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Phosphate reduction from the artificial sample of laundry wastewater by using bintaro (*Cerbera manghas*) fruit shell adsorbent

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Abstract. Laundry wastewater if it is immediately disposed into a river without treating it first. One of the chemicals contained in laundry wastewater is phosphate compound. If laundry wastewater is discharged directly into the river water it will increase the phosphate content as nutrient in river water which can be dangerous for living creatures. The high nutrient in river will cause eutrophication in the river which will adversely affect aquatic biota. One treatment that can be done is the process of adsorption with activated carbon made from bintaro (*Cerbera manghas*) fruit shells. **Objectives:** The objectives of this experiment are to determine the optimum contact time that result in the most decrease phosphate content and determine the optimum of doses of activated carbon. The last is to know the type of isotherm model that occur. **Method and results:** This research is divided into four parts, namely the production of activated carbon, preparation, experiment, and data analysis. The process of making activated carbon start from carbonization and then activation. Preparation is making the artificial sample. The experiment is doing the variation time and doses. The last is data analysis. **Conclusion:** The optimum contact time with the same dose of adsorbent is 30 minutes. The optimum doses of activated carbon are 3 grams. Finally, the type of isotherm model that occur in this adsorption tents to be the Langmuir isotherm.

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1 Introduction

Water is a natural resource which is the basic need for life of all living things, including people, animals and plants. The water needed is not just any water, but clear water that is not contaminated with pollutants that could endanger living beings. The river is one water source widely used to satisfy the needs of human life and other living things. However, the condition of the rivers in Indonesia is rather alarming. River in Indonesia with a dangerous and contaminated state hit 82% of the 550 rivers spread across Indonesia [1]. Existing river contamination makes river water unfit for use as a drinking water source. According to research [2], the rivers is going to have more impurities if it flows through human activity. Human activity is very influential as a source of river pollution, whether it is domestic, industrial or agricultural activity [3]. Some human and industrial activities carelessly dispose the wastewater into rivers and when viewed from the chemical, physical and biological perspectives, reduce water quality [4].

According to Government Regulation of Republic Indonesia Number 82 of 2001, wastewater is the residue from business and activity in liquid form. Wastewater can come from households (domestic) and industry. In general, it can be said that wastewater is a liquid that comes from households, industries or other public places, and usually contains substances that can harm human life and interfere with life sustainability [5].

One of the wastewaters that can pollute rivers is wastewater come from laundry wastewater both households and the laundry industry. Domestic wastewater is divided into two, namely domestic wastewater originating from latrines, such as shampoo, feces, soap, and urine, and second is domestic wastewater from washing water such as detergents, meth, oil, and pesticides. So it can be concluded that laundry wastewater is one of the domestic wastewater [6], [7].

In this modern era, a lot of people need something simple and functional to make easier some work. People are increasingly busy with so many things that they do not have time to do homework like washing and ironing their clothes. This situation lets the laundry business grow to become a solution for washing facilities and ironing clothing. The increase in business development in the laundry sector is definitely directly proportional to the increase the amount of wastewater to be produced. Increasing the amount of laundry runoff would lead to the poor quality of river water if it is dumped into the water body directly without any treatment being performed. Many laundries discharge wastewater straight through irrigation systems or water bodies without proper treatment [8].

Wastewater laundry has chemical content. One of the main chemical used in detergents is phosphate, which is useful as a builder for enhancing washing cycle performance by deactivating hardness-causing minerals. The phosphate used in the detergent help to prevent dirt in washed clothes from sticking back. Phosphate is generally found in form of Sodium Tri Poly Phosphate [9]. If the phosphate content of the water is higher, the environment around the body of water may be disrupted. One effect is occurrence of eutrophication, where the body of water contains many dissolved nutrients that increase the fertility of aquatic plants that inhibit sunlight, which reduces the dissolved oxygen content and disrupts the carrying capacity of water bodies in aquatic biota [10]. According to research [11], aquatic biota requires certain conditions to be able to carry on life. The permissible phosphate limit is based on quality standards of the Government Regulations of Republic Indonesia Number 82 of 2001 amounted to 2 ppm [5].

