

# Sorption Of Methylene Blue In Aqueous Solutions By Adsorption Material From Bagasse

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**Abstract**—This report presents the results of research on the adsorbents are made from bagasse by different methods: Bagasse was cut into small pieces, repeatedly washed by water to remove sugar, boiled at 100°C within 50 minutes and dried to have raw bagasse (VL1). The raw materials (VL1) will be continuously manufactured by virtue of anaerobic heat at 300°C (VL2) and 700°C (VL3) and activated by condensed sulfuric acid 98% within 48 hours (VL4). The characterization of the product was performed by Brunauer-Emmett-Teller (BET), X-ray diffraction (XRD), energy dispersive analysis of X-rays (EDX), scanning electron microscopy (SEM). The investigation reveals that bagasse thermalized at 700°C (VL3) may highly absorbent capacity for methylene blue, about 132.98 mg/g. That material have high activity nearly compare with commercial activated carbon (VL5). This materials can used to treatment organic compounds in wastewater

**Keywords**—Bagasse, adsorption, organic compounds, treatment, wastewater

## I. INTRODUCTION

At present, the problem of water pollution due to organic matters is quite serious, especially textile dyes. These pollutants can infiltrate in our body through the respiratory, oral, percutaneous ... If the content of organic compounds exceeds the allowable limits will cause physiological dysfunction of the living body, causing cancer, nerve... Therefore, researching on removing them from the environment is very important [1-7].

There are many methods of water pollution treatment were applied: biological methods, chemical methods, physicochemical methods [8-14]. Adsorption method which is one of physicochemical methods has so far been considered as a way to effectively treat these contaminants [15-34].

Agriculture residues is known for high carbon contents in this structure, is a potential source for making biochar. There are many research has been made the adsorption materials form agricultural residues, from sources as: Tea waste, rice straw, bamboo hydrochar, vegetable residues, oil extraction from almond peanut, corncob... [16, 19-25, 29-31]. Agricultural residues available in large quantities are bagasse-the fibrous byproduct resulting from the

milling of sugarcane. Sugarcane bagasse accounts for 25-30% of the weight of sugarcane. The annual global production of 800 million tonnes of sugarcane results in 240 million tonnes of bagasse [34]. Bagasse has many special applications: Be pressed and used as a fuel to replace firewood; an important source of raw materials for paper pulp, plywood, ceiling; be used as bedding for livestock pens; make natural water filter material, absorb heavy metals, absorb organic compounds; be a substitute for straw, grass; fermentation as fertilizer and potting media for growing mushrooms. In this study, we made biochar from bagasse by different methods: by heat, concentrated sulfuric acid to increase the adsorption capacity of the material, and the first study the adsorption of methylene blue in the laboratory

## II. MATERIAL AND METHODS

Bagasse was obtained from GiaLam in HaNoi, VietNam. Bagasse was cut into small pieces, repeatedly washed by water to remove sugar, boiled at 100°C within 50 minutes and dried in an oven at 110°C for 6h (VL1)

### A. Synthesis of biochar from bagasse

Raw material (VL1) was heated in a muffle at 300°C in 2h obtained VL2. Raw material (VL1) was heated in a muffle at 700°C in 2h obtained VL3. The raw material VL1 was immersed in H<sub>2</sub>SO<sub>4</sub> 98% with ratio VL1: H<sub>2</sub>SO<sub>4</sub> = 1g:1.5ml within 48h, washed several times with distilled water, then soaked in NaHCO<sub>3</sub> 5% in 24h. Filter and retrieve materials. Wash several times to neutral pH and then dried at 150°C in 6h to obtain VL4. And VL5 - activated carbon, was a commercial product, which was used to compare with the synthetic materials

### B. Characteristic structure of the materials

The physico-chemical structure of materials was analyzed by thermogravimetric analysis was measured on 4.000 Mettler TA TGA machine at a temperature range of 0-1000°C with heating speed of 10°C/min. X-ray diffraction (XRD) technique using a Bruker B8 Advance X-ray powder diffractometer. The elemental composition was determined by Energy dispersive analysis of X-rays (EDX, Varian Vista Ax). The size and morphology of materials was examined using scanning electron microscopy (SEM, Hitachi S-4800FEG). The surface area and pore distributions of the material sample was determined by a Beckman Coulter SA3100 surface area analyzer based on the

nitrogen adsorption-desorption isotherm at the temperature of liquid nitrogen (-196°C).

