

**MOLECULAR SIEVE UTILIZING CELLULOSE CORN FIBER, BENTONITE  
CLAY AND SILICA COMPOSITE FOR THE REMOVAL OF  
POLLUTANTS IN PIGGERY WASTEWATER**

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ACCEPTANCE SHEET

This undergraduate thesis entitled, "MOLECULAR SIEVE UTILIZING CELLULOSE CORN FIBER, BENTONITE CLAY AND SILICA COMPOSITE FOR THE REMOVAL OF POLLUTANTS IN PIGGERY WASTEWATER," prepared and submitted by RUEL M. BULATAO & CLARO N. DELA CRUZ in partial fulfillment of the requirements in BACHELOR OF SCIENCE IN AGRICULTURAL AND BIOSYSTEMS ENGINEERING (AB LAND AND WATER RESOURCES ENGINEERING), is hereby accepted:



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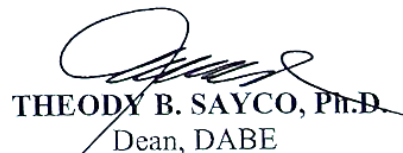
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## TABLE OF CONTENTS

	PAGE
LIST OF TABLES	xi
LIST OF FIGURES	xii
LIST OF APPENDIX TABLES	xiii
LIST OF APPENDIX FIGURES	xv
ABSTRACT	xvii
INTRODUCTION	1
Background of the Study	1
Statement of the Problem	5
Objectives of the Study	6
Significance of the Study	7
Scope and Limitation of the Study	8
Time and Place of the Study	8
REVIEW OF RELATED LITERATURE	9
Corn	9
Cellulose Fibers	9
Photocatalytic Effect of Silica Particle	11
Adsorption Property of Bentonite Clay	13
Extraction and Characterization of Cellulose Fiber	14
Corn Fibers in Water Treatment	16
Agricultural Waste Utilization for Water Conditioning	16
Cellulose	18
Biosorption	19
Water Pollution in the Philippines	20
Impact of Small-scale Pig Farming on the Environment	21
Anecdotal Report of a Local Water Pollution	22
Some Parameters Used in the Evaluation of Agricultural Water Quality	23
Water Temperature	23
Ammonia	24
pH Level	25

Dissolved Oxygen	25
METHODOLOGY	27
Conceptualization of Study	27
Materials and Instruments	28
Collection and Preparation of Samples	29
Characterization of Corn Stover	30
Moisture Content	30
Crude Ash Content	30
Crude Protein Content	31
Crude Fat Content	32
Crude Fiber Content	32
Carbohydrate Content	33
Extraction of Cellulose Corn Fiber	34
Preparation of Corn Pulp	34
Characterization of Cellulose Fiber	34
Determination of Percent Yield of Cellulose Corn Fiber	35
Instrumental Characterization	35
Scanning Electron Microscopy	35
Development and Fabrication of Molecular Sieves	36
Collection of Piggery Wastewater Samples	37
Characterization of Effluent Water Before and After Remediation	38
Characterization on the Physical and Chemical Properties of Water Samples	38
Determination of Fecal Coliform	38
Statistical Analysis	40
Cost Analysis	41
Variable Cost	41
Mark-up Price	41
Selling Price	41
Annual Profit	42
Investment Cost	42
Payback Period	43
RESULTS AND DISCUSSION	44
Proximate Compositions of Corn Stover	44
Percentage Yield of Cellulose Corn Fiber	45

Surface Morphology of the Cellulose Corn Fiber	47
Elemental Composition of the Cellulose Corn Fiber	48
Quality of Wastewater Before and After Treatment	50
Ammonia Concentration	50
pH Level	52
Water Temperature	54
Dissolved Oxygen	55
Fecal Coliform	56
<i>Escherichia coli</i>	57
Cost Analysis	58
SUMMARY, CONCLUSION, AND RECOMMENDATIONS	63
Summary	63
Conclusion	64
Recommendations	65
LITERATURE CITED	66
APPENDICES	72

