Project Notes:

Project Title:

Name:

Note Well: There are NO SHORT-cuts to reading journal articles and taking notes from them. Comprehension is paramount. You will most likely need to read it several times, so set aside enough time in your schedule.

Contents:

Knowledge Gaps:

This list provides a brief overview of the major knowledge gaps for this project, how they were resolved and where to find the information.

Knowledge Gap	Resolved By	Information is located	Date resolved
Biodegradation by bacteria	Reading a scientific article	Article 1: Biodegradation of synthetic dyes of textile effluent by microorganisms: an environmentally and economically sustainable approach	08/28/2024
MFC	Reading a scientific article	Article 5: Microbial Fuel Cell Construction Features and Application for Sustainable Wastewater Treatment	09/03/2024
Polymers coagulation and flocculation of dyes	Reading a scientific article	Article 9: Application of coagulation/flocculation in oily wastewater treatment: A review	10/06/2024
Bacteria transformation	Reading a scientific article	Article 10: Quorum Sensing Contributes to Natural Transformation of Vibrio cholerae in a Species-Specific Manner	09/30/2024
Dyeing process	Reading a patent	Patent 1: A kind of dyeing fabric sewage water treatment method, the first significant figure	10/09/2024
Fenton oxidation	Reading a patent	Patent 2: Method for treating dye wastewater	10/10/2024

Measuring the effectiveness of the degradation of dye	Reading a scientific article	Article 11: Decolourization and biodegradation of methylene blue dye by a ligninolytic enzyme-producing Bacillus thuringiensis: Degradation products and pathway	10/27/2024
Electrophoresis	Reading scientific articles	Article 10: Quorum Sensing Contributes to Natural Transformation of Vibrio cholerae in a Species-Specific Manner (to understand the results) Article 12: Construction of the RNAi plasmids to suppress the expression of chitin synthase-encoding genes (chs) in fungus Mucor lusitanicus (procedure)	10/27/2024
Ratio of materials for preparing Methylene Blue dye solution	Reading scientific articles	Article 13: Removal of methylene blue dye using shrimp shell chitin from industrial effluents Article 14: Methylene Blue biodecolorization and biodegradation by immobilized mixed cultures of Trichoderma viride and Ralstonia pickettii into SA-PVA-Bentonite matrix	12/18/2024
Process to obtain chitin from shrimp shells	Reading scientific articles	Article 13: Removal of methylene blue dye	12/18/2024

		using shrimp shell chitin from industrial effluents Article 16: A Review of the Chemical Extraction of Chitosan from Shrimp Wastes and Prediction of Factors Affecting Chitosan Yield by Using an Artificial Neural Network	
Evaluating chitosan quality	Reading scientific articles	Article 17: Chitinous polymers: extraction from fungal sources, characterization and processing towards value-added applications Article 18: Two-phase extraction, characterization, and biological evaluation of chitin and chitosan from Rhizopus oryzae	12/18/2024

Literature Search Parameters:

These searches were performed between 8/16/2024 and XX/XX/2025.
List of keywords and databases used during this project.

Database/search engine	Keywords	Summary of search
PubMed Central	Bacteria, wastewater, dye	Bacteria degrade dyes
WPI Gordon Library	Chitin, transformation, bacteria	Chitin-induced transformation in bacteria
Google Scholar	Coagulation/flocculation, organic polymers	Organic polymers to coagulate/flocculate dyes
Google Patent	Wastewater treatment for dyes	Inventions related to improving the wastewater treatment of textile wastewater
Google	Fungi, treatment, biodegradation, methylene blue dye	Using fungi for biodegradation of methylene blue dye
WPI Gordon Library	Chitin synthase, bacteria	Feasibility of transforming chitin synthase into bacteria
Google	Shrimp shell, chitin, extraction, percent yield	Optimization for extracting chitin from shrimp shells, and the corresponding percent yield
WPI Gordon Library	Chitin, extraction, yeast	Method to extract chitin from yeast

Tags:

Tag Name	

Article #1 Notes: Title

Article notes should be on separate sheets

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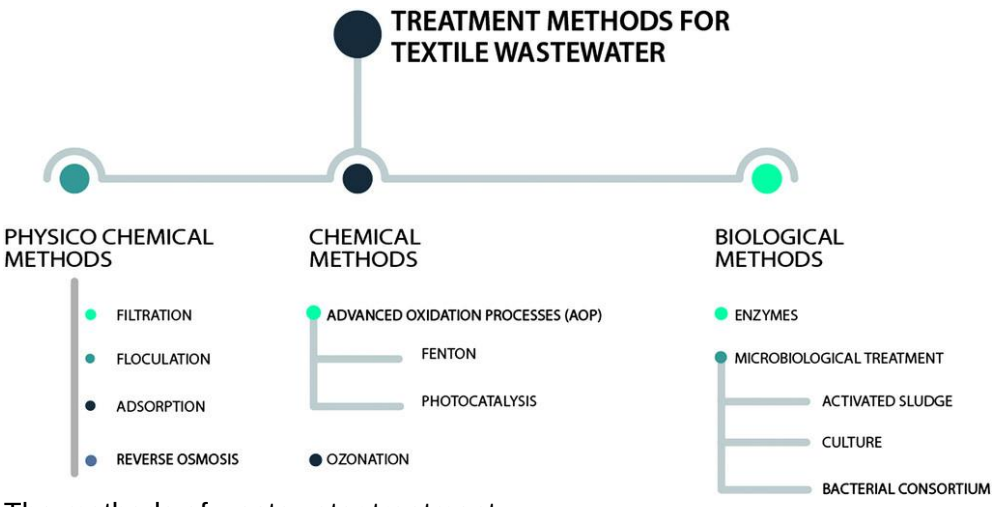
Source Title	
Source citation (APA Format)	
Original URL	
Source type	
Keywords	
#Tags	
Summary of key points + notes (include methodology)	
Research Question/Problem/ Need	
Important Figures	
VOCAB: (w/definition)	
Cited references to follow up on	
Follow up Questions	

Article #1 Notes: Biodegradation of synthetic dyes of textile effluent by microorganisms: an environmentally and economically sustainable approach

Source Title	Biodegradation of synthetic dyes of textile effluent by microorganisms: an environmentally and economically sustainable approach
Source citation (APA Format)	Jamee, R., & Siddique, R. (2019). Biodegradation of synthetic dyes of textile effluent by microorganisms: An environmentally and economically sustainable approach. *European Journal of Microbiology and Immunology*, *9*(4), 114–118. https://doi.org/10.1556/1886.2019.00018
Original URL	https://akjournals.com/view/journals/1886/9/4/article-p114.xml
Source type	Journal Article
Keywords	textile industry, Azo dyes, biodegradation
#Tags	Degradation of Dyes by Bacteria
Summary of key points + notes (include methodology)	The article compiles many different articles on wastewater treatment, so it can produce an incomprehensive summary of the topic. Microorganisms that live near the discharge of wastewater containing dyes have adapted to convert the complex chemicals to nitrogen and carbon for themselves. Therefore, microorganisms, specifically bacteria, are used as treatments for dyes because they are also cheap, environmentally friendly, and produce few byproducts. Past studies have shown that bacteria are generally successful in degrading azo dyes and decolorizing the water, but the dyes do not produce enough carbon for the bacteria, so additional sources of carbon are needed.
Research Question/Problem/ Need	How effective are microorganisms as a potential treatment for industrial dyes in wastewater?

Important Figures	 The methods of wastewater treatment
VOCAB: (w/definition)	Effluent: liquid waste or sewage discharged into a river or the sea Azo dye: synthetic organic compounds that contain nitrogen in the form of an azo group (N=N-) in their molecular structure
Cited references to follow up on	Chen, K.-C., Huang, W.-T., Wu, J.-Y., & Houng, J.-Y. (1999). Microbial decolorization of azo dyes by Proteus mirabilis. *Journal of Industrial Microbiology and Biotechnology*, *23*(1), 686–690. https://doi.org/10.1038/sj.jim.2900689
Follow up Questions	How will the microorganism function in an actual wastewater treatment plant? What type of bacteria is best needed to treat other types of dye? How fast is the evolutionary rate of bacteria to adapt to dye-containing effluent?

Article #2 Notes: Can Fungi Clean Up a Superfund Site?

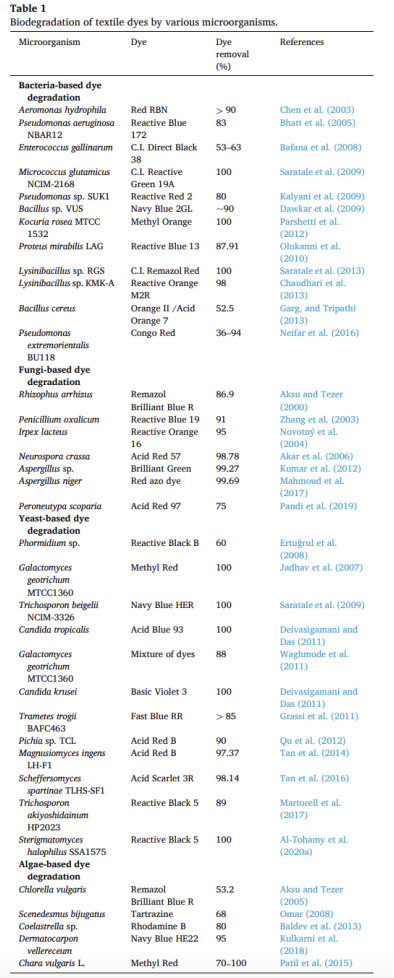
Source Title	Can Fungi Clean Up a Superfund Site?
Source citation (APA Format)	Parry, W. (2012, May 29). *Can fungi clean up a superfund site?*. LiveScience. https://www.livescience.com/20573-fungal-cleanup-newtown-creek.html
Original URL	https://www.livescience.com/20573-fungal-cleanup-newtown-creek.html
Source type	Newsletter Article

Keywords	Fungi, hydrocarbon bonds
#Tags	The secret of mycoremediation A tricky process
Summary of key points + notes (include methodology)	Newtown Creek in New York City is heavily polluted by fertilizers, sewage, oil, and petrochemical waste products. Therefore, an artist by the name of Jan Mun proposed to use oyster mushroom fungi filaments housed within a burlap to clean the water by decomposing the contaminants using the fungi's enzymes. Even though the fungi were effective at decomposing large molecules, bacteria were more favored as they were easier to grow and implement. However, the fungi were still considered to break down hydrocarbon bonds found in oil, and their mushrooms can absorb dangerous metals such as mercury from the creek. Still, implementing this method on the creek proved to be difficult as in the first trial, the mycelium disappeared once the burlap reached salty water. However, using fungi as a treatment to decontaminate wastewater on a large scale is a plausible method once the execution of the treatment is improved.
Research Question/Problem/ Need	Can fungi help decontaminate wastewater?
Important Figures	N/A
VOCAB: (w/definition)	Mycelium: The mass of branched, tubular filaments of fungi
Cited references to follow up on	N/A
Follow up Questions	How to increase the effectiveness of fungi? How to help fungi survive in saltwater? Do fungi work in a wastewater treatment plant?

Article #3 Notes: A critical review on the treatment of dye-containing wastewater: Ecotoxicological and health concerns of textile dyes and possible remediation approaches for environmental safety

Source Title	A critical review on the treatment of dye-containing wastewater: Ecotoxicological and health concerns of textile dyes and possible remediation approaches for environmental safety

Source citation (APA Format)	Al-Tohamy, R., Ali, S. S., Li, F., Okasha, K. M., Mahmoud, Y. A.-G., Elsamahy, T., Jiao, H., Fu, Y., & Sun, J. (2022). A critical review on the treatment of dye-containing wastewater: Ecotoxicological and health concerns of textile dyes and possible remediation approaches for environmental safety. *Ecotoxicology and Environmental Safety*, *231*, 113160. https://doi.org/10.1016/j.ecoenv.2021.113160
Original URL	https://www.sciencedirect.com/science/article/pii/S0147651321012720?via%3Dihub
Source type	Journal Article
Keywords	Hazardous pollutants, Textile wastewater, Dye removal, Toxicity, Treatment approaches, Environmental safety
#Tags	Impact of textile dyes on aquatic and terrestrial environments Impact of textile dyes on human health Coagulation-flocculation Bacteria-assisted degradation of dye-containing wastewater
Summary of key points + notes (include methodology)	The article compiles many research articles to explain different technologies to remove dye from wastewater. The first umbrella of methods discussed is the physical methods which include adsorption, membrane exchange, and ion exchange. These methods all use minimal equipment, are cost effective, and are resistant to other toxic chemicals. However, these methods are not usually preferred due to their limited application. Adsorption has several advantages including high reusability and time efficiency. Ion exchange used resins to bond with the dye and remove the resin after. This method is also efficient and provides more flexibility than adsorption. Membrane filtration is simple as gravity separates the large dye particles from water, but this method provides an inconvenience of having to frequently remove the filter. Next are the chemical methods coagulation-flocculation, electrochemical, and advanced oxidation. They all have collective disadvantages of being costly and energy consuming. Coagulation-flocculation uses chemicals and polymers to make the dye particles coagulate together and become heavier than the water, so the dyes can be removed by sedimentation. The disadvantage of this method is that its effectiveness is pH dependent. Advanced oxidation methods utilize hydroxides to break down dye chemicals into less toxic substances; these methods are also pH-dependent and may produce other toxic by-products. Electrochemical methods do not create toxic byproducts and sludge but require immense amounts of electrical power with less effectiveness than other methods. Finally, biological methods are the most favorable due to them creating nontoxic byproducts, less costly, lower sludge amount, less energy, and are environmentally friendly. There are 5 main methods are enzyme-assisted decomposition, and utilizing yeast, bacteria, fungi, and algae to break down the chemicals. All these methods are very similar as they rely on organisms to digest and decompose dyes into harmless materials, and each method has a slight advantage over the other in different circumstances. Decomposition with enzymes works the same as the methods utilizing live organisms.

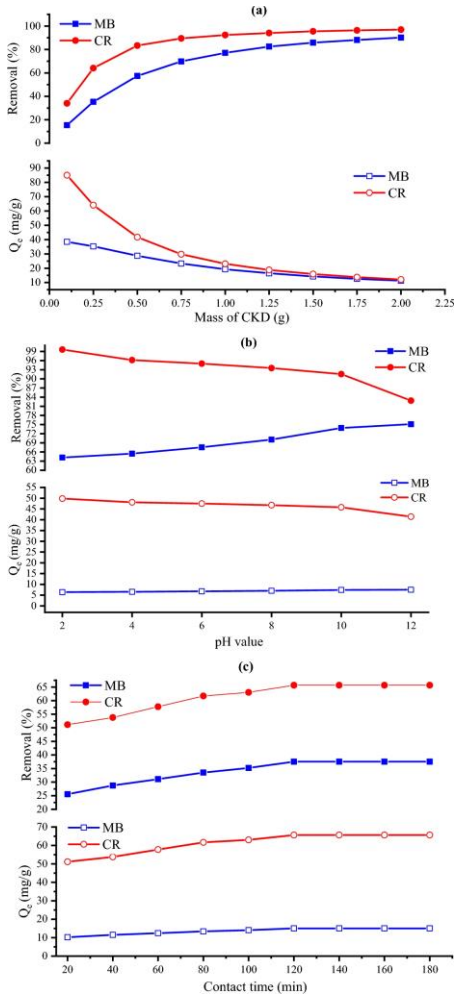
Research Question/Problem/ Need	What are the current methods of dye-containing wastewater treatment?
Important Figures	**Table 1** Biodegradation of textile dyes by various microorganisms.  Table 1: Biodegradation of textile dyes by various microorganisms. Examination of popular microorganisms for dye treatment
VOCAB: (w/definition)	Coagulation: The action or process of a liquid, especially blood, changing to a solid or semi-solid state. Flocculation: A process in which small particles in a liquid clump together to form larger particles, or flocs.
Cited references to follow up on	Lau, Y.-Y., Wong, Y.-S., Teng, T.-T., Morad, N., Rafatullah, M., & Ong, S.-A. (2014). Coagulation-flocculation of azo dye acid orange 7 with green refined laterite soil. *Chemical Engineering Journal*, *246*, 383–390. https://doi.org/10.1016/j.cej.2014.02.100 Neifar, M., Chouchane, H., Mahjoubi, M., Jaouani, A., & Cherif, A. (2016). Pseudomonas extremorientalis bu118: A new salt-tolerant laccase-secreting

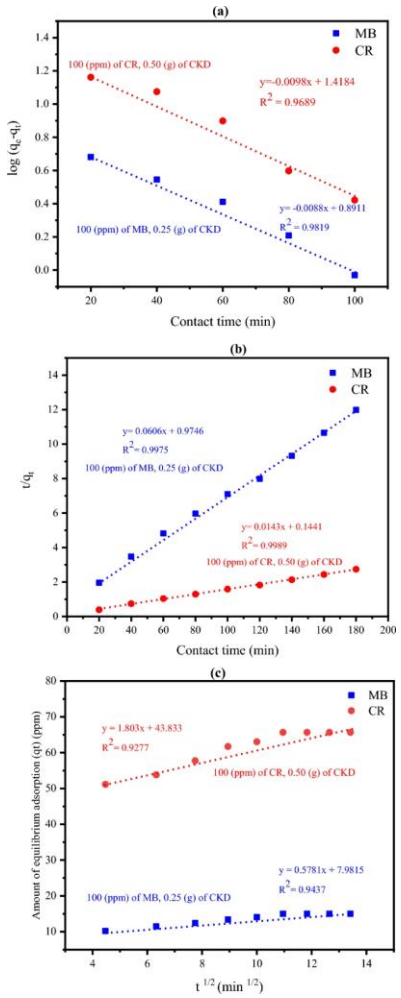
Microorganism	Dye	Dye removal (%)	References
Bacteria-based dye degradation			
Aeromonas hydrophila	Red RBN	> 90	Chen et al. (2003)
Pseudomonas aeruginosa NBAR12	Reactive Blue 172	83	Bhatt et al. (2005)
Enterococcus gallinarum	C.I. Direct Black 38	53–63	Bafana et al. (2008)
Micrococcus glutamicus NCIM-2168	C.I. Reactive Green 19A	100	Saratale et al. (2009)
Pseudomonas sp. SUK1	Reactive Red 2	80	Kalyani et al. (2009)
Bacillus sp. VUS	Navy Blue 2GL	~90	Dawkar et al. (2009)
Kocuria rosea MTCC 1532	Methyl Orange	100	Parshetti et al. (2012)
Proteus mirabilis LAG	Reactive Blue 13	87.91	Olukanni et al. (2010)
Lysinibacillus sp. RGS	C.I. Remazol Red	100	Saratale et al. (2013)
Lysinibacillus sp. KMK-A	Reactive Orange M2R	98	Chaudhari et al. (2013)
Bacillus cereus	Orange II /Acid Orange 7	52.5	Garg, and Tripathi (2013)
Pseudomonas extremorientalis BU118	Congo Red	36–94	Neifar et al. (2016)
Fungi-based dye degradation			
Rhizophus arrhizus	Remazol Brilliant Blue R	86.9	Aksu and Tezer (2000)
Penicillium oxalicum	Reactive Blue 19	91	Zhang et al. (2003)
Irpex lacteus	Reactive Orange 16	95	Novotný et al. (2004)
Neurospora crassa	Acid Red 57	98.78	Akar et al. (2006)
Aspergillus sp.	Brilliant Green	99.27	Kumar et al. (2012)
Aspergillus niger	Red azo dye	99.69	Mahmoud et al. (2017)
Peroneutypa scoparia	Acid Red 97	75	Pandi et al. (2019)
Yeast-based dye degradation			
Phormidium sp.	Reactive Black B	60	Ertuğrul et al. (2008)
Galactomyces geotrichum MTCC1360	Methyl Red	100	Jadhav et al. (2007)
Trichosporon beigelii NCIM-3326	Navy Blue HER	100	Saratale et al. (2009)
Candida tropicalis	Acid Blue 93	100	Deivasigamani and Das (2011)
Galactomyces geotrichum MTCC1360	Mixture of dyes	88	Waghmode et al. (2011)
Candida krusei	Basic Violet 3	100	Deivasigamani and Das (2011)
Trametes trogii BAFC463	Fast Blue RR	> 85	Grassi et al. (2011)
Pichia sp. TCL	Acid Red B	90	Qu et al. (2012)
Magnusiomyces ingens LH-F1	Acid Red B	97.37	Tan et al. (2014)
Scheffersomyces spartinae TLHS-SF1	Acid Scarlet 3R	98.14	Tan et al. (2016)
Trichosporon akiyoshidainum HP2023	Reactive Black 5	89	Martorell et al. (2017)
Sterigmatomyces halophilus SSA1575	Reactive Black 5	100	Al-Tohamy et al. (2020a)
Algae-based dye degradation			
Chlorella vulgaris	Remazol Brilliant Blue R	53.2	Aksu and Tezer (2005)
Scenedesmus bijugatus	Tartrazine	68	Omar (2008)
Coelastrella sp.	Rhodamine B	80	Baldev et al. (2013)
Dermatocarpon vellereceum	Navy Blue HE22	95	Kulkarni et al. (2018)
Chara vulgaris L.	Methyl Red	70–100	Patil et al. (2015)

	bacterium with biotechnological potential in textile azo dye decolourization. *3 Biotech*, *6*(1). https://doi.org/10.1007/s13205-016-0425-7
Follow up Questions	What is the best type of treatment for wastewater? How does each method compare with different dyes? What can be improved on these current methods?

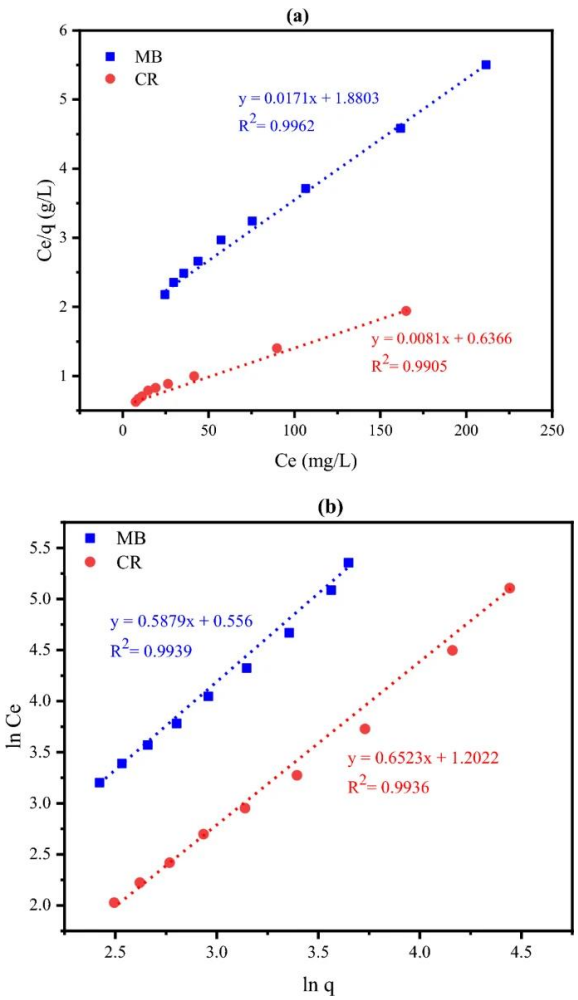
Article #4 Notes: The effective treatment of dye-containing simulated wastewater by using the cement kiln dust as an industrial waste adsorbent

Source Title	The effective treatment of dye-containing simulated wastewater by using the cement kiln dust as an industrial waste adsorbent
Source citation (APA Format)	Syala, E., Sadik, W. A., El-Demerdash, A.-G. M., Mekhamer, W., & El-Rafey, M. E. (2024). The effective treatment of dye-containing simulated wastewater by using the cement kiln dust as an industrial waste adsorbent. *Scientific Reports*, *14*(1). https://doi.org/10.1038/s41598-024-64191-5
Original URL	https://www.nature.com/articles/s41598-024-64191-5#citeas
Source type	Journal Article
Keywords	Wastewater, Methylene blue, Congo red, Dyes, Cement kiln dust
#Tags	Effects of various parameters on the removal of MB and CR dyes by CKD
Summary of key points + notes (include methodology)	Synthetic dyes are major pollutants in wastewater due to the textile industry. This pollutant can cause major diseases such as cancer in humans and animals and polluting the environment. Many biological, chemical, and physical methods are used to treat the dyes, and one of the most effective ways to reduce the dye's color is by adsorption. The experiment uses cement-kiln dust, a hazardous pollutant created as a waste product from creating cement, as an adsorbent. The CKD had been previously shown to effectively remove many types of dyes from wastewater, and this experiment was to test its effectiveness in removing Congo

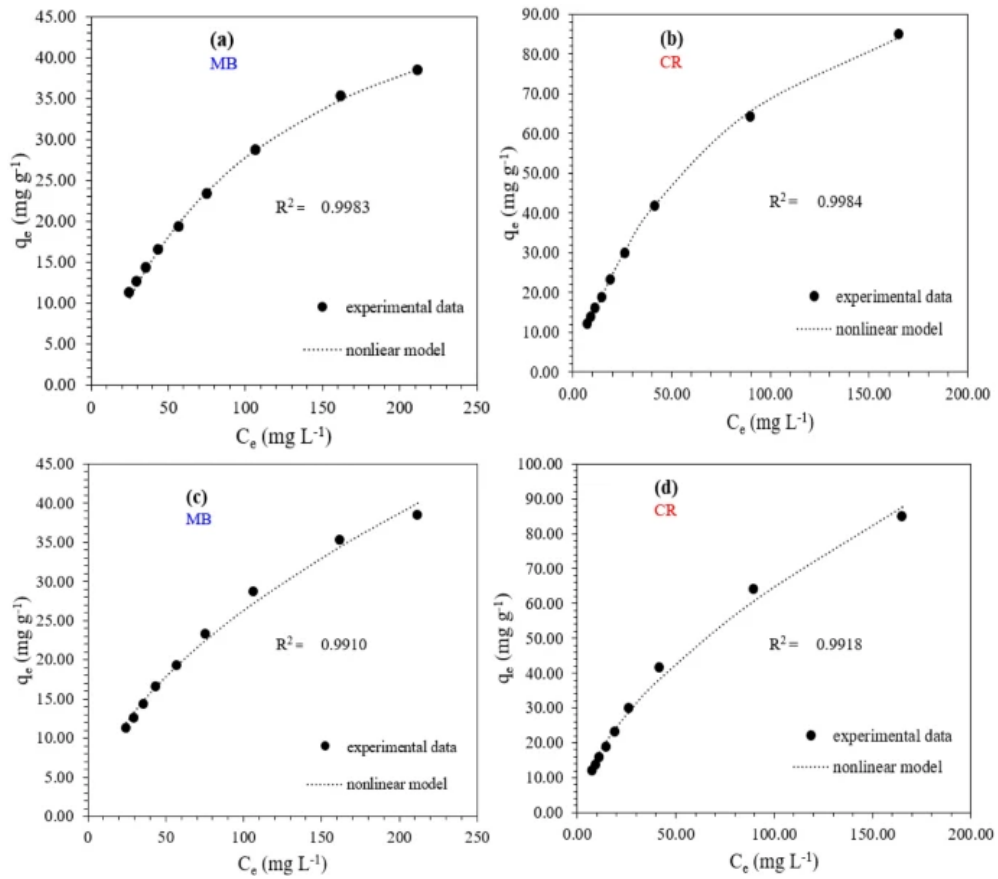
	red and Methylene blue dyes which are both widely used dyes. The study focuses on the influence of pH, initial concentration, temperature of the dyes, and the contact time it takes the adsorbent to be saturated. As the simulated wastewater's pH increases, adsorption of the MB dye increases by about 10% from a pH of 2 to a pH of 12. However, adsorption of the CR dye decreases by about 15%. The contact time when the CKD stopped removing both dyes is 120 minutes. The removal in the percentage of the MB and CR dyes from the wastewater solution decreases as the concentration of the dyes increases due to the CKN being saturated. Finally, as the temperature of the solution increases from 25 degrees to 55 degrees, the CKN removes more dyes from the simulated wastewater. The study provided a great method to treat two of the most common synthetic dyes and the necessary conditions to utilize CKD, a pollutant itself, in removing these pollutants.
Research Question/Problem/ Need	Can CKD be used to remove dyes from wastewater?
Important Figures	 The effect of (a) CKD dosage, (b) pH value, (c) contact time, (d) initial dye concentration, and (e) temperature on the removal (%) and the amount of equilibrium adsorption (Qe) of MB and CR dyes.



