Water Treatment Technology Selection Guide, Spring 2015

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Abstract

The Water Treatment Technology Selection Guide (WTTSG) team seeks to implement a webtool capable of providing recommendations regarding the efficacy and appropriateness of various water treatment options. This tool must be dynamic, responding appropriately to user input, and robust cross-culturally, recognizing cultural and language barriers. It must also adhere to principles of human-centered design, remaining accessible to populations with various degrees of skill while engendering a positive user experience. The current WTTSG team has continued the work of previous teams in creating a functional and attractive website. Significant strides were made this semester in passing data between pages of the site, the design and implementation of the results page, the construction of the administration panel, and the collection and population of data in the site. The site is now equipped to calculate regressions, provide automatic translations and log user input, and has been deployed on a MySQL-enabled server. