NORTHERN ARIZONA UNIVERSITY
College of Engineering, Informatics, and Applied Sciences

Letter of Transmittal

To: Fethiye Ozis, NAU Professor, Capstone Client
From: A-Maize Cob-oration
Date: January 28, 2020
Re: Final Proposal

Dr. Ozis,

As discussed throughout the semester, here is the final project proposal in accordance with the guidelines. The team is submitting a research proposal for the use of corncob as a biosorbent in the removal of Cadmium, Arsenic, and Total Coliforms. Enclosed is the project understanding, scope, schedule, staffing plan, and cost of engineering services. For additional information, please contact eip6@nau.edu.

Sincerely,

A-Maize Cob-oration

A-Maize Cob-oration

NORTHERN ARIZONA UNIVERSITY
College of Engineering, Informatics, and Applied Sciences

Memorandum

To: Fethiye Ozis, NAU Professor, Capstone Client and Technical Advisor
CC: Dr. Jeffrey Heiderscheidt, NAU Professor, Capstone Grading Instructor
From: A-Maize Cob-oration
Date: January 28, 2020
Re: Final Proposal

Dr. Ozis,

The following document contains corncob biosorption capstone's project understanding and scope with subsections on project purpose, project background, technical considerations, potential challenges, and stakeholders, in addition to tasks and sub-tasks for the project process. Along with this information, the project schedule and Gantt chart are also provided in this report, as well as a staffing plan and cost of engineering services. For additional information, please contact eip6@nau.edu.

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NORTHERN ARIZONA UNIVERSITY
College of Engineering, Informatics, and Applied Sciences

To: Dr. Jeffrey Heiderscheidt, NAU Professor, Capstone Grading Instructor
From: A-Maize Cob-oration
Date: January 28, 2020
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Dr. Heiderscheidt,

The following document contains the corncob biosorption capstone's project understanding and scope with subsections on project purpose, project background, technical considerations, potential challenges, and stakeholders, in addition to tasks and sub-tasks for the project process. Along with this information, the project schedule and Gantt chart are also provided in this report, as well as a staffing plan and cost of engineering services. For additional information, please contact eip6@nau.edu.

Sincerely,

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Project Proposal: Corncob Biosorption

Removal of Cadmium, Arsenic, and Total Coliform

CENE 476

Prepared For: Jeffrey Heiderscheidt

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January 28, 2020

Final Version

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List of Abbreviations

Northern Arizona University	NAU
Environmental Protection Agency	EPA
Maximum Contaminant Level	MCL
Maximum Contaminant Level Goal	MCLG
Personal Protective Equipment	PPE
Inductively Coupled Plasma-Mass Spectrometry	ICP-MS
Instrument Detection Limits	IDL

1.0 Project Understanding

1.1 Project Purpose

The purpose of this project is to determine the effectiveness of using corncob as a biosorbent to remediate cadmium and arsenic ions along with total coliforms within contaminated waters. In Arizona and specifically in communities that have limited access to resources and funds, there is a need for economically sound, environmentally safe, and efficient water treatment options. Traditional treatment methods for removing metal ions from aqueous solutions are chemical precipitation, filtration, ion exchange, electrochemical treatment, membrane technologies, adsorption on activated carbon, evaporation, and etcetera. [1]. Often times, these methods are extensive, expensive, and produce hazardous waste byproducts [1]. Using corncob as a biosorbent aims to reduce these issues by becoming a low-cost treatment option that is widely accessible and easily operated by those who lack technical training.

1.2 Project Background

Metal contamination in surface waters from mining efforts has serious effects on human health. The potential health effects from cadmium and arsenic exposure range from skin problems to kidney damage [2]. The Environmental Protection Agency (EPA) maximum contaminant level (MCL) for cadmium and arsenic, respectively, are 0.005 and 0.010 mg/L [2]. For both cadmium and arsenic contaminants, the maximum contaminant level goal (MCLG), respectively, are 0.005 and 0.00 mg/L [2]. These concentrations are in Table 1-1. While the health effects of total coliform, Table 1-2 below, are not as severe, it is still beneficial to aim for zero percent for the MCLG, which is slightly lower than the MCL at 5% TT [2]. Total coliform, while not particularly dangerous, can indicate pathogens contaminating the water. Removal of total coliform will ensure removal of pathogens.

Table 1-1: Drinking Water Regulations of Inorganic Chemicals [2]

Contaminant	MCLG (mg/L)	MCL (g/L)	Potential Health Effects from Long-Term Exposure Above the MCL	Sources of Contamination in Drinking Water
Arsenic	0	0.010 as of 01/23/16	Skin damage or problems with circulatory systems, and may have increased risk of getting cancer	Erosion of natural deposits; runoff from orchards, runoff from glass and electronics production wastes
Cadmium	0.005	0.005	Kidney damage	Corrosion of galvanized pipes; erosion of natural deposits; discharge from metal refineries; runoff from waste batteries and paints

Table 1-2: Drinking Water Regulations of Microorganisms [2]

Contaminant	MCLG (mg/L)	MCL (g/L)	Potential Health Effects from Long-Term Exposure Above the MCL	Sources of Contamination in Drinking Water
Total Coliforms	0	5.00% of all monthly tests	Not a health threat in itself; it is used to indicate whether other potentially harmful bacteria may be present	Coliforms are naturally present in the environment; as well as feces; fecal coliforms and E. coli only come from human and animal fecal waste

The Gold King Mine Spill incident that occurred in 2015 is the origin of this research [3]. The King's Mine Spill refers to the incident where a field investigation of the Gold King Mine in Colorado triggered an estimated release of 3 million gallons of mine-affected waters into the Animas River [4]. While not actively participating in the cleanup process, the incident sparked the research into looking for low-cost treatment options using biosorbents.

In 2017, Arizona released over 130 million pounds of toxic chemicals into the environment, over half of which was disposed of without treatment or recycling [5].

Figure 1-1, shown below, displays the amount of toxic release produced in Arizona from 2003 to 2017, depicting the amounts of waste that were recycled, treated, and disposed of [5]. Over half of the waste produced was from metal mining [5]. More specifically, the Tohono O'odham Tribal Community located in Southern Arizona, produced over 5 million pounds of toxic waste from metal mining, 100% of which was disposed of without recycling or treatment, see Figure 1-2 [5]. Accessible and cost effective treatment solutions can reduce and mitigate the spread of contamination of heavy metals within the environment.