(a) Pseudo-first-order (b) pseudo-second-order, and (c) intra-particle-diffusion kinetic models plots for the adsorption of MB and CR dyes on the surface of CKD particles.



Linear (a) Langmuir and (b) Freundlich isotherms' parameters for MB and CR dyes adsorption process on CKD surface.

	 Nonlinear fittings of Langmuir model for (a) MB and (b) CR dyes and Freundlich model for (c) MB and (d) CR dyes, respectively.
VOCAB: (w/definition)	Pseudo-first-order reaction: Reactions that are not first-order but appear to be first-order due to larger concentrations of one or more reactants than the other reactants (first-order-reaction: reactions in which the rate of reaction, the rate at which a reaction progresses, is directly proportional to the concentration of reactants present.) Isotherm: A curve on a diagram joining points representing states or conditions of equal temperature. Langmuir model: Explains adsorption by assuming an adsorbate to behave as an ideal gas at isothermal conditions. Freundlich model: An empirical adsorption model that states the amount of adsorbate bound per unit weight of adsorbent
Cited references to follow up on	Kandisa, R. V., KV, N. S., Shaik, K. B., & Gopinadh, R. (2021). Studies on effect of adsorption parameters for the methylene blue dye removal by using LOWCOST adsorbent. *Rasayan Journal of Chemistry*, *14*(03). https://doi.org/10.31788/rjc.2021.1436307

	Khan, I., Saeed, K., Zekker, I., Zhang, B., Hendi, A. H., Ahmad, A., Ahmad, S., Zada, N., Ahmad, H., Shah, L. A., Shah, T., & Khan, I. (2022). Review on methylene blue: Its properties, uses, toxicity and photodegradation. *Water*, *14*(2), 242. https://doi.org/10.3390/w14020242
Follow up Questions	Would CKD be viable in a wastewater treatment plant? How to remove CKD from treated wastewater? Would CKD maintain its effectiveness in the treatment of other dyes than congo red and methylene blue?

Article #5 Notes: Microbial Fuel Cell Construction Features and Application for Sustainable Wastewater Treatment

Source Title	Microbial Fuel Cell Construction Features and Application for Sustainable Wastewater Treatment
Source citation (APA Format)	Roy, H., Rahman, T. U., Tasnim, N., Arju, J., Rafid, Md. M., Islam, Md. R., Pervez, Md. N., Cai, Y., Naddeo, V., & Islam, Md. S. (2023). Microbial fuel cell construction features and application for sustainable wastewater treatment. *Membranes*, *13*(5), 490. https://doi.org/10.3390/membranes13050490
Original URL	https://www.mdpi.com/2077-0375/13/5/490
Source type	Journal Article
Keywords	MFCs, construction features, membrane, sustainable, wastewater
#Tags	Anode Materials, Cathode Type for MFCs, Membrane Materials, Membrane Electrode Assemblies, Organic Dye-Based Pollutant Removal through MFCs
Summary of key points + notes (include methodology)	This question is important as MFC is a new technology that aims to make wastewater treatment energy efficient, and environmentally friendly. However, developing an effective MFC system is challenging as different materials have different weaknesses and strengths ranging from cost to effectiveness in removing pollutants from wastewater. There is no definitive answer for which is the best

	possible configuration of MFCs as the most efficient configuration would result in high cost of the materials, or maintenance of the MFCs. Therefore, this invalidates the advantages of MFCs as a cost-effective method to treat wastewater. However, when costs are low, the amount of energy produced decreases, and the effectiveness of pollutants removal also decreases which leads to a less effective treatment than traditional methods. However, with continual developments on the research of MFCs, a more efficient and cheaper configuration for wastewater treatment is possible as MFCs have received major improvements already.
Research Question/Problem/ Need	What are the strengths and weaknesses of different permutations of microbial fuel cells?
Important Figures	**Table 1.** Advantages and disadvantages of different types of anode materials [21,35,36,39,44,45,47].

Anode Materials	Advantages	Disadvantages
Carbonaceous anode	• High conductivity • High stability • Biocompatibility	• Limited electrocatalytic activity • Low power density
Carbon nanotube (CNT)	• Large surface area • High mechanical strength • Stability • Electrical conductivity	• Clogging • High operational cost • Complex synthesis procedure
Graphene	• Excellent electrical conductivity • High mechanical strength • Large surface area • Biocompatibility • High electron mobility	Complex synthesis procedure
Conductive polymer	• Excellent conductivity • Better bacterial adhesion • Enhanced biochemical activity	• Accumulation of proton biofilm • Cathodic overpotential • Structural instability
Metal	• Expensive noble metals • High conductivity	• Poor biocompatibility • Corrosiveness • Low surface area
Metal oxide	• Reduction in internal resistance • Improved biocompatibility	Expensive for large-scale implementation

Advantages and disadvantages of different types of anode materials

Table 2. Advantages and disadvantages of different types of cathodes [22,49,57].

Cathode Type	Advantages	Disadvantages
Air-cathode and aqueous air-cathode	• Simple structure • Cathodes can be modified using cheap materials such as activated carbon or HNO_3 to enhance performance • Recycling of catholyte not required for air-cathode	• Performance of aqueous air-cathode limited by the solubility of oxygen • Oxygen crossover • Use of catalyst can lead to additional cost • Biofouling of the cathodes
Biocathodes	• Inexpensive • Sustainable • Protection against catalyst poisoning • Reduction in internal resistance	• Lower power output • Fluctuation of pH

Advantages and disadvantages of different types of cathodes

Table 3. Advantages and disadvantages of different types of membrane materials [69,70,71].

Membranes	Advantages	Disadvantages
Cation exchange membrane	• Lower ohmic resistance resulting in lower internal resistance • High proton conductivity	• pH splitting • Oxygen crossover • Biofouling resulting in a reduction in ionic conductivity
Anion exchange membrane	• Useful for alkaline fuel cells • Prevent pH splitting	• Substrate crossover • Biofouling on the cathode
Bipolar membrane	• Effective for desalination • Prevent proton accumulation in anodic chamber	• Polarization can be increased through water splitting • Higher polarization leads to increased internal resistance
Porous membrane	• Inexpensive compared with IEMs • Low internal resistance	• Non-selective to ions • Oxygen and substrate crossover • Biofouling

Advantages and disadvantages of different types of membrane materials

Table 6. Different dye removal efficiencies and power generation capacities for different MFC configurations.

Type of Dye in Wastewater	MFC Configuration	Microbe Sources	Initial Concentration (mg/L)	Color Removal Efficiency (%)	Electricity Generation	References
Acid orange 7	Two equal rectangular Perspex frames	Microbial consortium	0.06	--	0.31 ± 0.03 W/m^3	[145]
Diazo dye C.I. reactive blue 160 (RBu160)	Single-chamber MFC	Proteus hauseri ZMd44	450–600	--	197 W/m^2	[146]
Methyl orange	Dual-chamber MFC	Anaerobic sludge from Gaobeidian wastewater treatment plant	10–20	73.4	--	[147]
Congo red	Air-cathode	Mixture of aerobic and anaerobic sludge from Liede municipal wastewater treatment plant	300	90	192 mW/m^2	[148]
Thionine-based textile dye	Membrane-free air-cathode single-chamber MFCs	Proteus hauseri ZMd44	40	--	83.39 ± 0.28 m	[149]
Reactive brilliant red X-3B (ABRX3)	Microbial fuel cell coupled constructed wetland (CW-MFC)	Microbial fuel cell coupled constructed wetland (CW-MFC)	300	95.6	0.852	[144]

Different dye removal efficiencies and power generation capacities for different MFC configurations.

VOCAB: (w/definition)

Anode: the negatively charged electrode of a device supplying current such as a primary cell.
Cathode: the positively charged electrode of an electrical device, such as a primary cell, that supplies current.
Biofouling: unintended settlement and growth of aquatic species on submerged natural and artificial surfaces

Cited references to follow up on	Hou, B., Hu, Y., & Sun, J. (2012). Performance and microbial diversity of microbial fuel cells coupled with different cathode types during simultaneous azo dye decolorization and electricity generation. *Bioresource Technology*, *111*, 105–110. https://doi.org/10.1016/j.biortech.2012.02.017 Kalathil, S., Lee, J., & Cho, M. H. (2011). Granular activated carbon based microbial fuel cell for simultaneous decolorization of real dye wastewater and electricity generation. *New Biotechnology*, *29*(1), 32–37. https://doi.org/10.1016/j.nbt.2011.04.014
Follow up Questions	How to develop a large system of MFCs? Does MFCs' effectiveness rely on the type of bacteria? When developing an MFC system, should one prioritize treating wastewater first or the amount of energy produced to develop more treatment systems after the MFCs?

Article #6 Notes: Coagulation with polymers for nanofiltration pre-treatment of highly concentrated dyes: A review

Source Title	Coagulation with polymers for nanofiltration pre-treatment of highly concentrated dyes: A review
Source citation (APA Format)	Zahrim, A. Y., Tizaoui, C., & Hilal, N. (2011). Coagulation with polymers for nanofiltration pre-treatment of highly concentrated dyes: A Review. *Desalination*, *266*(1–3), 1–16. https://doi.org/10.1016/j.desal.2010.08.012
Original URL	https://www.sciencedirect.com/science/article/pii/S0011916410005771?casa_token=e2doS_x_rGIAAAAA:bu9ROUqJqVKvyyHUCtvuszbfuf-e9HOhKKIUqeBX5MAO285wPLKMzqtnLK2CcEE_KPjZds92
Source type	Journal Article
Keywords	Dye, Nanofiltration, Coagulation, Polymers
#Tags	Coagulation/flocculation of dyes

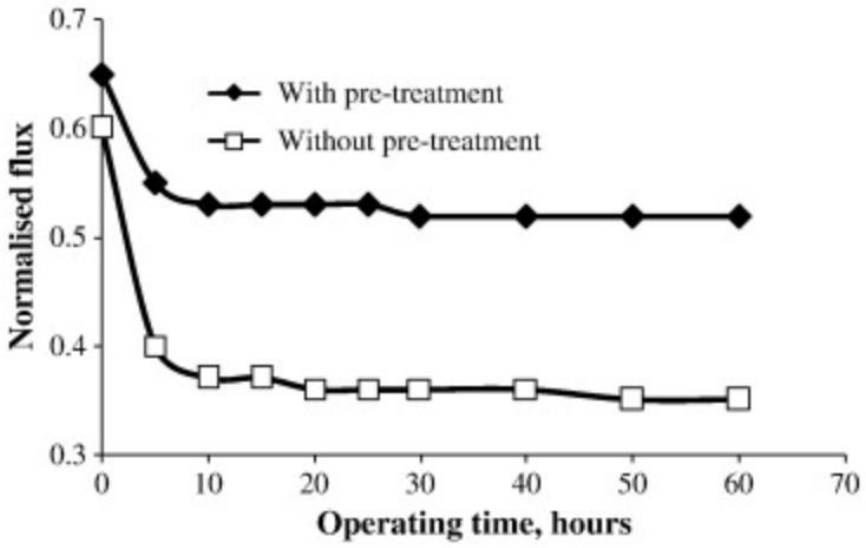
Summary of key points + notes (include methodology)	The research reviews many articles to assess the effectiveness of coagulation as a pretreatment for nanofiltration. Nanofiltration is used as a process to remove dyes from wastewater, but this method is not very effective as dyes can start fouling and blocking the pores of the membrane. Therefore, coagulation/flocculation of the dyes by polymers will prevent the dyes from creating a film that could not be filtered by nanofiltration membrane. The chromophore and auxochrome of dyes affect the effectiveness of coagulation greatly, so dyes with Azo, Xanthene, and Anthraquinone structure will not coagulate well. Coagulation is also dependent on pH. Metal coagulants are used widely, and they are effective, but they can be serious health hazards if they remain in the water. Natural polymers are not toxic, but they are less effective as they could not be easily modified as synthetic polymers (both are organic polymers). The type of dyes affected the effectiveness of natural polymers coagulation greatly as the amount of color reduced ranging from 40% to 99% with the type of dyes chosen, and the type of organic polymers also affected this greatly. Coagulation with the combination of nanofiltration allows water to be reused, which is an improvement as water treated by treatment plants could not be used for personal activities.
Research Question/Problem/ Need	What is the effectiveness of organic and metal coagulants in different situations?
Important Figures	Effect of the feed pre-treatment (alum-anionic polymer) for dyeing wastewater  With the coagulation pretreatment the rate of dyes passing throught the membrane is much higher which is the normalized flux

Table 4
The dye removal using inorganic coagulants with organic polymers as flocculant aids.

Type of dye(s)	Inorganic coagulant	Type of Polymer (dosage)	Condition	Performance	Reference
Real textile wastewater	Ferric based (2 g/l)	Cationic polymer, Cyanoguanidine-formaldehyde (500 mg/l)	Final pH: 3.5; Temperature = 40 °C; Mixing time = 11 min; Settling time = 30 min	Colour removal = 50% Turbidity removal = >90% COD removal = 29%	[131]
Real textile wastewater	Aluminium based (2 g/l)	Cationic polymer, Cyanoguanidine-formaldehyde (500 mg/l)	Final pH: 5; Temperature = 40 °C; Mixing time = 11 min; Settling time = 30 min	Colour removal = 60% Turbidity removal = 80% COD removal = 28%	[131]
Various reactive dyes (100 mg/l)	Aluminium based (1 g/l)	Cationic polymer, Cyanoguanidine-formaldehyde (250 mg/l)	Initial pH: 5; Temperature = 40 °C; Mixing time = 11 min; Settling time = 30 min	Colour removal = 100%	[131]
Various acid dyes (50–100 mg/l)	Aluminium sulphate (100 mg/l)	Cationic polymer, Cyanoguanidine-formaldehyde – SENKA (5 mg/l)	Initial pH: 6–8; Temperature = ambient; Mixing time = 2 min; Settling time = 30 min	Colour removal = >95% except C.I. Acid Blue 52 and Acid Blue 7	[85]
125 mg/l polyvinyl alcohol (PVA) + 20 mg/l Reactive Blue (R94H)	Ferric chloride (150 mg/l)	Anionic (2 mg/l) – KURI diafloc Ap-120, Japan	Initial pH = 4; Temperature = ambient; Mixing time = 40 min; Settling time = 30 min	COD removal = 66%; Colour removal = 12% (*Ferric chloride - 5 mg/l)	[139]
Real wastewater from cotton synthetic-textile factory	Ferrous sulphate (1000 mg/l)	Anionic (5 mg/l) – HENKEL 23500	Initial pH = 9.5; Temperature = 20 °C; Mixing time = 22 min; Settling time = 60 min	Colour removal = 50%; COD removal = 50%; Toxicity removal = 80%	[140]
Real wastewater from cotton synthetic-textile factory	Aluminium sulphate (1500 mg/l)	Anionic (5 mg/l) – HENKEL 23500	Initial pH = 7.0; Temperature = 20 °C; Mixing time = 22 min; Settling time = 60 min	Colour removal = 60%; COD removal = 56%; Toxicity removal = 70%	[140]
Dyeing and finishing mill	Polyaluminium chloride (PAC) (100 mg/l) + electrochemical treatment	Unknown polymer (100 mg/l)	Initial pH = 3.0; Temperature = ambient; Mixing time = 5 min; Settling time = 60 min	Colour removal = 97%; COD removal = 73%	[134]
100 mg/l Reactive Blue STE	Polyferric chloride*	Cationic (polyDADMAC*) (dosage of composite = 20 mg/l)	Initial pH = 7.0; Temperature = ambient; Mixing time = 15 min; Settling time = 12 min	Colour removal = 99%	[141]
Real textile wastewater	Polyferric chloride*	Cationic (polyDADMAC*) (dosage of composite = 150 mg/l)	Initial pH = 7.0; Temperature = ambient; Mixing time = 15 min; Settling time = 12 min	Colour removal = 90%	[141]
Real wastewater from fabric dyeing industry	Aluminium oxide, Al_2O_3 (1800 mg/l)	Cationic (polyDADMAC) – 30 mg/l	Initial pH = 5.7–5.90; Temperature = ambient; Mixing time = 11 min; Settling time = 30 min	Colour removal = 69% Turbidity removal = 99%	[128]
1000 mg/l reactive dye (Levafix Brill Blue EBRA)	Aluminium sulphate	Koaret PA 3230 (1 mg/l)	Initial pH = 5.0; Temperature = ambient; Mixing time = 13 min; Settling time = 24 min	Colour removal = 80%	[105]
1000 mg/l reactive dye (Levafix Brill Blue EBRA)	PAC	Koaret PA 3230 (1 mg/l)	Initial pH = 8.0; Temperature = ambient; Mixing time = 13 min; Settling time = 24 min	Colour removal = 80%	[105]
1000 mg/l reactive dye (Levafix Brill Blue EBRA)	Magnesium chloride	Koaret PA 3230 (1 mg/l)	Initial pH = 11.0; Temperature = ambient; Mixing time = 13 min; Settling time = 3 min	Colour removal = >90%	[105]
125 mg/l direct dye (Ciba-corb Yellow P-6GS)	Aluminium sulphate (70 mg/l)	Cationic (31 mg/l)	Temperature = ambient; Mixing time = 21 min; Settling time = 10 min	Colour removal = 50%; COD removal = 50%	[142]
Real textile wastewater	Ferric chloride (56 mg Fe/ l)	Cationic (5 mg/l)	Temperature = ambient; Mixing time = 32 min; Settling time = 30 min	Colour removal = 92%; Turbidity removal = 64%	[143]
Real textile wastewater	Aluminium sulphate (416 mg/l) + lime (213 mg/l)	Unknown polymer (11 mg/l)	Initial pH = 10; Temperature = 30 °C; Mixing time = 35 min; Settling time = 300 min	COD removal = 50%; BOD removal = 23%	[144]
Real textile wastewater	Ferrous sulphate (400 mg/l) + lime, $Ca(OH)_2$ (800 mg/l)	Cationic polymer (8 mg/l)	Initial pH = 12.5–13; Temperature = ambient; Mixing time = 22 min; Settling time = 45 min	Colour removal = 80–90%; COD removal = 50–55%	[107]
Real textile wastewater	Aluminium sulphate (20 mg/l)	Cationic polymer (2.5 ml/l)	Initial pH = 7; Temperature = ambient Mixing time = 22 min; Settling time = 30–150 min	Colour removal = 98%; COD removal = 45%; TOC removal = 50%	[46]

(continued on next page)

This table represents the many types of polymers and their effectiveness under different

	conditions **Table 4** (*continued*) Type of dye(s) | Inorganic coagulant | Type of Polymer (dosage) | Condition | Performance | Reference Real wastewater from textile bleaching and dyeing | Potassium Aluminium sulphate dodecahydrate (600 mg/l) | Anionic polyacrylamide, Excelfloc 204 (1.5 mg/l) | Initial pH = 7; Temperature = ambient Mixing time = 21 min; Settling time = 30 min | COD removal = 59% TSS removal = 65% Total dissolved removal = 37% Chromium removal = 76% Colour removal = 79% | [145] Real wastewater from textile bleaching and dyeing | PAC (800 mg/l) | Anionic polyacrylamide, Excelfloc 204 (1 mg/l) | Initial pH = 7.5; Temperature = ambient Mixing time = 21 min; Settling time = 30 min | COD removal = 65% TSS removal = 68% Total dissolved removal = 39% Chromium removal = 45% Colour removal = 75% | [145] Real wastewater from textile bleaching and dyeing | Ferrous sulphate (800 mg/l) | Anionic polyacrylamide, Excelfloc 204 (2 mg/l) | Initial pH = 10; Temperature = ambient Mixing time = 21 min; Settling time = 30 min | COD removal = 56% TSS removal = 34% Total dissolved removal = 34% Chromium removal = 20% Colour removal = 49% | [145] Reactive dye – Procion Brilliant Blue RS (100 mg/l) | PAC (0.05 mg/l) | Natural polymer – psyllium (2 mg/l) | Initial pH = 10; Temperature = ambient Mixing time = 50 min; Settling time = 60 min | Colour removal = 50%; | [89] Reactive dye – Procion Brilliant Blue RS (100 mg/l) | PAC (0.05 mg/l) | Natural polymer – chitosan (3 mg/l) | Initial pH = 10; Temperature = ambient Mixing time = 50 min; Settling time = 60 min | Colour removal = 65%; | [89] Acid dye – Sandolan Red RSNI (100 mg/l) | PAC (0.05 mg/l) | Natural polymer – chitosan (3 mg/l) | Initial pH = 10; Temperature = ambient Mixing time = 50 min; Settling time = 60 min | Colour removal = 90%; | [89] Direct dye – Kahi Green (100 mg/l) | PAC (0.05 mg/l) | Natural polymer – chitosan (3 mg/l) | Initial pH = 10; Temperature = ambient Mixing time = 50 min; Settling time = 60 min | Colour removal = >95%; | [89] Acid dye – Sandolan Red RSNI (100 mg/l) | PAC (0.05 mg/l) | Polyacrylamide-seed gum (3 mg/l) | Initial pH = 9.5; Temperature = ambient Mixing time = 21 min; Settling time = 60 min | Colour removal = >90%; | [89] Real textile wastewater | PAC (0.1 mg/l) | Polyacrylamide-seed gum (0.5 mg/l) | Initial pH = 8.5; Temperature = ambient Mixing time = 21 min; Settling time = 60 min | Colour removal = 80% (at λ = 499) and 55% (at λ = 313); Removal of suspended solid = 80% | [146]
VOCAB: (w/definition)	Normalized flux: the rate of mass transport (e.g. fluid, gas, or solute) across the membrane per unit area
Cited references to follow up on	Katayon, S., Megat Mohd Noor, M. J., Kien Tat, W., Abdul Halim, G., Thamer, A. M., & Badronisa, Y. (2007). Effect of natural coagulant application on microfiltration performance in treatment of secondary oxidation pond effluent. *Desalination*, *204*(1–3), 204–212. https://doi.org/10.1016/j.desal.2006.03.541
Follow up Questions	Can one obtain the natural polymer from organisms directly? Is there a way to effectively remove coagulants from wastewater? What is the effectiveness of natural coagulants when applied to methylene blue?

Article #7 Notes: Recent advances in polymer composite, extraction, and their application for wastewater treatment: A review

Source Title	Recent advances in polymer composite, extraction, and their application for wastewater treatment: A review
Source citation (APA Format)	Saravanan, A., Thamarai, P., Kumar, P. S., & Rangasamy, G. (2022). Recent advances in polymer composite, extraction, and their application for wastewater treatment: A Review. *Chemosphere*, *308*, 136368. https://doi.org/10.1016/j.chemosphere.2022.136368
Original URL	https://www.sciencedirect.com/science/article/pii/S0045653522028612
Source type	Journal Article
Keywords	Water pollution, Wastewater treatment, Natural polymers, Polymers extraction, Membrane separation, Adsorption
#Tags	Natural polymers, Wastewater and its impacts on environment, Extraction methods, Applications in wastewater treatment
Summary of key points + notes (include methodology)	The article is a review on the use of natural polymers in wastewater treatment Chitin: A natural polymer which can be found in some insects and crustaceans. It can also be produced by fungal fermentation. Can treat a wide range of pollutants. Cellulose: Can be found in plants, algae and some bacteria (bacteria's cellulose lacked wax, lignin, pectin and hemicelluloses). Cellulose has broad application in the treatment industry. Gelatin: Gelatin beads provide support for degradation of micro pollutants. Alginate: Adsorbed heavy metal ions by developing an insoluble gel structure. Effluents treatment: Membrane filtration: using polymers to create membrane with increase permeability, pollutants rejection, prevent fouling, and make the cleaning process of membranes easier. Adsorption: Shown in the table (Polymer adsorbent for the removal of toxic pollutants from wastewater). Overall, all the polymers worked well, but they require an optimal condition. However, in general, polymers are best used to remove dyes from wastewater. Coagulation: Used to remove suspended and color pollutants from water. Organic polymers produced less toxic sludge than inorganic polymers. However, natural coagulants are not as effective in treating water with high turbidity. Flocculation: Bio-flocculants are not used on a wide scale. However, they have the potential to become viable flocculants which provide a green approach to flocculation as inorganic flocculants are toxic to human health.
Research Question/Problem/ Need	What is the effectiveness and usage of organic polymers in wastewater treatment?

Important Figures

Table 1
Functional groups and extraction methods of polymers and their application in wastewater treatment.

