2014

# Adsorptive Capacity of Orange Peels and Zero Valent Iron Filings for Removal or Uranium and Arsenic

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## 1.0 Project Purpose

The purpose of the Adsorptive Capacity of Orange Peels and Zero Valent Iron for Water Treatment project is to find the removal efficiency and rate of removal of orange peels for uranium and zero valent iron for arsenic from water. The goal is to conduct research in order to determine the maximum water volume and chemical concentrations the orange peels and zero valent iron can treat prior to exhaustion. Overall, this project will provide further data that supports this inexpensive and unique method for arsenic and uranium removal from drinking water.

## 2.0 Background Information

This project is a continuation of the Low-Cost Water Filtration capstone project completed from the previous capstone year [1]. The goal for the original capstone team was to design a water filter for the removal of uranium, arsenic, and bacteria. The water filter needed to be low-cost, electricity free, and needed to have the capability of removing the contaminants below their maximum contaminant limits (MCLs). The team explored several removal methods that included the use of orange peels and zero valent iron. However, the lack of adsorption capacity data of the orange peels and zero valent iron made the team unable to incorporate the materials into the final water filter design. At the conclusion of the original capstone project, it was determined that orange peels were capable of removing uranium while zero valent iron was capable of removing both uranium and arsenic (see section 4.0 for removal efficiency data). At this juncture, it is necessary to determine the actual capacity of the orange peels and zero valent iron in order to design a water filter utilizing the materials.

## 3.0 Key Stakeholders

The key stakeholders of this project are the client, Cheryl Dilks, and any person that may be in need of an inexpensive and renewable removal method for uranium and arsenic. The data collected will allow for the utilization of orange peels and zero valent iron for a water filter design, making those interested in a low-cost removal method for arsenic and uranium stakeholders. The research community for arsenic and uranium removal from water is also a stakeholder.

## 4.0 Existing Conditions

The testing that the Low-Cost Water Filtration capstone team conducted included preparing a water sample contaminated with various concentrations of arsenic and uranium and running the water through the selected treatment options. The synthetic water had an average uranium concentration of 84.71 µg/L and an average arsenic concentration of 68.65 µg/L. The volumes of water tested included a 1 L, 3 L, 5 L, and 7 L samples of contaminated water. The orange peels removed uranium with a removal efficiency ranging from 99.03% to 99.39%, increasing with increased volume. The orange peels were not as effective at removing arsenic, with a removal efficiency ranging from 27.43% to 62.02%, decreasing with increased volume. The zero valent iron filings had a uranium removal efficiency ranging from 99.82% to 99.87%, and an arsenic removal efficiency ranging from 88.46% to 98.85% [1]. This data supports the uranium and arsenic removal capability of orange peels and zero valent iron filings. Figure 4.1 shows removal data of the original project. The red figures represent final concentrations above the maximum contaminant level (MCL) for the specific contaminant. The green figures represent final concentrations below the MCL.

| Comparison of all Materials | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | Filtered Water Volume (L) | | | |
| Contaminant | USEPA MCL Standard | Synthetic Water | Filter Media | 1 | 3 | 5 | 7 |
| Uranium Concentration (µg/L) | 30 (Primary Standard) | 84.71 | Sand | 77.65 | 77.64 | 84.13 | 81.43 |
| | | | Ion Exchange Resin | 0.13 | 0.09 | 0.09 | 0.09 |
| | | | Orange Peels | 0.82 | 0.52 | 0.57 | 0.52 |
| | | | ZVI Turnings | 27.91 | 49.64 | 70.92 | 41.69 |
| | | | ZVI Filings | 0.11 | 0.15 | 0.14 | 0.12 |
| | | | Rice Husks | 0.77 | 1.38 | 7.89 | 67.41 |
| Arsenic Concentration (µg/L) | 10 (Primary Standard) | 68.65 | Sand | 38.28 | 47.12 | 53.12 | 55.48 |
| | | | Ion Exchange Resin | 2.27 | 1.90 | 1.84 | 1.86 |
| | | | Orange Peels | 26.07 | 48.31 | 46.35 | 49.82 |
| | | | ZVI Turnings | 6.26 | 4.76 | 5.60 | 6.84 |
| | | | ZVI Filings | 7.92 | 2.29 | 1.29 | 0.79 |
| | | | Rice Husks | 29.63 | 51.48 | 56.36 | 61.02 |

