American Society of Civil Engineers Environmental Design Competition UGRADS Presentation

Alex Anzar, Shelby Carawan, Paige Reilly, Cameron Rhodes

April 27, 2018

Project Understanding

1.7 million deaths per year can be attributed to the unsafe water supply and unsanitary treatment methods within developing countries [1].

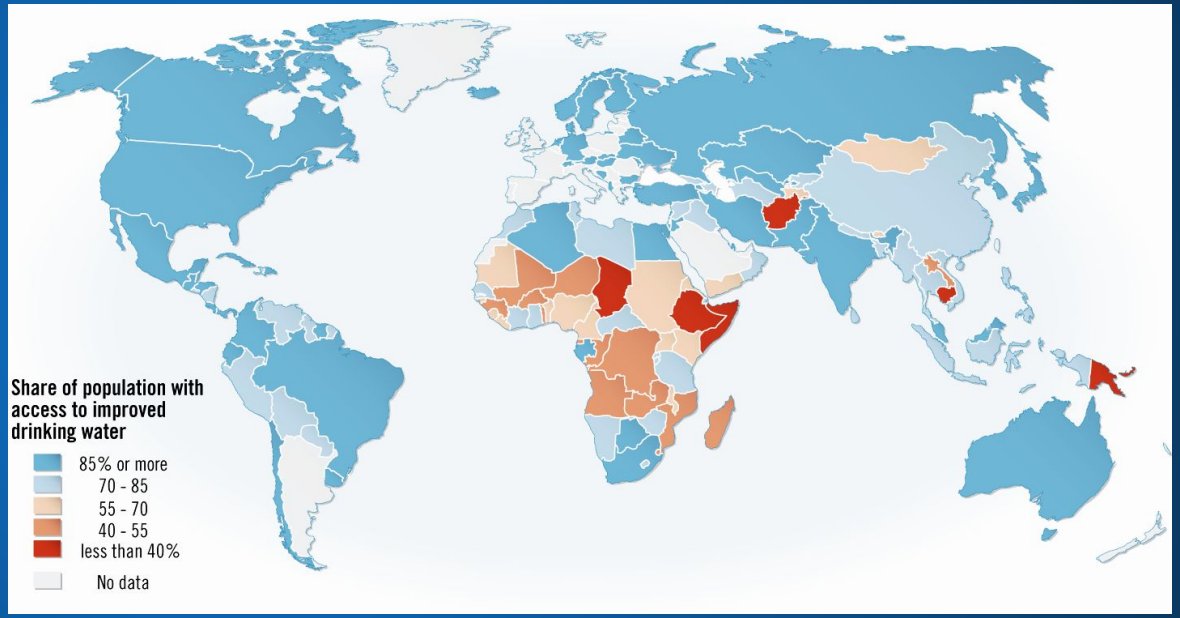


Figure 1: Global Distribution of Improved Drinking Water [1]

Project Understanding

The 2018 Pacific Southwest Conference (PSWC) took place in Tempe, Arizona on April 12th [2].

The goal of the project was to design and construct a reusable household water treatment system with a budget of $500 [2].

Figure 2: PSWC 2018 NAU Environmental Design Team (Photo courtesy of Shelby Carawan)

Project Understanding

Table 1: Contaminant Quantities Per 34L Sample [2]

Contaminant	*Quantity Per Nine Gallon Sample*
Miracle Gro All Purpose Plant Food	1000 g
Bulk Apothecary Kaolin Clay	1000 g
Star Kay White Pure Lavender Extract	30 mL
Wastewater Treatment Plant (WWTP) Effluent	20 mL

Table 2: Water Quality Testing Parameters and Water Quality Goals Compared to World Health Organization (WHO) Standards [2]

Parameters	*Competition Goal*	*WHO Standards*
Total P-PO_4^{3-}	≤ 1 mg/L	1 mg/L
Total N-NO_3^-	≤ 10 mg/L	10 mg/L
Turbidity	≤ 1 NTU	1 NTU
Chlorine	4 ± 1 ppm	4 ppm
Total Coliforms	No Coliforms	≤ 5%
Odor	No Odor	N/A

Project Understanding

Stakeholders:

- Populations of developing regions
- Northern Arizona University (NAU)
- NAU ASCE student chapter
- The client, Mark Lamer

Challenge:

- The difference in climate between Flagstaff and the competition location, Tempe [2].