### C. Sorption experiments

Adsorption of methylene blue (MB) onto different adsorbents was studied in batch experiments. A fixed amount of each dry adsorbent (0.5g) and 50ml methylene blue solution were carried out in 250ml glass beakers and shaken at 150rpm at room temperature. Then, the adsorbed samples were filtered. The methylene blue concentration in the solution after adsorption was determined by UV-VIS

Spectro 2550 spectrophotometer at its maximum absorbance wavelength of 660nm. To ensure the reproducibility of data, each experiment was conducted in triplicate and average of the three measurements was reported. The adsorbed amounts of substances were calculated from the mass balance equation:

$$Q_e = (C_0 - C_e) \cdot V/m$$

Investigate the effect of reaction time and methylene blue concentration on the adsorption capacity of the materials

Table 1. Experimental steps and conditions

No.	Experiment	Conditions		
		C <sub>MB</sub> (mg/L)	Time (min)	m <sub>Adsorption</sub> (g)
1	Effect of reaction time	100	0-150	0.5
2	Effect of MB concentration	50-2500	60	0.5

## III. RESULTS AND DISCUSSION

### A. Structure characteristics of materials

#### • The thermal gravimetric analysis diagram of bagasse

The bagasse used in this study are the local materials, was taken from Gia Lam, Ha Noi, Viet Nam. Thermal gravimetric analysis (TGA) is a

method of thermal analysis in which the mass of a sample is measured over time as the temperature changes. This measurement provides information about physical phenomena, such as phase transitions, absorption and desorption; as well as chemical phenomena including chemisorptions, thermal decomposition, and solid-gas reactions

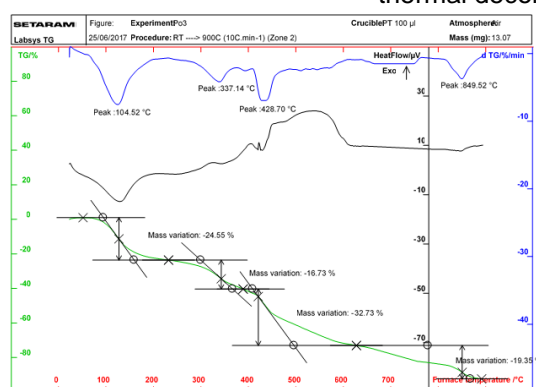


Fig 1. Thermal gravimetric analysis (TGA) of bagasse

Thermoanalytical techniques such as TGA have been widely used to study the thermal behavior of agricultural by-products such as bagasse. Therefore, it is possible that thermal analysis would make an important contribution to knowledge of the thermal behavior of biomass. The TGA showed that four steps of weight loss occur at the heating rate of 10°C/min, from the TGA curve. From the start of the experiment until the temperature of 104.52°C, the amount of weight loss recorded 24.55%. That was the endothermic process, was due to the loss of moisture present in the sample and the external water bound by surface tension. The second weight loss step occurred at 104.52– 337.14°C. This step was due to the removal of volatile matter which corresponded to the decomposition of the three major bagasse components, cellulose, hemicellulose and lignin, the weight loss 16.73%. The maximum rate of weight loss occurred at rapid decomposition of the sample and was observed between 200 and 337.14°C. The next broad weight loss step that occurs above 428°C, that is the exothermic process,

is due to carbonization process which may be attributed to cellulose, hemicellulose and lignin intermediates being transformed to gaseous materials and tars with the weight loss 32.73%. At the end of the combustion is the combustion of multi-ring organic compounds, that have a stable structure at about 849°C, with the weight loss 19.35%

Based on the evolution of the decomposition temperature of bagasse. We carried out bagasse at temperature about 300°C and 700°C that was the temperature range is occurring the decomposition structure of bagasse

#### • The results of elements analysis in the samples

The EDX method allows to determine the composition of the chemical elements present in the material. The carbon content of the initial material is about 44%. This is mainly a cellulose component with the structure of β-D-Glucoside linking together to form long chains.

Table 2. Results of elemental analysis of materials from bagasse

Materials	Elements (%)											
	C	O	Si	N	P	K	Zn	Cu	Mg	Fe	Ca	Al
VL1	44.75	46.28	1.94	1.27	0.3	4.58	0.05	0.09	0.05	0.14	0.09	0.46
VL2	54.20	24.74	13.7	-	-	5.03	0.08	0.1	1.02	0.09	0.25	0.79
VL3	60.61	10.93	16.03	-	-	6.01	0.25	0.46	2.06	1.13	0.51	2.01
VL4	60.55	34.37	5.08	-	-	-	-	-	-	-	-	-
VL5	95.18	4.59	0.19	-	-	0.01	-	-	-	0.02	0.01	-

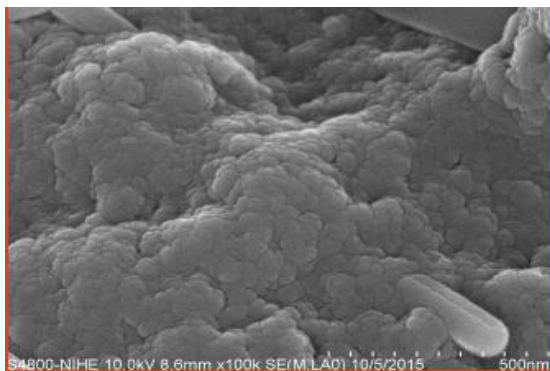
Bagasse has high cellulose content, the carbon content is about 44.75%, under the treatment by high temperature and acid  $H_2SO_4$  concentration, the dehydrate reactions and hydrolysis reactions will occur and the cellulose chain will be cut off to formed the shorter chain and the results will increase the –COOH functional groups, increase the specific surface area and that leading increase adsorption and exchange capacity of the samples

In anaerobic digestion, the composition of oxygen is significantly altered. Under the effect of high temperatures, the organic matter was

decomposed, the water was strongly evaporated. There fore, the material have low oxygen content. In VL2 has 24.74% and in VL3 has 10.93% of oxygen. In acid modification, under the very strong oxydizing agents. All of the metals in the samples were dissolve. Thus, after formation, the sample only have C, O and Si elements

- *The SEM images of material samples*

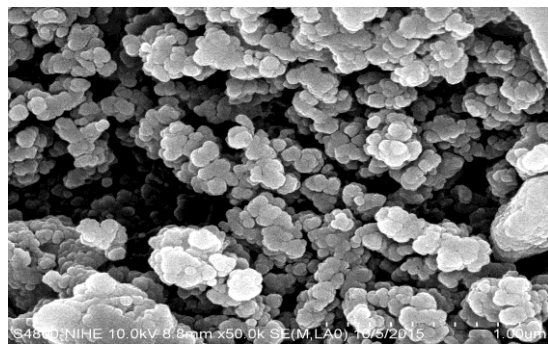
SEM images allow to determine the surface and particle size of the material. The results of the SEM analysis are shown in figure 2



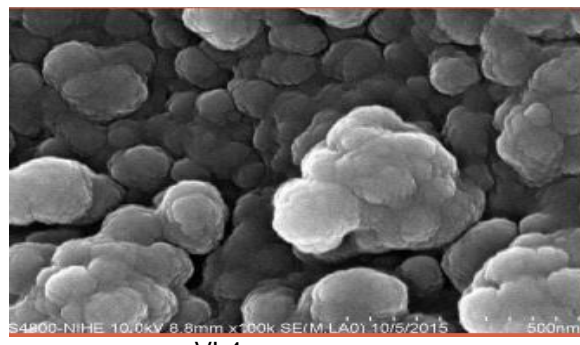
VL1



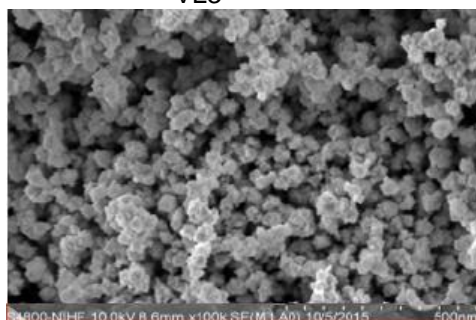
VL2



VL3



VL4



VL5

Fig 2. The SEM analysis of materials

Bagasse has a stable structure, created by  $\beta$ -D-glucose monomers that link each other by  $\beta$ -1,4-glucoside. The products obtained under treatment by temperature and acid have a small grain structure, about 50-100nm

- *The XRD diffraction diagram*

XRD diffraction allows to determine the structure of the material, the results of the XRD diffraction analysis of the materials are shown in figure 3.

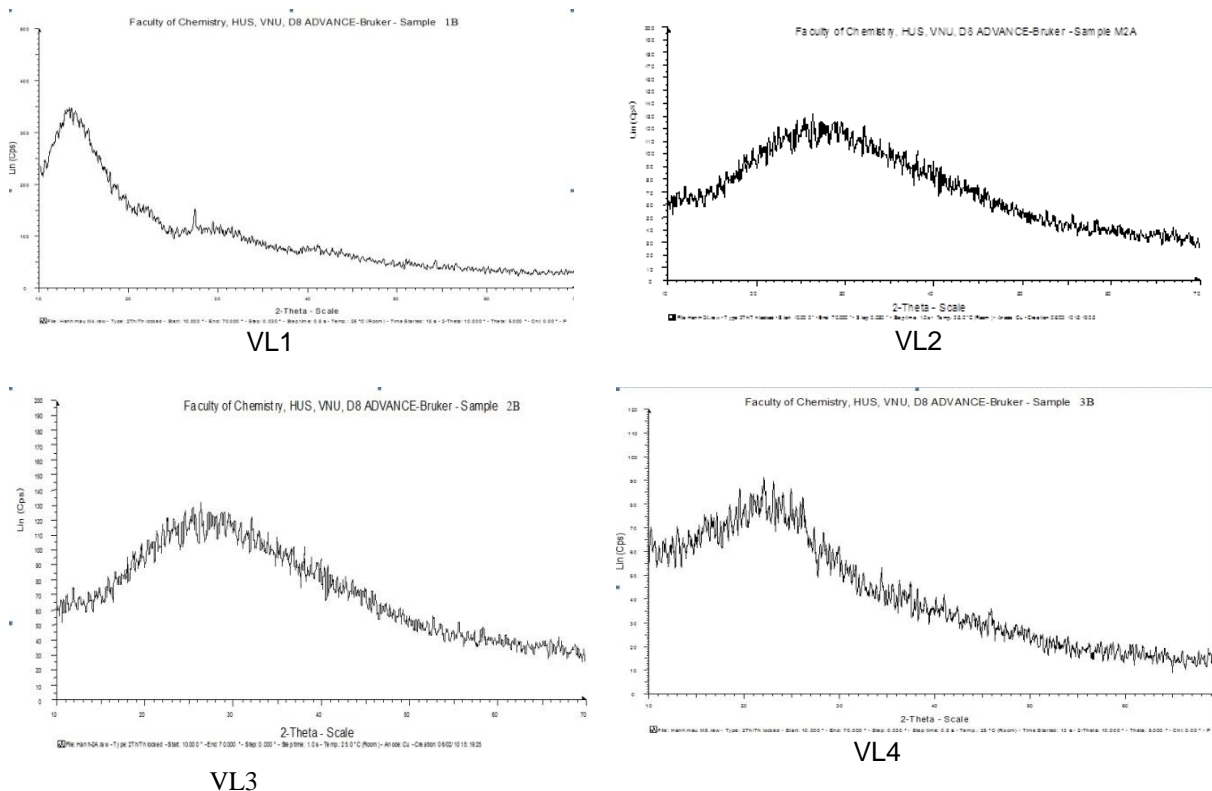


Fig 3. The XRD diffraction of materials

The XRD scheme of pure cellulose shows the peaks at angles of  $2\theta = 14.5; 16.3; 22.6^\circ$ . In modified material, under the treatment of temperature and acid, the cellulose chain would be broken down, make the peaks in the  $2\theta$  corners more fluid the the original. Specifically, all four samples of modified material are no longer retain peak peak pic at  $2\theta = 14.5^\circ$ . Thus, X-ray diffraction pattern (XRD) shows that the structure of the denatured material has been broken and changed a lot compared to the original

material. These characteristics will determine the absorption capacity of the viral load.

- *Specific surface area of these samples*

The surface area and pore distributions of the material sample was determined by a Beckman Coulter SA3100 surface area analyzer based on the nitrogen adsorption-desorption isotherm at the temperature of liquid nitrogen ( $-196^\circ\text{C}$ ).

Table 3. The results determine the specific surface area of the materials

Samples	VL1	VL2	VL3	VL4	VL5
$S_{\text{BET}}$ ( $\text{m}^2/\text{g}$ )	14.82	280.35	487.61	389.12	327.86

The raw material has a small surface area about  $14.82 \text{ m}^2/\text{g}$ . Modified materials under the reactions of temperature, acid... The hydrate reactions would be occur and they made the change on the structure of materials, significantly increase the surface area. The highest surface area of VL3 reached  $487.61 \text{ m}^2/\text{g}$  when treated at temperature of  $700^\circ\text{C}$

B. *Investigate the absorption capacity of Methylene blue solution*

- *The effect of time on the adsorption capacity of the materials on the MB solution*

Preparation of methylene blue with concentration at  $100 \text{ mg/l}$ , shaking for a period of 0 to 150 minutes at  $150 \text{ rpm}$ . The results of the adsorption capacity of these materials for the methylene blue solution are shown in the fig 4

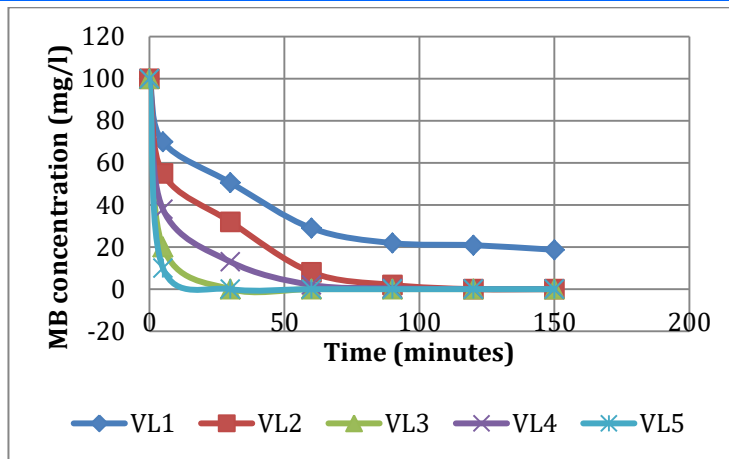


Fig 4. The effect of time on the adsorption capacity of the material on the MB solution

The results showed that, during the period from 0 - 150 minutes, when increasing the shaking time, the absorption capacity of materials increased. Raw material adsorption (VL1) slow occurred, after 60 minutes adsorption efficiency is about 71%, then the concentration was slow down. These materials are capable of high absorption, VL3, VL5 completely absorbed MB solution after 30 minutes. VL2, VL4 adsorption was about 92.3% and 98.7% respectively. The further experiments will be conducted at 60 minutes

- The effect of MB concentration on the adsorption capacity of the materials

Carry out adsorption with different initial concentrations of MB solutions (50 - 1500 mg/l), adsorption time 60 minutes, the speed 150 rpm (especially with VL3 and VL5 would be experimented with higher concentrations until 2000 and 2500mg/l). The adsorption capacity of these materials for methylene blue were calculated and the results were shown in fig 5.

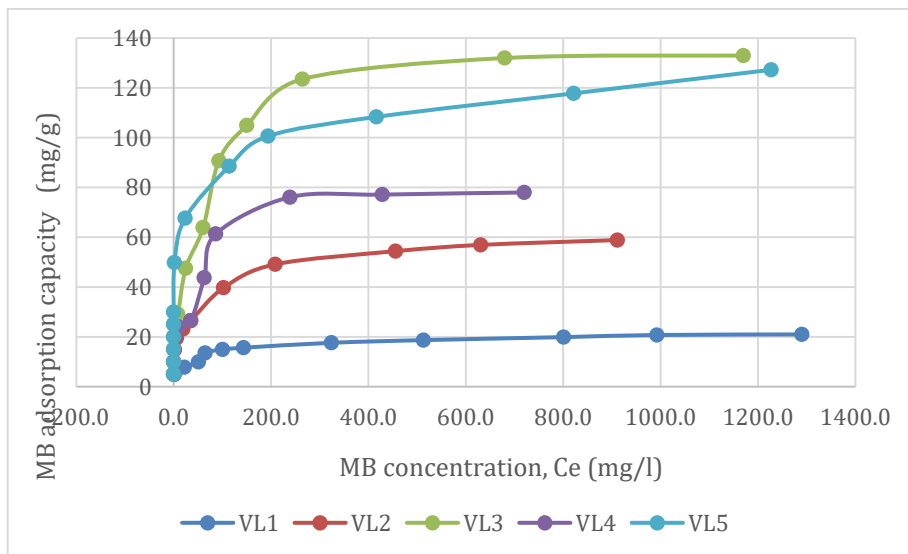


Fig 5. The effect of MB concentration on the adsorption capacity of the material

The adsorbents made from bagasse have a good capacity to absorb MB, as the concentration increases, the adsorption capacity increases. The adsorption capacity will increase to a limit value, called the maximum adsorption capacity of the material ( $q_{max}$ ). From Fig 2, the maximum adsorption capacity of the following materials can be seen:

$Q_{max} \text{ VL1} = 20.96 \text{ mg/g};$   
 $Q_{max} \text{ VL2} = 58.86 \text{ mg/g};$

$Q_{max} \text{ VL3} = 132.98 \text{ mg/g};$   
 $Q_{max} \text{ VL4} = 77.98 \text{ mg/g};$   
 $Q_{max} \text{ VL5} = 127.27 \text{ mg/g}$

The results show that these materials have highly absorbable to MB solution. Modified materials, which have higher adsorption capacity than the original bagasse from 2.81 times (VL2) to 6.34 times (VL3). VL3 has as good adsorption capacity as commercial activated carbon

Table 4. Reported MB adsorption capacities of various carbon-based sorbents

No	Materials	Treatment methods	S <sub>BET</sub> (m <sup>2</sup> /g)	Q <sub>max</sub> (mg/g)	Reference
1	Sugarcane bagasse	300 <sup>0</sup> C, 2h 700 <sup>0</sup> C, 2h H <sub>2</sub> SO <sub>4</sub> 98%	280.35 487.61 389.12	58.86 132.98 77.98	This work
2	Sugarcane bagasse	300 <sup>0</sup> C, 1.5h 450 <sup>0</sup> C, 1.5h 600 <sup>0</sup> C, 1.5h	- - 359	169 300 260	[18]
3	Bamboo	300 <sup>0</sup> C, 1.5h 450 <sup>0</sup> C, 1.5h 600 <sup>0</sup> C, 1.5h	- - -	202 250 225	[18]
4	Hickory chips wood	300 <sup>0</sup> C, 1.5h 450 <sup>0</sup> C, 1.5h 600 <sup>0</sup> C, 1.5h	- - 222	114 250 240	[18]
5	Foumanat tea waste	NaOH 0,05M, 4h	45	461	[19]
6	Rice husk	H <sub>3</sub> PO <sub>4</sub> 85%	571	88.65	[20]
7	Rice husk	oxalic acid 1.2M	-	29.15	[21]
8	Bamboo	NaOH 0.25M	26.249 31.602	655.76 268.93	[22]
9	Prickly pear peel	H <sub>3</sub> PO <sub>4</sub> 85%	1025	416.7	[23]
10	Corn cob	saline conditions.	-	163.93	[24]
11	Maize silk	Grind to powder	-	71.6	[25]

#### IV. CONCLUSIONS

From this study, the modified materials has demonstrated its capability in removing methylene blue from aqueous solutions. The sorption of methylene blue on bagasse and modified materials was studied as a function of various parameter such as: contact time, concentration of MB in solutions. The rates of sorption for MB dye at various initial concentrations were rapid at the beginning, followed by a more gradual process and equilibrium was attained within 60 minutes. The maximum adsorption capacity of these materials was 132.98 mg/g (VL3) and this adsorbent can served as a good low cost adsorbent to replace costly adsorbents in dye removal.