**Figure 4.0: Uranium and Arsenic Removal Data [1]**

## 5.0 Technical Tasks

The main technical task for this project includes developing and implementing a testing plan that will allow the team to determine the capacity of orange peels and zero valent iron for removal of arsenic and uranium from water. In order to determine the capacity the following variables will be considered:

- Arsenic and uranium concentration levels
- Orange peel and zero valent iron volumes
- Orange peel and zero valent iron particle size distribution

The testing plan will include various experiments, with each experiment focusing on one of the variables listed above. With the results of the experiments, isotherm models will be created. Isotherm models represent the affinity of a compound for a solid in water or gas at constant temperature [2]. With respect to the project, the isotherm models will show the affinity of uranium in water for orange peels and the affinity of arsenic in water for zero valent iron filings.

## 6.0 Potential Challenges

One of the potential challenges the team faces is obtaining a water source. Groundwater would be the ideal water source as it has not gone through any prior treatment. Additionally, the majority of areas that are dealing with uranium and arsenic contamination are utilizing a groundwater source. Another challenge is locating a testing source to send all of the water samples. Due to the various experiments that will be carried out, and the amount of samples that will be obtained from each experiment, there will be a high number of samples that need to be tested for uranium and arsenic concentrations. Northern Arizona University does not have the technology to test for uranium and arsenic in water, therefore finding a lab that will conduct these tests at an affordable cost is critical. The handling and disposal of the hazardous materials is another challenge that must be addressed.

## 7.0 Scope of Services

The scope of services for the project have been predetermined and are listed below. The services include the research that must be conducted, the experimentation and analysis that must be conducted, and all of the deliverables to the client.

### 7.1 Task 1: Background Research

The initial task is to conduct background research. Research on the theory of adsorption will be conducted, including the effects of the particle size of the adsorbent materials. Further research on orange peels and zero valent iron filings for water treatment will also be conducted in order to give the team background information on what is currently available in regards to the two treatment materials. Research on experimental designs for adsorption isotherms will also be conducted so significant data may be obtained throughout the testing process. This includes the various analytical test methods and the equipment that will be needed. The lab in which the samples will be analyzed must also be identified.

### 7.2 Task 2: Experimental Design

The second task is to design an experimental protocol to determine the adsorption capacity of the orange peels and zero valent iron filings.

#### *7.2.1 Subtask 2.1: Experimental Matrix*

An experimental matrix will be developed based upon pre-defined data quality needs. Parameters of concern will be varied so that statistically significant data can be obtained. The team will need to use professional and technical judgment, however, the opinions of the client will be considered at this stage in order to ensure that the end product produces data that meets the client’s expectations. It is expected that significant parameters within each experiment include uranium and arsenic concentration, adsorbent material volume, and adsorbent material size. Due to time constraints, the lab design will exclude any testing for kinetics, or the rates of reaction, which is needed for final design of a filter. Therefore, the design of a filter be excluded from the project.

### 7.2.2 Subtask 2.2: Safety, Sample Labeling, Shipping Protocols

A lab safety plan will be created prior to beginning lab work. This will serve as a contract the between team members assuring every team member has completed the required training to work in the lab, all personal protective equipment (PPE) will be worn when necessary, and all hazardous materials will be handled and disposed of properly. Furthermore, all of the samples will be labeled properly to avoid confusion and error within the lab. Outlining the shipping protocols will also be included in the lab safety plan to avoid complications throughout sample shipment process and in turn create errors with the sample analysis.

### 7.2.3 Subtask 2.3: Lab Testing Protocols & Procedures Write-Up

A lab testing protocols and procedures will be created to serve as a contract between the team members, as well. This will outline all of the procedures and protocols that must be followed for the experiments. A data sheet will also be created as part of the write-up to serve as a template for data collection throughout the testing. The data sheet will make sharing data between team members effective and understandable. The write-up will also increase accuracy and meticulous work in the lab.

