NORTHERN ARIZONA UNIVERSITY

College of Engineering, Forestry & Natural Sciences

Task 2: Drinking Water Stabilization

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Task Number:

Task 2- Drinking Water Stabilization

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Table of Contents

EXECUTIVE SUMMARY

The optimum mineral solution by RAVA Fontus Engineering Inc can be seen in Table 1.

Table 1: Optimum Mineral Composition and its Percent Daily Values.

Mineral (cation or anion)	Regulatory Max Concentration (mg/L)	Optimum Mineral Composition (mg/L)	% DV (3 Liters/day)
Calcium	**Not Regulated**	8	2%
Iron	**0.3**	0.005	0%
Magnesium	**Not Regulated**	10	11%
Iodine	**Not Regulated**	0.001	3%
Potassium	**Not Regulated**	7	1%
Zinc	**5.0**	1	17%
Sodium	**Not Regulated**	12	2%
Chloride	**250**	3.54	N/A
Sulfate	**250**	29.05	N/A

This mineral composition satisfies all regulations and has daily percent values from 0% to 17%. These minerals are needed by children, adults, and seniors and will increase the mineral content in reverse osmosis bottled water. Furthermore, if this product was sold through an independent company, the price of the product and possible profit can be seen in Table 2. Now, if the product is sold through a current bottled water distributor, the possible profit can be seen in

Table *3*.

Table 2: Price and Profit Scenario by Selling Through an Independent Company.

Material	Quantity	Price	Total
4 oz bottle w/ lid	9000	$ 2.99	$ 26,910.00
8 oz bottle w/lid	4500	$ 5.49	$ 24,705.00
16 oz bottle w/ lid	3240	$ 11.99	$ 38,847.60
		TOTAL GAIN	$ 90,462.60
		TOTAL COST	$ 33,880.82
		TOTAL PROFIT	***$ 56,581.78***

Table 3: Profit by Selling Through a Current Bottled Water Distributor.

Material	Quantity	Price/ Share	Total
1 mL mineral salt composition	500,000	$ 0.60	$ 300,000.00
		TOTAL GAIN	$ 300,000.00
		TOTAL COST	$ 8,980.00
		TOTAL PROFIT	***$ 291,020.00***

1. TASK IDENTIFICATION

For this project, RAVA Fontus Engineering Inc. will find an innovative way to stabilize drinking water that uses the Reverse Osmosis (RO) treatment method. The purpose is to design an optimum mineral composition to be added into RO bottled water taking into account the nutritional requirements for children, adults, and seniors to prevent leaching of minerals from the skeletal system.

The main focus areas are:

- Nutritional requirements for humans;
- Nutritional requirements for livestock;
- Reducing the corrosion impact in the water distribution system due to RO bottled water;
- The development of a marketing plan to sell the optimum mineral additive to the public taking into account possible impacts;
- Development and completion of a cost analysis that takes into account the implementation of adding the supplementary minerals into the bottling process for current bottled waters, and the cost of the added minerals to independent production.

2. TECHNICAL EVALUATION

2.1. Reverse Osmosis

During the RO treatment, all the particles that are larger than a water molecule, including the minerals, are removed through a pressurized membrane. Therefore, when RO bottled water is consumed, the minerals from the skeletal system replace the ones that were lost in the RO process[11]. Thus, there is a need to reinstitute minerals into the pure RO water for many beneficial reasons, such as preventing osteoporosis, cardiovascular disease, kidney stones, and high blood pressure[4]. It is important to know what the variance of minerals in RO bottled water are and how they compare to the Environmental Protection Agency (EPA) and Food and Drug Administration (FDA) standards under the Code of Federal Regulations (CFRs) for bottled water, which will be further discussed in 2.6.2 Regulatory Requirements section. Additionally, information from the U.S. Department of Health and Human Services as well as the World Health Organization will help to determine the maximum mineral concentrations that can be added into RO bottled water.

2.2. Minerals Required per Age Group

For the human health portion, there needs to be the consideration of multiple age groups which are children, adults, and seniors. Each group has a specific list of minerals that are needed for daily nutritional health requirements. The minerals for each age group are shown below in Table 4.

Table 4: Recommended Dietary Mineral Allowances by Age Group.

Children	Adults	Seniors
Calcium (1,300 mg/day)*	Calcium (1200 mg/day)*	Calcium(≤ 2,500 mg/day)*
Zinc (9 mg/day)*	Chromium (1.5 mg/day)*	Iron (10 mg/day)*
Iron (11 mg/day)*	Copper (2 mg/day)*	Zinc(2.5 mg/day)*
Sodium (460 to 920 mg/day)*	Iodine (0.150 mg/day)*	Magnesium (320 to 42 mg/day)*
Potassium (4,700 mg/day)*	Iron (18 mg/day)*	Copper (700 to 900 micrograms/day)*
Magnesium (400 mg/day)*	Magnesium (40 mg/day)*	
Iodine (0.115 mg/day)*	Phosphorus (1000 mg/day)*	
	Potassium (10 mg/day)*	
	Selenium (50-200 micrograms/day)*	
	Zinc (15 mg/day)*	

* All values and minerals were retrieved from U.S. Department of Health & Human Services[8].

Calcium, magnesium, potassium, copper, iron, iodine, sodium, and zinc are all minerals that all three age groups require. Therefore, RAVA Fontus Engineering Inc. will take them into consideration for the optimum mineral composition.

2.3. Maximum Mineral Concentrations in RO Bottled Water

Drinking water reports from the World Health Organization (WHO) were used to find the recommended mineral concentration that should be in RO bottled water[12, 13, 14, 22]. Also, since each group has a different recommended dietary allowance (RDA) for each of the eight minerals, the average values were tabulated for future percentage daily value (% DV) calculations, which will be discussed in section 3.1 Identification of Alternatives. The RDAs were obtained from the U.S. Department of Health & Human Services, Colorado State University, Centers for Disease Control and Prevention, and the American Cancer Society. Table 5 shows the WHO mineral concentration recommendation in mg/L and the RDA average in mg/day.

