

Verde Valley Water Treatment System

50% Design Report



CRKL Engineering

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LIST OF ABBREVIATIONS

ElectroChemical Arsenic Remediation (ECAR)
Environmental Protection Agency (EPA)
Maximum Contaminant Levels (MCL)
Metro State University Denver (MSUD)
Standard Method (SM)

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PROJECT OVERVIEW

CRKL Engineering was tasked with designing and creating a bench scale water treatment system for a hypothetical community of 10,000 members located in the Verde Valley. The groundwater in this community is contaminated with arsenic and nitrate with concentrations of 1-2 mg/L and 25-40 mg/L, respectively [1]. Arsenic and nitrate can be naturally occurring in groundwater and can also enter the water source through runoff from agriculture, fertilizers, animal and human wastes, and industrial activities [1]. CRKL Engineering was tasked with these two contaminants due to their harmful nature and common occurrence.

The presence of arsenic and nitrate in water has multiple adverse health effects. Prolonged exposure to arsenic can directly affect the skin, bladder, and lungs, including skin and lung cancer [2]. Noncancerous effects of arsenic include pregnancy complications, joint pain, loss of hearing, and increased risk for developing type two diabetes [1]. When nitrate is ingested, the human body changes nitrate into nitrite, causing issues in all ages, but specifically babies aging from newborns to three month olds. The ingestion of nitrate in infants and toddlers causes Blue Baby Syndrome, which develops because their immune systems are still developing, causing them to convert all of the ingested nitrate to nitrite. While babies convert 100% of the nitrate, humans with developed immune systems only convert about 10% of the total ingested nitrate to nitrite [1]. Even though only some of the nitrate is converted, vascular collapse typically occurs in older humans [1]. The health effects above were found to occur when the nitrate concentration within the subject was 10 mg/L and above, where anything below that level had no observable effects. Due to the health effects associated with these contaminants, the EPA has set forth standards for arsenic and nitrate [1].

The EPA has set forth maximum contaminant levels (MCL) to regulate arsenic and nitrate within water sources. Arsenic has a MCL of 0.01 mg/L and nitrate has a MCL of 10 mg/L [2]. CRKL Engineering is designing the water treatment system to treat the water to EPA drinking water standards.

TECHNICAL COMPONENTS

Water Treatment Design Alternatives

Each team member completed a literature review to determine feasible treatment methods for the removal of arsenic and nitrate. There were three categories of treatment method alternatives identified: nitrate removal, arsenic removal, and dual treatment. Both the arsenic and nitrate treatment options were broken into three different categories: conventional, innovative, and sustainable. The team was most interested in the sustainable treatment options, therefore two team members completed reviews for sustainable treatment methods.

One conventional nitrate removal method researched was an ion exchange process where water is passed through a chloride filled material, which would then retain the nitrate ions in exchange for a less harmful chloride ion. This was a viable option because the materials are readily available, less costly, and the research done on this method can be used to determine the correct doses for the team's needs. One sustainable option for nitrate removal was the use of autotrophic bacteria as a biofilm. This method grows bacteria that converts nitrate to nitrogen gas, which replaces the nitrogen within the nitrate with a hydrogen molecule. This was considered because of the low waste production and the opportunity to conduct further research on a new technology. Another sustainable method was running water through woodchips that serve as a permeable reactive barrier. The woodchips supply an organic carbon source, which is an adsorptive material. The water then flows through a sand filter bed to complete the filtration process. This option was considered for its relatively low cost design, which could be easily employed in developing areas.

A conventional method researched for arsenic removal was an oxidation process where water is saturated with oxygen. For this method, a pretreatment method to convert arsenic to arsenite is needed because the ability of arsenite to oxidize faster than arsenic. This method was researched as a low cost and well-known method with extensive research to reference when creating the design. The innovative treatment method for arsenic was called ElectroChemical Arsenic Remediation (ECRA) [1]. ECRA requires the use of an electrical current passing through the contaminated water with surface-modified iron nanoparticles, which then attract the charged arsenic particles, helping them to settle out. This option was considered because of its proven ability to remove high percentages of arsenic. A sustainable method of removing arsenic was phytoremediation, which is the use of plants up taking minerals from soils, or in this case water, and storing it within the plant. The plant suggested for this method is hyacinth roots [1]. This method was suggested because it could easily be used in developing areas where disposal of byproducts is nearly impossible. Another sustainable treatment method was passing the water through specifically designed ceramic fibers. The reasoning behind this method was to use newly researched materials to absorb contaminants. This material was a viable design option due to high availability in all communities and low operation and maintenance costs. The water would need to be passed through porous alumina tubes where the arsenic is deposited because of its affinity for bonding with alumina.