S. No	Natural Polymers	Functional groups	Extraction/Synthesis method	Source of Wastewater	Treatment Technology	Removal Percentage	References
Plant Origin							
1.	Cellulose	-COOH, –OH	Alkalization, bleaching, Acid hydrolysis process	Remazol Dye	Adsorption	95.90%	Janaki et al. (2013)
2.	Starch	Acetal	wet milling process and alkali method	Filter backwash water	Flocculation	94.00%	Macczak et al., 2022
3.	Pectin	Carboxyl, hydroxyl, and acylamino groups	Water bath heating method	Textile wastewater	Coagulation and flocculation	54.20%	Wei et al., (2018)
				Methylene blue dye	Adsorption	45.00%	Aisyah et al. (2014)
4.	Gums	-COOH	Mechanical process of roasting, differential attrition, sieving and polishing	Direct dyes	Coagulation and flocculation	> 70.00%	Sanghi et al. (2006)
5.	Hemicellulose	-COOH, –OH	Microwave assisted extraction	Petroleum industry wastewater	Coagulation and flocculation	95.40%	Peng et al. (2020)
6.	Tannin	C–O, C–C, C–O–C	Maceration	Crystal violet dye	Coagulation and flocculation	89.00%	Aboulhassan et al. (2016)
7.	Inulin	-COOH, –OH	Pulsed Electric field extraction	Municipal sewage wastewater	Flocculation	62.00%	Rahul et al. (2014)
Animal Origin							
8.	Gelatin	-NH_2, –OH, –COOH	Acid treatment, Alkaline treatment	Plant wastewater	Coagulation	73.6%	Tawfik et al. (2021)
9.	Collagen	Amide or carboxylic acid	Chemical and enzymatic hydrolysis	Dyes	Adsorption	83.86%	Shalaby et al. (2021)
10.	Chitin	Amyl group	Demineralization and Deproteinization	Dyes, Metallic ions	Adsorption	94.00%	Ribeiro and dos Santos (2019)
11.	Chitosan	-NH_2, –OH	Deacetylation	Wastewater from ghee industry	Coagulation and flocculation	72.5%	Nechita (2017)
				Palm oil mill effluent	Coagulation and flocculation	95.24%	Jagaba et al. (2018)
12.	Hyaluronic Acid	-COOH,-OH	Enzyme Assisted Extraction	Manganese (Mn) Heavy metal	Adsorption	88.8%	Tasdelen et al. (2021)
13.	Resin (Ion exchange)	Quaternary ammonium or amine groups	Solvent Extraction	Olive oil-washing wastewater	Adsorption	57.3%	Camacho et al. (2021)
Microbial Origin							
14.	Alginate	-COOH,-OH	Alkali treatment	Textile wastewater	Adsorption	97.00%	Sharmila et al. (2021)
15.	Dextran	-COOH,-OH	Alcohol Precipitation	Coal-washing sewage	Flocculation	86.60%	Li et al. (2016)

Different extraction methods of natural polymers.

Table 2
Polymer adsorbent for the removal of toxic pollutants from wastewater.

S. No	Natural Polymer	Adsorbent	Pollutant	Parameters				Removal Percentage	Adsorption Capacity (mg/g)	Modeling		References
				pH	Temp	Time	Dose			Isotherm	Kinetics	
1.	**Cellulose**	Cellulose fibers from corn straw as oil sorbent	Marine oil spills	6.2	25 °C	7 h	0.005 g	90%	6.754	Langmuir	Pseudo-Second-order	Li et al. (2013)
2.		Nanocellulose fibers	Pb (II) Cd (II) Ni (II)	6.0	50–900 °C	40 min	0.5 g	91.71% 88.79% 82.61%	9.42 9.7 8.55	Freundlich and Langmuir	Pseudo-Second-order	Kardam et al. (2014)
3.		TEMPO -oxidized fibers	Cr (III) Ni (II) Zn (II)	5.0 6.0 6.0	20 °C	20 h	0.1 g	62.5% 58.6% 68.4%	58 49 66	Langmuir	Pseudo-Second-order	Sehaqui et al., 2014
4.		Phosphorylated nanocellulose	Ag (I) Fe (III) Cu (II)	7.0	20 °C	3 h	0.2 g	60% 14.5% 40.7%	120 73 114	Langmuir	Pseudo-Second-order	Liu et al. (2015)
5.		APTS modified microfibers	Ni (II) Cu (II) Cd (II)	5.0	22 °C	5 min	0.86 g	83% 75% 97%	160.47 200.17 471.56	Langmuir	Pseudo-second-order	Hokkanen et al. (2014)
6.		EDTA modified microfibers	Pb (II) Cd (II)	5.0–9.0	23 °C	60 min	5 g	92% 96%	227.3 102	Temkin	Pseudo-Second-order	d'Halluin et al., 2017
7.		MBCNF/GOPA	Malachite green	7.0	24.85 °C	20 min	5 mg	91%	270.27	Langmuir	Pseudo-second-order	Arabkhani and Asfaram (2020)
8.	**Chitin**	Chitin nanofibrils with cysteine	As (III)	7.0	20 °C	24 h	100 g	75%	149	Langmuir	Pseudo-Second-order	Yang et al. (2015)
9.		Ultrasonicated chitin	Methylene blue	4.5	25 °C	370 min	10 mL/min	51.5%	51.8	Dynamic model	Pseudo-Second-order	Dotto et al. (2015)
10.		Chitin/clay microsphere	Methylene blue	1.0–11.0	30 °C	20 min	10 mg/g	99.9%	156.7	Langmuir	Pseudo-Second-order	Xu et al. (2018)
11.		Chitin-bentonite composite	Cr (VI)	4.0	–	45 min	1.0 g	91%	443.71	Freundlich and Langmuir	Pseudo-Second-order	Saravanan et al. (2013)
12.		Chitin nanofibrils with maleic acid	Au (III)	4.0	4 °C	10 min	1.0 g	75%	532.5	Langmuir	Pseudo-Second-order	Dwivedi et al. (2017)
13.		Chitin suspensions after enzymolysis	Congo red	6.0	20 °C	60 min	2 mg	90%	232	Langmuir	Pseudo-Second-order	Hou et al. (2021)
14.		Chitin	Eriochrome black T	5.0	25 °C	3 h	1.0 g	99%	167.31	Langmuir	Pseudo-Second-order	Boumya et al. (2021)
15.		Ultrasound modified α -chitin (UCHT)	Methylene blue	8.0	369 °C	80 min	0.5 g	48%	95	Langmuir	Pseudo-Second-order	Abloub et al. (2020)
16.		MGO/CH NC	Methylene blue	8.0	24.85 °C	5 min	20 mg	–	332.61	Langmuir	Pseudo-Second-order	Gautam and Hooda (2020)
17.		MGO/CH NC	Crystal violet	9.0	24.85 °C	5 min	20 mg	–	403.78	Langmuir	Pseudo-Second-order	Gautam and Hooda (2020)
18.	**Chitosan**	Chitosan beads with carboxymethyl groups	Cu (II)	5.0	40 °C	24 h	6.0 mmol dm^{-3}	99.98%	130	Langmuir	Pseudo-Second-order	Yan et al. (2011)
19.		Chitosan spun hollow fiber with iron oxide nanoparticles	Se (IV)	3.5–9.5	40 °C	5 h	1.0 g	89%	15.62	Freundlich and Langmuir	Pseudo-second-order	Dorraji et al. (2017)
20.		Magnetic carboxymethyl chitosan/branched PEI	Pb (II)	4.5	30 °C–50 °C	10 min	0.4 mg/L	85%	124.0	Langmuir-Freundlich	Pseudo-second-order	Wang et al. (2017)
21.		Silica gel-chitosan	Fluoride	7.0	30 °C	30 min	0.1 g	45%	1.55	Langmuir-Freundlich	Pseudo-second-order	Viswanathan et al. (2014)
22.		Chitosan/Polyurethane foam	Acid violet	3.0–11.0	30 °C	24 h	0.1 g	58%	29.6	Langmuir	Pseudo-Second-order	Lee et al. (2009)
23.		Chitosan-tapioca peel biochar (S-CS @TB composite)	Malachite green	8.0	350 °C	120 min	10 mg	–	53.35	Langmuir	Pseudo-Second-order	Vigneshwaran et al. (2021)
24.		Chitosan-tapioca peel biochar (S-CS @TB composite)	Rhodamine B	8.0	350 °C	120 min	10 mg	–	40.86	Langmuir	Pseudo-Second-order	Vigneshwaran et al. (2021)

(*continued on next page*)

Table 2 (*continued*)

S. No	Natural Polymer	Adsorbent	Pollutant	Parameters				Removal Percentage	Adsorption Capacity (mg/g)	Modeling		References
				pH	Temp	Time	Dose			Isotherm	Kinetics	
25.		CS-BmImBr impreganated chitosan beads	Methylene blue	11.0	25 °C	25 min	4 mg	86%	10.63	Type II	Pseudo-first-order	Karimi-Maleh et al., 2021
26.		Chitosan -CNTs	Pb (II)	2.0	25 °C	1 h	1 g	89.36%	83.20	Langmuir	Pseudo-Second-order	Wang et al. (2020b)
27.	**Alginate**	Alginate beads with nano-geothite	Congo red	3.0	30 °C	180 min	0.07 g	94%	181.1	Langmuir	Pseudo-Second-order	Munagapati and Kim, 2017
28.		Alginate beads with bentonite	Methylene blue	2.5–10.0	25 °C	48 h	0.2 g	89.7%	799.4	Langmuir	Pseudo-second-order	Djebri et al. (2016)
29.		Alginate with carbon nanotubes	Cu (II)	2.1	25 °C	2 h	0.05 g	69.9%	84.88	Langmuir-Freundlich	Pseudo-second-order	Li et al. (2010)
30.		Alginate beads with bentonite and activated carbon	Methylene blue	8.97	30 °C	1 h	0.2 g	70%	756.97	Freundlich	Pseudo-second order	Benhouria et al. (2015)
31.	**Hemicellulose**	C6-acetylated,C2,C3-carboxylated hemicelluloses	Malachite green	6.5	50 °C	60 min	5.0 mg	67%	456.23	Freundlich	Pseudo-second order	Gautam et al. (2018)
32.		Hemicelluloses with PEGDE	Methylene blue	5.0	25 °C	300 min	0.1 g	80%	148.8	Langmuir-Freundlich	Pseudo-second order	Cheng et al. (2016)
33.		Hemicellulose containing latex	Methylene blue	3.0–7.0	25 °C	24 h	0.1 g	93.8%	42.73	Langmuir	Pseudo-Second-order	Zhang et al. (2015)
34.	**Starch**	C6-carboxylated starch hydrogel	Cu (II)	7.0	40 °C	2 h	0.1 g	81%	128.26	Langmuir-Freundlich	Pseudo-second order	Chauhan et al. (2010)
35.		Starch NiFE-LDH composite	Methyl orange	3.0	25 °C-45 °C	5 min	0.01 g	90%	358.42	Langmuir	Pseudo-second order	Zubair et al. (2018)
36.		Starch-g-polyacrylic acid	Cu (II)	2.7–5.0	30 °C	60 min	50 mg	42%	2.83	Langmuir	Pseudo-second order	Zheng et al. (2010)
37.		Starch-g-N,N-Diethyl aminoethyl methacrylate	Direct red 81	10.0	30 °C	50 min	2.5 g	95%	112	Langmuir	Pseudo-second order	Abdel-Halim, 2013
38.	**Cyclodextrin**	Chitosan/cyclodextrin/ glutaraldehyde	Methyl orange	5.0	25 °C	600 min	10 mg	90.96%	392	Langmuir	Pseudo-second order	Jiang et al. (2018)

Comparing different types of polymers and their effectiveness in adsorping different pollutants in wastewater.

VOCAB: (w/definition)

Polymeric Membrane: A thin, semipermeable barrier between two gaseous phases.
Sorption: a phenomenon of binding of a gas or vapor by a sorbent substance in a condensed state (solid or liquid) through less intense interactions.

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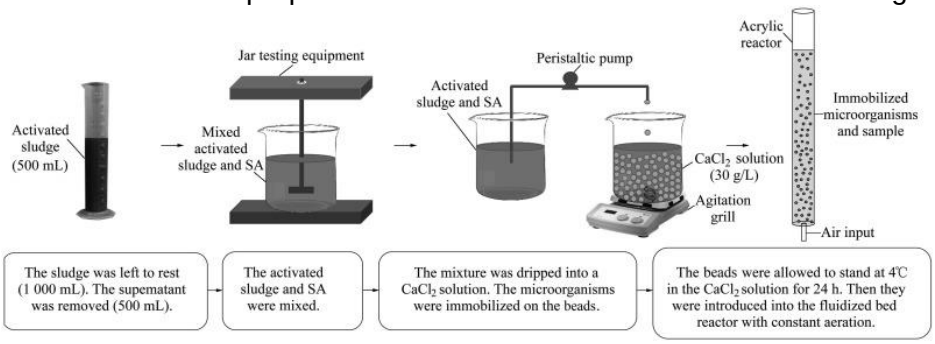
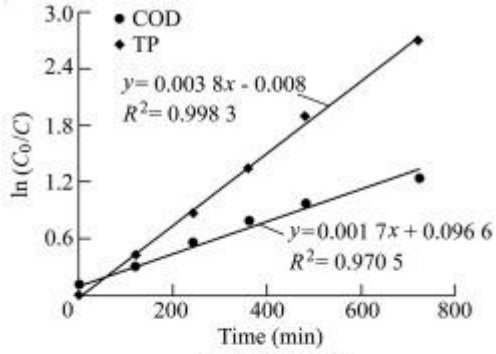
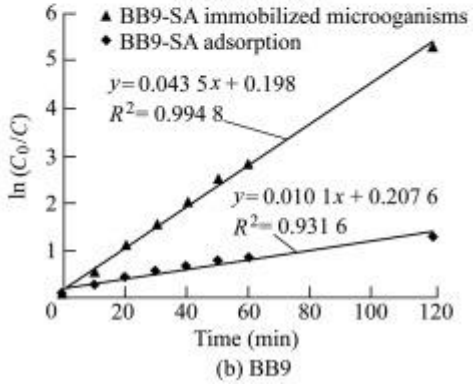
	Environmental Chemical Engineering, *9*(5), 106060. https://doi.org/10.1016/j.jece.2021.106060
Follow up Questions	How to improve the effectiveness of natural polymers? Can bacteria be genetically modified to produce chitin, cellulose, etc.? How do natural polymers compare to synthetic ones?

Article #8 Notes: Enhanced biological wastewater treatment using sodium alginate-immobilized microorganisms in a fluidized bed reactor

Source Title	Enhanced biological wastewater treatment using sodium alginate-immobilized microorganisms in a fluidized bed reactor
Source citation (APA Format)	Bustos-Terrones, Y. A., Bandala, E. R., Moeller-Chávez, G. E., & Bustos-Terrones, V. (2022). Enhanced biological wastewater treatment using sodium alginate-immobilized microorganisms in a fluidized bed reactor. *Water Science and Engineering*, *15*(2), 125–133. https://doi.org/10.1016/j.wse.2022.02.002
Original URL	https://www.sciencedirect.com/science/article/pii/S1674237022000163?via%3Dihub
Source type	Journal Article
Keywords	Domestic wastewater, Basic blue 9, Immobilized microorganisms, Fluidized bed reactor, Sodium alginate
#Tags	Fluidized bed reactor
Summary of key points + notes (include methodology)	Methods: Using simulated textile wastewater with a concentration of BB9 dye measured by a spectrophotometer, the researchers put sodium-alginate beads containing immobilized microorganisms into the solution. The fluidized bed reactor is a tube that was pumped with air to make the SA beads suspending in the water. The scientist measures the oxygen uptake rate by aerating the beads until they are filled with dissolved oxygen which will be measured in a 30-minute interval to plot a DO to time graph. Results: The beads work in the pH range of a typical treatment plant, and there were pores to allow diffusion of particles. The SA beads degrade toxic pollutants well as time went on as shown by Figure 5. Furthermore, the treatment of BB9 dye is

	improved with the microorganisms within the beads. The treatment result was summarized in Table 2. After 2 hours, the SA beads with microbes have removed almost all of the dye.
Research Question/Problem/ Need	How effective is the Sodium-Alginate beads with immobilized microorganisms at removing pollutants from effluents?
Important Figures	Schematic view of preparation of SA beads with immobilized microorganisms.  The makings of SA beads Fig. 5 Kinetics of degradation of COD, TP, and BB9 with SA and SA-immobilized microorganisms.  (a) COD and TP  (b) BB9 The graphs show that as time went on, the degradation of COD, TP, and BB9 increases. BB9 adsorption with the microorganisms is significantly higher.

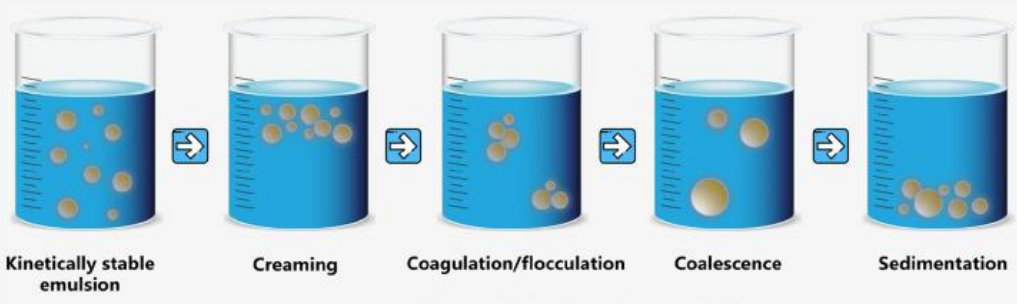
	Statistical summary of BB9 degradation by SA beads. Table 2 Statistical summary of BB9 degradation by SA beads. With microorganisms: 0 min, 3, 9.53, 9.87, 9.69, 0.140, 1.45 10 min, 3, 5.65, 5.90, 5.77, 0.135, 2.34 20 min, 3, 3.13, 3.22, 3.19, 0.041, 1.28 30 min, 3, 1.70, 2.00, 1.85, 0.153, 8.25 40 min, 3, 0.98, 1.14, 1.03, 0.074, 7.20 50 min, 3, 0.50, 0.57, 0.54, 0.032, 6.00 60 min, 3, 0.36, 0.42, 0.40, 0.025, 6.22 90 min, 3, 0.26, 0.33, 0.29, 0.029, 9.95 120 min, 3, 0.15, 0.27, 0.20, 0.046, 22.33 Without microorganisms (adsorption): 0 min, 3, 9.44, 9.86, 9.64, 0.175, 1.82 10 min, 3, 8.45, 8.62, 8.52, 0.072, 0.85 20 min, 3, 7.04, 7.87, 7.43, 0.361, 4.85 30 min, 3, 6.29, 6.87, 6.65, 0.253, 3.80 40 min, 3, 5.89, 6.23, 6.03, 0.145, 2.41 50 min, 3, 5.35, 5.46, 5.42, 0.053, 0.98 60 min, 3, 4.92, 5.16, 5.02, 0.105, 2.08 90 min, 3, 4.14, 4.56, 4.29, 0.184, 4.29 120 min, 3, 3.59, 3.99, 3.76, 0.170, 4.53 240 min, 3, 2.56, 2.99, 2.78, 0.174, 6.25 360 min, 3, 2.01, 2.37, 2.11, 0.173, 8.21 480 min, 3, 1.51, 1.81, 1.70, 0.137, 8.04 1 440 min, 3, 1.02, 1.56, 1.16, 0.265, 22.78 Note that the original concentration for BB9 is around 9.6 mg/L
VOCAB: (w/definition)	Fluidized Bed Reactors: Granular systems of solid-particles subjected to a vertical upward flow of fluid. Michaelis–Menten model: A general explanation of the velocity and gross mechanism of enzyme-catalyzed reactions
Cited references to follow up on	Çifçi, D. İ., Atav, R., Güneş, Y., & Güneş, E. (2019). Determination of the color removal efficiency of laccase enzyme depending on dye class and chromophore. *Water Science and Technology*, *80*(1), 134–143. https://doi.org/10.2166/wst.2019.255
Follow up Questions	How effective is the SA beads with other types of dyes? How to sustainably obtain sodium alginate? What other materials can be used to create the beads they may provide more adsorption of the pollutants?

Article #9 Notes: Application of coagulation/flocculation in oily wastewater treatment: A review

Source Title	Application of coagulation/flocculation in oily wastewater treatment: A review
Source citation (APA Format)	Zhao, C., Zhou, J., Yan, Y., Yang, L., Xing, G., Li, H., Wu, P., Wang, M., & Zheng, H. (2021). Application of coagulation/flocculation in oily wastewater treatment: A

	Review. *Science of The Total Environment*, *765*, 142795. https://doi.org/10.1016/j.scitotenv.2020.142795
Original URL	https://www.sciencedirect.com/science/article/pii/S0048969720363245?via%3Dihub
Source type	Journal Article
Keywords	Coagulants/flocculants, Coagulation mechanism, Demulsification, Cost estimation, Combined technology
#Tags	Natural polymeric flocculants, Evaluation of coagulants/flocculants, 3.1.2. pH, 3.1.4. Temperature
Summary of key points + notes (include methodology)	The author compiles many research articles to generate an overview of this wastewater treatment method. Coagulation/flocculation efficiency increases with the dosage of the coagulant/flocculant. However, there is an upper limit to this as when there is too much coagulant, the oils stabilize in small areas, and do not merge with each other. For coagulation to occur, the coagulant destabilizes the oil for them to clump up. pH affects the coagulation process because it affects how the coagulant will neutralize charges of the oils. For oil concentration, lower oil concentration in the wastewater will often produce a satisfactory result, because as the oil concentration rises in the wastewater, saturation becomes an issue as the coagulant could not destabilizes the charges of the oil molecules even with more coagulant is added. Cold temperature affects coagulation by slowing down the speed of the hydrolysis reaction, so the coagulant takes a longer time to destabilize oils. This is because hydrolysis needs to absorb heat to occur, the frequency of particles interaction is decrease, and the water is more viscous which slows flocculation. High temperature can denature the polymers used for coagulation and makes coagulated oils unstable which breaks the flocs. More natural polymers are needed for coagulation than synthetic polymers, but natural polymers create denser flocs, are environmentally friendly, and are cheaper. Cationic polymers attract negatively charged oils and create a chain of molecules via this process. Anionic polymers help fortify the particle flocs formed this way. Of all organic polymers, chitosan (a derivative of chitin) shows the best performance due to its high positive charge.
Research Question/Problem/ Need	How effective is coagulation/flocculation treatment of wastewater?

Important Figures



Most common coagulation/flocculation process in oily wastewater: creaming, coagulation/flocculation, coalescence and sedimentation.

Table 2
Applications of various natural polymeric flocculants in oily wastewater treatment.

Flocculant	Oily wastewater type	pH	Dosage (mg/L)	Oil concentration		COD		Suspended solids		Turbidity		Refs
				Influent (mg/L)	Removal rate (%)	Initial (mg/L)	Removal rate (%)	Initial (mg/L)	Removal rate (%)	Initial NTU	Removal rate (%)	
Chitosan	Palm oily wastewater	4	500	2000	>99	50,000	/	990	97.7	550	/	(Ahmad et al., 2006)
CS(56%)-g-PDBC(44%)	Petrochemical oily wastewater	7.3	500	2954	99.58	8400	82.1	2675	95.4	2755	98.5	(Lü et al., 2019)
Amphoteric chitosan-based grafting flocculants (CM-chi)-g-PDMDAAC(5)	oil recovery wastewater	7.2	2.8	/	/	3162	98.88	154	99.3	/	/	(Peng et al., 2018)
Quaternized chitosan-grafted magnetic nanoparticles	Diesel-in-water emulsion	4,7,10	17,17,19	2000	>95	/	/	/	/	/	/	(Lu et al., 2018)
Starch-acrylamide(1:3)	Grease wastewater	5.5	8	/	/	2840	45.64	/	/	/	/	(Zheng et al., 2008)
Modified starch	Simulating oily wastewater	9	22.4	1200	88.2	3775	95.7	/	/	400	97.1	(Chi et al., 2009)

Comparison of natural polymers in removing oils from wastewater

Table 3
A summary of diverse coagulants/flocculants in oily wastewater treatment.

Coagulants/flocculants	Representatives	Dose (mg/L)	pH range	Temperature	Floc properties		Efficiency	Price	Toxicity
					Size	Compactness			
Inorganic coagulants	$FeCl_3$, $Al_2(SO_4)_3$, PAC	High	Moderate (5–9)	Sensitive	Moderate	Denser	Moderate	Low	High (Al^{3+})
Synthetic polymeric flocculants	PAM, CPAM, PAA	Moderate	Wide (2−12)	Insensitive	Big	Moderate	Good	High	High (AM-)
Natural polymeric flocculants	Chitosan, starch, cellulose	Moderate	Wide (2–12)	Insensitive	Big	Moderate	Good	Low	Low

Rudimentary comparison of types of polymers for wastewater treatment

VOCAB: (w/definition)

Particle bridging: the occurrence when a segment of a polymer chain adsorbs to multiple particles, resulting in the linkage of these particle
Demulsify: to undergo or cause to undergo a process in which an emulsion is permanently broken down into its constituents.

Cited references to follow up on

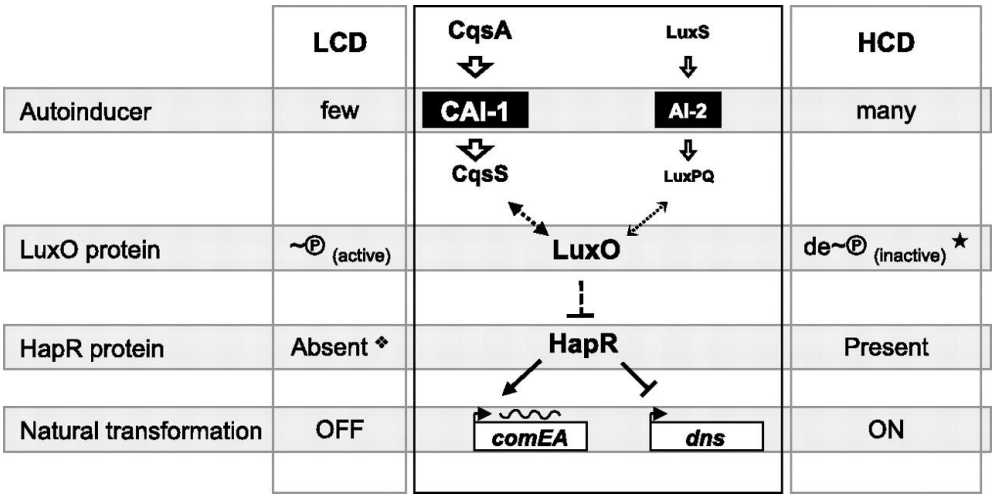
Ahmad, A. L., Sumathi, S., & Hameed, B. H. (2006). Coagulation of residue oil and suspended solid in palm oil mill effluent by Chitosan, alum and pac. *Chemical Engineering Journal*, *118*(1–2), 99–105. https://doi.org/10.1016/j.cej.2006.02.001

Follow up Questions

What would a system incorporating coagulation/flocculation and biological treatment method look like?
How to control the pH and temperature of wastewater prior to the treatment?
Could the polymers used in coagulation/flocculation be recycled and used again?