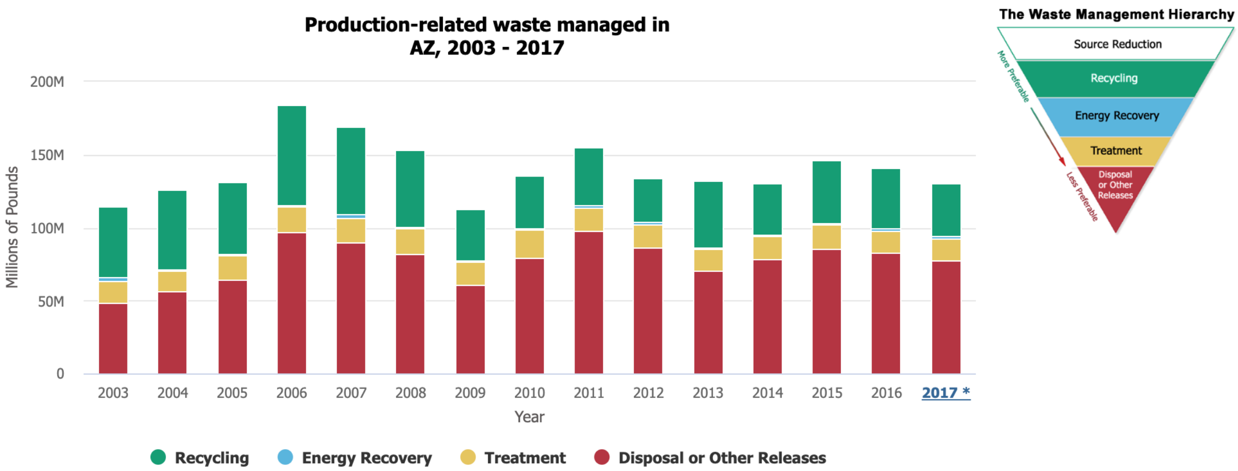

Figure 1-1: Toxic Waste Releases for 2003 to 2017 for Arizona [5]

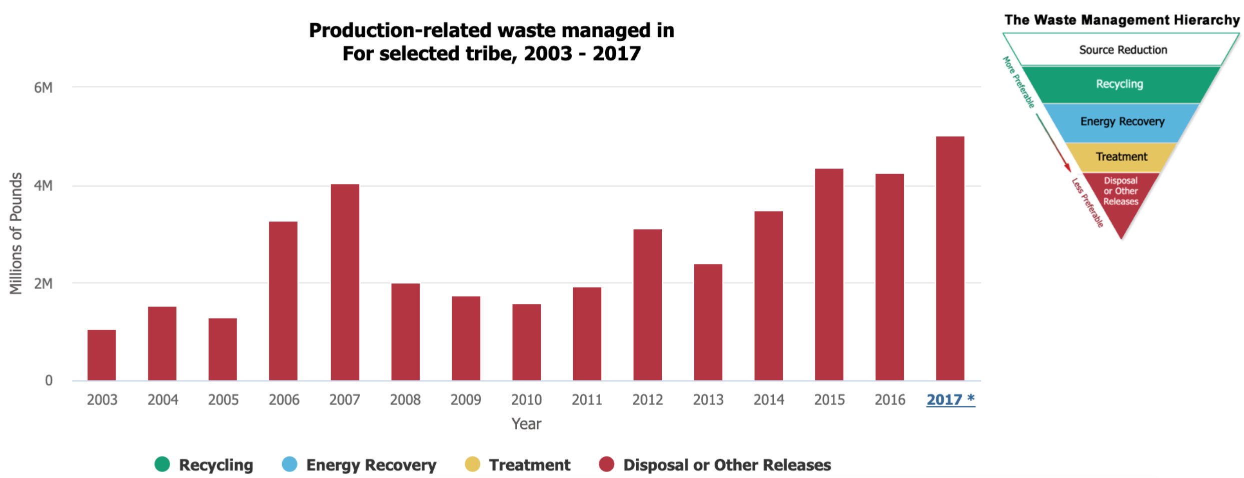

Figure 1-2: Toxic Waste Releases for 2003 to 2017 for Tohono O'odham Tribe [5]

This biosorbent project is a continuation of the previous year's Senior Design Capstone Project, and the structure will mimic prior corn biosorbent research done at NAU [6]. Building off the results reported last year, this project aims to further validate the Cadmium removal efficiency results and begin arsenic and Total Coliform removal testing. This will be done by replicating the testing performed from the previous year's capstone, while also adding on testing of natural corn, weak acid activated corn, and strong acid activated corn in the treatment of Arsenic and Total Coliforms. All treatment methods will use corncobs as a biosorbent aiming to be a cost-effective treatment option in contamination mitigation. For the project, within NAU's Environmental and Geotechnical labs, testing will take place. The final results from previous research done by NAU's 2018 Senior Design Capstone is outlined in Tables 1-3, 1-4, and Figure 1-3 [6]:

Table 1-3: Final Cadmium Readings for ICP-MS Testing of Treated Corn [6]

Initial Conc (ug/L)	Sample A Final Conc (ug/L)	Sample B Final Conc (ug/L)
8.47	ND	ND
25.6	ND	1.05
35.4	1.28	1.35
48.4	1.43	1.92
70.6	2.2	2.11

Table 1-4: Final Results for Treated Corn Isotherm [6]

Initial Conc (ug/L)	Average Final Conc (ug/L)	Standard Deviation	95% Confidence Interval (±)	Removal Efficiency (%)
8.47	N/A	N/A	N/A	N/A
25.6	1.05	N/A	N/A	96
35.4	1.32	0.05	0.44	96
48.4	1.68	0.35	3.11	97
70.6	2.16	0.06	0.57	97

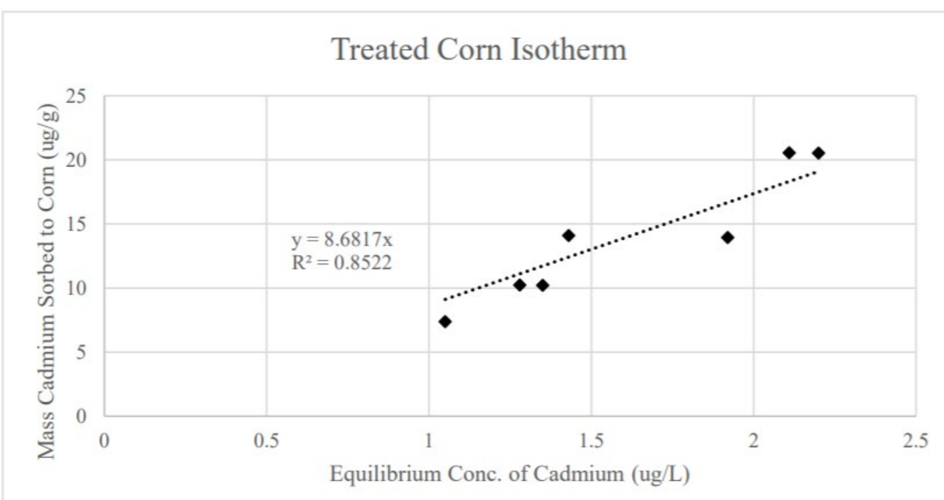

Figure 1-3: Treated Corn Linear Isotherm Model [6]