Table 5: WHO Mineral Concentration (mg/L) and RDA Average (mg/day).

Mineral	WHO Mineral Concentration Recommendation (mg/L)	RDA Average (mg/day)
Calcium	$\geq$20	1000[8]
Iron	$\leq$0.3	11[8]
Copper	$\geq$1	0.9[7]
Magnesium	$\geq$10	270[8]
Iodine	$\leq$0.004	0.12[8]
Potassium	$\geq$8	3450[3]
Zinc	$\geq$1.1	18[8]
Sodium	$\geq$200	>2300[17]

2.4. Livestock Nutritional Requirements

The minerals for the nutritional requirements of livestock need to reported, but will not be taken into consideration when designing the optimum mineral composition. The daily nutritional mineral values vary from animal to animal. However, the common minerals that are required for the nutritional health of livestock are as follows[8]:

- Calcium
- Phosphorus
- Magnesium
- Potassium.
- Sodium
- Chlorine
- Sulfur

2.5. Water Distribution System

The water distribution system is the "piping system that delivers potable water from the treatment plant to consumers"[18]. Since RO water is demineralized, it has similar effects on the water distribution system to the effects on the skeletal system. Demineralized water is also considered soft water, which means "it contains only small amounts of dissolved minerals such as calcium and magnesium"[18].When RO water flushes through the pipes, it does not only corrode them, but it leaches metals and other materials from the pipes. Chemicals such as calcium carbonate, sodium bicarbonate, or limestone must be added to reduce corrosion on the piping system[18]. The team has decided to use sodium bicarbonate to stabilize the pH of the water because it will also account for some of the daily sodium intake required in everyday diets.

2.6. Existing Conditions

Currently, the bottled water industry profits from advertisements that claim their water is as fresh as natural spring water, or their water is pure[21]. Many of these statements can be misleading because of the lack of nutritional labeling.

2.6.1. Current and Popular Water Companies

The RAVA Fontus Engineering Inc. team decided to look into three RO bottled water brands for future comparison purposes and lab work. The description of three popular brands are shown below in Table 6.

Table 6: Three Popular and Current RO Bottled Water Brands.

Brand	Description
Popular Brand #1	This specific brand uses RO for their purification process which makes it potentially unhealthy, but yet they claim their water is "pure with a perfect taste"[21].
Popular Brand #2	This bottled water company claims to sell water enhanced with minerals for a "pure and fresh taste"[21]. Yet, they also use the RO process to remove contaminants from the water which makes the water soft.
Popular Brand #3	Popular Brand #3 uses RO water, but they do add minerals back into it[21]. The firm wants to analyze the concentrations of each of the minerals they added. This information will help to the design of the final optimum mineral additive.

2.6.2. Regulatory Requirements

Bottled water is under the jurisdiction of the FDA. Currently there are regulations about the maximum chemical concentrations allowed in bottled water in the CFRs under Title 21: Food and Drugs, part 165-beverages, subpart B-requirements for specific standardized beverages. Table 7 shows the regulatory maximum concentrations pertaining to this project.

Table 7: Regulatory Maximum Concentrations in Bottled Water (mg/L).

Mineral	Regulatory Maximum Concentration (mg/L)
Calcium	Not Regulated
Copper	1.0
Iron	0.3
Magnesium	Not Regulated
Iodine	Not Regulated
Potassium	Not Regulated
Zinc	5.0
Sodium	Not Regulated
Chloride	250
Sulfate	250
Total Dissolved Solids	500

As shown above, calcium, magnesium, iodine, potassium, and sodium are not regulated in the CFRs under the FDA.

2.7. Testing Required

Preliminary testing is needed to determine the physical and chemical qualities of the water that already exist in the market today. Once these are found the focus can be directed to testing the optimum mineral compositions. The criteria for the tests are specified in CFR 165.110(a-b) for bottled water. The tests that will be performed are: acidity, alkalinity, cation and anion identification, color, conductivity, odor, pH, total dissolved solids, and turbidity.

3. BENCH-SCALE/ PROTOTYPE LAB RESULTS

3.1. Identification of Alternatives

Three alternatives were originally designed; however, it was necessary to design two additional mineral compositions because the pH was too high for drinking water standards. This will be further discussed in section 3.2 Testing/Analysis.

3.1.1. Round 1

Composition 1 can be seen in Table 8.

Table 8: Composition 1 with Regulatory, RDA, and Percentage Daily Values.

Mineral (cation or anion)	Regulatory Max Concentration (mg/L)	WHO Mineral Concentration Recommendation (mg/L)	RDA Average (mg/day)	Composition 1 (mg/L)	% DV (3 Liters/day)
Calcium	**Not Regulated**	**≥20**	**1000[8]**	30	9%
Copper	**1.0**	**≥1**	**0.9[7]**	1	333%
Iron	**0.3**	**≤0.3**	**11[8]**	0.3	8%
Magnesium	**Not Regulated**	**≥10**	**270[8]**	26	29%
Iodine	**Not Regulated**	**≤0.004**	**0.12[8]**	0.004	10%
Potassium	**Not Regulated**	**≥8**	**3450[3]**	8	1%
Zinc	**5.0**	**≥1.1**	**18[8]**	5	83%
Sodium	**Not Regulated**	**≥200**	**>2300[17]**	100	13%
Chloride	**250**	**Not Applicable**	**Not Applicable**	42.46	Not Applicable
Sulfate	**250**	**Not Applicable**	**Not Applicable**	95.37	Not Applicable

As shown above, composition 1 has high percent daily values for each of the minerals since the team was aiming to be at the regulatory maximum concentrations. The reason for designing a composition at the maximum allowable concentrations was to represent the additive with the highest nutritional value. Composition 2 can be seen in Table 9.

Table 9: Composition 2 with Regulatory, RDA, and Percentage Daily Values.