The increasing amount of laundry was followed by an increase in the volume of phosphate in wastewater. Wastewater treatment of the laundry therefore necessary before discharge to the river. One way to reduce the phosphate content of laundry wastewater is through adsorption. The adsorption process generally uses activated carbon. The method of adsorption was chosen because the method of adsorption using activated carbon is one of the most commonly used methods of wastewater treatment because the method is simple, the cost is cheap, suitable for toxic substance and easy to use [12], [13]. Some examples of activated carbon used in previous studies are rice husk [14], zeolite [15], and coconut shells [16].

The adsorbent used in this study is activated carbon extracted from bintaro fruit sheels. Bintaro fruit shells have been selected because bintaro trees are common and abundant planted as reforestation plants both along the road and in the garden because do not require special maintenance. Nevertheless, the fruit formed by the bintaro tree can not be eaten because it is poisonous. As a consequence, bintaro fruit will be scattered on the street or park and become trash that can even clog waterways that are next to bintaro trees. Based on research before [17], seeds from bintaro fruit have potential to be used as raw materials for the manufacture of biodiesel. But the use of bintaro fruit shell is still limited, so that many bintaro fruit shells are wasted. Previous research [18] reported that bintaro fruit shells contain fiber and lignocellulose that are almost identical to coconut shells. This support the bintaro fruit shells are potential to be used as raw material for activated carbon. Revering to the previous research, this study aims to determine the optimum contact time, the optimum dose of activated carbon used in the process of phosphate adsorption in wastewater and determine the type of isotherm that occurs.

2 Method

The methods of this research shown in fig. 1. This research is divided into 4 parts, namely the production of activated carbon, preparation, experiment, and data analysis. Making activated carbon includes carbonization and activation. Preparation include making artificial sample and preliminary test. The experimental stage to do experiment to find the phosphate reduction. Data analysis is process the data into graph and find out the optimum contact time, doses, and type of isotherm.

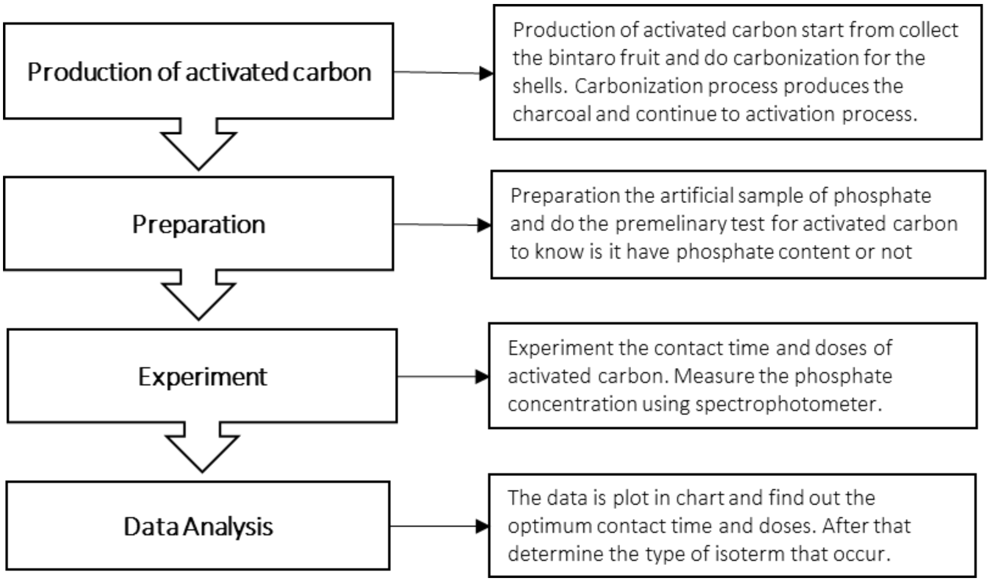

Fig. 1. The step of the research

2.1 Production of Activated Carbon

The first stage of making activated carbon from the bintaro (*Cerbera manghas*) fruit shells are by collecting bintaro fruit then washing and skinning the bintaro fruit. Then the skinned Bintaro fruit is cut and take out the seed.

