Turkish Online Journal of Qualitative Inquiry (TOJQI)
Volume 12, Issue 7, July 2021: 14076 – 14084

A Review of Green Chemistry and Its Impact on Organic Synthesis

TusharVishwasraoRajale Associate Professor
Department of Chemistry
Pratap College Amalner(Atonomous)
District-Jalgaon,Maharashtra,India

ABSTRACT

Environmental degradation and global warming are major sources of concern in our daily lives. Since the need for human everyday appliances has expanded significantly over the past few years, organic chemicalbased companies have responded to this growth in demand by boosting the efficiency of their manufacturing processes. It is as a result of this that environmental contamination is becoming more severe. It was therefore necessary to establish green chemistry in order to convince the chemical companies to aim for greater environmental sustainability. Over the course of 20 years, green chemistry concepts have had considerable impact on the organic chemistry area, particularly given the large number of researchers who have concentrated their efforts in that sector. Therefore, waste control, cleaner solvents, design for high energy efficiency, and use of renewable feedstocks have all been addressed in the synthesis of organic molecules up to this point. This study examines in detail and in short the application of green chemistry concepts and their applications in the synthesis of organic molecules, as well as the implementation of green chemistry principles in general.

Keywords: environmental sustainability, green chemistry, organic compound, synthesis process.

I. INTRODUCTION

The current degradation of environmental quality has reached an alarming degree and has a significant impact on human existence [1]. Pollution of the environment is described as a hazardous environmental condition in which the concentration of a pollutant is greater than the usual level as a result of either natural or manmade contamination. Environmental pollution, in its most basic definition, is a state of imbalance in any system of environmental life [2]. Environmental contamination, which includes soil, water, and air pollution, worsens with the passage of time, mostly as a result of industrial operations. Furthermore, greenhouse gases released into the atmosphere degrade the environmental situation by raising the temperature of the globe (known as global warming). Those issues demand immediate response if we are to maintain a sustainable ecosystem. Because of this, industrial operations should not be oriented only toward economic gain at the expense of environmental preservation [3].

In the ancient past, chemical manufacturers focused primarily on the yield of the reaction and the purity of the intended product [4], and they paid little attention to environmental concerns, energy consumption, and the efficiency of the chemical process. Despite the fact that national and international rules for chemical companies have been established, environmental contamination seems to be a never-ending concern, particularly in developing nations [5]. Consequently, since the government's approach to environmental sustainability seems insufficiently efficient, researchers are putting forth their best efforts to grow the chemical industries in a "green" and environmentally friendly stage [6]. Many attempts have been made to enhance and improve those environmental challenges since the introduction of the green chemistry idea by Anastas and Warner in 1998. When it comes to the design, production, and use of chemical goods, green chemistry is described as the application of a set of principles that lowers or eliminates the use or creation of hazardous compounds [7]. As seen in Figure 1, there are 12 fundamental concepts of green chemistry.

However, due to the length restriction of the text, we have concentrated our study on four basic themes, namely, waste control, safer solvents, design for high energy efficiency, and the use of renewable feedstocks, among others. The presentation of those four principles, on the other hand, dilates the other principles for a little period of time. Furthermore, the implementation of green chemistry principles as well as their application in the synthesis of organic chemicals will be discussed in this study.

Figure 1. 12 Principles of green chemistry [8]

II. WASTE PREVENTION

"Tt always better to prevent the generationof waste rather than to manage or treat oreliminate them." Waste is defined as any by-product material that is produced throughout the course of a process. Due to the fact that it is poisonous, nonbiodegradable, and radioactive, waste from chemical operations has long posed a threat to the human population. Furthermore, as long as the chemical industries are in operation, these wastes will continue to be created [8]. Solid wastes and liquid wastes are the two basic categories of trash that may be found in most households. Liquid and solid wastes are characterised by their phase, which may be either liquid or solid depending on the kind of waste. Typical components of liquid waste include acid, base, metal ions (precious metals, alkali and base metals, and heavy metals), organic pollutants (dyes, biomolecules, and so on), and other contaminants. Meanwhile, solid trash is often made up of plastics, paper, solid metals, ceramics, and glassware [9], among other things [10].

