Land-Based Artwork as a Predictor of Microbial Diversity and Salt Composition

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Project Summary

Metabolic Studio is a unique organization, exploring art-science synergies and promoting the regeneration of the life web through self-sustaining systems. The desiccated Owens Lakebed has provided Metabolic Studio with the landscape for a unique project, developing photos on the lakebed, producing unique images. Understanding the complex relationship between the microbiome of Owens Lake and the salt compositions offers insight on the relationship of microbes to toxic chemicals partitioned in the salts. This research will determine how the halophilic microbial communities of Owens Lakebed, as well as salt compositions of the lakebed, differ pre and post film development. This information will help to investigate the possibility of lakebed photo development as a detection tool, and product, of specific microbes and salts. Previous research on the Owens Lakebed has determined how certain elements, such as arsenic and fluorine, are partitioned into the ground waters and salts, as well as identification of some microbial species present in the Owens Lakebed (Levy et al. 1999). The findings from the proposed research will help to unify these separate ideas, working to determine effects of photo development on both microbial populations and salt compositions. Utilizing photo development as a detection tool will bring forth a new, transdisciplinary approach to detecting microbial populations and chemicals present. To accomplish this, microbial populations pre- and post- film development will be isolated and sequenced through 16s rRNA analysis. Samples pre- and post-film development will also be characterized by their salt compositions and concentrations. The findings from these steps will then be compared to photos developed on the lakebed to determine if photo development can be used as a detection tool of microbial species and salt compositions and concentrations.

Intellectual Merit

The methods of the aforementioned research highlight a fundamental shift in the traditional techniques used to answer, and ask, scientific questions. Using art to glean information on traditional core sciences—chemistry and biology—is a novel technique of transdisciplinary research.

Broader Impacts

Collaboration is a foundation of the proposed research. Sample collection and analysis will be done in collaboration with Metabolic Studio, illustrating the transdisciplinarity of this work. There will also be collaboration with high school students to communicate environmental injustices and land agency further promoting collaboration and learning. The findings from this research will be pertinent to other dry, salt lakebeds to further understanding of the microbial and chemical relationships. The findings will also potentially bring forth a new tool to be used as detection of halophilic organisms and salt compositions with partitioned toxins.

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Statement of Problem and Significance

Owens (dry) lake has long been known as a dry, toxic wasteland—a problem that needs to be solved. In 1913, Owens salt Lake was subjected to an accelerated drying process fueled by the rerouting of its water to the new, at the time, Los Angeles Aqueduct. Due to the human driven desiccation, along with the high salinity of the area, toxic, and often carcinogenic, chemicals are able to come to the surface of the lakebed. The salinity and toxicity of the lake, however, help to provide a unique environment that both allows (1) microbial populations to thrive and (2) land-based art to manifest the distinctive features of the dry lake. The environment—its salinity, toxicity, chemical makeup, and microbiome—can be mapped onto the land, mapped onto the body, and mapped onto art giving a necessary reminder that the land is not simply a human health hazard, but a landscape capable of supporting unique life and creating unique art.

The hazards of Owens Lake can be seen through the land. Due to the drying events of the lake, salt crusts are generated at the surface of the lakebed through evaporation of up flowing groundwater (Levy et al. 1999). When high salinities are reached in the surface salts, ground waters indicate that toxins, such as arsenic and fluorine, are partitioned into these surface salts (Levy et al. 1999).

By many estimates, Owens dry Lake is the largest single source of PM-10 pollution in the United States. Exposure to PM-10 pollution is shown to have both short- and long-term affects ranging from worsening of respiratory diseases, high blood pressure, heart attacks, and increased risk of cancer ("Inhalable Particulate," n.d.). Additionally, acute exposure to arsenic can alter cellular metabolism, causing problems for both energy production and biosynthesis ("Medical Management," 2014). These effects of PM-10 pollution and chemical exposures can be mapped onto the human-body, seen through the effects of the lakebed produced dust storms on the surrounding population.

Not only are humans affected by the unique biome of Owens Lake, but also microbial life. The toxic salt crusts of the dry lake offer a unique microbial environment. Halophilic microorganisms can thrive as well as organisms that are able to utilize or resist the toxic chemicals present such as arsenic.