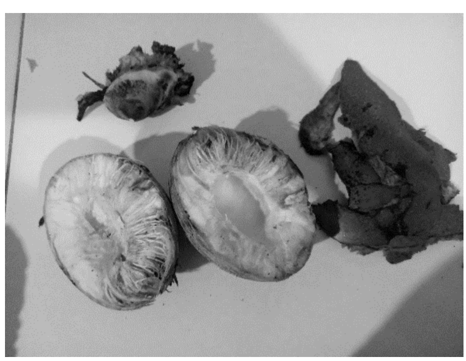

Fig. 2. Bintaro fruit section

The next step is carbonization where the bintaro fruit shells that have been cut into peaces are heated in a furnace at 400 ^{o}C for 1 hour following a previous study [19]. In the furnace, in that temperature range cellulose degradation will occur, lignin begins to decompose to produce the tar, CO, CH_4, and H_2 gases increases. The charcoal produced from heating in the furnace is pulverized using a mortar pestle. The next step is the activation of charcoal according to research before [20], activation by immersing the charcoal in 5% HCl solution for 24 hours. Then, the charcoal that has been soaked is washed using distilled water to neutral pH. The charcoal is dried in oven at 105 ^{o}C for 1 hour. After drying the activated carbon can be used as an adsorbent.

2.2 Preparation

2.2.1 Artificial Sample Preparation

Artificial sample is making based on previous research [21]. 2.5 grams of commercial detergent is dissolved in 1 liter of water. Detergent samples were measured with the result average phosphate is 3 ppm. Artificial samples that containing phosphate were made from Potassium Dihydrogen Phosphate (KH_2PO_4), that is by weighing 0.43 grams of KH_2PO_4 dissolved into 100 ml of distilled water for 1000 ppm phosphate content. Then 100 ppm phosphate solution is made by piping 10 ml of 1000 ppm phosphate solution and dissolving to 100 ml. Then make artificial sample of 3 ppm phosphate content by piping 30 ml of 100 ppm phosphate solution and dissolved to 1000 ml. The used of artificial sample is due to eliminating the permeation of light which can disrupt the result of spectrophotometer readings [22]. By measuring the turbidity of detergent water sample using turbidity meter the laundry sample has a turbidity of 69.5 NTU. Therefor an artificial sample is used to reduce disruption on spectrophotometer when measuring the sample.

2.2.2 Preliminary Test

Preliminary test were carried out because it was suspected that activated carbon from bintaro (*Cerbera manghas*) fruit shells contained phosphate. Sample study with activated carbon doses difference is applied to 400 ml distilled water and mixed for 30 minutes with jar test. It is purified and analyzed for amount of phosphate. In the preliminary test, the variations of adsorbent were added are 0.2, 0.4,0.6, 0.8 grams. The samples were stirred with 150 rpm using jar test.

2.3 Determine optimum Contact Time and Doses

2.3.1 Contact Time Experiment

0.8 grams of activated carbon is put into a 1000 ml glass beaker containing 400 ml of sample. Then stir with a jar test with a rotate of 150 rpm for a contact time of 15.30.45.60 minutes[23]. The experiment was carried out two repetitions. Then the optimum phosphate reduction time is obtained.

2.3.2 Doses Experiment

After getting the optimum contact time, proceed with the experiment to find out the optimum dose. 1,2,3,4,5 gr of activated carbon was put into a beaker glass containing 400 ml sample and then stirred with jar during the optimum time that was obtained during the time experiment [21]. Experiments carried out by two repetitions.

2.4 Data Analysis

The data that has been obtained from experiment will plot into chart to find out the optimum contact time, doses, and isotherm that occur.

3 Results and Discussion

3.1 Preliminary Test Result

Table 1. shows that there was an increase in phosphate along with the addition of an adsorbent dose. An increase in phosphate levels is suspected because the adsorbent itself contains phosphate. Phosphate levels decrease at a dose of 0.8 gr. At a dose of 0.8 grams, the adsorbent begins to adsorb phosphate, causing a decrease in phosphate levels. The dose of 0.8 gr will be used for testing the optimal contact time.

Table 1. Data concentration of phosphate in distilled water with adsorbent

Mass (g)	Conc(mg/l)
0.2	0.027
0.4	0.068
0.6	0.105
0.8	0.096

3.2 Effect of Contact Time on Phosphate Adsorption

In the phosphate adsorption experiment with an initial phosphate concentration of 3.13 mg / l, the results of the effect of contact time on phosphate reduction by the adsorption process can be seen in Table 2.

