of CO gas with a coconut shell adsorbent is 62.6% (Nurullita & Mifbakhuddin, 2016). Filtration with natural adsorbents used in this study still follows previous research that varies the type of pumice used. The two types of filtration differ in the mesh size (pores) of the pumice used. Sieve A has a lower mesh count or larger pores (8-30 mesh), while sieve B has a higher mesh count or smaller pores (30-100 mesh). In contrast, sieve B utilizes pumice

with a high mesh count (30-100 mesh), which creates a smaller. This mesh difference gives different results in the absorption of pollutants from workshop laundry waste (Silalahi *et al*., 2023).

Method

This research employed an experimental study to design a workshop hand-washing waste treatment tool utilizing a filtration process with three types of natural adsorbents. The research design for this study was a one-group pre-test and post-test. This research used a one-group pre-test and post-test design. The study took place at a workshop on Sekip Sei Putih Timur I Street, Medan Petisah District, Medan City. The testing was conducted at the Environmental Laboratory UPT, Environmental Service for the North Sumatra Provincial Government. The samples were comprised of workshop hand washing waste, which was collected using a purposive sampling technique. This study's sample consisted of effluent waste generated from the workshop's washing processes, specifically from mechanics washing their hands and tools soiled with used oil. A 20-liter sample of this wastewater was collected in the afternoon, after the workshop had ceased operations, and was subsequently prepared for filtration.

The filtration unit consists of a 60 cm diameter barrel containing three distinct layers of adsorbents. The bottom layer is composed of hair waste (20 cm in height), followed by a middle layer of pumice (40 cm in height), and is topped with a layer of coconut shell charcoal (20 cm in height). To allow the filtered wastewater to be collected for laboratory analysis, a hole was created 3 cm from the base of the barrel. The filtration was repeated three times, as mandated by the Completely Randomized Design for experiments with two or more filtration variations. It included a control group and three repetitions: the first, second, and third repetitions. The samples were then analyzed in the laboratory with an AAS spectrophotometer according to SNI 6989.8-2009.

Results and Discussion

The sampled effluent contained the same brands of oil, namely Unioil, Evalube 2T, and Yamalube. The mechanics wash their hands and dirty limbs, as well as workshop equipment, not in running water, but in water collected in a plastic container (a black bucket). The water used for washing comes from a borehole.

The difference between sieve A (workshop filtration I) and sieve B (workshop filtration II) is in the number of meshes or the size of the pores on the surface of the pumice, which affects the absorption of Pb on the pumice adsorbent. The coconut shell charcoal adsorbent with hair has no difference. The type of hair waste used is hair that has never been exposed to hair color, thereby avoiding the influence of chemicals contained in hair paint on the polluting components of workshop laundry waste.

The decrease in Pb metal concentration reveals the relationship between the variation of pumice mesh and Pb metal concentration; the more pumice mesh or the smaller the pore size of pumice, the faster the anion and

Table 1. Pb Lead Test Result

Parameters	Treat	Concentration (mg/L) in Workshop		Quality Standard KEP-03/BAPEDAL/09/1995
		A Filtration	B Filtration	
Pb	Control	0,042	0,550	0,1 mg/L
	Repeat 1	0,039	0,290	
	Repeat 2	0,014	0,018	
	Repeat 3	0,010	0,012	
Pb Average after treatment (mg/L)		0,021	0,106	
Decreasing efficiency (%)		50,00	80,00	

Source : Primary Data, 2021

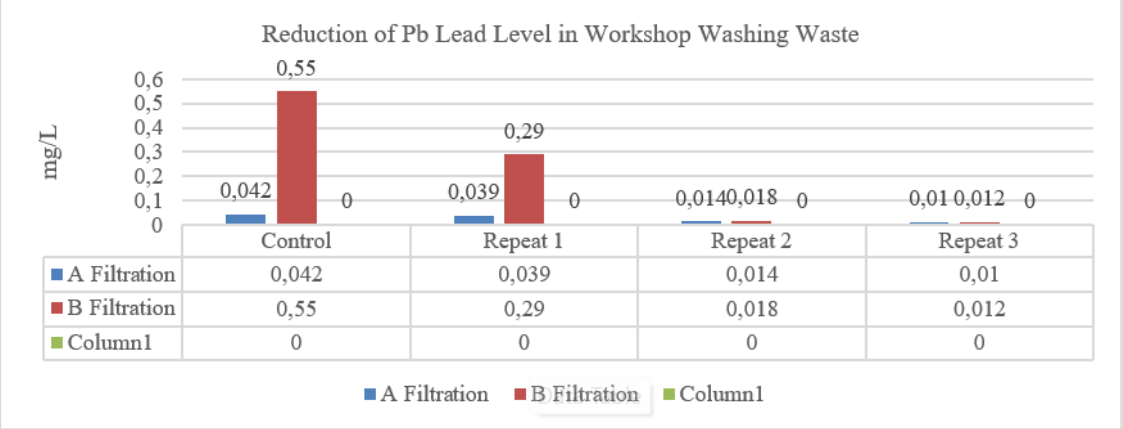

Figure 1. Reduction of Pb Lead Level in Workshop Washing Wastewater Using Natural Adsorbent Filtration

cation content react more quickly with metals contained in wastewater. The more dissolved ions in the wastewater that pumice absorbs, the greater the resulting conductivity value. The smaller the variation in the pore size of pumice, the greater the electrical conductivity of a liquid used. It indicates the influence of pumice pore size in absorbing the metal content in the waste liquid. The regeneration efficacy of modified pumice adsorbents may vary from that of unmodified pumice. This difference can be attributed to the distinct pH activity resulting from the metal surface doping. Modification of pumice with alkali was shown to increase its efficiency in adsorbing magnesium and calcium (Çifçi & Meriç, 2016).

Several studies have investigated the potential of pumice as an adsorbent for water purification, with promising results. Initial research suggests that pumice is effective in removing fluoride, with its efficiency increasing with longer contact times and higher dosages (Singh *et al*., 2020). Although the ability of natural pumice to adsorb nitrate decreases with rising concentrations, as higher inflow concentrations increase the amount of nitrate and lead to an earlier breakthrough time (Helard *et al*., 2023). Other studies have found that physical (such as heating) and chemical (using acid solutions) modifications can significantly enhance its efficiency and capacity for nitrate removal, making it a more effective solution for reducing groundwater pollution (Indah *et al*., 2021).

A study proved the ability of coconut shell-activated charcoal to remove heavy metals from 21.1414 g/dm3 to 19.2228 g/dm3 for Cu and from 28.3497 g/dm3 to 13.4420 g/dm3 for Pb (Sarkingobir *et al*., 2020). The KOH-activated carbon from coconut shells demonstrated effective Pb2+ removal from an aqueous solution. Metal removal efficiency and adsorption capacity are highly dependent on adsorbent concentration, agitation time, and initial ion concentration (Song *et al*., 2014). Absorbent made from activated carbon from coconut shell, combined with corn cob, may be more effective in adsorbing Pb2+ ions in water (Saputro *et al*., 2019). Adsorbents modified from coconut shells and limestone can potentially remove Cr (III) from synthetic industrial wastewater. The percentage removal increased with the length of contact time. The results showed that this adsorbent can remove Cr (III) up to 98% (Bakar *et al*., 2021).

When compared to coconut coir adsorbent, there is a difference in effectiveness in absorbing lead. The optimum mass of coco coir adsorbent for Cu and metal adsorption was 0.9 grams, while the optimum mass of commercial activated charcoal for Cu metal adsorption was 0.65 grams, and for Pb adsorption was 0.4 grams. The adsorption efficiency (%) of Pb metal ions on coconut coir adsorbent (Cocos nucifera Linn.) was 34.28%, and 62.85% for commercial activated charcoal (Safitri & Kristianingrum, 2021). To increase the effectiveness of charcoal adsorption, the concentration of the 30% KOH solution can be increased as an activator with a contact time

of 60 minutes to expand the average pore area produced. It resulted in the best adsorption rate of 98.59% for Pb metal (Suryaningsih *et al*., 2021). Using bio-adsorbents derived from charcoal fines should be considered a modern and crucial approach to water treatment. Further thermodynamic studies predict that the adsorption of effluent pollutants onto Modified Charcoal Fines (MCF) and Unmodified Charcoal Fines (UCF) adsorbents is a spontaneous and feasible process (Mungwari *et al*., 2024).