The salts and chemicals of the lakebed not only create a diverse-eye-catching, toxic landscape, but also map onto land-based artwork created by Metabolic Studios. Images developed by Metabolic Studios in the surface waters on the Owens Lakebed show unique development patterns, lacking uniformity on many of the images. Different coloration patterns occurred, with some veining and cloudiness. These images help to show differences in the development process, and potential roles of microbes and chemicals in this process.

Reflection on the ways the Owens Lakebed maps on the land, on life, and on art brings forth the unique mechanism of art, developing photos, as a detection tool of specific microorganisms, salts, and consequently, portions of the lake with high toxins partitioned into the surface salts. In addition to photo development as a detection tool, it is important to understand the microbial population of the lake pre- and post- film development and their metabolic role in the Owens Lake life web. Utilizing photo development as a detection tool offers a new method to visualize and understand both the toxins of the lake and the microbes, creating a unique piece of art as a product. This method not only offers microbial and chemical information, but also helps to show that Owens Lake is not simply a wasteland, but a unique environment capable of producing beautiful art. The process of photo development as a detection tool could be used at other desiccated salt lakes to get multifaceted results and provide scientific evidence in a mode that community members can appreciate and understand. The findings from this research could help to guide understanding of microbial populations of desiccated salt lakes, and offer new ways to pinpoint toxic chemical partitioning.

Introduction and Background

Relevant Literature

Only when high salinities are reached in the surface salts of Owens Lake, ground waters indicate that arsenic and fluorine are partitioned into these surface salts (Levy et al. 1999) where they can be "readily leached from lakebed salts when exposed to natural precipitation" (Levy et al. 1999). This dry, chemical filled dust and debris can then be spread through wind-blown, PM-10 dust storms with significant amounts of arsenic, fluorine, and salts.

PM-10 pollution refers to airborne particulate matter with a diameter of 10 micrometers or smaller—making it possible for inhalation of the matter. According to the Environmental Protection Agency, as of 2017, Owens Lake emits approximately 300,000 tons of PM-10 yearly with 30 tons of this emission being attributed to arsenic (EPA, n.d.).

Residents from the shoreside town of Keeler have expressed concern at the number of people dying from lung disorders and claimed the dust storms are causing a "slow death" (Roderick, 1989) demonstrating how the environment of Owens Lake bed can be mapped onto the human body.

The microbiome of Owens Lake contains a cycle of trophic chains. Phototrophs, organisms that utilize light for energy, are the primary producers (Pikuta et al. 2003). This includes cyanobacteria and algae. *Spirochaeta* and *Tindallia* genuses are also present in this tropic chain as the primary microorganisms destructing organic materials in anaerobic conditions (Pikuta et al. 2003). Additionally, there are secondary anaerobes that utilize the end products of primary anaerobes (Pikuta et al. 2003). This demonstrates the complex microbial community, and its synergy, present at Owens Lake.

Prior research has determined that salts of Owens Lake are mostly trona, halite, and burkeite (Friedman et al., 1976); however, burkeite, mirabilite, and thenardite are other saline minerals that have been present in the salt flats (“Owens Lake, California”). Sodium carbonate specifically has been seen to be the dominate salt present in water samples (Herbst and Prather, 2014).

Film development involves five main steps; developing, stop bath, fixing, washing, and drying. The step of interest for the proposed research is fixation. Fixation makes a photographic silver image permanent, after development. The image is bathed in a thiosulfate containing solution which forms a “soluble thiosulfate complex with the residual silver halide” (Pope, 1960). Fixation determines the permanence of a silver image by the degree of sulfiding of the silver in the image and the amount of thiosulfate which remains after drying (Pope, 1960).