## LIST OF TABLES

TABLE		PAGE
1	Materials and instruments used in the study	29
2	Different treatments used in the study	36
3	Different time immersion applied per treatment	37
4	Water body classification and usage of freshwater	39
5	Water quality guidelines for primary parameters	40
6	Proximate compositions of corn stover	44
7	Percent yield of cellulose fiber from corn stover	46
8	Elemental composition of the cellulose corn fiber	50
9	Ammonia concentration (mg/L) of piggery wastewater before and after treatment with different immersion times	51
10	pH level of piggery wastewater before and after soaking of treatments with different immersion time	52
11	Temperature (°C) of piggery wastewater before and after soaking of treatments with different immersion times	54
12	Dissolved oxygen (mg/L) level of piggery wastewater before and after soaking of treatments with different immersion time	55
13	Fecal coliform count of piggery wastewater before and after soaking in different treatments	57
14	<i>E. coli</i> count of piggery wastewater before and after soaking in different treatments	58
15	Cost per unit production (Php/kg) of producing the Control	59
16	Cost per unit production (Php/kg) of producing Treatment 1	60
17	Cost per unit production (Php/kg) of producing Treatment 2	61
18	Cost per unit production (Php/kg) of producing Treatment 3	62

## LIST OF FIGURES

FIGURE		PAGE
1	Conceptual framework of the study	28
2	Schematic diagram for the sample preparation and image using SEM	35
3	Extracted cellulose corn fiber	45
4	Scanning electron micrographs of cellulose corn fiber at (a) 100x and (b) 200x magnification	47
5	Elemental mapping and composition of delignified corn fiber	49

## LIST OF APPENDIX TABLE

APPENDIX TABLE	PAGE
1a Raw Data - Multiparameter Readings Initial Data of Control Group	73
1b Raw Data - Multiparameter Readings Initial Data of Treatment 1	73
1c Raw Data - Multiparameter Readings Initial Data of Treatment 2	73
1d Raw Data - Multiparameter Readings Initial Data of Treatment 3	74
2a Raw Data – Multiparameter Readings After 12 hours of Control Group	74
2b Raw Data – Multiparameter Readings After 12 hours of Treatment 1	74
2c Raw Data – Multiparameter Readings After 12 hours of Treatment 2	75
2d Raw Data – Multiparameter Readings After 12 hours of Treatment 3	75
3a Raw Data – Multiparameter Readings After 24 hours of Control Group	75
3b Raw Data – Multiparameter Readings After 24 hours of Treatment 1	76
3c Raw Data – Multiparameter Readings After 24 hours of Treatment 2	76
3d Raw Data – Multiparameter Readings After 24 hours of Treatment 3	76
4a Raw Data - Multiparameter Readings After 36 hours of Control Group	77
4b Raw Data - Multiparameter Readings After 36 hours of Treatment 1	77

4c	Raw Data - Multiparameter Readings After 36 hours of Treatment 2	77
4d	Raw Data - Multiparameter Readings After 36 hours of Treatment 3	78
5	Summary Table of Mean Values of Ammonia, pH, Temperature and DO of Piggery Wastewater at Varying Treatments and Soaking Time of Molecular Sieves	78
6a	ANOVA of Ammonia Concentration	78
6b	Pairwise comparisons between time points	79
6c	Pairwise comparisons for treatment variable	79
7a	ANOVA of pH	79
7b	Pairwise comparisons between time points	80
7c	Pairwise comparisons for treatment variable	80
8a	ANOVA of Temperature	80
8b	Pairwise comparisons between time points	81
8c	Pairwise comparisons for treatment variable	81
9a	ANOVA of Dissolved Oxygen	81
9b	Pairwise comparisons between time points	82
9c	Pairwise comparisons for treatment variable	82
10a	ANOVA of Fecal Coliform	83
10b	Pairwise comparisons for treatment variable	83
11a	ANOVA of <i>E.coli</i>	83
11b	Pairwise comparisons for treatment variable	83

## LIST OF APPENDIX FIGURES

APPENDIX FIGURE		PAGE
1	Collection of Corn Stover	84
2	Corn Stover Cut into Small Pieces	84
3	Drying of Corn Stover	85
4	Soaking in NaOH Solution	85
5	Adding Acetate Buffer	86
6	Extracted corn cellulose fiber	86
7	Composites (CMC, Bentonite Clay, Silica & Cellulose Fiber )	86
8	Pelletized molecular sieves	87
9	Weighing of molecular sieves per replication	87
10	Backyard piggery	88
11	Collecting of wastewater	88
12	Collected piggery wastewater	89
13	Fecal coliform counts	89
14	Wastewater samples prepared before soaking of molecular sieves	89
15	0 hours of soaking	90
16	After 12 hours of soaking	90
17	After 24 hours of soaking	90
18	After 36 hours of soaking	90
19	Data Gathering	91
20	Multiparameter Readings (Initial data)	92

21	Multiparameter Readings (Data after 12 hours)	93
22	Multiparameter Readings (Data after 24 hours)	94
23	Multiparameter Readings (Data after 36 hours)	95

## ABSTRACT

**BULATAO, RUEL M. and DELA CRUZ, CLARO N.**, Department of Agricultural and Biosystems Engineering, College of Engineering, Central Luzon State University, Science City of Muñoz, Nueva Ecija, Philippines, **December 2023**, **MOLECULAR SIEVE UTILIZING CELLULOSE CORN FIBER, BENTONITE CLAY AND SILICA COMPOSITE FOR THE REMOVAL OF POLLUTANTS IN PIGGERY WASTEWATER.**

Adviser: Wendy C. Mateo, Ph.D.

Agricultural residues, such as corn stover, are typically burned in the field after harvesting. The burning of these residues can lead to air pollution and may also affect the health of people in a farming community. In this research, cellulose fiber extracted from corn stover was mixed with bentonite clay and silica produce molecular sieves (pellets) to investigate their effectiveness for improving the quality of piggery wastewater. The proximate composition of fiber was determined such as crude fiber and crude ash content which has a value of 29.4% and 14.2% respectively. The percent yield of corn stover for extraction of fiber was found to be at 41.61% which lies between the usual range of other related studies. Fiber was also undergone characterization through SEM-EDX to identify the components of the fiber which makes it a good material in water remediation. The molecular sieve produced was then mixed with varying amount of silica and bentonite clay. This product was tested in improving the quality of water in terms of ammonia, pH, dissolved oxygen, pressure and microbial load such as fecal coliform and *Escherichia coli*. The addition of components such as bentonite clay and silica aids in improving the efficiency of cellulose fiber in improving the quality of piggery wastewater. The results reported here show that cellulose fiber, bentonite clay, and silica have outstanding potential for removing certain type of water pollutants. To improve pollution control, it is still

necessary to determine the practical applicability of these adsorbents on a commercial scale.

Keywords: Agricultural Residues; Cellulose Fiber; Corn Stover; Molecular Sieve; Piggery Wastewater

## LITERATURE CITED

- Abdelfattah, I., Abdelwahab, W. & El-Shamy, A. (2022). Environmental remediation of contaminated wastewater with ammonium using clay-based adsorbents. *Nature Environment and Pollution Technology*, 21(4), 1971-1982. [https://neptjournal.com/upload-images/\(52\)D-1387.pdf](https://neptjournal.com/upload-images/(52)D-1387.pdf)
- Abdelhamid, H., & Mathew, A. (2021). Cellulose-based materials for water remediation: adsorption, catalysis, and antifouling. *Front. Chem. Eng.*, 3. <https://doi.org/10.3389/fceng.2021.790314>
- Abdel-Rahim, M. M., Elhetawy, A., Refaey, W. M., Lotfy, A. M., El-Zaeem, S. Y., Elebiary, E. H., & El-Dahhar, A. A. (2023). Potential benefits of natural bentonite as a water clarifier on ammonia removal, performance, immunity, antioxidant, and histology of *Dicentrarchus labrax*. *The Egyptian Journal of Aquatic Research*, 49(2), 253-260. <https://doi.org/10.1016/j.ejar.2023.04.002>
- Addy, K., Green, L., & Herron, E. (2004). pH and alkalinity. *Department of Natural Resources Science*. <https://web.uri.edu/wp-content/uploads/sites/1667/pHalkalinityFINA L.pdf>
- Allan, G. L., Maguire, G. B., & Hopkins, S. J. (1990). Acute and chronic toxicity of ammonia to juvenile *Metapenaeus macleayi* and *Penaeus monodon* and the influence of low dissolved-oxygen levels. *Aquaculture*, 91(3-4), 265-280. [https://doi.org/10.1016/0044-8486\(90\)90193-Q](https://doi.org/10.1016/0044-8486(90)90193-Q)
- Arif, M., Kumar., R, Parveen., Shagufta. (2020). Reduction in water pollution in yamuna river due to lockdown under COVID-19 pandemic. *ChemRxiv. Cambridge: Cambridge Open Engage*. <https://chemrxiv.org/engage/chemrxiv/article-details/60c74c8ebdbb8978eba397ef>
- Bailey, D., Nelson, P., and Fonteno, W. (nd). Substrate pH and water quality. [www.nurserycrops.com/info/water/source-water-quality/other-references/substrate-ph-and-water-quality.pdf](http://www.nurserycrops.com/info/water/source-water-quality/other-references/substrate-ph-and-water-quality.pdf)
- Boyd, Claude E. (2013). Ammonia toxicity degrades animal health and growth. *Global Aquaculture Alliance*, 40-43. [https://aquafishcrsp.oregonstate.edu/sites/aquafishcrsp.oregonstate.edu/files/gaa\\_boyd\\_nov13\\_1.pdf](https://aquafishcrsp.oregonstate.edu/sites/aquafishcrsp.oregonstate.edu/files/gaa_boyd_nov13_1.pdf)
- Bozorg-Haddad, O., Delpasand, M., & Loáiciga, H. A. (2020). Water quality, hygiene, and health. *Economical, Political, and Social Issues in Water Resources*, 217-257. <https://doi.org/10.1016/B978-0-323-90567-1.00008-5>
- Cao, Y., Bai, Z., Misselbrook, T., Wang, X., & Ma, L. (2021). Ammonia emissions from