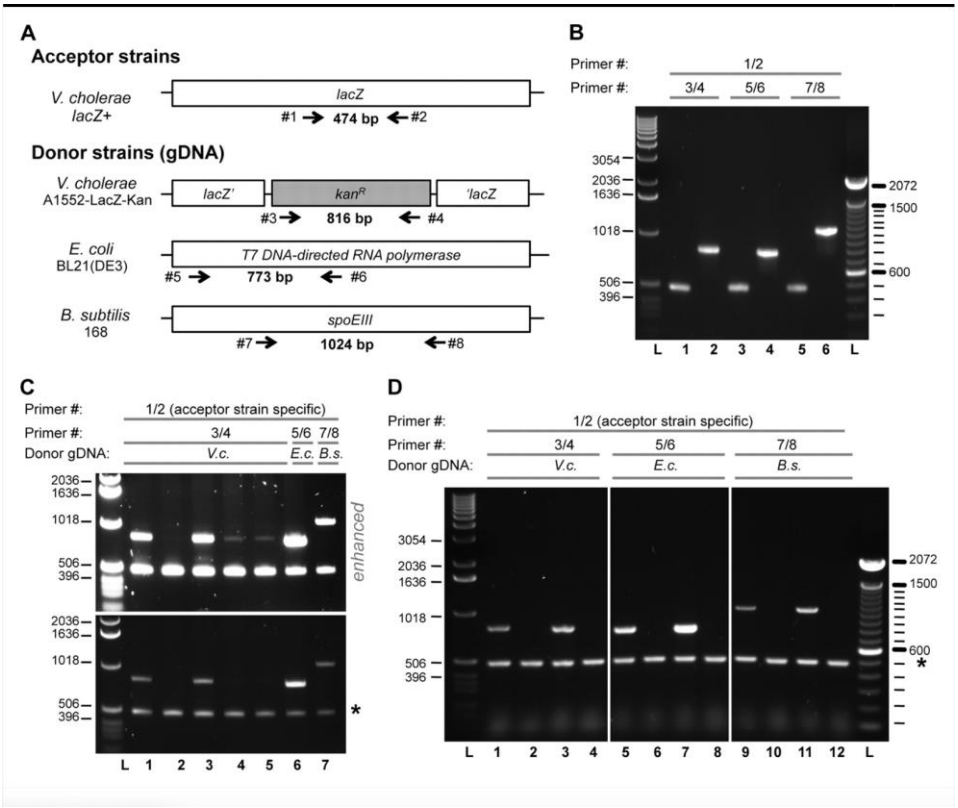
Article #10 Notes: Quorum Sensing Contributes to Natural Transformation of Vibrio cholerae in a Species-Specific Manner

Source Title	Quorum Sensing Contributes to Natural Transformation of Vibrio cholerae in a Species-Specific Manner
Source citation (APA Format)	Suckow, G., Seitz, P., & Blokesch, M. (2011). Quorum sensing contributes to natural transformation of vibrio cholerae in a species-specific manner. *Journal of Bacteriology*, *193*(18), 4914–4924. https://doi.org/10.1128/jb.05396-11
Original URL	https://journals.asm.org/doi/10.1128/jb.05396-11
Source type	Journal Article
Keywords	Quorum sensing, natural transformation, autoinducer, plasmid
#Tags	Uptake of non-species-specific DNA by naturally competent V. cholerae cells. Decrease in the transformability of V. cholerae strains with defects in autoinducer synthesis. Regulation of natural competence and transformation by quorum-sensing system 1 occurs through the canonical quorum-sensing cascade.
Summary of key points + notes (include methodology)	Vibrio cholerae live with zooplankton that have a chitinous shell, so there is much free-floating chitin, and this helps the bacteria to recombine DNA and transform. The DNA was thought to be consumed as food for the bacteria, but several findings challenge this conjecture. They hypothesized that V. Cholerae can uptake other species DNA using a DUS, and another feature. This is because the DUS of V. Cholerae is unusually short, so it may not be the sole reason to encourage genetic uptake. Bacteria secrete autoinducers for other bacteria to notice to change their cellular function for the community. Because the largest contributor to transformation in quorum sensing is the CAI-1 autoinducer, quorum sensing contributes to species-specific transformation. Methods: DNA strains and plasmids from V. Cholerae are used. Cultures are made in Lysogeny broth. Some plasmids were removed from the bacteria which cause the formation of different DNA strains. These DNA strains make able the differentiation from autoinducer sensing to autoinducer producing strains. Chitin flakes were provided as a source of carbon bacteria to induce transformation. Cells

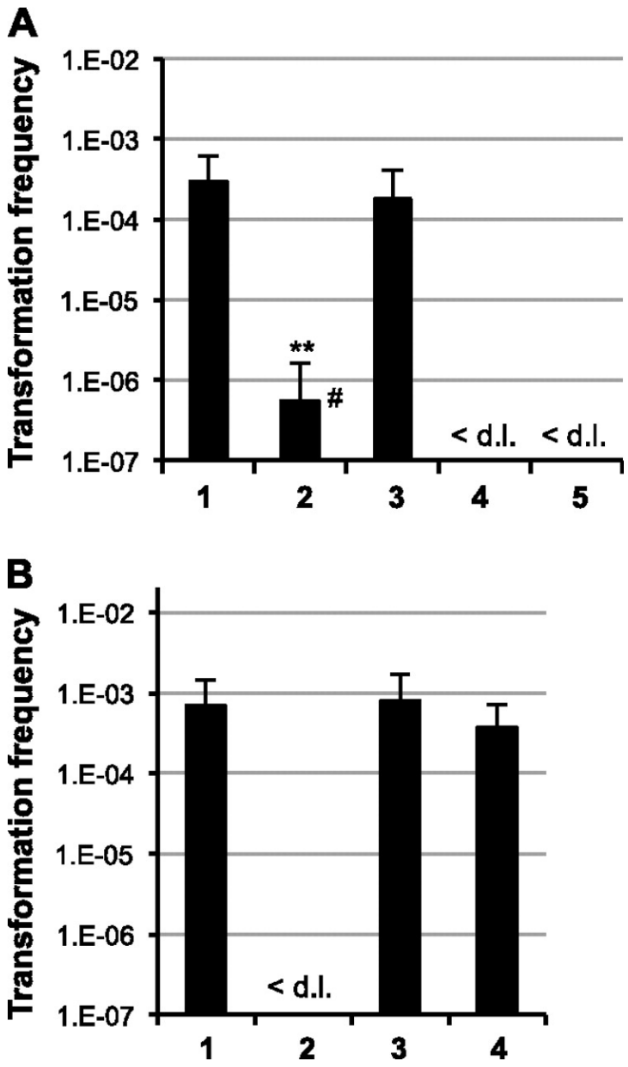
	removed from chitin flakes by vortexing and centrifuge into pellets. The control is the V. Cholerae with much lower primer content. The number of acceptors that cells released is measured and DNA uptake of gDNA by V. Cholerae from interspecies bacteria. Results: After analyzing the diagrams, it can be concluded that the DNA uptake is stored in the periplasmic zone. Therefore, interspecific transformation was not demonstrated for V Cholerae. Hence, the DNA uptake process does not depend on species. Additionally, quorum sensing of intraspecies affects transformation in V. Cholerae. Discussion: Bacteria were originally thought to take up only certain DNA, but this distinction was blurred with this experiment as V. Cholerae does not distinguish between the gDNA of donor bacteria that is not in the same species. However, quorum sensing of intraspecies does affect the rate of transformation. Furthermore, CAI-1 prevent V. Cholerae to form biofilms which will prove as an effective treatment for these bacteria
Research Question/Problem/ Need	Does quorum sensing contribute to the transformation of Vibrio Cholerae?
Important Figures	 Model of how quorum sensing contributes to natural transformation

Autoinducer-producing strain (autoinducer produced)[a]	Autoinducer-sensing strain (autoinducer produced)	Transformation frequency[b] (±SD)
A1552"*str*" (C^+, A^+)	None	1.4×10^{-4} ($\pm 1.3 \times 10^{-4}$)
None	A1552ΔcqsAΔluxS"*str*" (–)	<d.l.
A1552ΔcomEA (C^+, A^+)	None	<d.l.
A1552ΔcomEA (C^+, A^+)	A1552ΔcqsAΔluxS"*str*" (–)	1.8×10^{-4} ($\pm 1.3 \times 10^{-4}$)
A1552ΔcomEAΔcqsA (A^+)	A1552ΔcqsAΔluxS"*str*" (–)	<d.l.
A1552ΔcomEAΔluxS (C^+)	A1552ΔcqsAΔluxS"*str*" (–)	1.8×10^{-4} ($\pm 8.2 \times 10^{-5}$)
A1552ΔcomEAΔcqsAΔluxS (–)	A1552ΔcqsAΔluxS"*str*" (–)	<d.l.

Cholera autoinducer-1 is of major importance for natural transformation



Uptake of non-species-specific DNA by naturally competent V. cholerae cells

	 Regulation of natural competence and transformation by quorum-sensing system 1 occurs through the canonical quorum-sensing cascade.
VOCAB: (w/definition)	Nature competence: the ability of prokaryotes to take up DNA from the environment and insert it into their own genome by homologous recombination. DUS (DNA uptake sequence): short, conserved sequences facilitate the exchange of endogenous DNA Quorum sensing: Bacteria produce small molecules, designated autoinducers, and secrete them into the environment. By sensing the abundance of these molecules, bacteria can estimate the cell density of the community and adjust cellular functions accordingly. Autoinducer: A molecule produced and secreted by bacteria that when present at a threshold concentration in a population of bacteria signals genetic expression in the same bacteria from which it was produced. Synthase: An enzyme that catalyzes the linking together of two molecules, especially without the direct involvement of ATP. Electroporation: The process of using an electric pulse to introduce DNA into cells

	by creating temporary pores in the cell membrane gDNA: DNA found in chromosomes.
Cited references to follow up on	Meibom, K. L., Blokesch, M., Dolganov, N. A., Wu, C.-Y., & Schoolnik, G. K. (2005). Chitin induces natural competence in *vibrio cholerae*. *Science*, *310*(5755), 1824–1827. https://doi.org/10.1126/science.1120096
Follow up Questions	Do other bacteria also distinguish between interspecies DNA? Can Vibrio Cholerae be used to treat dyes? Can Vibrio Cholerae be transformed to produce chitin?

Patent #1 Notes: A kind of dyeing fabric sewage water treatment method

Source Title	A kind of dyeing fabric sewage water treatment method
Source citation (APA Format)	Yang, J., Du, W., Wu, Y., & Weng, S. (2019). *A kind of dyeing fabric sewage water treatment method* (C.N. Patent No. CN108558140B). Chinese Patent Agency. https://patents.google.com/patent/CN108558140B/en
Original URL	https://patents.google.com/patent/CN108558140B/en
Source type	Patent
Keywords	Wastewater, dye, recycle, divided
#Tags	The waste water of serious pollution (for insoluble dye), For dyeing link (for soluble dye), The subsequent technique (removal of particles that are not to be recycled)
Summary of key points + notes (include methodology)	The invention aims to recycle dyes and reduce the overall expense of wastewater treatment utilizing a biochemical treatment. This is because the previous treatment methods such as coagulation and aerobic biodegradation are inefficient as the dye and polymers are not efficiently recycled. The invention is for textile wastewater before treatment. For insoluble dyes, after the coagulation/flocculation step, the sediments are filtered into the coagulated dyes to be recycled, and other materials that will be removed. Then, evaporate the leftover wastewater and collect the acid that can be reused to wash dyed fabric. Sieve filtration removes particles that are greater than 5mm in length. Air bearing can remove suspended particles that are greater than 0.8mm. Fenton oxidation

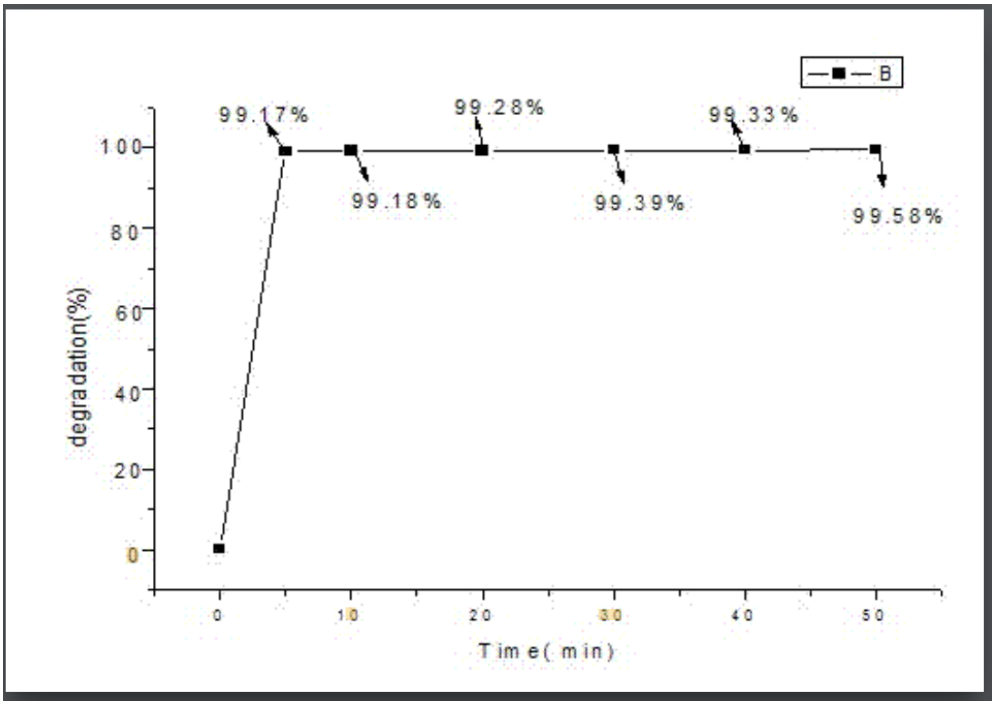
	removes the rest of the organic particles. For water-soluble dyes, collect them via filtration and precipitation. These methods reduce the pollution level of wastewater before chemical treatment, so less chemical is used, and the materials used in the previous methods are mostly recycled. Hence, carbon adsorption and further filtration can be utilized to clean the remaining waste. Steps: 1. Collected textile wastewater that does not contain dyes, coagulate to remove foreign particles. Evaporate to recycle salts used in the dyeing industry. 2. Textile wastewater with dyes is then separated into soluble and insoluble components which are then subjected to treatments described in the summary. 3. Repeat step 1 and 2 to meet wastewater treatment standards This procedure is efficient because of the ease of treating the wastewater due to separating wastewater into different categories that requires a small number of steps to complete. Furthermore, collecting and recycling dyes decreases the cost of wastewater treatment because of reusing materials due to the classification system, and not combining all wastes into one treatment. The dye is recycled from the mud obtained after coagulation. The researchers elaborated that the mud is dried and then smashed to obtain the dye.
Research Question/Problem/ Need	How to improve the efficiency of wastewater treatment?
Important Figures	Cotton fabric dyeing process includes multiple dyeing links, and main flow includes that → water is dyed → soaped in fabric → oxygen bleaching → washing → → final finishing → finished product is washed, the dyeing flow of dacron is main are as follows: fabric → pre-treatment → dyeing → reduction cleaning → washing → final finishing → finished product, the dye type being related to mainly include direct dyes, reactive dye, reducing dye, insoluble idol The day colouring power of nitrogen The process of textile dyeing

Serial number	pH	CODcr/mg/L	Coloration/times	Conductivity/μS/cm	1	10.5-11.5	1257	9398	21000
2	10-10.5	795	6300	8500	3	4.5-5	1700	2750	3900
4	5.4-7.1	856	1100	2200	5	7.1-8.6	600	1985	1900
6	6.9-7.8	460	798	1356	7	7-7.5	275	410	860
8	7-7.5	235	197	770	9	7-7.5	240	103	745
10	6-7.5	390	60	712	11	6.2-7.2	299	16	700

	Comparison of different class of textile dyes
VOCAB: (w/definition)	Fenton oxidation: An AOP [Advance Oxidation process] in which the oxidation of organic compounds takes place in the presence of a solution of hydrogen peroxide (H2O2) and iron ions (Fe2+ and/or Fe3+) acting as the catalyst Acid pickling: reaction between an aqueous acid medium and an oxide scale
Cited references to follow up on	Mehmet, S. K. (2020, August 19). *Process for recycling sulphur black dye from a dyeing process and producing recycled dye in leuco form* (E.P. Patent No. EP3696236A1). European Patent Office. https://patents.google.com/patent/EP3696236A1/en
Follow up Questions	How did the inventor separate wastewater into different categories to be treated differently? Are recycled materials worse than the original materials? Why does the method for extracting dyes from mud to be recycled work?

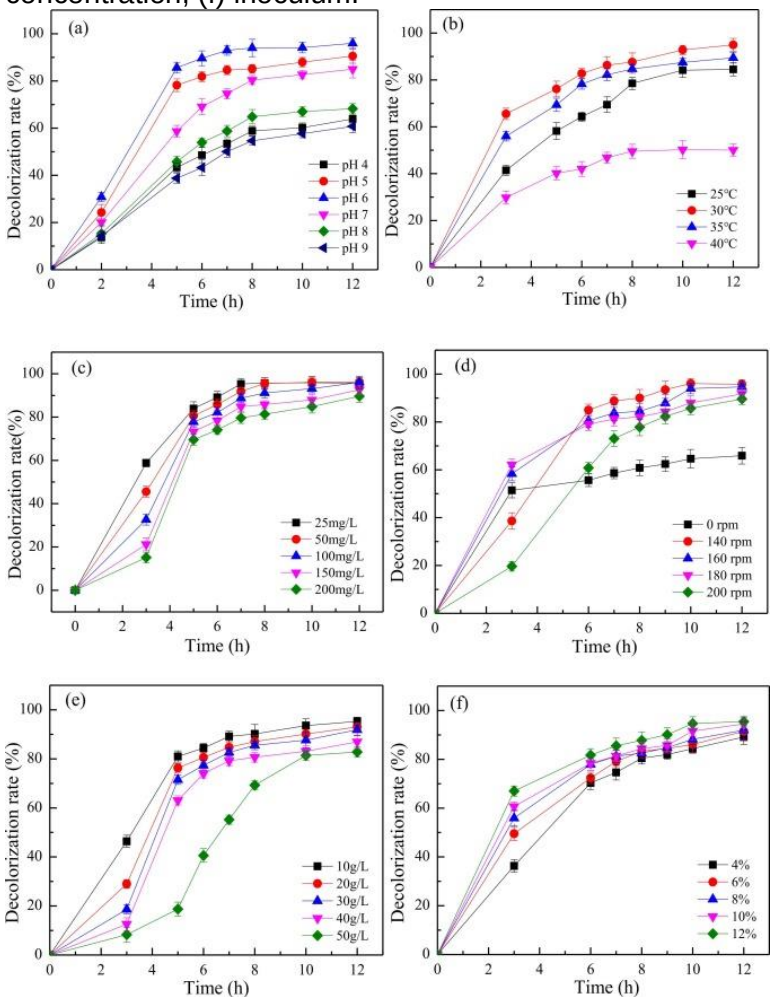
Patent #2 Notes: Method for treating dye wastewater

Source Title	Method for treating dye wastewater
Source citation (APA Format)	Li, Q., Guo, J., Huan, C., Li, C., & Tu, Y. (2013). *Method for treating dye wastewater* (C.N. Patent No. CN102659235B). Chinese Patent Agency. https://patents.google.com/patent/CN102659235B/en
Original URL	https://patents.google.com/patent/CN102659235B/en
Source type	Patent
Keywords	Fenton oxidation, dyestuff, decolorization, precipitation
#Tags	comprises following concrete steps (procedure), Fenton oxidation exists (benefits of invention)
Summary of key points + notes (include methodology)	The invention improved upon the Fenton oxidation treatment of wastewater to make it quick and efficient as less amount of acid is used for this process due to the method being independent of pH, large amount of electricity and energy is needed, and catalysts used in the process can be recycle. Fenton oxidation is when Fenton reagent (Fe^{2+} and H_2O_2) creates many free floating OH molecules to combine with dyes for decomposition. However, Fenton oxidation may produce

	precipitation which causes further pollution. The disadvantages of a Fenton reaction are that it is expensive and can only be used for a small amount of dye. Invention: A method of heterogenous Fenton oxidation that produces oxychlorination of iron which does not need a specific pH, the precipitation is not a pollutant, iron III chloride is insoluble, so the wastewater color does not change which helps with decolorization, utilized less energy, and the iron catalyst can be recycle.
Research Question/Problem/ Need	How to improve Fenton oxidation treatment for better efficiency, and less pollution?
Important Figures	Degradation of methyl orange dye over time with the heterogenous Fenton oxidation reaction 
VOCAB: (w/definition)	Oxychlorination: a process for generating the equivalent of chlorine gas (Cl2) from hydrogen chloride and oxygen
Cited references to follow up on	吴, 兆亮., 张, 晓龙., 卢, 珂., & 丁, 红梅. (2010, November 17). *Printing and dyeing wastewater processing technique* (C.N. Patent No. CN101381178B). Chinese Patent Agency. https://patents.google.com/patent/CN101381178B/en
Follow up Questions	Can this invention be used with highly concentrated dyes in wastewater? How to reclaim the iron catalyst after the reaction? What causes the initial surge in degradation and the leveling off after that?

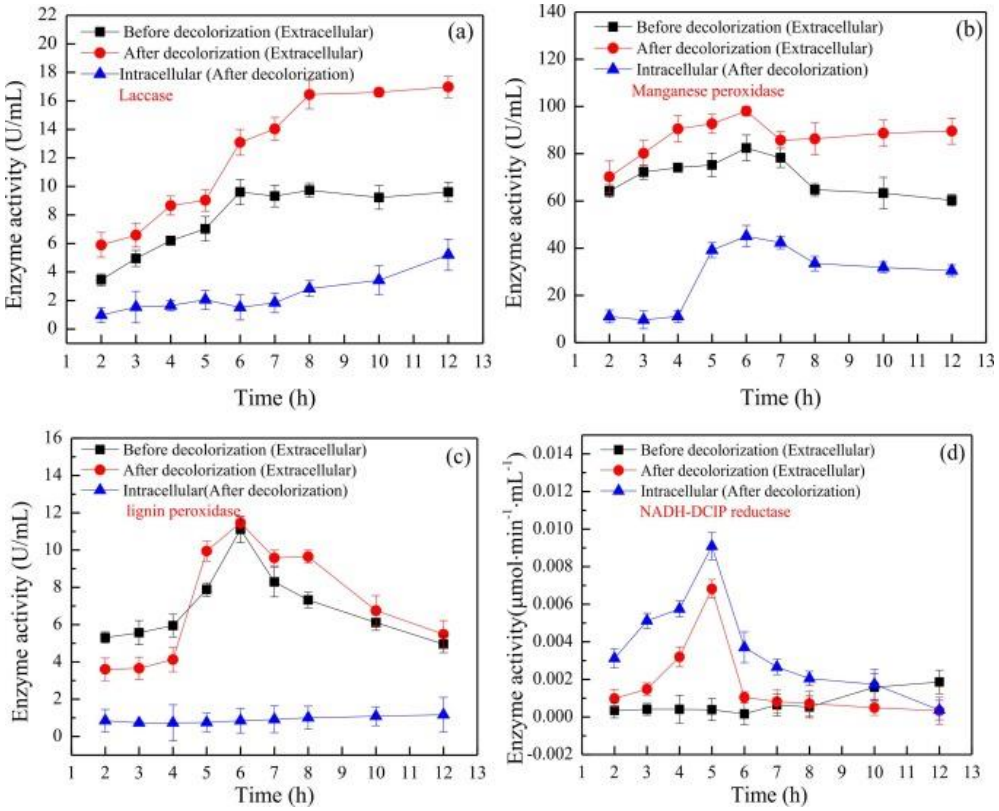
Article #11 Notes: Decolourization and biodegradation of methylene blue dye by a ligninolytic enzyme-producing *Bacillus thuringiensis*: Degradation products and pathway

Source Title	Decolourization and biodegradation of methylene blue dye by a ligninolytic enzyme-producing Bacillus thuringiensis: Degradation products and pathway
Source citation (APA Format)	Wu, K., Shi, M., Pan, X., Zhang, J., Zhang, X., Shen, T., & Tian, Y. (2022). Decolourization and biodegradation of methylene blue dye by a ligninolytic enzyme-producing bacillus thuringiensis: Degradation products and pathway. *Enzyme and Microbial Technology*, *156*, 109999. https://doi.org/10.1016/j.enzmictec.2022.109999
Original URL	https://www.sciencedirect.com/science/article/pii/S0141022922000187
Source type	Journal Article
Keywords	Methylene blue, Bacillus thuringiensis, Biodegradation, Degradation pathway, Phytotoxicity
#Tags	Chemicals and medium (preparation of simulated wastewater), Isolation of MB degrading bacteria, Enzyme activity.
Summary of key points + notes (include methodology)	Methods: Preparation of dyes: Methylene blue without bacteria contamination, and the bacteria environment is a solution of yeast extract, glucose, and other chemicals. Getting the bacteria: Use guaiacol to identify bacteria that produce a specific enzyme, and culture them in agar. Test the bacteria capability to degrade dye by putting a small amount of MB dye and observe the formation of a degradation circle in the agar culture of Luria broth Experiment: Done in a 150ml Erlenmeyer flask with 50 ml of solution of the medium and varying concentration of MB. Enzyme effectiveness: Measured with the absorbance magnitude. One unit of absorbance means that the enzyme converts 1 micromol in 1 minute. => to obtain the best bacterial population for dye degradation Results: pH effects: The most optimal pH was 6, and as the pH deviates from this point, the effectiveness drops due to pH condition affecting enzyme activity by changing the shape of the enzyme and transportation of materials through the cell's membrane. Temperature effects: 30 degrees is optimal, and higher temperature causes cells to be stressed and dye, and denaturation of enzyme. Initial dye concentration:

	Dye concentration: As the concentration increases, the removal rate decreases due to saturation of dye relative to the enzyme. Furthermore, this could also be due to the dye being too toxic for the bacteria. Salt concentration: As the salt concentration increases, the decolorization rate decreases due to salt affecting osmosis of the bacteria. However, the decrease is very small showing the bacteria's resistance to salt. Enzyme analysis: 4 enzymes are particularly prevalent to decolorize dyes: laccase, manganese peroxidase, lignin oxidase, and NADH-DCIP reductase which degrade the dye. This conclusion was reached due to the increase in activity of these enzymes while degrading dyes. Degradation results: The MB dyes mostly degrade into less toxic metabolites that are tested by the growth of plants. These metabolites are not truly harmless as they still inhibit the plants' growth, but to a lesser degree than MB dye.
Research Question/Problem/ Need	What is the effectiveness of degradation of Methylene Blue dye by Bacillus thuringiensis?
Important Figures	Name: "Effects of different parameters on the decolorization of MB. (a) pH, (b) temperature, (c) initial dye concentration, (d) rotational speed, (e) NaCl concentration, (f) inoculum." 

