ISSN: 2338-1345 e ISSN 2808-8948 – Vol. 10 (1) 22-27 https://ojs.bakrie.ac.id/index.php/APJSAFE/about

Asia Pacific Journal of Sustainable Agriculture Food and Energy (APJSAFE)

Exposure to Ammonia Concentration from the Processing of Crumb Rubber on Environmental Quality: A Review

Nurul Amri Komarudin[1]*, Elsera Br Tarigan[2], Yahya Shafiyuddin Hilmi[3], and Ashemir B Velasco[4]

[1]*Program Study of Environmental Engineering, Faculty of Environment and Mineral Technology, Sumbawa University of Technology, Sumbawa Besar, NTB, Indonesia*
[2]*Indonesian Centre for Estate Crops Research and Development, Ministry of Agriculture Republic Indonesia, Bogor, West Java Indonesia*
[3]*Department of Agricultural Socioeconomics, Faculty of Agriculture, Universitas Gadjah Mada, Sleman, D.I. Yogyakarta Indonesia*
[4]*College of Agriculture, New Era University – Rizal Campus, Philippines*

**Corresponding author's E-mail address: amrigfm49@gmail.com*

Abstract— Nowadays, processed natural rubber products such as crumb rubber have become the demands of global consumers who are oriented towards export markets. Therefore, the economic impact is felt more, but there are still other consequences. The consequences are not only economically beneficial but are also detrimental to the environment. The process of making natural rubber into crumb rubber imposes negative impacts. Air pollution is one of its negative impacts. Air pollution in the form of odour is rarely noticed. The purposes of this study were to analyse the ammonia concentration caused by processing of natural rubber into crumb rubber, and to identify the impact of ammonia contamination on the environment. The impact considered is particular to human health. This research was conducted using a review method through *colandr* machine learning. The results of the review showed that the concentration of ammonia produced from the processing of natural rubber into crumb rubber in Indonesia has passed the specified quality standard threshold. It also showed that the process has adverse impacts to the environment. Such adverse impacts are damage to aquatic ecosystems and air quality, and to human health resulting in respiratory problems.

Keywords— **ammonia, crumb rubber, environmental quality, human health, natural rubber.**

Received : 8 February 2022
Accepted : 24 March 2022

INTRODUCTION

As a major natural rubber producer together with Thailand, Indonesia has contributed 82% to the global natural rubber production. In 2018, Indonesia produced 3 million tons of rubber sheets and only Thailand can surpass Indonesia's natural rubber production (FAOSTAT, 2020). Having the largest natural rubber plantations in the world, it is dominated by the smallholders with a share of 88.9% of the total area of natural rubber plantations in Indonesia (FAOSTAT, 2020). Natural rubber is one of the key commodities in the Indonesian economy since its production generates job opportunities and helps alleviate poverty in rural. Its production also contributes to the country's export activities. In Indonesia, natural rubber became the second largest export commodity after palm oil (ANRPC 2021). The natural rubber was processed into many forms, mostly the TSR20, before it was exported to major importing countries such as United States, Japan, and China (Angraini et al. 2019).

The need for rubber is estimated to continue to increase with the growth of the automotive industry, industrial equipment, hospital needs, medical devices, textiles, household needs, and so on. Meanwhile, the development of the rubber industry has a positive effect on increasing the country's foreign exchange and the population's economic growth (Sari et al. 2020). In terms of rubber exports, rubber is generally in the form of crumb rubber. It is classified based on the Indonesian Rubber Standard (SIR): high levels (SIR 3CV, SIR 3L, SIR3WF, SIR 5); and low levels (SIR 10, SIR 20) (Nainggolan 2019). Crumb Rubber is a latex production factory that processes the remaining latex that has spent the night in a bowl and forms unused lumps (Andriani et al. 2019).

The most exported material for SIR 20 is a coagulum that meets the requirements of SNI 06-2047-2002. Rubber SIR 20 is generally produced from smallholder rubber which has low quality that it requires a longer stage (Utomo et al. 2010). Making crumb rubber generally requires a lot of water and electrical energy. This is

because latex, as a raw material, quickly coagulates. Rubber that is rapidly coagulated will produce a lot of dirt and an unpleasant aroma, which will be a problem if the processing industry is near a settlement (Nurhayati et al. 2013).