different pig production scales and their temporal variations in the North China Plain. *Journal of the Air & Waste Management Association* (1995), 71(1), 23–33. <https://doi.org/10.1080/10962247.2020.1815895>

Carpenter, Alexis Wells, de Lannoy, Charles-François & Wiesner, Mark R. (2015). Cellulose Nanomaterials in water treatment technologies. *Journal of Agricultural and Food Chemistry*, 49(9), 5277–5287. <https://pubs.acs.org/doi/10.1021/es506351r>

Chopra, L. & Manikanika. (2021). Extraction of cellulosic fibers from the natural resources: A short review. *Materials Today Proceedings*. DOI:10.1016/j.matpr.2021.08.267

Colt, J. (2009). Nitrogen toxicity to fish, crustaceans and molluscs. *Department of Civil Engineering, University of California*, 30. [https://openlibrary.org/books/OL15181508M/Nitrogen\\_toxicity\\_to\\_fish\\_crustaceans\\_and\\_molluscs](https://openlibrary.org/books/OL15181508M/Nitrogen_toxicity_to_fish_crustaceans_and_molluscs)

Des Costa, L., Fonseca, A., Pereira, F., & Druzian, J. (2015). Extraction and characterization of cellulose nanocrystals from corn stover. *Cellulose Chemistry and Technology*. [https://cellulosechemtechnol.ro/pdf/CCT2\(2015\)/p.127-133.pdf?fbclid=IwAR3MacNXyCJs3LwLAWxqLU4\\_8cSwcMbaR0UisPudDk1JbE1fJ3EMF\\_ZoQsk](https://cellulosechemtechnol.ro/pdf/CCT2(2015)/p.127-133.pdf?fbclid=IwAR3MacNXyCJs3LwLAWxqLU4_8cSwcMbaR0UisPudDk1JbE1fJ3EMF_ZoQsk)

Dey, S., Charan, S. S., Pallavi, U., Sreenivasulu, A., & Haripavan, N. (2022). The removal of ammonia from contaminated water by using various solid waste biosorbents. *Energy Nexus*, 7, 100119. <https://doi.org/10.1016/j.nexus.2022.100119>

Dhar, A.K., Himu, H.A., Bhattacharjee, M. et al. Insights on applications of bentonite clays for the removal of dyes and heavy metals from wastewater: a review. *Environ Sci Pollut Res* 30, 5440–5474 (2023). <https://doi.org/10.1007/s11356-022-24277-x>

Doekhi-Bennani, Y., Leilabady, N., Fu, M., Rietveld, L., Hoek, J.P., & Heijman, S. (2021). *Water Research*, 188. <https://doi.org/10.1016/j.watres.2020.116472>

Du, X., Goss, G., & Faramarzi, M. (2020). Impacts of Hydrological Processes on Stream Temperature in a Cold Region Watershed Based on the SWAT Equilibrium Temperature Model. *Water*, 12(4), 1112. <https://doi.org/10.3390/w12041112>

Erickson, R. J. (1984). An evaluation of mathematical models for the effects of pH and temperature on ammonia toxicity to aquatic organisms. *Water Research*, 19(8), 1047–1058. [https://doi.org/10.1016/0043-1354\(85\)90375-6](https://doi.org/10.1016/0043-1354(85)90375-6)

Fadzlu-Ilah, A., M Ismail Yusof, Azavitra Zainal, Aisyah Azhar, Ainul Hakimah Karim, Mohd Aliff, Sairul Izwan Safie. (2020). Design and simulation of PID controller for pH neutralization process. *International Journal of Innovative Technology and Exploring Engineering*, 9(3). [https://www.researchgate.net/profile/Mohd-Aliff/publication/350689956\\_Design\\_and\\_Simulation\\_of\\_PID\\_Controller\\_for\\_P](https://www.researchgate.net/profile/Mohd-Aliff/publication/350689956_Design_and_Simulation_of_PID_Controller_for_P)

H\_Neutralization\_Process/links/629d6341a3fe3e3df860f121/Design-and-Simulation-of-PID-Controller-for-PH-Neutralization-Process.pdf

- Fink, J. C. (2005, August). CHAPTER 4 – ESTABLISHING A RELATIONSHIP BETWEEN SEDIMENT CONCENTRATIONS AND TURBIDITY . In *The Effects of Urbanization on Baird Creek, Green Bay, WI* (Thesis). Retrieved from [http://www.uwgb.edu/watershed/fink/Fink\\_Thesis\\_Chap4.pdf](http://www.uwgb.edu/watershed/fink/Fink_Thesis_Chap4.pdf) 28
- Han, B., Butterly, C., Zhang, W., He, J., & Chen, D. (2021). Adsorbent materials for ammonium and ammonia removal: A review. *Journal of Cleaner Production*, 283. <https://doi.org/10.1016/j.jclepro.2020.124611>
- Ho, L., & Ho, G. (2012). Mitigating ammonia inhibition of thermophilic anaerobic treatment of digested piggery wastewater: Use of pH reduction, zeolite, biomass and humic acid. *Water Research*, 46(14), 4339-4350. <https://doi.org/10.1016/j.watres.2012.05.016>
- Ivanova-Peneva, S., Aarnink, A. & Verstegen, M. (2008). Ammonia emissions from organic housing systems with fattening pigs. *Biosystems Engineering* 99, 412-422. [https://www.researchgate.net/publication/263172732\\_Ammonia\\_emissions\\_from\\_organic\\_housing\\_systems\\_with\\_fattening\\_pigs](https://www.researchgate.net/publication/263172732_Ammonia_emissions_from_organic_housing_systems_with_fattening_pigs)
- Jiang, N., Shang, R., Heijman, S. G., & Rietveld, L. C. (2018). High-silica zeolites for adsorption of organic micro-pollutants in water treatment: A review. *Water Research*, 144, 145-161. <https://doi.org/10.1016/j.watres.2018.07.017>
- Karri, R.R., Jaya Narayan Sahu, & Venkateswarlu Chimmiri (2018). Critical review of abatement of ammonia from wastewater. *Journal of Molecular Liquids*, 261, 21-31. <https://doi.org/10.1016/j.molliq.2018.03.120>
- Kurusu, R. S., Lapointe, M., & Tufenkji, N. (2022). Sustainable iron-grafted cellulose fibers enable coagulant recycling and improve contaminant removal in water treatment. *Chemical Engineering Journal*, 430, 132927. <https://doi.org/10.1016/j.cej.2021.132927>
- Lacroix, E., Brovelli, A., Barry, D. A., & Holliger, C. (2014). Use of Silicate Minerals for pH Control during Reductive Dechlorination of Chloroethenes in Batch Cultures of Different Microbial Consortia. *Applied and Environmental Microbiology*, 80(13), 3858-3867. <https://doi.org/10.1128/AEM.00493-14>
- Lala, A., Marlina, M., Yusuf, M., Suhendra, R., Maulydia, N.B. Muslem, M. Reduction of microbial content (*Escherichia coli*) in well water using various processes: microfiltration membranes, aeration and bentonite adsorption. *Heca Journal of Applied Sciences*, 1(1). <https://doi.org/10.60084/hjas.v1i1.17>
- Li, X., Tabil, L.G. & Panigrahi, S. (2007). Chemical Treatments of Natural Fiber for Use

