Chloride Mitigation
Testing Salt Softener Alternatives for Wisconsin Salt Wise

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Submitted to—
Wisconsin Salt Wise

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Executive Summary

Wisconsin experiences water hardness levels at up to 250 mg/L of calcium carbonate. Many residents install water softeners in their homes in order to combat the side effects of hard water, like scaling in pipes, and harshness on the skin and hair. Traditional water softeners use salt, which can then be discharged into main bodies of water and cause salt pollution. Salt pollution of aquatic ecosystems can be devastating and can lead to issues like algal blooms and death of aquatic creatures.

This team has partnered with Wisconsin Salt Wise to evaluate alternative, salt-free, water conditioning devices that residents can use instead of the traditional devices. The team has conducted preliminary research and economic analysis to determine which devices are accessible to the average Wisconsin resident and has tested the AquaRex and Yarna in a lab with methods further outlined later on to determine if these devices work similar or better than a traditional softener.

After testing both devices under the team's methods, the results show that there is little to no difference in calcium ion activity when the device is on versus when it is off.

Statement of Problem

Hard water affects the water quality of about 85% of the U.S., as naturally occurring soft water only occurs in 15% of the nation (1). Figure 1 displays the degree of hardness areas across the U.S. experience their water as. The figure classifies hard and soft water according to their calcium carbonate ($CaCO_3$) concentration. Soft water may contain anywhere from 0 - 60 mg/L of $CaCO_3$, shown as dark purple, while hard water contains from 121 - 180 mg/L, shown in white (1). The design project is focused in Wisconsin, which the graph displays to contain a combination of hard and very hard water.

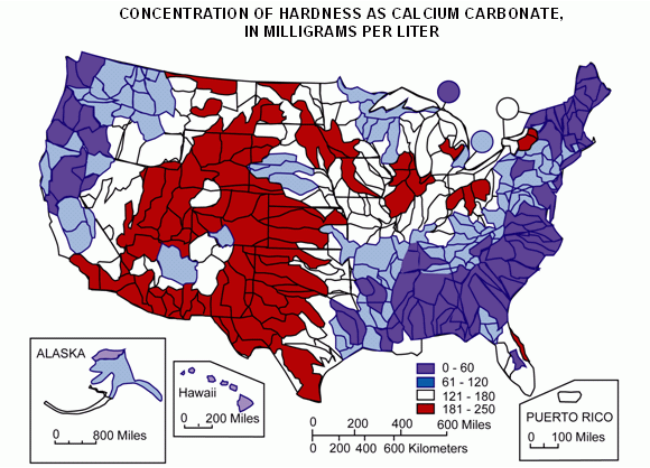

Figure 1. Average hardness as calcium carbonate at water-monitoring sites (1)

Hard water is problematic as it causes issues to building infrastructure, appliances, and human health. Hard water causes pipe scaling, where $CaCO_3$ mineral deposits accumulate on the pipe walls. Over time, scaling leads to faucet blockages, which often results in reduced water pressure. The clogged pipes and reduced pressure causes water-consuming appliances (dishwashers, washing machines, water heaters, etc.) to work inefficiently. This leads to a reduced lifespan of such appliances. The health effects caused by hard water are mainly due to the consumption of dissolved salts, which can lead to problems such as diarrhea or laxative effects, or with long-term consumption, kidney dysfunction (3). Hard water also creates more cosmetic problems such as dry skin and brittle hair.

Current water softening techniques require an excessive amount of salt (sodium chloride, NaCl), and even more so when not being programmed efficiently by residents. The cartridge containing the resin must be replaced every 6 months, and disposed of, usually ending up in a

landfill. As water flows through a water softener, the salt acts as resin, for calcium (Ca^{2+}) and magnesium (Mg^{2+}) to attach to (4). The resin attaches to the calcium and magnesium within the hard water, and releases salt into the water. The softened water now consists of sodium chloride, and when output into bodies of water affects various ecosystems (5).

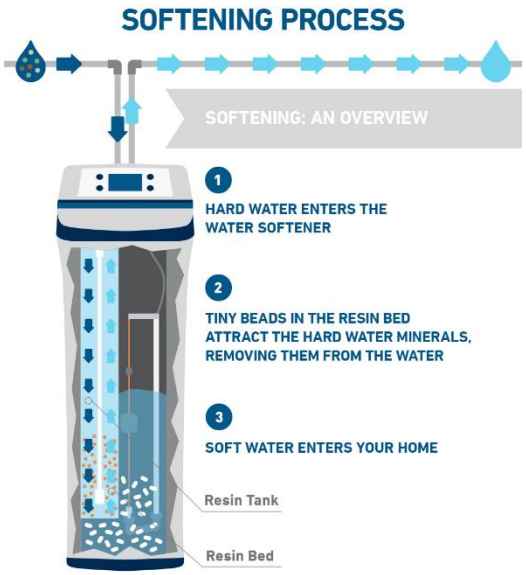

Figure 2. Conventional water softener process (6)

While humans cannot feel the direct impacts of increased chloride, the aquatic ecosystems within these bodies of waters are completely altered. Elevated levels of chloride harm aquatic life by disrupting osmoregulation, the biological process that allows organisms to maintain the proper concentration of solutes in their bodily fluid (7). Interferences with osmoregulation leads to growth and reproduction challenges, in turn hindering survival. Some organisms that are the most vulnerable to increased chloride concentrations are zooplankton (7). Zooplankton play a significant role in the food web of aquatic ecosystems. They feed on algae, helping control the succession of eutrophication, the process by which oxygen is depleted from bodies of water due to an accumulation of nutrients. They also serve as a valuable food source for fish and amphibians, some of which are harmed simultaneously by their lower tolerance of chloride concentration. Amphibians such as salamanders and frogs lay their eggs in isolated bodies of water, which cannot be flushed of its chloride concentration, leading to lower survival rates during their offspring's metamorphosis stage of life (7). The repercussions on zooplankton

and amphibians due to these elevated chloride concentrations lead to detrimental effects on the water quality and food web, negatively affecting the entire aquatic ecosystem.

The community that this research project is focused on is the state of Wisconsin, where the team's project partner, Wisconsin Salt Wise, is based.

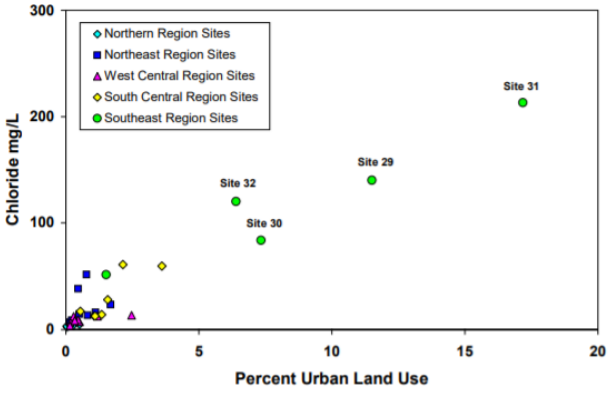

Figure 3. Relationship between chloride concentrations and urban use at Wisconsin's long term trend sites (9)

This region is primarily dependent on groundwater as their source of supply. This brings up another concern with increasing chloride concentrations, especially for future generations (10). Groundwater is replenished slowly with water from nearby watersheds, which are increasing in chloride concentration. This suggests that there will be lag time between which chloride is discharged into a surface waterbody and when that same chloride enters groundwater through infiltration, meaning it will be too late for action to be taken. The potential for contamination of aquifers, especially shallow ones, increases with the increasing discharge into watersheds, developing a significant threat to the quality of life in Southeastern Wisconsin (10). Under the Federal Clean Water Act, bodies of water that do meet the standards of water quality are considered "impaired". Five streams in Southeastern Wisconsin have been considered impaired as of 2014, due to "acute aquatic toxicity" resulting from high chloride concentrations (10). The five streams listed are sections of the following rivers:

- Ulao Creek - entire 0.9 mi
- Kinnickinnic River - 2.7 mi section
- Lincoln Creek - entire 9.7 mi

- Oak Creek - entire 13.3 mi
- Root River - 23.5 mi section; originally listed as impaired in 1998

Figure 4 displays chloride concentrations in surface water samples from Root r\iver, where the increase in the average can be seen. However, it is important to note that 2012 can be viewed as an outlier due to the drought Wisconsin was experiencing that year, explaining the abnormally high concentrations.

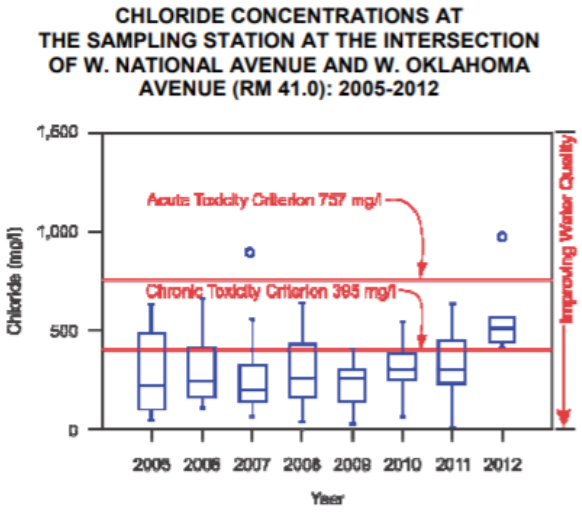

Figure 4. Chloride concentrations at the sampling station of Root River at the intersection of W. National Ave and W. Oklahoma Ave (10)

Some things to consider moving forward are the other sources of chloride in bodies of water such as winter deicing, salt storage areas, large agricultural feedlots, fertilizers, landfills, chemical manufacturing, and food processing (10). The highest chloride concentrations are seen during the months of December - February (9), demonstrating that road salt is a big contributor to chloride in surface water bodies. The Southeastern Wisconsin Region is currently working on a study to identify their chloride contributors (10). This would further help understand the amount of chloride ions water softeners are contributing to municipal wastewater facilities, and in turn the watersheds listed above. For example, the city of Alexandria, MN performed a citywide chloride source mass balance to its wastewater treatment facility (11). They found the distributions of chloride loading to be as listed:

- 10% from source water (such as high concentrations in groundwater)

- 17% from industrial users
- 73% from residential loading (water softeners)

Until an in-depth mass balance is done in the Southeastern Wisconsin Region and there is a better understanding on the anthropogenic salt loadings to WWTP, furthermore into the Milwaukee River Basin, chloride mitigation cannot be efficiently tackled.