Graph of the results

Name" "Fig. 3. The changes of enzyme activity at different times. (a) laccase, (b) manganese peroxidase, (c) lignin oxidase, (d) NADH-DCIP reductase."



The enzymes that contribute to dye decolorization

Name: "Phytotoxicology study of MB and its degradation products"

	Triticum aestivum			*Vigna radiata*		
Parameters	**DW**	**DMB**	**MB**	**DW**	**DMB**	**MB**
Germination (%)	100 ± 1.88	86 ± 1.89	57 ± 2.87	97 ± 2.36	80 ± 4.08	60 ± 4.08
Root Length (cm)	5.71 ± 1.26^{a}	3.24 ± 1.34^{b}	1.40 ± 0.38^{c}	4.94 ± 1.38^{a}	3.86 ± 1.02^{b}	1.90 ± 1.06^{c}
Shoot Length (cm)	8.28 ± 1.72^{a}	6.99 ± 1.83^{b}	3.80 ± 1.87^{c}	6.67 ± 1.54^{a}	5.52 ± 1.73^{b}	3.82 ± 1.99^{c}
Fresh weight (g)	3.34 ± 0.21^{a}	3.24 ± 0.14^{ab}	2.90 ± 0.36^{b}	8.45 ± 0.18^{a}	8.18 ± 0.26^{ab}	7.93 ± 0.21^{b}

DW: Distilled water, DMB: Degraded MB, MB: Methylene blue

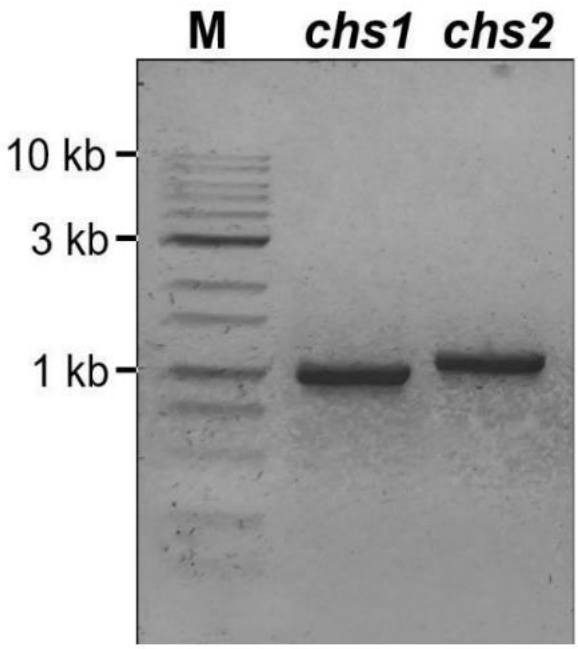
VOCAB: (w/definition)

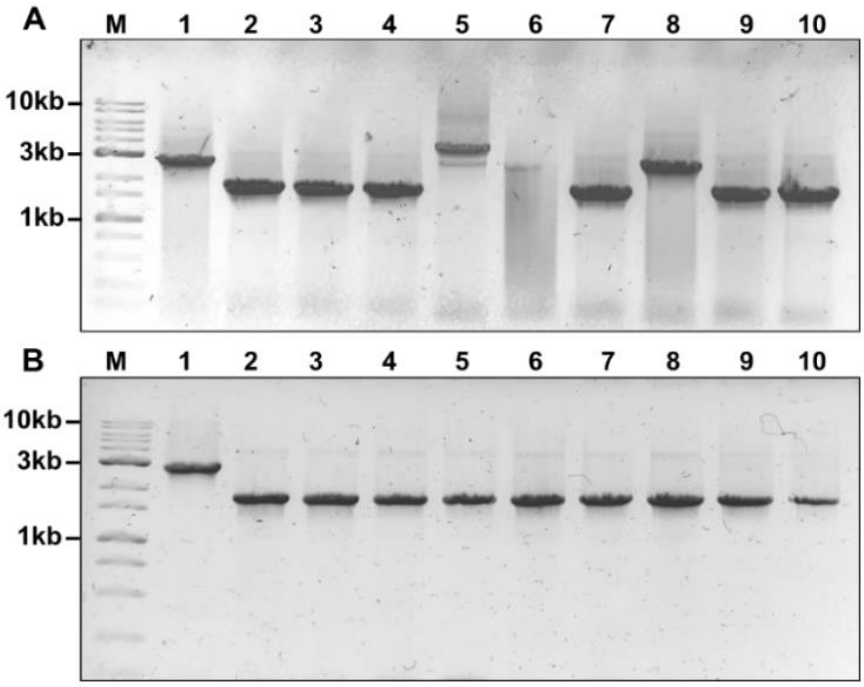
Aseptic Processing: An aseptic processing facility is a building containing clean rooms in which air supply and equipment are regulated to control microbial contamination, and the products are processed and then packaged without any further contamination.
Bacterial Strain: A biovar represents a group of bacterial strains distinguishable

	from other strains of the same species on the basis of physiological or biochemical characters. Supernatant: Denoting the liquid lying above a solid residue after crystallization, precipitation, centrifugation, or other process. Inoculum: An inoculum can be defined as the population of microorganisms or cells that is introduced in the fermentation medium or any other suitable medium.
Cited references to follow up on	Kishor, R., Saratale, G. D., Saratale, R. G., Ferreira, L. F. R., Bilal, M., Iqbal, H. M. N., & Bharagava, R. N. (2021). Efficient degradation and detoxification of methylene blue dye by a newly isolated ligninolytic enzyme producing bacterium Bacillus albus MW407057. *Colloids and Surfaces B: Biointerfaces*, *206*, 111947. https://doi.org/10.1016/j.colsurfb.2021.111947
Follow up Questions	How effective are other bacteria? Can these bacteria be transformed using a fungal plasmid? How did the bacteria evolved to develop the enzymes suitable for dye degradation?

Article #12 Notes: Construction of the RNAi plasmids to suppress the expression of chitin synthase-encoding genes (chs) in fungus *Mucor lusitanicus*

Source Title	Construction of the RNAi plasmids to suppress the expression of chitin synthase-encoding genes (chs) in fungus *Mucor lusitanicu*s
Source citation (APA Format)	Mai, L. N., Duc, L. M., Quang, D. M., & Trung, T. A. (2024). Construction of the rnai plasmids to suppress the expression of chitin synthase-encoding genes (chs) in fungus mucor lusitanicus. *Vietnam Journal of Biotechnology*, *22*(1), 125–132. https://doi.org/10.15625/vjbt-20234
Original URL	https://vjs.ac.vn/index.php/vjbt/article/view/20234
Source type	Journal Article
Keywords	chitin, chitin synthase, cell wall, mucormycosis, Mucor lusitanicus
#Tags	Isolation of genomic DNA and plasmids (procedure), PCR and electrophoresis (procedure)

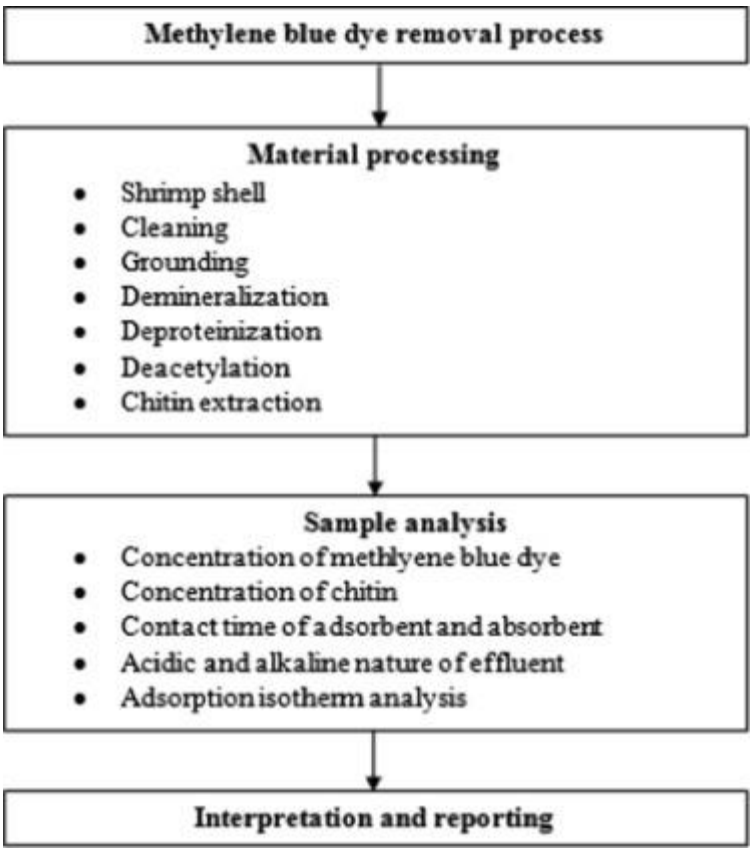
Summary of key points + notes (include methodology)	Mucormycosis is a very difficult fungal infection to cure as the traditional treatment for fungi does not work. The study aims to analyze the gene that codes to create the fungal cell wall as it may be related to the infectiousness of the fungi. Chs1 and Chs2 genes code for chitin synthase, and the use of RNAi plasmid to inhibit the expression of these genes. Method & materials: PMAT1812 was used to promote the production of RNAi. Isolation of bacteria gene and the plasmid dna for transformation. Then, perform electrophoresis where the result is displayed on agarose gel with UV light. Steps for electrophoresis are denaturation, annealing, and extensions. Creating a plasmid with chs1 and chs2 and transforming the bacteria. Next step: putting the plasmid into the fungi to see its effect on the fungi that causes mucormycosis
Research Question/Problem/ Need	Can one construct a plasmid to inhibit chitin production in fungi?
Important Figures	Name: “PCR results of 1 kb fragment from chs1 and chs2 genomic DNA of strain R7B.”  The chs1 and chs2 are successfully transformed into the bacteria Name: “Results of the colony PCR to select the recombinant plasmids for Chs1 gene (A) and Chs2 gene (B).”

	 Almost all colonies of E coli successfully transformed
VOCAB: (w/definition)	Recombination: the rearrangement of genetic material, especially by crossing over in chromosomes or by the artificial joining of segments of DNA from different organisms Heat shock method: By exposing cells to a sudden increase in temperature, or heat shock, a pressure difference between the outside and the inside of the cell is created, that induces the formation of pores, through which supercoiled plasmid DNA can enter.
Cited references to follow up on	Calo, S., Nicolás, F. E., Vila, A., Torres-Martínez, S., & Ruiz-Vázquez, R. M. (2012). Two distinct RNA-dependent RNA polymerases are required for initiation and amplification of RNA silencing in the basal fungus Mucor circinelloides. *Molecular Microbiology*, *83*(2), 379–394. https://doi.org/10.1111/j.1365-2958.2011.07939.x
Follow up Questions	How to extract the chs1 and chs2 genes from fungi? How much chitin did the bacteria produce? Does the transformed bacteria's physiology differ greatly from the untransformed bacteria?

Article #13 Notes: Removal of methylene blue dye using shrimp shell chitin from industrial effluents

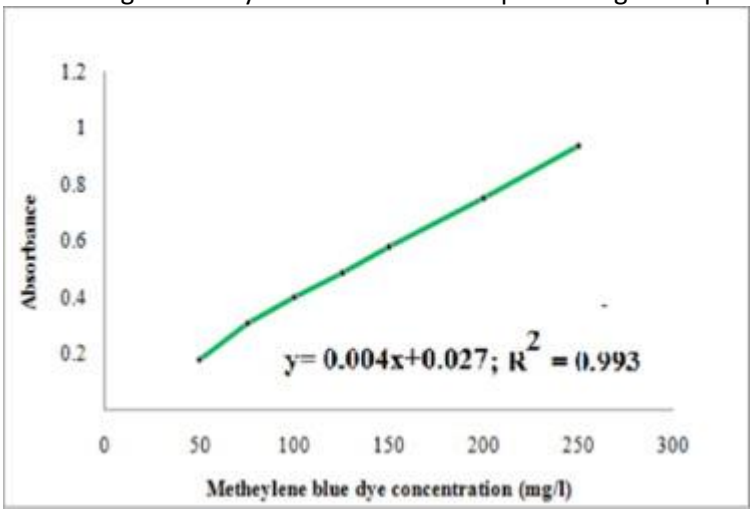
Source Title	Removal of methylene blue dye using shrimp shell chitin from industrial effluents
Source citation (APA Format)	Karthi, S., Sangeetha, R. K., Arumugam, K., Karthika, T., & Vimala, S. (2022). Removal of methylene blue dye using shrimp shell chitin from industrial effluents. *Materials Today: Proceedings*, *66*, 1945–1950. https://doi.org/10.1016/j.matpr.2022.05.428
Original URL	https://www.sciencedirect.com/science/article/pii/S2214785322037488
Source type	Journal Article
Keywords	Chitin, Effluent, Methylene blue dye, Shrimp shell, Industrial effluents
#Tags	Adsorption batch experiment (procedure and calculation for absorption capacity), Adsorption isotherm examination (calculation for adsorption with the adsorbent)
Summary of key points + notes (include methodology)	Introduction: Chitin is extracted from crustaceans, especially shrimp, through the deproteinization and demineralization process. Chitin was proven to be able to remove heavy metal from textile effluent. Methods: Here, chitin is used as an adsorbent of the methylene blue dye. However, the process, which will be discussed later, is largely the same if chitin is to be used as a coagulant. Isotherm analysis was used to determine the effectiveness of chitin as an adsorbent. Extraction of chitin from shrimp shells: Grind dried, clean shrimp cells and submerged the particles in HCl for demineralization (1 solid volume to 14 solvent volume ratio) to remove calcium carbonate. Deproteinization was conducted with NaOH at 400 degrees Celsius with the same ratio. Finally, acetone is used to remove the color. Preparation of methylene blue dye: A solution of methylene blue dye is created using MB powder, de-ionized water, ethyl alcohol, and KOH solution. Experiment: Differing amount of chitin (0.1g to 0.6g) is mixed in with 250 mL of MB dye. Absorbance capacity is measured with the equation: $\text{Quantity of dye adsorbed/unit mass} = \frac{(C_i - C_e)\,V}{M}$ Adsorption of dye in relation to the amount of adsorbent present is calculated with the equation: $Log(Qe) = Log(Kf) + 1/nLog(Ce)$ log re-expression of fruenlich model for linearizing data pH effect on Methylene blue dye treatment: pH range of 4 to 9 with different

	concentration of dye as well (25mg/L to 250 mg/L) with 0.5 g of chitin. pH of 7 performed the best for removal efficiency. 0.5g of chitin and 25mg/L of MB dye results in the highest removal rate of 98%. pH away from 7 decreased the electrostatic force between the chitin and the dye causing the chitin to be unable to stick to the dye. This is confirmed through an alkaline medium. Chitin reaches maximum sorption capacity, so as concentration increases, the percentage of dye removed decreases. So, a concentration of 25mg/L and a pH of 7 is the best combination. Amount of chitin to removal of MB dye at 7pH, 25mg/L concentration, and at room temperature for 250mL dye solution: More chitin correlates to a better removal efficiency until the trend levels out as seen from 0.5g to 0.6g. So, the best amount of chitin is 0.5g. With similar condition except the amount of chitin is kept constant at 0.5g, but the time for the treatment ranges from 30-150 minutes: As time increases, the removal efficiency increases until 90 minutes to 150 minutes where the trend levels out. Therefore, the most effective time is 90 minutes. Adsorption dye with constant conditions and 2g of chitin: As the amount of methylene dye increases and the sorption is not at maximum capacity, the amount of methylene dye removed increases logarithmically. Due to the results agreeing with the Freundlich model for adsorption, chitin is established as a good adsorbent for methylene blue dye.
Research Question/Problem/ Need	What are the optimal conditions for chitin to remove Methylene Blue dye through adsorption?
Important Figures	Name: “Fig 3. Flow chart for methylene blue dye removal process.”



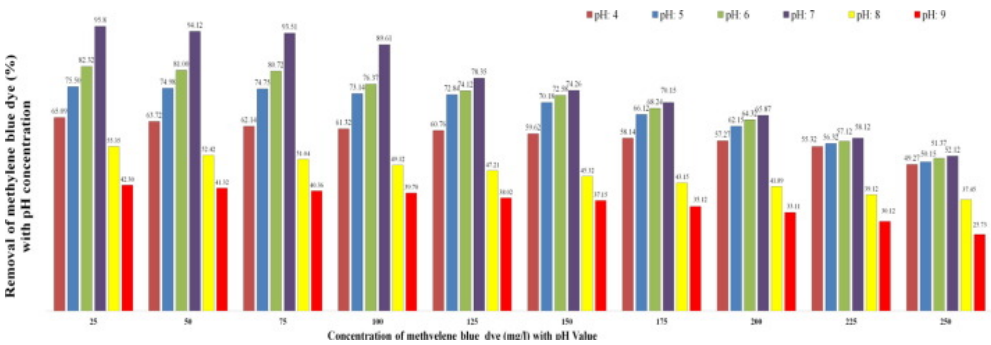
Shows the process of analysis to quantify adsorption

Name: “Fig. 4. Methylene blue solution representing data quality analysis.”



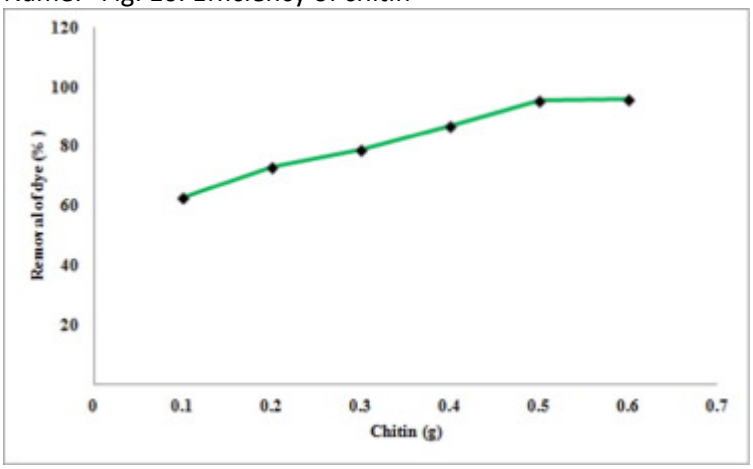
As the concentration of MB dye power increases, the more light is absorbed after using spectroscopy.

Name: “Fig. 9. Removal of methylene blue dye in pH variation.”



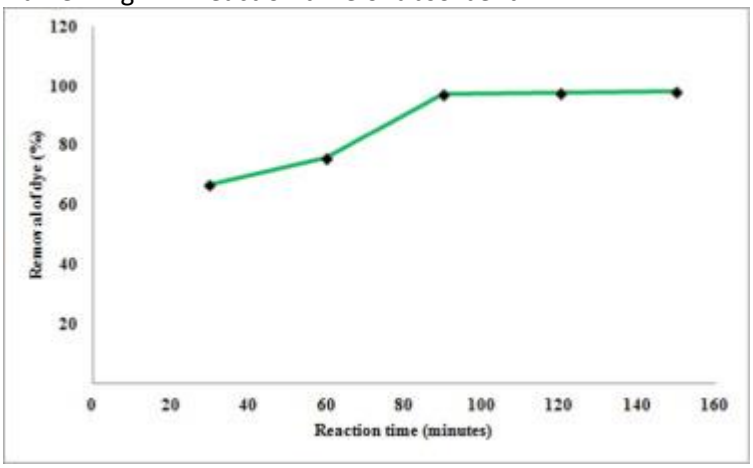
As pH deviates from 7, adsorption decreases. A similar trend is also noticeable when the amount of concentration of MB dye increases.

Name: “Fig. 10. Efficiency of chitin”



Linear increase of removal efficiency with more chitin until from 0.5 to 0.6g levels out.

Name: “Fig. 11. Reaction time of absorbent.”



The percentage of dye removed increases seemingly exponentially with the amount of time increase.

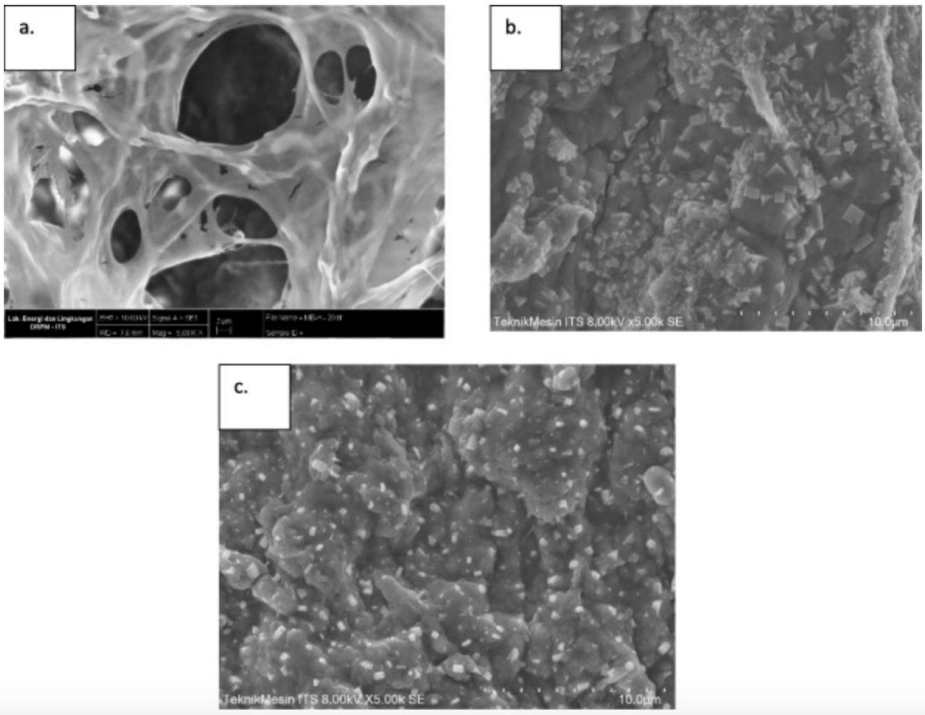
VOCAB: (w/definition)	Deproteinization: Deproteination is the process of removing protein by disrupting

	chemical bonds using chemicals to depolymerize the biopolymer. Demineralization: Demineralization is the process of removing calcium, magnesium, and inorganic phosphate ions from a material, resulting in a less compact and less viscous substance. Equilibrium Concentration: The partition coefficient is defined as the ratio of the equilibrium concentrations of a dissolved substance in a two-phase system consisting of two largely immiscible solvents. Alkaline medium: An electroreforming process is the electrochemical generation of hydrogen by reducing proton concentrations in acidic media or reducing water concentrations in alkaline media at the cathode of an electrolysis cell and oxidising oxygenated organic molecules from biomass at the anode.
Cited references to follow up on	Ferreira, A. M., Coutinho, J. A. P., Fernandes, A. M., & Freire, M. G. (2014). Complete removal of textile dyes from aqueous media using ionic-liquid-based aqueous two-phase systems. *Separation and Purification Technology*, *128*, 58–66. https://doi.org/10.1016/j.seppur.2014.02.036
Follow up Questions	How would these results change if chitin is subjected to a mixture of dyes other than Methylene blue? How could chitin be extracted from fungi? How does temperature affect the treatment process?

