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BIOET401Q
Annotated bibliography
Title: Penn State should install filters to remove microplastic from on-campus laundry effluent
Submitted: 17 March 2020

1. Agrawal, K., Chaturvedi, V. & Verma, P. Fungal laccase discovered but yet undiscovered. *Bioresour. Bioprocess.* **5**, (2018).

   Summarizes the laccase enzyme molecular structure, redox mechanisms. Proposal relevance: Fungal laccases secrete laccase which can degrade plastic. Filtration system may be mechanical or biological.

2. Bilal, M., Rasheed, T., Nabeel, F., Iqbal, H. M. N. & Zhao, Y. Hazardous contaminants in the environment and their laccase-assisted degradation – A review. *J. Environ. Manage.* **234**, 253–264 (2019).

   Documents laccase ability to chemically reduce a range of emerging contaminants including endocrine disruptors. Proposal relevance: Table 2 summarizes laccase immobilizing materials used for pharmaceutical contaminants.

3. Bornscheuer, U. T. Insights | *Science (80-.).* 1154–1155 (2016).

   Describes the I. sakaiensis bacterium PETase enzyme degradation of PET plastic into MHET. Proposal relevance: Bacteria exist with the capability to degrade PET. This can be explored for biological filtration.

4. Browne, M. *et al.* Accumulation of Microplastic on Shorelines Worldwide: Sources and Sinks - Environmental Science & Technology (ACS Publications). (2016).

   Experimentally quantifies microplastic fibers produced by washing polyester clothing. Provides evidence showing the microplastic composition of laundry effluent to the microplastic content of sediment in off-shore sewage disposal sites is similar. Proposal relevance: Justification for why laundry effluent is potentially a significant source of microplastic pollution.

5. Fujisawa, M. Degradation of polyethylene and nylon-66 by the laccase-mediator system. *J. Polym. Environ.* **9**, 103–108 (2001).

   Demonstrates the laccase mediator system is capable of degrading polyethylene by 10-fold in three days, and nylon-66 by 4-fold. Proposal relevance: 4-10 fold degradation of plastic in 3 days demonstrates potential feasibility for incorporating biological filter experiments in Penn State laundry effluent treatment system.

6. Geyer, R., Jambeck, J. R. & Law, K. L. Production, use, and fate of all plastics ever made. *Sci. Adv.* **3**, 19–24 (2017).

   Estimates the global pollution load by plastic type from 1950-2015. Also estimates plastic end-of-life destination which shows that landfill and marine environments are significant sinks for plastic waste. Proposal relevance: Quantitative justification for addressing the need to reduce microplastic pollution.

7. Habib, D., Locke, D. C. & Cannone, L. J. Synthetic fibers as indicators of municipal sewage sludge, sludge products, and sewage treatment plant effluents. *Water. Air. Soil Pollut.* **103**, 1–8 (1998).

   Lint samples were taken from washing machines and dryers. Plastic fibers make it into municipal sewage. Polarized light microscopy is used to detect plastic fibers in sewage sludge. This method can be used to trace sewage effluent into water bodies. Proposal relevance: Microplastic pollution are significant in sewage effluent and make it through the sewage treatment plant processes.

8. Hock, O. G., Lum, H. W., Qin, D. De, Kee, W. K. & Shing, W. L. The growth and laccase activity of edible mushrooms involved in plastics degradation. *Curr. Top. Toxicol.* **15**, 57–62 (2019).

   Three types of edible mushrooms produce the laccase enzyme which are capable of degrading polyethylene and polystyrene. Proposal relevance: Plastic waste filtered from waste water can potentially serve as compost nutrient for mushroom agriculture.

9. Jacquin, J. *et al.* Microbial ecotoxicology of marine plastic debris: A review on colonization and biodegradation by the “plastisphere”. *Front. Microbiol.* **10**, 1–16 (2019).

   Review article summarizes bacteria and fungi capable of degrading specific plastic types, genomic techniques used to identify microorganisms, geographic sampling locations. Enzymatic degradation pathways are detailed. Degradation rates are noted to be low even in optimized laboratory conditions. Proposal relevance: Plastic degradation at sea is difficult. Therefore mitigation should occur upstream from marine environments.