Design Objectives

This study will test salt-free conditioning devices and analyze their effectiveness at reducing the effects of hard water. Two salt-free conditioning devices have been selected:

1) Aqua Rex Physical Water Conditioner - EMF
2) Yarna CWD24 Capacitive Water Descaler – CDI

The AquaRex Physical Water Conditioner is an Electromagnetic Forces (EMF) technology which uses electromagnetic fields to alter the properties of dissolved minerals. Such that, as hard water runs through the device, the crystallization of minerals is altered so the minerals do not attach themselves to pipes and create scaling. The AquaRex EMF device was chosen specifically because of the accessibility. After learning that a research team at the Milwaukee School of Engineering was performing similar analysis with a borrowed device, the team reached out to AquaRex asking to also borrow a device, with the return for free testing and data. The company is based in the UK, which may decrease accessibility to the product for the average Wisconsin homeowner, however they do have various offices in the United States, including one in Brookfield, WI. The average price for this device is around $450, which is relatively cheap for a water conditioning device.

Capacitive deionization (CDI) is accomplished by placing anode and cathode plates on either side of the flowing water, which then attracts ions. The Yarna device was selected because it was found to be accessible to purchase as it is available on Amazon and claims to not require maintenance. The Yarna device is also only about $300, a low cost for a water conditioner.

The team has ruled out other salt-free water softener technologies for analysis, including reverse osmosis (RO), template-assisted crystallization (TAC), electrically induced precipitation

(EIP), and chelation systems. This is due to being too costly (RO, TAC), inaccessible to the average homeowner (EIP) or lack of supporting data (Chelation).

The research project includes performing 2 different testing procedures, Intermittent Testing and Longevity Testing, each of which was performed on both treatment devices, along with control tests. Testing took place in the Purdue Instructional Teaching Lab (HAMP 2186). Every test used laboratory tap water, as the water at Purdue University is traditionally very hard, but was tested beforehand to measure its calcium ion concentration.

Design Apparatus

This testing procedure was determined by the team with the purpose of replicating real time plumbing systems. The system apparatus starts with clear PVC plastic tubing that is connected to a barbed sink faucet. Water runs through the tubing, into copper pipe with the device fitted according to the specific device manual. Lastly, the copper pipe connects to more PVC plastic tubing, all of which is secured by metal fittings to avoid leaking. The flow all dispels into a neighboring sink. A full schematic representation is shown in **Figure 5**.

Copper was chosen as the pipe material as it is a commonly used for residential plumbing and can withstand temperatures up to 400F. The PVC plastic tubing was also selected for its temperature capacity of 150F as well as its flexibility for aligning the apparatus horizontally, and its clear color, to visibly notice any scale build-up after passing the treatment device.

Figure 5. Schematic of Intermittent Testing Apparatus

Testing Procedure

We created two types of tests: Intermittent Testing and Longevity Testing.

Intermittent Testing

The purpose of this testing procedure was to determine the impacts of the following variables on the functionality of each device:

- Time (15 min, 30 min)
- Flow Rate (0.3 gpm, 1.3 gpm)
- Temperature (15C, 50C)

Essentially, the testing consisted of four 15-minute intervals, followed by four 30-minute intervals, in which the device would alternate between being ON or OFF. At the end of each time interval, the flow rate was measured and two samples were taken and their mV reading was recorded. We repeated the testing at the different flow rate and temperatures listed above.

Longevity Testing

The purpose of this testing was to determine whether the devices worked better over longer periods of time. According to the manuals, there is no "start time" or delay for the devices to begin effectively modifying the ions, however we were wondering if it would behave any better than just 15 or 30-minute intervals. By modifying the apparatus, we were able to simultaneously receive the control tap water and the treated water, as demonstrated in **Figure 6**.

Figure 6. Schematic of Longevity Testing Apparatus

Design Reasoning and Limitations

There are many limitations and constraints of our design and procedure. To begin, an average and peak flow rate of a home, 6 -12 gpm, would be a much better method of testing the devices. We decided to test at a much lower flow rate because the highest flow rate reached from the faucet was 3 gpm, and running that peak capacity for 3 hours, would drop drastically over time. Both devices also did not indicate a minimum flow rate or pressure necessary to function on their specifications or when we reached out to.

Secondly, an apparatus that would better mimic a residential home would have a way to heat water, after it has run through the device. Originally, we attended for a heating coil to do so, however the copper was not able to heat the water to the extent we wanted which was to 50 C, the temperature of an average water heater. Not to mention, with budgetary limits, we were not able to buy a water heater to thoroughly conduct our testing.

Lastly, the longevity testing was only tested under the variables of 15 C, with a flow rate of 0.3 gpm. The low flow rate was chosen as the faucet was now splitting through two outlets. We did not change the temperature as we predicted more calcium carbonate would only be produced, and none of our results thus far really proved that we needed to there would a drastic difference. Another aspect was time limitations – as each testing is a 3hr period.

Standard Preparation

To produce 500 mL standard solutions, a 1000 ppm of Ca2+ stock solution can be used and diluted accordingly. As demonstrated in Equation 1, 1 ppm of Ca2+, will receive 0.005 mL of the stock solutions, increasing by a factor of 10 for a standard of 10 and 100 ppm of Ca2+.

$$C_1V_1 = C_2V_2$$

$$1000\ ppm\ x\ V_1 = (1\ ppm) * (0.5\ L) \rightarrow V_1 = 5\ x\ 10^{-3}\ L = 0.5\ mL \quad (1)$$

Standards will be prepared in concentrations of 1, 10, and 100 ppm Ca^{2+}, which corresponds to 2.5, 25, and 250 mg/L $CaCO_3$, respectively, as shown in Equation 1.

$$1\ Ca^{2+}\ ppm * \frac{100\ CaCO_3\left(\frac{mg}{L}\right)}{40\ Ca^{2+}\left(\frac{mg}{L}\right)} = 2.5\frac{mg}{L}CaCO_3 \quad (2)$$

Identifying Client Needs

The groundwater aquifers in the state of Wisconsin are mostly limestone and dolomitic limestone aquifers. The water that is drawn out from these aquifers are classified as “hard water” because of the high levels of calcium and magnesium that is absorbed by the water. When this water runs through pipes and other home appliances, the calcium and magnesium ions can form a scale. The most common home solution to preventing this scale build-up is the use of residential water softening systems. Because these traditional water softening systems account for about 70% of freshwater salt pollution in Wisconsin, residents need an alternative method of preventing scale build-up without the use of salt.

Initially, the team’s project partner, Wisconsin Salt Wise, requested a side-by-side consumer reports style product testing of salt-free water conditioner/scale reduction devices. They requested that the team test several devices according to the International Association of Plumbing and Mechanical Officials IAPMO / ANSI Z601 standard. If any of these devices were effective in reducing scale without the use of salt, they could be promoted for use by homeowners.

After the first few meetings with WI Salt Wise, expectations and any constraints relevant to the project objectives were analyzed. After researching the different types of water conditioning technologies and devices that are accessible to the average homeowner, and discussing budget and time constraints with WI Salt Wise, the team collectively agreed that they would gather research on and test a total of 2 devices of 2 different technologies.

Additionally, the client allowed the team to design their own testing standards that would be used to test the devices for their ability to remove calcium carbonate from water. The standards that were recommended did not allow any salt-free conditioning devices to pass the standards testing because of the way it was designed. Additionally, the team was not able to test for scaling on pipes as that would require months or years of testing for true results.

Identifying Target Specifications

For the final device recommendations, the team needed to select salt-free alternatives to traditional water softening devices that were practical for use in residential homes. In order to

convince residents in Wisconsin to use these new water conditioners in their homes, they needed to be affordable, practical, and low maintenance compared to traditional water softeners. If the recommended devices were significantly more expensive and required much more maintenance than traditional water softening systems, residents would likely be reluctant to change. Additionally, the recommended water conditioning systems must be successful in reducing scale within the piping and other appliances in the home, as is the main purpose of using water softeners or conditioners alike.

Traditional water softening devices generally require that new salt be added to the system every six to eight weeks. Any water conditioning device that is selected would need to require less maintenance than this. Through research, it was decided that the selected devices should require maintenance and/or replacement of any resin or media every six to nine months. Requiring less maintenance from homeowners would help convince them to switch from a water softener to a salt-free water conditioner.

It was also important to test devices of different technologies that were practical for use by homeowners. Initial research was done on devices of 6 different water conditioning technologies; these different technologies included TAC, EMF, CDI, reverse osmosis (RO), electrically induced precipitation (EIP), and chelation systems. Some of these technologies we decided were impractical for use within residential homes, specifically the reverse osmosis, electrically induced precipitation, and chelation systems. RO systems were most recommended for use on singular faucets. Trying to use reverse osmosis for a whole house would be extremely expensive, costing somewhere between $10,000 and $20,000, which is not feasible for our criteria. EIP technology was impractical because very few commercial systems were available. Finally, chelation systems were not recommended for use in areas with higher hardness levels, and Wisconsin has many areas with very high hardness zones. Therefore, the team was able to limit water conditioning technologies down to EMFs and capacitive deionization.