Article #14 Notes: Methylene Blue biodecolorization and biodegradation by immobilized mixed cultures of Trichoderma viride and Ralstonia pickettii into SA-PVA-Bentonite matrix

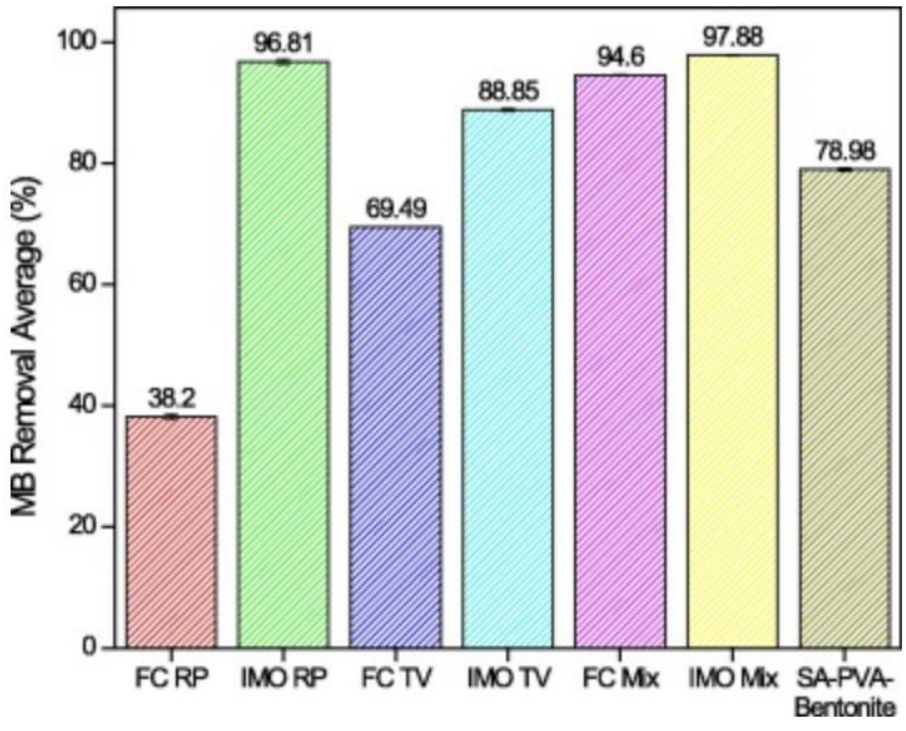
Source Title	Methylene Blue biodecolorization and biodegradation by immobilized mixed cultures of Trichoderma viride and Ralstonia pickettii into SA-PVA-Bentonite matrix
Source citation (APA Format)	Nabilah, B., Purnomo, A. S., Prasetyoko, D., & Rohmah, A. A. (2023). Methylene Blue biodecolorization and biodegradation by immobilized mixed cultures of Trichoderma viride and Ralstonia pickettii into SA-PVA-Bentonite matrix. *Arabian Journal of Chemistry*, *16*(8), 104940. https://doi.org/10.1016/j.arabjc.2023.104940
Original URL	https://www.sciencedirect.com/science/article/pii/S1878535223004021
Source type	Journal Article

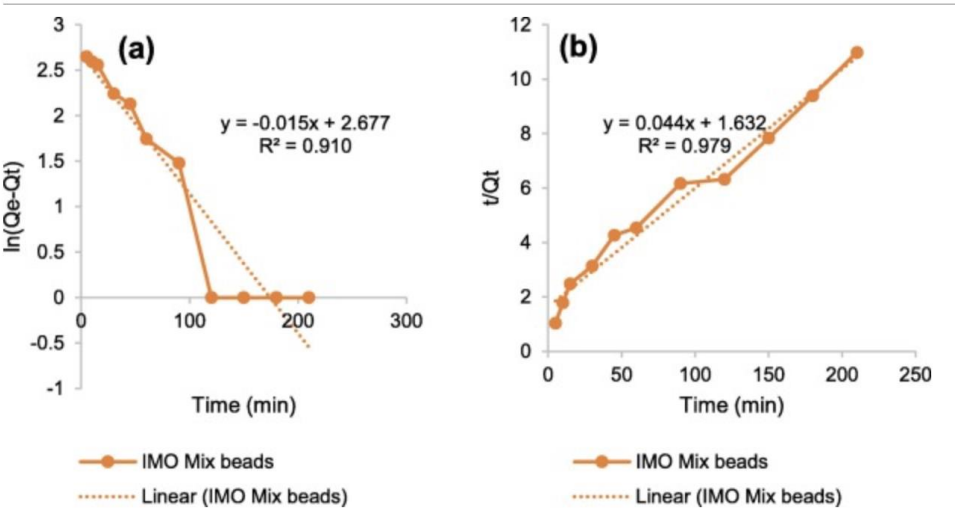
Keywords	Methylene Blue, Biodecolorization, *Ralstonia pickettii*, *Trichoderma viride*, Immobilization, Pollution
#Tags	
Summary of key points + notes (include methodology)	Introduction: Fungi can be more resistant to the dye than bacteria. The fungus present in this study (*richoderma viride*) was shown to be able to degrade heavy metal, polylactic acid, and MB dye as well. The bacteria *Ralstonia pickettii* was also shown to be able to degrade aromatic compounds. Furthermore, the bacteria have shown symbiotic relationship with other fungi to degrade other inorganic substances. The technique used in this research is called cell immobilization as the free cell method lacking in reusability and stability. Cells are trapped in beads made with sodium alginate, Polyvinyl Alcohol, and bentonite. Methods: Culture: The bacteria were incubated in nutrient agar at 37 C for a day, then incubated in a shaker for 2 days. The fungi were incubated in Potato dextrose agar for 7 days at 30 C. Then the fungi are mixed in 25 ml of demineralized water. 1ml of this mixture is put into potato dextrose broth. This mixture is incubated for 7 days at 30 C. Immobilization process: Create the matrix using 1 sodium alginate, 4 Polyvinyl Alcohol, and 1 bentonite (the ratio is of weight percentage of the whole / volume of the whole). The immobilized microorganisms are added to the matrix, and the mixture is put into a 0.4M CaCl2 and mixed. The resulting beads are added to CaCl2 solution for 24h, and then they are cleaned with sterile, pure water. Degradation of MB dye: 40g of beads were added to 50 mg/L concentration of 100mL in volume solution. The solution is then incubated at 35 degrees for 48h. The result is measured using spectroscopy. The bentonite used to create the beads increase the sorption capability of the beads by creating pores to increase the surface area. The result of biodegradation created azure A compounds which degrade to Azure C which is degraded into Thionine. These metabolites are adsorbed to the bentonite after degradation.
Research Question/Problem/ Need	What is the effectiveness of immobilized bacteria and fungi in treating Methylene Blue dye?
Important Figures	Name: “Fig. 1. Morphological structure of a) cross-section SA-PVA-B beads and b) immobilized mixed culture before decolorization c) immobilized mixed culture after decolorization.”



The cross section of the beads shown in figure b and c shows the small squares which are bentonite infused with alginate structure. The structure of the bentonite is porous as shown in figure a. After degradation, the structure is less rigid as shown in figure c.

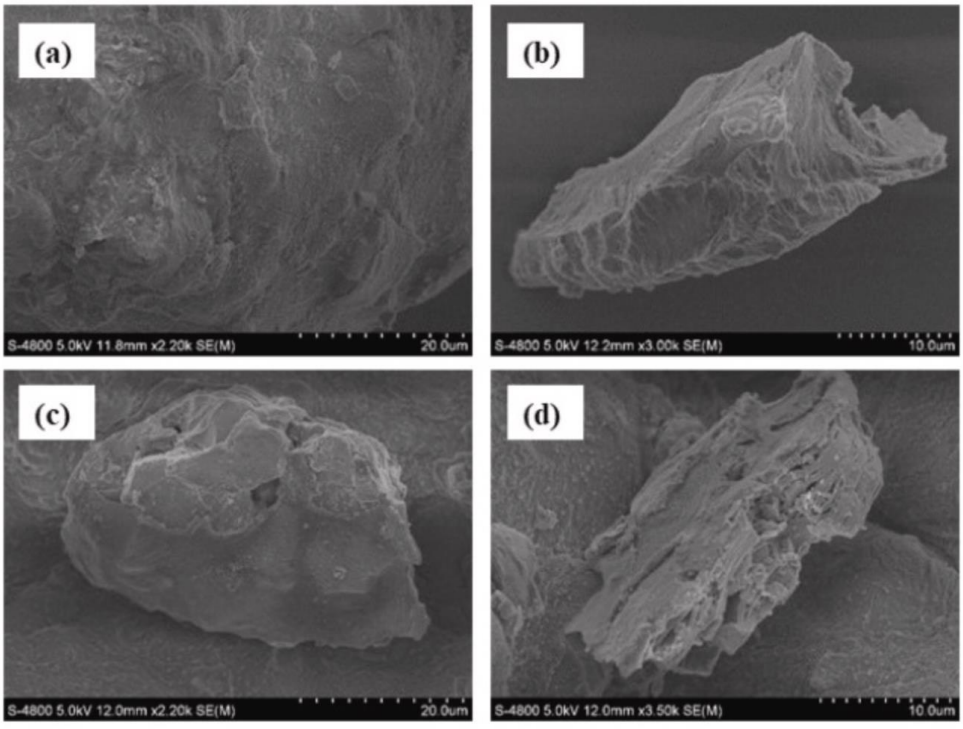
Name: “Fig. 3. MB removal percentage.”

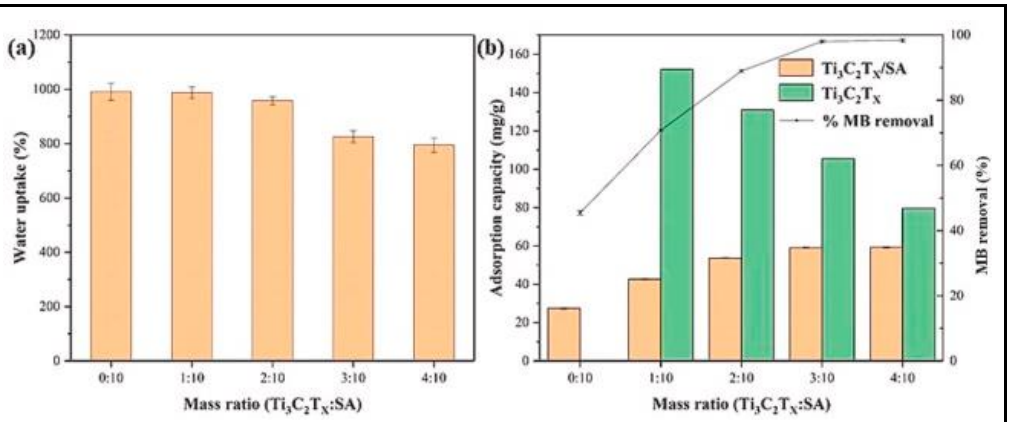


	When RP (the bacteria) is added to the fungi (TV), the result is an immobilized mix that has the highest MB removal rate of 97.88%, an increased from 96.81% for the bacteria (IMO RP) and 88.85% for the fungi (IMO TV). Name: “Graphic of (a) pseudo-first and (b) pseudo-second order kinetic models.”  Graph a: As time increases the number of adsorbed materials decreases until it levels out at a little over 100 minutes. Graph B: The total amount of materials adsorbed increases over time and shows no sign of stopping even after 200 minutes. However, this model was built upon the concept that the amount of material adsorbed is not affected by the capacity of the adsorbent. So, this model reflects if the adsorbent could theoretically continue to adsorb dyes without reaching its limit.
VOCAB: (w/definition)	Cell immobilization: Cell immobilization is defined as the method of entrapping/attaching the intact cell in a suitable matrix with the preservation of desired catalytic activity of the cell. Inoculum: The population of microorganisms or cells that is introduced in the fermentation medium or any other suitable medium.
Cited references to follow up on	Zhang, Z. H., Xu, J. Y., & Yang, X. L. (2021). MXene/sodium alginate gel beads for adsorption of methylene blue. *Materials Chemistry and Physics*, *260*, 124123. https://doi.org/10.1016/j.matchemphys.2020.124123
Follow up Questions	How effective is sodium-alginate beads without bentonite? How to degrade thionine further? How to easily harvest chitin from the fungi?

Article #15 Notes: MXene/sodium alginate gel beads for adsorption of methylene blue

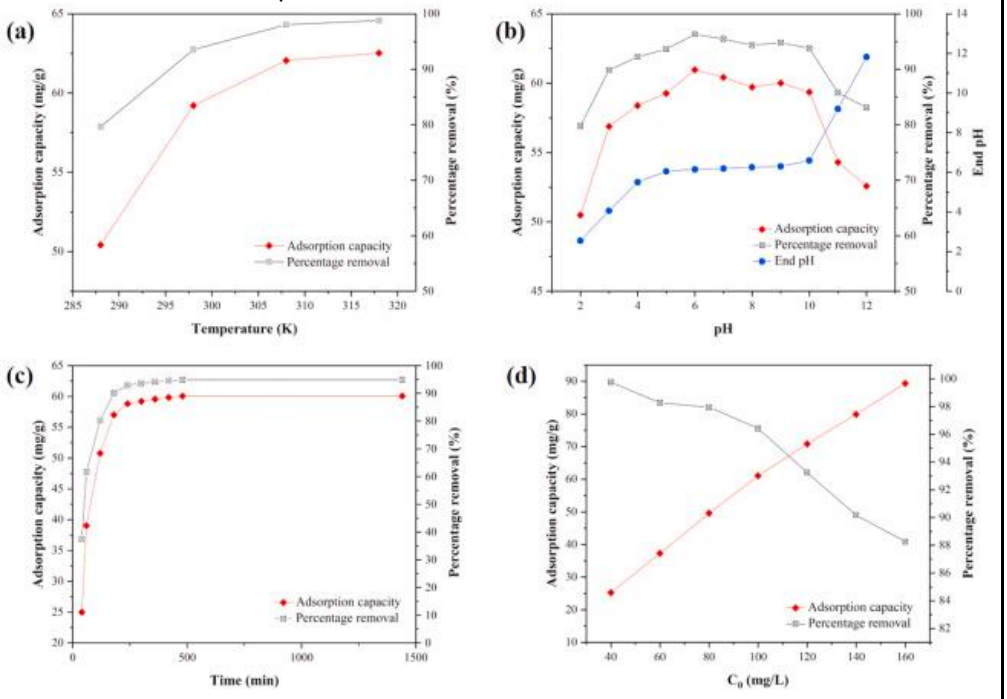
Source Title	MXene/sodium alginate gel beads for adsorption of methylene blue
Source citation (APA Format)	Zhang, Z.-H., Xu, J.-Y., & Yang, X.-L. (2021). MXene/sodium alginate gel beads for adsorption of methylene blue. *Materials Chemistry and Physics*, *260*, 124123. https://doi.org/10.1016/j.matchemphys.2020.124123
Original URL	https://www.sciencedirect.com/science/article/pii/S0254058420314838
Source type	Journal Article
Keywords	$Ti_3C_2T_x$, Sodium alginate, Ionic crosslinking, Methylene blue, Adsorption
#Tags	Experiment: “MB adsorption batch experiments”, Create beads: “Preparation of Ti3C2TX/SA beads”
Summary of key points + notes (include methodology)	Introduction: MXene: A 2D matrix made with transitional metal carbides, nitrides, and carbonitrides. Its chemical formula is $Ti_3C_2T_x$; T_x is the groups of chemicals attached to the exterior of the chemical structure that are O, OH, F. The material is biocompatible and has a large surface area. However, its hydrophilicity property poses a problem for separating it with water. Hence, polymer sodium alginate is used to form hydrogels that are easily removed from water. This helps preserve the graphene adsorbent. SA is used to adsorped MB dye in previous studies, and it adsorbed 414 mg of MB dye/g. Methods: Add the $Ti_3C_2T_x$ into a solution of sodium alginate and distilled water. The solution was stirred for 6h to obtain the gel which is then placed in $CaCl_2$ solution for 24 hours to create the beads. Then, they are freeze-dried after being washed thoroughly. Experiment: Testing 4 separate variables that may affect adsorption: ratio of graphene and SA, pH, temperature, and concentration of MB. 50 beads into 50mL of solution containing MB dye. The solution was oscillated at 130 rpm for 24h at 25 C. Test for recyclability: After the adsorption test, the beads are rinsed, put into acidic ethanol solution with 0.1 M HCl and 80% of ethanol. Shake them continuously for 6h and 35 C. Result: SA increases the surface area of the graphene which increases sorption. Mass ratio: As the graphene amount increases the adsorption of MB dye increases. The removal rate of MB dye increases to a maximum of 98.04% as tested in the

	experiment with the ratio of 4 (Graphene) :10 (SA). However, the change is extremely minimal so a ratio of 3:10 is chosen to not waste materials. Temperature: Adsorption increases dramatically with temperature up until 35 C. After that, the change is much more gradual and slighter. This shows that the beads are resistant to high temperatures. pH: 6pH is optimal as this is when the beads have the highest adsorption rate. This is because the MB dye is cationic, the SA beads are anionic, so a mild alkaline condition works best. Time: Increases drastically during the first 4h. The removal rate becomes much more gradual after this time and reaches an equilibrium after 8h. Reusability: The effectiveness decreases from 98.04% to 81.36% after 3 trials which demonstrates that the material is reusable to a certain extent.
Research Question/Problem/ Need	Can sodium alginate improve the adsorption capabilities of $Ti_3C_2T_x$?
Important Figures	Name: "Fig. 2. SEM image of SA beads (a, b) and Ti3C2Tx/SA-30% beads (c, d)."  When SA is added, the beads are more jagged when compared to the relatively smooth surface of just the graphene. Name: "Fig. 4. Water uptake capacity (a) and MB adsorption behavior (b) of different beads."



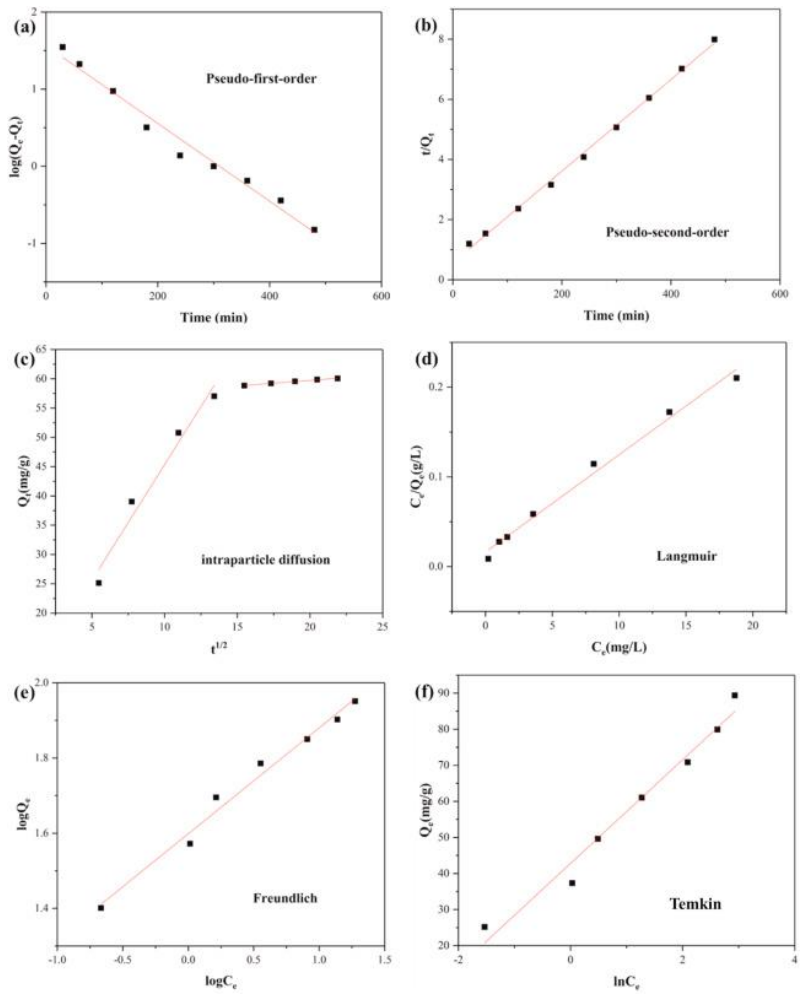
As the graphene amount increases the adsorption of MB dye increases. However, the result seems to look like a logarithmic function and levels of after 3:10 ratio. Water uptake decreases to adsorb more dyes.

Name: “Fig. 5. (a) Effect of temperature on MB adsorption; (b) Effect of pH on MB adsorption; (c) Effect of contact time on MB adsorption; (d) Effect of initial MB concentration on adsorption.”



Adsorption capacity increases with temperature, time, and concentration. Peaked at 6 pH and varies from that amount of pH causes lower capacity.
Similarly, removal rate of Mb follows a similar trend except for concentration which decreases due to the beads being saturated.

Name: “Fig. 7. (a) Pseudo-first-order model for MB adsorption; (b) Pseudo-second-order model for MB adsorption; (c) Intraparticle diffusion model for MB adsorption; (d) Langmuir model for MB adsorption; (e) Freundlich model for MB adsorption; (f) Temkin model for MB adsorption.”

	 A: the adsorption capacity over time increases with time that it becomes larger than the adsorption capacity when removal rate of MB dye is stagnant. B: The slope of this model shows the inverse of the adsorption capacity at certain times which is 0.0269 Also, the chemical reaction is pseudo second order due to the data fitting with B more than A with R^2 being 0.998 > 0.976. C: Shows the time when the adsorption capacity with time reaches an equilibrium R^2 of the Langmuir model is the greater than both Freundlich and Temkin at 0.990 which shows that the reaction behaves like an ideal gas, so the adsorption occurs mostly on the surface of the beads.
VOCAB: (w/definition)	Carbide: any of a class of chemical compounds in which carbon is combined with a metallic or semimetallic element. XRD patterns: The diffraction pattern is called a Kikuchi diffraction pattern, which consists of pairs of parallel lines, each of which represents a set of atomic planes. Intraparticle diffusion: The transfer of adsorbate in the pores of the adsorbent
Cited references to follow up on	Wei, Z., Peigen, Z., Wubian, T., Xia, Q., Yamei, Z., & ZhengMing, S. (2018). Alkali treated Ti3C2Tx MXenes and their dye adsorption performance.

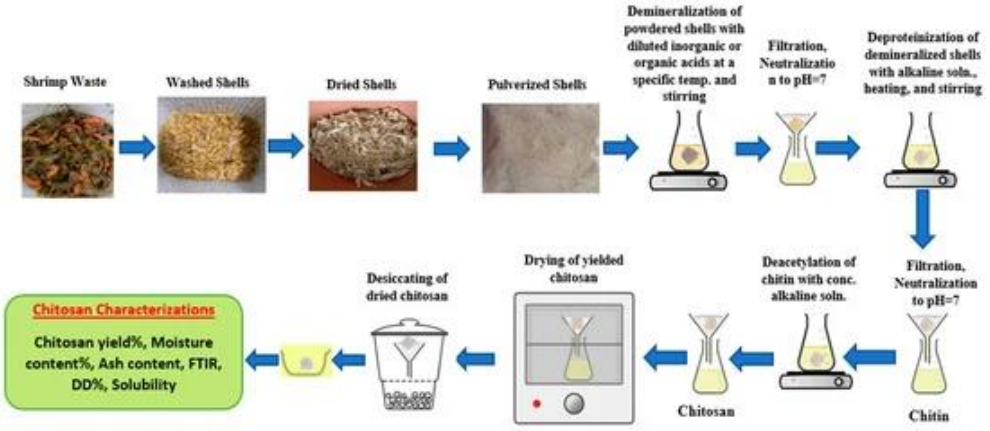
	Materials Chemistry and Physics, *206*, 270–276. https://doi.org/10.1016/j.matchemphys.2017.12.034
Follow up Questions	How would other materials be used with graphene affect adsorption? Can immobilized fungi be incorporated into these beads to provide biodegradation? How does the mixing rate affect adsorption?

Article #16 Notes: A Review of the Chemical Extraction of Chitosan from Shrimp Wastes and Prediction of Factors Affecting Chitosan Yield by Using an Artificial Neural Network

Source Title	A Review of the Chemical Extraction of Chitosan from Shrimp Wastes and Prediction of Factors Affecting Chitosan Yield by Using an Artificial Neural Network
Source citation (APA Format)	Hosney, A., Ullah, S., & Barčauskaitė, K. (2022). A review of the chemical extraction of chitosan from shrimp wastes and prediction of factors affecting chitosan yield by using an artificial neural network. *Marine Drugs*, *20*(11), 675. https://doi.org/10.3390/md20110675
Original URL	https://www.mdpi.com/1660-3397/20/11/675
Source type	Journal Article
Keywords	shrimp shells, chitosan, chemical extraction, neural networks
#Tags	“The impact of the independent parameters” (for the influence of different variables in the during extraction); “2.1. Chemical Demineralization of Shrimp Shells” (for the processes within the extraction method); “2.5.1. Moisture Content Determination” (for ways to determine chitosan’s quality and the effectiveness of each method).
Summary of key points + notes (include	This is a review article, so its methodology is compiling research from many other articles. Furthermore, neural network is employed to comprise many research

methodology)	articles to predict a method with the highest chitosan yield. Shrimp waste is a major pollutant, so it is necessary to repurpose them. Chitosan, which is a derivative of chitin, has many potential uses, such as medicinal values and for wastewater treatment. There are 3 primary ways to extract chitosan: chemical extraction which is cheap and efficient but produce relatively more waste; biochemical extraction is more eco-friendly but takes a longer time and is not as effective at removing the minerals and proteins from the shell; and biological extraction, which has the same problem. General methodology for extraction of chitosan: Demineralization, deproteinization, and deacetylation Demineralization: This step is to get rid of minerals found in shrimp shells, which are mostly calcium carbonate. Hence, hydrochloric acid works best by converting the carbonate into other materials. Organic acids can also be used, such as citric or acetic acid, but they are less effective. Deproteinization: This step is to get rid of proteins from the shell by subjecting it to an alkaline solution that will separate the bond of the proteins from the chitosan. Sodium Hydroxide is the most effective agent for this method. Removing more proteins will produce a higher quality of chitosan. Deacetylation: This step is very similar to the last step as an alkaline solution is used to replace an acetyl group from chitin and replace it with an amino group. The concentration of the alkaline is much higher than that for the deproteinization process. Sodium Hydroxide remains the most effective agent for this process. The degree of deacetylation, which is how many amino groups are in the chemical, directly affects the quality of chitosan. Determining the chitosan quality: The moisture content of chitosan affects its longevity, so a lower percentage is preferred. It is determined with the equation: (wet weight – dry weight)/wet weight. The solubility of the chitosan is one of the most important indications of chitosan's quality, and a higher solubility is preferred. This is to measure the success of the deacetylation process. The ash content percentage is obtained by burning the chitosan and measuring the ashes' weight relative to the pre-burned chitosan. This is a great indication of the success of the demineralization process. In high quality chitosan, this number should be less than or close to 0.01. Results obtained from the multilayer perceptron network: The network's model's predictions fit well with the 65 articles that it reviewed showing the viability of the model, and the close relationship between the steps of the process for obtaining chitosan. The model shows that the alkaline concentration for deacetylation is the most important as it affects the percent yield of chitosan the greatest, and the concentration of the agents is the most influential variable in all three processes.
Research	How do different variables (concentration of agents, temperature, and time)

Question/Problem/ Need	within the extraction method affect the percent yield of chitosan?
Important Figures	Name: “Figure 2. Chitin and chitosan chemical extraction from shrimp shells.”



Shows the general process of obtaining chitosan from shrimp shell waste. Up until the pulverization process, the shrimp shell is cleaned thoroughly to remove any other materials than pure shrimp shells before treatment. Then, acid is used for demineralization, alkaline is used for both deproteinization and deacetylation.

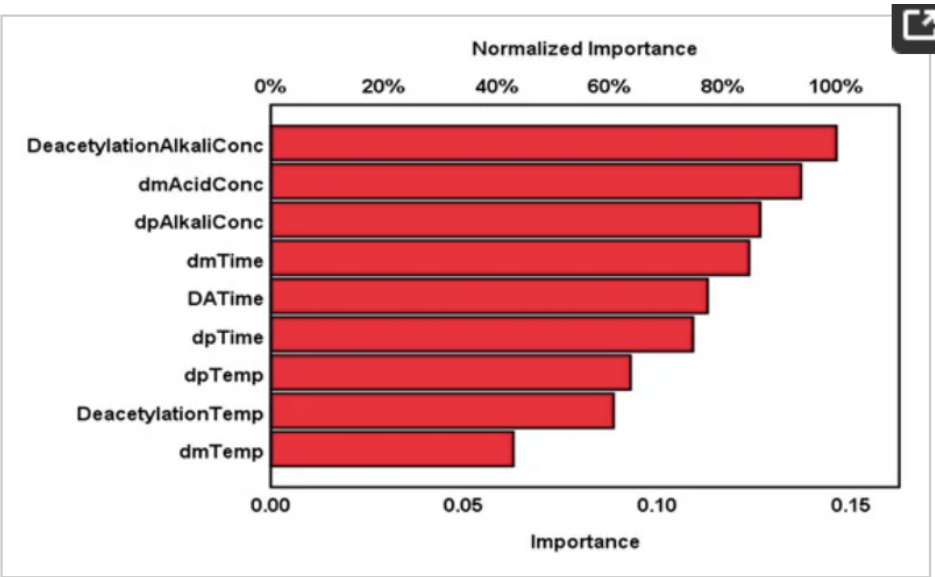
Name: “Table 1. Chitin and chitosan yield percentage under distinctive chemical extraction conditions”

Table 1. Chitin and chitosan yield percentage under distinctive chemical extraction conditions [51].

Demineralization Acid Concentration (%)	Deproteinization Alkali Concentration (%)	Chitin Yield %	Deacetylation Alkali Concentration (%)	Deacetylation Temperature (°C)	Chitosan Yield %
10	1.5	30.6	50	60–70	30.00
10	3	29.1	50	60–70	28.00
10	6	28.7	50	60–70	27.00
10	8	27.7	50	60–70	25.20
20	1.5	28	50	60–70	27.80
20	3	27.7	50	60–70	27.50
20	6	26.4	50	60–70	25.80
20	8	24.9	50	60–70	24.30
30	1.5	24.4	50	60–70	24.10
30	3	24	50	60–70	23.80
30	6	22.6	50	60–70	21.76
30	8	21.8	50	60–70	20.50
40	1.5	23.8	50	60–70	22.80
40	3	22.6	50	60–70	22.20
40	6	21.1	50	60–70	20.60
40	8	20.2	50	60–70	19.50
50	1.5	22.1	50	60–70	20.90
50	3	20.7	50	60–70	19.50
50	6	19.4	50	60–70	17.80
50	8	18.2	50	60–70	15.40

This table is obtained from an optimization study for the concentration of acid and alkaline solution for the demineralization and deproteinization process respectively. It seems that a lower concentration of acid and alkaline is needed for higher chitosan yield.

Name: “Figure 9. Independent variables important chart of chemical extraction parameters.”

	 The result of the neural network. Dm is demineralization, and dp is deproteinization.
VOCAB: (w/definition)	Neural Network Modeling: A machine learning program, or model, that makes decisions in a manner similar to the human brain, by using processes that mimic the way biological neurons work together to identify phenomena, weigh options and arrive at conclusions. Multilayer Perceptron: a type of artificial neural network that consists of multiple layers of neurons, or nodes, arranged in a hierarchical structure.
***Cited references to follow up on**	Aitboulahsen, M., Chairi, H., Laglaoui, A., Arakrak, A., Zantar, S., Bakkali, M., & Hassani, M. (2018). Optimization and characterization of gelatin and chitosan extracted from fish and shrimp waste. *E3S Web Conf.*, *37*, 02006. https://doi.org/10.1051/e3sconf/20183702006
Follow up Questions	Is this also true with chitosan obtained from yeast? Can the quality of chitosan be raised after the extraction? What is the total cost of the extraction?

Article #17 Notes: Chitinous polymers: extraction from fungal sources, characterization and processing towards value-added applications

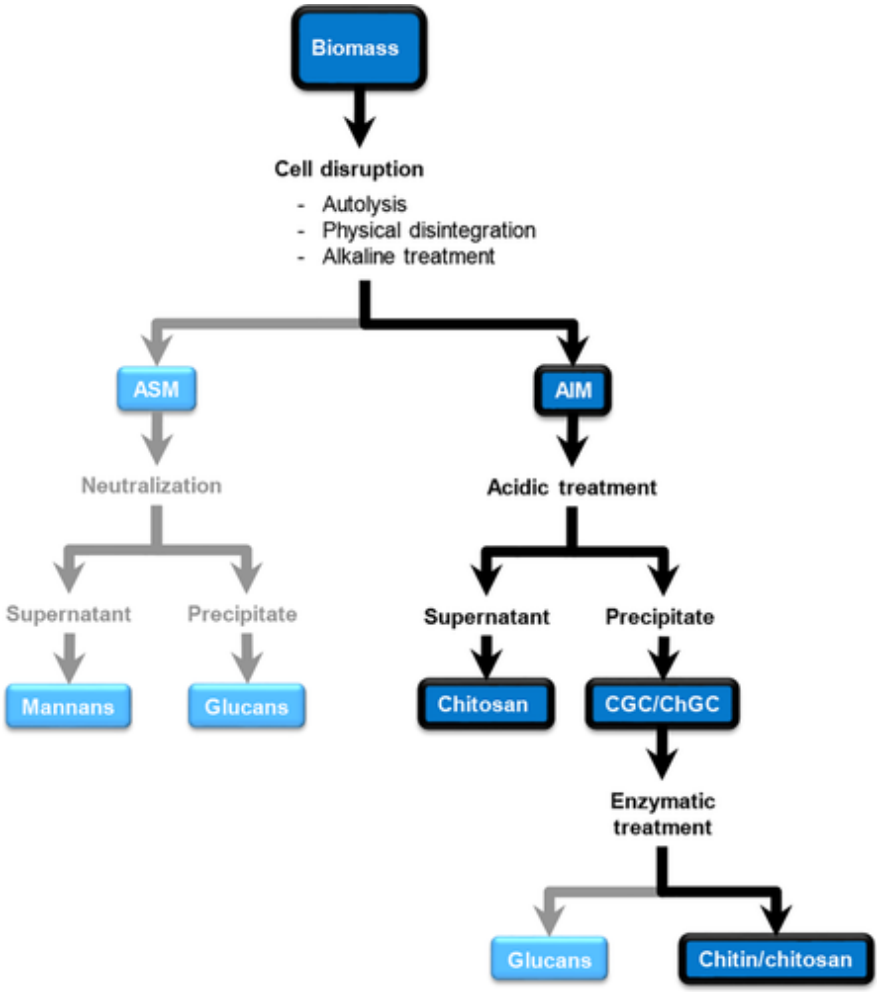
Source Title	Chitinous polymers: extraction from fungal sources, characterization and processing towards value-added applications
Source citation (APA	

Format)	Araújo, D., Ferreira, I. C., Torres, C. A., Neves, L., & Freitas, F. (2020). Chitinous polymers: Extraction from fungal sources, characterization and processing towards value-added applications. *Journal of Chemical Technology & Biotechnology*, *95*(5), 1277–1289. https://doi.org/10.1002/jctb.6325
Original URL	https://scijournals.onlinelibrary.wiley.com/doi/10.1002/jctb.6325
Source type	Journal Article
Keywords	Chitosan, fungi, extraction, polymer
#Tags	EXTRACTION OF POLYMERS FROM THE FUNGAL CELL-WALL, “Several procedures have also been used” (for methods to purify chitosan), “the most commonly used being infrared (IR) spectroscopy” (method for evaluating chitosan purity)
Summary of key points + notes (include methodology)	This is a review article that combines many articles that contribute to understanding the extraction of chitin from fungi. Chitosan obtained from crustaceans are not consistent as different animals have different amounts of chitosan. However, the amount of chitin in fungal cells is more consistent, so the extraction from fungal cells is more reliable. Chitin is found in the fungi’s cell wall where the chemical makes a fiber-like structure. The methods discussed in this article can also be applied to fungal biomass waste. General procedure for extraction: It starts with disrupting the cell wall by subjecting the cell to an alkaline solution that will dissolve many of the cell wall’s components except chitin. Then, use an acid solution to generate a pH of 4.0 to dissolve the chitosan, as the other materials within the fungi are insoluble, so they can be later separated through centrifugation. After that, the chitosan is extracted from the solution through a precipitation after subjecting the solution to a potent alkaline, changing the pH to 9.0 pH. Other techniques for making purer chitosan by using other chemicals for decolorization and supporting the deproteinization and demineralization process, such as subjecting the chitosan to potassium permanganate. Determine the quality of then chitosan through spectroscopy analysis where the chitosan is mixed with Potassium Bromide. The formula to obtain the percentage of the acetyl group to show the effectiveness of the deacetylation process: **(1655 cm^-1 / 3450cm^-1) * 115,** the higher the value the better. Chitosan has a lot of uses besides wastewater treatment such as providing medicinal values and other biological uses.
Research Question/Problem/ Need	What is the process of extracting chitosan from fungi?
Important Figures	Name: “Table 1. Chitinous polymer production by different organisms using different cultivation modes and substrates”

Product	Organism	Cultivation mode	Substrate	Production yield (%)	Reference
Chitosan	*Gongronella butleri*	Submerged	Sweet potato	12.7	25
		Solid state		9.2	
Chitosan	*Rhizopus arrhizus*	NA	Corn steep liquor and honey	3.0	26
Chitosan	*Rhizopus arrhizus*	NA	Molasses and corn steep liquor	4.9	10
Chitosan	*Cunninghamella elegans*	NA		3.3	
Chitin	*Rhizopus arrhizus*	NA		8.3	
Chitin	*Cunninghamella elegans*	NA		7.2	
Chitin	*Cunninghamella elegans*	NA	Glucose	24	27
Chitin	*Cunninghamella elegans*	Submerged	Yam bean	6.6	28
Chitin	*Aspergillus terreus*	Submerged	Glucose	34	21
Chitosan				4.8	
CGC	*Schizophyllum commune*	Submerged	Sucrose	15.2–30.2	12
CGC	*Komagataella pastoris*	Fed-batch mode	Crude glycerol	18–26	16
CGC	*Komagataella pastoris*	Fed-batch mode	Glucose	16	29
			Xylose	15	
			Glucose/xylose	18	

Shows the percent yield of the method in extracting chitin and its derivatives. This is useful for determining the expected percent yield.

Name: “Figure 2: Schematic representation of cell-wall fractionation procedures for recovery of polymers from fungal biomass (ASM, alkali-soluble matter; AIM, alkali-insoluble matter; CGC, chitin–glucan complex; ChGC, chitosan–glucan complex).”

	 This is for the general procedure of the extraction of chitin and its derivatives
VOCAB: (w/definition)	Microfibril: One of the submicroscopic elongated bundles of cellulose of a plant cell wall N-acetyl group: An N-Acetyl Group is defined as a crucial moiety found in chitin and chitosan, playing a significant role in molecular recognition, binding with specific receptors, and influencing the solubility and antibacterial activity of these compounds. Moiety: Each of two parts into which a thing is or can be divided.
Cited references to follow up on	Cardoso, A., Lins, C. I., Dos Santos, E. R., Silva, M. C., & Campos-Takaki, G. M. (2012). Microbial enhance of chitosan production by Rhizopus Arrhizus using agroindustrial substrates. *Molecules*, *17*(5), 4904–4914. https://doi.org/10.3390/molecules17054904
Follow up Questions	How much cheaper is obtaining chitosan from fungi than obtaining chitosan from crustaceans?

	How much purer are the chitosan after subjecting it to the decolorization method? How is yeast cultured?

Article #18 Notes: Two-phase extraction, characterization, and biological evaluation of chitin and chitosan from *Rhizopus oryzae*

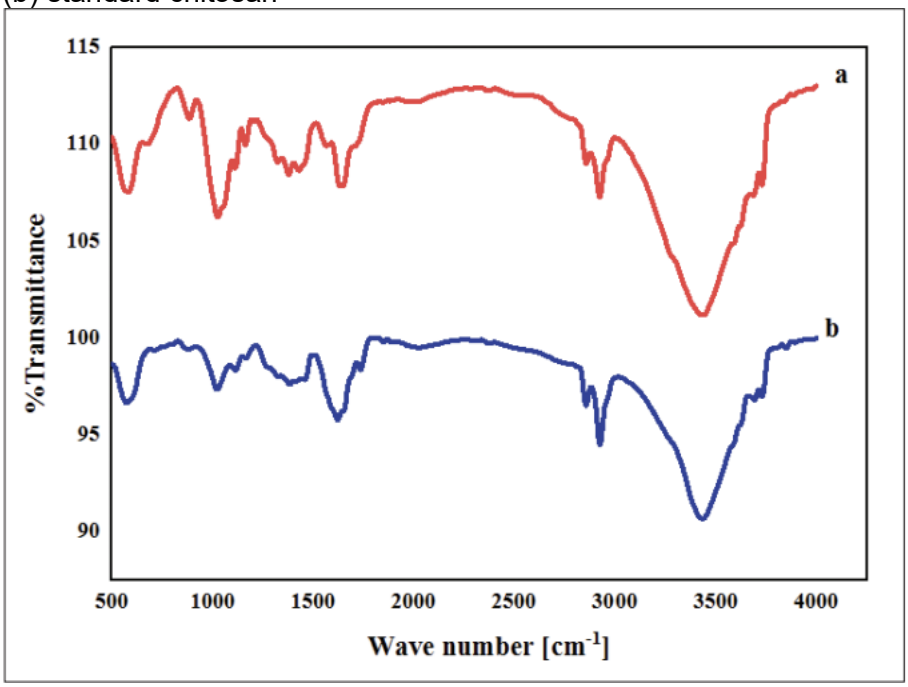
Source Title	Two-phase extraction, characterization, and biological evaluation of chitin and chitosan from *Rhizopus oryzae*
Source citation (APA Format)	Gachhi, D. B., & Hungund, B. S. (2018). Two-phase extraction, characterization, and biological evaluation of chitin and chitosan from Rhizopus oryzae. *Journal of Applied Pharmaceutical Science*, *8*(11), 116–122. https://doi.org/10.7324/japs.2018.81117
Original URL	https://japsonline.com/admin/php/uploads/2771_pdf.pdf
Source type	Journal Article
Keywords	Chitin, chitosan, FTIR, XRD, anti-bacterial activity, antioxidant activity.
#Tags	“Materials and Methods,” “Material characterization”
Summary of key points + notes (include methodology)	Chitosan is soluble in organic acid such as citric acid, but its solubility in inorganic acid such as HCl is limited. Because a large amount of potent alkaline is needed to obtain chitosan from crustaceans, there is a need for an alternative method to obtain chitosan. Obtaining chitosan from fungi is a potential solution because instead of using alkaline solution, chitosan can be produced from fungi through fermentation. Chitosan has many medicinal values, is used in agriculture, wastewater treatment, and other prominent industries. The method in this article only employed sulphuric acid. Methodology: Fungal culture: The fungi is grown in a dextrose agar, incubated for 5 days at room temperature, and is chilled at 4 C. Two phase extraction: The fungi is filtered and dried. Then, dealkylation was carried out using 1N NaOH. After that, deacetylation was conducted using 1% sulphuric acid at a high temperature. Then, it was subjected to the alkaline treatment again, and is homogenized and autoclaved at 121 C. Then, centrifuge at 6000 rpm. The liquid was obtained and cooled. Then, subject the liquid to centrifugation again to obtain the chitosan. The chitosan’s degree of deacetylation. The degree of deacetylation was determined through the use of spectroscopy to find the ratio of absorbance of wavelength 1655 cm^-1 and

	wavelength 3450cm^-1. Results: This method performed better than the traditional HCl because the acid tends to leave phosphate impurities which the H2SO4 will not. The chitosan obtained was 72.51% deacetylated which is about 16% less than standard chitosan but is still a respectable amount for the simplicity of this method. Furthermore, the amount of chitosan obtained was doubled from the original method for obtaining the chemical from fungi.
Research Question/Problem/ Need	How effective is the two-phase extraction method developed in this article at obtaining chitosan?
Important Figures	Name: "Table 1. Degree of deacetylation, molecular weight, and viscosity of chitin and chitosan from Rhizopus oryzae (NCIM 877)."

Sl. No	Sample	Degree of deacetylation (%)	Molecular weight (Da)	Viscosity (cP)
1	Standard chitin	23.84	4.32×10^5	4.90
2	Standard chitosan	88.08	2.12×10^5	1.68
3	Chitin from *Rhizopus oryzae*	10.24	2.7×10^6	5.63
4	Chitosan from *Rhizopus oryzae*	72.51	3.5×10^5	3.08

This figure shows the effectiveness of the method being comparable to standard chitosan without producing much waste.

Name:" Figure 3. FTIR spectrum of (a) chitosan from Rhizopus oryzae and (b) standard chitosan"



This graph shows that chitosan obtained from the experiment is comparable to standard chitosan. However, the chitosan obtained from the experiment is slightly worse because less absorption of light is observed.

VOCAB: (w/definition)	Sabouraud's dextrose medium: A type of agar growth medium containing

	peptones. It is used to cultivate dermatophytes and other types of fungi.
Cited references to follow up on	Alagesan, M., Panneerselvam, A., & Rathinam, K. M. S. (2016). Extraction, Optimization and Characterization of Chitosan from Penicillium chrysogenum. *International Journal of Current Microbiology and Applied Sciences,* 19-26. https://api.semanticscholar.org/CorpusID:212447092
Follow up Questions	How well does this method work on baker's yeast? How to improve the quality of chitosan using this method? Could hot sulphuric acid be used for extracting chitosan from crustaceans as well?

Article #19 Notes: New insights on the decolorization of waste flows by *Saccharomyces cerevisiae* strain – A systematic review

Source Title	New insights on the decolorization of waste flows by *Saccharomyces cerevisiae* strain – A systematic review
Source citation (APA Format)	Ghodsi, S., Kamranifar, M., Fatehizadeh, A., Taheri, E., Bina, B., Hublikar, L. V., Ganachari, S. V., Nadagouda, M., & Aminabhavi, T. M. (2024). New insights on the decolorization of waste flows by Saccharomyces cerevisiae strain – A systematic review. *Environmental Research*, *249*, 118398. https://doi.org/10.1016/j.envres.2024.118398
Original URL	https://www.sciencedirect.com/science/article/pii/S0013935124003025?via%3Dihub
Source type	Journal Article
Keywords	Baker's yeast, Textile wastewater, Dyes and color, Saccharomyces cerevisiae
#Tags	"Yeast immobilization," "3.1.3. Biodegradation,"
Summary of key points + notes (include methodology)	Introduction: Millions of tons of dyes pollute human's water sources each day. Hence, the caliber of pollution due to dyes within wastewater is tremendous. Synthetic dye is more popular than natural dye due to them being cheaper. Furthermore, methylene blue dye, which is an ionic dye, is dangerous because of its reactivity and other health concerns, such as acting as a catalyst for cancer.

	Methods of decolorization: Advanced oxidation process, photocatalytic degradation, electrocatalytic degradation, coagulation/flocculation, Fenton oxidation method, filtration, and adsorption. Most of these methods are expensive and require a lot of energy, but adsorption, leading to coagulation and flocculation is cheap. Methods: Review past particles and compile their results. Removal rate declines as dye concentration increases. As the amount of yeast increases, the efficiency of the reaction increases. Optimal pH varies with the type of dye used, but for Methylene blue dye, the optimal pH is mostly close to 7pH. Methods for the yeast to remove dye: **Biosorption**: Yeast biomass adheres to the dye and extracts it from the wastewater. This is because the yeast cell walls have functional groups that allow it to bind with the pollutant in the effluent. At high pH, the cell wall becomes negatively charged which helps with adsorption of cationic dyes, in this case is Methylene Blue. More yeast would increase the number of active sites for biodegradation and adsorption, leading to a higher removal rate of dyes. For Methylene blue dye, the temperature of the environment should not be above 35 C to decrease the efficiency of its removal. **Bioaccumulation** in yeast happens when Carbon and Nitrogen is provided, so the dye accumulates within the cell as it longer needs to degrade the dye into those materials. This method requires a constant supply of those two elements, making it more expensive. **Biodegradation**: The yeast adapts to the dye and degrades it into simple nontoxic chemicals. Biodegradation by yeast may be slow, but it is effective. The pH affects the growth of the fungi, so maintaining a pH of 4-5 is preferable for biodegradation. **Immobilization of yeast cells**: By adsorption: Immobilize the cell using electrostatic force for the yeast to be attracted to Fe3O4 By contact to surface: Less chance to lose cells than the previous method. Covalent bond between the carrier used to immobilize the yeast and the yeast. By entrapment: Most common method, the cell is within a polymer matrix. This is nontoxic, cheap, and fast to catalyze the yeast's ability of biodegrade. By encapsulation: Similar to the previous method, but the carrier's walls are semipermeable, making it less efficient due to it promoting cell growth, breaking the membrane. By self-aggregation: Yeasts themselves grow in large mass, and the cells deep within the mass are immobilized. Used in wastewater treatment.
Research Question/Problem/ Need	How effective is ye
Important Figures	Name: "Comparison of the affecting parameters on biosorption process by S. cerevisiae during dye removal."

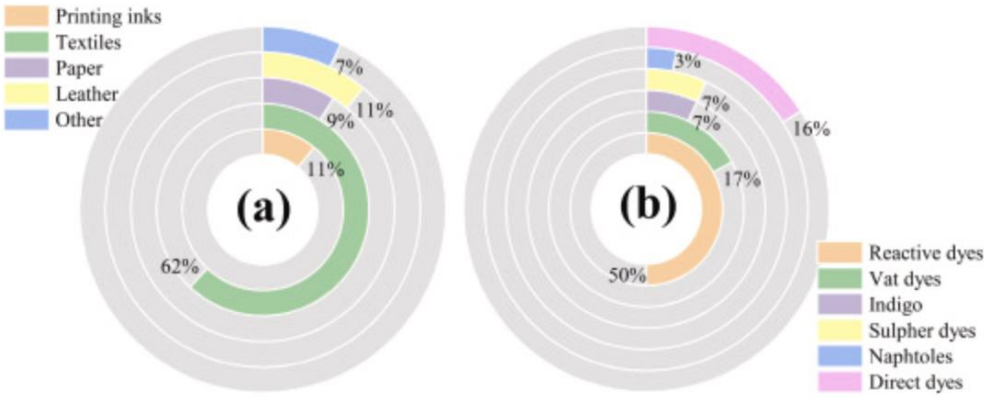
Table 2
Comparison of the affecting parameters on biosorption process by *S. cerevisiae* during dye removal.

Sorbent type	Modification method	Pollutant	Conditions	Removal efficiency (%) or sorption capacity (mg/g)	Ref
$ZnFe_2O_4$ nanoparticle functionalized baker's yeast, Pure yeast	Functionalized, Pre-treat	Methylene blue (MB)	Yeast dose: 2.5 g/L, dye concentration: 100 mg/L, pH: 7, time: 90 min.	Sips = 108.3 mg/g (composite), Sips = 70.5 (pure yeast)	Zhang and Zhang (2020)
S. cerevisiae	Pre-treat	C. I. Reactive Red 2	Yeast dose:1.25 g/L, pH: 2, temperature: 30 °C, time: 90 min.	500 mg/g	Zhang and Wang (2013)
baker's yeast modified with Peat	Immobilization via adsorption, Pre-treat	Crystal violet	Yeast dose: 0.2 g/L, dye concentration: 100 mg/L, pH: 10, time: 150 min.	Sips = 17.9 mg/g, Langmuir = 15.1 mg/g	Zehra et al. (2016)
Poly (methacrylic acid) modified baker's yeast	Functionalized	MB, Rhodamine B (RB), Basic magenta (BM)	Yeast dose: 0.05 g/L, dye concentration: 1×10^{-3} mol/L, pH: 6.5, time: 70 min, temperature: 35 °C	MB, RB, and BM were 869.6, 267.4, and 719.4 mg/g	Yu et al. (2009)
S. cerevisiae	–	Remazol Orange RR	Yeast dose: 2 g/L, dye concentration: 200 mg/L, pH: 3, temperature: 25 °C.	84.9%	Ulas and Ergun (2019)
baker's yeast modified by nano-Fe_3O_4	Functionalized, Pre-treat	Methyl violet	Yeast dose: 0.5 g/L, pH: 6, dye concentration: 300 mg/L, time: 30 min, temperature: 25 °C.	60.8 mg/g	Tian et al. (2010)
S. cerevisiae immobilized on calcium alginate	Immobilization via encapsulation	Methylene green (MG)	Yeast dose: 0.25 g/L, dye concentration: 140 mg/L, pH: 5, temperature: 35 °C, time: 240 h.	17 mg/g	Godbole and Sawant (2006)
xanthate-modified baker's yeast	Functionalized	MB	Yeast dose: 0.2 g/L, dye concentration: 100 mg/L, pH: 7, temperature: 35 °C.	64.5 mg/g	Song et al. (2019)
Baker's yeast modified MnO_2 composites.	Functionalized	MG	Yeast dose: 1 g/L, dye concentration: 100 mg/L, pH: 10, temperature: 25 °C, time: 120 min.	Sorption capacity: 86.7 mg/g, Langmuir = 243.9 mg/g	Santos et al. (2019)
S. cerevisiae immobilized calcium alginate (SC-A-5%), *S. cerevisiae* immobilized chitosan (SC–C-2.5%)	Immobilization via encapsulation	Orange II, Indigo Carmine	Yeast dose: 1 g/L, OII concentration: 30 mg/L, IC concentration: 50 mg/L, pH: 5	27.8% and 58.3% (alginate), 17.2% and	Rusu et al. (2021)
Yeast (*S. cerevisiae*) extract capped on the surface of Ag nanoparticles	–	MB	Yeast dose: 0.2 g/L, dye concentration: 10 mg/L, time: 6 h	80%	Roy et al. (2015)
S. cerevisiae	–	Alizarin Red S	Yeast dose: 0.4 g/L, dye concentration: 75 mg/L, pH: 3, time: 120 min	69%	Ramavandi et al. (2019)
S. cerevisiae	–	m-[(4-dimethylamino) phenylazo] benzenesulfonic acid, methyl orange	Yeast extract (0.25%, wt/vol), glucose (2%, wt/vol), and 0.2 mmol/L of the tested dye	–	Ramalho et al. (2005)
S. cerevisiae	–	Reactive Red 120	Yeast dose: 8.25 g/L, dye concentration: 16.25 mg/L, pH: 4.75, time: 52.5 min.	99.9%	Navaeia et al. (2019)
S. cerevisiae immobilized on Luffa	–	Direct Red 23	Yeast dose: 100 mg/L, pH: 2.5, time: 240 h, temperature: 30 °C	49.42% (disks), 65.5% (powder)	Morão et al. (2017)
Chitosan Beads with Immobilized *S. cerevisiae*	–	Acid Blue 25 dye	Yeast dose: 50 g/L, dye concentration: 100 mg/L, pH: 2.5, time: 240 min.	28.2 mg/g	Mendes et al. (2021)
S. cerevisiae	–	Direct Orange 2 GL	Yeast dose: 0.5 g/L, dye concentration: 50 mg/L, pH: 4, time: 90 min	0.06 mg/g	Mendes et al. (2015)
S. cerevisiae	–	MB	Yeast dose:1.32 g/L, dye concentration: 14.37 mg/L, pH: 9.35, time: 50.81 min	99.16%	Mazloomi et al. (2021)
S. cerevisiae	–	Ramazole blue (Vinyl sulfone)	Yeast dose: 0.25 g/L, dye concentration: 100 mg/L, pH: 2, time: 60 min, temperature: 25 °C	100%	Mahmoud (2016)
S. cerevisiae	–	MG	Yeast dose: 1 g/L, dye concentration: 100 mg/L, pH: 6, time: 60 min, temperature: 30 °C	75.18%	Liu et al. (2019)
S. cerevisiae	–	C.I. Reactive Black 8, C.I. Reactive Brown 9, C.I.Reactive Green 19, C.I. Reactive Blue 38, and C.I. Reactive Blue 3	Yeast dose: 1 g/L, dye concentration: 50 mg/L, pH: 6, time: 15 min, temperature: 30 °C	71–91%	Kumari and Abraham (2007)
Diatomite modified yeast	Functionalized	MB	Yeast dose: 1 g/L, dye concentration: 1000 mg/L, time: 96 h, temperature: 25 °C	93.3 mg/g	Ma et al. (2019)
S. cerevisiae, Pretreatment *S. cerevisiae*	Pre-treat	MB	Yeast dose:10 g/L, dye concentration: 100 mg/L, pH: 5, time: 1440 min, temperature: 20 °C	Raw *S. cerevisiae* = 91%, Pretreated *S. cerevisiae* = 94%	Guler and Sarioglu (2014)