For the last few years, the waste from the natural rubber industry processes has become a significant problem considering that people are starting to be aware of the presence of air pollution and are currently disturbed by it. As such, there are several residents around certain industries who have been raising complaints about the terrible smell. These complaints occurred due to the proximity of residential areas to industrial areas. Pollutants from the rubber industry that cause odour come from several activities. One of which is the activity of making natural rubber into crumb rubber (Susilawati et al. 2018).

Another problem caused by processing of natural rubber into crumb rubber is the wastewater or effluents. Wastewater is used water in the processes of washing, shredding, milling, crushing, and drying. It contains high levels of organic matter, residual rubber-processed compounds, carbon compounds, nitrogen, phosphorus, and other compounds such as ammonia which are of quite high level (Gapkindo 1992). Therefore, to conduct a study on the exposure from ammonia concentration caused by the waste of crumb rubber production is needed. This study aimed to analyse the ammonia concentration from the processing of natural rubber into crumb rubber, and to identify the impacts of ammonia contamination on the environment and human health.

METHODS

A. Key Search Term

The researchers have established the generic key search terms using English language to answer the research questions. The initial search terms being generated are related to the elements of the primary research questions. These are “natural rubber” AND “Ammonia”. These terms were then developed for the establishment of search strings by looking at the synonyms or alternative words that are commonly used within the topics. To obtain the appropriate results, the researchers modified and retained only search terms that produce relevant articles by pilot testing the strings in Scopus iteratively.

Moreover, as the researchers are interested to see the distinguished nature of relations between natural rubber processing industry, and economics and environment, they proposed two different exposure and outcome terms according to the research questions as follows: Subject terms (("Natural Rubber" OR "rubber crops" OR "rubber industry") OR ("Ammonia" OR "alkali" OR "salts" OR "spirits" OR "vapor") OR ("Crumb Rubber" OR "bit rubber" OR "morsel")) AND (("Water quality" OR "drinking water quality" OR "bathing water quality" OR "good water" OR "quality of the water" OR "quality of water" OR "") OR ("Air Quality" OR "air pollution") OR ("Human Health" OR "good health")) .

B. Searching the literature

Searching the literature process using publication databases and organizational websites were undertaken. The literature that we considered as a reference includes journal articles published in the last 10 years. Publication databases were utilized to collate the peer-reviewed articles including multidisciplinary and publisher’s databases which were described respectively as follow: (1) Multidisciplinary bibliographic sources including Scopus, Web of Science, Directory of Open Access Journals (DOAJ), Science Publishing Groups, AGRICOLA National Agricultural Library and Citation Database, AGRIS Agricultural Science and Technology Information Systems; and (2) Publisher’s databases including Elsevier’s, ScienceDirect, and Springer Link.

Besides peer-reviewed articles, the researchers decided to include grey literature as not merely as it is suggested by the CEE guidelines but to owe to its usefulness to minimize publication bias and to collect the relevant articles that probably are not published in the common peer-reviewed bibliographic sources. However, as searching and assessing grey literature could be time- and resource-consuming (Yani et al. 2012), the researchers selected and synthesised only the grey literature that were very relevant to the objectives of the study. The types of grey literature which were looked at include working paper, proceedings, theses, dissertations, policy briefs, and reports (Utomo et al. 2025). These literatures were searched through organizational databases (i.e., repositories of universities, non-profit organizations, and governmental institutions) and subject-related websites as shown in Table 1.

Table 1 The list of organization database to be used for searching grey literature

Organizational	URL
Center for International Forestry Research (CIFOR)	https://www.cifor.org
Consultative Group for International Agricultural Research (CGIAR)	https://ciat.cgiar.org/publications/ciat-library-resources/
Repository IPB University	https://www.repository.ipb.ac.id
French Agricultural Research and International Cooperation Organization for The Sustainable Development of Tropical and Mediterranean Regions	www.cirad.fr
International Institute for Environment and Development (IIED)	https://pubs.iied.org/
South Asian Network for Development and Environmental Economics (SANDEE)	http://www.sandeeonline.org/publicationdisp_main.php

RESULTS AND DISCUSSIONS

The impact of the natural rubber processing on the concentration

Crumb rubber, which is included in the technical specified rubber group, is processed through a series of stages of the washing, shredding, milling, crushing, drying, and pressing process of bokar. However, through the processing of crumb rubber, some forms of smoke sit, thick or thin sit, thick or thin slab or lump are discharged as wastes.