#### REFERENCES

- [1]. Liu Yu, İlhami Yıldız (2018), 1.24 Energy and Water Pollution, *Comprehensive Energy Systems*, Vol. 1, pp. 950-979
- [2]. Qing Wang, Zhiming Yang (2018), *Industrial water pollution, water environment treatment, and health risks in China*, *Environmental Pollution*, Vol. 218, pp. 358-365
- [3]. S. Galassi, L. Guzzella, M. Mingazzini, L. Viganò, S. Capri and S. Sora [1992], Toxicological and chemical characterization of organic micropollutants in river PO water (Italy), *Water Research Institute*, Vol. 26, No. 1, pp. 19-27
- [4]. Zhao Chen, Matthew E. Kahn, Yu Liu, Zhi Wang [2018], The consequences of spatially differentiated water pollution regulation in China, *Journal of Environmental Economics and Management*, Vol. 88, pp. 468-485
- [5]. Shuzhen Chen, Desheng Wu [2018], Adapting ecological risk valuation for natural resource damage assessment in water pollution, *Environmental Research*, Vol. 164, pp. 85-92
- [6]. Tetyana M. Budnyak, Selda Aminzadeh, Ievgen V. Pylypchuk, Dariusz Sternik, Valentin A. Tertykh, Mikael E. Lindstrom, Olena Sevastyanova [2018], methylene blue dye sorption by hybrid materials from technical lignins, *Journal of Environmental Chemical Engineering*, <https://doi.org/10.1016/j.jece.2018.07.041>
- [7]. Chengmei Shi, Furong Tao, Yuezhi Cui [2018], Evaluation of nitriloacetic acid modified cellulose film on adsorption of methylene blue, *International Journal of Biological Macromolecules*, Vol. 114, pp. 400-407
- [8]. Ján Derco, Jozef Dudáš, Mária Valicková, Katarína Šimovicová, Juraj Kecskés [2015], Removal of micropollutants by ozone based processes, *Chemical Engineering and Processing*, Vol. 94, pp. 78-84
- [9]. Changlin Yu, Zhen Wu, Renyue Liu, Dionysios D. Dionysiou, Kai Yang, Chunying Wang, Hong Liu [2017], Novel fluorinated Bi<sub>2</sub>MoO<sub>6</sub> nanocrystals for efficient photocatalytic removal of water organic pollutants under different light source illumination, *Applied Catalysis B: Environmental*, Vol. 209, pp. 1-11
- [10]. Panpan Zhou, Yu Xie, Jing Fang, Yun Ling, Changling Yu, Xiaoming Liu, Yuhua Dai, Yuancheng Qin, Dan Zhou [2018], CdS quantum dots confined in mesoporous TiO<sub>2</sub> with exceptional photocatalytic performance for degradation of organic pollutants, *Chemosphere*, Vol. 178, pp. 1-10
- [11]. Soma Banerjee, Poonam Benjwal, Milan Singh, Kamal K. Kar [2018], Graphene oxide (rGO)-metal oxide (TiO<sub>2</sub>/Fe<sub>3</sub>O<sub>4</sub>) based nanocomposites for the removal of methylene blue, *Applied Surface Science*, Vol. 439, pp. 560-568
- [12]. Zhijie Zhang, Yan Yang, Lei Sun, Rui Liu [2018], Direct conversion of metal-polyphenolic coordination assembly to MnOx -Carbon nanocomposites

for catalytic degradation of methylene blue, *Materials Letters*, Vol. 221, pp. 97-100

[13]. Roger B.D. Tian, Shady Asmar, Claude Napez, Hubert Lépidi, Michel Drancourt [2018], Effectiveness of purified methylene blue in an experimental model of *Mycobacterium ulcerans* infection, *International Journal of Antimicrobial Agents*, Vol. 49, pp. 290-295

[14]. Morteza Farrokhi-Rad, Mehrdad Mohammadipour, Taghi Shahrabi [2018], Electrophoretic deposition of titania nanostructured coatings for photodegradation of methylene blue, *Ceramics International*, Vol. 44, pp. 10716-10725

[15]. Nur Hidayati Othman, Nur Hashimah Alias, Munawar Zaman Shahrudin, Noor Fitrah Abu Bakar, Nik Raikhan Nik Him, Woei Jye Lau [2018], Adsorption kinetics of methylene blue dyes onto magnetic graphene oxide, *Journal of Environmental Chemical Engineering*, Vol. 6, pp. 2803-2811

[16]. Masoud Erfani, Vahid Javanbakht [2018], Methylene Blue removal from aqueous solution by a biocomposite synthesized from sodium alginate and wastes of oil extraction from almond peanut, *International Journal of Biological Macromolecules*, Vol. 114, pp. 244-255

[17]. J.Oliva, A.I. Martinez, A.I. Oliva, C.R. Garcia, A. Martinez-Luevanos, M. Garcia-Lobato, R. Ochoa-Valiente, A. Berlanga [2018], Flexible graphene composites for removal of methylene blue dye-contaminant from water, *Applied Surface Science*, Vol. 436, pp. 739-746

[18]. Honghong Lyu, Bin Gao, Feng He, Andrew R. Zimmerman, Cheng Ding, Jingchun Tang, John C. Crittenden [2018], Experimental and modeling investigations of ball-milled biochar for the removal of aqueous methylene blue, *Chemical Engineering Journal*, Vol. 335, pp. 110-119

[19]. Azadeh Ebrahimian Pirbazari, Elham Saberikhan, Moslem Badrouh, Mohammad Saeed Emami [2014], Alkali treated foumamat tea waste as an efficient adsorbent for methylene blue adsorption from aqueous solution, *Water Resources and Industry*, Vol. 6, pp. 64-80

[20]. V. Fierro, G. Muniz, A.H. Basta, H. El-Saied, A. Celzard [2010], Rice straw as precursor of activated carbons: Activation with ortho-phosphoric acid, *Journal of Hazardous Materials*, Vol 181, pp. 27-34