Keratin, found not only in hair but also in sheep's wool, has a mechanism for removing pollutants from solutions or the atmosphere. This mechanism involves a combination of physisorption and chemisorption. Physisorption refers to the trapping of pollutants in the pores or on the surfaces of keratin materials, while chemisorption involves the chemical functions of keratin proteins, which actively remove metal ions and organic volatiles such as formaldehyde (Ghosh & Collie, 2014). It has been demonstrated that human hair can absorb various harmful oils, including motor oil, bilge oil, and crude oil, as well as oils that may spill in land or water environments. Testing the effectiveness of different hair types revealed that hair with an overall black color yielded the best results for oil absorption. Additionally, male hair performed better than female hair in removing oil from wastewater (Ingole & Dharpal, 2014). The results of this study support the findings related to the filtration of workshop wash water, which typically contains oil derived from used oil.

The bleaching and dyeing processes enhance the ability of hair to act as a biosorbent for absorbing heavy metal ions. This improvement is due to the formation of more active functional groups on the hair's surface, such as sulfonate groups. As a result, human hair can be a potential material for water treatment (Zhang *et al*., 2020). Another study also showed that keratin from human and sheep hair can absorb heavy metal ions from water, with the highest absorption capacity for chromium ions and the lowest for cadmium ions. For lead ions, the absorption process is endothermic (absorbs energy) with an enthalpy of 85–97 kJ/mol in human hair. Human hair and sheep's wool have a competitive absorption capability, and both of these biomaterials have the potential to serve as a cost-effective and sustainable alternative for treating wastewater contaminated with heavy metals (Olawale *et al*., 2022).

This filtration method can be beneficial for removing heavy metal particles. There is growing interest in using the filtered and removed heavy metals as catalysts, a topic currently being explored in various advanced studies. Recent research not only highlights the efficiency in removing toxic metal particles but also emphasizes the importance of reusing the metals as catalysts. This review examines the different types of heavy metals extracted from wastewater, as well as the physicochemical methods commonly used for their recovery (Das & Poater, 2021).

Conclusion

The percentage reduction of Pb parameters in filter A is 50.08%, and filter B is 80.61%, where the final results of the third repetition show numbers below the environmental quality standards based on the Regulation of the Minister of Environment of the Republic of Indonesia Number 5 of 2014 concerning Wastewater Quality Standards (at 0.1 mg/L). The filter containing a combination of coconut shell charcoal, pumice stone with a small mesh count (resulting in large pores), and hair waste demonstrated a higher effectiveness in reducing Pb levels compared to filter B, which utilized a combination of coconut shell charcoal, pumice stone with a large mesh count (resulting in small pores), and hair waste.

References

Azharuddin, Anwar, S.A., & Ade, A.M., 2020. Proses Pengolahan Limbah B3 (Oli Bekas) Menjadi BahanBakar Cair Dengan Perlakuan Panas Yang Konstan. *Jurnal Austenit*, 12(2), pp.48–53.

Bakar, A.A.A., Razak, N.F.A., Akbar, N.A., Daud, N.M., & Ali, K.A.M., 2021. Removal of Cr (III) from Industrial Wastewater Using Coconut Shell Carbon and Limestone as Adsorbents. *IOP Conference Series: Earth and Environmental Science*, 646(1).

Basha, N.A., Rathinavel, T., & Sridharan, H., 2023. Activated Carbon from Coconut Shell: Synthesis and Its Commercial Applications

- A Recent Review. *Applied Science and Engineering Progress*, 16(2).

Çifçi, D.İ., & Meriç, S., 2016. A Review of Pumice for Water and Wastewater Treatment. *Desalination and Water Treatment*, 57(39), pp.18131–18143.

Das, T.K., & Poater, A., 2021. Review on the Use of Heavy Metal Deposits from Water Treatment Waste Towards Catalytic Chemical Syntheses. *International Journal of Molecular Sciences*, 22(24).

Dinas Lingkungan Hidup Kota Surabaya., 2019. Pengelolaan Air Limbah Kegiatan Bengkel. *Materi Sosialisasi Perencanaan Pembangunan Instalasi Pengolahan Air Limbah (IPAL) Untuk Kegiatan Bengkel Pemerintah*, 15.

Ghosh, A., & Collie, S.R., 2014. Keratinous Materials as Novel Absorbent Systems for Toxic Pollutants. *Defence Science Journal*, 64(3), pp.209–221.

