Response Surface Method Application in Tofu Production Liquid Waste Treatment

Hefni Effendi[1,*], Romi Seroja[2], and Sigid Hariyadi[2]

[1]*Center for Environmental Research, Bogor Agricultural University,*
PPLH IPB Building, Jl. Lingkar Akademik, IPB Darmaga Campus, Bogor 16680, West Java, Indonesia

[2]*Department of Aquatic Resources Management, Bogor Agricultural University,*
Jl. Rasamala, IPB Darmaga Campus, Bogor 16680, West Java, Indonesia

* ***Corresponding author:***

email: hefni_effendi@yahoo.com

Received: December 25, 2017
Accepted: April 27, 2018

DOI: 10.22146/ijc.31693

Abstract: *Liquid waste of tofu production has a high content of organic matter which can lead to a decrease in water quality. This study was aimed to obtain an optimal combination of duration and waste concentration in tofu liquid waste treatment using* Chrysopogon zizanioides. *Response surface method using Design Expert 7.0 software was applied to optimize combination response of duration (3, 9, 15 days) and waste concentration (20, 40, 60%), aided by Design Expert 7.0 software. The optimum treatment was 15 days with 20% waste concentration, reducing 55.48% of COD, 37.86% BOD, 93.51% TSS, 87.86% Turbidity, increasing DO to 7.2 mg/L and pH to 7.2.*

Keywords: *phytoremediation; response surface method;* Chrysopogon zizanioides*; wastewater; tofu*

■ INTRODUCTION

There is a lot of tofu production in Indonesia and most are small-scale industries. The tofu production generates liquid waste. Such liquid waste is generally not properly treated and discharged directly into the aquatic environment. Tofu liquid waste contains organic matter which promotes the rapid growth of microbes in the waters and results in decreased oxygen levels in the water. The liquid waste of tofu also contains suspended materials, resulting in an increase in turbidity of the waters.

The effluent characteristics of tofu liquid waste prior to treatment were COD (5759 mg/L), BOD (580 mg/L), TSS (552 mg/L), and pH (3.9) [1]. Those values are not in accordance with the quality standard of Government Regulation No. 05 of 2014 on the Quality Standard of Industrial Wastewater namely BOD (150 mg/L), COD (300 mg/L), TSS (200 mg/L) and pH (6-9). Under such conditions, the tofu liquid waste disposed of without processing will cause environmental problems. Water quality parameters influenced included increased water turbidity, high organic matter, low DO, the development of pathogenic bacteria, and the emergence of bad smell. Several attempts have been made to reduce the levels of organic matter in tofu production waste such as the use of *Chlorella vulgaris* as an autotrophic microalga applied to bioreactors of the raceway pond type [2].

Many studies have been done on improving wastewater quality, among others by using certain chemical adsorbents [3-8]. In this study, we used the plant as a pollutant adsorbent which is also known as phytoremediation. Phytoremediation is a way of eliminating or reducing pollutants by using certain plants in cooperation with microorganisms in the medium (soil and water). Some of the benefits of phytoremediation are potentially applicable, relatively inexpensive operating costs, capable of reducing contaminants in large volumes, and safe [9]. Several types of plants play crucial roles in waste treatment, such as water spinach [10], lettuce [11-13], and vetiver [14]. *Chrysopogon zizanioides* is a water-based land plant which is capable of absorbing soluble nutrients such as N and P and is able to accumulate heavy metals [15]. *C. zizanioides* has been widely utilized for waste treatment in contaminated environments of heavy metals [16], organic wastewater of tapioca factories [17], Tetracycline (TC) wastes in the antibiotic industry [18].

This plant is also capable of being applied to the aquaponic system [19].

This study was aimed to remediate tofu liquid waste using *Chrysopogon zizanioides* by analyzing the optimum combination of liquid waste concentration and duration of the process based on response surface method, which has never been conducted previously, employing Response Surface Methodology (RSM) and Central Composite Design (CCD) methods [20]. RSM is a set of mathematical and statistical techniques to analyze the response in which some independent variables influence the dependent variables and the ultimate goal to optimize the response in various research topics [21]. RSM has been widely used in analyzing various water treatment experiments [4,22-33].

■ EXPERIMENTAL SECTION

C. zizanioides was used for phytoremediation as a filter to reduce organic matter in tofu liquid waste. Vetiver was selected based on the similar age, the height of 10-15 cm and a wet weight of approximately 30 g. *C. zizanioides* was stored in a 30 × 20 × 25 cm^3 container. Acclimatization for 7 days aimed for adjustment so that plants can grow well. Wastewater quality characteristic of tofu was pointed out by COD, BOD, TSS and pH parameters [34]. A similar experiment by addition of zeliac to the system is published elsewhere.

The removal efficiency of water quality was determined (eq. (1)) [35]. In addition, the specific growth rate was calculated by the eq. (2) [36].

$$\%\ \text{removal efficiency} = \frac{a-b}{a} \times 100 \quad (1)$$

where a is water quality parameter before treatment and b is water quality parameter after treatment.

$$SGR = \left(\frac{\ln X_t - \ln X_0}{t - t_0} \right) \times 100 \quad (2)$$

where SGR is specific growth rate (%), X_0 is initial *C. zizanioides* wet weight at time 0 (g), X_t is final *C. zizanioides* wet weight at time t, t_0 is an initial time of observation (day) and t is research duration (day).

In this study, RSM/CCD analysis applied a waste concentration of 20, 40 and 60% and observation time of 3, 9, and 15 days. Design Expert 7.0 software was used to determine the optimized combination response of the waste concentration and duration (13 treatment combinations). Replication of each treatment was selected by the system namely 20% waste (3 replicates), 40% waste (6 replicates), 60% waste (4 replicates), representing 3, 9, 15 days observation.

■ RESULTS AND DISCUSSION

C. zizanioides is a grass plant that grows upright to 1–2.5 m, has stand-up but soft stems and a strong root system with a length of 3–4 m. *C. zizanioides* can grow in

Table 1. The growth of roots stems and SGR of vetiver on tofu liquid waste treatment

Run	Time (Days)	Waste (%)	Roots (cm)	Stems (cm)	SGR (%)
1	9	20	14.00	32.00	0.032
2	9	40	13.75	32.00	0.019
3	3	20	13.25	25.25	0.042
4	9	60	15.00	27.75	0.025
5	15	40	14.25	45.25	0.017
6	15	20	14.25	36.75	0.019
7	15	60	16.00	37.25	0.016
8	9	60	14.25	30.50	0.026
9	3	40	13.00	27.25	0.042
10	9	40	13.25	30.75	0.026
11	3	60	14.75	28.75	0.032
12	9	40	12.25	33.00	0.023
13	9	40	11.50	34.00	0.026

a variety of extreme climatic conditions [37]. Each treatment had an increment of root length, stem and specific growth rate (SGR) (Table 1). Furthermore, in wastewater treatment using plants occurs the process of filtering, ion exchange and absorption by roots and stems [38].

C. zizanioides root had a length of 10 cm prior to treatment, while the length of the stem was 20 cm. The roots grew to 11.5–16 cm (Table 1). Longer roots will provide an opportunity to absorb more nutrients [11]. When plants grow quickly, nutrient uptake will be greater. The nutrient elements in the tofu liquid waste derived from the decomposition of organic matter by microorganisms were absorbed by *C. zizanioides* and served as a source of new tissue formation. Nutritional requirements are fulfilled from nutrients derived from the decomposition of organic matter contained in water, which was utilized by autotrophic organisms, such as aquatic plants and phytoplankton [39].

COD removal increased from 12.18% (3 days, 20% waste) to 60.96% (15 days, 40% waste) (Table 2). *C. zizanioides* is potential as a biofilter to absorb organic material [10,40]. Fig. 1(a) represents the 3D surface response of COD decrease showing waste concentration and which greatly affect the decrease of COD. The color difference in the graph shows the change in the COD decrease response rate. The blue shows the lowest COD decrease response rate, while the red indicates the highest COD decrease response. BOD removal increased from 11.90% (3 days, 20% waste) to 56.36% (15 days, 60% waste) (Table 2) (Fig. 1(b)).