There were two treatment methods researched that act as dual treatment. These options were

considered because the cost of a single process system is significantly less than a dual process and a single treatment method can be better used in rural areas. The first dual treatment option was an ion exchange using titanium dioxide-based hybrid media to attract both the arsenic and nitrate ions. Since ion exchange is a common process, the research done on this method and other similar methods would help the team in determining how to apply such concepts to the given situation. The second dual treatment system was also an ion exchange process using activated alumina as the treatment media. Research conducted showed this media effectively removes arsenic and nitrate individually, however, activated alumina has not been used as a dual treatment media yet. This media is a viable treatment option because of the low cost compared to titanium oxide and the ability to easily regenerate the material.

Design Decision

The final design was determined based off the creation of a decision matrix. The previously described alternatives were put into a decision matrix, as seen in Appendix 1. Figure 1 illustrates a condensed version of the decision matrix used, showing the top ranked options to treat for arsenic, nitrate, and both. The criteria used to determine the best options are seen in the left column of the table. The criteria for the system are to be low cost and low energy, being feasible for the team to create, the lifetime of the system, and a low by-product produced.

The parameters were assigned percentages by the team to properly weigh the importance of the criteria. A 1, 3, 9 system was used for scoring each design alternative. In this system, a 1 represents the worst option, 3 represents a viable option, and a 9 represents the best possible solution. The “Raw Score” was determined based on the number assigned to each design parameter and multiplied by the weighted percent and then summed for all the criteria for each design.

			Nitrate	Arsenic	Dual Treatment	
			Ion Exchange: Chloride	Phytoremediation Hyacinth Roots	Ion Exchange: Titanium Oxide	Ion Exchange: Activated Alumina
	Criteria	Weights (%)				
Parameters	1 Low-Cost	30	9	9	9	9
	2 Low-Energy	30	3	9	9	9
	3 Feasibility	20	9	3	9	9
	4 System Life-Time	15	3	3	3	9
	5 Minimal by-product	5	1	1	3	3
	6					
		Raw score		5.9	6.5	7.8
	Relative Rank		3	3	2	1

Figure 1: Condensed Decision Matrix

Using the raw score, each design was then given a relative rank. In the full matrix in Appendix 1, it is seen that there are duplicate ranks. This is because the alternatives for arsenic were ranked separately from the alternatives for nitrate to determine the best combination. The two highest ranked alternatives fall under the category of dual treatment, which is a single material, or

method, that can be used to treat both arsenic and nitrate. The dual-treatment ranked highest for both arsenic and nitrate and was given the 1st and 2nd ranks for both contaminants. From there, the rankings continued for arsenic and nitrate independently.

The final design is the one highlighted in green since it was the highest-ranking alternative. The team determined ion exchange using activated alumina was the best option based on the availability of activated alumina, the feasibility, cost, energy, and lifetime of the product. With this decision, the team determined to create a gravity-fed system using a packed column filled with the activated alumina.

Final Design

The CRKL Engineering team determined the best design alternative to be a gravity-fed packed column system using activated alumina as the treatment media. The base that holds the packed column is constructed of segments cut from an 8' long 2" x 4" beam and segments from a 2' x 2' medium density fiberboard. The column is constructed of a 3' long and 3" diameter clear plastic tube, a plastic pipe adapter, caulk, a 3" PVC cap, a PVC ball valve, PVC fittings, Teflon tape, PVC pipe cement and ASB to PVC cement. The materials used for construction are pictured below. Not pictured are the stain, pipe adapter, and ASB to PVC cement due to complications experienced during construction that are discussed later.