Figure 3: PSWC 2018 NAU Environmental Design Team Construction (Photo courtesy of Paige Reilly)

Scope of Services

1. Literature Review
   - 1.1 Developing Country Resources
   - 1.2 Treatment Methods
2. Unit Design Selection
   - 2.1 Component Prototyping
   - 2.2 Software Schematic
3. Acquisition of Materials
4. 30% Report

Figure 4: Water Collection at a Borehole by Children in Salima, Malawi [3]

Scope of Services

5. Fabrication
   - 5.1 Prototyping
   - 5.2 Final Design
6. Prototype Testing
   - 6.1- 6.6 Test Each Parameter Unit
7. Compile Results and Construct Final Design
   - 7.1 Component Integration and Optimization
8. 60% Report

Figure 5: A Local Village Collecting Water in Sub-Saharan Africa [4]

Scope of Services

9. Perform at PSWC Competition
   - 9.1 Construct and Operate Device
   - 9.2 Present Process Flow Diagram
   - 9.3 Technical Presentation
10. Website
11. UGRADS Presentation
12. Final Report
13. Project Coordination

Figure 6: Children in Nigeria Collecting Water at a Local Water Source [4]

Water Treatment Process

1. Sedimentation
2. Sand filter
3. Ion-exchange resin
4. Granular activated carbon
5. Collection bucket

Note: 100% cotton cloth layers will cover the bottoms of the buckets

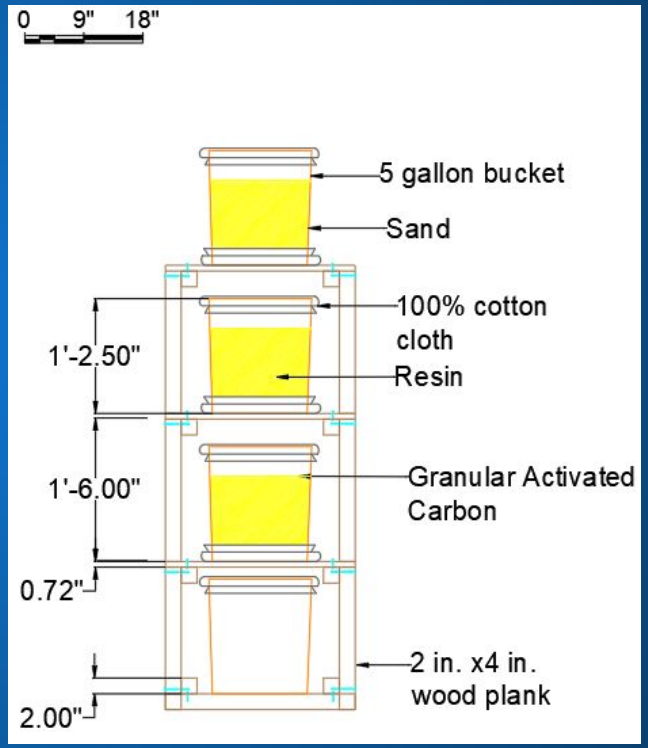
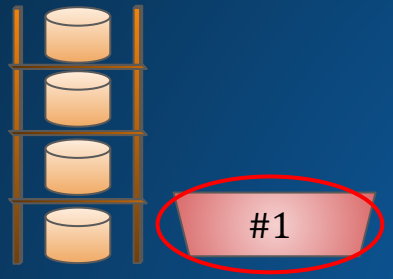


Figure 7: AutoCAD Drawing of Wastewater Treatment System Final Design



Step 1: Sedimentation

Sedimentation reduces initial turbidity by allowing suspended kaolin clay particles to settle.

Equation 1: Settling Velocity

Settling Velocity of Clay = Distance Settled/Time = 0.762 cm/min

$\therefore$ 0.745 m^2 ideal size of settling area for 6 min settling

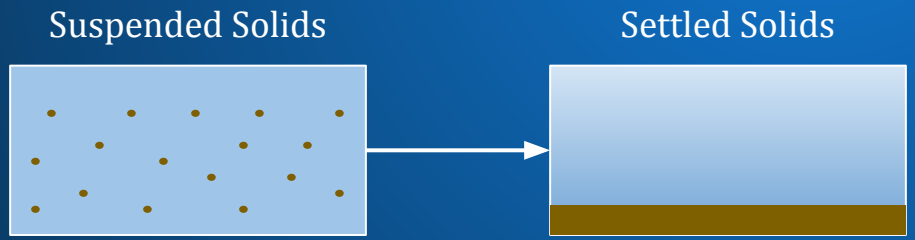
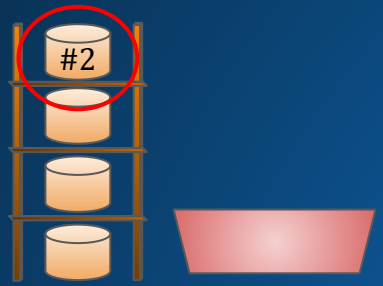