[21]. Sook-Mun Lee and Siew Teng Ong [2014], Oxalic acid modified rice hull as a sorbent for methylene blue removal, *Apccbe Procedia*, Vol. 9, pp. 165-169

[22]. Wei-Cong Qian, Xi-Ping Luo, Xing Wang, Ming Guo, Bing Li [2018], Removal of methylene blue from aqueous solution by modified bamboo hydrochar, *Ecotoxicology and Environmental Safety*, Vol. 157, pp. 300-306

[23]. Alejandra-Alicia Peláez-Cid, Ana-María Herrera-González, Martín Salazar-Villanueva, Alejandro Bautista-Hernández [2016], Elimination of textile dyes using activated carbons prepared from vegetable residues and their characterization, *Journal of Environmental Management*, Vol. 181, pp. 269-278

[24]. Huan Ma, Jia-Bao Li, Wei-Wei Liu, Miao Miao, Bei-Jiu Cheng, Su-Wen Zhu [2015], Novel synthesis of a versatile magnetic adsorbent derived from corncob for dye removal, *Bioresource Technology*, Vol. 190, pp. 13-20

[25]. Seyed Mohammadreza Miraboutalebi, Soheil Kordmirza Nikouzad, Mohammad Peydayesh, Nima Allahgholi, Leila Vafajoo, Gordon McKay [2017], Methylene blue adsorption via maize silk powder: Kinetic, equilibrium, thermodynamic studies and residual error analysis, *Process Safety and Environmental Protection*, Vol. 106, pp. 191-202

[26]. Jinsong He, Anan Cui, Shihuai Deng, J. Paul Chen [2018], Treatment of methylene blue containing wastewater by a cost-effective micro-scale biochar/polysulfone mixed matrix hollow fiber membrane: Performance and mechanism studies, *Journal of Colloid and Interface Science*, Vol. 512, pp. 190-197

[27]. Pathireddy Manoj Kumar Reddy, Priyanka Verma, Challapalli Subrahmanyam [2016], Bio-waste derived adsorbent material for methylene blue adsorption, *Journal of the Taiwan Institute of Chemical Engineers*, Vol. 58, pp. 500-508

[28]. Mónica Berrios, María Ángeles Martín, Antonio Martín [2012], Treatment of pollutants in wastewater: Adsorption of methylene blue onto olive-based activated carbon, *Journal of Industrial and Engineering Chemistry*, Vol. 18, pp. 780-784

[29]. Vesna M. Vucurović, Radojka N. Razmovski, Uros D. Miljic, Vladimir S. Puskas [2014], Removal of cationic and anionic azo dyes from aqueous solutions by adsorption on maize stem tissue, *Journal of the Taiwan Institute of Chemical Engineers*, Vol. 45, pp. 1700-1708

[30]. Yan Wang, Yong Zhang, Shiyin Li, Wenhui Zhong, Wei Wei [2018], Enhanced methylene blue adsorption onto activated reed-derived biochar by tannic acid, *Journal of Molecular Liquids*, doi: 10.1016/j.molliq.2018.07.085

[31]. Apurva A. Narvekar, J.B. Fernandes, S.G. Tilve [2018], Adsorption behavior of methylene blue on glycerol based carbon materials, *Journal of Environmental Chemical Engineering*, Vol. 6, pp. 1714-1725

[32]. Wenhao Wang, Lishuang Yang, Haibin Sun, Zanzhong Yang, Qingyang Du, Chengfeng Li [2018], Improved photodynamic efficiency for methylene blue from silica-methylene blue tannic acid-Fe(III) ions complexes in aqueous solutions, *Advanced Powder Technology*, Vol. 29, pp. 341-348

[33]. Shichang Kang, Yunliang Zhao, Wei Wang, Tingting Zhang, Tianxing Chen, Hao Yi, Feng Rao, Shaoxian Song [2018], Removal of methylene blue from water with montmorillonite nanosheets/chitosan hydrogels as adsorbent, *Applied Surface Science*, vol. 448, pp. 203-211

[34]. Dimitrios Kalderis, Sophia Bethanis, Panagiota Paraskeva, Evan Diamadopoulos (2008), Production of activated carbon from bagasse and rice husk by a single-stage chemical activation method at low retention times, *Bioresource Technology*, Vol. 99 (15), pp. 6809-6816