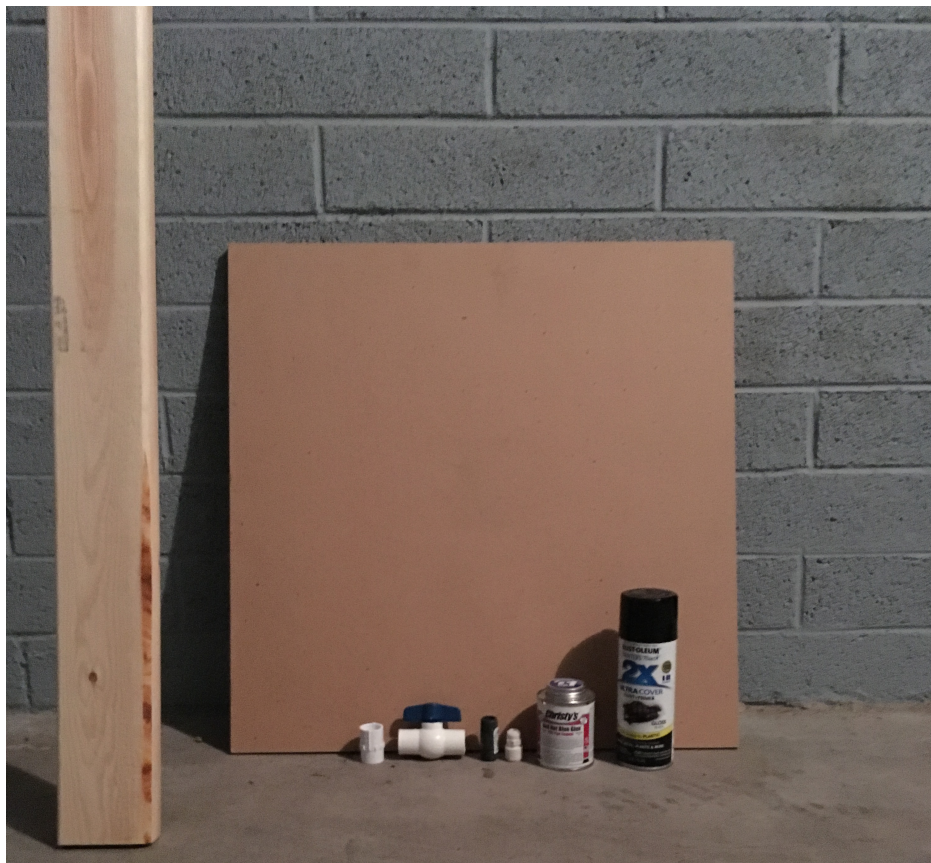


Figure 2: Construction materials

Four 1' segments of the 2" x 4" compose the legs of the base. Nailed to the legs is a 1' x 1' piece of the medium density fiberboard with a hole cut in the middle. This hole was cut so that the valve on the end of the packed column could fit through, but the rest of the column could not. Two 8" segments of the 2" x 4" were nailed adjacent to the hole and a 6" x 12" piece of the medium density fiberboard was nailed to the top of those. Similarly to the other piece, the team cut a hole in the middle; however, this hole was cut slightly bigger so that the entire column could slide easily out of the base. Triangle edges were cut off of the top piece for aesthetic appeal. This piece was constructed to act as support for the column. The entire base was coated in a stained sealant to give the base a dark, glossy finish as well as prevent any water from seeping into the wood. Pictures of the base before and after the stain was applied are shown below.



Figure 3: Base before stain

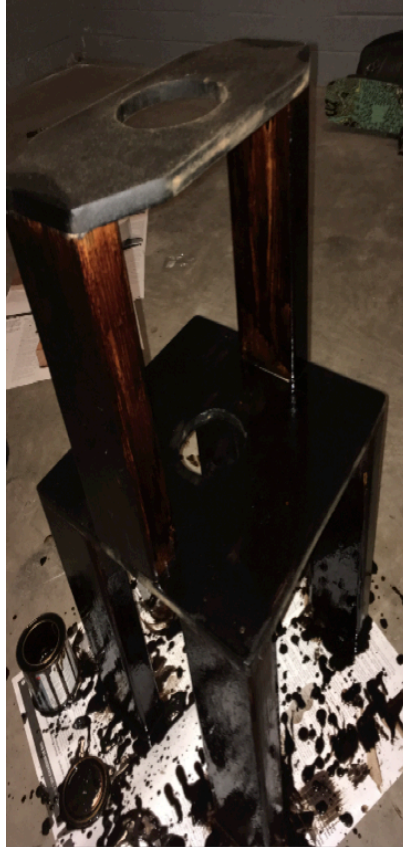


Figure 4: Base with one coat of stain

The first step to constructing the column was assembling the nozzle apparatus. The team decided to use a ball valve on the end of their column so they could take samples at desired times. The team purchased a threaded PVC ball valve and screwed a reducer into the end of that using Teflon tape and PVC pipe cement. The team did this to reduce the stream of effluent from the column to make collecting samples easier. On the other end of the valve the team attached a female-to-female adapter that was attached to a small (about 1" diameter) PVC fitting, completing the nozzle apparatus, which is pictured below.



Figure 5: Nozzle Apparatus

The team drilled a hole in the PVC cap as close to the same size as the fitting as possible to ensure a tight fit. The team sealed the nozzle apparatus to the cap using caulk. A half-inch layer of caulk was applied to the rim of the inside of the cap and then the end of the tube was placed into the cap within the layer of caulk to seal the tube to the cap. After 36 hours, the cap and cylinder did not create a strong bond and easily came apart, so the team purchased the pipe adapter and ASB to PVC cement. This adapter is slightly larger than the cap so the team had to drill a larger hole in the top support to allow the column to fit through. The cap fit extremely snug into one end of the adapter, and the other end of the adapter fit snug into the column. The team used ASB to PVC cement to seal these pieces together and caulk to seal the outer rim where the adapter fits into the column. The completed column is pictured below.