Figure 8: The Sedimentation Process over a Period of Time

Table 3: Turbidity Testing Results from Sedimentation

Turbidity Results	
Units	NTU
WHO Standard	1
Raw Water Result	2,590
Final Water Result	190
Percent Eliminated	93%



Step 2: Sand Filtration

Sand filtration further reduces turbidity by decreasing the presence of kaolin clay and Miracle Gro potting mix.

Table 4: Turbidity Testing Results from Sand Filtration

Turbidity Results	
Units	NTU
WHO Standard	1
Raw Water Result	2,590
Final Water Result	980
Percent Eliminated	62%

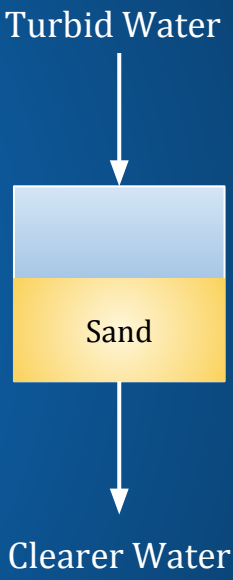
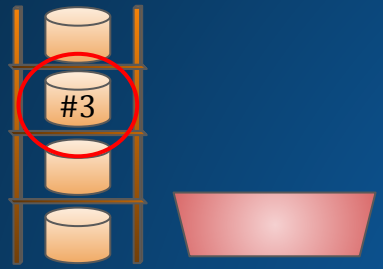


Figure 9: Sand Filtration of Turbid Water to Produce Clearer Water



Step 3: Ion-Exchange Resin

An ion-exchange resin was implemented to remove Nitrate and Phosphate levels.

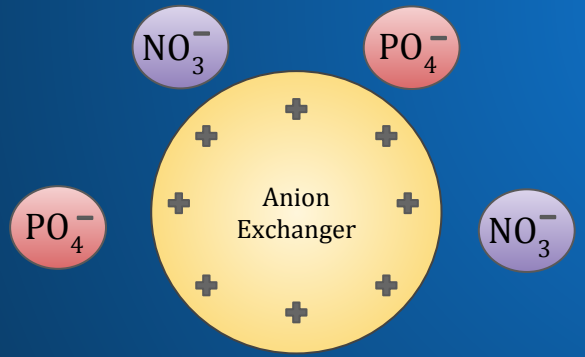


Figure 10: Anion Exchange Resin Attracts Negatively Charged Nitrate and Phosphate [5]

Table 5: Phosphorus and Nitrogen Testing Results from Ion-Exchange Resin

Variable	*$P\text{-}PO_4^{3-}$ Results*	*$N\text{-}NO_3^-$ Results*
Units	mg/L	mg/L
WHO Standard	1	10
Raw Water Result	3390	50
Final Water Result	200	2.1
Percent Eliminated	94%	96%

Step 4: Granular Activated Carbon

Granular Activated Carbon aims to remove odor and any additional turbidity.

Table 6: Odor Results from Granular Activated Carbon Filtration

Odor Results	
Raw Water Result	Present
Final Water Result	Present*
Percent Eliminated	N/A

*Reduced but still present

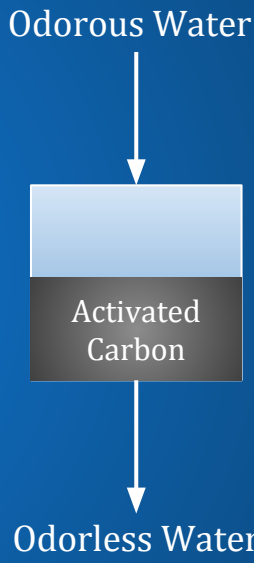
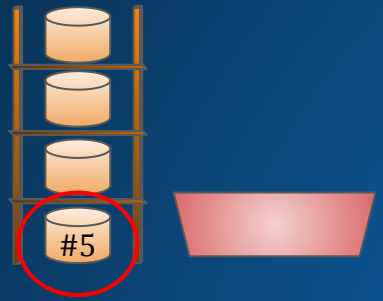


Figure 11: Granular Activated Carbon Filtration of Turbid Water to Produce Clearer Water



Step 5: Disinfection

Clorox bleach was used to remove bacteria and fecal coliforms.