- in Natural Fiber-Reinforced Composites: A Review. *J Polym Environ* 15, 25–33. <https://doi.org/10.1007/s10924-006-0042-3>
- Lovell, T. (1989). Nutrition and feeding of fish. [https://openlibrary.org/books/OL381892M/Nutrition\\_and\\_feeding\\_of\\_fish](https://openlibrary.org/books/OL381892M/Nutrition_and_feeding_of_fish)
- Malik, D.S., Jain, C.K. & Yadav, A.K. (2017). Removal of heavy metals from emerging cellulosic low-cost adsorbents: a review. *Appl Water Sci* 7, 2113–2136. <https://doi.org/10.1007/s13201-016-0401-8>
- Mallya, Y.J. (2007). The effects of dissolved oxygen on fish growth in aquaculture. UNU-Fisheries Training Programme. <https://www.grocentre.is/static/gro/publication/58/document/yovita07prf.pdf>
- Mayer, T. D. (2012). Controls of summer stream temperature in the Pacific Northwest. *Journal of Hydrology*, 475, 323-335. <https://doi.org/10.1016/j.jhydrol.2012.10.012>
- Mishra, R., Militky, J., & Venkataraman, M. (2018). Electrospun nanofibers. *Nanotechnology in Textiles*, 35-161. <https://doi.org/10.1016/B978-0-08-102609-0.00002-X>
- Mugwanya, M., Dawood, M. A., Kimera, F., & Sewilam, H. (2022). Anthropogenic temperature fluctuations and their effect on aquaculture: A comprehensive review. *Aquaculture and Fisheries*, 7(3), 223-243. <https://doi.org/10.1016/j.aaf.2021.12.005>
- Olivier, J.G.J., A.F. Bouwman, K.W. Van der Hoek, & J.J.M. Berdowski (1998). Global air emission inventories for anthropogenic sources of NO<sub>x</sub>, NH<sub>3</sub> and N<sub>2</sub>O in 1990. *Environmental Pollution*, 102 (1), 135-148. [https://doi.org/10.1016/S0269-7491\(98\)80026-2](https://doi.org/10.1016/S0269-7491(98)80026-2)
- Parvathy, A. J., Das, B. C., Jifiriya, M. J., Varghese, T., Pillai, D., & Rejish Kumar, V. J. (2023). Ammonia induced toxico-physiological responses in fish and management interventions. *Reviews in Aquaculture*, 15(2), 452-479. <https://doi.org/10.1111/raq.12730>
- Pazdar, S. et al. (2019). Removal of coliform content in sewage treatment plant using a sand filtration system with potassium permanganate powder. *American Journal of Engineering and Applied Sciences*. <https://thescipub.com/pdf/ajeassp.2019.309.318.pdf>
- Peng, B., Yao, Z., Wang, X., Crombeen, M., Sweeney, D. G., & Tam, K. C. (2019). Cellulose-based materials in wastewater treatment of petroleum industry. *Green Energy & Environment*, 5(1), 37-49. <https://doi.org/10.1016/j.gee.2019.09.003>
- Singh, H., Patil, T., Vineeth, S., Das, S., Pramanik, A., & Mhaske, S. (2019). Isolation of