## 7.3 Task 3: Experimentation

The third task is experimentation. This includes the acquisition of necessary lab materials and the sample water, the creation of the test water, and running the experiments and collecting data.

### 7.3.1 Subtask 3.1: Acquiring Lab Materials

The majority of all glassware needed should be available in the Northern Arizona University CECMEE Environmental Water Quality Lab, where the experiments will take place. There are also extra materials from the previous capstone year's Low-Cost Water Filter team that can be utilized for the experiment. Materials that are not available will be purchased with sufficient lead time in order to maintain the schedule. The orange peels will obtained by purchasing orange peels at a grocery store, peeling and preparing the peels in the lab. The ZVI filings will be purchased online, using the same source as the previous capstone year [1].

### 7.3.2 Subtask 3.2: Acquiring Water Source & Creating Test Water

The client has stated a preference for a well water source, and therefore utilizing well water in the testing will remain a priority. Dr. Paul Gremillion, the technical advisor for the project, has informed the team that he is willing to provide his tap water which comes directly from a well water source. Dr. Gremillion has also offered to transport the water from his home to the NAU CECMEE Environmental Water Quality Lab.

Once the water sample has been acquired, the team will need to contaminate the water with uranium and arsenic. The concentrations of uranium and arsenic will already have been pre-determined in the experimental design process. Uranium and arsenic should be available in the Water Quality Lab's chemical storage. If the amount does not meet the required amount for testing, more arsenic and uranium will be ordered. An inventory of the lab will be conducted prior to the beginning of the experiments, giving enough time for the order and arrival of the required chemicals and materials.

#### *7.3.3 Subtask 3.3: Collect Data*

Throughout the testing process, the data will be collected according to the pre-defined protocols in Task 7.2.3 above in order to promote data consistency and quality. The obtained data will be recorded using the data sheet created in the Lab Protocols and Procedures Write-up. The concentrations of uranium and arsenic will be determined using an outsourced lab. The water quality parameters that the team will test for while in the lab include uranium and arsenic concentration. Additional water quality parameters include alkalinity, pH, and turbidity in order to better understand the characteristics of the source water.

### 7.4 Task 4: Data Analysis

The fourth task consists of analyzing the experimental results. Expected analyses are as follows.

#### *7.4.1 Subtask 4.1: Building Isotherm Models*

The isotherm models will be built utilizing Excel spreadsheets. The possibility of utilizing other water quality analysis software for this task will be considered. The isotherm model will include a comparison of the quantity of chemical adsorbed per unit concentration of treatment material in liquid to the equilibrium concentration of the chemical.

#### *7.4.2 Subtask 4.2: Particle Size Distribution*

Finding the most effective particle size distribution for orange peels and zero valent iron filings will help in any future designs for a water filter that will utilize these treatment materials.

### 7.5 Task 5: Project Management

The fifth task of project management includes the team and client management that will be carried out throughout the entirety of the project, as well as the deliverables to the client.

### *7.5.1 Subtask 5.1: Team & Client Management*

Team and client management will be implemented in order to promote organization throughout the span of the project. Team management includes task breakdown and logging hours for completed work, effective communication between team members, and structured team meetings which will take place once a week. Client management includes effective communication between the team and the client, and keeping the client updated with all deliverables and accomplished milestones.

### *7.5.2 Subtask 5.2: Deliverables*

The deliverables for the client are outlined below.

#### *7.5.2.1 Subtask 5.2.1: Project Schedule*

Task management will be tracked throughout the project by use of a Gantt chart. This tool will help the team manage and organize all of the work, as well as assure that the various tasks are completed on time. Adaptive management will be incorporated into this task in order to reduce work time loss in the event of any changes to the prepared schedule.

#### *7.5.2.2 Subtask 5.2.2: 50% Design Report*

Throughout the testing process, the team will deliver a 50% design report to the client, technical advisor, and class instructors in order to inform them of the progress of the project.

#### *7.5.2.3 Subtask 5.2.3: Final Design Report*

At the completion of the testing and results analysis, a final report will be delivered to the client, technical advisor, and class instructors. The final design report will include all of the information from the design and research stage, testing stage, results analysis, and an evaluation of the broader impacts of the research findings.