Preliminary Data

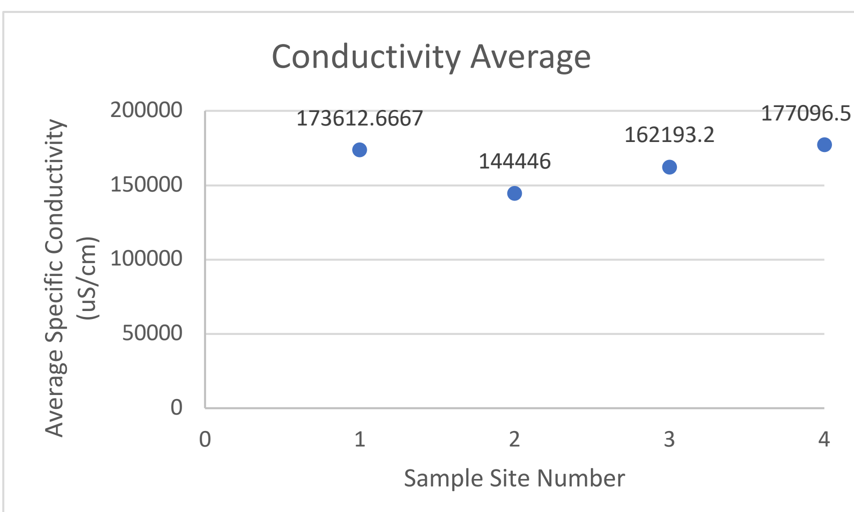


Figure 1.

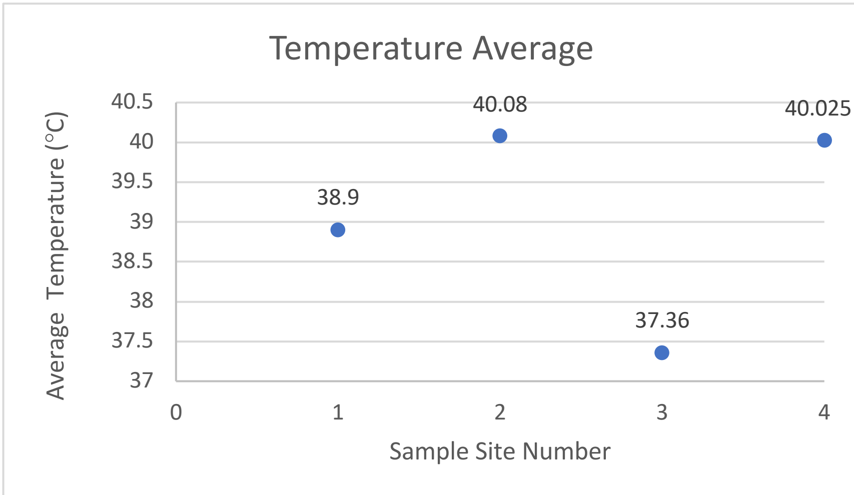
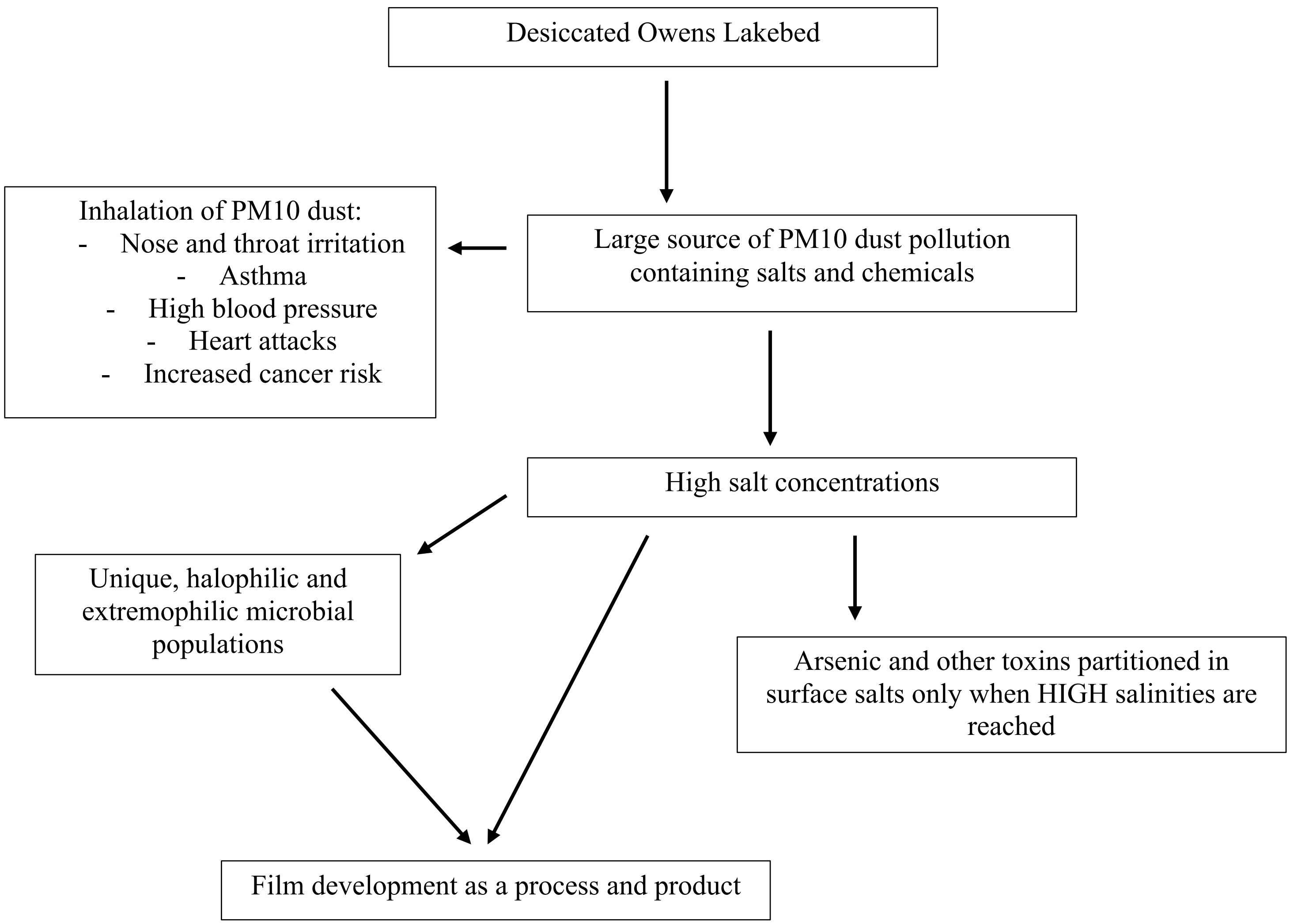