Mineral (cation or anion)	Regulatory Max Concentration (mg/L)	WHO Mineral Concentration Recommendation (mg/L)	RDA Average (mg/day)	Composition 2 (mg/L)	% DV (3 Liters/day)
Calcium	**Not Regulated**	**≥20**	**1000[8]**	20	6%
Copper	**1.0**	**≥1**	**0.9[7]**	0.5	167%
Iron	**0.3**	**≤0.3**	**11[8]**	0.2	5%
Magnesium	**Not Regulated**	**≥10**	**270[8]**	20	22%
Iodine	**Not Regulated**	**≤0.004**	**0.12[8]**	0.003	8%
Potassium	**Not Regulated**	**≥8**	**3450[3]**	7.5	1%
Zinc	**5.0**	**≥1.1**	**18[8]**	4	67%
Sodium	**Not Regulated**	**≥200**	**>2300[17]**	75	10%
Chloride	**250**	**Not Applicable**	**Not Applicable**	24.77	Not Applicable
Sulfate	**250**	**Not Applicable**	**Not Applicable**	70.12	Not Applicable

Composition 2 was an intermediate composition in the first series of options. The amount of minerals in this composition are moderately lower than the values in the first mineral additive. This choice was an attempt to achieve a balance between nutritional value and aesthetics to obtain a truly optimum mineral additive. Composition 3 can be seen in Table 10.

Table 10: Composition 3 with Regulatory, RDA, and Percentage Daily Values.

Mineral (cation or anion)	Regulatory Max Concentration (mg/L)	WHO Mineral Concentration Recommendation (mg/L)	RDA Average (mg/day)	Composition 3 (mg/L)	% DV (3 Liters/day)
Calcium	**Not Regulated**	**≥20**	**1000**[8]	15	5%
Copper	**1.0**	**≥1**	**0.9**[7]	0.2	67%
Iron	**0.3**	**≤0.3**	**11**[8]	0.1	3%
Magnesium	**Not Regulated**	**≥10**	**270**[8]	15	17%
Iodine	**Not Regulated**	**≤0.004**	**0.12**[8]	0.002	5%
Potassium	**Not Regulated**	**≥8**	**3450**[3]	7	1%
Zinc	**5.0**	**≥1.1**	**18**[8]	2	33%
Sodium	**Not Regulated**	**≥200**	**>2300**[17]	50	7%
Chloride	**250**	**Not Applicable**	**Not Applicable**	15.92	Not Applicable
Sulfate	**250**	**Not Applicable**	**Not Applicable**	49.12	Not Applicable

The third composition had the lowest amounts of minerals in the first round of compositions. This alternative was designed with aesthetics in mind and did not focus too much on the nutritional value. This selection was a failsafe in case compositions 1 and 2 negatively affected water too much that they could not be used.

3.1.2. Round 2

After identifying that the first round of compositions did not meet the drinking water pH range, it was necessary to test to additional compositions for quality control results. Composition 4 can be seen in Table 11. This composition does not have copper and the sodium concentration had to be adjusted substantially since it was making the pH too basic (greater than 8.5), which will be later explained in sub-section 3.2.2 Five Mineral Composition Testing Results.

Table 11: Composition 4 with Regulatory, RDA, and Percentage Daily Values.

Mineral (cation or anion)	Regulatory Max Concentration (mg/L)	WHO Mineral Concentration Recommendation (mg/L)	RDA Average (mg/day)	Composition 4 (mg/L)	% DV (3 Liters/day)
Calcium	**Not Regulated**	**≥20**	**1000**[8]	8	2%
Copper	**1.0**	**≥1**	**0.9**[7]	Not Considered	Not Considered
Iron	**0.3**	**≤0.3**	**11**[8]	0.005	0%
Magnesium	**Not Regulated**	**≥10**	**270**[8]	10	11%
Iodine	**Not Regulated**	**≤0.004**	**0.12**[8]	0.001	3%
Potassium	**Not Regulated**	**≥8**	**3450**[3]	7	1%
Zinc	**5.0**	**≥1.1**	**18**[8]	1	17%
Sodium	**Not Regulated**	**≥200**	**>2300**[17]	13	2%
Chloride	**250**	**Not Applicable**	**Not Applicable**	3.54	Not Applicable
Sulfate	**250**	**Not Applicable**	**Not Applicable**	29.05	Not Applicable

Composition 4 had significantly less minerals which allowed it to be in the appropriate pH range, but greatly reduced the nutritional value. Composition 5 can be seen in Table 12. Again, this composition does not have copper.

Table 12: Composition 5 with Regulatory, RDA, and Percentage Daily Values.

Mineral (cation or anion)	Regulatory Max Concentration (mg/L)	WHO Mineral Concentration Recommendation (mg/L)	RDA Average (mg/day)	Composition 5 (mg/L)	% DV (3 Liters/day)
Calcium	**Not Regulated**	**≥20**	**1000**[8]	8	2%
Copper	**1.0**	**≥1**	**0.9**[7]	Not Considered	Not Considered
Iron	**0.3**	**≤0.3**	**11**[8]	0.005	0%
Magnesium	**Not Regulated**	**≥10**	**270**[8]	10	11%
Iodine	**Not Regulated**	**≤0.004**	**0.12**[8]	0.001	3%
Potassium	**Not Regulated**	**≥8**	**3450**[3]	7	1%
Zinc	**5.0**	**≥1.1**	**18**[8]	1	17%
Sodium	**Not Regulated**	**≥200**	**>2300**[17]	12	2%
Chloride	**250**	**Not Applicable**	**Not Applicable**	3.54	Not Applicable
Sulfate	**250**	**Not Applicable**	**Not Applicable**	29.05	Not Applicable

The last composition is nearly identical with the 4th one, but the only difference is the concentration of sodium. The sodium was reduced by 1 mg/L from alternative 4 to 5 because it was sodium that had the biggest effect on the pH. Composition 5 was designed to contain the least amount of minerals out of all of the options, but it will still improve the nutritional value of RO bottled water.

3.2. Testing/Analysis

This section discusses the three RO bottled water and five mineral composition testing results. The three RO bottle water test results helped the team determine which popular brand was going to be used for the five mineral compositions, which is why it was completed first.

3.2.1. Three Current and Popular RO Bottle Water Brands Testing Results

The results of the three different brands of RO bottle water testing can be seen in Table 13.