The chemical process should be developed in such a way that it incorporates all of the ingredients utilised to the greatest extent feasible in order to produce the desired output. Therefore, waste prevention should be demonstrated through the rational and effective design of the chemical process, which incorporates green chemistry quantitative metrics, such as effective mass yield, product efficiency, carbon efficiency, atom economy, reaction mass efficiency, ecoscale, environmental factor, and biologic tool plots [10], among others. The effective mass yield of a chemical process is defined as the ratio between the mass of the intended product and the mass of all non-beneficial ingredients (such as water, dilute alcohol, sodium chloride, and other salts) employed in the chemical process [11]. However, this metric is very subjective when it comes to defining "non-beneficial" materials, and it does not accurately characterise the amount of toxicity caused by the chemical process. A more technical term for this is product efficiency. Product efficiency is defined as the relationship between actual mass of a desired product and the theoretical total atomic mass of the desired product. Carbon efficiency is a measure that indicates how well the carbon atoms are used in a product's manufacturing process. This characteristic, although useful in the pharmaceutical business, is completely worthless in inorganic industries such as the manufacturing of metal oxide, inorganic paint, inorganic polymer, and advanced materials, among others.

This formula was developed by Barry Trost in 1995 and is based on how much of each reactant is present in a given amount of desired product. Despite the fact that the homogeneous catalyst and utilised solvents are excluded from the atom economy calculation since they are not regarded to be reactants in the chemical process, atom economy is still considered to be a useful parameter for organic and inorganic processes in modern times. Although it should be highlighted that atom economics is only studied from the perspective of the handwritten response equation [12] [13], it should be recognised that it is merely a theoretical parameter. Reaction mass efficiency, on the other hand, takes into account the atom economy, chemical yield, and reaction stoichiometry. However, similar to the carbon efficiency parameter, the reaction mass efficiency parameter is still an ideal calculation that indicates the "green-ness" of the reaction but not the actual process since it does not account for any solvent or energy use. Van Aken and colleagues [14] introduced the ecoscale measure in 2006, and it has since gained widespread acceptance. Its score ranges from zero to one hundred, similar to the effective mass yield parameter, and takes into account cost, safety, technical set-up, energy and purification considerations as well as other factors.

In order to calculate it, first assign a value of 100 to an ideal reaction defined as "Compound A undergoes a reaction with compound B to yield the desired compound C in 100 percent yield at room temperature with minimal risk to the operator and minimal impact on the environment," and then subtract penalty points from that value for non-ideal circumstances. In practise, however, this perfect situation is seldom achieved over the course of a chemical reaction. So far, the environmental factor (E-factor) has shown to be one of the most adaptable quantitative measures for green chemical applications. When Roger A. Sheldon created the E-factor formula in 2007, he defined it as the ratio between total waste and the intended result. [15] The E-factor takes into account the solvent and catalyst consumption, making it comprehensive enough to determine if a chemical process is ecologically beneficial or not. The yearly output of oil refining, bulk chemicals, fine chemicals, and pharmaceutical processes is 106-108 tonnes, 104-106 tonnes, 102-104 tonnes, and 10-103 tonnes, respectively, according to the United Nations Development Programme. Meanwhile, the amount of trash generated by oil refining, bulk chemicals, fine chemicals, and pharmaceutical operations is 105-107, 104-105, 10-104, and 102-105 tonnes, respectively, compared to the total amount of garbage created by the whole world. This information indicates that the E-factors of oil refining, bulk chemicals, fine chemicals, and pharmaceutical processes are 0.1, 1-5, 5-50, and 25-100, respectively, in comparison to the global average. In other words, as of now, the oil refining sector is the cleanest chemical business, whereas the pharmaceutical industry is the worst chemical industry according to the E-factor. Lie et al. [16] established the biologic tool plot, which is the most recent quantitative green chemistry measure to be developed. This parameter allows for a straightforward description of a chemical route based on the data that is provided, such as the starting material, intermediates and products names and chemical formulas, as well as the yields of the reaction steps themselves. It is necessary to plot the mass proportion of heteroatoms in the materials against their molar masses in order to acquire the biologic tool score. The closer the biologic tool score gets to one, the more logical the chemand's energy consumption becomes.