Figure 2.

Preliminary data has shown a range in specific conductivity of the four sample sites. Sample sites 1 and 4 had similar conductivity, averaging at 173,612.67 uS/cm and 177,096.5 uS/cm respectively. Sample site 2 had the lowest conductivity averaging at 144,446 uS/cm, while sample site 3's conductivity was in the middle of this range at 162,193.2 uS/cm. These specific conductivity values can be seen in Figure 1. Variations in conductivity suggest differences in salt concentrations and the saline minerals present between sample sites. Preliminary data also has shown similar temperatures for the four sample sites at around 40 °C; however, sample site 3 is somewhat of an outlier at 37.36 °C. The sample sites' average temperatures can be seen in Figure 2. Differences in temperature of the sample sites could be reflected in the microbial species present. To determine the averages for conductivity and temperature for the sample sites, gross outliers were Q-tested out. Each site had three to five readings taken and averaged.

Conceptual Model



Justification of Approach

To determine the microbial populations of the Owens Lakebed, 16s rRNA gene analysis will be utilized. 16s rRNA gene analysis is widely used to study bacterial phylogeny and taxonomy due to its universal presence, conserved function, and sequence size (Janda and Abbott, 2007). To determine the composition of salts, ion chromatography will be used to determine the cations and anions that comprise the salt. This method has high sensitivity and a wide operating range (Pohl, 2005) making it a useful approach. Photo analysis will be accomplished through multiple techniques. A word bank will be developed in collaboration with Metabolic Studio and local artists in order to have a consistent approach to describing the photos. Additionally, ImageJ will be used to analyze the areas of the photos that have significant disparities. Utilizing ImageJ will allow for a quantification of differences between the photos.