Sorbent type	Modification method	Pollutant	Conditions	Removal efficiency (%) or sorption capacity (mg/g)	Ref
S. cerevisiae	–	MB, brilliant green	Yeast dose: 0.3 g/L, dye concentration: 8 mg/L for each dye, time = 5 min, room temperature.	100%	Ghaedi et al. (2013)
S. cerevisiae	–	Astrazone Blue basic	Yeast dose: 4 g/mL, dye concentration: 200 mg/L, pH: 7, time: 120 min, temperature: 30 °C	70 mg/g	Farah et al. (2007)
S. cerevisiae	–	Levafix brilliant blue	Yeast dose: 0.05 g/L, dye concentration: 250 mg/L, pH: 3, time: 10–15 min, temperature: 30 °C	172 mg/g	Erkurt and Olaifa (2021)
S. cerevisiae Immobilized Pumice Stone		Remazol Yellow	Yeast dose: 2.5 g/L, dye concentration: 400 mg/L, pH: 3, time: 450 min, temperature: 25 °C	99% and 140 mg/g	Erdem and Ergun (2020)
S. cerevisiae	–	Yellow 2 (BY2), Basic Green 4 (BG4)	Yeast dose: 1 g/L, dye concentration: 40 mg/L, pH: 5, time: 240 min, temperature: 30 °C	96% (BG4), 93% (BY2)	Kelewou et al. (2014)
S. cerevisiae	–	Acid Blue 161	Yeast dose: 2.5 g/L, dye concentration: 100 mg/L, pH: 2.5, time: 180 min, temperature: 20 °C	Sorption capacity: 1.25 mg/g and Langmuir: 0.86 mg/g	Dilarri et al. (2016)
Immobilization of *S. cerevisiae* by contact (ICC), Encapsulation of *S. cerevisiae* matrix (ECM) in cross-linked chitosan beads,	Immobilization via contact to surface	Direct Orange 2 GL	Yeast dose: 2.5 g/L, dye concentration: 100 mg/L, pH: 2.5, time: 300 min, temperature: 40 °C	34.7 mg/g (pure yeast), 35.2 mg/g (ECM), 31.7 mg/g (ICC)	Dilarri and Corso (2018)
S. cerevisiae	–	Acid Orange 7, Direct violet 51	Yeast dose: 4 mL of 30% S.M in 10 mL of dye, dye concentration: 3700 mg/L, time: 312 h, temperature: 30 °C	84%	Almeida et al. (2018)
S. cerevisiae immobilized on Fe_3O4 magnetic nanoparticles	Functionalized	Methyl orange	Yeast dose: 1.5 g/L, dye concentration: 50 mg/L, pH: 6.5, time: 140 min, temperature: 35 °C	96.5%	Azeez and Al-Zuhairi (2022)
S. cerevisiae	–	Methyl Green	Yeast dose: 0.075 g/L, dye concentration: 50 mg/L, pH: 7, time: 80 min, temperature: 40 °C	20.1 mg/g	Al-Tameemi et al. (2022)
S. cerevisiae	–	Remazol Blue reactive	Yeast dose: 1 g/L, dye concentration: 91 mg/L, pH: 2, time: 80 min, temperature: 25 °C	89 mg/g	Aksu and Dönmez (2003)
Baker's yeast and mix with nano-polyaniline	–	Acid Red 14	Yeast dose: 0.1 g/L, dye concentration: 500 mg/L, pH: 4, time: 60 min, temperature: 25 °C	86%(mix), 63% (alone)	Ahmed et al. (2016)
S. cerevisiae	–	Eosin Y, Eosin B	Yeast dose: 2 g/L for Y and 0.1 g/L for B, dye concentration: 200 mg/L, pH: 4 for Y and 2 for B, time: 180 min, temperature: 45 °C	1000 mg/g for B and	Bahramifar et al. (2015)
S. cerevisiae	–	Methyl orange	Yeast dose: 5 g/L, dye concentration: 50 mg/L, pH: 5, time: 48 h	dry (90.7%), wet (94.5%)	El-Sayed et al. (2018)
S. cerevisiae	–	Acid Red 14	Yeast dose: 0.4 g/L, dye concentration: 520 mg/L, pH: 3, time: h, temperature: 45 °C		Farah and El-Gendy (2013)
S. cerevisiae	–	M-Anisidine	Yeast dose: 2 g/L, dye concentration: 50 mg/L, time: 100 min, temperature: 30 °C	88.8%	Asiagwu (2019)
S. cerevisiae	–	Remazol Blue, Remazol Black B, Remazol Red RB	dye concentration: 10.8 mg/L (Blue), 13.3 mg/L (Black), 46.7 mg/L (Red RB), pH: 3, time: h, temperature: 25 °C	88.5 mg/g (Black B), 84.6 mg/g (Blue), 48.8 mg/g (Red RB)	Aksu (2003)
S. cerevisiae	Pre-treat	MB	Acid concentration: 2 N, biosorbent dose: 10 g/L, time: 48 h	117.4 mg/g (treated), 45.7 mg/g (untreated)	Pratibha et al. (2010)
S. cerevisiae	–	Brilliant Red HE-3B	Yeast dose: 4 g/L, dye concentration: 50 mg/L, pH: 2.3, temperature: 20 °C	104.2 mg/g	Suteu et al. (2013)
S. cerevisiae immobilized on calcium alginate	Immobilization via entrapment	MG	Yeast dose: 0.49 g/L, dye concentration: 188 mg/L, pH: 6.8, time: 60 min, temperature: 20 °C	96.25%	Singh et al. (2012)

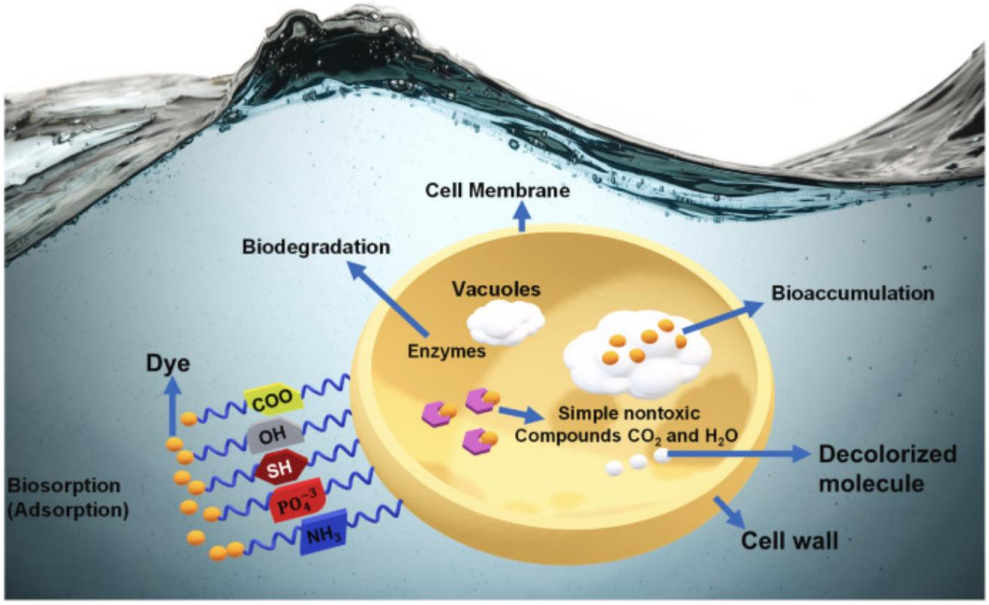
The optimal pH for treatment of MB dye is around 7pH.

Name: “Fig. 1. (a) Industry with high dyes application (Bulk Chemicals Industry, 2023) and (b) worldwide consumption of dyes for dyeing of cellulose fibers (Božič and Kokol, 2008).”



The textile industry is responsible for 62% of the usage of dyes. Methylene blue dye is a direct dye which encompasses 16% of the total dye consumption.

Name: “Fig. 5. Schematic of the mechanisms of dye removal by S. cerevisiae.”



The diagram shows how the yeast degrades dyes: the dye enters the cell and accumulates, so the enzyme degrades it into nontoxic molecules, which leaves the cell wall.

Name: “Table 4. Comparison of biodegradation of dyes by various S. cerevisiae-based biomass during the biodegradation process.”

biomass type	Modification method	Pollutant type	Conditions	Removal efficiency (%)	Ref
S. cerevisiae (ATCC 9763) immobilized in calcium alginate	Immobilization via encapsulation	Methyl red	Dye concentration: 100 mg/L, time: 6 h, temperature: 30 °C	100%	Vatandoostarani et al. (2018)
S. cerevisiae immobilized on calcium alginate	Immobilization via entrapment	Acid Blue 161, Procion Red MX-5B	Dye concentration: 200 mg/L (100 mg/L Acid Blue 161 + 100 mg/L Procion Red MX-5B), biomass suspension volume: 3 g/L	100%	de Almeida et al. (2019)
Immobilized *S. cerevisiae* with polyethyleneimine-treated sugarcane bagasse	–	Acid Black 48	Yeast dose: 5 g/L, dye concentration: 100 mg/L, pH: 2.5, time: 216 h, temperature: 30 °C	26% (immobilized), 90% (free)	Mitter and Corso (2013)
S. cerevisiae	–	Carmoisine	Dye concentration: 50 mg/L, time: 7 h, temperature: 30 °C	100%	Kiayi et al. (2019)
S. cerevisiae	–	MG	Yeast dose: 2 g/L, dye concentration: 100 mg/L, time: 7 h (distilled water) and 4 h (glucose medium), temperature: 33 °C	85% (distilled water), 95.5% (5% glucose medium)	Jadhav and Govindwar (2006)
S. cerevisiae catalyzed by NZVI	Functionalized	Direct Blue 71	Yeast dose (presence of NZVI):1 g/L, dye concentration: 200 mg/L, pH: 6.5, time: 48 h (present catalyst) 72 h (absent catalyst), temperature: 28 °C	Absence of the catalyst: 96%, in the presence of 0.1% NZVI: 100%	Fetyan et al. (2016)
S. cerevisiae	–	MB	Yeast dose: 0.2 g/L, dye concentration: 20 mg/L, pH: 3.5, time: 24 h, temperature: 30 °C	83.50%	Acosta Rendon (2020)
S. cerevisiae	–	Carmoisine, Reactive Black 5	biosorbent dose: 10 g/L, dye concentration: 25 (RB5) and 50 (C) mg/L, time: 24 h, temperature: 28 °C	85% (RB5), 53% (C)	Sadeghi et al. (2014)
S. cerevisiae	–	Methyl orange	Yeast dose: 5 g/L, dye concentration: 50 mg/L, pH: 5, time: 48 h	Dry (90.7%), wet (94.5%)	El-Sayed et al. (2018)
S. cerevisiae	–	m-[(4-dimethylamino) phenylazo] benzenesulfonic acid, methyl orange	yeast extract (0.25%, wt/vol), glucose (2%, wt/vol), and 0.2 mmol/L of the tested dye	–	Ramalho et al. (2005)
Secretion of Three Fungal Laccases from *S. cerevisiae*	–	Methyl red, saturn blue, coomassie brilliant blue G-250, bromophenol blue, remazol brilliant blue	pH: 4.6, time: 4 d, temperature: 25 °C	–	Antošová et al. (2018)
the consortium of *Canna indica* and *S. cerevisiae*		Congo red	Dye concentration: 100 mg/L, time: 72 h, temperature: 30 °C	73%	Jadhav et al. (2023)

Although immobilizing the yeast would result in more efficiency, the yeast themselves still removes a considerable percentage of dyes, so a cost analysis needed to be conducted to determine if immobilization is necessary.

	Name: “Table 6. Kinetics, isotherm, and thermodynamic of dye adsorption by S. cerevisiae yeast.”

Condition	Kinetic	Isotherm	Thermodynamic	Ref
Immobilized *S. cerevisiae* by $AnFe_2O_4$ (2.5 g/L), MB (100 mg/L), pH: 7, time: 90 min	Pseudo-second order (PSO) (composite), Pseudo-first order (PFO) (pure yeast)	Freundlich (composite), Langmuir (pure yeast)	–	Zhang and Zhang (2020)
Pre-treated *S. cerevisiae* (1.25 g/L), C. I. Reactive Red 2, pH: 2, time: 90 min.	–	Langmuir	$\Delta G<0$, $\Delta H>0$, $\Delta S>0$	Zhang and Wang (2013)
Modified *S. cerevisiae* with peat (0.2 g/L), Crystal violet (100 mg/L), pH: 10, time: 150 min.	PSO	Sips	$\Delta G<0$, $\Delta H>0$, $\Delta S>0$	Zehra et al. (2016)
Poly (methacrylic acid) modified baker's yeast (0.05 g/L), MB, RB, and BM (1 mM), pH: 6.5, time: 70 min	–	Langmuir	MB: Decrease in efficiency with temperature increasing, RB and BM: efficiency increasing with temperature increasing	Yu et al. (2009)
S. cerevisiae (2 g/L), remazol orange RR (200 mg/L), pH: 3	PSO	Langmuir	$\Delta G<0$, $\Delta H>0$, $\Delta S>0$	Ulas and Ergun (2019)
Modified *S. cerevisiae* by nano-Fe_3O_4 (0.5 g/L), methyl violet (300 mg/L), pH: 6, time: 30 min	PSO	Langmuir	$\Delta G<0$, $\Delta H>0$, $\Delta S>0$	Tian et al. (2010)
S. cerevisiae immobilized on calcium alginate (0.25 g/L), MG (140 mg/L), pH: 5, time: 240 min	–	Freundlich	–	Godbole and Sawant (2006)
Xanthate-modified *S. cerevisiae* (0.2 g/L), MB (100 mg/L), pH: 7	PSO	Langmuir	$\Delta G<0$, $\Delta H>0$, $\Delta S>0$	Song et al. (2019)
Modified *S. cerevisiae* by MnO2 composites (1 g/L), MG (100 mg/L), pH: 10, time: 120 min.	PSO	Langmuir	$\Delta G<0$, $\Delta H>0$, $\Delta S>0$	Santos et al. (2019)
S. cerevisiae (0.4 g/L), Alizarin Red S (75 mg/L), pH: 3, time: 120 min	–	Alizarin Red S	Yeast dose: 0.4 g/L, dye concentration: 75 mg/L, pH: 3, time: 120 min	Ramavandi et al. (2019)
S. cerevisiae (8.25 g/L), Reactive Red 120 (16.25 mg/L), pH: 4.75, time: 52.5 min.	PSO	Langmuir	–	Navaeia et al. (2019)
S. cerevisiae immobilized on Luffa (100 mg/L), Direct Red 23, pH: 2.5, time: 240 min	–	Langmuir	–	Morão et al. (2017)
Chitosan Beads with Immobilized *S. cerevisiae* (50 g/L), acid blue 25 (100 mg/L), pH: 2.5, time: 240 min.	PSO	Langmuir	$\Delta G>0$, $\Delta H>0$, $\Delta S>0$	Mendes et al. (2021)
S. cerevisiae (0.5 g/L), direct orange 2 GL (50 mg/L), pH: 4, time: 90 min	–	Langmuir	–	Mendes et al. (2015)
S. cerevisiae (0.25 g/L, ramazole blue (vinyl sulfone) (100 mg/L), pH: 2, time: 60 min	–	Freundlich	–	Mahmoud (2016)
S. cerevisiae (1 g/L) reactive dyes (50 mg/L), pH: 6, time: 15 min	–	Langmuir	Temperature: 20–40 °C, lowest efficiency at 20 °C and highest efficiency at 30 °C.	Kumari and Abraham (2007)
Diatomite modified yeast (1 g/L), MB (1000 mg/L), time: 96 h	–	Langmuir	–	Ma et al. (2019)
Pretreated *S. cerevisiae* (10 g/L), MB (100 mg/L), pH: 5, time: 1440 min	PSO	Langmuir	R-MB: $\Delta G<0$, $\Delta H<0$, $\Delta S<0$ and P-MB: $\Delta G<0$, $\Delta H<0$, $\Delta S>0$	Guler and Sarioglu (2014)
S. cerevisiae (0.3 g/L), MB and brilliant green (8 mg/L, time = 5 min	PSO	Freundlich	–	Ghaedi et al. (2013)
S. cerevisiae catalyzed by NZVI (1 g/L), direct blue 71 (200 mg/L), pH: 6.5, time: 48 h	–	–	Increasing decolorization activity with incubation temperature increasing (25–37 °C). Highest activity at 28 °C (100%)	Fetyan et al. (2016)
S. cerevisiae (4 g/L), astrazone blue (200 mg/L), pH: 7, time: 120 min	–	Langmuir	Endothermic system. Sorption of astrazone blue improved with increasing temperature from 20 °C to 50 °C	Farah et al. (2007)
S. cerevisiae (0.05 g/L), levafix brilliant blue (250 mg/L), pH: 3, time: 10–15 min	PSO	Langmuir	$\Delta G<0$, $\Delta H<0$, $\Delta S>0$	Erkurt and Olaifa (2021)
S. cerevisiae (1 g/L), BY2 and BG4 (40 mg/L), pH: 5, time: 240 min	PFO	–	–	Kelewou et al. (2014)
S. cerevisiae (2.5 g/L), acid blue 161 (100 mg/L), pH: 2.5, time: 180 min	PSO	Langmuir	$\Delta G>0$, $\Delta H>0$, $\Delta S>0$	Dilarri et al. (2016)
Immobilization of *S. cerevisiae* by contact, encapsulation of *S. cerevisiae* matrix in cross-linked chitosan beads, immobilization via contact to surface (2.5 g/L), direct orange 2 GL (100 mg/L), pH: 2.5, time: 300 min	PSO	*S. cerevisiae* biomass: Langmuir, all cross-linked chitosan beads: Freundlich	*S. cerevisiae* biomass: $\Delta G<0$, $\Delta H>0$, $\Delta S>0$, Cross-linked chitosan beads: $\Delta G>0$ at 10–30 °C and $\Delta G<0$ at 50 °C, $\Delta H>0$ and $\Delta S>0$ for all temperature, Cross-linked chitosan beads $\Delta G>0$ at 10–30 °C and $\Delta G<0$ at 50 °C, $\Delta H>0$ and $\Delta S>0$ for all temperature, Cross-linked chitosan beads: $\Delta G>0$ at 10–20 °C and $\Delta G<0$ at 30–50 °C, $\Delta H>0$ and $\Delta S>0$ for all temperature	Dilarri and Corso (2018)
S. cerevisiae immobilized on Fe_3O_4 (1.5 g/L), methyl orange (50 mg/L), pH: 6.5, time: 140 min	–	Freundlich	$\Delta G<0$, $\Delta H<0$, $\Delta S>0$	Azeez and Al-Zuhairi (2022)
S. cerevisiae (0.075 g/L), methyl green (50 mg/L), pH: 7, time: 80 min	PSO	Langmuir	$\Delta G<0$, $\Delta H>0$, $\Delta S>0$	Al-Tameemi et al. (2022)
S. cerevisiae (1 g/L), remazol blue reactive (91 mg/L), pH: 2, time: 80 min	PSO	Langmuir	–	Aksu and Dönmez (2003)
S. cerevisiae mix with nano-polyaniline (0.1 g/L), acid red 14 (500 mg/L), pH: 4, time: 60 min	PSO	–	–	Ahmed et al. (2016)

Freundlich and Langmuir isotherm models are the ones that are most used for assessing yeast’s removal of dyes.

VOCAB: (w/definition)	Advanced oxidation process: The chemical advanced oxidation (CAO) is defined as the process which uses strong oxidants to transform contaminants or pollutants in the aquatic system to a less toxic or non-toxic substance by the reduction-oxidation system (Redox). Photocatalytic process: an advanced oxidation process, which can be used to degrade pollutants with high concentration, complexity and low biodegradability. The process uses light energy to drive pollutant degradation Electrocatalytic degradation: An electrocatalytic reaction is defined as an inner sphere electrochemical reaction where reactants interact with the electrode surface. It involves the use of electrocatalysts to lower activation energy without affecting reaction thermodynamics, aiming to carry out desired reactions with high efficiency.
Cited references to follow up on	Mazloomi, S., Bonyadi, Z., Haghighat, G. A., Nourmoradi, H., Soori, M. M., & Eslami, F. (2021). Removal of methylene blue by Saccharomyces cerevisiae:

	Process modelling and optimization. *Desalination and Water Treatment*, *236*, 318–325. https://doi.org/10.5004/dwt.2021.27679
Follow up Questions	Is the modification or immobilization of yeast cells necessary?

Article #20 Notes: Removal of methylene blue by *Saccharomyces cerevisiae*: process modelling and optimization

Source Title	Removal of methylene blue by *Saccharomyces cerevisiae*: process modelling and optimization
Source citation (APA Format)	Mazloomi, S., Bonyadi, Z., Haghighat, G. A., Nourmoradi, H., Soori, M. M., & Eslami, F. (2021). Removal of methylene blue by Saccharomyces cerevisiae: Process modelling and optimization. *Desalination and Water Treatment*, *236*, 318–325. https://doi.org/10.5004/dwt.2021.27679
Original URL	https://www.sciencedirect.com/science/article/pii/S1944398624069741?ref=cra_js_challenge&fr=RR-1
Source type	Journal Article
Keywords	Biodegradation, Saccharomyces cerevisiae, Methylene blue, Response surface methodology
#Tags	“2.2. Preparing the reaction mixtures” (methodology), “Results and discussion” (for optimal condition)
Summary of key points + notes (include methodology)	Methylene blue dye is one of the major pollutants within industrial wastewater. Yeast can biodegrade and adsorb the dye, thereby effectively removing it. Hence, using yeast would be cheap, and not dangerous due to the nontoxicity and nonpathogen nature of the yeast. Methodology: Various amounts of methylene blue dye, pH, reaction time, and amount of yeast were mixed in a solution. To assess the effectiveness of the yeast at removing the dye, spectroscopy was employed, and the wavelength of 660 nm was used. An equation was developed to determine the importance of the 4 mentioned, separate factors that affect

	yeast's removal rate of MB. A fourier transformation was employed to find the absolute condition to maximize yeast's efficiency. Results: The optimal condition for yeast is pH of 9.35, 50.81 minutes reaction time, dye concentration of 14.37 mg/L, and 1.32 g/L of yeast. This results in removing 99.16% of the methylene blue dye present in the solution. After conducting multiple statistical tests, the model was determined to be statistically significant and viable at determining the optimal conditions. Furthermore, the model is best fitted to a quadratic with an R^2 of 0.984. Relationship of MB concentration and removal rate: Increasing concentration leads to a decrease of the yeast's effectiveness. Relationship of yeast dosage and removal rate: Increasing the concentration leads to an increase of the yeast's effectiveness. This is because more yeast provides more active sites, so the methylene dyes are detected by the yeasts more often. Relationship of contact time and removal rate: Increasing contact time leads to an increase of the yeast's effectiveness, until the change levels out at 55 about minutes. Relationship of pH and removal rate: Increasing the pH leads to an increase in removal rate because that makes the yeasts have a negative charge to attract the cationic dye easier.
Research Question/Problem/ Need	What is the optimal condition for the yeast to remove methylene blue dye for a solution?
Important Figures	$$R(\%) = \frac{(C_0 - C_e)}{C_0} \times 100$$ The equation for determining the removal rate of the dye. C is the concentration of methylene blue dye within the solution. Name: "Range and levels of independent factors in the study"

Factor	Variable level			
	Code	–1	0	+1
MB (mg/L)	*A*	10	55	100
Reaction time (min)	*B*	10	35	60
S. cerevisiae dosage (g/L)	*C*	0.2	0.85	1.5
Solution pH	*D*	4	7	10

This table is necessary to understand the following table that shows the result of the experiment.

Name: "BBD matrix for MB removal by S. cerevisiae"

Run no	Coded variable				Removal (%)	Run no	Coded variable				Removal (%)
	A	*B*	*C*	*D*			*A*	*B*	*C*	*D*	
1	1	1	0	0	47.12	16	–1	0	0	–1	52.03
2	0	–1	0	1	62.13	17	0	1	0	–1	38.03
3	0	–1	1	0	63.15	18	0	0	0	0	63.24
4	–1	–1	0	0	72.01	19	0	0	0	0	65.01
5	–1	1	0	0	77.03	20	0	1	–1	0	36.15
6	0	1	1	0	61.23	21	1	0	0	–1	52.16
7	–1	0	1	0	93.14	22	0	0	–1	1	49.36
8	0	0	0	0	66.05	23	0	1	0	1	56.12
9	0	0	1	–1	47.12	24	1	0	0	1	51.02
10	1	0	–1	0	48.12	25	–1	0	0	1	96.11
11	–1	0	–1	0	57.09	26	0	0	–1	–1	36.12
12	0	0	0	0	67.19	27	0	–1	0	–1	46.13
13	0	0	1	1	71.23	28	1	–1	0	0	58.03
14	1	0	1	0	54.02	29	0	0	0	0	67.08
15	0	–1	–1	0	45.29						

This table shows that the highest removal of MB in the experiment was 96.11% with the condition of 10 MB (mg/L), 35 minutes, 0.85 g/L of the yeast, and 10 pH. This shows that a high pH is preferred, the dosage of yeast should be somewhat close to 1, a longer reaction time is preferred, and a lower dosage of MB dye is preferred.

VOCAB: (w/definition)

Response surface plot: A graph that provides a three-dimensional visual representation of the data to aid interpretation. A response surface for a similarity effect is shown in Figure 1 as an example. The two predictor variables X and Y are located on the two axes at the bottom of the coordinate cube.

Cited references to follow up on

Aksu, Z. (2003). Reactive dye bioaccumulation by Saccharomyces cerevisiae. *Process Biochemistry*, *38*(10), 1437–1444. https://doi.org/10.1016/S0032-9592(03)00034-7

Follow up Questions

Do the optimal conditions change if different types of pollutant were added in addition to MB dye?
What variable affects the removal rate the greatest?
How would the yeast perform in other types of dye?