Table 2. Data of contact time with the concentration of phosphate

Time (min)	Initial concentration (mg/l)	Final concentration (mg/l)	Removal efficiency (%)
15	3.13	2.694	13.907
30	3.13	2.518	19.522
45	3.13	2.600	16.926
60	3.13	2.790	10.858

In this study, the time variation test is 15,30,45,60 minutes. Table 6 show the final concentration after contact with activated carbon. Based on fig. 3 at 15 minutes contact time removal efficiency was obtained at 13.9% with a final concentration of 2.69 mg / l from an initial concentration of 3.13 mg / l. At 30 minutes of contact time, the removal efficiency of 19.5% was obtained with a final concentration of 2.5 mg / l. At 45 minutes of contact time, the removal efficiency of 16.9% was obtained with a final concentration of 2.6 mg / l. At the contact time of 60 minutes, the removal efficiency was obtained at 10.8% with a final concentration of 2.79 mg / l.

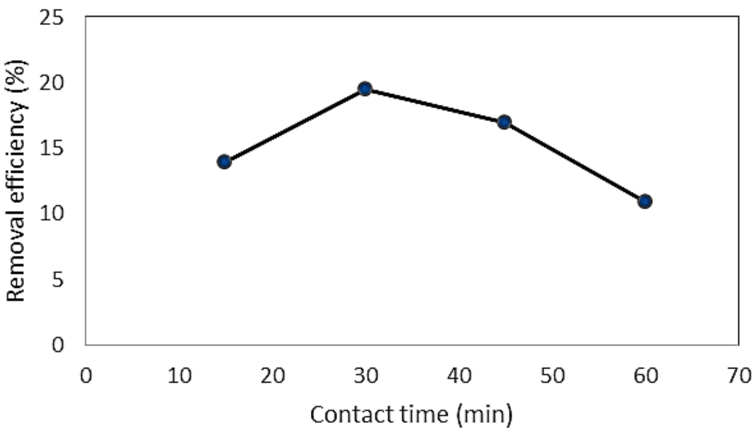

Fig. 3. The effect of contact time on the percentage of phosphate removal

At 45 minutes the percentage of adsorption decreased from 19.5% to 16.9%. This happens because in the application of adsorbent in wastewater a desorption process occurs where adsorbate that has been adsorbed is released again from the adsorbent [21]. Then the contact time of 30 minutes is the optimal time in the process of adsorption of activated carbon of the Bintaro (*Cerbera manghas*) fruit shell to reduce phosphate levels.

3.3 Effect of Activated Carbon Doses on Phosphate Adsorption

In addition to the contact time of activated carbon with wastewater, the activated carbon dose used is another parameter that affects the effectiveness of adsorption. In this research, a variety of activated carbon dosage variations were conducted to determine the maximum ability of activated carbon to adsorb phosphate. In the study of dose variations based on previous research [21] namely 1,2,3,4 and 5 grams at the optimum time that was obtained in the previous experiment that was 30 minutes. Experiments carried out by repeating twice. The results of the removal efficiency can be seen in Fig. 4.

Table 3 Data of Doses with a concentration of phosphate

Dose (gr)	Initial concentration (mg/l)	Final concentration (mg/l)	Removal efficiency (%)
1	3.13	2.493	20.337
2	3.13	2.428	22.420
3	3.13	2.349	24.926
4	3.13	2.624	16.141
5	3.13	2.877	8.080

In the variation test of activated carbon doses also obtained different removal efficiency from the initial content of phosphate 3.13 mg / l.