1.3 Technical Considerations

The technical work and considerations required for testing biological material as biosorbents stretches from how to uniformly contaminate water samples to the removal of contaminants from the water samples to testing the water samples for the remaining levels of contaminants. Water samples must be contaminated with the same amounts of Cadmium, Arsenic, and Total Coliform in such a way that variation amongst samples is nearly undetectable. Concentration of the contaminant will increase throughout the samples. A batch reactor method will be most effect in analyzing the peak level of adsorption by the corncob. All water samples will go through uniform treatment processes, altering only one variable at a time in order to guarantee consistent results. This variable will most likely be the amount of contaminants added to each water sample, while the amount of biosorbent remains consistent. The contaminants will need to be ordered from a chemical supply company. Because of the sensitivity of coliform, when it arrives a broth will need to be created in order to keep the bacteria alive through the duration of the lab testing. To measure the amounts of Cadmium, Arsenic, and Total Coliform remaining in the water samples, the Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) method will be sourced through the NAU Chemistry Department. Along with the water sample treatment and testing, there will be a consistent method to pretreat and activate the corncob sorption sites. When all of the data is collected, the results will be put together with the results from last year's research in order to move forward in concluding the efficiency and viability of corncobs as a biosorbent.

1.4 Potential Challenges

There are several challenges involved in using corncobs as a biosorbent for the removal of cadmium, arsenic, and total coliforms. Some of these constraints include: gaining proper lab access depending on the biosorption stage; having the correct equipment within the lab, and have it be operational; obtaining appropriate materials; using personal protective equipment (PPE) at all times; and health risks involved with each testing method. Specifically for gaining lab access, an Emergency Response Plan will need to be prepared when working with these contaminants. Additionally, communicating with the Chemistry Department at NAU regarding ICP-MS testing methods may have positive or negative impacts on the cost and time estimates of the lab research. For example, the device could have technical difficulties that can cause the team to outsource the samples to outside labs or increase the amount of time needed to test for cadmium and arsenic. Another difficulty could be finding someone to aid the team in learning how to operate the equipment, which means scheduling would need to be planned beforehand.

However, further challenges may arise if the predicted time in lab is longer than expected, causing the scheduled time working with the chemistry lab to be extended and accounted for.

Another challenge is finding materials and methods that produce non-hazardous wastes. Currently, nitric acid is the activation agent used in the current adsorption testing, but this produces hazardous waste, which needs additional procedures and cost of disposal. Time is also of concern. Essentially, the potential users of these methods should not have to dedicate a long time to the pretreatment process. Regarding the possible time constraint, the team may need to test multiple methods, especially for total coliforms, to determine the method that is most reliable and easiest to perform under non-laboratory conditions.

1.5 Stakeholders

One of the goals of the project is to remove heavy metals and total coliform from contaminated wastewater in rural areas with limited resources. Specifically, in Arizona, rural communities do not have the resources and technology to remove contaminants efficiently, for example, the Navajo Nation located in Northeastern Arizona. These rural communities are a stakeholder in this project, in addition to the surrounding environment and wildlife affected by metal mining. The use of biosorbents as a treatment method creates a low cost, high removal technique [7]. A secondary goal of this project is to further verify the previously determined cadmium isotherm. The conclusion from this will aid in providing further data to publish a technical paper for the client, Dr. Fethiye Ozis, who is a stakeholder in this project.

2.0 Scope of Services/Research Plan

2.1 Task 1.0: Weak Acid Decision Matrix

Task 1.0 defines the procedures and methods used to determine a weak acid for corncob activation for further analysis of corncob as a plausible biosorbent material. In Cadmium testing, in order to properly follow lab procedure, nitric acid will be the only activation agent used with the biosorbent for testing. However, Arsenic and Total Coliform (*E. coli*) testing will be tested using natural corn, weak acid activated corn, and strong acid activated corn in correspondence with the biosorbent. The strong acid will remain nitric acid, whereas the weak acid will be determined by the team using a decision matrix.

2.1.1 Task 1.1: Weak Acid Determination

Task 1.1 defines the weak acids and parameters for the activation of the corncob.

2.1.1.1 Task 1.1.1: Weak Acid Information

The team will research previously used weak acids of biosorbent activation processes, as well as conduct individual assessments of other weak acids. Research will be done using only peer-reviewed journal articles that have been published in the field of water remediation. Three weak acids were chosen based on the relevant research, of which where mercaptocetic acid, citric acid, and tartaric acid.

2.1.1.2 Task 1.1.2: Decision Matrix

A decision matrix will be created and used in the determination of the weak acid. This matrix will be comparing three separate weak acids, all of which were used previously in biosorbent research that has been published. These acids, as identified before, were chosen based on relevant research in the field of food waste biosorption. The parameters set for the decision matrix will focus on the cost of the acid, the effectiveness of the acid for activation, the ease of use, and the hazards of use. The decision matrix can be found in the Appendix (Appendix A). The various weak acids were compared in the decision matrix, with the lowest score of 3 indicating less maintenance of the acid and the highest score of 3 being given to each parameter indicating the more maintenance of the acid. With these scores, citric acid was determined to be the best choice for the project and the parameters set for the decision matrix as it had the lowest score for the decision matrix.

2.2 Task 2.0 XRF Method Development

A method will need to be developed for the use of the XRF machine for both the corncob biosorbent and the solution obtained after the batch reaction testing.

2.2.1 Task 2.1: XRF Corncob Testing Method

A method will need to be developed for the use of the XRF machine and the corncob byproduct after the biosorbent has been used in the treatment of Arsenic contamination. Due to the fact that this material is food waste, the team will be using the normal method of testing for the XRF machine. If problems arise during the analysis portion of the project, the team will then look into other methods of testing for the dried corncob. The corncob will be tested to ensure efficiency and accuracy with the XRF machine as well and the ICP machine.

2.2.2 Task 2.2: XRF Solution Testing Method

A method will need to be developed for the use of the XRF machine and the solution obtained after the batch reaction tests. The XRF machine that will be used, located in the Engineering Department, is mostly used to test soils. With the fact that the solution will be in liquid form, the team will need to develop a method based on the user manual as well as guidance from the graduate students at NAU currently working with the XRF machine. Once familiar with the user manual, the team will develop a method for all analysis for the semester.

2.3 Task 3.0: Biosorbent Preparation

Task 3.0 defines the preparation requirements of the biosorbent used in the analysis.

2.3.1 Task 3.1: Corn Preparation

Task 1.1 defines the specific preparation methods and procedures of the corncob.

2.3.1.1 Task 3.1.1: Biosorbent

The corncobs must be prepared to be used as the biosorbent. There is no official methodology published for preparing corncobs to be used as biosorbents, however the previous procedure done for this research project will be mimicked [6]. As soon as the corncobs are bought and acquired, the preparation and activation process may begin. This procedure consists of drying, separating the corn kernels from the corncobs, grinding the corncobs and sieving the corncob to the desired particle diameter.