The industries processing natural rubber into crumb rubber have the potential to produce large amounts of liquid waste (Lenggo et al. 2014). The waste generated by the crumb rubber industries made from bokar as raw material reached 38,671 m^3 tonnes of crumb rubber. Meanwhile, those made from latex were 24,518 m^3 / tonne of dry rubber (Gapkindo 1992 and Marlita 2014). The wastes released by the crumb rubber industries come from various sources such as washing the processed waste at the breaking, milling, and crushing stages (Ratnani 2008). Crumb rubber industrial wastes contain high levels of organic matter derived from the remaining compounds of rubber processed materials, carbon compounds, nitrogen, phosphorus, and other compounds such as ammonia which are high enough to adversely impact the environment (Gapkindo 1992).

Rubber industrial wastes, especially crumb rubber, have ammonia content as the most dominant specific characteristic. Every rubber industry should have a proper Wastewater Treatment Plant (IPAL) so that the processed liquid waste can meet quality standards in accordance with the Regulation of the Minister of Environment of the Republic of Indonesia Number 5 of 2014. Wastewater quality standards for dry rubber business or industry include Biological Oxygen Demand (BOD) at 60 mg / L; Chemical Oxygen Demand (COD) at 200 mg / L; Total Suspended Solid (TSS) at 100 mg / L; and total ammonia at 5 mg / L (Saputra 2018).

This study focused on the advers impacts of ammonia as a waste from the crumb rubber industry. Based on some literature (Table 2), the range of ammonia content in the Indonesian crumb rubber industry is from 1.7 to 83.0 mg / L with an average of 13.01 mg / L. Based on the average value, the ammonia concentration produced has not met the ammonia standard, which is 2.0 mg / L.

Table 2 Concentration of ammonia produced from the process of making natural rubber into crumb rubber.

No	Concentration (mg/L)	Source	Quality Standard (mg/L)
1	11.4	(Susilawati et al. 2018)	
2	5	(Hakim et al. 2019)	
4	83	(Nainggolan 2019)	
5	4.2	(Ratnani 2008)	
6	2.2	(Eriska et al. 2019)	
7	10.7	(Murti 2007)	
8	1.7	(Utomo et al. 2010)	2.0
9		(Nashrullah 2017)	
	19.1		
10	8.3	(Nasir et al. 2019)	
11	2.7	(Leong et al. 2003)	
12	7.1	(Kementan 2021)	
14	19.6	(Hakim et al. 2016)	
Avg		13.01	2.0

In terms of the impacts on air quality, rubber waste produces an unpleasant aroma caused by microbial activities allowed by the moisture content (around 40-50%) of the rubber (Yuwini 2008).

The Effect of Ammonia Concentration on Water and Air Quality

High ammonia levels are an indication of organic matter contamination from domestic and industrial wastes. One of the sources of high ammonia levels is the industrial waste produced by processing natural rubber into crumb rubber. Ammonia content is relatively small in water, with a much high oxygen content (Mohammadi et al. 2010). As such, the ammonia content increases with increasing depth in the water (Sari et al. 2015). This is probably due to the relatively small content of dissolved oxygen at the bottom of the water. With this, the high ammonia concentration on the surface of the water will cause fish kills in these waters (Murti et al. 2007). Moreover, ammonia toxicity is influenced by pH which is indicated by low pH conditions. It will be harmful if the amount of ammonia is large, whereas with high pH conditions only a small amount of ammonia will be harmful (Nashrullah 2017).

Another sources of ammonia are the reduction of nitrogen gas from the diffusion process of atmospheric air, and the wastes generated by industrial and domestic activities (Nasir et al. 2019). Ammonia contained in minerals enters water bodies through soil erosion. In natural waters, at normal temperature and pressure, ammonia is in the gaseous form and forms an equilibrium with ammonia gases (Ngteni et al. 2020 & Yuwono 2008). The balance between ammonia and ammonium gas is shown in the reaction equation: $NH_3 + H_2O \rightarrow NH_4^+ + OH^-$ The effect on air quality is evident when the surrounding air becomes unpleasant or having a smell foul odor. Ammonia can have negative impacts on human health if its

levels have exceeded the stipulated quality standards (Rosman et al. 2013).