#### *7.5.2.4 Subtask 5.2.4: Final Presentation*

A final presentation will be completed for the grading instructors, as well as the general public. The final presentation will cover the information discussed in the final design report.

#### *7.5.2.5 Subtask 5.2.5: Website*

Using Dreamweaver, a web editor software package, a website will be created. The website will include a home page, project information page, and documents page. The goal of the website is to present information regarding the design project to any interested person. It also serves as a method for archiving the research and design work for future use.

## 8.0 Project Schedule

A project schedule has been created using a Gantt chart. The official start date of the project is October 7th, 2014 and the end date is April 23rd, 2015. The critical path for the project has been determined and is outlined in the Gantt chart. The critical path includes the experimental design and experimentation. Since the goal of the project is to conduct research and testing in order to determine the adsorption capacity of orange peels and zero valent iron, the project will not be successful without a proper design experiment and effective experimentation. The following table outlines the critical path for success.

**Table 8.1: Critical Path for Success**

| Task | Start | End |
|---|---|---|
| Subtask 2.1 Experimental Matrix | 11/7/14 | 11/14/14 |
| Subtask 2.2 Safety, Sample Labeling, Shipping Protocols | 11/14/14 | 11/21/14 |
| Subtask 3.1 Acquiring Lab Materials | 1/12/15 | 1/16/15 |
| Subtask 3.2 Acquiring Water Source & Creating Test Water | 1/12/15 | 1/16/15 |
| Subtask 3.3 Collect Data | 1/19/15 | 3/13/15 |

The Gantt chart also includes the deliverables of the project. The following table outlines the various deadlines and the respective due dates. For any unknown deliverable dates, estimated dates were determined.

**Table 8.2: Deliverable Due Dates**

| Task | Due Date |
|---|---|
| Subtask 5.2.1 Project Schedule | October 10th, 2014 |
| Subtask 5.2.2 50% Design Report | March 2015 |
| Subtask 5.2.3 Final Design Report | May 1st, 2015 |
| Subtask 5.2.4 Final Presentation | April 24th, 2015 |
| Subtask 5.2.5 Website | May 1st, 2015 |

The Gantt chart is shown in Appendix A. The critical path is outlined in red in the Gantt chart.

## 9.0 Cost of Engineering Services

The personnel for the project includes senior engineer (SENG), engineer (ENG), lab technician (LAB), intern (INT), and administrative assistant (AA). The outline for the total project cost is shown in Table 9.1.

**Table 9.1: Total Project Cost**

| Item | Classification | Hours | Rate $/hr | Cost |
|---|---|---|---|---|
| 1.0 Personnel | SENG | 112 | 146 | $16,336 |
| | ENG | 320 | 81 | $25,907 |
| | LAB | 72 | 48 | $3,450 |
| | INT | 152 | 22 | $3,371 |
| | AA | 96 | 50 | $4,847 |
| | Total Personnel | | | $53,911 |
| | | | | |
| 2.0 Subcontract | Analytical | | | |
| | 150 samples + 2 shipments | | | $300 |
| | | | | |
| 3.0 Total | | | | **$54,211** |

The hours were assigned to each personnel based on the various tasks outlined in the scope of services. With the overhead calculated into the rate, the total cost for personnel is $53,911. Dr. Michael Ketterer, professor and chair of the chemistry department at Metropolitan State University of Denver (MSUD), has been contacted to conduct the tests for uranium and arsenic in the MSUD chemistry lab. Dr. Ketterer offered a price of $300 for 150 samples in two separate shipments for the uranium and arsenic testing. This leads to a final project cost of $54,211.

## 10.0 References

[1] D. Cummings, C. Dilks, Y. Sun, & T. Weir, "Final Design Report: Water Filter for Uranium, Arsenic and Bacteria Removal," Northern Arizona University, Flagstaff, Arizona. May 1st, 2014.

[2] J.R. Mihelcic and J.B. Zimmerman, "Chemistry," in Environmental Engineering: Fundamentals, Sustainability, Design, 1st ed. Hoboken, NJ: John Wiley & Sons, Inc., 2010, ch. 3, sec. 10, pp. 76-89.

## 11.0 Appendices

Appendix A:

Figure A.1 Shows the Gantt chart with the critical path outlined in red.

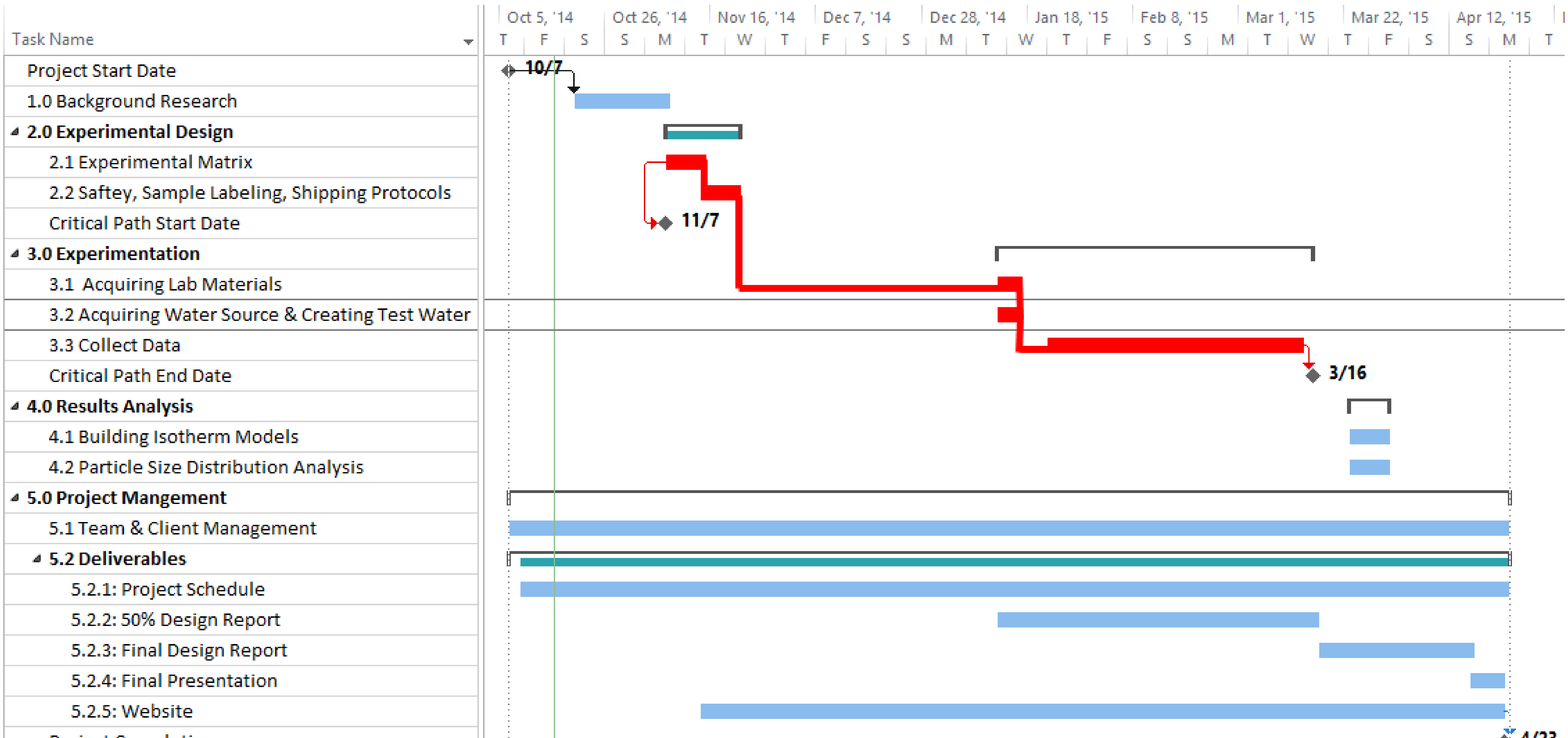


**Figure A.1: Gantt Chart**