Research Plan

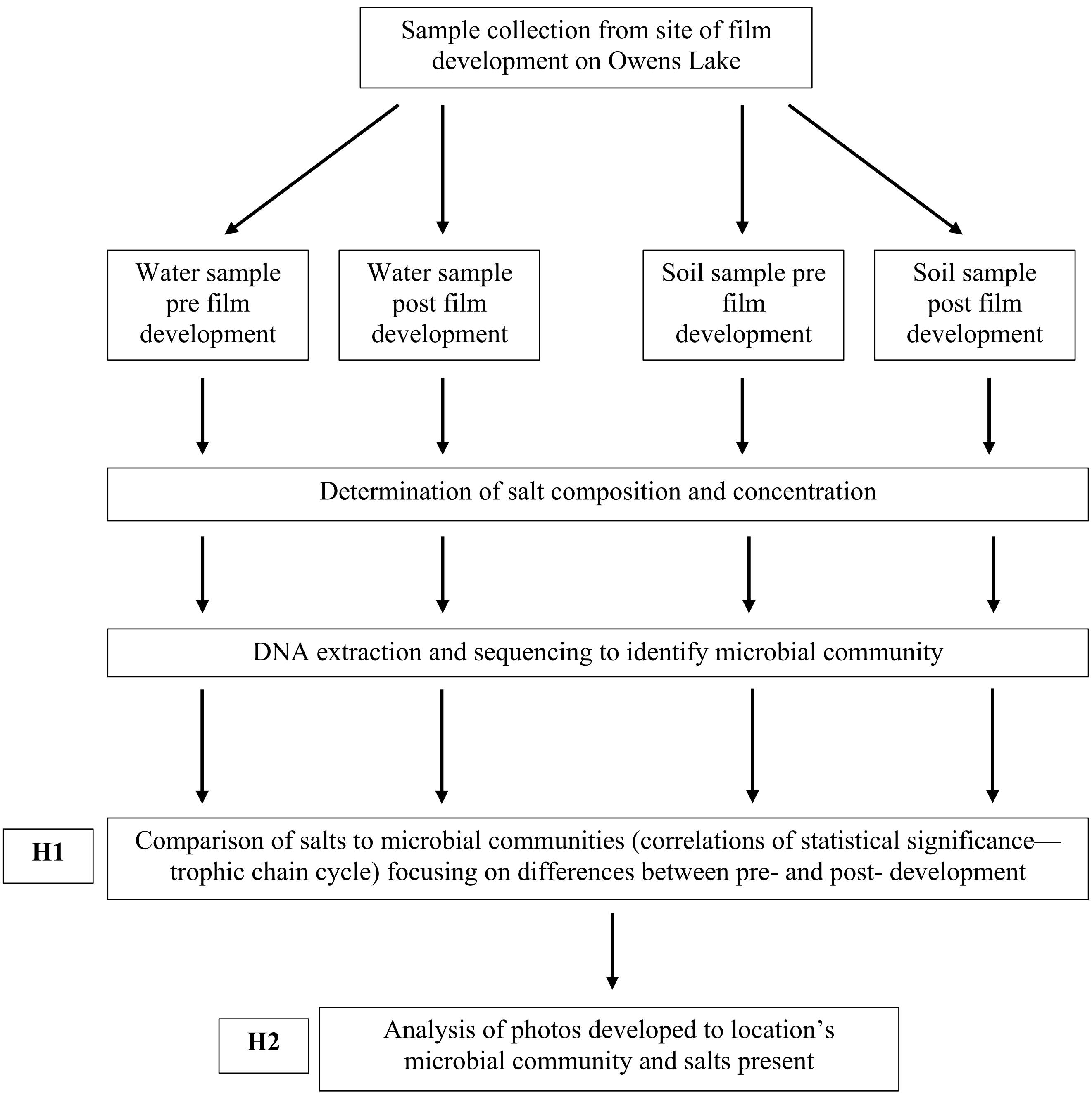
Objectives, Hypotheses, and Aims

The objectives of this research are multifaceted. First, we plan to understand how the microbial communities of the Owens Lakebed are related to the salt compositions and concentrations present and how these factors change pre- and post- film development. Additionally, we will investigate the possibility of photo fixation on the lakebed as a detection tool, and product, of specific microbes and salts.

- Hypothesis 1: *The microbial populations, as well as salt concentrations, will differ pre- and post- film fixation*. This hypothesis be tested through 16s rRNA gene sequencing and analysis of both bacterial and archaeal populations. Testing of salt compositions and concentrations will be done in collaboration with the Ecology and Biogeochemistry Core Lab of University of Wyoming. The results of the gene sequencing and salt testing will then be compared and analyzed for significant correlations.
- Hypothesis 2: *The qualities of photos post-fixation can predict microbial population and salt compositions*. Photos developed on the lakebed will be analyzed utilizing a word bank made in collaboration with Metabolic Studio, as well as quantification of differences between the photos. The photo analyses will

then be compared with the salts and microbial populations to determine if there are significant correlations.