Hasanah, F., Anwar, S., Hartono, A., & Sudadi, U., 2019. Potential Use of Alkaline-Activated Indonesian Pumice Powder as a Lead Adsorbent in a Solution System. *Sains Tanah*, 16(2), pp.203–215.

Helard, D., Indah, S., & Kiflia, D.P., 2023. Retraction: Removal of Nitrate from Groundwater by Column Using Pumice as Adsorbent as an Effort for Water Resources Conservation, *IOP Conference Series: Materials Science and Engineering*, 846(1), pp.1–7.

Indah, S., Helard, D., Lusiani, G., & Hapsari, D., 2021. Removal of Nitrate Using Modified Pumice as an Adsorbent for Reducing Groundwater Pollution. *E3S Web of Conferences*, 331, pp.1–4.

Ingole, N.W., & Dharpal, S., 2014. Adsorption of Oil from Waste Water by Using Human Hair: Environmental Science Adsorption of Oil from Waste Water by Using Human Hair. *Journal of Environmental Science, Computer Science and Engineering and Technology*, 3, pp.207–217.

Khayan., Husodo., Astuti., Sudarmadji., & Sugandawaty., 2017. Use of Filter Tube To Reduce Pb, Turbidity, And Increase Ph Of Rain Water Flowing Through Zinc Rooftop House. *Jurnal Kesehatan Masyarakat*, 13(1), pp.42–49.

Khotijah., Sjarifa, I., Mahendra, P.G. ., Widyaningsih, V., & Setyawan, H., 2017. The Effects Of Lead (Pb) Exposure To Blood Pb Concentration And Hemoglobin Levels In Book Sellers And Street Vendors Of Surakarta. *Jurnal Kesehatan Masyarakat*, 13(2), pp.286–290.

Maddusa, S.S., Joseph, W.B.S., Pomantow, S.M.T., Asrifuddin, A., Akili, R.H., & Bahrain, N.E.A., 2023. Environmental Health Risks Assessment of Human Exposure to Pb Pollution Around Soyoan River, Indonesia. *Diversity: Disease Preventive of Research Integrity*, 3(2), pp.87–94.

Mondal, N.K., & Basu, S., 2019. Potentiality of Waste Human Hair Towards Removal of Chromium(VI) from Solution: Kinetic and Equilibrium Studies. *Applied Water Science*, 9(3).

Muliyadi., Mukono, H.J., & Notopuro, H., 2015. Paparan Timbal Udara terhadap Timbal Darah, Hemoglobin, Cystatin C Serum Pekerja Pengecatan Mobil. *Jurnal Kesehatan Masyarakat*, 11(1), pp.87–95.

Mungwari, P.C., Chipangura, W., Ndlovu, B., Madziwa, N.T., Simende, K.C., Nyenyayi, K., & Chewu, C.C., 2024. Kinetic and Equilibrium Modelling of Lead, Zinc and Copper Ions Sorption from Aqueous Solution Using Charcoal Fines. *Asian Journal of Applied Science and Technology*, 8(1), pp.14–32.

Musfirah., & Rangkuti, A.F., 2019. The Lead Exposure Risk Due to Wells Water Consumption in Code Riverside Community, Yogyakarta City. *Jurnal Kesehatan Masyarakat*, 14(3), pp.318–325.

Nurullita, U., & Mifbakhuddin., 2016. Adsorption Of Carbon Monoxide (CO) In A Room By Coconut Shell And Durian Skin Activated Carbons. *Jurnal Kesehatan Masyarakat*, 12(1), pp.60–67.

Olawale, S.A., Bonilla-Petriciolet, A., Mendoza-Castillo, D.I., Okafor, C.C., Sellaoui, L., & Badawi, M., 2022. Thermodynamics and Mechanism of the Adsorption of Heavy Metal Ions on Keratin Biomasses for Wastewater Detoxification. *Adsorption Science and Technology*, 2022, pp.1–13.

Owamah, H.I., Akpoedafe, T.O., Ikpeseni, S.C., Atikpo, E., Orugba, H.O., & Oyebisi, S., 2023. Spatial Distribution of Heavy Metals in Groundwater Around Automobile Workshops in a Popular Niger-Delta University Town, Nigeria. *Journal of Engineering and Applied Science*, 70(1), pp.1–15.