Figure 6: Nozzle Aparatus connected to Column resting on Base

Testing/Analysis

The following sections highlight the testing and analysis processes that are being used within the design.

Water Contamination

The first analysis method completed by the team was the creation of the water solution that would be used in testing. Three different solutions were created: one with arsenic and nitrate, one with only arsenic, and one with only nitrate. These solutions had to be created to ensure the starting conditions of 1-2 mg/L of arsenic and 25-40 mg/L of nitrate. The team targeted starting concentrations of 1.5 mg/L and 35 mg/L of arsenic and nitrate, respectively. The team chose to create the three solutions so that the activated alumina could be tested to treat each contaminate individually and together. Calculations were completed to determine the amount of sample that was needed for each of the three stock solutions. These numbers were based on needing 100 mL of solution for arsenic testing and 10 mL of sample for nitrate testing. The amount of chemicals necessary to contaminate the solution to appropriate levels was then calculated. The hand calculations done to complete this section can be seen in Figures 11 and 12 in Appendix 2.

Table 1 below presents the important information found through calculations to create all three water solutions. This table provides the amount of the solution that will be created and the chemical amounts necessary to contaminate the water.

Table 1: Stock Solution Data

Solution	Amount (L)	Arsenic pentoxide	Sodium Hydroxide	Sodium Nitrate
Arsenic and Nitrate	8.5	19.5585 mg	51 mg	407.83 mg
Arsenic	2.5	5.752 mg	15 mg	-
Nitrate	1.5	-	-	71.97 mg

A Standard Method (SM) was used to determine the combination of arsenic pentoxide and sodium hydroxide that was needed to contaminate the stock solutions with arsenic. The Standard Methods for the Examination of Water and Wastewater, 18th Edition 1992 was used to find this process. Stoichiometry was used, with the help of Dr. Terry Baxter and Gary Slim, to determine the amount of sodium nitrate that was needed to contaminate the stock solution with nitrate. The stock solutions were all created using distilled water, determined by the Standard Methods book. A picture of the procedure that was followed for arsenic contamination can be seen in Figure 13 of Appendix 3.

Water Testing using Constructed Design

The second task to be completed within the lab will be the water testing using CRKL Engineering's bench scale model with the solution containing both contaminants. Activated alumina, the adsorbent material, will be placed inside the completed design. 800 mL of the contaminated stock solution will be poured onto the activated alumina within the model. There will be enough activated alumina in the model so that all of the liquid will be in contact with the beads. The team chose this testing method with the help of the technical advisor, Dr. Terry Baxter, who recommended all of the contaminated water stays at the same level, or below, the level of activated alumina.

The team will collect 150 mL of water from the model using the valve on the bottom of the clear PVC tube at four different time increments for each trial. Based on previous research of activated alumina reducing arsenic levels, the team will collect samples after the water has sat in the column for 1, 5, 20, and 60 minutes. 150 mL must be collected each time because it is necessary to have 10 mL of sample for the nitrate test, 50 mL of solution for the arsenic HACH test kit, and 50 mL of sample to send Dr. Ketterer. Ten trials will be completed to have a total of 40 samples for the solution that contains arsenic and nitrate.

Following the sampling and testing of the solution with both contaminants, testing will be completed for the solutions that contain each contaminant individually. Five trials will be completed for each solution and the same time increments will be used while collecting samples. Since the samples will need to be tested for one of the contaminants instead of both, less sample will be collected during these trials. During each trial, at each time increment, for the nitrate and arsenic solutions, 50 mL and 110 mL will be collected, respectively.

The work plan explained in this section will begin the first week of March 2017. The water testing containing arsenic will be completed by the second week in March to ensure the samples are sent for arsenic testing in a timely manner. The arsenic testing procedures will be explained in the sections below.

Nitrate Testing

The method that will be used to test each sample for nitrate will be HACH Method #8171, Cadmium Reduction Method. A DR 3900 spectrophotometer, NitraVer5 powder pillow indicator, sample bottles, deionized water and sample will be used to test the water samples for nitrate [4]. A powder pillow will be poured into 10 mL of a sample and shaken for 1 minute. The sample will then sit for 5 minutes. A 10 mL sample bottle filled with deionized water will be placed into the DR 3900 and used as the “blank.” This means that the machine will recognize the level of nitrate in the deionized water, which is zero, as the zero reading. The sample containing the powder pillow will then be put in the spectrophotometer and a reading will be taken. The readings collected will be reported as mg/L of nitrate concentration. The full detailed procedure can be seen in Figure 14 in Appendix 4.