When deciding the testing specifications, the team first began thinking about using similar tests to those used for traditional water softening systems. It was learned that these tests were likely to fail, especially those testing for actual water softness, as the calcium and magnesium in the treated water would still be present, just deactivated. Therefore, the team decided that one good way to measure the effectiveness of these devices would be to test for

scale build up on a sample pipe. However, it was quickly realized that this testing was out of our scope range, as it would take months to years of testing, which we did not have time for. Ultimately it was decided that the team would test for calcium ion activity using a calcium ion testing probe that was already in the lab.

Generating Design Concepts

For the experimental procedure, there were many different design concepts the team had to consider in order to create the most accurate and successful system, including what devices we were testing, what standards and specifics we would be running tests for, and the type of system that would be used. There were many different variables the team could test for with the generated system. Purdue University professors, experts in the field, and preliminary research presented many different options to consider, both quantitative and qualitative. At first, we considered measuring the amount of calcium and/or magnesium in the treated water samples to determine if the water was truly softened. Since we were testing salt-free water conditioners, however, the hardness ions would still be present in the water samples and show little change before and after the water conditioning. Therefore, we also proposed using an ion selective electrode to test for calcium activity instead of calcium presence. Additionally, we considered running an inductively coupled plasma (ICP) analysis of treated water samples to measure the individual isotopes of each element present but would need the assistance of a professor or a graduate student to perform this. We also generated many qualitative test ideas to use for our treated samples. Some of these ideas include boiling treated samples repeatedly to observe scale build up, using only clear piping in order to watch how scale builds up over the testing process, and using a simple soap test to check for hardness.

Aside from generating design concepts for our testing standards, we also had to generate several concepts for our actual testing system. Aside from just lending us an Aquarex conditioning device, the company also had provided us with a rig with which we could test the device. This testing rig had a central beaker in which water samples were collected, treated, and heated in. Because of this, there were concerns about such a small sample size and if the results obtained with this testing rig would be comparable to a device used in a residential home. We also generated a new design concept for a continuous flow system where water is treated

constantly as it passes through pipes and hoses upon leaving a faucet head. The flow rate in the system would be comparable to that of sinks and showers in the average home. This way, we would be able to treat the water and then determine how effective the device was under similar conditions to a residential system.

Selecting Design Concept

When selecting the design concept we would use for our experimental procedure, we had many possibilities to decide between. We believe, however, that we selected the best possible design concepts to successfully replicate a residential system. As described earlier, we selected the Yarna capacitive deionization device as well as the Aquarex EMF device, as these are two separate water conditioning technologies that are practical for the majority of homeowners. For our testing system, we decided to not use the Aquarex testing rig we were provided and instead use our own designed continuous flow system. We decided against using the provided rig because the water sample being treated was only a very small amount in a beaker. When these water conditioning devices are treating water in a residential setting, the water is moving quickly through piping as it gets treated. Therefore, by using our own continuous flow system, we were able to replicate this and then evaluate the effect of the devices on water as it moved at different flow rates through a copper pipe.

When considering our testing standards, we had to consider time constraints, resources available, and the science behind water conditioning technologies. Because scale testing would take months to years of testing and observing to make a real conclusion, we could not realistically test for scale build up for each device. Because of this the majority of our testing would have to be on the hardness characteristics of the water samples, we narrowed our primary testing options to using a calcium selective electrode and an ICP analysis. We were told by our professors, however, that to run an ICP analysis, we would need the assistance of a qualified graduate student. Based on the number of tests we would be running under different conditions, this would become too much to ask from an outside source. Therefore, we selected the design concept of the calcium selective electrode. This tool would measure the calcium *activity* in the samples, not just the calcium presence. Since the calcium that exits in the treated samples should have been “deactivated” by the conditioning devices, this was the perfect tool to use.

Economic Analysis

When looking at the economic analysis for our project, we decided to compare the costs of installing a water softener with the costs of installing our water conditioners, the Aquarex and Yarna. When analyzing the costs of installing a water softener in a residential home, something to consider is what is suitable for the house size and number of inhabitants. Another factor to consider is the system type being installed and installation costs. When looking at the economic analysis, we decided to look at ion exchangers that use salt and brine to compare against the water conditioners since the goal of the project is to explore salt free water softening devices.

To determine the cost of installing an ion exchange water softener, first we conducted the size of home calculation as shown below. For the calculation we assumed the average home holds four people, each person uses 90 gallons of water per day, and the average hardness in our location was 19 grains. From this calculation we determined that the water softener capacity needed was 48000 grains. We determined this by calculated the grains per day, then looking at the corresponding grains per gallon to find the water softener capacity, Figure 6. With this water softener capacity, the purchase cost ranges from $500-800, the average cost being $650 to purchase a device.

$$No.of\ people\ in\ home\ x\ avg.water\ usage\ x\ water\ hardness$$

Water Softener Price Comparison by Capacity

Grains per Gallon	Water Softener Capacity	Cost Range*
0 - 3,500	24,000 Grains	$300 - $500
3,501 - 4,500	32,000 Grains	$400 - $600
4,501 - 6,850	48,000 Grains	$500 - $800
6,851 - 9,150	64,000 Grains	$600 - $1,200
9,151 - 11,500	80,000 Grains	$1,300 - $2,000

$$4\ people\ x\ 90\frac{gallon}{\frac{day}{person}}\ x\ 19\ grains \rightarrow 6{,}840\frac{grains}{gallon} \rightarrow 4{,}501 - 6{,}580\frac{grains}{gallons}$$

$$= 48{,}000\ grain\ water\ softener\ capacity$$

Figure 7. Water Softener Price Comparison by Capacity (13)

Figure 8. Water Softener Prices by Type (13)

Along with purchase cost, other factors to consider are labor and installation costs, maintenance, water testing, and electrical and plumbing costs for water softeners. According to Figure 7, the average installation cost for an ion exchange is $1250, with maintenance costs averaging to $200 every 3-4 months from regular salt refills, inspection, flushing, and replenishing of the unit. Extra costs for an ion exchange include water testing kits, which have an average cost of $30 per kit. Overall, the yearly cost for an ion exchange is as follows.

Water Softener Prices by Type

Softener Type	Average Price Range	Total Install Cost
Ion Exchangers (Salt & Brine)	$300 – $1,000	$500 – $2,000
Water Distiller	$50 – $1,500	$50 – $2,000
Salt Free	$500 – $3,000	$800 – $4,000
Reverse Osmosis	$100 – $1,800	$1,000 – $2,800
Magnetic	$200 – $400	$200 – $600

Traditional Water Softener	Cost ($)
Traditional Water Softener	650
Installation	1,250
Maintenance	800
Testing Kits	120
Total	**~ 2,820**
Salt-Free Alternative	**Cost ($)**
Device #1: Yarna	350
Device#2: AquaRex	450

Figure 9. Cost of Traditional vs. Salt-Free Treatment Devices

For an ion exchange water softener, the yearly expense would be around $2820. When compared to the water conditioning devices, Aquarex and Yarna, this price is significantly higher. For water conditioners, the only costs to take into account are the market prices of the devices. This

is because they can be installed without professional help, and have a life span of up to 10 years, with no maintenance or upkeep required. The market price for the Aquarex and Yarna respectively are $450 and $350. These do not include shipping costs, as Aquarex is based in the United Kingdom. This analysis also does not include the costs of appliance life span that may be shortened from the salt free alternatives. According to our testing, the salt free alternatives demonstrate just as much damage to appliances as if the alternatives were not utilized. Looking at both the water softener and water conditioners, it is prevalent that the water softener is more expensive due to market price, installation costs, and continuous maintenance.

Recommended Design Option

Along with the devices and procedures listed above, our group recommends looking into TAC technology, specifically the Springwell FutureSoft – TAC. The Springwell device was not compatible with this testing rig, so we have chosen to analyze existing research and data on this device, as Template Assisted Crystallization (TAC) is the technology with the most information available for it.

TAC technology uses resin beads as nucleation sites to catch minerals as they float in the water and bond them into small crystal groups. These crystals grow until they reach a big enough size to break off the resin bead. These crystals remain in the water as deactivated hard minerals and are completely safe to drink and use. TAC technology has the most research available on it to the public, making it easy to analyze for recommendation. We chose the Springwell FutureSoft device because they were very responsive to our questions and were able to provide us with a lot of information about their product. This is a very helpful quality for a company to have if we recommend this device to residents that may have questions of their own that they need answered. The cost of the Springwell FutureSoft is relatively high, priced on their website at $1,483. However, from initial analysis, we believe this technology is likely to have the best result.

From the tests conducted by measuring calcium ion activity with the Yarna and Aqua Rex devices being turned on or off, there was no difference found in calcium ion activity, and therefore this project cannot scientifically endorse these two devices. For future testing, the team recommends creating a testing method that can run a larger amount of water through the device

for longer periods of time if feasible. There also needs to be an established standards to test against specifically for salt-free softeners in order to properly qualify them.

Results

In order to test the devices, we created standards to calibrate the electrode for a reference of different water hardness, seen in Figure 10. There was almost no difference between the samples of the devices ON compared to when they were OFF.