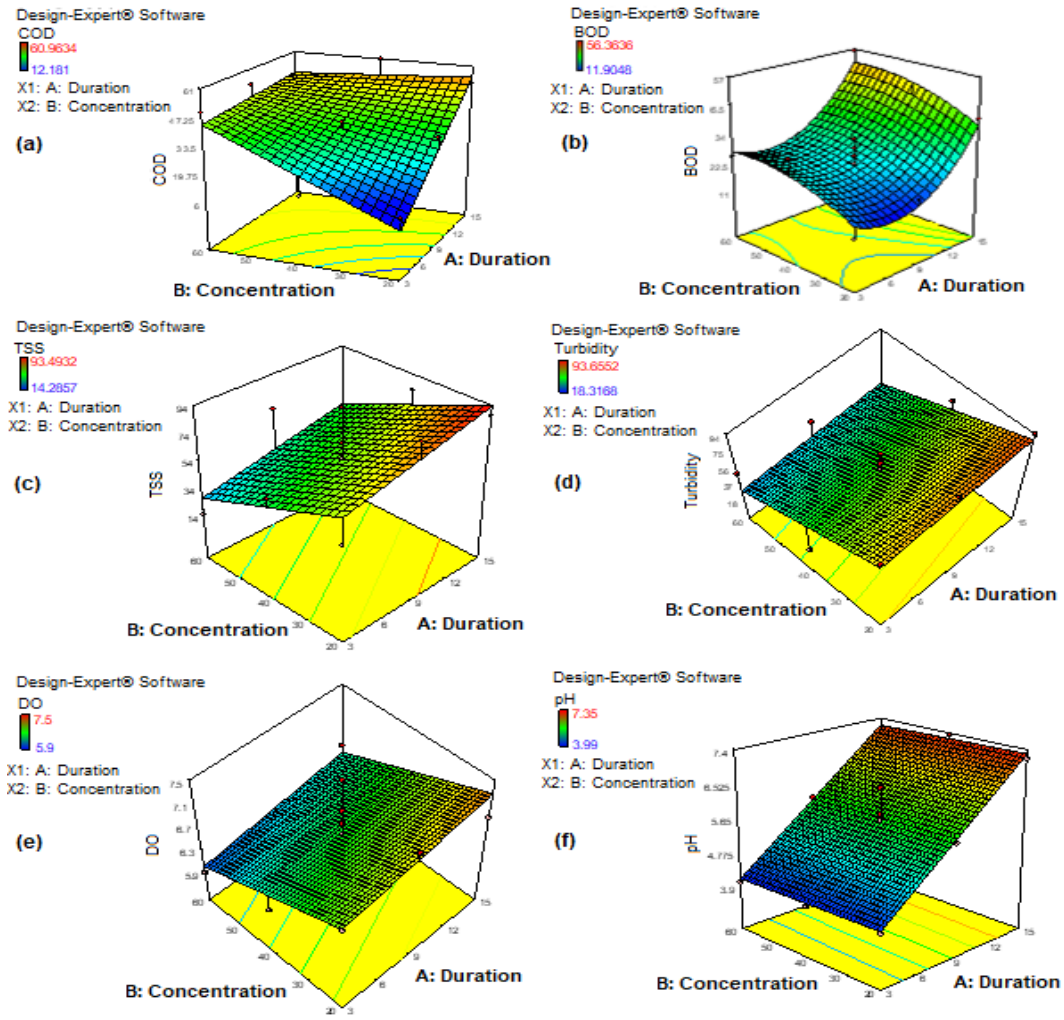

Fig 1. Plot of 3D surface (a) COD, (b) BOD, (c) TSS, (d) Turbidity, (e) DO, (f) pH

Table 2. Percentage removal of (COD, BOD, TSS, Turbidity), an increase of DO and pH

Run	Time (Days)	Waste (%)	COD (%)	BOD (%)	TSS (%)	Turbidity (%)	DO	pH
1	9	20	36.62	16.66	93.49	88.44	7.2	5.63
2	9	40	33.85	16.32	56.74	72.84	6.4	5.63
3	3	20	12.18	11.90	50.68	81.65	6.9	4.12
4	9	60	53.28	23.63	68.57	50.49	5.9	5.68
5	15	40	60.96	40.81	82.58	72.84	6.7	7.35
6	15	20	52.47	40.47	86.98	93.65	6.9	7.18
7	15	60	46.76	56.36	20.00	18.31	6.5	7.00
8	9	60	38.60	25.45	48.57	55.44	6.6	5.45
9	3	40	16.02	32.65	53.93	22.31	6.2	4.05
10	9	40	36.26	28.57	92.97	63.44	6.8	5.76
11	3	60	49.87	25.45	14.28	50.49	5.9	3.99
12	9	40	31.56	22.44	48.31	31.98	7.5	5.71
13	9	40	39.27	32.65	67.41	61.55	7.0	6.44

