BREN SCHOOL OF ENVIRONMENTAL SCIENCE & MANAGEMENT
MESM GROUP PROJECT PROPOSAL 2024-20 25:

Safety and sustainability assessment of pyrolyzed biochar produced from wastewater treatment plant biosolids for agricultural applications

Student authors:

Matilde Saucedo	msaucedo@bren.ucsb.edu	MESM Candidate 2025
Lauren Londoño	llondono@bren.ucsb.edu	MESM Candidate 2025

Client: Santa Ynez Band of Chumash Indians

Julie Randall	JRandall@chumash.gov	Environmental Director

Faculty Advisor:

Dr. Arturo Keller	arturokeller@ucsb.edu	Bren School Professor

Significance and Background

Any community with wastewater treatment plants, from large cities to small towns, has to deal with sewage sludge, which refers to the solid by-product that results from the biological treatment of water (Gopinath et al., 2021[1]). Sewage sludge that is further treated to meet safety standards is referred to as biosolids. The U.S. EPA's 2022 Biosolids Annual Report reveals that 56% of biosolids are used for land applications, mostly agriculture, while 43% are disposed of via landfill or incineration (EPA, 2023[2]). Biosolids are commonly directly used as fertilizer for agricultural purposes, since they are rich in nutrients like nitrogen and phosphorus.

Unfortunately, the routine application of biosolids to land coupled with the increasing amount of contaminants in wastewater that bypass treatment processes (e.g. microplastics, heavy metals, pharmaceuticals, and pathogens), has led to an accumulation of contaminants in the soil over the years (Mohajerani and Karabatak, 2020[3]). This presents health risks to humans since such contaminants can be transferred to crops that are harvested for consumption and leak into sources of drinking water. Consequently, many regions are beginning to ban the use of sludge or biosolids as fertilizer.

One potential solution to this issue is to further process the biosolids via pyrolysis to create biochar, a substance that is rich in nutrients while containing less pollutants and pathogens. Pyrolysis is the process of decomposing biosolids using very high temperatures in conditions without oxygen (Liu et al., 2021[4]). This process is able to remove pollutants such as microplastics, PFAS, chemicals in pharmaceuticals, and personal care products. Biochar has the potential for several applications as a soil amendment to retain moisture, increase nutrient levels, and remove contaminants. It also has the potential to sequester carbon given that biochar is rich in stable carbon that does not easily degrade, so when it is applied to soil it can fix carbon into

the ground for many years (Zhao et al., 2023[5]). Besides producing biochar, pyrolysis also creates pyrolysis gas and bio-oil, making it a valuable process with additional benefits, like useful energy recovery (Liu et al., 2021). Pyrolysis also provides heat energy that can be used for internal wastewater treatment plant processes.

Objectives

The goal of this project is to evaluate whether pyrolyzed biochar from biosolids is a sustainable and safe fertilizer alternative to the use of stand-alone biosolids directly on agricultural fields. More specifically, the objectives are to:

1. Apply biosolid-based biochar and biosolids as fertilizers to grow various CA native plants and food crops on a nursery of the Santa Ynez Band of Chumash Indians.
2. Conduct literature reviews to compare benefits of each fertilizer option, considering the following factors: (a) soil health and nutrient content, (b) contaminant levels, (c) water quality impacts, (d) carbon sequestration potential, and (e) miscellaneous climate change impacts.
3. Compare the life-cycle impacts on water quality and toxicity of biosolids-based biochar vs biosolids.
4. Explore the financial and economic implications of using biosolids-based biochar as a fertilizer for small-scale farming and gardening. This objective could also explore the economic valuation opportunities for other pyrolysis byproducts (i.e. gas and bio-oil) and market-based innovations (e.g. carbon offset or credits).

Equity

Improper disposal of contaminated biosolids and sludge disproportionately affects agricultural communities of lower socioeconomic status. This group project will address this issue by proposing solutions that can mitigate and prevent the contamination of food crops, water, and soil in these affected areas. The findings may help address environmental justice concerns for communities impacted by contaminated biosolids and offer potential economic benefits to affected communities, especially within the Santa Ynez Band of Chumash Indians Reservation. Implementing solutions such as the application of biochar can reduce pollutants and pathogens in biosolids-based fertilizer and also generate jobs and resources, particularly in less affluent regions of Santa Barbara County. The potential for job creation is something we hope to explore through this project. This dual focus on environmental and socioeconomic aspects highlights the importance of mitigating the adverse impacts of contaminated biosolids while fostering equity and justice for affected communities.

Available Data

- Amount of biosolids generated in Santa Barbara County
    - Santa Barbara County Wastewater System Annual Report
- Environmental Protection Agency's Biosolids Library Database
- Literature reviews and case studies on LCA for biochar from pyrolysis LCA
- Available financial and economic data associated with biosolids

- Experimental data from Keller Lab studies (Draft publication: Elimination of microplastics, PFAS, and PPCPs from biosolids via pyrolysis to produce biochar: feasibility and economic analysis)

Possible Approaches

- Source biosolids-based biochar and biosolids to test each as a fertilizer on a nursery of the Santa Ynez Band of Chumash Indians Reservation (~ 0.1 acres). Chemical properties of each substance will be documented and also undergo lab testing prior to application. Research will be conducted before application to determine viable plants and food crops to test with each fertilizer.
- Compare the benefits of biosolids-based biochar vs biosolid fertilizer using public literature sources and data observed through direct testing in the Keller Lab (e.g. nutritional content of soil, presence of contaminants, impacts on water quality, and carbon sequestration).
- Gather relevant publicly available LCA data for biochar and biosolids to compare overall water quality impacts, toxicity, and emissions associated with each fertilizer.
- Dive into the financial and economic impacts of biochar as a fertilizer using literature reviews and previous studies to understand implications for small-scale agriculture and at-home applications. Through this approach we will also be able to explore the valuation potential for pyrolysis gas and bio-oil as well as other market-based innovations that capitalize on the carbon sequestration potential of biochar.

Deliverables

In addition to the required Bren School deliverables (i.e. a final report, executive summary, and final presentation), this project will produce one or more of the following:

- Biowaste management recommendations for the wastewater plant on the Santa Ynez Band of Chumash Indians.
- Repository of specific metrics tested for each fertilizer option before and after application to the soil, in addition to crop nutrition profiles of what is harvested.
- Detailed LCA results of biosolids-based biochar vs biosolids.
- Financial overview of costs associated with biosolid-based biochar for small-scale farmers / individuals.

Internships

The Santa Ynez Band of Chumash Indians will be able to provide $6,000 for part-time internships for 1-2 Bren student(s) in the Group Project during summer 2024. See attached client letter of support.

APPENDIX

Citations

1. Gopinath, A., Divyapriya, G., Srivastava, V., Laiju, A., Nidheesh, P., & Kumar, M. S. (2021). Conversion of sewage sludge into biochar: A potential resource in water and wastewater treatment. *Environmental Research, 194,* 110656. https://doi.org/10.1016/j.envres.2020.110656
2. *Basic Information about Biosolids* | US EPA. (2023, December 15). US EPA. https://www.epa.gov/biosolids/basic-information-about-biosolids
3. Mohajerani, A., & Karabatak, B. (2020). Microplastics and pollutants in biosolids have contaminated agricultural soils: An analytical study and a proposal to cease the use of biosolids in farmlands and utilise them in sustainable bricks. *Waste Management, 107*, 252–265. https://doi.org/10.1016/j.wasman.2020.04.021
4. Liu, Z., Hughes, M., Tong, Y., Zhou, J., Kreutter, W., Valtierra, D., Singer, S., Zitomer, D., & McNamara, P. (2021). Enhanced energy and resource recovery via synergistic catalytic pyrolysis of byproducts from thermal processing of wastewater solids. *Renewable Energy*, *177*, 475–481. https://doi.org/10.1016/j.renene.2021.05.125
5. Zhao, L., Sun, Z. F., Pan, X. W., Tan, J. Y., Yang, S. S., Wu, J. T., Chen, C., Yuan, Y., & Ren, N. Q. (2023). Sewage sludge derived biochar for environmental improvement: Advances, challenges, and solutions. *Water research X*, *18*, 100167. https://doi.org/10.1016/j.wroa.2023.100167

Budget

Other than the internships, it is not anticipated that the proposed project will require additional funding beyond the $1,000 contributed by the Bren School.

Santa Ynez Chumash Environmental Office
P.O. Box 517, Santa Ynez, CA 93460
Phone (805) 688-7997 Email syceo@chumash.gov

January 11, 2024

Group Project Committee
Bren School of Environmental Science & Management
University of California, Santa Barbara

Dear Group Project Committee,

The Santa Ynez Chumash Environmental Office (SYCEO) is pleased to support the group project proposal "*Assessment of sustainability of biochar produced from wastewater treatment plant biosolids for agricultural applications".* This project aims to look at the production of biochar from wastewater biosolids using a process known as pyrolysis to remove contaminants before its application on agricultural lands.

The SYCEO was established in 1998 to provide support to the tribal government and to serve the Chumash tribal community with a mission to prepare tribal lands for environmental adaptation, to protect and regenerate natural resources, and to cultivate the connection between culture, spirit, and community through collaboration and education. As stewards of the land, the SYCEO recognizes the importance of acknowledging and addressing environmental injustices that disproportionately impact communities of color and low-income populations. This project will look at how the application of contaminated biosolids as a fertilizer for crops has led to an accumulation of soil pollutants (i.e., PFAS, metals, pharmaceuticals) in agricultural communities and will evaluate the feasibility of pyrolyzed biochar as a sustainable alternative.

Currently, the SYCEO manages a tribal nursery and propagates native plants for Chumash community members and for habitat restoration projects on the reservation. The proposed project will provide highly useful insight on utilizing biochar as fertilizer to grow native plant species at the nursery. The Chumash tribe also owns and operates a wastewater treatment plant (WWTP) that serves the residents on the reservation, casino and hotel complex, administration buildings, and health clinic. Data collected from this project can be used to provide recommendations to the Chumash WWTP about its biosolids storage, treatment and disposal.

As a client for this project, we are committed to providing guidance and funding support in the amount of $6,000 to the group for 1-2 paid internships during the summer of 2024. We will also provide space at our tribal nursery on the reservation to grow crops and native plants for applying the pyrolyzed biochar as a fertilizer.

If there is any additional information that we can provide to support this project, please let us know. We look forward to the opportunity to work with the students and Professor Keller on this group project.

Sincerely,

Julie Colbert, MESM 2009
Environmental Director
Santa Ynez Chumash Environmental Office
(805) 303-7487 | jrandall@chumash.gov