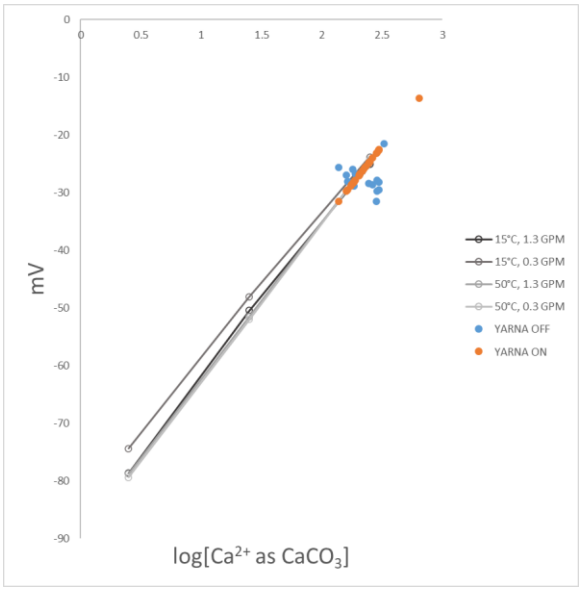

Figure 10. Yarna calibration curve with standards

We decided to measure everything in terms of Calcium as calcium carbonate as that is the way it is referred to most often. Thus, applying the Nernst equation we were able to convert everything as such.

Looking at the Intermittent testing, these is very inconsistent changes in results. We cannot determine that the Yarna or AquaRex have directly softened the water by any degree as shown in **Figure 11.** The longevity testing also showed no differences.

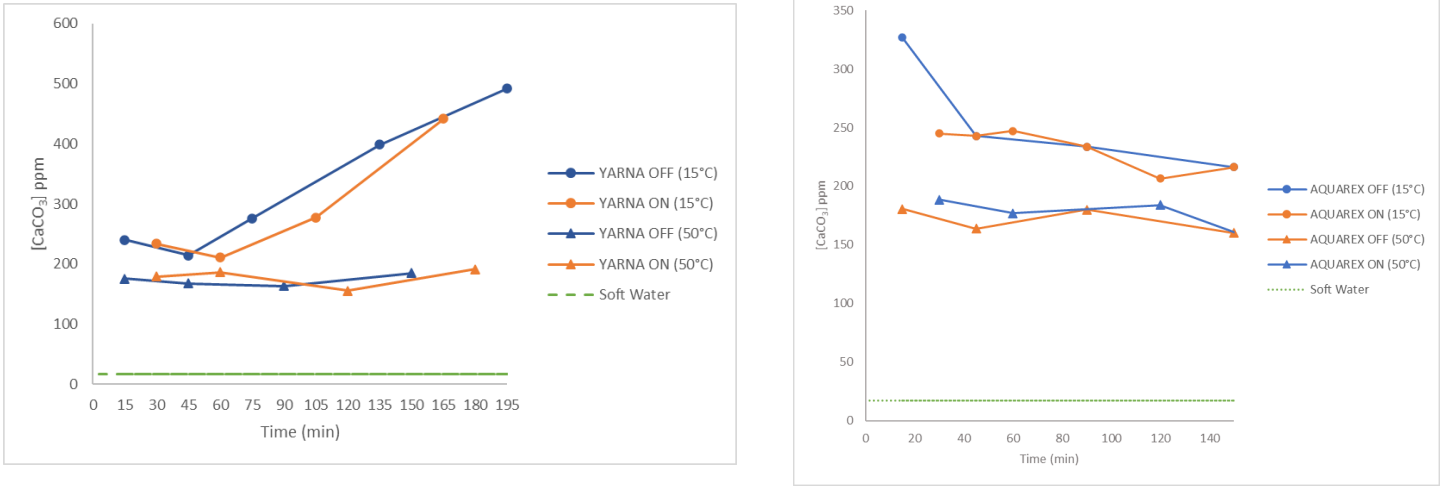

Figure 11. Intermittent testing at different flow rates of Yarna (left) and Aquarex (right)

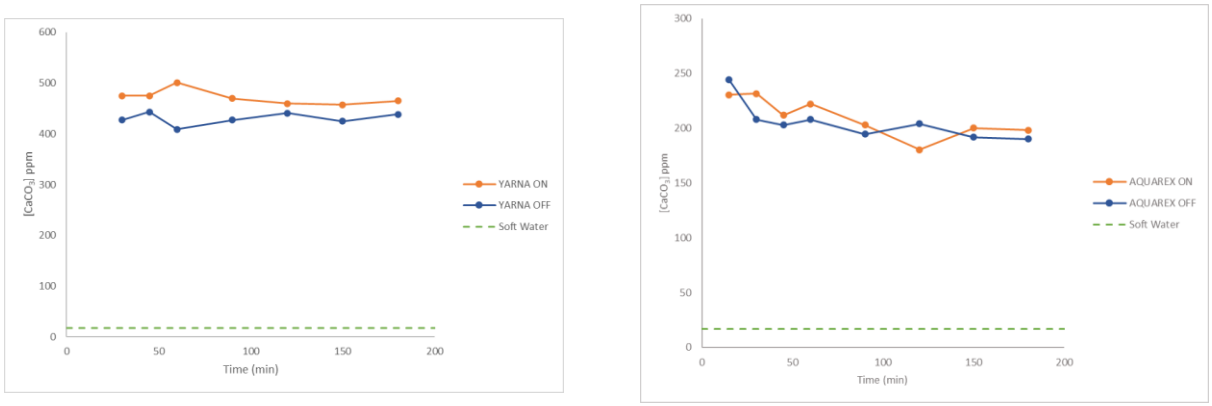

Figure 12. Longevity testing at different flow rates of Yarna (left) and Aquarex (right)

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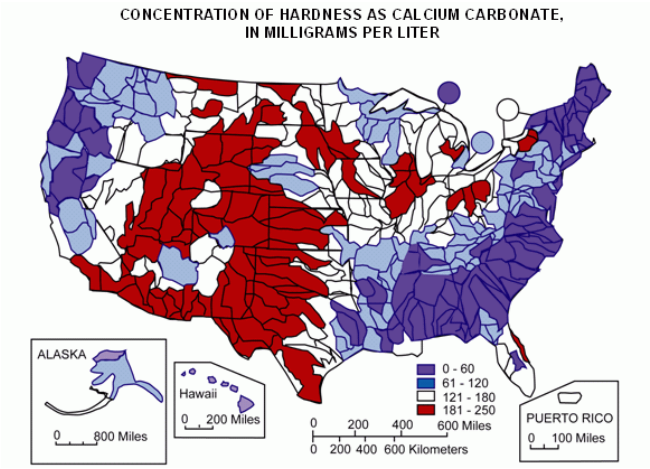
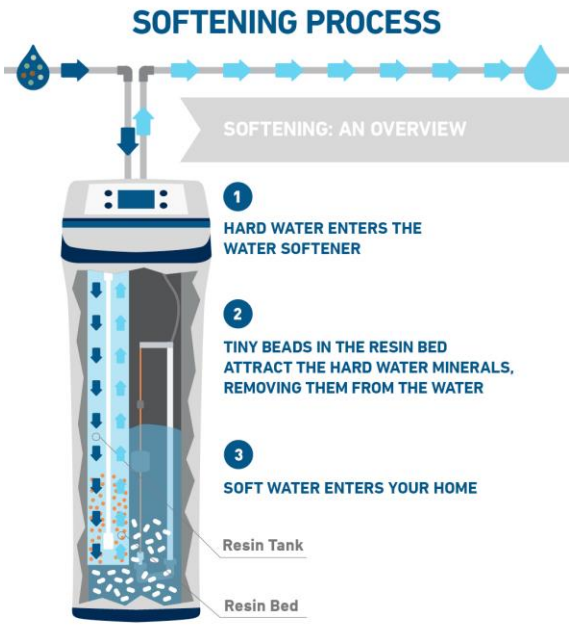
Appendix A:

Figures

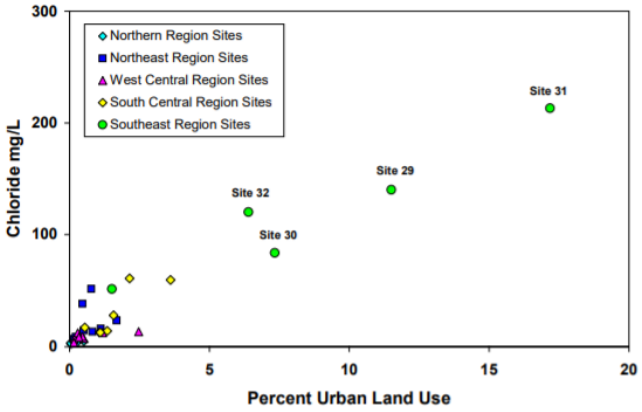
1. Average hardness as calcium carbonate at water-monitoring sites



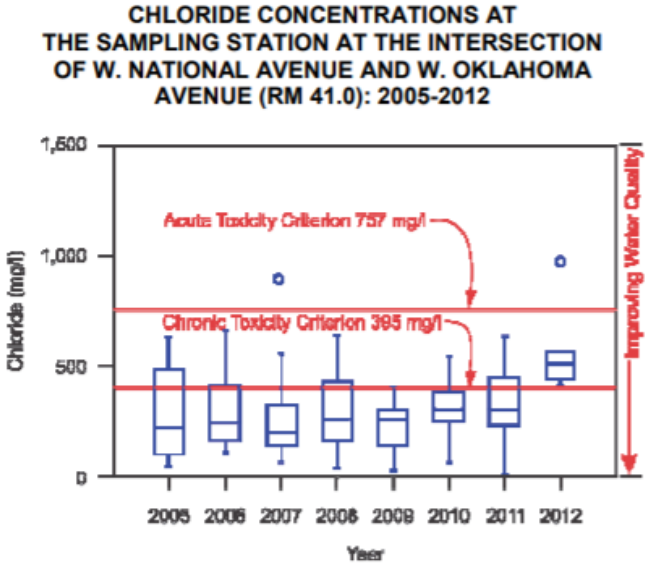
2. Conventional water softener process



3. Relationship between chloride concentrations and urban use at Wisconsin's long term trend sites



4. Chloride concentrations at the sampling station of Root River at the intersection of W. National Ave and W. Oklahoma Ave