The change in TSS removal is seen in the color difference (Fig. 1(c)). The red indicates the highest TSS decrease response rate (93.49%) at 9 days and 20% waste, while the blue shows the lowest TSS decrease (14.28%) at 3 days and 60% waste (Table 1). High TSS has an effect on increasing turbidity. This will inhibit the penetration of sunlight into the waters and ultimately affect photosynthesis [41]. TSS shows the number of substances suspended in water. *C. zizanioides* can reduce TSS since the root might be a place of attachment for suspended solids. The higher the plant biomass, the more the fibrous roots and the more colloids that stick to those roots [42].

Removal percentage of COD, BOD and TSS increased likely because of organic substance decomposition and the process of photosynthesis of plants that produce sufficient oxygen supply for microorganisms, rhizosphere to degrade waste more effectively. The process of photosynthesis in *C. zizanioides* allows the release of oxygen into the air and then diffused into the water around root (rhizosphere). The condition of the rhizosphere zone rich in oxygen causes the development of aerobic bacteria to decompose the organic compounds, thereby decreasing the concentration of COD, BOD, and TSS. Some of the organic compounds have been decomposed into other simpler compounds, then absorbed by plants for metabolic processes [1].

Removal of turbidity occurred from 18.31% (15 days, 60% waste) to 93.65% (15 days, 20% waste) (Table 2). The blue indicates the lowest response and the red indicates the highest response (Fig. 1(d)). Turbidity occurs due to the suspended material in the form of colloids and fine particles. Suspended solids are positively correlated with turbidity [40], the higher the suspended solids, the higher the turbidity.

DO on tofu liquid waste prior to treatment was 4.3 mg/L. The process of organic matter decomposition affects the decrease of DO. If the available oxygen is not sufficient then the decomposition process will occur anaerobically. DO ranged 5.9–7.5 mg/L (Table 2). High photosynthetic activity increased DO. The change in the DO response is seen in the color difference (Fig. 1(e)).

The pH of unprocessed tofu liquid waste was 4.45, below the quality standard (6–9). Optimum pH for water plant growth is ≤ 7 [43]. For aquatic plants, pH has an effect on metabolism and the absorption of nutrients and carbon [44]. pH affects the rate of decomposition of organic matter [45]. The pH ranged from 3.99 to 7.35 (Table 2) (Fig. 1(f)).

CCD method has a higher predictor of quality than other methods. This method has the advantage of shortening the optimization research duration [46]. The response values of optimum conditions analyzed by Design Expert 7.0 is presented in Table 3. The optimum condition occurred at 15 days and waste concentration of 20% which could decrease COD up to 55.48%, BOD

Table 3. Response value at optimum condition

Factor		Response					
A (days)	B (waste %)	COD (%)	BOD (%)	TSS (%)	Turbidity (%)	DO	pH
15	20	55.48	37.86	93.51	87.86	7.2	7.2

A: Duration; B: Waste concentration

up to 37.86%, TSS up to 93.51%, turbidity up to 87.86%, increase DO up to 7.2 and an increase of pH up to 7.2.

The capability of *C. zizanioides* in improving the water quality of oil-contaminated water was investigated by [23] in which six pot plants during 4 weeks of experiment could reduce the oil content of 91.39%, 84.60% COD, and 84.25% BOD.

■ CONCLUSION

The optimum condition of tofu liquid waste treatment using *C. zizanioides* (L) was 15 days with 20% waste concentration which could decrease COD (55.48%), BOD (37.86%), TSS (93.51%), Turbidity (87.86%), increase DO to 7.2 and increase pH to 7.2. *C. zizanioides* can be used in improving the quality of tofu production wastewater as long as a sufficient duration time is applied.

■ ACKNOWLEDGMENTS

We express our deepest gratitude and appreciation to BOPTN for making this research possible.

■ REFERENCES

[1] Seroja, R., Effendi, H., and Hariyadi, S., 2018, Tofu wastewater treatment using vetiver grass (*Vetiveria zizanioides*) and zeliac, *Appl. Water Sci.*, 8 (1), 2.