Research Design Schematic



Methods and Materials

To begin testing the proposed hypotheses, first, samples taken on July 27th and 28th will be cataloged to determine which samples will be used. The samples needed are: water pre-film development, soil pre-film development, water post-film development, and soil post-film development. The soil samples have been stored in Whirl-Paks and kept at -80 °C. To identify microbial populations of the soil samples, an Omega E.Z.N.A. Soil DNA Extraction kit will be used to isolate the DNA. DNA will be extracted from the water samples utilizing an Omega E.Z.N.A. Water DNA Extraction Kit. The extracted DNA will be cleaned and concentrated using a ZYNO kit. At this point, the samples DNA concentrations will be checked with a Nanodrop to confirm that DNA is present. The samples will then undergo PCR with primers flanking the V3/V4 region of the 16s rRNA gene. PCR will also include barcodes from a 16s Bar Coding Kit for MinIon for differentiation of the products. The 16s amplicons will be pooled and differentiated by bar code. These amplicons can then be sequenced using MinIon with minKnow software. The sequences will be analyzed with RStudio to determine bacterial and archael abundances and beta diversity for each site.

The composition and concentrations of the salts present in the samples will be determined in collaboration with the Ecology and Biogeochemistry Core Lab. A salt analysis will be used to determine the cations and anions that compose the salt. Data on the salts and microbes will then be analyzed to look for significant correlations between species and salt concentrations or compositions as well as differences pre- and post- film fixation. Following these characterizations, analysis of photos developed on the lakebed by Metabolic Studio will be completed. Photos will be analyzed utilizing a word bank made in collaboration with Metabolic

Studio and local artists, as well as quantification of differences between the photos. Finally, the specific salts and microbes discovered will be compared to the photo analyses.

Expected Results

It is expected that the microbial communities will differ pre- and post- film development. It is also expected that salt concentrations and compositions will differ pre- and post- film development. There is also a likely link between what microbial species are present to the salt concentrations and the toxins partitioned into the salts. The photos developed on the lake are expected to act as a detection tool of what microbes and salts are present.

Timeline

The proposed research is expected to be completed in a timeframe of two months. It is expected that microbial diversity and salt composition can be determined within a month. Photo analyses will be able to occur simultaneously with microbial diversity and salt composition. The second month will involve analysis of the microbial diversity to salt composition, and comparison of those factors to the photo analyses.

References and Annotations

"Inhalable Particulate Matter and Health (PM2.5 and PM10) | California Air Resources Board." California Government. California Air Resources Board. Accessed September 4, 2022. https://ww2.arb.ca.gov/resources/inhalable-particulate-matter-and-health.

This webpage was accessed through the state of California's government website. The webpage does not offer a publication date. The webpage includes information on PM-10 pollution, exposure health risks, and national standards. It is beneficial for this paper due to its thorough assessment and explanation of PM-10 pollution.

EPA. "Air Actions, California." Environmental Protection Agency. Accessed September 4, 2022. https://19january2017snapshot.epa.gov/www3/region9/air/owens/qa.html.

This webpage was published by the Environmental Protection Agency. It was accessed through the EPA's previous website. This source has been used for its information on the amount of PM-10 emissions from the Owens Lake. There is no publication date on the webpage; however, it was most recently updated on February 14, 2017.

Friedman, Irving, George I. Smith, and Kenneth G. Hardcastle. "Studies of Quaternary Saline Lakes—II. Isotopic and Compositional Changes during Desiccation of the Brines in Owens Lake, California, 1969–1971." *Geochimica et Cosmochimica Acta* 40, no. 5 (1976): 501–11. https://doi.org/10.1016/0016-7037(76)90218-0.

This source was accessed through the University of Wyoming Libraries website and viewed on Science Direct. The source lacks recency but offers important information on the salt contents of Owens Lake. This journal article was peer reviewed and includes ample citations for its work.

Herbst, David B, and Michael Prather. "Owens Lake – From Dustbowl to Mosaic of Salt Water Habitats." *Lakeline Magazine* 34, no. 3, 2014.