5. Schematic of Intermittent Testing Apparatus

6. Schematic of Longevity Testing Apparatus

7. Water Softener Price Comparison by Capacity

Water Softener Price Comparison by Capacity

Grains per Gallon	Water Softener Capacity	Cost Range*
0 – 3,500	24,000 Grains	$300 – $500
3,501 – 4,500	32,000 Grains	$400 – $600
4,501 – 6,850	48,000 Grains	$500 – $800
6,851 – 9,150	64,000 Grains	$600 – $1,200
9,151 – 11,500	80,000 Grains	$1,300 – $2,000

8. Water Softener Prices by Type

Water Softener Prices by Type

Softener Type	Average Price Range	Total Install Cost
Ion Exchangers (Salt & Brine)	$300 – $1,000	$500 – $2,000
Water Distiller	$50 – $1,500	$50 – $2,000
Salt Free	$500 – $3,000	$800 – $4,000
Reverse Osmosis	$100 – $1,800	$1,000 – $2,800
Magnetic	$200 – $400	$200 – $600

8. Cost of Traditional vs. Salt-Free Treatment Devices

Traditional Water Softener	Cost ($)
Traditional Water Softener	650
Installation	1,250
Maintenance	800
Testing Kits	120
Total	**~ 2,820**
Salt-Free Alternative	**Cost ($)**
Device #1: Yarna	350
Device#2: AquaRex	450

Appendix B:

Data Tables

Graphs

Appendix C:

Yarna Specs:

YARNA CAPACITIVE WATER DESCALER | SOLUTION AGAINST HARD WATER

WHAT IS HARD WATER COSTING YOU?

MAINTENANCE

Around 6mm of limescale will build up in an average household over 4 years and can cause up to a 40 % reduction in your home's energy efficiency. Cleaning also takes longer and uses more chemicals. ***A household of four spends about $800 per year on cleaning supplies.***

APPLIANCES

Eventually, untreated hard water can cause appliances to leak, malfunction and use more energy. Also, the heating elements of water heaters are highly susceptible to damage from limescale. ***Hard water can lead to as much as a 48% loss of efficiency in water heaters.***

PIPES/FAUCETS

Pretty much any plumbing fixture is negatively affected to some degree by hard water. Typical examples are ruined finishes, damaged washers and seals, valve blockages. Steel pipes are particularly susceptible to blockages.
Faucets need to be replaced 40% sooner.

YOUR BODY

Hard water can leave your hair feeling frizzy, dull and brittle, and your scalp feeling dry and itchy. It also makes it difficult to rinse away soap from the surface of your skin, leaving your body dry and potentially irritated.
Hard water makes moisturizers and cosmetics less effective.

Know This Before Installing

You need a minimum of 10" (25cm) of exposed pipe.

For optimal water treatment, YARNA is best installed near the water meter or at the main water supply. Make sure you have access to a power outlet. Our power adapter has 5ft (1.5m) of cable.

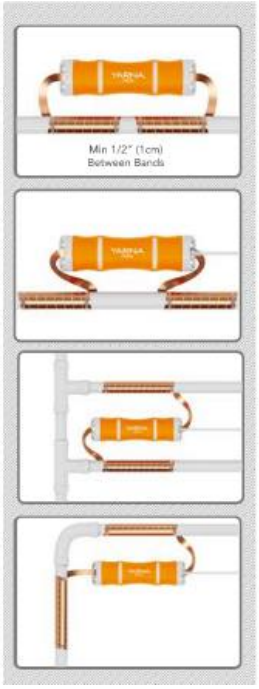
Different installation positions are possible. Please observe different placement examples, shown in the images to the right. Leave a minimum safe distance of at least ½" (1 cm) between the two impulse bands.

The main unit can be installed on the wall or directly to the pipe. To secure it to the wall use the screws and anchors provided in the box. To mount it on the pipe run the zip ties through the top and bottom holes of each side of the main unit. The position of the main unit relative to the pipe is not important. You may also install the unit over the impulse bands.

Each impulse band has a total length of 58" (147cm). You need to wind at least 4" of pipe length.

In case of limited space, the windings can be placed partly on the main pipe and partly on the distributor pipe. All these different installations are possible because the treatment impulses extend over several meters to either side of the pipes.

The unit is effective up to 1.2 miles from the installation point along with your pipe system. Depending on ambient temperatures this effect can last up to 7 days after water exits your pipe system. Minerals remain in the water as ions. This prevents the lime-scale to stick to your skin or solid surfaces.



Instructions

ENGLISH

1. Secure the main unit to the wall by using the screws inside or directly onto the pipe using the plastic zip ties.

2. Use a zip tie to secure the impulse band to the pipe.

3. Wind the impulse band around the pipe producing a coil. ***Make sure you wind the band tightly to the pipe and place the windings close to each other***. Latch the end of the impulse band to the pipe using another zip tie. Now repeat steps 2 and 3 with the second impulse band.

4. Time to power up the unit. First plug the power adaptor to the main unit, and then connect the power supply to an electrical outlet. The power adapter has a LED light that must be visible. The main unit has two white diagnostic lights that will come on, showing that both impulse bands are operating normally. Your YARNA water softener works from now on maintenance-free.

Your Hardware Warranty

YARNA One (1) Year Limited Warranty
for your Water Descaler
YARNA Branded Products Only

WHAT IS COVERED BY THIS WARRANTY?
YARNA warrants the water softener product and accessories contained in the original packaging against defects in materials and workmanship when used normally in accordance with this user manual guidelines. The standard warranty is valid for a period of ONE (1) YEAR from the date of original retail purchase by the end-user purchaser ("Warranty Period"). YARNA's guidelines include but are not limited to information contained in technical specifications, user manuals and service communications.

You can extend your warranty to TEN (10) YEARS by registering your product on www.yarna.com.

The manufacturer does not undertake to repair or replace the unit where there is evidence that damage or failure of the unit has been caused by improper installation or operation, or if there is evidence of tempering with the unit in any way. In addition, the warranty does not extend to include damage from external causes or natural disasters. Also the warranty is limited to the product and does not apply to parts of the water system (pipes, faucets) or appliances.

The YARNA softener has no serviceable parts. In case of valid warranty claim, YARNA will proceed to REPLACING the damaged unit. In such an event, the customer will always receive a new product, and NOT a reconditioned/refurbished one.

Garantía de su equipo

YARNA Tiene una garantía limitada de un (1) año para su ablandador de agua y solo para productos de marca YARNA

¿QUÉ ESTÁ CUBIERTO POR ESTA GARANTÍA?
YARNA garantiza el producto y los accesorios del ablandador de agua que se encuentran en el embalaje original, contra defectos de materiales y mano de obra siempre y cuando se usen normalmente de acuerdo con las pautas de este manual de usuario. La garantía estándar es válida por un período de UN (1) AÑO desde la fecha de compra original al por menor realizada por el comprador final ("Período de garantía"). Las pautas de YARNA incluyen, pero no están limitadas a la información contenida en las especificaciones técnicas, los manuales de usuario y las comunicaciones del servicio.
Puede ampliar su garantía a DIEZ (10) AÑOS registrando su producto en www.yarna.com.

El fabricante no se compromete a reparar o reemplazar la unidad cuando exista evidencia de que el daño o falla de la unidad ha sido causado por una instalación u operación inadecuadas, o si hay evidencia de algún tipo de alteración de la unidad. Además, la garantía no incluye daños por causas externas o desastres naturales. La garantía se limita al producto y no se aplica a partes del sistema de agua (tuberías, grifos) o electrodomésticos.

Garantie Ihres Gerätes

Einjährige (1 Jahr) beschränkte Herstellergarantie von YARNA für Ihren Wasserenthärter
Diese Garantie gilt ausschließlich für YARNA-Markenprodukte.

WAS WIRD VON DIESER GARANTIE ABGEDECKT?
YARNA leistet Garantie bei Material- und Verarbeitungsfehlern des Wasserenthärters und Zubehörs in der Originalverpackung bei normalem Gebrauch gemäß den Anweisungen dieser Bedienungsanleitung. Die Standardgarantie gilt für einen Zeitraum von EINEM (1) JAHR ab dem ursprünglichen Kaufdatum des Endverbrauchers (Käufers) („Garantiezeit"). Zu den Anweisungen von YARNA gehören u. a. Informationen in technischen Spezifikationen, Bedienungsanleitungen und Service-Mitteilungen.
Sie können Ihre Garantie auf ZEHN (10) JAHRE verlängern, indem Sie Ihr Gerät auf der Website www.yarna.com registrieren.

Der Hersteller ist nicht zur Reparatur oder zum Austausch des Gerätes verpflichtet, sofern es Anzeichen darauf gibt, dass Schäden oder Fehler am Gerät durch eine unsachgemäße Installation oder Bedienung verursacht wurden, oder Anzeichen für irgendeine Form von Temperierung am Gerät vorliegen. Darüber hinaus deckt die Garantie keine Schäden durch äußere Ursachen oder Naturkatastrophen ab. Zudem beschränkt sich die Garantie auf das Gerät und gilt nicht für Teile des Wassersystems (Rohre, Armaturen) oder Vorrichtungen.

Der Wasserenthärter von YARNA verfügt über keine zu wartenden Teile. Im Falle eines berechtigen Gewährleistungsanspruchs wird YARNA für den ERSATZ des beschädigten Gerätes sorgen. In diesem Fall erhält der Kunde immer ein neues Gerät und NICHT ein repariertes/wieder instandgesetztes Gerät.

Der YARNA-Weichspüler hat keine zu wartenden Teile. Im Falle eines gültigen Garantieanspruchs wird YARNA mit dem ERSETZEN der beschädigten Einheit fortfahren. In einem solchen Fall erhält der Kunde immer ein neues Produkt und NICHT ein überholtes / aufgearbeitetes Produkt.

Votre garantie matérielle

YARNA Un (1) an de garantie limitée pour votre adoucisseur d'eau
Pour les produits de marque YARNA uniquement

QUE COUVRE CETTE GARANTIE?
YARNA garantit le produit de l'adoucisseur d'eau et les accessoires contenus dans l'emballage d'origine contre les défauts de matériaux et de fabrication lorsqu'il est utilisé normalement conformément aux présentes instructions pour une période d'UN (1) AN à compter de la date d'achat, acheteur ("Période de garantie"). Les lignes directrices de YARNA incluent, sans s'y limiter, les informations contenues dans les spécifications techniques, les manuels d'utilisation et les communications de service. Vous pouvez prolonger votre garantie à DIX (10) ANS en enregistrant votre produit sur www.yarna.com

Le fabricant ne s'engage pas à réparer ou à remplacer l'unité lorsqu'il existe des preuves que l'installation ou le fonctionnement de l'unité a été endommagé ou défectueux, ou qu'il y a des signes de tempérage avec l'unité de quelque façon que ce soit. En outre, la garantie ne couvre pas les dommages causés par des causes externes ou des catastrophes naturelles. De plus, la garantie est limitée au produit et ne s'applique pas aux parties du système d'eau (tuyaux, robinets) ou aux appareils.

L'adoucisseur YARNA ne contient aucune pièce réparable. En cas de demande de garantie valide, YARNA procédera au REMPLACEMENT de l'unité endommagée. Dans un tel cas, le client recevra toujours un nouveau produit, et non un produit reconditionné / remis à neuf.

www.yarna.com

What To Expect & Important Notes

Yarna CWD24 is a physical water treatment system. It treats the water with electric impulses which are generated in the electronic unit and are controlled by a computerized micro-chip. The signal-frequencies are transmitted via the impulse coils that are wrapped around the pipe. The bands interact as pairs and form a frequency-field that changes the crystals in the water as it flows by. Thus, the limescale particles lose their adhesive power.

If you have a home or small business that uses water, the Yarna will help protect against : Blocked piping systems, Dull surfaces and malfunctioning machinery, High costs for heating, High expenses for cleaning, Rust accumulation in the pipe that leads to corrosion, Bacterial growth in drinking water carrying pipes, and Others. Depending on the condition of your plumbing (how large the limescale deposits are), it might take up to three months to notice best results.

WHY DESCALING IS BETTER THAN SOFTENING: Yarna does NOT eliminate wanted minerals like Calcium and Magnesium. Minerals are good and a necessary part of our diet. Yarna does NOT use salt or waste any water. Water descaling is a process used to reduce the negative effects of hard water. It prevents the minerals from forming scale deposits, which is the main disadvantage of hard water.

Your YARNA water softener WILL NOT make your water potable.

Your YARNA water softener is suitable for all pipe materials: iron, copper, plastic, stainless steel, PVC, compound pipes, PE-X, etc.

Protect the electronic unit and the power supply against direct water. The unit is IP65 rated (protected against jets of water)

Use the provided electronic power adapter only. You can use an extension cord if there is no outlet around the installation point.

Do not cut the impulse bands nor the 24V power cord of the power supply unit. It is better to overlap the turns in the impulse bands as opposed to cutting them.

Clean the device with water only using a soft cloth.

The operating temperature of YARNA ranges from -13°F to 122°F (-25°C to +50°C).

This water softener is suitable to use on pipes with a maximum diameter of 1.5".

AquaRex Specs:

Specifiers Guide

WK1

WK1-E

WK1P

WK2

WK3

WK4

AQUA REX®

Physical Water Conditioner To Treat Hard Water

Introduction

Aqua-Rex is the name used in the USA for the product known as Water-King in the rest of the world. Aqua-Rex is an electronic Physical Water Conditioner that inhibits scale formation in hot and cold water services, removes existing scale deposits and partially softens hot water. It is effective at reducing scaling in plumbing systems, shower heads, swimming pools, cooling towers, water features - in homes, hotels, apartment buildings, offices, prisons; anywhere that calcium can build up. It is installed by wrapping wires around the cold water supply pipe which can be made of any material. It requires no pipe cutting for installation and there is no need for ongoing maintenance or servicing.

The technology explained

Aqua-Rex uses pre-programed microchips to transmit pulses of electrical charge into the water at varying frequencies and amplitudes. These radio "signals" cause some of the minerals in the water to form sub-microscopic clusters. When the water is then heated, the clusters act as nucleation seeds upon which the calcium carbonate (limescale) precipitates. Instead of the hard encrustation on pipes and heating elements that normally occurs when water is heated, the precipitation takes the form of tiny calcium carbonate crystals that float suspended in the water. These ultra-fine crystals are carried away with the flowing water. Aqua-Rex has been performance tested under IAPMO IGC 335-2018 Rapid Scaling Test and proven to reduce scaling by up to 83% at 180^{0} F. To see a full IAPMO R&T Lab report go to the Technical Library on our website.

Applications

With over 300,000 installations around the world since 1993, Aqua-Rex is a well proven reliable product that has demonstrated its effectiveness in most applications where conventional water softeners would normally be used. Aqua-Rex is less expensive to install and maintain than ion exchange softeners. Aqua-Rex requires very little space, no special plumbing, no waste water connection and no supply of salt. There is no loss of water pressure nor any additional corrosion problems. Aqua-Rex can provide most of the benefits of a water softener, without any chloride discharge and at much reduced initial and ongoing running costs.

How Is The Water Softened Without Removing The Calcium?

The nucleation seeds created by Aqua-Rex stimulate the conversion of more of the dissolved calcium bicarbonate in the water into crystals in suspension than would otherwise occur. The resulting hot water, with less calcium bicarbonate, is now chemically softer. Aqua-Rex is the only electronic device of its kind that has been proven by independent laboratory tests to produce softer hot water.

Drinking Water and Salinity

Unlike ion exchange softened water, where minerals are removed and replaced by sodium, Aqua-Rex treated water is good for drinking. There is no need for a separate drinking water supply, no health risks and no chloride effluent. It can be used for reducing scale in irrigation systems.

Removal of Existing Scale Deposits

Aqua-Rex is very effective at removing existing scale deposits from water heaters, general plumbing and cooling towers. Descaling occurs within a few weeks. The scale breaks away in flakes as it loses adhesion with the surface that it is encrusting. In existing systems, that are already badly scaled, it may be worth installing one or more filters to protect sensitive equipment such as heaters and heat exchangers. We also suggest scheduling a hot water tank drain and clean after three months.

Lifecycle Costs

Running costs of all units is just a few dollars per month. The design life is in excess of 25 years with a 20-year manufacturer's warranty. Aqua-Rex comes with an unconditional 100-day money-back satisfaction guarantee. This is extendable subject to negotiation.

Aqua-Rex LLC, 3301 Spring Mountain Road,
Suite 18. Las Vegas, NV 89102
Tel: 877 640 2170 Fax: 702 256 2175
www.aqua-rex.com email: info@aqua-rex.com

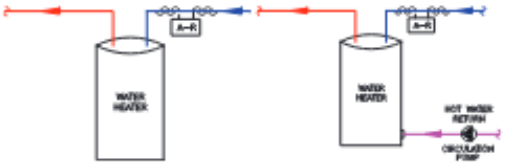
Location of Units

Correctly Locating Aqua-Rex is essential to ensure optimum performance. The flexibility of Aqua-Rex is helped by the Signal Propagation whereby the effect is transmitted both upstream (back signal) and downstream. Unlike other water treatment products it is not necessary to pass the water through the unit to get effective treatment. It is also capable of treating static water in a tank. On the negative side, water passed through a pump loses most of the treatment imparted by Aqua-Rex. As a general rule, wherever there is a pump, an Aqua-Rex should be located downstream of it.

Aqua-Rex can be installed at the point of entry to the property or plant room, or on a softener loop, but in general it is more effective when it is placed close to where the scale is likely to form – on the cold inlet to the water heater. It is frequently more effective to install a number of units close to dispersed water heaters, especially when they are electric heaters, than one large unit on the main cold supply.

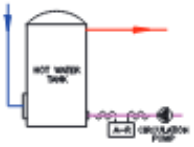
Tank Water Heater in the Home

Install the Aqua-Rex on the cold inlet to the heater. The flexible connection is a good place to wrap the wires. The back signal will treat all the cold water in the home. If a hot water return (HWR) is attached to the tank drain, the unit on the cold supply close to the tank will treat all the water in the tank.



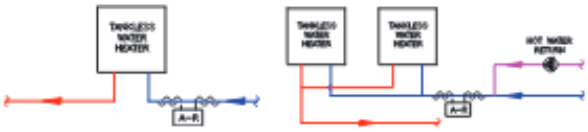
Tank Water Heater in Larger Properties

Treat the cold water supply but also install a unit on the hot water return after the pump.



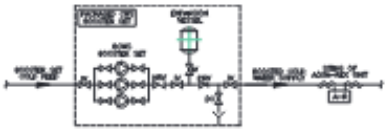
Tankless Water Heater

Install the Aqua-Rex on the cold inlet to the heater, close to the heater. If there are multiple heaters in parallel with a hot water return, install the unit on the cold supply, preferably after the junction with the return.



Dishwashers

Because a dishwasher uses an internal pump, treatment with Aqua-Rex may not be very effective. We recommend using hard water rinse aids, or a dedicated softener for large commercial dishwashers. Aqua-Rex can be used to reduce scaling in an electric booster heater.



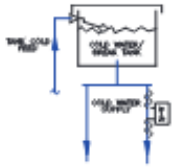
Installation Of Aqua-Rex On A Booster Pump And Circulation Pump

Booster Pumps.