Table 7: Chlorine Disinfection Quantities using Liquid Household Bleach (5% Sodium Hypochlorite) [6]

Storage Tank		*Concentration*	
(gal)	*(L)*	*1 ppm*	*5 ppm*
500	1,890	15 mL	177 mL
250	946	7.4-10 mL	88.7 mL
100	378	5 mL	22.2 mL

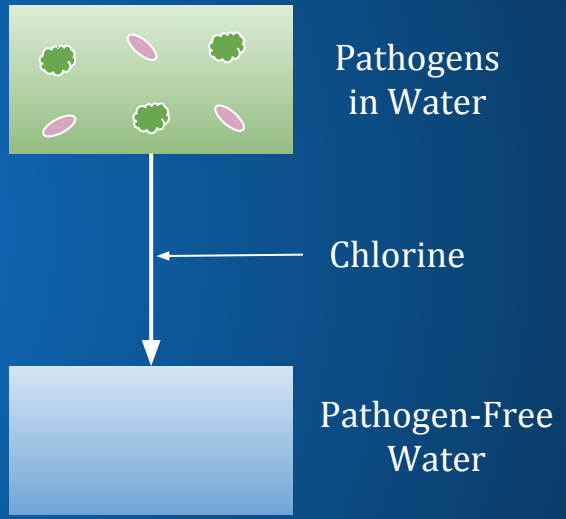


Figure 12: Chlorine Disinfection

Final Design Water Quality

Table 8: Final Design Water Quality Parameter Testing Results

Parameter	*Units*	*Competition Goal*	*WHO Standard*	*Raw Water Result*	*Final Water Result*	*Percent Eliminated*
$P\text{-}PO_4^{3-}$	mg/L	≤ 1	1	3,390	200	94%
$N\text{-}NO_3^-$	mg/L	≤ 10	10	50	2.1	96%
Turbidity	NTU	≤ 1	1	2,590	275	89%
Chlorine	ppm	4 ± 1	4 ppm	0 ppm	4 ppm	N/A
Total Coliforms	Unitless	No Coliforms	$\leq 5\%$	Present	Not Present	100%
Odor	Unitless	No Odor	N/A	Present	Present	N/A

PSWC Performance

1st place in Arizona
4th place overall

Table 9: Lab Testing Performance at PSWC 2018

Parameter	Control	Results
Nitrate (mg/L)	35.8	6.3
Phosphate (mg/L)	2.75	2.75
Chlorine (ppm)	2.2	2.2
Coliforms	ND	ND
Turbidity (NTU)	461	461

Figure 13: Water Treatment System Construction at PSWC 2018 (Photo Courtesy of Cameron Rhodes)

Figure 14: Constructed Water Treatment System at PSWC 2018 (Photo Courtesy of Cameron Rhodes)

Figure 15: Environmental Design Team at PSWC 2018 (Photo Courtesy of Teresa Carawan)