In the use of a dose of 1 gram obtained removal efficiency of 20.3% with phosphate concentration after treatment that is equal to 2.49 mg / l. Whereas

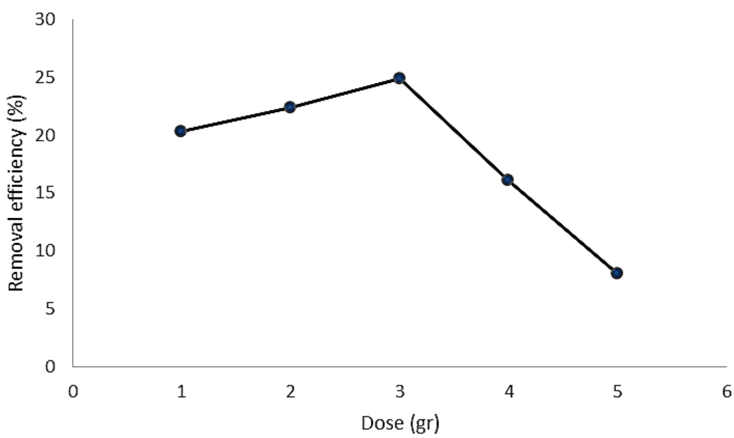

Fig.4. The effect of dose on the percentage of phosphate removal

at a dose of 2 grams, the efficiency of phosphate removal increased to 22.4% with a final concentration of 2.42 mg / l. At a dose of 3 g, the percentage of efficiency decreased in phosphate decreased by 24.9% with a final concentration of 2.34 mg / l. However, in the use of a 4 g dose, the efficiency of phosphate removal decreased to 16% with a final concentration of 2.6 mg / l. Furthermore, at a dose of 5 grams, the efficiency of phosphate removal becomes 8% with a final concentration of 2.8 mg / l.

The efficiency of removal decreasing in the use of 4 grams of activated carbon. This is indicated because too much adsorbent is used with an incomparable volume of wastewater making the solution thicker and stirring heavier than the 3 gr adsorbent. This is supported by previous research [24] which states that differences in the results of the reduction in efficiency are caused by an increase in the amount of excess adsorbent in the wastewater solution which results in the coincidence of the adsorbent.

3.4 Adsorption Isotherm

The isotherm model of adsorption aims to determine the adsorption mechanism that occur in water but also be used to determine maximum absorption capacity [25]. The bonding that occurs between phosphate with adsorbents can occur physisorption and chemisorption. In this study, will try to analyze what type of isotherm occurs in phosphate adsorption with activated carbon of bintaro fruit shells.

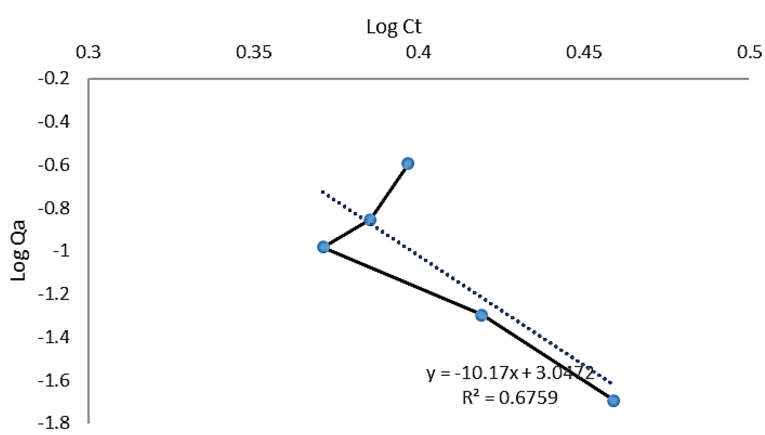

Fig. 5. Isotherm Freundlich

The Freundlich isotherm graph can be seen in fig. 5 with a linear equation y = 4.3322x - 1.5777 and R^2 = 0.6759. While the Langmuir isotherm can be seen in fig. 6 With a linear equation y = -0.0015x + 0.42 and the value R^2 = 0.8196.

Based on the comparison of R^2, the linearity of the Freundlich isotherm is smaller than the Langmuir isotherm. Based on previous research [26], if the value of R^2 is getting closer to the value of one, it can be said that the relationship between one variable and another variable is getting stronger. This shows that the type of isotherm is more likely to be the type of Langmuir isotherm. The adsorption that occurs is chemical which forms a monolayer in the adsorption process [13].

Based on Langmuir model equation with linear equation y = -0.0015x + 0.42 and the value R2 = 0.8196, the value of the maximum adsorption capacity per adsorbent mass is 2,38 mg/g.