The effect of ammonia contamination on human health

Air is one of the important biological neccesities. Its quality can decrease as urban and industrial centers progress (Ratnani 2008 & Pahrul et al. 2019). The public generally perceives environmental nuisance, especially air pollution, as caused by industries such as the crumb rubber industry (Lenggo et al. 2014). The primary sources of odor gas production in the rubber processing industry are the lump storage warehouse, lump cutting, and grinding, as well as drying rooms. Hence, the closer the settlement to the rubber factory, the higher the NH_3 pollution distance (BPOM RI 2012). Rubber contains a moisture content of around 40-50% which has the potential to increase microbial activity resulting in the breakdown of organic compounds into ammonia, organic acids, and so on (Saputra 2018). These compounds evaporate and produce an unpleasant aroma. It also causes air pollution in residential areas around the industry. Pollutants in the form of gases or small particles enter into the air (Daud et al. 2020).

In general, the compounds found in rubber preparations are R-NH_2-SH-RS, R-NH_2-COOH and R-CO-NH-R which decompose to produce unpleasant aromas (Eriska et al. 2019). Free ammonia in waters is toxic to biota (Hakim et al. 2016). Likewise, in the atmosphere, ammonia is unhealthy because it can irritate the respiratory tract and cause pulmonary edema, depending on the concentration and duration of exposure. Ammonium hydroxide concentration at a concentration of 5 ppm ammonia gas causes mild irritation; 9-50 ppm causes dry nose, nervous fatigue (olfactory fatigue), and irritation is not severe; and 150 ppm causes laryngeal spasms (Rosyidah et al. 2020, Sari et al. 2019 & Springfield 2020). Exposure for 30 minutes causes cyclic hyperpnea, increased blood pressure and pulse, and irritation of the upper respiratory tract that sometimes occurs for 24 hours. Exposure at 700 ppm causes moderate irritation while at 1500 - 10,000 ppm causes dyspnoea, coughing spasms, chest pain, respiratory spasms, frothy pink sputum, asphyxia, and delayed pulmonary edema (Yulianti et al 2015 & Kementan 2021). Other effects include swelling of the lips, glottal edema, pharyngitis, tracheitis, and difficulty speaking. Chematine causes bronchopneumonia or asphyxia which causes spasms, inflammation or edema of the larynx. The residual effect causes hoarseness, cough productive, decreased respiratory function, chronic airway dysfunction, alveolar disease, bronchiectasis, emphysema, and anxiety neuroses (Hien et al. 2012).

The inhaled ammonia will be absorbed by the lungs and bind to the blood where some of the NH_3 will be absorbed by H_2O into new compounds, namely NH_4 and OH^- and some remain as NH_3. Ammonia (NH_3) in the blood can interfere with the O_2 diffusion process which causes an increase in free radicals resulting in oxidative stress (Eriska et al. 2019 ; Hien et al. 2012). The results also showed that people exposed to ammonia would experience an increase in serum levels of SGOT, especially the risk group (19.42 ± 3.06), higher than the non-risk group (19.40 ± 4.18) with p-value = 0.984. Likewise, the mean serum SGPT level in the risk group (15.74 ± 4.57) was higher than the non-risk group (15.68 ± 4.49) with p-value = 0.971 [30]. SGOT (Serum Glutamic Oxaloacetic Transaminase) and SGPT (Serum Glutamic Pyruvic Transaminase) can be an indication of liver damage. The maximum standard of continuous exposure (24 hours) to odor (ammonia) in residential areas is 2.0 ppm (Yani et al. 2012, Marlita 2014 and Yuwono 2008).

CONCLUSIONS

Based on the results of the study conducted, the ammonia deposition resulting from the process of making natural rubber into crumbs in Indonesia has passed the established quality standard threshold. Ammonia concentration also affects the quality of waters and air. A high concentration of ammonia on the atmosphere surface will cause fish death in these waters. The toxicity of ammonia can be seen by the pH which is indicated by low pH conditions which will be harmful if the amount of ammonia is significant, whereas with a high pH condition only a small amount of ammonia will be toxic. As for effect on air quality, it causes the surrounding air to be unpleasant or smells terrible and can cause adverse health impacts such as respiratory problems, chest pain, sore throat, and eye organ disorders.