Table 13: Test Results for Three Current and Popular RO Bottled Water Brands.

Test Results	Popular Brand #1	Popular Brand #2	Popular Brand #3
pH	6.58	6.03	7.35
Total Dissolved Solids (mg/L)[6]	0.01	0.04	0.08
Turbidity (NTU)[6]	0.21	0.22	0.43
Alkalinity (mg $CaCO_3$/L)[6]	Below Detectable Limit	Below Detectable Limit	0.71
Acidity (mg $CaCO_3$/L)[6]	Below Detectable Limit	Below Detectable Limit	-0.71
Conductivity (mA/V*m)[6]	3.42	7.44	14.30
Hardness (mg $CaCO_3$/L)[6]	0.00	12.35	24.04
Hardness Classification[6]	Soft	Soft	Slightly Hard
Color (PtCo)[6]	2.00	7.00	0.00
Odor[6]	No Smell	No Smell	No Smell

The results show that all of the brands are very detrimental for human health. There is a very low amount of turbidity dissolved solids, turbidity, and conductivity which means that there is a minimum amount of minerals for all three brands. Additionally, both Popular Brands #1 and #2 are soft waters which means that they negatively affect the water distribution system by scaling.

Since Popular Brand #1 had the lowest amount of minerals and worst hardness value, RAVA Fontus Engineering Inc. decided to choose this brand for the testing of the five optimum mineral compositions.

3.2.2. Five Mineral Composition Testing Results

The tests results for all five compositions can be seen in

Table *14*. It is important to mention that the team decided to eliminate cupric sulfate from the mineral additive since it precipitated easily when each composition was being prepared. None of the compositions that were tested had cupric sulfate, even though the first three compositions were designed to have copper.

Table 14: Test Results for the Five Optimum Mineral Compositions.

Test Results	Composition 1	Composition 2	Composition 3	Composition 4	Composition 5
pH	8.90	8.75	8.60	7.60	7.50
Total Dissolved Solids (mg/L)[6]	290.67	212.00	148.33	56.67	55.67
Turbidity (NTU)[6]	23.22	5.73	4.31	0.97	0.43
Alkalinity (mg $CaCO_3$/L)[6]	54.90	39.33	28.07	10.77	10.63
Acidity (mg $CaCO_3$/L)[6]	176.00	134.00	102.67	26.33	25.50
Conductivity (mA/V*m)[6]	N/A	N/A	N/A	-23.33	-21.50
Hardness (mg $CaCO_3$/L)[6]	181.98	132.30	66.28	48.80	48.80
Hardness Classification[6]	Very Hard	Hard	Slightly Hard	Slightly Hard	Slightly Hard
Color (PtCo)[6]	10.00	7.33	5.33	4.00	3.33
Odor[6]	Slight Smell	No Smell	No Smell	No Smell	No Smell

3.2.2.1. pH Discussion

The pH measures the hydrogen ion concentration. The EPA recommends drinking water to have pH between 6.5 and 8.5[9]. For round 1 of testing, compositions 1, 2, and 3 are above the 8.5 maximum pH limit, which is why two additional compositions were designed for round 2 of testing. Compositions 4 and 5 had a pH of 7.6 and 7.5, respectively, which are within the in the range of 6.5 and 8.5. The sodium bicarbonate salt concentration was changed to adjust the pH and to obtain a positive Langlier Saturation Index (LSI). A positive LSI value will not corrode the water distribution system.

3.2.2.2. Total Dissolved Solids (TDS), Turbidity, and Conductivity Discussion

The TDS test[6] measures the solids that pass through the filter in mg/L. The turbidity test[6] measures the suspended and colloidal matter in nephelometric turbidity units (NTU). Lastly, the conductivity test[6] measures the ability of an aqueous solution to carry an electric current in milliAmperes per Volt meter (mA/(Vm)). The conductivity test equipment can read an estimation of TDS because of the small amount of mineral concentration and volume, therefore the conductivity test was also used to find the TDS for the five optimum mineral concentrations. The lower the TDS, turbidity, and conductivity, the higher the chance people would want to drink the water sine less particulate matter will be suspended.

From the round 1 of testing, composition 1 had the highest minerals, followed by composition 2, and lastly composition 3. From round 2 testing composition 4 had less minerals than composition 3, and composition 5 had the lowest amount of minerals out of all five compositions. From the TDS, turbidity, and conductivity test results, the trend found was that the higher the mineral concentration, the higher the TDS, turbidity, and conductivity values, and vice versa. Therefore composition 1 had the highest TDS, turbidity, and conductivity values, while composition 5 had the lowest values.

3.2.2.3. Alkalinity and Acidity Discussion

The alkalinity and acidity tests[6] are both performed by titrations. For alkalinity, sulfuric acid with a normality of 0.01 was used to bring down the pH to a pH endpoint of 4.5. For acidity, sodium hydroxide titrant with a normality of 0.01 was used to increase the pH to a pH endpoint of 8.3.

Alkalinity of water is its acid-neutralizing capacity. The higher the alkalinity in drinking water, the better it is because the water can remain at a stable pH. The alkalinity trend results also showed the correlation that the higher the mineral composition, the higher the alkalinity. Therefore, composition 1 had the highest alkalinity and compositions 4 and 5 had the lowest alkalinity.

Acidity helps to measure the corrosiveness capacity of the water. The optimum mineral composition should not be acidic. Since the pH for compositions 1, 2, and 3 were higher than 8.3, the acidity tests could not be completed. Having a pH greater than 8.3 means that the solution is not acidic. Compositions 4 and 5 both had a negative acidity value, which represented the net alkalinity. A negative value must be reported because of the standard methods procedure. A negative value means that the water has more alkalinity than acidity, which is good so the mineral composition does not corrode the water distribution system when being incorporated with the RO water.

3.2.2.4. Hardness Discussion

Hardness is the sum of the calcium and magnesium concentrations in calcium carbonate mg/L. It is more beneficial to have a lower hardness because it means a smaller impact on the water distribution system since the water will have a lower capacity to precipitate soap.