This magazine article was accessed as a PDF online. The article is lacking in that it is not peer reviewed; however, the authors are extremely qualified to provide the information of interest. The article is largely about the habitat of the Owens Lake, but includes useful information on the salt contents of Owens Lake.

Janda, J. Michael, and Sharon L. Abbott. "16S Rrna Gene Sequencing for Bacterial Identification in the Diagnostic Laboratory: Pluses, Perils, and Pitfalls." *Journal of Clinical Microbiology* 45, no. 9 (2007): 2761–64. https://doi.org/10.1128/jcm.01228-07.

This journal article was accessed through the University of Wyoming Libraries website. It is a peer reviewed source that offers useful information on 16s rRNA sequencing for bacterial identification.

Levy, D.B., J.A. Schramke, K.J. Esposito, T.A. Erickson, and J.C. Moore. "The Shallow Ground Water Chemistry of Arsenic, Fluorine, and Major Elements: Eastern Owens Lake, California." *Applied Geochemistry* 14, no. 1 (January 1999): 53–65. https://doi.org/10.1016/s0883-2927(98)00038-9.

This is a peer-reviewed article. It was accessed through the University of Wyoming Libraries website and viewed on Science Direct. It is relevant to discussions about what chemicals are present in the ground water at Owens Lake (eastern). Additionally, this article offers information on the dust storm contents. This article is fairly old, published in 1999. This does hurt the information on the composition of the lake as there have likely been changes in the past 20 years.

“Medical Management Guidelines for Arsenic (As) and Inorganic Arsenic Compounds.” Centers for Disease Control and Prevention. Centers for Disease Control and Prevention, October 21, 2014. https://wwwn.cdc.gov/TSP/MMG/MMGDetails.aspx?mmgid=1424&toxid=3.

This article was published on the Centers for Disease Control and Prevention website on the Agency for Toxic Substances and Disease Registry. It offers information on different routes of consumption of arsenic and the possible long and short term effects caused by ingesting arsenic. It is important for this paper to understand the effects arsenic can be causing on Lake Owens surrounding populations.

“Owens Lake, California.” Owens lake. Accessed September 2022. https://saltworkconsultants.com/owens-lake-/.

This source gave information on the salt compositions of Owens Lake. While it is not a peer-reviewed journal article, the source is expert consultants in saline geosystems. They provide professional expertise in saline geosystems and carbonate reservoirs. This source was useful for information on the salt composition of Owens Lake.

Pikuta, Elena V., Ekaterina N. Detkova, Asim K. Bej, Damien Marsic, and Richard B. Hoover. “Anaerobic Halo- Alkaliphilic Bacterial Community of Athalassic, Hypersaline Mono Lake and Owens Lake in California.” *Instruments, Methods, and Missions for Astrobiology V* 4859 (January 2003). https://doi.org/10.1117/12.463322.

This article was accessed through the University of Wyoming Libraries and viewed on Research Gate. The article discusses the microbial communities of Mono Lake and Owens Lake. It specifically states novel bacterial strains in Mono Lake, but not Owens Lake. However, it does provide useful information on the basics of the microbiome of Owens Lake.

Pope, Chester I. “Formation of Silver Sulfide in the Photographic Image during Fixation.” *Journal of Research of the National Bureau of Standards, Section C: Engineering and Instrumentation* 64C, no. 1 (1960): 65. https://doi.org/10.6028/jres.064c.010.

This source was accessed online. While the journal lacks recency, it offers relevant information on the chemistry of the photo development process.

Pohl, Christopher. “Ion Chromatography.” Essay. In *Separation Science and Technology* 6, 6:219–54. Taylor and Francis Ltd. , 2005.

This source comes from a book and was accessed online. The chapter used offers information on methods to determine salt compositions, including ion chromatography.

Roderick, Kevin. “Owens Lake's Dust: Airborne Health Hazard.” Los Angeles Times. Los Angeles Times, April 2, 1989. https://www.latimes.com/archives/la-xpm-1989-04-02-mn-1380-story.html.

This article details the issues with Owens Lake. It also includes residents’ first-hand accounts of what it is like to live near the Owens Lakebed. The article was published 30 years ago, making it lacking in recency; however, the accounts from residents are very valuable.