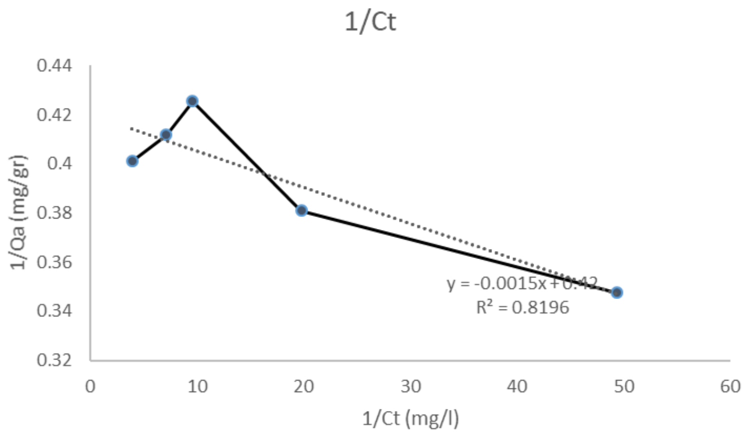

Fig. 6. Isotherm Langmuir

4 Conclusions

The optimum contact time with the same dose of adsorbent is 30 minutes. The oftimum doses is 3 grams. Finally, the type of isotherm in this adsorption tends to be the Langmuir isotherm with a linearity value larger approaches 1.

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6 References

[1] N. Zuraya, "82 Persen Sungai di Indonesia Tercemar dan Kritis | Republika Online," 22-Mar-2019. [Online]. Available: https://nasional.republika.co.id/berita/nasional/umum/porsc1383/82-persen-sungai-di-indonesia-tercemar-dan-kritis.

[2] R. Hakiki and T. Wikaningrum, "the Prospect of Digitally Enhanced Colorimetry As an Analytical Method for Water Quality Determination," *Indones. J. Urban Environ. Technol.*, vol. 2, no. 2, pp. 146–163, 2019.

[3] W. P. Utomo *et al.*, "Penurunan Kadar Surfaktan Anionik dan Fosfat dalam Air Limbah Laundry di Kawasan Keputih, Surabaya menggunakan Karbon Aktif," *Akta Kim. Indones.*, vol. 3, no. 1, pp. 127–140, 2018.

[4] M. Arizuna, D. Suprapto, and M. R. Muskananfola, "Kandungan nitrat dan fosfat dalam air pori sedimen di sungai dan muara sungai wedung demak," *J. Maquares*, vol. 3, pp. 7–16, 2014.

[5] T. P. of T. R. of Indonesia, *Management of water quality and control over water pollution*, no. 82. Indonesia, 2001, pp. 20–29.

[6] A. R. Utami, "Pengolahan Limbah Cair Laundry Dengan Menggunakan Biosand Filter dan Activated Carbon," *J. Tek. sipil Untan*, vol. 13, no. 1, pp. 59–72, 2013.

[7] S. W. Astuti and M. S. Sinaga, "Pengolahan Limbah Laundry Menggunakan Metode Biosand Filter Untuk Mendegradasi Fosfat," *J. Tek. Kim. USU*, vol. 4, no. 2, pp. 53–58, 2015.

[8] D. A. Setyorini, "Ini Solusi Atasi Pencemaran Limbah Laundry _ beritajatim," *Berita Jatim.com*, 2019. [Online]. Available: https://beritajatim.com/pendidikan-kesehatan/ini-solusi-atasi-pencemaran-limbah-laundry/, July 3, 2019 [Nov.28, 2019].

[9] G. Rajasa, "Pemanfaatan Biofilm Mikrobentos untuk Menurunkan Kadar Fosfat pada Limbah Deterjen Laundry," Program Studi Biologi Universitas Atma Jaya Yogyakarta, 2010.

[10] A. R. Simbolon, "Pencemaran Bahan Organik dan Eutrofikasi di Perairan Cituis, Pesisir Tangerang," *J. Pro-Life*, vol. 3, no. 2, pp. 110–118, 2016.

[11] R. Hakiki, "Mikroalga Sebagai Bioindikator Kualitas Air Permukaan (Studi Awal : Hubungan Antara Konsentrasi Pigmen dan Berat Kering dalam Penentuan Kandungan Mikroalga Pada Sampel Air Artifisial)," *J. env. Eng. Waste Manag.*, vol. 1, no. 1, pp. 46–54, 2016.