This test will be completed for each of the samples containing nitrate that the team collects from the bench scale model. This will also be performed on the original contaminated stock solutions to ensure the team is beginning at a level of 25-40 mg/L of nitrate. Nitrate testing will begin the first week of March and continue through the end of March 2017.

Arsenic Testing

The method that will be used to test each sample for arsenic was provided with the HACH Arsenic Test Kit. The team will use their treated and untreated sample along with the provided materials from the test, which includes test strips, the reaction vessel, a cap with a slot for test strips, a small scoop, five reagents (Reagent #1 through #5), and a color chart that indicates arsenic concentration [5]. The first step is placing a test strip into the cap. 50 mL of sample will be added to the reaction vessel followed by Reagent #1, followed by Reagent #2. Each time a reagent is added, the vessel is swirled to allow the reagent to dissolve and mix. A three-minute waiting period begins following the addition of Reagent #2. Next, Reagent #3 is added, followed by a two-minute waiting period. A level scoop of Reagent #4 is added, mixed, and then lastly Reagent #5 is added. As soon as the final reagent is added the vessel is capped, swirled, and set aside for 30 minutes. After the final waiting period, the test strip is removed from the reaction vessel and compared to the color chart to obtain an approximate arsenic concentration. The full detailed procedure can be seen in Figure 15 in Appendix 4.

This test will first be conducted on each of the stock solutions containing arsenic as well as on each treated sample originally containing arsenic. The initial test will be conducted to ensure that the stock solutions began within the range of 1-2 mg/L of arsenic. The team is conducting their own arsenic testing in addition to the full analysis to be conducted by Dr. Ketterer to ensure that the samples that they treat are near the desired concentrations. The team will send all treated samples containing arsenic solution to Dr. Ketterer at MSUD to analyze the arsenic levels using an inductively coupled plasma mass spectrometry method. This form of testing will allow the team to obtain precise and accurate final arsenic levels. The data received from Dr. Ketterer

regarding the arsenic levels will be analyzed and discussed in the final design report.

Project Implementation Cost (NOT required for 50%)

CRKL Engineering will provide a full cost breakdown of the implemented design within the final design report. The implementation cost cannot be justified so far due to adjustments that may need to be made throughout testing.

SUMMARY OF PROJECT COSTS (NOT REQUIRED FOR 50%)

Within the design process that began in August 2016, CRKL Engineering created a basic schedule for the spring 2017 semester to ensure the project would be carried out in a timely manner. CRKL Engineering planned for work to begin over winter break 2017 and continue through May 2017, when the final report is due. Figure 7 shows the original schedule that was made by CRKL Engineering.

Task Name	Duration	Start	End
4.0 Design Preparations	27 days		
<i>4.1 Acquire Lab Space</i>	<i>5 days</i>	<i>1/9/17</i>	<i>1/13/17</i>
<i>4.2 Lab Certifications</i>	<i>5 days</i>	<i>1/9/17</i>	<i>1/13/17</i>
<i>4.3 Acquire Lab Materials</i>	<i>11 days</i>	<i>1/19/17</i>	<i>2/2/17</i>
<i>4.4 Water Contamination</i>	<i>6 days</i>	<i>2/2/17</i>	<i>2/9/17</i>
5.0 Design Development	67 days		
<i>5.1 Design Construction</i>	<i>16 days</i>	<i>2/2/17</i>	<i>2/23/17</i>
<i>5.2 Water Testing</i>	<i>5 days</i>	<i>2/23/17</i>	<i>2/28/17</i>
<i>5.2.1 Send Samples for Testing</i>	<i>4 days</i>	<i>2/28/17</i>	<i>3/3/17</i>
<i>5.3 Analyze Test Results</i>	<i>9 days</i>	<i>3/20/17</i>	<i>3/30/17</i>
<i>5.4 Final Presentation</i>	<i>9 days</i>	<i>4/17/17</i>	<i>4/27/17</i>
<i>5.5 Final Design Report & Website</i>	<i>75 days</i>	<i>1/23/17</i>	<i>5/5/17</i>
6.0 Project Management			
<i>6.1 Team Meetings</i>		<i>ongoing</i>	
<i>6.2 Client Meetings</i>		<i>ongoing</i>	
<i>6.3 Technical Advisor Meetings</i>		<i>ongoing</i>	

Figure 7: Original schedule [1]

With the guidance and assistance of those involved, CRKL Engineering did not account for the amount of communication that was needed to complete this project. Throughout a few components of the design, more meetings were necessary than were planned. This set CRKL Engineering back slightly in the beginning of the design phase. The design preparations task took longer than expected due to ongoing communication with the lab manager, Gary Slim, and the need for an experimental plan to begin work. Since the “acquiring lab space” task was slightly postponed, this created a delay in receiving all the chemicals and tests that were ordered through

the lab facilities.