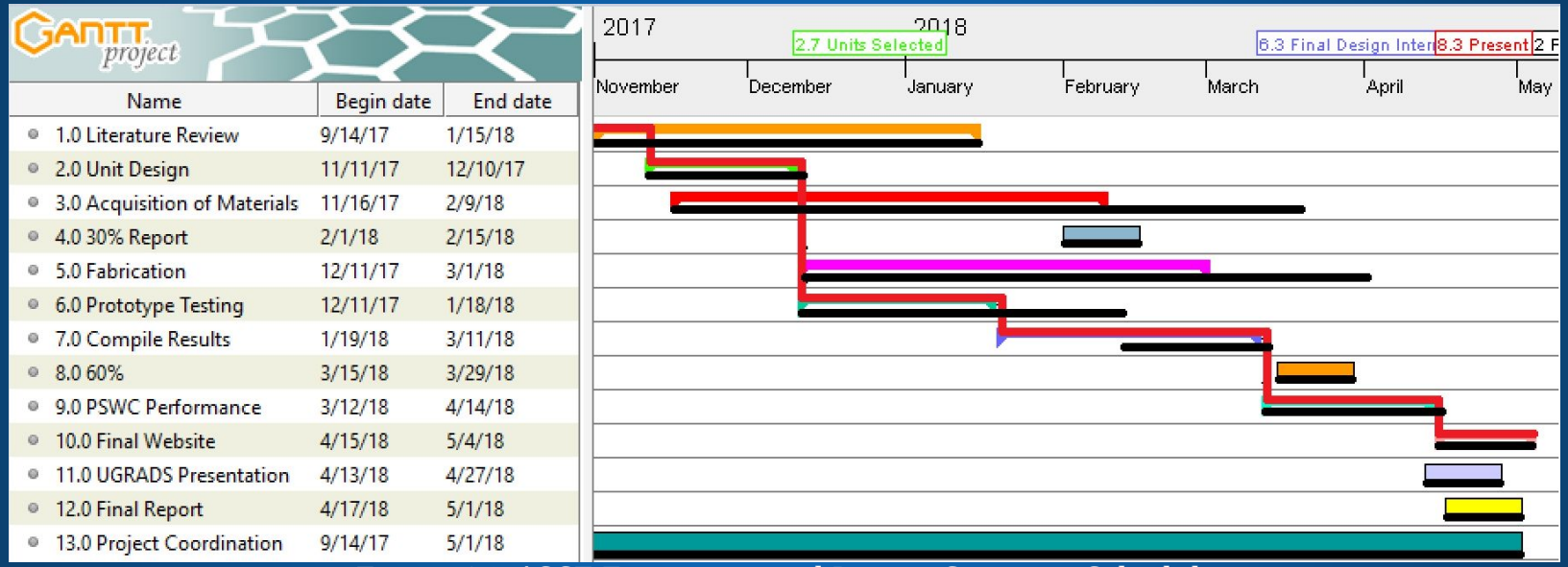
Final Design Recommendations

1. Competition rules also prohibited coagulants and flocculants to eliminate turbidity.
2. Time constraints did not allow biological methods to be used.
3. Moringa seeds were a cost-effective option for removing turbidity, but they require 1-2 hours to treat.

Figure 13: Water Treatment Using Moringa Seeds [7]

Schedule

(Sept. 14, 2017 - May 1, 2018)



Name	Begin date	End date
1.0 Literature Review	9/14/17	1/15/18
2.0 Unit Design	11/11/17	12/10/17
3.0 Acquisition of Materials	11/16/17	2/9/18
4.0 30% Report	2/1/18	2/15/18
5.0 Fabrication	12/11/17	3/1/18
6.0 Prototype Testing	12/11/17	1/18/18
7.0 Compile Results	1/19/18	3/11/18
8.0 60%	3/15/18	3/29/18
9.0 PSWC Performance	3/12/18	4/14/18
10.0 Final Website	4/15/18	5/4/18
11.0 UGRADS Presentation	4/13/18	4/27/18
12.0 Final Report	4/17/18	5/1/18
13.0 Project Coordination	9/14/17	5/1/18

Figure 16: ASCE Environmental Design Capstone Schedule

- RED - Critical Path defined by design tasks and presentation deadlines
- BLACK - Actual Schedule

Staffing

Table 10: Actual and Proposed Staffing Hours of Specified Tasks

Task	*Staff (hrs)*				*Proposed Total (hrs)*	*Actual Total (hrs)*	*Difference (hrs)*
	PE	*PM*	*EIT*	*Tech*			
1. Literature Review	0	0	40	0	40	40	0
2. Unit Design	5	10	20	20	55	65	+10
3. Acquisition of Materials	0	0	3	3	6	6	0
4. 30% Report	6	6	6	0	18	21	+3
5. Fabrication	4	25	50	60	139	152	+13
6. Prototype Analysis	5	5	25	40	75	80	+5
7. Finalize Design	30	25	25	35	115	120	+5
8. 60% Report	10	10	15	0	35	35	0
9. PSWC Requirements	14	24	35	10	83	85	+2
10. Website	0	5	10	0	15	15	0
11. Final Presentation	5	5	7	0	17	21	+4
12. Final Proposal	10	10	10	0	30	35	+5
13. Project Coordination	10	10	10	10	40	40	0
Staff Total	*99*	*135*	*256*	*178*	*668*	*715*	*+47*