Since composition 1 had the highest calcium and mineral concentration, it had the highest hardness value which classified it as “very hard” under the hardness classifications[19]. Composition 2 had lower mineral concentrations than composition 1, which classified the water as “hard.” Compositions 3, 4, and 5 had a hardness classification of “slightly hard” since their calcium and magnesium mineral content were fell under the range of that classification.

3.2.2.5. Color and Odor Discussion

Color is measured by the dissolved solids of each composition in units of Platinum-Cobalt (PtCo). The lower the color is, the higher the chance people would want to drink the water. Once again, the higher the mineral composition, the higher the color units. Therefore, composition 1 had the highest color and composition 5 the lowest color result.

For the odor test, only composition one had a “slight smell” while the rest of the compositions had “no smell.” Composition 1 had the maximum amount of mineral concentration which is why it had a "slightly smell" result.

3.3. Cost of Salts per Composition

The cost of the salts can be seen in Table 15. All of the prices are considering the salts to be in food grade quality so the consumer can be able to drink it. Furthermore, RAVA Fontus Engineering Inc. plans on only purchasing the food grade salts from companies who follow sustainable and eco-friendly practices, so the final optimum mineral composition can be seen as a green product in the market.

Table 15: Cost of Each Mineral Composition.

Salts	Cost ($)	$/g	Composition 1	Composition 2	Composition 3	Composition 4	Composition 5
Calcium Chloride	165.00[5]	0.007	$0.24	$0.14	$0.09	$ 0.02	$0.02
Ferrous Sulfate	120.00[20]	0.005	$0.00	$0.00	$0.00	$0.00	$0.00
Magnesium Sulfate	80.00[10]	0.003	$0.18	$0.13	$0.10	$0.06	$0.06
Potassium Iodide	60[15]	0.083	$0.00	$0.00	$0.00	$0.00	$0.00
Potassium Sulfate	2688.00[1]	0.108	$0.24	$0.18	$0.12	$0.12	$0.12
Sodium Bicarbonate	51.10[16]	0.102	$17.93	$12.51	$8.59	$1.68	$1.49
Zinc Acetate	158.80[2]	0.159	$1.33	$1.07	$0.53	$0.27	$0.27
		TOTAL	**$19.92**	**$14.03**	**$9.43**	**$2.14**	**$1.96**

Composition 5 was the cheapest choice because it will only cost $1.96 to make 1 liter of the mineral additive stock solution. The team only needs 1 mL of the mineral composition to be added into each 500 mL RO bottled water to achieve the desired optimum mineral concentrations, so with 1 L of stock solution, there are 1000 mineral composition products.

4. FULL-SCALE DESIGN DESCRIPTION

4.1. Identification of Selected Design

RAVA Fontus Engineering Inc. selected the best option for the mineral composition based on the following criteria; turbidity, color, odor, conductivity, total dissolved solids (TDS), cost, nutritional value, and impact on the water distribution system. Depending the importance of the criteria to the overall success of the project, a weighted score was determined for each factor. The scale ranged from 1 to 10, 1 being the worst and 10 being the best. The decision matrix used to evaluate all five mineral compositions can be seen in Table 16.

Table 16: Decision Matrix to Evaluate the Five Mineral Compositions.

Criteria	Weight	Composition 1	Composition 2	Composition 3	Composition 4	Composition 5
Color	0.10	4.5x0.10=0.45	5.0x0.10=0.50	6.0x0.10=0.60	7.5x0.10=0.75	8.0x0.10=0.80
Odor	0.10	5.0x0.10=0.50	7.0x0.10=0.70	9.0x0.10=0.90	9.0x0.10=0.90	9.0x0.10=0.90
TDS	0.10	4.0x0.10=0.40	5.0x0.10=0.50	6.0x0.10=0.60	8.5x0.10=0.85	8.5x0.10=0.85
Turbidity	0.10	3.0x0.10=0.30	3.0x0.10=0.30	6.0x0.10=0.60	9.0x0.10=0.90	9.0x0.10=0.90
Conductivity	0.10	5.0x0.10=0.50	5.5x0.10=0.55	7.0x0.10=0.70	8.0x0.10=0.80	8.0x0.10=0.80
Nutritional Value	0.30	8.5x0.30=2.55	7.0x0.30=2.10	6.0x0.30=1.80	4.0x0.30=1.20	4.0x0.30=1.20
Cost	0.15	3.0x0.15=0.45	5.0x0.15=0.75	6.0x0.15=0.90	9.0x0.15=1.35	9.0x0.15=1.35
Water Distribution System Impact	0.05	3.0x0.05=0.15	4.0x0.05=0.20	4.0x0.05=0.20	7.0x0.05=0.35	7.0x0.05=0.35
Total	***1.0***	***5.30***	***5.60***	***6.30***	***7.10***	***7.15***

Criteria color, odor, TDS, conductivity, and turbidity all received a weighted score of 0.10 because together these criteria make up the aesthetics of the composition and since it is important that the aesthetics of the drinking water is not negatively affected by the mineral additive, half of the weighted score would be dedicated to aesthetics. The next most important criteria is nutritional value of the additive which received a score of 0.30. The reason for giving nutritional value the second highest weighted score was because the improvement of the nutritional value of the water was determined by the concentrations of the different minerals in the composition. Cost received a score of 0.15 because the project requires a marketing plan and a cornerstone of that plan is the profitability of the product. Keeping costs down will create more profit and thus make the item more economically feasible. Lastly, the impact on the water distribution system received a score of 0.05. This value is low because how the additive affects the water distribution system is a task for this project, but it is a minor one compared to the nutritional value and aesthetics of the composition.