Van Aken and colleagues [14] introduced the ecoscale measure in 2006, and it has since gained widespread acceptance. Its score ranges from zero to one hundred, similar to the effective mass yield parameter, and takes into account cost, safety, technical set-up, energy and purification considerations as well as other factors. In order to calculate it, first assign a value of 100 to an ideal reaction defined as "Compound A undergoes a reaction with compound B to yield the desired compound C in 100 percent yield at room temperature with minimal risk to the operator and minimal impact on the environment," and then subtract penalty points from that value for non-ideal circumstances. In practise, however, this perfect situation is seldom achieved over the course of a chemical reaction. So far, the environmental factor (E-factor) has shown to be one of the most adaptable quantitative measures for green chemical applications. When Roger A. Sheldon created the E-factor formula in 2007, he defined it as the ratio between total waste and the intended result. [15] The E-factor takes into account the solvent and catalyst consumption, making it comprehensive enough to determine if a chemical process is ecologically beneficial or not. The yearly output of oil refining, bulk chemicals, fine chemicals, and pharmaceutical processes is 106-108 tonnes, 104-106 tonnes, 102-104 tonnes, and 10-103 tonnes, respectively, according to the United Nations Development Programme. Meanwhile, the amount of trash generated by oil refining, bulk chemicals, fine chemicals, and pharmaceutical operations is 105-107, 104-105, 10-104, and 102-105 tonnes, respectively, compared to the total amount of garbage created by the whole world. This information indicates that the E-factors of oil refining, bulk chemicals, fine chemicals, and pharmaceutical

processes are 0.1, 1-5, 5-50, and 25-100, respectively, in comparison to the global average. In other words, as of now, the oil refining sector is the cleanest chemical business, whereas the pharmaceutical industry is the worst chemical industry according to the E-factor. Lie et al. [16] established the biologic tool plot, which is the most recent quantitative green chemistry measure to be developed.

This parameter allows for a straightforward description of a chemical route based on the data that is provided, such as the starting material, intermediates and products names and chemical formulas, as well as the yields of the reaction steps themselves. It is necessary to plot the mass proportion of heteroatoms in the materials against their molar masses in order to acquire the biologic tool score. It is more reasonable to use a chemically friendly solvent generated from renewable sources that has a low net cumulative energy demand throughout the manufacturing process when the biologic tool score is closer to 1. Ethanol, for example, is considered a "greener" solvent than N, Ndimethylformamide because ethanol can be readily manufactured on a big scale from biomass waste via a fermentation process on a huge scale. In general, the physicochemical parameters of the solvent are taken into consideration when considering solvent substitution. It is feasible to replace the used solvent with an alternative solvent as long as the alternative solvents have approximately the same physicochemical characteristics as the used solvent. Solubility (d), acidity (a), basicity (b), and polarity (p*) are some of the physicochemical qualities measured by the Kamlet-Taft parameters, which are defined as follows: A sensible design for solvent substitution might be obtained by a thorough analysis of those characteristics.

III. DESIGN FOR HIGH ENERGY EFFICIENCY

"If possible, all chemical processes should beconducted at room temperature and pressure."

High temperatures are sometimes required for chemical reactions in order to pass the activation energy and/or make the reaction feasible from a thermodynamic standpoint. As an example, certain inorganic materials need calcination at temperatures more than 700 degrees Celsius in order to achieve the correct crystal structure. [17] Organic reactions, on the other hand, are often carried out by the use of the reflux technique. Modern research has successfully produced numerous "green" reaction circumstances, including sonochemistry, microwave chemistry, photocatalysis reaction, and microfluidics reaction, among others. The fundamental goal of using an alternate reaction technique is to provide energy to the chemicals as quickly as possible from the heat sources, allowing the reaction time to be dramatically reduced. Using catalyst material to shorten the reaction and purification processes [18] is another method of lowering the energy consumption of chemical processes.

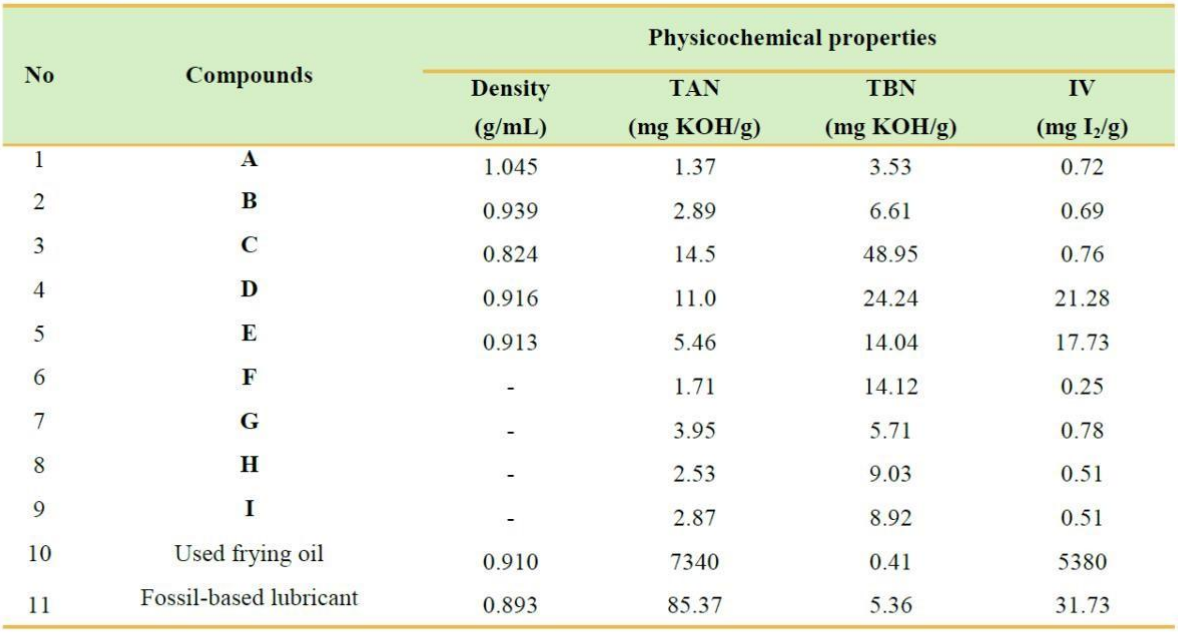
It is a chemical compound that speeds up a reaction by lowering its activation energy, but it does not undergo any irreversible chemical changes in the process of speeding up the reaction. It is feasible to regulate the reaction selectivity as well as the stereochemistry of the reaction by varying the catalyst materials, resulting in the production of the desired product in very high yields and purity percentages. It means that the high selectivity and catalytic efficiency of the catalyst material is far superior to the time-consuming process of obtaining a racemic mixture from the catalyst material.

IV. USAGE OF RENEWABLE FEEDSTOCKS

“Feedstocks are better in renewable stage thus itcould be stable either in technically or economically practice.”

Due to the depletion of fossil fuel resources over time, renewable energy sources are becoming more visible, and bio-resources are being extensively employed [19]. The plastics sector, which uses petroleum feedstocks as raw materials, is in a precarious state since demand exceeds supply by a factor of many times. As a result, various businesses are attempting to transition away from petroleum-based polymer and toward biomassderived polymer [20]. Due to the fact that it may be carried out under moderate conditions, atom transfer radical polymerization (ATRP) polymerization has been hailed as an ecologically benign approach for the preparation of biopolymers. Moreover, by using an appropriate catalyst material, it is possible to maintain tight control over the polymerization rate, polymerization degree, and polymerization selectivity [21]. The catalyst material is often created using an impregnation process on silica materials, which makes the method inexpensive and easy for use in large-scale applications such as chemical processing. So far, polylactide (polylactic acid) has been shown to be a viable alternative to polystyrene and/or polyethene-based products. Under part, this was due to the fact that polylactide could be dissolved readily in aerobic conditions or under UV irradiation, which was far easier than the decomposition of either the polyester or polyethylene structures. It is possible to create cyclic ketal of 9,10-dihydroxyoctadecanoates [22] from biolubricant chemical A-K oil as a starting material for the production of additional heterocyclic compounds. To get 9,10dihydroxyoctadecanoic acid, the utilised frying oil was first trans esterified, then hydrolyzed, and finally oxidised, as described above. The esterification of that fatty acid resulted in the formation of the desired product, which was then further processed using carbonyl chemicals. A number of chemicals, including dioxane-dione (A), dioxepame (B), dioxolane (C, F-I), and dioxaspiro (D and E), have been effectively synthesised as a result of this procedure.

Table 1: Physicochemical properties of several bio lubricants, bio greases, and biosurfactants synthesized from used frying oil waste



No	Compounds	Physicochemical properties			
		Density (g/mL)	TAN (mg KOH/g)	TBN (mg KOH/g)	IV (mg I_2/g)
1	**A**	1.045	1.37	3.53	0.72
2	**B**	0.939	2.89	6.61	0.69
3	**C**	0.824	14.5	48.95	0.76
4	**D**	0.916	11.0	24.24	21.28
5	**E**	0.913	5.46	14.04	17.73
6	**F**	-	1.71	14.12	0.25
7	**G**	-	3.95	5.71	0.78
8	**H**	-	2.53	9.03	0.51
9	**I**	-	2.87	8.92	0.51
10	Used frying oil	0.910	7340	0.41	5380
11	Fossil-based lubricant	0.893	85.37	5.36	31.73

Figure 2 depicts their chemical structures, while Table 1 depicts their physicochemical qualities. Figure 2: Chemical structures of the compounds It was discovered that the biolubricants A-E had a decent density value, as well as much lower total acid number (TAN) and iodine value (IV) than either utilised frying oil or fossilbased lubricant, which was rather exceptional in comparison to the other two options. While this is happening, the total base number (TBN) varies from low to medium depending on how the connected substituents on the heterocyclic moiety are distributed throughout the molecule. Biogreases F-I, on the other hand, produced lower TAN and IV but greater TBN, suggesting that they have the potential to be used as biomaterials in machine-based chemical processes [20]. Preparation of non-ionic biosurfactants J and K from plant oils is a further use of plant oils. It was discovered from the investigation of their physicochemical properties that their surface tensions are 16.1 and 14.2 mN/m, their foam stability values for 100 mins are 3.0 and 42 mL, and their critical micelle concentrations are 1.5 and 1.5 gL, respectively, and that their emulsion indexes are 10.0 and 68.0 percent after 4 days of observation. These physicochemical results indicate that the non-ionic biosurfactants that have been developed are suitable candidates for industrial use.