[2] Nugroho, W.A., Hermanto, M.B., Lutfi, M., and Fakhri, M., 2014, Phosphorus removal of tofu processing wastewater in recirculated raceway pond bioreactor by *Chlorella vulgaris*, *Nat. Environ. Pollut. Technol.*, 13 (4), 859–863.

[3] Ahmaruzzaman, M., and Gupta, V.K., 2011, Rice husk and its ash as low-cost adsorbents in water and wastewater treatment, *Ind. Eng. Chem. Res.*, 50 (24), 13589–13613.

[4] Asfaram, A., Ghaedi, M., Agarwal, S., Tyagi, I., and Gupta, V.K., 2015, Removal of basic dye Auramine-O by ZnS:Cu nanoparticles loaded on activated carbon: Optimization of parameters using response surface methodology with central composite design, *RSC Adv.*, 5 (24), 18438–18450.

[5] Gupta, V.K., and Saleh, T.A., 2013, Sorption of pollutants by porous carbon, carbon nanotubes and fullerene- An overview, *Environ. Sci. Pollut. Res.*, 20 (5), 2828–2843.

[6] Gupta, V.K., Srivastava, S.K., Mohan, D., and Sharma, S., 1998, Design parameters for fixed bed reactors of activated carbon developed from fertilizer waste for the removal of some heavy metal ions, *Waste Manage.*, 17 (8), 517–522.

[7] Gupta, V.K., Nayak, A., and Agarwal, S., 2015, Bioadsorbents for remediation of heavy metals: Current status and their future prospects, *Environ. Eng. Res.*, 20 (1), 1–18.

[8] Jain, A.K., Gupta, V.K., Bhatnagar, A., and Suhas, 2003, A comparative study of adsorbents prepared from industrial wastes for removal of dyes, *Sep. Sci. Technol.*, 38 (2), 463–481.

[9] Reeves, R., Berti, W., Blaylock, M., Brown, S., Clijsters, H., Correll, R., Dandridge, K., DeSouza, M., Dunham, S., Edwards, R., Gilis, A., Goldsbrough, P., Gragson, G., Gupta, S., Hari, T., Herren, T., Homer, F., Horne, A., Hwang, S., Jhee, E., Kato, N., Kochian, L., Kramer, U., Krebs, R., Lasat, M., Li, Y.M., Lin, Z.Q., Llugany, M., Lodewyckx, C., Macnair, M., Malik, M., McGrath, S., Noe, L., Pilon-Smits, E., Raskin, I., Schat, H., Smith, J., Smith, R., Smith, S., Spelmans, N., Taghavi, S., Tilstone, G., van der Lelie, D., Vangronsveld, J., Wenger, K., Zayed, A., Terry, N., Banuelos, G., Lepp, N., Mench, M., Meagher, R., Chaney, R., Diels, L., Angle, J., Rugh, C., Fan, T.M., Higashi, R., Salt, D., Baker, A., Bernhard, R., Pollard, A., Wang, N., and Mergeay, M., 2000, *Phytoremediation of Contaminated Soil and Water*,

Terry, N., and Banuelos, G. (Eds.), CRC Press, Boca Raton.

[10] Effendi, H., Utomo, B.A., and Darmawangsa, G.M., 2015, Phytoremediation of freshwater crayfish (*Cherax quadricarinatus*) culture wastewater with spinach (*Ipomoea aquatica*) in aquaponic system, *AACL Bioflux*, 8 (3), 421–430.

[11] Effendi, H., Wahyuningsih, S., and Wardiatno, Y., 2017, The use of nile tilapia (*Oreochromis niloticus*) cultivation wastewater for the production of romaine lettuce (*Lactuca sativa* l. var. *longifolia*) in water recirculation system, *Appl. Water Sci.*, 7 (6), 3055–3063.

[12] Purwandari, Y., Effendi, H., and Wardiatno, Y., 2017, The use of gouramy (*Osphronemus goramy*) rearing wastewater for growing romaine lettuce (*Lactuca sativa* l. var. *longifolia*) in aquaponic system, *Asian J. Microbiol. Biotechnol. Environ. Sci.*, 19 (2), 359–366.

[13] Wahyuningsih, S., Effendi, H., and Wardiatno, Y., 2015, Nitrogen removal of aquaculture wastewater in aquaponic recirculation system, *AACL Bioflux*, 8 (4), 491–499.

[14] Danh, L.T., Truong, P., Mammucari, R., Tran, T., and Foster, N., 2009, Vetiver grass, *Vetiveria zizanioides*: A choice plant for phytoremediation of heavy metals and organic wastes, *Int. J. Phytoremediation*, 11 (8), 664–691.

[15] Truong, P., Van, T.T., and Pinners, E., 2008, *Vetiver System Applications: Technical Reference Manual*, 2nd ed., CreateSpace Independent Publishing Platform, North Charleston SC, United States.

[16] Roongtanakiat, N., Tangruangkiat, S., and Meesat, R., 2007, Utilization of vetiver grass (*Vetiveria zizanioides*) for removal of heavy metals from industrial wastewaters, *ScienceAsia*, 33 (4), 397–403.

[17] Indrayatie, E.R., Utomo, W.H., Handayanto, E., and Anderson, C.W.N., 2013, The use of vetiver (*Vetiveria zizanioides* l.) for the remediation of wastewater discharged from tapioca factories, *Int. J. Environ. Waste Manage.*, 2 (1), 1–16.

[18] Datta, R., Das, P., Smith, S., Punamiya, P., Ramanathan, D.M., Reddy, R., and Sarkar, D., 2013, Phytoremediation potential of vetiver grass [*Chrysopogon zizanioides* (L.)] for tetracycline, *Int. J. Phytorem.*, 15 (4), 343–351.

[19] Effendi, H., Delis, P.C., Krisanti, M.K., and Hariyadi, S., 2015, The performance of nile tilapia (*Oreochromis niloticus*) and vetiver grass (*Vetiveria zizanioides*) concurrently cultivated in aquaponic system, *Adv. Environ. Biol.*, 9 (24), 382–388.

[20] Box, G.E.P., and Draper, N.R., 1987, *Wiley Series in Probability and Mathematical Statistics. Empirical Model-Building and Response Surfaces*, John Wiley & Sons, Oxford, England.

[21] Bezerra, M.A., Santelli, R.E., Oliveira, E.P., Villar, L.S., and Escaleira, L.A., 2008, Response surface methodology (RSM) as a tool for optimization in analytical chemistry, *Talanta*, 76 (5), 965–977.

[22] Adlan, M.N., Palaniandy, P., and Aziz, H.A., 2011, Optimization of coagulation and dissolved air flotation (DAF) treatment of semi-aerobic landfill leachate using response surface methodology (RSM), *Desalination*, 277 (1-3), 74–82.

[23] Bashir, M.J.K., Aziz, H.A., Yusoff, M.S., and Adlan, M.N., 2010, Application of response surface methodology (RSM) for optimization of ammoniacal nitrogen removal from semi-aerobic landfill leachate using ion exchange resin, *Desalination*, 254 (1-3), 154–161.

[24] Effendi, H., Munawaroh, A., and Ayu, I.P., 2017, Crude oil spilled water treatment with vetiveria zizanioides in floating wetland, *Egypt. J. Aquat. Res.*, 43 (3), 185–193.

[25] Kim, S.C., 2016, Application of response surface method as an experimental design to optimize coagulation-flocculation process for pre-treating paper wastewater, *J. Ind. Eng. Chem.*, 38, 93–102.

[26] Liu, X., Li, X.M., Yang, Q., Yue, X., Shen, T.T., Zheng, W., Luo, K., Sun, Y.H., and Zeng, G.M., 2012, Landfill leachate pretreatment by coagulation-flocculation process using iron-based coagulants: Optimization by response surface methodology, *Chem. Eng. J.*, 200-202, 39–51.

[27] Moghaddam, S.S., Moghaddam, M.R.A., and Arami, M., 2010, Coagulation/flocculation process for dye removal using sludge from water treatment

plant: Optimization through response surface methodology, *J. Hazard. Mater.*, 175 (1-3), 651–657.

[28] Ölmez, T., 2009, The optimization of Cr(VI) reduction and removal by electrocoagulation using response surface methodology, *J. Hazard. Mater.*, 162 (2-3), 1371–1378.

[29] Sharma, S., Malik, A., and Satya, S., 2009, Application of response surface methodology (RSM) for optimization of nutrient supplementation for Cr(VI) removal by *Aspergillus lentulus* AML05, *J. Hazard. Mater.*, 164 (2–3), 1198–1204.