CRKL Engineering was able to collect design construction materials on their own and therefore moved the design construction task ahead of the water contamination task. This change created a one-week shift in the water-testing task. Figure 8 shows the schedule that CRKL Engineering has followed up to this point.

Task Name	Duration	Start	End
4.0 Design Preparations	28 days		
<i>4.1 Acquire Lab Space</i>	<i>22 days</i>	<i>1/16/17</i>	<i>2/7/17</i>
<i>4.2 Lab Certifications</i>	<i>3 days</i>	<i>1/19/17</i>	<i>1/21/17</i>
<i>4.3 Acquire Lab Materials</i>	<i>28 days</i>	<i>1/16/17</i>	<i>2/13/17</i>
<i>4.4 Water Contamination</i>	<i>2 days</i>	<i>2/27/17</i>	<i>2/28/17</i>
5.0 Design Development	67 days		
<i>5.1 Design Construction</i>	<i>16 days</i>	<i>2/10/17</i>	<i>2/25/17</i>
<i>5.2 Water Testing</i>	<i>10 days</i>	<i>2/28/17</i>	<i>3/10/17</i>
<i>5.2.1 Send Samples for Testing</i>	<i>4 days</i>	<i>3/10/17</i>	<i>3/13/17</i>
<i>5.3 Analyze Test Results</i>	<i>14 days</i>	<i>3/27/17</i>	<i>4/10/17</i>
<i>5.4 Final Presentation</i>	<i>10 days</i>	<i>4/17/17</i>	<i>4/27/17</i>
<i>5.5 Final Design Report & Website</i>	<i>75 days</i>	<i>1/23/17</i>	<i>5/5/17</i>
6.0 Project Management			
<i>6.1 Team Meetings</i>		<i>ongoing</i>	
<i>6.2 Client Meetings</i>		<i>ongoing</i>	
<i>6.3 Technical Advisor Meetings</i>		<i>ongoing</i>	

Figure 8: Updated schedule

It was decided that our samples would be sent to Dr. Ketterer at MSUD for arsenic testing. After a phone call with him, it was decided that the team's samples would be sent to him to week of March 13 - March 17. Dr. Ketterer estimated a two-week turn around period for the samples. The team had estimated a three-week turn around period and had added an additional week to the analysis of the test results just in case any adjustments needed to be made throughout the semester. With the additional time that CRKL Engineering added to their original schedule, the actual schedule that is being followed will allow enough time for the project to be completed on time. The final design report will include the full schedule that was followed by CRKL Engineering to complete the Verde Valley Water Treatment System.

Along with this section, the original cost proposal with time/effort for each employee compared to the actual time/effort will be included in the final design report. The original cost proposal hours of each team member can be seen in Figure 9.

Task	SENG Hours	ENG Hours	LAB Hours	INT Hours	AA Hours
Research	0	40	0	20	0
Water Contamination Preparation	24	0	80	80	0
Model Construction	40	56	40	24	0
Modeling	16	24	24	16	0
Result Analysis	32	32	0	0	160
Total	112	152	144	140	160
Total Project Hours	708				

Figure 9: Project Hours [1]

A table will be provided in the final report to show each team member's contributions toward the project.

REFERENCES

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APPENDICES

Appendix 1: Full Decision Matrix

			Nitrate			Arsenic				Dual Treatment	
	Criteria	Weights (%)	Ion Exchange: Chloride	Bio Film Reactor	Permeable Reactive Barrier	Oxidation	Electro Chemical	Phytoremediation Hyacinth Roots	Ceramic membrane filters	Ion Exchange: Titanium Oxide	Ion Exchange: Activated Alumina
Parameters	1 Low-Cost	30	9	3	1	9	3	9	9	9	9
	2 Low-Energy	30	3	9	3	1	1	9	9	9	9
	3 Feasibility	20	9	1	1	3	1	3	1	9	9
	4 System life-Time	15	3	3	9	9	9	3	3	3	9
	5 Minimal by-product	5	1	9	3	1	3	1	1	3	3
	6										
	7										
	Raw score		5.9	4.7	2.9	5	2.9	6.5	6.1	7.8	8.7
	Relative Rank		3	4	5	5	6	3	4	2	1

Figure 10: Full Decision Matrix [1]

Appendix 2: Hand Calculations

Water solution calculations (arsenic)

Mixed solution (As and NO₃⁻)

10 trials → 4 sample times of 150 mL

800 mL per trial (200 mL extra)

Solution must be 8 L ; make 8.5 L in case.