REFERENCES

Andriani, Y., Sari, I. R. J., Fatkhurrahman, J. A., Harihastuti, N. 2019. Potensi Cemaran Lingkungan Di Industri Karet Alam Crumb Rubber. Prosiding SNPBS (Seminar Nasional Pendidikan Biologi Dan Saintek) Ke-4, 445–451.

Angraini, S., Pinem, J. A., Saputra, E. S. 2019. Pengaruh Kecepatan Pengadukan dan Tekanan Pemompaan pada Kombinasi Proses Koagulasi dan Membran Ultrafiltrasi dalam Pengolahan Limbah Cair Industri Karet. Jom FTEKNIK, 3(1), 1–9.

Association of Natural Rubber Producing Countries (ANRPC). 2021. Direktorat Jenderal Perdangan Internasional Indoensia, Jakarta.

BPOM RI. 2012. Ammonia water 1. (2).

Central Bureau Statistics of Indonesia. (2021).

Daud, Z., Santiagoo, R., Tajarudin, H. A., Gomesh, N., Awang, H., Nasir, N., Detho, A. 2020. Experimental approach for chemical oxygen demand and ammonia nitrogen removal from natural rubber wastewater via adsorption by kaolin. IOP Conference Series: Earth and Environmental Science, 616(1). https://doi.org/10.1088/1755-1315/616/1/012070.

Eriska, R., Rahmi, S. W., Yolanda, F. F., Akbar, D., Ramadani, S., Putri, W., Zurialdi. 2019. Identifikasi

Dampak Aktivitas Pengolahan Karet di PT. Lembah Karet Kota Padang Terhadap Lingkungan. Jurnal Kapita Selekta Geografi, 2(6), 39–43.

FAOSTAT_data_2-26-2021. Rome, Italy. (2020).

Gapkindo. 1992. Rencana Pengendalian Pencemaran Limbah Crumb Rubber. Jakarta.

Hakim, A. R., Citra, Fauzi, M. D. N. 2019. Industri Pengolahan Karet di Indonesia.

Hakim, W. N., Pinem, J. A., & Saputra, E. 2016. Pengolahan Limbah Cair Industri Karet dengan Kombinasi Proses Pretreatment dan Membran Ultrafiltrasi. Jom FTEKNIK, 3(1), 1–9.

Hien, N., and Thao, T. 2012. Situation of wastewater treatment of natural rubber latex processing in the Southeastern region, Vietnam. Journal of Vietnamese Environment, 2(2), 58–64.

Igiebor, F. A., Okoye, P. C., & Evbuomwan, O. N. 2018. Treatment of rubber effluent from rubber processing plant with fungi. Studia Universitatis Babeş-Bolyai Biologia, 63(2), 107–114. https://doi.org/10.24193/subbbiol.2018.2.08.

Kementan. Kementerian Pertanian - Pemerintah Terus Berupaya Dongkrak Harga Karet Rakyat. Retrieved February 26, 2021, from https://www.pertanian.go.id/home/?show=news&act=view&id=3825.

Kementan. Outlook: Karet Komonitas Pertanian Subsektor Perkebunan. Jakarta: Pusat Data dan Sistem Informasi Pertanian Kementerian, 2015.

Komala, P. S., Primasari, B., Rini, E., Putri, D. 2005. Pengolahan Limbah Cair dengan Tumbuhan Scirpus grossus L.f. Jurnal Purifikasi, 6 No.2, 157–162.

Komala, P. S., Sy, S., Teknik, J., Fakultas, L., 2007. Peran Media Pendukung Perlit Dalam Pengolahan Limbah Cair Industri Karet Menggunakan Tumbuhan Mensiang (Scirpus Grossus L.F). (Studi Kasus: Limbah Cair Industri Karet Remah PT. Batang Hari Barisan Padang). Bionatura, 9 No 3, 258–278.

Lenggo, F. M., Budjiono, Hasbi, M. 2014. Remediation of TSS and Ammonia in the Rubber Liquid Waste by the Filter Media and the Water Plants (Limmnocharis flava, Echinodorus palaefolius) for Live Fish Media. JOM, (3–4), 1–10.