2.3.1.2 Task 3.1.2: Activated Biosorbent

To mimic the exact activation process of the prior research conducted for cadmium, the dried corncob powder will be combined with nitric acid to further activate the sorption sites of the biosorbent. For the other contaminants, Arsenic and Total Coliform, the biosorbent will be activated using three different treatment methods. These include using nitric acid, a weak acid determined with a decision matrix, and natural corn (untreated). This is to maintain sustainable and feasible options for marginalized communities that may not have access to chemicals such as nitric acid to activate their biosorbent.

2.4 Task 4.0: Testing of Contaminants

Task 4.0 defines the procedures and requirements for the testing of the contaminants, cadmium, arsenic, and total coliforms.

2.4.1 Task 4.1 Sample Preparation

A range of concentrations must be determined as the initial concentrations for each experimental sample of Cadmium, Arsenic and Total Coliform (*E. coli*). The ranges for each contaminant will differ due to differences in contamination levels that occur in real life contamination scenarios as well as the levels of each contaminant as regulated by the EPA.

2.4.1.1 Task 4.1.1: Cadmium Sample Preparation

The range will have a minimum initial concentration as the EPA Maximum Contaminant Level (MCL) for Cadmium, 5 µg/L. The maximum initial concentration will be the maximum recorded concentration as reported by the World Health Organization of 100 µg/L [8].

2.4.1.2 Task 4.1.2: Arsenic Sample Preparation

The MCL of arsenic is 10 µg/L and the maximum initial concentration of Arsenic contamination will be the mean level in groundwater, 500 µg/L, according to the World Health Organization (WHO) [9].

2.4.1.3 Task 4.1.3: Total Coliform (E. coli) Sample Preparation

EPA regulates Total Coliform (*E. coli*) MCL as a maximum of 5% of all samples taken in a month can be contaminated. All samples will be contaminated with a known number of coliform bacteria and the samples will be tested to be marked as a successful sorption process.

2.4.1.4 Task 4.1.4: Batch Reactor Sample Preparation

A mass of 1 gram of corncob biosorbent will be added to each sample of Cadmium for uniformity throughout the project, as was consistent with the previous year's capstone project. For the treatment of Arsenic, the team will be preparing tests to determine how much corn is needed to extract 50 to 70 percent of the contaminant from the sample. This is due to the fact that the team will be using the XRF machine and the detection limits of the machine have yet to be verified. With this, the team will leave enough of the contaminant in the sample such that the XRF machine will be able to detect the concentration of the contaminant without error.

2.4.2 Task 4.2 Cadmium Testing

Cadmium testing will be performed using EPA Method 6020B Inductively Coupled Plasma – Mass Spectrometry. For Cadmium testing, only corn treated with nitric acid will be used for analysis, as to follow the previous year's capstone procedure. Typically, the instrument detection limit (IDL), for relatively simple matrices, will be less than 0.1 μg/L [10]. The concentrations that will be tested can be found in the table below. The concentrations tested will focus on the potential publication of the results, three concentrations of Cadmium determined by the previous capstone team and four new concentrations will be determined to further the research process. The three concentrations that are replicates are highlighted. Triplicates of each concentration will be tested for reproducibility.

Table 2-1: Concentrations of Cadmium that will be tested with the activated biosorbent.

Cadmium (Treated) Testing Concentrations		
1	5	μg/L
2	10	μg/L
3	20	μg/L
4	40	μg/L
5	60	μg/L
6	75	μg/L
7	100	μg/L

Along with the proper lab procedure for the testing of Cadmium, proper safety protocols will be followed in the lab to ensure the safety of all personnel. To prepare for this, multiple lab trainings will be completed by all personnel. During the testing process, hazardous waste will be produced, and proper safety protocols will be executed by the team to ensure that exposure to all hazardous materials is minimal. Multiple contacts within the Engineering Department as well as the Environmental Health and Safety Department have been made to prepare for any potential incidents within the lab.

2.4.3 Task 4.3 Arsenic Testing

Arsenic will be tested using natural corn, strong acid corn treated with nitric acid, and weak acid as determined by the decision matrix. Arsenic will be tested using X-Ray Fluorescence (XRF). Typically, XRF analysis requires a sample to be larger than 1 gram, and it is not suitable to analyze at concentrations between and below 2 to 5 microns [10]. The team will also send a few sample concentrations to be testing using ICP-MS to confirm the accuracy of the XRF results. The concentrations that will be tested for Arsenic can be found in the table below. Triplicates of each concentration will be tested for reproducibility. It should the noted that the concentrations of Arsenic are subject to change due to the detection limits of the XRF machine used for the analysis.

Table 2-2: Concentrations of Arsenic that will be tested with the biosorbent.

Arsenic (U, T, WAT) Testing Concentrations		
1	10	μg/L
2	20	μg/L
3	35	μg/L
4	50	μg/L
5	65	μg/L
6	80	μg/L
7	125	μg/L
8	250	μg/L
9	500	μg/L

If the level of detection of the XRF is not sufficient for the concentration levels chosen for Arsenic, multiple courses of action may be taken for the continuation of the project. This includes adjusting the concentration levels of Arsenic from parts per million to parts per billion. Otherwise, to ensure the concentration levels of Arsenic are representative of levels found naturally and after toxic waste spills or dumps, the team may also try to adjust the sample size before the analysis occurs. This would include taking the sample after batch testing and heating the water from the sample, but making sure that none of the metal was taken from the sample. Once some of the water has been evaporated from the solution, the sample could then be tested by the XRF machine. This method does increase the amount of human error in the analysis and will be thoroughly considered before use by the team.

Along with the proper lab procedure for the testing of Arsenic, proper safety protocols will be followed in the lab to ensure the safety of all personnel. To prepare for this, multiple lab trainings will be completed by all personnel. During the testing process, hazardous waste will be produced, and proper safety protocols will to executed by the team to ensure that exposure to all hazardous materials is minimal. Multiple contacts within the Engineering Department as well as the Environmental Health and Safety Department have been made to prepare for any potential incidents within the lab.

2.4.3.1 Task 4.3.1 Chemistry Department Planning

This sub-task also applies to Cadmium. Seeing as the ICP-MS method should only be operated by spectroscopists knowledgeable in the recognition and correction of spectral, chemical, and physical interferences in this analysis process, the team will be requesting the help of Grant Hettleman, a fellow student at NAU, who is permitted to operate the ICP-MS through his job [10]. The team will need to determine times to meet with Grant to learn how to operate to spectrometer and perform the tests.

2.4.4 Task 4.4 *E. coli* Testing

There are three methods to choose from to test for the removal of *E. coli* from contaminated water sources. Standard Method 9222 J Total Coliform and *E. coli* by Dual Chromogen Membrane Filter Procedure [11], EPA Method 1604 Total Coliforms and *Escherichia coli* in Water by Membrane Filtration Using a Simultaneous Detection Technique (MI Medium), and HACH Method 10029 Coliforms, Total and *E. coli*.