SM 18th Edition 1992 page 3-30

Stock As(V) solution :

• Dissolve 1.534g arsenic pentoxide, As₂O₅, in distilled water containing 4g NaOH. Dilute to 1L;
1.00 mL = 1.00 mg As(V)

1.534g of As₂O₅ in 1 L = 1.534 mg/L As(V)
to create solution with 1.5 mg/L As(V) :

1.534 mg of As₂O₅ in 1 L = 1 mg/L As(V)
then :

2.301 mg of As₂O₅ in 1 L = 1.5 mg/L As(V)

for 8.5 L → (2.301 mg)(8.5)

$$= \boxed{19.5585 \text{ mg As}_2\text{O}_5}$$

for every 1.534 mg As₂O₅ → need 4 mg of NaOH

$$\left(\frac{19.5585 \text{ mg As}_2\text{O}_5}{1.534 \text{ mg As}_2\text{O}_5} \right) \left(\frac{4 \text{ mg NaOH}}{1.534 \text{ mg As}_2\text{O}_5} \right) = \boxed{51 \text{ mg NaOH}}$$

Arsenic Solution

(5 trials)(4 times)(110 mL) = 2100 mL solution
≈ 2.5 L solution

for 2 L → (2.301 mg As₂O₅)(2.5) = $\boxed{5.7525 \text{ mg As}_2\text{O}_5}$

$$\left(\frac{5.7525 \text{ mg As}_2\text{O}_5}{1.534 \text{ mg As}_2\text{O}_5} \right) \left(\frac{4 \text{ mg NaOH}}{1.534 \text{ mg As}_2\text{O}_5} \right) = \boxed{15 \text{ mg NaOH}}$$

Figure 11: Stock Solution Calculations Page 1

water solution calculations (nitrate)

mixed solution

using NaNO_3^- : MW = 85 g/mol

NO_3^- : MW = 62 g/mol

$$\frac{62 \text{ g/mol } \text{NO}_3^-}{85 \text{ g/mol } \text{NaNO}_3} = 0.7294$$

Target concentration: 35 mg/L NO_3^-

$$\text{NaNO}_3 = \frac{35 \text{ mg/L } \text{NO}_3^-}{0.7294} = 47.98 \text{ mg/L } \text{NO}_3^-$$

using NaNO_3^- to make a 35 mg/L NO_3^- solution:

47.98 mg needed per L of solution

for 8.5 L of solution = 407.83 mg NaNO_3^-

Nitrate Solution

(5 trials)(4 samples)(50 mL) = 1000 mL solution needed

make 1.5 L of solution for some excess

$$47.98 \text{ mg} = 1 \text{ L}$$

then:

$$1.5 \text{ L} = \boxed{71.97 \text{ mg } \text{NaNO}_3}$$

Figure 12: Stock Solution Calculations Page 2

Appendix 3: Standard Methods

1. Arsenic(V) solutions:

1) *Stock As(V) solution:* Dissolve 1.534 g arsenic pentoxide, As_2O_5 , in distilled water containing 4 g NaOH. Dilute to 1 L; 1.00 mL = 1.00 mg As(V).

2) *Intermediate As(V) solution:* Prepare as for As(III) above; 1.00 mL = 10.0 μg As(V).

3) *Standard As(V) solution:* Prepare as for As(III) above; 1.00 mL = 0.100 μg As(V).

Figure 13: Arsenic Contamination Method

Appendix 4: Testing Method Procedures



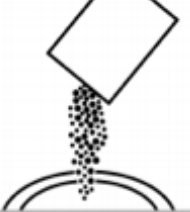

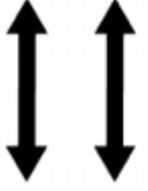







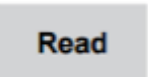
 <p>Start</p>	 <p>10 mL</p>		 <p>01:00</p>
<p>1. Start program 353 N, Nitrate MR PP. For information about sample cells, adapters or light shields, refer to Instrument-specific information on page 1.</p>	<p>2. Prepare the sample: Fill a sample cell with 10 mL of sample.</p>	<p>3. Add the contents of one powder pillow to the sample cell.</p>	<p>4. Start the instrument timer. A 1-minute reaction time starts.</p>
	 <p>05:00</p>	 <p>10 mL</p>	
<p>5. Put the stopper on the sample cell. Shake the sample cell vigorously until the timer expires. Some solid material will not dissolve. Undissolved powder will not affect results.</p>	<p>6. Start the instrument timer. A 5-minute reaction time starts. An amber color shows if nitrate is present.</p>	<p>7. Prepare the blank: Fill a second sample cell with 10 mL of sample.</p>	<p>8. When the timer expires, clean the blank sample cell.</p>
	 <p>Zero</p>		
<p>9. Insert the blank into the cell holder.</p>	<p>10. Push ZERO. The display shows 0.0 mg/L NO_3^--N.</p>	<p>11. Clean the prepared sample cell.</p>	<p>12. Within 2 minutes after the timer expires, insert the prepared sample into the cell holder.</p>
 <p>Read</p>			
<p>13. Push READ. Results show in mg/L NO_3^--N.</p>			