There were 5 compositions in the project. The first two options have significantly higher concentrations of minerals than the other compositions. These two options were designed to be the most nutritionally beneficial, but with the large amounts of minerals the aesthetics of the water suffered, so compositions 1 and 2 received the lowest and second lowest scores respectively. Compositions 3 and 4 had intermediate amounts of minerals which gave the two designs an adequate score, but composition 5 had a better score. All the options were analyzed using the decision matrix and composition 5 scored the highest. This option won mainly because it had high scores in criteria linked to aesthetics. The 5 components of aesthetics (conductivity, turbidity, TDS, color, and odor) are dependent on the concentration of the minerals. The lower the amount of minerals, the higher the score. Since composition 5 had the lowest amount of minerals, it received a high score for all of those criteria as well as cost. Composition 5 was also the cheapest choice because of its relatively low amounts of minerals. Even though it received the lowest score for nutritional value, composition 5 was chosen to be the final design of the project.

4.2. Cost for Implementing Design through an Independent Company

As can be seen in Table 17, it would cost RAVA Fontus Engineering Inc. $33,880.82 to sell the optimum mineral composition product through an independent company in Flagstaff, AZ. The team chose to start the company in Flagstaff, AZ because the community has an environmentally-conscious social mentality which matches with the product's goal of sustainable product distribution. The team members believe that if the product sells successfully in Flagstaff, then there is a possibility of being able to expand the company and sell the product in the Southwest Region of the U.S.

Table 17: Independent Company Costs.

Independent Company (Costs)			
Material	**Quantity**	**Price**	**Total**
4 oz bottle w/ lid[23]	9000/month	$ 0.18	$ 1,620.00
8 oz bottle w/lid[23]	4500/month	$ 0.34	$ 1,530.00
16 oz bottle w/ lid[23]	3240/month	$ 0.40	$ 1,296.00
Vegetarian Pear Shaped- 1mL capsules[24]	975600/month	$ 0.02	$ 19,512.00
Tamper Evident Heat Shrink Seal[24]	16740/month	$ 0.06	$ 954.18
Bottle Labels[25]	16740/month	$ 0.12	$ 2,056.47
Capsule Filling Machine[26]	1/one-time cost	$ 5,000.00	$ 5,000.00
1 mL mineral salt composition	975600/month	$ 0.00196	$ 1,912.18
		TOTAL	***$ 33,880.82***

4.3. Cost for Implementing Design in Bottling Process Production

As can be seen in Table 18, it would cost $8,980 to sell the product within a current bottled water distributor. It is much cheaper to sell the optimum mineral composition through a current bottled water distribution since the set-up is already there, the team only needs to add one more machine at the end of the distribution line so the optimum mineral composition can be added.

Table 18: Selling with Current Bottled Water Distributor Costs.

Selling with Current Bottled Water Distributor (Costs)			
Material	**Quantity**	**Price**	**Total**
Liquid Handling Robot[27]	1	$ 8,000.00	$ 8,000.00
1 mL mineral salt composition	500,000/month	$ 0.00196	$ 980.00
		TOTAL	***$ 8,980.00***

4.4. Marketing Plan

The purpose of the marketing plan is to connect the consumer with the product. A marketing plan consists of four consecutive stages; the purpose statement, the target market, the SWOT analysis, and the final execution. There will be two different scenarios on how the product will be sold. One scenario will include the team working for a popular brand of reverse osmosis water as a third party that will solely add the mineral additive during the bottling process. The second scenario is the team starting a small business in Flagstaff, AZ that will sell the mineral additive in bottles containing individual capsules. Since the team is only providing the mineral additive to the water bottle company, the team is not responsible for the marketing strategies for scenario one, thus the following information only pertains to the second option.

a) **Purpose Statement:** The purpose statement sets up how the marketing plan will be conducted. The purpose statement contains, but isn't limited to the price range of the product, the image of the product, and the style of marketing. This initial step will set up the guiding principles of the marketing plan**.** The purpose statement of the team's marketing plan is to create an economic, healthy beverage.

b) **Target Market:** Determining a specific target market for this product is a vital component of the marketing plan. This step primarily comprises of brain storming specific markets the product will be more likely to succeed in, by analyzing the pros and cons of the market. There will be three different markets that will be analyzed. The three alternatives are; the elderly (65 and up) and adults (18-64), families, and the environmentally conscious.

c) **SWOT Analysis:** The SWOT analysis can be seen in Table 19, and it stands for strengths, weaknesses, opportunities, and threats. Strengths are words, phrases, or facts pertaining to the product that appeals to the target market. A few strengths of the team's product has for the elderly include phrases such as lowers blood pressure, osteoporosis prevention, and strengthening the skeletal system. Weaknesses are problems within the creation or image of the product that can weaken sales. These problems are internal and can be controlled by the team. The product poses a choking hazard to young children, which is a weakness when marketing to families. But child-proof caps will be installed on the bottles to prevent this weakness. Opportunities are essentially partnerships, avenues, and social/political/global movements that the team can work with to appeal to the target market. If a product is being marketed as environmentally friendly, one opportunity the team can utilize is getting a contract to sell at a whole foods supermarket or donating money toward environmental restoration. Threats to a product include unforeseen events and pre-existing market conditions. What differentiates threats from weaknesses is threats are external and cannot be controlled by the team. One threat to the team is if the market is already heavily populated with successful competitors.

d) **Final Execution:** The last step of the marketing plan is the final execution, which in itself has 3 steps. The first step is to determine the marketing mix which are the avenues of marketing (i.e. magazine ads, tv ads, social media, etc). The separate marketing avenues will differ for each alternative, but all marketing mixes will be designed to target the specified markets. The next step is creating a marketing calendar which outlines when and where the team's product will be released. The beginning of the marketing calendar includes the team setting up contracts with supermarkets and other entities in September 2014 and releasing the product for sale in July 2015. The last step of the final execution is the promotion. During this step, the physical aspect of the marketing plan is put in the public. This final component satisfies the goal of the marketing plan, which is to connect the consumer with the product.

Table 19: SWOT Analysis.

SWOT	Alt 1: Elderly & Adults	Alt 2: Families	Alt 3: Environmentally Friendly
Strengths	-Osteoporosis prevention -Strengthens heart -Anti-aging -Vital Elements -Mineral Rich	-Natural -Alt for sugary drinks -Hydration -Best for your family -Exceptional water -No BPA	-Natural -100% recycled plastics -1% for the planet -Eco-friendly suppliers -No BPA in bottle -Capsules bio-degradable
Weaknesses	-Possible overdose if improperly added -Knowledgeable of possible bad side-effects of minerals -Breaking capsules may prove difficult	-Possible overdose if improperly added -Capsules can be choking hazard	-Possible overdose if improperly added -Plastic waste generation -Possible eco-unfriendly suppliers -Bad press on water bottles
Opportunities	-Some profits go to NOF -Work with NOF -Working with Flagstaff medical center -Advertise at medical businesses	-Partnership with elementary schools about -Work with local children sport organizations	-Partnership with NAU Dining -Set up refill stations on NAU -1% for the planet
Threats	-Droughts -NAU gave pouring rights to one specific company -Competition	-Droughts -NAU gave pouring rights to one specific company -Competition	-Droughts -NAU gave pouring rights to one specific company -Competition

5. WASTE GENERATION CONSIDERATIONS

5.1 Waste Generation for an Independent Company

For the independent company the waste consideration is much more detailed than for the other option. Waste generation occurs during and after manufacturing. According to the Pacific Institute it takes 3 L of water to produce 1 L of bottled water and that in 2006 over 2.5 million tons of carbon produced by bottling water. While these are country wide estimates the amount of water used and carbon generated is still relevant. Shown below is a diagram of the life cycle of a plastic bottle:

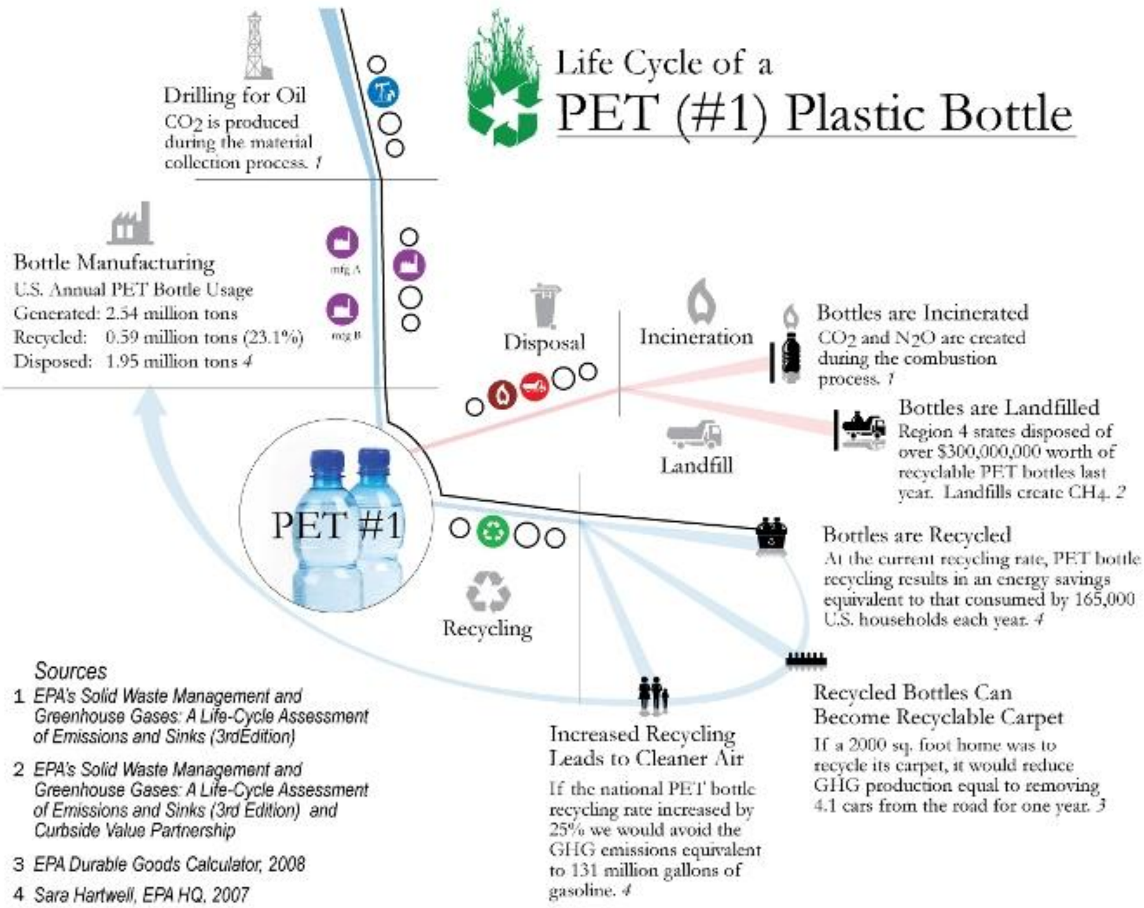

Figure 1: Life Cycle of a PET Plastic Bottle.

Figure 1 shows the main end paths for water bottles, while incineration is show as one it is not considered because Flagstaff does not do any incineration all waste goes to the landfill.

The company is producing three different types of water bottles that includes the additive and a capsule of the mineral additive for multiple uses in bottled waters. Each of the bottles has a bottle cap and a label. There are two different waste paths that the water bottles and capsules can take after the contents are consumed the municipal landfill/dump or to a recycling center. The EPA stated that in 2012 the United States recycled 9% of the total plastic waste generated. Assuming RAVA Fontus Engineering Inc. will be making 16,740 water bottles and 975,600 pear shaped plastic capsules a month as well as using 975,600 pipettor tips then 177,115 of the mix will be recycled.

5.2 Waste Generation for an Implementing Design into a Bottling Process Production

For implementing design into a bottling the waste generation is during the shipping to the bottling process production. The reason that only the shipping is being considered is because once the product is shipped it belongs to the bottling company. Since the company is only looking at Flagstaff AZ the maximum distance for shipping would be less than 30 miles thus the maximum amount of carbon dioxide is 33,326.25 grams of CO_2.