Total Coliform testing will quantify the removal of contaminants using a membrane filtration technique. The scope allows for the testing to assume that the biosorbent may not effectively remove total coliform. Various samples and dilutions will expand the level of measuring the number of Colony Forming Units (CFU) in the sample to quantify the effectiveness of corncob as a biosorbent in the removal of total coliform. There will be nine concentrations tested for the Total Coliforms, with each concentration tested with natural corn, strong acid activated corn, and weak acid activated corn. Triplicates of each concentration will be tested for reproducibility.

Along with the proper lab procedure for the testing of total coliform, proper safety protocols will be followed in the lab to ensure the safety of all personnel. To prepare for this, multiple lab trainings will be completed by all personnel. During the testing process, hazardous waste will be produced, and proper safety protocols will to executed by the team to ensure that exposure to all hazardous materials is minimal. Multiple contacts within the Engineering Department as well as the Environmental Health and Safety Department have been made to prepare for any potential incidents within the lab.

2.5 Task 5.0: Analysis

Task 5.0 details the requirements for the analysis of the biosorbent removal efficiency.

2.5.1 Task 5.1: Cadmium Analysis

Since the capstone team last year created a cadmium isotherm using the Freundlich model, the data collected will be analyzed using the same method in order to continue to improve the best fit line. The Freundlich Isotherm, Equation 1, can be found below. A linear version is seen in Equation 2.

Equation 1: Freundlich Model

$$q_e = K_F(C_e)^{\frac{1}{n}}$$

q_e: equilibrium adsorption loading for mass of material adsorbed per mass adsorbent

K_F: Freundlich parameter related to the thermodynamics of the adsorption process ($(mg/g)(mg/L)^{-1/n}$)

C_e: equilibrium solution concentration of the adsorbed material (mg/L)

1/n: Freundlich parameter that is often related to adsorption intensity or heterogeneity of the absorbent's surface

Equation 2: Freundlich Linear Model

$$log(q_e) = log(K_F) + (\frac{1}{n}log(C_e))$$

2.5.2 Task 5.2: Arsenic Analysis

Arsenic is a new contaminant, leaving the analysis method open to various isotherm methodologies. The team will consider the Langmuir, Freundlich, and Sips methods and determine which one has the best fit line based on the acquired data. The

Langmuir and Sips Methods, in the normal and linear forms, are seen below in Equations 3, 4, 5, and 6, respectively:

Equation 3: Langmuir Model

$$q_e = q_m \frac{K_L C_e}{1 + K_L C_e}$$

q_m: a Langmuir parameter expressing the maximum adsorption loading capacity in the same units as q_e

K_L: a Langmuir parameter related to the thermodynamics of the adsorption process, changes with temperature $(mg/L)^{-1}$

C_e: equilibrium solution concentration of the adsorbed material (mg/L)

Equation 4: Langmuir Linear Model

$$\frac{1}{q_m K_L} * \frac{1}{C_e} + \frac{1}{q_m} = \frac{1}{q_e}$$

Equation 5: Sips Model

$$q_e = q_m \frac{K_S C_e^{1/n}}{1 + K_S C_e^{1/n}}$$

K_S: a parameter related to the thermodynamics of the adsorption process (mg/L) based on $k^{1/n}$

Equation 6: Sips Linear Model

$$\frac{1}{q_m K_S} * \frac{1}{C_e^{1/n}} + \frac{1}{q_m} = \frac{1}{q_e}$$

2.5.3 Task 5.3: Total Coliform (*E. coli*) Analysis

Total coliform (*E. coli*) does not have a specific analysis method. The team is solely determining whether the corncob biosorbent removes total coliform (*E. coli*) from the sample through quantifying the results.

2.6 Task 6.0 Project Impacts

Task 6.0 details the impacts of the project and how these impacts will affect the project in the future.

2.6.1 Task 6.1: Environmental Impacts

With the treatment of heavy metals and total coliform using strong acids for steps of the process, extreme environmental impacts will be encountered throughout the project and potential implementation of a prototype and full-scale removal system. The impacts have yet to be defined, but will be outlined once testing and research is underway. Another environmental impact that will be evaluated concerns the disposal of the hazardous waste. The potential disposal methods for the implementation of the project will be evaluated. These could include incineration, disposal at a hazardous waste site, or even the possibility of extracting the heavy metals from the biosorbent after removal. The specific impacts of the strong acid compared to the weak acid used during testing will also be determined and explored during the duration of the project. These impacts have yet to be defined, but will be outlined once testing and research is underway.

2.6.2 Task 6.2: Social Impacts

With the potential implementation of a water treatment system that utilizes corn as a biosorbent for the removal of heavy metals and total coliform, changes will be made to the surrounding communities and areas of impact. For example, these changes have the potential to create more jobs focused around the treatment of contaminated water, an increase in recreational use of local surface water bodies, and an increase of overall community health. Social impacts also include health impacts to the personnel working on the project. Proper safety procedures and lab safety trainings need to be completed before the start of the project. Proper procedure for handling hazardous waste is also needed for the completion of the project and to ensure the health of all personnel. These impacts have yet to be defined, but will be outlined once testing and research is underway.

2.6.3 Task 6.3: Economic Impacts

With potential implementation of a water treatment system for contaminated surface waters, the local communities and economy will be impacted. For example, these changes can include an increase in local jobs for treatment management, as well as an increase in the local economy due to recreation with the treatment of contaminated waters. This treatment method, if implemented, could potentially cost less than other methods communities may be utilizing.

2.7 Task 7.0: Project Deliverables

Task 7.0 details all project deliverables for Spring 2020 for the project.

2.7.1 Task 7.1: CENE 486C

Task 7.1 identifies the deliverables required for CENE 486C in Spring 2020.

2.7.1.1 Task 7.1.1: 30% Deliverables

Task 7.1.1 identifies the deliverables required for the team by February 14, 2020, which should encompass the completion of Task 1.

2.7.1.1.1 Task 7.1.1.1: 30% Report

The team will submit the 30% report to assess whether the project is on schedule and properly managed for the allotted timeframe.

2.7.1.1.2 Task 7.1.1.2: 30% Presentation

The team will present results based off the 30% report submittal.

2.7.1.2 Task 7.1.2: 60% Deliverables

Task 7.1.2 identifies the deliverables required for the team by March 20, 2020, which should encompass the completion of Tasks 1.0, 2.0, and 3.0.

2.7.1.2.1 Task 7.1.2.1: 60% Report

The team will submit the 60% report to assess whether the project is on schedule and properly managed for the allotted timeframe.

2.7.1.2.2 Task 7.1.2.2: 60% Presentation

The team will present results based off the 60% report submittal.

2.7.1.3 Task 7.1.3: 90% Deliverables

Task 7.1.3 identifies the deliverables required for the team by April 24, 2020, which should encompass the completion of Tasks 1.0, 2.0, 3.0, 4.0, and 5.0.

2.7.1.3.1 Task 7.1.3.1: 90% Report

The team will submit the 90% report to assess whether the project is on schedule and properly managed for the allotted timeframe.

2.7.1.3.2 Task 7.1.3.2: 90% Presentation

The team will present results based off the 90% report submittal.

2.7.1.4 Task 7.1.4: Final Deliverables

Task 7.1.4 identifies the deliverables required for the team by May 8, 2020, which should include the completion of the entire project and all tasks.

2.7.1.4.1 Task 7.1.4.1: Final Website Design

A website will be created by the team to showcase all results and relevant submittals. This will be made accessible to the public.

2.7.1.4.2 Task 7.1.4.2: Final Report

The final report will be a culmination of the analysis results concluded from the project.

2.7.1.4.3 Task 7.1.4.3: Final Presentation

The team will present results based off the final report submittal.

2.7.2 Task 7.2: Other Professional Deliverables

Task 7.2 defines various deliverables for the team that are not required for CENE 486C but are requested for completion by the client.

2.7.2.1 Task 7.2.1: Project Presentations – Water Symposium

Due to the nature of this project, the results will be presented to a wide-scale audience at the student water symposium. The project will be entered in a competition with other water related projects that have been completed during the academic year 2019-2020 at Northern Arizona University.

2.7.2.2 Task 7.2.2: Compiled Project Results Publication

This project combined with previous project results will be compiled and submitted for publication under the guidance of Dr. Fethiye Ozis.

2.8 Task 8.0: Project Management

Task 8.0 identifies the project management required for the completion of the project.

2.8.1 Task 8.1: Meetings

Task 8.1 identifies the various meetings required for the team to complete for the project.

2.8.1.1 Task 8.1.1: Meeting with Client and Technical Advisor (TA)

The client and technical advisor (TA), Dr. Fethiye Ozis, will be consulted biweekly throughout the duration of the project. The purpose of these meetings is to update the client of the current status of the project as well as set expectations for future directions. The meetings will provide the team feedback on previous assignments and give suggestions for future work. All team members are required to attend these meetings except under special circumstances.

2.8.1.2 Task 8.1.2: Meeting with Grading Instructor (GI)

The Grading Instructor (GI), Dr. Jeffrey Heiderscheidt, will be consulted before and after every deliverable is submitted in order to receive feedback about the deliverable quality. These meetings will also expand on the comments given upon previous deliverables that have already been graded. All team members are required to attend these meetings except under special circumstances.

2.8.1.3 Task 8.1.3: General Meeting Requirements

All meetings require a prepared agenda that will be sent out via email to all meeting attendees at least 24 hours in advance. Each meeting will be headed by the appointed meeting leader and will discuss the relevant agenda items. In addition, all the meeting's events will be recorded by an acting secretary who will organize the document and share it with all the team members via email and Google Drive Documents. Meetings with the Client/Technical Advisor and Grading Instructor are official and shall be documented as such. Team meetings will be scheduled weekly to discuss upcoming project tasks and deliverables, as well as reviewing the final version of deliverables before submitting for a grade. In the instance that the team is falling behind schedule, the team needs to discuss what must be done to get the project back on schedule. All team members are required to attend except under special circumstances.

2.8.2 Task 8.2: Project Schedule

Task 8.2 identifies the schedule that the team will follow for the successful completion of the project.

2.8.2.1 Task 8.2.1: Project Schedule

The project schedule is based on the deliverable due dates, as well as the major tasks needed to be completed. It will be updated as necessary throughout the semester and as the project develops further.

2.8.3 Task 8.3: Resource Management

Funding is a large part of the project and greatly influences the project management and project schedule. Resource management keeps track of the funding and expenditures.

2.9 Exclusions

For the corncob research, the exclusions include field sample testing, such as collecting contaminated water samples from mine spill discharge areas, as well as the creation of a design prototype, and using column testing to further verify the proposed testing methods. Additionally, the project will not identify the physiochemical characteristics of the corncob biosorbent.

3.0 Scheduling

The total duration from start to finish of all tasks is 148 days. Lab time will begin on November 17, 2019 and will span until March 20, 2020. Task 1.0 has been estimated to last 22 days, Task 2.0 has been estimated to last 31 days, Task 3.0 has been estimated to last a 73 days, Task 4.0 has been estimated to span for 70 days, Task 5.0 has been estimated to last 47 days, Task 6.0 has been estimated to last 80 days, Task 7.0 has been estimated to last 70 days, and Task 8.0 has been estimated to last 146 days. For a further breakdown of the durations for each subtask for each major task, see Appendix A for the Gantt chart created with all required tasks.

Milestones were defined as the deliverables of the project, which were mentioned in the scope. A general timeline was created in regards to lab time needed to prepare the biosorbent, test the sorption process for each contaminant of interest and the required analysis for each contaminant.

The critical path is 92 days and that is because the critical path shows the duration of Task 2.0 with the development of the XRF Method, and leads into Task 4.1.1 Cadmium Sample Preparation, and goes into Task 4.2 for Cadmium Testing, and ends with Task 7.1.4 Final Deliverables on May 8th, 2020. The critical path is defined by all lab work required to be completed in order to submit a final report and present all of the appropriate results.

4.0 Staffing Plan

A staffing plan was created and defined for the project from start to completion. This plan identified the hours required for staff to complete all tasks defined for the project. Four positions were identified for the team, including Senior Engineer (SENG), Engineer (ENG), Lab Technician (LAB), Intern (INT), and Administrative Assistant (AA).

Senior Engineer must have competence in lab procedures, waste management, lab analysis, specifically proficient with Microsoft Excel, as well as technical writing and presenting. For the Senior Engineer, a strong work ethic and the qualities of a leader are desirable. This job position requires the senior engineer to advise and guide the project to the best of the engineer's ability and to make ethical decisions for the project. It is also desirable that the Senior Engineer is proficient in lab procedures, chemical handling and disposal, and isotherm analysis to verify all project progress. The Senior Engineer will overlook the completion of the project, as well as contribute the most time to the isotherm analysis as well as the project deliverables. The Engineer must possess a strong work ethic and the characteristics of a leader, as this position will be the main point of contact for all other positions and the project. The Engineer must be organized, as the schedule and tasks need to be accurately followed to ensure the completion of the project, as well as being proficient in lab procedures, chemical handling and disposal, and isotherm analysis. The Engineer will be involved with the testing of the biosorbent and the isotherm analysis most during the duration of the project.

The Lab Technician must be proficient at proper lab procedure and safety, as well as chemical handling and disposal. The Lab Technician must have a strong work ethic and be willing to take responsibility in the lab for the preparation process. The Technician will contribute most to the biosorbent preparation in Task 1 as well as the Cadmium, Arsenic, and Total Coliform testing for Task 2.