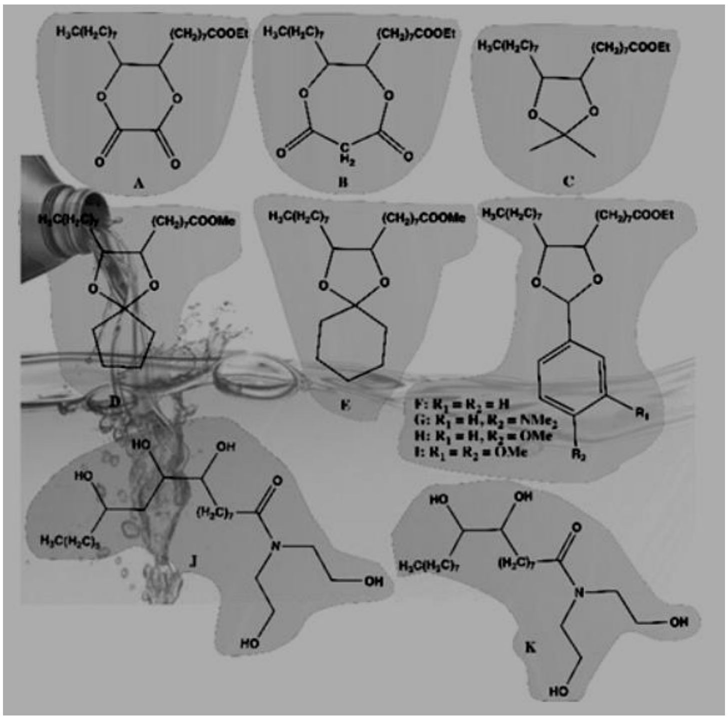


Figure 2: Structure of Biolubricant compound A-K

V. CONCLUSION

It is critical to pay close attention to every detail in order to develop an efficient and effective design for the organic synthesis process, as well as to ensure that we retain our environmental sustainability. Achieving this condition can be accomplished by employing green chemistry principles, which include: (1) eliminating waste generated through observation of green chemistry quantitative metrics, (2) using safer and biofriendly solvents, 3) employing a high-energy-efficiency synthesis method, and 4) considering the use of renewable feedstocks such as those derived from waste. This eliminates any justification for ignoring the green chemistry approach when it comes to managing the chemical industry for a better future for our planet.

REFERENCES

[1]. B. A. de Marco, B. S. Rechelo, E. G. Tótoli, A. C. Kogawa, and H. R. N. Salgado. (2019). "Evolution of green chemistry and its multi-dimensional impacts: A review". *Saudi Phar-maceutical Journal*. 27 (1): 1–8. 10.1016/j.jsps.2018.07.011.

[2]. S. K. Singh, D. N. Rao, M. Agrawal, J. Pan-dey, and D. Naryan. (1991). "Air pollution tolerance index of plants". *Journal of Envi-ronmental Management*. 32 (1): 45–55, 1991, doi: 10.1016/S0301-4797(05)80080-5.

[3]. C. J. Li and B. M. Trost. (2008). "Green chemistry for chemical synthesis". *Proceed-ings of the National Academy of Sciences of the United States of America*. 105 (36): 13197–13202. 10.1073/pnas.0804348105.

[4]. J. B. Manley, P. T. Anastas, and B. W. Cue. (2008). "Frontiers in Green Chemistry: meet-ing the grand challenges for sustainability in R&D and manufacturing". *Journal of Clean-er Production*. 16 (6): 743–750. 10.1016/j.jclepro.2007.02.025.

[5]. M. Poliakoff, J. M. Fitzpatrick, T. R. Farren, and P. T. Anastas. (2002). "Green chemistry: Science and politics of change". *Science*. 297 (5582): 807–810. 10.1126/science.297.5582.807.

[6]. M. J. Mulvihill, E. S. Beach, J. B. Zimmer-man, and P. T. Anastas. (2011). "Green chemistry and green engineering: A frame-work for sustainable technology develop-ment". *Annual Review of Environment and Resources*. 36: 271–293. 10.1146/annurev-environ-032009-095500.

[7]. J. A. Linthorst. (2010). "An overview: Ori-gins and development of green chemistry". *Foundations of Chemistry*. 12 (1): 55–68. 10.1007/s10698-009-9079-4.

[8]. P. Anastas and N. Eghbali. (2020). "Green Chemistry: Principles and Practise". *Chemi-cal Society Reviews*. 29: 301–12. 10.1039/b918763b.