6. REFERENCES

[1]*105153 potassium sulfate*. (2014). Retrieved from https://www.emdmillipore.com/chemicals/potassium-sulfate/MDA_CHEM-105153/p_tbSb.s1L7zYAAAEWEeEfVhTl?WFSimpleSearch_NameOrID=potassium+sulfate+&BackButtonText=search+results.

[2]*108802 zinc acetate dihydrate*. (2014). Retrieved from https://www.emdmillipore.com/chemicals/zinc-acetate-dihydrate/MDA_CHEM-108802/p_tbSb.s1L7zYAAAEWEeEfVhTl?WFSimpleSearch_NameOrID=zinc+acetate+&BackButtonText=search.

[3]Bellows, L., & Moore, R. (2014). Potassium and the diet. Retrieved from http://www.ext.colostate.edu/pubs/foodnut/09355.html.

[4]*Calcium*. (2013). Retrieved from http://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en2.

[5]*Calcium chloride food grade*. (2014). Retrieved from http://www.myspicesage.com/calcium-chloride-food-grade-p-997.html.

[6]Clesceri, L., Greenberg, A., & Eaton, A. (1998). *Standard methods for the examination of water and wastewater*. (20th ed., pp. 2-1 to 4-180). Washington, DC: American Public Health Association.

[7]Copper. (2011). Retrieved from http://www.cancer.org/treatment/treatmentsandsideeffects/complementaryandalternativemedicine/herbsvitaminsandminerals/copper.

[8]Dietary supplement fact sheets. (2014). Retrieved from http://ods.od.nih.gov/factsheets/list-all/.

[9]*Drinking water contaminants*. (2013). Retrieved from http://water.epa.gov/drink/contaminants/#SecondaryList

[10]*Food Grade Magnesium Sulfate*. (2013). Retrieved from http://ysmining.en.alibaba.com/product/283365055209469675/Food_Grade_Magnesium_Sulphate.html.

[11]Kozisek, F. (2004). Health risks from drinking demineralized water. *World Health Organization*, 1-22. Retrieved from http://www.aqualiv.com/images/WHO_RO_Warning.pdf.

[12]*Iodine in drinking-water*. (2003). Retrieved from http://www.who.int/water_sanitation_health/dwq/chemicals/iodine.pdf.

[13]*Iron in drinking-water.* (2003). Retrieved from http://www.who.int/water_sanitation_health/dwq/chemicals/iron.pdf.

[14]*Potassium in drinking-water*. (2009). Retrieved from http://whqlibdoc.who.int/hq/2009/WHO_HSE_WSH_09.01_7_eng.pdf.

[15]*Potassium Iodide (Feed grade).* (2013). Retrieved from http://www.alibaba.com/product-detail/Potassium-iodide-Feed-grade-_103769675.html.

[16]SX0322 *potassium bicarbonate*. (2014). Retrieved from https://www.emdmillipore.com/chemicals/sodium-bicarbonate/EMD_CHEM-SX0322/p_N0qb.s1L7wcAAAEW6cgfVhTm?WFSimpleSearch_NameOrID=sodium+bicarbonate+&BackButtonText=search+results.

[17]Sodium: thefacts. (2013). Retrieved from http://www.cdc.gov/salt/pdfs/sodium_fact_sheet.pdf.

[18]*Water distribution system definition*. In (2012). Retrieved from http://www.muellerwaterproducts.com/about/glossary.php.

[19]Wellcare information for you about hardness in drinking water. (2014).

[20]*Wholesale ferrous sulfate*. (2014.). Retrieved from http://www.ebiochem.com/product/ferrous-sulfate-2016.

[21]*WomansDay.com*. 2013. Retrieved from http://www.womansday.com/food-recipes/8-bottled-water-brandsunscrewed-72193.

[22]*Zinc in drinking-water*. (2003). Retrieved from http://www.who.int/water_sanitation_health/dwq/chemicals/zinc.pdf.

[23]*Wide mouth plastic packer bottles* . (n.d.). Retrieved from http://www.freundcontainer.com/wide-mouth-plastic-packer-bottles-hdpe/p/v36001/.

[24]*Total pharmacy supply, inc.*. (n.d.). Retrieved from http://www.totalpharmacysupply.com/browse.cfm/

[25]*Product ol125 - 4" x 2" shipping labels*. (n.d.). Retrieved from http://www.onlinelabels.com/OL125.htm.

[26]*Popular soft gelatin capsule filling machine*. (n.d.). Retrieved from http://www.alibaba.com/product-detail/26-Popular-soft-gelatin-capsule-filling_1248663862.html.

[27]*Tecan genesis freedom 100 4 automated elisa liquid handling handler robot liha*. (n.d.). Retrieved from http://www.ebay.com/itm/Tecan-GENESIS-FREEDOM-100-4-Automated-Elisa-Liquid-Handling-Handler-Robot-Liha-/230820376915?_trksid=p2054897.l4276.

To: RAVA Fontus Engineering Inc.
From: Gerjen Slim, EIT
CC: Vivianna Gamez Molina
Date: 3/20/2014
Re: Drinking water stabilization, Task 2, Audit Review

The review of the report on Drinking Water Stabilization was conducted and focused on professional presentation and the completeness of the study. Some of the presentation concerns could be related to the PC/Mac incompatibility. There was some inconsistent formatting throughout the tables including font and centering.

The first concern is the cost per unit and the potential profit per unit was not mentioned thoroughly in the report. Table 3 discusses the sale of the additive to distributors at a different scale than through the independent company. This inequitable comparison makes the comparison unclear. In Table 15 the cost of mixtures were discussed but the cost did not specify the unit size.

The report also discussed the nutritional needs for livestock but then failed to specify certain stock and their specific potential needs. The nutritional needs of livestock could focus on easily controlled stock such as factory chickens or pigs. These animals are commonly held in small areas and depend on food and water sources being brought to them.

The range of pH recommended by the regulatory agencies and the maximum allowed constituent levels set by the EPA and FDA set an upper bound for the drinking water. The lower bounds of pH influence the leaching potential of the mixture. The report does not go into depth on what minimum level of mineral constituents is sufficient to prevent leaching of minerals out of the body.