Pumps cause a significant reduction in the effectiveness of Aqua-Rex so, wherever there is a pump, in general there should be an Aqua-Rex unit located downstream from it.

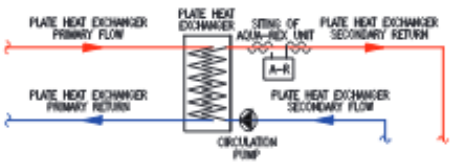
Cold Water Tanks and Break Tanks

Cold water tanks generally cause a discontinuity in the signal transmission resulting in decay of the nucleation seeds generated by the Aqua-Rex. This problem can be overcome by installing a unit on one of the outlet pipes from the tank or on a drop from the header and making use of the back signal to treat the stored water within the tank.



Heat Exchangers

We recommend that both the cold inlet and the heated discharge of heat exchangers are treated. This is more easily achieved with one of the units which has four antennas, by applying one pair of antennas to each of the inlet and discharge pipes. If a pump is close coupled to the heat exchanger, treat only the discharge side. This applies especially to plate heat exchangers.



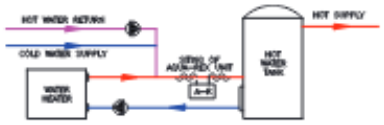
Installation Of Aqua-Rex On A Plate Heat Exchanger

Cold Water Supply to Mixing Valves and Showers

Most of the scale formed in these fittings is precipitated from the cold water. The cold water supply to these appliances should also be treated with an Aqua-Rex unit. When a conventional water softener is installed to treat only the hot water services, it is common to find scale forming in mixing valves, shower heads and faucets. An Aqua-Rex unit installed on the cold services will reduce this scaling.

Water Heaters (Boilers) with Stored Hot Water Tank

Generally there is a pump on the supply line from the tank to the water heater or there may be a pump attached to the water heater. An Aqua-Rex unit should be installed on the return line from the water heater to the tank. The signal travels back into the heater at its hottest point and the cold make up water and hot water return are also treated.

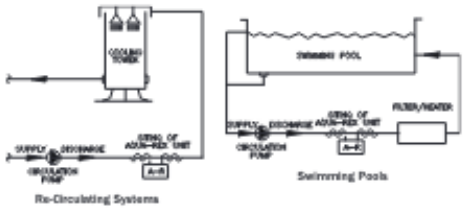


Installation Of Aqua-Rex On Copper Fins

Re-Circulating Systems & Swimming Pools

Where water is being constantly circulated, such as through a cooling tower or swimming pool, the Aqua-Rex unit should be fitted on the circulating system downstream from the pump and as close as possible to where the heating process or pressure drop is occurring. There is no need to treat the make up water. Adequate provision must be made for filtering to remove suspended solids.

On a swimming pool the unit should be installed between the pump and the filter or heater. In most cases Aqua-Rex will reduce phosphates by causing them to flocculate, making the water clearer, and also reduce or stabilise total dissolved solids.



Installation Of Aqua-Rex On Re-Circulating Systems And Swimming Pools

Irrigation Systems and Misters

Install an Aqua-Rex unit after the pump. On high pressure mister lines we recommend a WK1 unit is installed on each line

Installation Of Aqua-Rex On Irrigation Systems

Plumbing Requirements and Pipe Material

Each Aqua-Rex antenna requires about 3 inches of pipe. There is no minimum nor maximum gap between aerials. They can be fitted either side of bends on horizontal or on vertical pipes. Aqua-Rex can be fitted to pipes of any material. The pipe does not need to be cut, there is no plumbing involved, nor is there any requirement for an isolating bypass with associated valves. Insulation may be fitted over the antennas after installation.

Power Requirements

Each unit requires an outlet within three feet of the unit except the WK1P which can be extended to six feet. Each of the units with external transformers can have the low voltage two core lead extended by splicing in suitable cable such as speaker cable. Tests have shown this extension to be satisfactory over half a mile. The unit should be located within eighteen inches of the pipe that is being treated. In many cases it can be suspended from the pipe it is treating with plastic ties rather than being fixed to a surface.

Evaporative Systems

Where systems are designed to operate with make up water for evaporation, such as cooling towers or humidifiers, adequate provision must be made to clear any deposits by regular "blow down" or other means.

Suggested Specification For Water Treatment

One or more Aqua-Rex Physical Water Conditioners shall be provided on the CW supply and HWR in accordance with the manufacturer's recommendations. The unit shall have one or more pairs of open ended antennas wrapped around the pipework generating a series of square waves of random length and occurrence between 1 kHz and 10 kHz. The peak to peak output voltage will be in excess of 80 volts. The device shall have been tested under IAPMO IGC 335 and shown to reduce scaling by at least 80%.

Selecting the Correct Size of Unit

Pipe Diameter
Having decided where to locate the Aqua-Rex, select the appropriate sized unit according to the pipe diameter.

Flow Rate and Water Hardness
When specifying Aqua-Rex neither the flow rate nor the water hardness is an issue. Only when Fe is less than 10ppb and/or Mg is high relative to Ca is there a reduction in performance.

* The WK1 and WK1-E can be installed on a 1¼" softener loop

Maximum pipe diameter	WK1 1" *	WK1-E 1" *	WK1P See Note under "Product Features" below	WK2 1½"	WK3 3"	WK4 4"	WK5 6"
Antenna number/length	2/6'	4/6'	2/10'	4/6' 6"	4/16'	4/23'	6/30'
Minimum antenna wraps	12 wraps	12 wraps	12 wraps	12 wraps	15 wraps	15 wraps	15 wraps
Frequency range	1-10 kHz.	1-10 kHz.	1-10 kHz.	1-10 kHz.	1-10 kHz.	1-10 kHz.	1-10 kHz.
Peak to peak output voltage	82 V.	82 V.	82 V.	82 V.	82 V.	82 V.	82 V.
Power supply required	120 V.	120 V.	120 V.	120 V.	120 V.	240 V. or 120 V.	240 V. or 120 V.
Input current	0.02 A.	0.03 A.	0.02 A.	0.03 A.	0.04 A.	0.08 A.	0.1 A.
Power consumption	1 W.	1 W.	1 W.	1 W.	2 W.	2 W.	3 W.
Transformer output	9 V. ac	9 V. ac	9 V. ac	9 V. ac	9 V. ac	Internal	Internal
Lead length	5'	5'	10'	5'	5'	5'	5'
Dimensions (inches.)	5 x 3 x 2	5 x 3 x 2	5 x 3 x 2	8 x 6 x 2	8 x 6 x 2	11 x 8 x 5	11 x 8 x 5
Weight	1lb	2lb	2lb	2.2lb	2.2lb	6.6lb	7lb
Ambient temperature	160°F	160°F	160°F	160°F	160°F	160°F	160°F
Humidity non-condensing	80%	80%	100%	80%	80%	80%	80%
BMS output	No	No	No	No	Yes	Yes	Yes

Product Features

WK 1 An easy to install unit with an external transformer. Suitable for most residential installations, especially gas water heaters on city water.

WK 1-E This unit should be used with electric water heaters with up to 1" inlets, and also when treating well water with gas or electric heaters.

WK 1P The same output as the WK1 but fully waterproof so it can be left outside exposed to the weather. It can be used to reduce scaling in swimming pools by attaching it to 2" re-circulation pipes between the pump and the water filter. It can be used on 1" supply pipes to externally mounted water heaters. It must not be used on 2" supply pipes. The transformer is rated for internal use only so it requires protection from the weather.

WK 2 An intermediate sized unit with external transformer. The extra pair of antennas can be used for treating a second pipe as well as reinforcing the signal applied to a single pipe. The WK2 is ideal for larger properties and treating especially hard water where a WK1 might be less effective.

WK 3 A powerful unit that will handle the majority of commercial applications. It is frequently specified to treat the cold supply to direct fired water heaters and paired with a WK1 on the hot water return. It has output for a Building Management System (BMS) to detect power failure.

WK 4 This unit is designed to treat larger pipe sizes up to 4". It has internal transformers, rated at either 120 or 240 volts. The enclosure is rated IP65.

WK 5 This is the largest standard Aqua-Rex unit with the same dimensions, transformer options and features as the WK4. It has six antenna outputs arranged as three pairs and is capable of treating pipe sizes up to 6".

Larger units than the WK5 are available as a special order.

Approvals and certification
All external transformers are UL approved. The WK4 and WK5 are UL approved as Physical Water Conditioners and listed under manufacturer Lifescience Products Ltd E353945. IAPMO R&T Lab certify that the Aquq-Rex WK1-E reduced scaling by 83% when applied to Las Vegas water heated to 180°F.

Self-Diagnostic "Guard Chip"
Aqua-Rex units are equipped with an additional "Guard Chip" program which monitors the performance of the main program and resets the system automatically if it detects a variation or system failure. There is no need for manual resetting after power outage.

Technical Assistance for specifications
Our technical department is very experienced at advising consultants and contractors of the most effective way of treating water using Aqua-Rex technology. We are able to receive drawings by email to specifier@aqua-rex.com and will respond immediately.