- microcrystalline cellulose from corn stover with emphasis on its constituents: Corn cover and corn cob. *Materials Today: Proceedings*, 27, 589-594. <https://doi.org/10.1016/j.matpr.2019.12.065>
- Smart, G.R. (1978), Investigations of the toxic mechanisms of ammonia to fish–gas exchange in rainbow trout (*Salmo gairdneri*) exposed to acutely lethal concentrations. *Journal of Fish Biology*, 12: 93-104. <https://doi.org/10.1111/j.1095-8649.1978.tb04155.x>
- Song, H., Jia, H., Wang, Q., Zhao, X., Yang, G., Zhang, M., Zhou, H., Xu, S., Zang, Y., Wang, Y., Ma, L. (2020). A new environmentally-friendly system for extracting cellulose from corn straw: the low temperature laccase system. *Materials (Basel)* 13(2):437-446. doi: 10.3390/ma13020437
- Thakur, V., Sharma, E., Guleria, A., Sangar, S., & Singh, K. (2019). Modification and management of lignocellulosic waste as an ecofriendly biosorbent for the application of heavy metal ions sorption. *Materials Today: Proceedings*, 32, 608-619. <https://doi.org/10.1016/j.matpr.2020.02.756>
- Thurston, R., Phillips, G., Russo, R., and Hinkins, S. (1981). Increased Toxicity of Ammonia to Rainbow Trout (*Salmo gairdneri*) Resulting from Reduced Concentrations of Dissolved Oxygen. *Canadian Journal of Fisheries and Aquatic Sciences*. 38(8): 983-988. <https://doi.org/10.1139/f81-133>
- Tran-Ngoc, K. T., Dinh, N. T., Nguyen, T. H., Roem, A. J., Schrama, J. W., & Verreth, J. A. (2016). Interaction between dissolved oxygen concentration and diet composition on growth, digestibility and intestinal health of Nile tilapia (*Oreochromis niloticus*). *Aquaculture*, 462, 101-108. <https://doi.org/10.1016/j.aquaculture.2016.05.005>
- United States Environmental Protection Agency. (2023). Ammonia. <https://www.epa.gov/caddis-vol2/ammonia#tab-6>
- Water Science School. (2018). Temperature and water. United States Geological Survey. <https://www.usgs.gov/special-topics/water-science-school/science/temperature-and-water>
- Wei, Y., Jiao, Y., An, D., Li, D., Li, W., & Wei, Q. (2018). Review of Dissolved Oxygen Detection Technology: From Laboratory Analysis to Online Intelligent Detection. *Sensors*, 19(18), 3995. <https://doi.org/10.3390/s19183995>
- World Health Organization. (1986). Ammonia. International Programme on Chemical Safety. <https://iris.who.int/bitstream/handle/10665/39087/9241541946-eng.pdf>

- Wu, S., Wu, S., Yi, Z., Zeng, F., Wu, W., Qiao, Y., Zhao, X., Cheng, X., & Tian, Y. (2018). Hydrogel-Based Fluorescent Dual pH and Oxygen Sensors Loaded in 96-Well Plates for High-Throughput Cell Metabolism Studies. *Sensors*, 18(2), 564. <https://doi.org/10.3390/s18020564>
- Younis, M., Soleiman, H., & Elmagd, K.A. (2003). Microbial and chemical evaluation of bentonite as a new technique for sewage water treatment, Aswan City, Egypt. Seventh International Water Technology Conference Egypt. [https://www.researchgate.net/profile/Hussain-Soleiman/publication/237238740\\_MICROBIOLOGICAL\\_AND\\_CHEMICAL\\_EVALUATION\\_OF\\_BENTONITE\\_AS\\_A\\_NEW\\_TECHNIQUE\\_FOR\\_SEWAGE\\_WATER\\_TREATMENT\\_ASWAN\\_CITY\\_EGYPT/links/00b7d526198a070cf7000000/MICROBIOLOGICAL-AND-CHEMICAL-EVALUATION-OF-BENTONITE-AS-A-NEW-TECHNIQUE-FOR-SEWAGE-WATER-TREATMENT-ASWAN-CITY-EGYPT.pdf](https://www.researchgate.net/profile/Hussain-Soleiman/publication/237238740_MICROBIOLOGICAL_AND_CHEMICAL_EVALUATION_OF_BENTONITE_AS_A_NEW_TECHNIQUE_FOR_SEWAGE_WATER_TREATMENT_ASWAN_CITY_EGYPT/links/00b7d526198a070cf7000000/MICROBIOLOGICAL-AND-CHEMICAL-EVALUATION-OF-BENTONITE-AS-A-NEW-TECHNIQUE-FOR-SEWAGE-WATER-TREATMENT-ASWAN-CITY-EGYPT.pdf)
- Zhong, X., Yuan, R., Zhang, B., Wang, B., Chu, Y., & Wang, Z. (2021). Full fractionation of cellulose, hemicellulose, and lignin in pith-leaf containing corn stover by one-step treatment using aqueous formic acid. *Industrial Crops and Products*, 172, 113962. <https://doi.org/10.1016/j.indcrop.2021.113962>