[30] Trinh, T.K., and Kang, L.S., 2011, Response surface methodological approach to optimize the coagulation-flocculation process in drinking water treatment, *Chem. Eng. Res. Des.*, 89 (7), 1126–1135.

[31] Wang, Y., Chen, K., Mo, L., Li, J., and Xu, J., 2014, Optimization of coagulation-flocculation process for papermaking-reconstituted tobacco slice wastewater treatment using response surface methodology, *J. Ind. Eng. Chem.*, 20 (2), 391–396.

[32] Wu, Y., Zhou, S., Qin, F., Ye, X., and Zheng, K., 2010, Modeling physical and oxidative removal properties of fenton process for treatment of landfill leachate using response surface methodology (RSM), *J. Hazard. Mater.*, 180 (1-3), 456–465.

[33] Zahrim, A.Y., Nasimah, A., and Hilal, N., 2015, Coagulation/flocculation of lignin aqueous solution in single stage mixing tank system: Modeling and optimization by response surface methodology, *J. Environ. Chem. Eng.*, 3 (3), 2145–2154.

[34] American Public Health Association, Franson, M.A.H., American Water Works Association, and Water Pollution Control Federation, 1989, *Standard Methods for the Examination of Water and Wastewater*, 17th ed., American Public Health Association, Washington, D.C.

[35] Khan, S., Ahmad, I., Shah, M.T., Rehman, S., and Khaliq, A., 2009, Use of constructed wetland for the removal of heavy metals from industrial wastewater, *J. Environ. Manage.*, 90 (11), 3451–3457.

[36] Kittiwongwattana, C., and Vuttipongchaikij, S., 2013, Effects of nutrient media on vegetative growth of lemna minor and *Landoltia punctata* during in vitro and ex vitro cultivation, *Maejo Int. J. Sci. Technol.*, 7 (1), 60–69.

[37] Weragoda, S.K., Jinadasa, K.B.S.N., Zhang, D.Q., Gersberg, R.M., Tan, S.K., Tanaka, N., and Jern, N.W., 2012, Tropical application of floating treatment wetlands, *Wetlands*, 32 (5), 955–961.

[38] Reed, S.C., Crites, R.W., and Middlebrooks, E.J., 1995, *Natural Systems for Waste Management and Treatment.*, McGraw-Hill, Inc., New York, USA.

[39] Effendi, H., Utomo, B.A., Darmawangsa, G.M., and Hanafiah, D.A., 2015, Wastewater treatment of freshwater crayfish (*Cherax quadricarinatus*) culture with lettuce (*Lactuca sativa*), *Int. J. Appl. Environ. Sci.*, 10 (1), 409–420.

[40] Delis, P.C., Effendi, H., Krisanti, M.K., and Hariyadi, S., 2015, Treatment of aquaculture wastewater using *Vetiveria zizanioides* (Liliopsida, Poaceae), *AACL Bioflux*, 8 (4), 616–625.

[41] Effendi, H., 2003, *Telaah Kualitas Air, Bagi Pengelolaan Sumber Daya dan Lingkungan Perairan*, Kanisius, Yogyakarta.

[42] Fachrurozi, M., Utami, L.B., and Suryani, D., 2010, Pengaruh variasi biomassa *Pistia stratiotes* L. terhadap penurunan kadar BOD, COD, aan TSS limbah cair tahu di dusun Klero Sleman Yogyakarta, *KesMas*, 4 (1), 1–75.

[43] Owens, C.S., Smart, R.M., Honnell, D.R., and Dick, G.O., 2005, Effects of pH on growth of *Salvinia molesta* Mitchell, *J. Aquat. Plant Manage.*, 43 (11), 34–38.

[44] Mitchell, D.S., 1982, *Aquatic Vegetation and Its Use and Control*, Unipub, New York.

[45] Boyd, C.E., 1982, *Water Quality Management for Pond Fish Culture.*, Elsevier Scientific Publishing Co., Amsterdam, Netherlands.

[46] Tobias, P., and Trutna, L., *Comparisons of Response Surface Designs*, https://www.itl.nist.gov/div898/handbook/pri/section3/pri3363.htm, accessed on January 1, 2016.