[12] O. Hamdaoui and M. Chiha, "Removal of Methylene Blue from Aqueous Solutions by Wheat Bran," no. May 2014, 2019.

[13] K. Aditya, Yusnimar, and Zultiniar, "Penentuan Model Isoterm Adsorpsi Ion Cu(II) Pada Karbon Aktif Tempurung Kelapa," *Jom FTEKNIK*, vol. 3, no. 2, pp. 1–6, 2016.
[14] Budiman and Amirsan, "Efiktifitas Abu Sekam Padi dan Arang Aktif dalam Menurunkan Kadar BOD dan COD pada Limbah Cair Industri Tahu Super Afifah Kota Palu," *J. Kesehat. Tadulako*, vol. 1, no. 2, pp. 23–32, 2015.
[15] F. Syafaat, A. Suseno, and Arnelli, "Kinetika Adsorpsi Anion Nitrat dan Fosfat pada Zeolit Alam Termodifikasi Surfaktan Hexadesiltrimetilammonium Klorida," *J. Kim. Sains dan Apl.*, vol. 16, no. 3, p. 73, 2013.
[16] A. Alimsyah and A. Damayanti, "Penggunaan Arang Tempurung Kelapa dan Eceng Gondok untuk Pengolahan Air Limbah Tahu dengan Variasi Konsentrasi," *J. Tek. Pomits*, vol. 2, no. 1, pp. D6–D9, 2013.
[17] Khairil, A. Rizki, Iskandar, Jalaluddin, A. S. Silitonga, and H. H. Masjuki, "The potential biodiesel production from Cerbera odollam oil (Bintaro) in Aceh," in *MATEC web of Conferences*, 2018, vol. 01049, pp. 1–6.
[18] G. Iman and T. Handoko, "Pengolahan Buah Bintaro sebagai Sumber Bioetanol dan Karbon Aktif," *Pros. Semin. Nas. Tek. Kim. "Kejuangan,"* vol. 2005, pp. 1–5, 2011.
[19] A. Y. Pratiwi and S. Tjahjani, "Karakteristik Karbon Aktif Cangkang Bintaro (Cerberra odollamG.) dengan Aktivator H2SO4," *Pros. Semin. Nas. Kim. dan Pembelajarannya*, no. September, pp. 1–6, 2016.
[20] L. I. W. P, "Aktivasi Karbon dari Sekam Padi dengan Aktivator Hcl dan Pengaplikasiannya pada Limbah Pengolahan Baterai Mobil untuk Mengurangi Kadar Timbal (Pb)," Universitas Sumatera Utara, 2017.
[21] P. T. R. Rajagukguk, "Pemanfaatan Kulit Durian Sebagai Adsorben untuk Penyisihan Detergen dan Fosfat dalam Pengolahan Limbah Cair Laundry," Universitas Sumatera Utara, 2018.
[22] E. W. Prasetia and H. Sunarno, "Variasi Nilai Absorbansi terhadap pH Larutan NaOH dan H 2 SO 4 untuk Panjang Gelombang 380 nm – 750 nm," pp. 4–8, 2012.
[23] Utami, S. Elystia, and Y. Aziz, "Adsorpsi Zat Warna Rhodamin B Menggunakan Karbon Aktif Dari Tandan Kosong Kelapa Sawit (Elaeis Guneensis Jacq)," vol. 4, no. 1, pp. 1–14, 2017.
[24] T. Teka and S. Enyew, "Study on effect of different parameters on adsorption efficiency of low cost activated orange peels for the removal of methylene blue dye," *Int. J. Innov. Sci. Res.*, vol. 8, no. 1, pp. 106–111, 2014.
[25] D. M. Elektrospinning, C. Using, and P. N. Synthesized, "Adsorption of Cu 2+ Using Polisulfon-FeOOH Nanofiber Synthesized with Electrospinning Method," *J. Litbang Ind.*, vol. 3, no. 2, pp. 101–108, 2013.
[26] H. Apriyanti, I. N. Candra, and Elvinawati, "Karakteristik Isoterm Adsorpsi dari Ion Logam Besi (Fe) Pada Tanah di Kota Bengkulu," *ALOTROP J. Pendidik. dan Ilmu Kim.*, vol. 2, no. 1, pp. 14–19, 2018.