Lenggo, FM, Budjiono, & Hasbi, M. 2014. Remediation of TSS and Ammonia in the Rubber Liquid Waste by the Filter Media and the Water Plants (Limmnocharis flava, Echinodorus palaefolius) for Live Fish Media. JOM, (3–4), 1–10 (2014).

Leong, S. T., Muttamara, S., Laortanakul, P. 2003. Reutilization of wastewater in a rubber-based processing factory: a case study in Southern Thailand. Res., Conserv. Recycle., 37: 159 – 172.

Marlita, D. 2014. Air Pollution Due to Motor Vehicle Exhaust Emissions. 01(03).

Marlita, D., Nlql, V., Gdq, N., Dnledw, N., Whumdglq, G., Xgdud, D. S., Nhqgduddq, N. 2014. Pencemaran Udara Akibat Emisi Gas Buang Kendaraan Bermotor. 01(03).

Menteri Negara Lingkungan Hidup. Peraturan Menteri Lingkungan Hidup RI No. 5 Tahun 2014 Tentang Baku Mutu Air Limbah. Kementrian Lingkungan Hidup Dan Kehutanan, 1–83.

Mohammadi, M., Man, H. C., Hassan, M. A., Yee, P. L. 2010. Treatment of wastewater from rubber industry in Malaysia. African Journal of Biotechnology, 9(38), 6233–6243. https://doi.org/10.5897/AJB09.031.

Murti, N. 2007. Peranan Media Pendukung Perlit dalam Pengolahan Limbah Cair Industri Karet pada Instalasi Tumbuhan Mensiang (Scirpus grossus L.f). Universitas Andalas. Padang.

Nainggolan, A. 2019. Program studi s1 kesehatan masyarakat fakultas kesehatan masyarakat universitas sumatera utara.

Nashrullah, S. 2017. Pengolahan Limbah Karet dengan Fitoremediasi Menggunakan Tanaman Typha angustifolia. Jurnal Teknologi Lingkungan Lahan Basah, 5(1), 1–10. https://doi.org/10.26418/jtllb.v5i1.18546.

Nasir, N., Daud, Z., Abd, A., Aziz, A., Latiff, A., Ahmad, B. Abdul, A. 2019. Removal of ammonia nitrogen from rubber industry wastewater using zeolite as adsorbent. Malaysian Journal of Fundamental and Applied Sciences, 15(6), 862–866.

Ngteni, R., Hossain, M. S., Kadir, M. O. A., Asis, A. J., & Tajudin, Z. 2020. Kinetics and isotherm modeling for the treatment of rubber processing euent using iron (II) sulphate waste as a coagulant. Water (Switzerland), 12(6). https://doi.org/10.3390/W12061747.

Nurhayati, C., Hamzah, B., Pambayun, R. 2013. Optimasi pengolahan limbah cair karet remah menggunakan mikroalga indigen dalam menurunkan kadar bod, cod, tss liquid. Jurnal Dinamika Penelitian Industri, 24(1), 16–26.

Pahrul, D., Irfannuddin, I., & Swanny, S. 2019. Exposure to Rubber Ammonia Gas to Changes in Serum Levels of MDA (Malondialdehyde). Biomedical Journal of Indonesia, 3(3), 113–119. https://doi.org/10.32539/bji.v3i3.8601.

Pahrul, D., Irfannuddin, I., Swanny, S. 2019. Paparan Gas Amonia Karet Terhadap Perubahan Kadar Serum MDA(Malondialdehyde). Biomedical Journal of Indonesia, 3(3), 113–119. https://doi.org/10.32539/bji.v3i3.8601.

Pekanbaru, P. K. 2017. Kumpulan data status lingkungan hidup daerah kota pekanbaru. Pekanbaru, Riau.

Ratnani, R. D. 2008. Teknik pengendalian pencemaran udara yang diakibatkan oleh partikel. Teknik Pengendalian Pencemaran Udara Yang Diakibatkan Oleh Partikel, 4 No 2, 27–32.

Ratnani, RD. 2008. Air Pollution Control Techniques Caused by Particles. 4 No 2, 27–32.

Rosman, N. H., Nor Anuar, A., Othman, I., Harun, H., Sulong, M. Z., Elias, S. H., Ujang, Z. 2013. Cultivation of aerobic granular sludge for rubber wastewater treatment. Bioresource Technology, 129, 620–623. https://doi.org/10.1016/j.biortech.2012.12.113.