Figure 14: HACH Method for Nitrate [4]

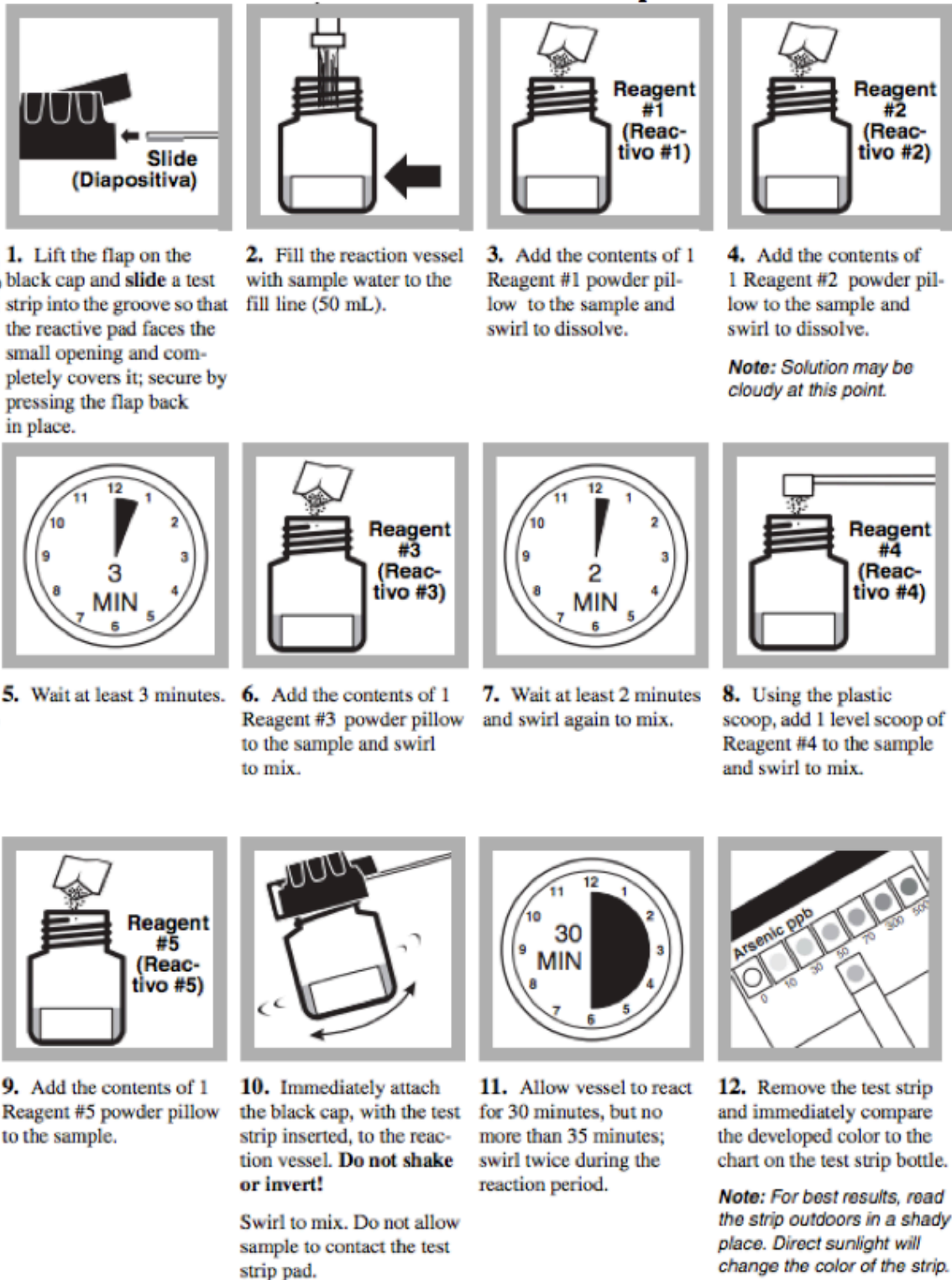


Figure 15: HACH Method for Arsenic