Packialakshmi, S., Anuradha, B., Nagamani, K., Sarala Devi, J., & Sujatha, S., 2021. Treatment of Industrial Wastewater Using Coconut Shell-Based Activated Carbon. *Materials Today: Proceedings*, pp.1–3.

Ramadhani, P.K., Karuniawan, M.F.A., Fauziah, S., & Hartono., 2023. Pemanfaatan Limbah

Rambut Manusia dan Limbah Karbit sebagai Substitusi Plafond. *Sipil Dan Arsitektur*, 1(3), 1–7.

Safitri, S.T., & Kristianingrum, S., 2021. The Decreasing of Copper (Cu) and Lead (Pb) Concentration in Electroplating Liquid Waste with Coconut Coir Adsorbent. *Indonesian Journal of Chemistry and Environment*, 3(2), pp.1–10.

Şahan, T., & Öztürk, D., 2014. Investigation of Pb(II) Adsorption Onto Pumice Samples: Application of Optimization Method Based on Fractional Factorial Design and Response Surface Methodology. *Clean Technologies and Environmental Policy*, 16(5), pp.819–831.

Saputro, S., Mahardiani, L., Masykuri, M., & Jazuli, A.Z., 2019. The Effectiveness of Activated Carbon from Coconut Shell and Corn Cob to Adsorb Pb(II) Ions and Its Analysis Using Solid-Phase Spectrophotometry. *IOP Conference Series: Materials Science and Engineering*, 578(1).

Sarkingobir, Y., Dikko, M., & Ladan, Z.A., 2020. Removal of Lead, Copper, and Colour from Wastewater Using Raw Coconut Shell, Activated Carbon, and ctivated Nanocomposite. *Frontiers of Knowledge Journal Series| International Journal of Medical and Biosciences|*, 3(1), pp.2635–3628.

Sholehah, H., Abdullah, T., Azwarudin., & Aprianti, S., 2023. Using Pumice as an Alternative to Reduce Biological Oxygen Demand and Chemical Oxygen Demand in Tough Waste. *Jurnal Pijar Mipa*, 18(6), pp.1034–1039.

Silalahi, M.I., Hartono, H., Manalu, P., Panggabean, V.T., Nababan, W.T., & Ginting, M., 2023. Kombinasi Adsorben Alam Dalam Pengolahan Air Limbah Cucian Pada Bengkel. *Jurnal Kesehatan Lingkungan Indonesia*, 22(2), pp.122–127.

Singh, S.K., Shweta, S., Shrivastava, M., & Aggarwal, S., 2020. Fluoride Removal from Drinking Water by Pristine Pumice as an Adsorbent. *Rasayan Journal of Chemistry*, 13(4), pp.2603–2608.

Song, C., Wu, S., Cheng, M., Tao, P., Shao, M., & Gao, G., 2014. Adsorption Studies of Coconut Shell Carbons Prepared by KOH Activation for the Removal of Lead(ii) from Aqueous Solutions. *Sustainability (Switzerland)*, 6(1), pp.86–98.

Suryaningsih, S., Sholihah, F.L., & Aprilia, A., 2021. Analysis of Lead Waste Absorption (Pb) with Activated Charcoal Absorbent from Palm Shell. *Jurnal Matwrial Dan Energi Indonesia*, 11(01), pp.34–43.

Widiyanto, A.F., Yuniarno, S., & Kuswanto., 2015. Land and Water Pollution from Industrial Waste and Domestic. *Jurnal Kesehatan Masyarakat*, 10(2), pp.246–254.

Wijayanti, F.D., & Purnomo, Y.S., 2023. Pengolahan Limbah Cair Bengkel Dengan Menggunakan Grease Trap Dan Fitoremediasi. *Envirous*, 2(1), pp.115–123.

Yehezkiel, W.O., Rini, I.D.W.S., & Gunawan, A., 2023. Analisis Penurunan Konsentrasi Logam Berat Timbal (Pb) Pada Limbah Berbahaya Beracun Pelumas Bekas Menggunakan Metode Acid Clay Treatment dengan Substitusi Bentonit Sebagai Adsorben. *Conference Proceeding on Waste Treatment Technology*, 6(1), pp.280–284.

Zhang, H., Carrillo-Navarrete, F., & Palet, C., 2020. Human Hair Biogenic Fiber as a Biosorbent of Multiple Heavy Metals from Aqueous Solutions. *Journal of Natural Fibers*, 19(4), pp.1–16.