The Intern must be proficient in proper lab procedure and safety protocols, as well as the proper handling and disposal of hazardous chemicals. This position requires a person who is willing to learn, possesses leadership qualities, and is responsible in the work place. The Intern will contribute most during Task 1 of corn preparation and also aid in the cadmium, arsenic, and total coliform testing.

The Administrative Assistant must be proficient in technical writing along with PowerPoint and presentations. This position requires a person that is willing to work on the deliverables for the project, which requires a lot of technical writing and communication. The Admin. Assistant would contribute most to the deliverables, management, and project impacts during the duration of the project completion.

Table 4-1 below identifies the hours required for each member for every task identified for the project. The total is both identified as the total amount of hours and working days it is estimated to complete the project. The Excel spreadsheet developed for the project breakdown can be provided upon request.

As estimated by the team, the total hours of the project were estimated to be 997 hours. This is accurate for the projected analysis requirements, as the project will encompass Cadmium, Arsenic, and Total Coliform testing. The estimation of hours was based on the previous capstone team's logged hours as well and the time estimated by each testing method. The majority of the hours will be completed in the lab with biosorbent preparation, as well as, the cadmium, arsenic, and total coliform adsorption testing methods. A breakdown of the total hours estimated for the completion of the project can be found in the Appendix (Appendix C).

5.0 Cost of Engineering Services

Personnel rates were based on the information provided in CENE 476 class by Professor Mark Lamer with exceptional professional experience. The hours estimated based on the amount of lab work and analysis needed for each contaminant can be found in Table 5-1 below. While travel costs are not necessary to meet with the client, the team will need to buy corn from the local farmers market for grinding and preparation. The Excel spreadsheet developed for the project breakdown can be provided upon request.

Included in the rate of the employees are the base pay, benefits, and profit percent. This allows for the consideration of the base pay of the position, the benefits of each position, as well as the profit that the company is expecting to gain from the project. The amount determined is based on the overhead of the company, which includes the cost of each position, the cost of supplies, and the cost of the subcontract, as well as the project profit.

For Task 3.0 Supplies, ICP-MS tests were priced at the upper end of the given quote of between $20 and $30. Corncobs were estimated to be around $0.75 each due to their purchasing location. The team will be creating the standards for each contaminant. However, from previous experiments, there are leftover Cadmium and Arsenic standards with sufficient volumes for testing. On the other hand, it is unknown whether Total Coliform testing kits are available. Choosing one of the three methods researched for E. coli testing, it was decided that MilliporeSigma m-Coliblue24 Broth Culture Media would be purchased at $150. Additionally, 0.45 micrometer filters were added to the cost estimate since the team was informed this filter size would be the best for ICP-MS testing based on the biosorbent medium. Citric acid, the chosen weak acid for the project, was estimated to be $36 at 100 grams of use. The environmental and geotechnical labs were also billed for daily access throughout the project, each with a cost of $100 per day. The total cost of the project was estimated to be $92,882. A breakdown of the estimated costs can be found in the Appendix (Appendix D).

6.0 References

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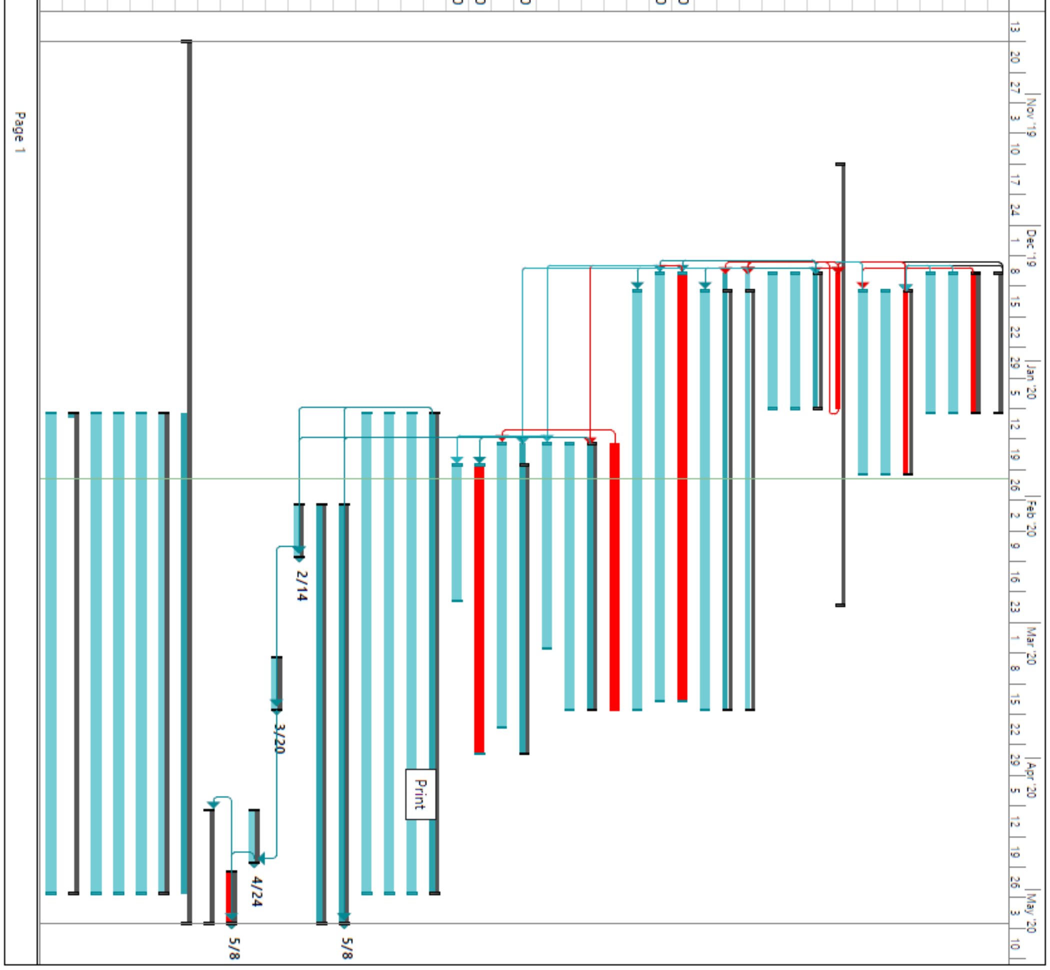
Appendix

Appendix A: Decision Matrix for the Determination of the Weak Acid.

Acid	**Decision Matrix Categories**				*SUM*
	Cost	*Effectiveness*	*Ease of Use*	*Hazardous*	
Mercaptoacetic	2	2	2	3	9
Citric	2	1	1	1.5	5.5
Tartaric	3	2	3	1.5	9.5

Appendix B: Gantt Chart Task List

ID	Task Name	Duration	Start	Finish
1	**Task 1.0 - Weak Acid Decision Matrix**	22 days	Thu 12/12/19	Sun 1/12/20
2	Task 1.1 Weak Acid Determination	23 days	Thu 12/12/19	Sun 1/12/20
3	Task 1.1.1 Weak Acid Information	23 days	Thu 12/12/19	Sun 1/12/20
4	Task 1.1.2 Decision Matrix	23 days	Thu 12/12/19	Sun 1/12/20
5	**Task 2.0 XRF Method Developmemt**	31 days	Mon 12/16/19	Sun 1/26/20
6	Task 2.1 XRF Corn Cob Testing Method	31 days	Mon 12/16/19	Sun 1/26/20
7	Task 2.2XRF Solution Testing Method	31 days	Mon 12/16/19	Sun 1/26/20
8	**Task 3.0 Biosorbent Preparation**	73 days	Sun 11/17/19	Tue 2/25/20
9	Task 3.1 Corn Preparation	23 days	Thu 12/12/19	Sat 1/11/20
10	Task 3.1.1 Biosorbent	23 days	Thu 12/12/19	Sat 1/11/20
11	Task 3.1.2 Activated Biosorbent	23 days?	Thu 12/12/19	Sat 1/11/20
12	**Task 4.0 Testing of Contaminants**	70 days	Mon 12/16/19	Fri 3/20/20
13	Task 4.1 Sample Preparation	70 days	Mon 12/16/19	Fri 3/20/20
14	Task 4.1.1 Cadmium Sample Preparation	70 days	Mon 12/16/19	Fri 3/20/20
15	Task 4.1.2 Arsenic Sample Preparation	70 days	Thu 12/12/19	Wed 3/18/20
16	Task 4.1.3 Total Coliform (E. Coli) Sample Preparation	70 days	Thu 12/12/19	Wed 3/18/20
17	Task 4.1.4 Batch Reactor Sample Preparation	70 days	Mon 12/16/19	Fri 3/20/20
18	Task 4.2 Cadmium Testing	45 days	Mon 1/20/20	Fri 3/20/20
19	Task 4.3 Arsenic Testing	45 days	Mon 1/20/20	Fri 3/20/20
20	Task 4.3.1 Chemistry Department Planning	45 days	Mon 1/20/20	Fri 3/20/20
21	Task 4.4 E. Coli Testing	35 days	Mon 1/20/20	Fri 3/6/20
22	**Task 5.0 Analysis**	47 days	Sat 1/25/20	Mon 3/30/20
23	Task 5.1 Cadmium Analysis	47 days	Mon 1/20/20	Tue 3/24/20
24	Task 5.2 Arsenic Analysis	47 days	Sat 1/25/20	Mon 3/30/20
25	Task 5.3 Total Coliform (E. coli) Analysis	22 days	Sat 1/25/20	Mon 2/24/20
26	**Task 6.0 Project Impacts**	80 days	Mon 1/13/20	Fri 5/1/20
27	Task 6.1 Environmental Impacts	80 days	Mon 1/13/20	Fri 5/1/20
28	Task 6.2 Social Impacts	80 days	Mon 1/13/20	Fri 5/1/20
29	Task 6.3 Economic Impacts	80 days	Mon 1/13/20	Fri 5/1/20
30	**Task 7.0 Project Deliverables**	70 days	Mon 2/3/20	Fri 5/8/20
31	Task 7.1 CENE 486C	70 days	Mon 2/3/20	Fri 5/8/20
32	Task 7.1.1 30% Deliverables	10 days	Mon 2/3/20	Fri 2/14/20
35	Task 7.1.2 60% Deliverables	10 days	Mon 3/9/20	Fri 3/20/20
38	Task 7.1.3 90% Deliverables	10 days	Mon 4/13/20	Fri 4/24/20
41	Task 7.1.4 Final Deliverables	10 days	Mon 4/27/20	Fri 5/8/20
45	Task 7.2 Other Professional Deliverables	20 days	Mon 4/13/20	Fri 5/8/20
48	**Task 8.0 Project Management**	146 days	Sun 10/20/19	Fri 5/8/20
49	Task 8.1 Meetings	80 days	Mon 1/13/20	Fri 5/1/20
50	Task 8.1.1 Meeting with Client and Technical Advisor (	80 days	Mon 1/13/20	Fri 5/1/20
51	Task 8.1.2 Meeting with Grading Instructor (GI)	80 days	Mon 1/13/20	Fri 5/1/20
52	Task 8.1.3 General Meeting Requirements	80 days	Mon 1/13/20	Fri 5/1/20
53	Task 8.2 Project Schedule	80 days	Mon 1/13/20	Fri 5/1/20
55	Task 8.3 Resource Management	80 days	Mon 1/13/20	Fri 5/1/20



Appendix C: Staffing Plan Breakdown

Task	SENG hrs	ENG hrs	LAB hrs	INT hrs	AA hrs
1.0 Weak Acid Decision Matrix	--	2	--	4	--
2.0 XRF Method Development	4	5	10	5	--
3.1 Corn Preparation	4	10	125	50	--
3.1.1 Biosorbent	2	5	50	20	--
3.1.2 Activated Biosorbent	2	5	75	30	--
4.2 Cadmium Testing	--	30	50	10	--
4.3 Arsenic Testing	--	40	70	30	--
2.1 Cadmium Testing	--	25	40	10	--
2.2 Arsenic Testing	--	30	60	10	--
4.4 E. coli Testing	--	25	50	30	--
5.1 Cadmium Analysis	15	30	--	5	5
5.2 Arsenic Analysis	20	35	--	10	5
5.3 Total Coliform (E. coli) Analysis	10	20	--	5	5
6.0 Project Impacts	6	10	--	2	5
7.0 Project Deliverables	20	20	--	10	30
Subtotal	79	282	405	181	50
Total Hours	997				
Total (person-days)	125				

Appendix D: Cost of Engineering Services Breakdown

Cost Table				
	Classification	Hours	Rate, $/hr	Cost
1.0 Personnel	SENG	79	194	$ 15,326
	ENG	282	117	$ 32,994
	LAB	405	82	$ 33,210
	INT	181	19	$ 3,439
	AA	50	23	$ 1,150
	Total Personnel			$ 86,119
	Item	Quantity	Cost	Total
2.0 Supplies	Corncob	100	0.75	$ 75
	MilliporeSigma™ m-ColiBlue24™ Broth Culture Media, 50 plastic ampules	1	150.40	$ 150
	MilliporeSigma™ PD20047S0, Dish with pad, 150 pack	1	86.60	$ 87
	0.45 µm filters, 100 units	1	3.79	$ 4
	Citric Acid, 100 g	1	36.10	$ 36
	Environmental Lab Access, per day	45	100	$ 4,500
	Geotechnical Lab Access, per day	10	100	$ 1,000
	Total Supplies			$ 5,852
	Item	Quantity	Cost	Total
3.0 Subcontract	NAU Chemistry Dept, ICP Testing	30	30	$ 900
4.0 Total				$ 92,882