Rosyidah, M., Sholekah, L., Oktarini, D. 2020. Optimasi Green Productivity pada Industri Karet di PT X Palembang. 21, 59–66.

Saputra, A., Irfannuddin, I., Swanny, S. 2018. Pengaruh Paparan Gas Amonia Terhadap Perubahan Kadar Serum SGOT dan SGPT pada Kelompok Berisiko. Biomedical Journal of Indonesia: Jurnal Biomedik Fakultas Kedokteran Universitas Sriwijaya, 4(1), 32–39. https://doi.org/10.32539/bji.v5i1.7956.

Saputra, A., Irfannuddin, I., Swanny, S. 2018. The Effect of Ammonia Gas Exposure on Changes in Serum Levels of SGOT and SGPT in the Risk Group. Biomedical Journal of Indonesia: Journal of Biomedicine Faculty of Medicine Sriwijaya University, 4(1), 32–39. https://doi.org/10.32539/bji.v5i1.7956.

Sari Dewi, D., Eko Prasetyo, H., Karnadeli, E. 2020. Pengolahan Air Limbah Industri Karet Remah (Crumb Rubber) Dengan Menggunakan Reagen Fenton. Jurnal Redoks, 5(1), 47. https://doi.org/10.31851/redoks.v5i1.4120.

Sari, I. R. J., Fatkhurrahman, J. A., Marlena, B., Harihastuti, N., Crisnaningtyas, F., Andriani, Y., Nasuka, N. 2019. Wet Scrubber Performance Optimization Application Assisted with Electrochemical-Based Ammonia Sensors. Jurnal Riset Teknologi Pencegahan Pencemaran Industri, 10(2), 36–42. https://doi.org/10.21771/jrtppi.2019.v10.no2.p36-42 (2019).

Sari, M., Muntalif, BS, & Suwardin, D. 2015. Removal of NH3 and H2S gases from Crumb Rubber Factory Waste Using a Biofilter. Environmental Engineering.

Springfield Centre. Rubber in Indonesia. Australia, 2020.

State Minister for the environment and Forestry of Indonesia, 2014.

Susilawati, N., Daud, D. 2018. Efisiensi Unit Pengolah Limbah Industri Crumb Rubber di Sumatera Selatan. Prosiding Seminar Nasional Hasil Litbangyasa Industri II, 1(1), 66–73.

Utomo, T. P., Hasanudin, U., Suroso, E. 2010. Comparative study of low and high-grade crumb rubber processing energy. WCE 2010 - World Congress on Engineering, 2449–2453.

Utomo, Tanto Pratondo, Nawansih, O., Komalasari, A., Jurusan, D., Hasil, T., Pertanian, F., Lampung, U. 2015. Penentuan jenis outlet untuk pertumbuhan mikroalga Utomo et al Utomo et al Penentuan jenis outlet untuk pertumbuhan mikroalga. Jurnal Teknologi Industri & Hasil Pertanian, 20(2), 109–120.

Yani M, Purwoko, Ismayana A, Nurcahyani PR, Pahlevi D. 2012. Ammonia Removal from Leum Storage at Crumb Rubber Industry by Biofiltration Technique. Journal of Indonesia Agricultural Science. Vol. 17 No. 1. ISSN 0853 – 4217.

Yani, M., Ismayana, A., Nurcahyani, P. R., Pahlevi, D. 2012. Penghilangan Bau Amoniak Dari Tempat Penumpukan Leum Pada Industri Karet Remah Dengan Menggunakan Teknik Biofilter. Jurnal Ilmu Pertanian Indonesia, 17(1), 58–64.

Yulianti, D., Winarno, K., Mudyantini, W. 2015. Pemanfaatan Limbah Cair Pabrik Karet PTPN IX Kebun Batu Jamus Karanganyar Hasil Fitoremediasi dengan Azolla microphylla Kaulf untuk Pertumbuhan Tanaman Padi (Oryza sativa Linn.). BioSMART, 7(2), 125–130.

Yuwono, 2008 Odor Quantification and Odor Pollution in Indonesia. Journal of Purification, 9(2), 175–186 (2008).

Yuwono, A. S. 2008. Odor Quantification and Odor Pollution in Indonesia. Jurnal Purifikasi, 9(2), 175–186.