[9]. L. Giusti. (2009). "A review of waste man-agement practices and their impact on human health". *Waste Management*. 29 (8): 2227–2239. 10.1016/j.wasman.2009.03.028.

[10]. C. Brown, M. Milke, and E. Seville. (2011). "Disaster waste management: A review arti-cle". *Waste Management*. 31 (6): 1085–1098. 10.1016/j.wasman.2011.01.027.

[11]. M. Tobiszewski, M. Marć, A. Gałuszka, and J. Namieś nik. (2015). "Green chemistry met-rics with special reference to green analytical chemistry". *Molecules*. 20 (6): 10928–10946. 10.3390/molecules200610928.

[12]. T. Hudlicky, D. A. Frey, L. Koroniak, C. D. Claeboe, and L. E. Brammer Jr. (1999). "Toward a 'reagent-free' synthesis". *Green Chemistry*. 1 (2): 57–59. 10.1039/a901397k.

[13]. B. M. Trost. (1995). "Atom Economy—A Challenge for Organic Synthesis: Homogene-ous Catalysis Leads the Way". *AngewandteChemie International Edition in English*. 34 (3): 259–281. 10.1002/anie.199502591.

[14]. K. van Aken, L. Strekowski, and L. Patiny. (2006). "EcoScale, a semi-quantitative tool to select an organic preparation based on eco-nomical and ecological parameters". *Beilstein Journal of Organic Chemistry*. 2. 10.1186/1860-5397-2-3.

[15]. R. A. Sheldon. (2007). "The E Factor: Fif-teen years on". *Green Chemistry*. 9 (12): 1273–1283. 10.1039/b713736m.

[16]. Y. Lie, P. Ortiz, R. Vendamme, K. Van-broekhoven, and T. J. Farmer. (2019). "BioLogicTool: A Simple Visual Tool for Assisting in the Logical Selection of Path-ways from Biomass to Products". *Industrial and Engineering Chemistry Research*. 58 (35): 15945–15957. 10.1021/acs.iecr.9b00575.

[17]. Y. S. Kurniawan, M. Anwar, and T. D. Wahyuningsih. (2017). "New lubricant from used cooking oil: Cyclic ketal of ethyl 9,10-dihydroxyoctadecanoate". *Materials Science Forum*. 901: 135–141. 10.4028/www.scientific.net/MSF.901.135.

[18]. J. Jumina, Y. Priastomo, H. R. Setiawan, Mutmainah, Y. S. Kurniawan and K. Ohto. (2020). “Simultaneous removal of lead(II), chromium(III) and copper(II) heavy metal ions through an adsorption process using C-phenylcalix[4] pyrogallolarene material”. *Journal of Environmental Chemical Engi-neering*. 8: 103971. 10.1016/j.jece.2020.103971.

[19]. L. G. C. Villegas, N. Mashhadi, M. Chen, D. Mukherjee, K. E. Taylor and N. Biswas. (2016). “A Short Review of Techniques for Phenol Removal from Wastewater”. *Current Pollution Reports*. 2 (3): 157–167. 10.1007/s40726-016-0035-
3.

[20]. Y. S. Kurniawan, K. Anggraeni, R. Indrawa-ti, and L. Yuliati. (2020). “Functionalization of titanium dioxide through dye sensitizing method utilizing red amaranth extract for phenol photodegradation”. *IOP Conference Series: Materials Science and Engineering*.

[21]. D. Ariyanti, D. Iswantini, P. Sugita, N. Nur-hidayat, and Y. S. Kurniawan. (2020). “Highly Sensitive Phenol Biosensor Utilizing Selected Bacillus Biofilm Through an Elec-trochemical Method”. *Makara Journal of Science*. 24 (1). 10.7454/mss.v24i1.11726.

[22]. M. M. Khan, S. F. Adil, and A. Al-Mayouf. (2015). “Metal oxides as photocatalysts”. *Journal of Saudi Chemical Society*. 19 (5): 462–464. 10.1016/j.jscs.2015.04.003.