10. Jambeck, J. *et al.* Plastic waste inputs from land into the ocean. *Science (80-.).* **347**, 3–6 (2015).

    Data on population density and solid waste provide estimate for marine plastic pollution. Proposal relevance: Recommends improvements to waste management systems in order to avoid plastic waste entering the ocean.

11. Koelmans, A. A. *et al.* Microplastics in freshwaters and drinking water: Critical review and assessment of data quality. *Water Res.* **155**, 410–422 (2019).

    Review summarizes estimates quantity and types of microplastics in bottled water, treated and untreated tap water, groundwater, rivers, lakes, waste water treatment plant effluent and influent. Proposal relevance: Evidence across multiple studies documenting the presence of microplastics in water resources.

12. Krueger, M. C., Harms, H. & Schlosser, D. Prospects for microbiological solutions to environmental pollution with plastics. *Appl. Microbiol. Biotechnol.* **99**, 8857–8874 (2015).

    Review summarizes plastic polymer chemistry, microorganisms capable of degrading specific plastic types, enzymes involved in plastic degradation. Proposal relevance: Transitioning degradation technology to real world application may be difficult. Filtration may require mechanical techniques instead of biological techniques.

13. Logan, B. E. & Rabaey, K. Conversion of Wastes into Bioelectricity and Chemicals by Using Microbial Electrochemical Technologies. *Science (80-.).* **337**, 686–690 (2019).

    Microbial electrochemical technologies use biofilm formation on anodes. Plastic polymers can serve as anode for biofilms to form. Redox reactions result in plastic oxidation and proton release serving as charge flow. Proposal relevance: Plastic acquired from filtration systems may be used for electrochemical applications. Capabilities and limitations of implementing microbial fuel cells are addressed.

14. Mate, D. M. & Alcalde, M. Laccase engineering: From rational design to directed evolution. *Biotechnol. Adv.* **33**, 25–40 (2015).

    Review paper outlining laccase enzyme modification techniques for plastic degradation. Summary of microorganism sources of laccase. Proposal relevance: Krueger et al. and prior papers note the challenges of transitioning microorganism degradation of plastic to real world applications. Biological filtration systems may require modified microorganisms and enzymes to degrade plastic waste in effluent.

15. Ma, B. *et al.* Removal characteristics of microplastics by Fe-based coagulants during drinking water treatment. *J. Environ. Sci. (China)* **78**, 267–275 (2019).

    Documents microfiltration and coagulation technique of microplastics using iron catalysts. Proposal relevance: Penn State can be used as a living laboratory to address microplastic pollution. Non-biological coagulation is a candidate filtration method.

16. Mehra, R., Muschiol, J., Meyer, A. S. & Kepp, K. P. A structural-chemical explanation of fungal laccase activity. *Sci. Rep.* **8**, 1–16 (2018).

    Documents laccase mediator interaction with laccase enzyme. Proposal relevance: Biological filtration systems may need mediator chemistry to enable degradation.

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17. Michels, J., Stippkugel, A., Lenz, M., Wirtz, K. & Engel, A. Rapid aggregation of biofilm-covered microplastics with marine biogenic particles. (2018).

Documents mechanism by which marine microbial coagulation on microplastics results in transfer of plastic waste to ocean floor. Proposal relevance: Evidence documenting the presence of microplastics in water resources.

18. Talvitie, J., Mikola, A., Koistinen, A. & Setälä, O. Solutions to microplastic pollution – Removal of microplastics from wastewater effluent with advanced wastewater treatment technologies. *Water Res.* **123**, 401–407 (2017).

Quantifies performance of microbial bioreactors to remove microplastics during water treatment. Implementation of bioreactor in final stage wastewater treatment can significantly reduce microplastics entering aquatic and marine environments. Proposal relevance: Evidence documenting 20-100 um textile fibers were the predominant microplastic types before and after final water treatment stages. This point emphasizes the need to remove very small fibers from wastewater before the water is re-introduced to watersheds.