Cost of Engineering Services

Table 11: Actual and Proposed Staffing Costs

Position Title	*Base Pay Rate/Hour*	*Benefits % of Base Pay*	*Actual Pay/Hour*	*Proposed Hours*	*Proposed Total Cost*	*Actual Hours*	*Actual Total Cost*
PE	$90.00	40.00%	$126.00	99	$12,474	110	$13,860
PM	$70.00	40.00%	$98.00	135	$13,230	150	$14,700
EIT	$50.00	30.00%	$65.00	256	$16,640	265	17,225
Tech	$40.00	30.00%	$52.00	178	$9,256	190	$9,880
Total				*668*	*$51,600*	*715*	*$55,665*

$4,065 (8%) increase from proposed amount

Cost of Engineering Services

Table 12: Total Materials Cost of Wastewater Treatment System

Item	*Vendor*	*Unit*	*Cost Per Unit*	*Quantity*	*Total cost*
2 in. by 4 in. Prime Stud	Home Depot	100 in. Stud	$3.77	4	$15.08
Plywood		48 in. x 96 in. Sheet	$9.98	1	$9.98
5 Gallon Bucket		1 Bucket	$3.25	5	$16.25
Screws		90 Nails	$8.38	1	$8.38
30 Gallon Storage Tote		1 Tote	$9.97	1	$9.97
Screwdriver		1 Screwdriver	$0.87	4	$3.48
Men's Crew T-Shirts	Walmart	10 T-Shirt Pack	$19.93	1	$19.93
Rubber Bands		64 Bands	$1.27	1	$1.27
Deionization Resin	Amazon	5 Pounds	$45.00	4	$180.00
Bleach		30 Ounces	$8.14	1	$8.14
Activated Carbon		39 Ounces	$16.99	8	$135.92
Sand		50 Pounds	$28.41	1	$28.41
Total Cost					*$436.81*

Cost of Engineering Services

Table 13: Actual and Proposed Travel Costs to Pacific Southwest Conference

Expense	*Units*	*Quantity*	*Average Cost Per Unit*	*Proposed Total Cost*	*Actual Total Cost*
Rental Car	Days	4	$55.00	$220	$208
Gasoline	Gallons	40	$3.00	$120	$110
Hotel Rooms	2 Rooms	4	$400.00	$1,600	$1,240
Meals	3 Meals	16	$30.00	$480	$320
Total Travel Costs				*$2,420*	*$1,878*

Table 14: Actual and Proposed Total Cost of Project

Average Cost Per Unit	*Proposed Total Cost*	*Actual Total Cost*	*Difference*
System Costs	$500	$436.81	- $63.81
Staffing Costs	$51,600	$55,665	+$4,065
Travel Costs	$2,420	$1,878	- $542
Total Cost	***$54,710***	***$57,980***	***+ $3,270 (6%)***

References

[1] "WHO | Environment and health in developing countries", Who.int, 2017. [Online]. Available: http://www.who.int/heli/risks/ehindevcoun/en/.

[2] American Society of Civil Engineers Environmental Design Competition. (2017). Flagstaff: Northern Arizona University, pp.1-9.

[3] D. Armstrong. "Groundwater resources mapped in Africa", (2012).Earth Times. [Online]. Available: http://www.earthtimes.org/scitech/groundwater-resources-africa-mapped/1937/.

[4] "Papplewick pumping station: Demand for water", *Papplewickpumpingstation.org.uk*, 2017. [Online]. Available: http://www.papplewickpumpingstation.org.uk/water_supply_in_developing_countries.html.

[5] Central Department of Microbiology. “Ion Exchange Chromatography”. (2018). Tribhuvan University. Institute of Science and Technology. [Online]. Available: https://microbiotu.edu.np/.

[6] G. Bulfin, G. Bulfin, G. Bulfin, G. Bulfin, G. Bulfin and V. →, "How Much Chlorine in storage tank can Kill Bacteria?", Clean Well Water Report, 2018. [Online]. Available: https://www.cleanwaterstore.com/blog/how-much-chlorine-should-be-added-to-a-storage-tank-to-kill-bacteria/.

[7] “Des graines d’arbre magiques pour purifier l’eau sale.” *Irin. (2011). [Online].*

Figure 17: PSWC 2018 NAU Environmental Design Team (Photo courtesy of Taylor Erdmann)