Aqua-Rex LLC, 3301 Spring Mountain Road, Suite 18. Las Vegas, NV 89102
Tel: 877 640 2170 Fax: 702 256 2175
www.aqua-rex.com email: info@aqua-rex.com

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03/20

Résumés of Team Members:

Martina Macaggi

1405 W Concord Dr., Arlington Heights, IL 60004
Cell: (224) 465-4682 Email: mmacaggi@purdue.edu

Education

Purdue University, West Lafayette, IN **GPA: 3.4** **12/2022**

- Bachelor of Science in Environmental & Ecological Engineering
- Minor in Organizational Leadership and Supervision

Relevant Experience

Trane Technologies, La Crosse, WI **Marketing Engineer Co-Op** **01/2021-08/2021**

- Hosted national and international customers during 14 virtual product tests, typically consisting of 3-20 engineers on one call
- Supported over 200 USA and Latin America sales offices through email and phone communication
- Refreshed marketing material on Trane website for sales office usage

SINCS Research Group, Purdue University **Undergraduate Research Fellow** **01/2020-08/2020**

- Selected as one of 140 for fellowship
- Modeled hog feed and consumption, population growth, and GHG emissions using MATLAB
- Created spatial CO_2 emissions map for IL hog farms using MS Excel and USDA 2012 Survey Data
- Presented results at the 2020 AIChE Annual Meeting

ViPER Research Group, Purdue University **Undergraduate Researcher** **05/2019-12/2019**

- Publication: Ghosh, S., Makeev, M., Macaggi, M., Qi, Z., … Pol, V. (2020, June 27). Dipotassium terephthalate as promising potassium storing anode with DFT calculations. *Materials Today Energy*. Volume 17.
- Researched impact of chemically recycling post-consumer plastic bottles into secondary potassium-ion battery cells
- Reviewed scientific literature and interpreted results in lab
- Presented work and literature reviews at group meetings of 10-15 graduate and PhD students

Purdue University Office of Sustainability **Student Intern** **05/2019-12/2019**

- Directed five interns at weekly Farmer's Market to maximize efficiency of market
- Communicated with interns and supervisors to ensure "All Hands-on Deck" projects ran smoothly
- Redesigned recycling visibility and layout at eleven campus buildings to increase waste diversion rates

Leadership Experience

Purdue Student Sustainability Council **President** **04/2019-05/2020**

- Elected to represent over fifty club members and led monthly club meetings
- Built network of eight eco-organizations on campus to encourage event and project collaboration
- Designed and oversaw a Virtual Earth Week that reached over 200 students

Engineering Projects in Community Service **Design Lead** **01/2019-05/2019**

- Delegated project tasks to 5 team members
- Designed and built a custom PVC cart for toy storage for a local humane animal shelter

Skills and Certifications

Skills: Native Spanish Speaker, MATLAB, AutoCAD, RStudio
Certifications: OSHA 10-hr General Industry, plan to take FE exam in Aug. 2022

David A Perry

perry181@purdue.edu https://www.linkedin.com/in/davidperry2727/ (414) 698-8498

Education

Purdue University, *West Lafayette, IN* **Expected Graduation: May 2022**

- Major: Bachelor of Science in Environmental and Ecological Engineering
- Minor: Environmental Politics and Policy
- GPA: 3.0

Work Experience

Project Engineering Intern, Veolia Water North America, *Milwaukee, WI* **June 2021 – January 2022**

- Performed the duties of a project engineer for Material Capital Repair and Replacement (MCRR) projects at the Jones Island Water Reclamation Facility
- Prepared work request forms, organized asset transmittals, and drafted bid packages for contractors to complete various projects throughout the facility
- Worked with outside contractors to obtain project quotes, negotiate bid contracts, and ensure our projects were completed in a timely and satisfactory manner

Purdue University Senior Design Project, Wisconsin Salt Wise, *Madison, WI* **August 2021 – Present**

- Partnered with Wisconsin Salt Wise to find viable salt-free alternatives to traditional water softeners
- Researched different salt-free water conditioning methods and devices, while developing appropriate testing standards and procedures
- Tested salt-free water conditioners in a lab environment for their ability to successfully reduce scale build up

Student Service Associate, Au Bon Pain, *West Lafayette, IN* **January 2020 – May 2021**

- Prepared sandwiches and beverages for customers efficiently while adhering to all safety protocols
- Worked collaboratively with coworkers in a high-pressure, high-volume environment
- Provided excellent customer service while ensuring high quality of product

Maintenance Worker, The Town Club, *Fox Point, WI* **May 2020 – August 2020**

- Maintained the quality of fifteen clay tennis courts and three hard tennis courts
- Provided a wide variety of services such as landscaping, mulching, minor repairs, demolition, construction, and janitorial services
- Trained new maintenance staff

Activities/Leadership

Society of Environmental and Ecological Engineers (SEEE), Purdue University **August 2019 – Present**

- Through the SEEE, I am connected with others in the Environmental and Ecological Engineering field
- Collaborates and learns from experts in the field and participates in professional development opportunities

Environmental and Ecological Engineering Student Ambassador, Purdue University **September 2019 – May 2020**

- Appointed as a student leader ambassador for the Environmental and Ecological Engineering (EEE) department at Purdue University
- Conferred with prospective EEE students in high school or first year engineering about EEE to help determine if this engineering field is right for them

ASHLEY SANCHEZ

sanch215@purdue.edu | 574-350-3112

EDUCATION

Purdue University, West Lafayette, IN GPA: 3.2
B.S. Environmental & Ecological Engineering May 2022
Minor: Spanish for the Professions
M.S. Environmental & Ecological Engineering May 2023

RELEVANT EXPERIENCE

Purdue University | Undergraduate Research; West Lafayette, IN *August 2021 – Current*

- Study the effects of nutrients on the development of antibiotic resistance for the research of Dr. Zhou

Purdue University | Teaching Assistant EEE 355; West Lafayette, IN *August 2021 – Current*

- Evaluate and revise lesson plans and course content to facilitate team discussions of a 120-student course
- Lead class in discussion on global-scale resource utilization, population dynamics, and ecosystem impacts

Xylem Inc | Process Engineer Intern; Milwaukee, WI (virtual) *May 2021 – August 2021*

- Collected data on primary treatment processes from 20 wastewater facilities on a global scale, to create and update databases
- Prepared multiple operational descriptions regarding the design of the facility's effluent goals

Purdue University | Teaching Assistant EEE 350; West Lafayette, IN *August 2020 – December 2020*

- Assisted professor with instructional responsibilities of an 80-student course
- Attended weekly meetings for class preparation and evaluated student work under confidentiality policies

Weavers Consultant Group | Intern; Granger, IN *May 2020 – August 2020*

- Supervised construction quality assurance of environmental control systems such as soil and geomembrane liner testing for 20 acre landfill installations
- Designed and prepared AutoCAD drawings for supervisor, to be sent to clients

Purdue University | Undergraduate Research; West Lafayette, IN *January 2020 – May 2020*

- Investigated how physical and chemical processes affect water quality and treatment with proper lab protocol for the research of Dr. Amisha Shah

Waitress | El Camino Real #4; Goshen, IN *April 2015 – August 2018*

- Provided prompt, attentive service in a fast-paced environment
- Trained new waiters in restaurant practices and menu memorization

LEADERSHIP EXPERIENCE

Society of Environmental and Ecological Engineers | President *May 2020 – Current*

- Supporting 100+ environmental engineering students with professional and social opportunities
- Established student programs: FE Review & Reimbursement, Mentor/Mentee, and Student Research Panels

Purdue University Run Club | Competitor *August 2018 – Current*

- Training daily in preparation for competitions, individually and as a team
- Competing at multiple meets including Cross Country & Track Nationals

Phi Sigma Rho | Environmental Coordinator *August 2020 – May 2021*

- Elected out of 80 members to educate members on sustainable practices
- Organized projects for composting and volunteer work

Residence Hall Student Government | President *June 2019 – May 2020*

- Supporting 1,600 Purdue undergrads, grads, and families, hosting events fitting for all
- Created meeting agendas, worked with a budget of 24K, and selected entire executive team

RACHEL RULLA

17807 DURKIN ROAD TINLEY PARK, IL / (708)704-1123 / RACHELRULLA@YAHOO.COM

Education

Purdue University / West Lafayette, IN / GPA: 3.33

Bachelor of Science: Environmental and Ecological Engineering **May 2022**

Minor: Spanish Language

Experience

Purdue University: West Lafayette, Indiana

Teaching Assistant **January 2022 – Current**

Provide curriculum and classroom support for EEE 430, *Industrial Ecology and Life Cycle Analysis*, to enhance the student experience. Facilitate small group discussion and special topic days. Includes grading of quizzes, assignments, and final exam. Attending meetings, providing input, design, and deliver course curriculum and assessments.

Design Lead **January 2021 – Current**

Research work with Purdue University working with communities in the Dominican Republic to design, build, and implement community-scale water treatment systems. Apply Spanish minor to work with affected communities to implement business models to provide for sustained use of systems, as well as public health education programs for use in local schools and clinics.

Research Assistant **September 2020 – December 2020**

Research work with Purdue University on LED-UV disinfection of water after treatment with slow sand filters in order to implement cost efficient disinfection stations in Peru by 2022. Applying Spanish minor to communicate and translate between Purdue and UNSA associates in Peru.

CRADLE Corporation: Lucerne Valley, California

Remote Engineering Intern **June 2020 – August 2020**

Communicated with intern team to create Requirements Document for company and potential investors. Applied bioastronautics, telerobotics and ISRU to Requirements Document as well as presentation given at end of internship to Aerospace executives.

Leadership and Activities

Purdue Filipino Association

Positions Held: Philippine Culture Night Director, Vice President External, Outreach Committee Head

Aims to support and educate Filipino Culture through various activities and an annual show, Philippine Cultural Night. Officer positions aid in communication and presentation skills, networking assets, as well as leadership and time management.

Midwestern American Filipino Association

Positions Held: Presidential Cohort Internship, Logistics Internship

Organization throughout the Midwest in which various schools come together to support Philippine culture through various events held in the Midwest. Officer positions demonstrate the techniques needed to manage and administer an organization. Trained to improve skills regarding leadership and connections with other organizations.

Society of Environmental and Ecological Engineers

This organization helps spread sustainable awareness both on and off campus. It also aids in connecting various students to opportunities within the community and campus to practice and promote sustainable techniques.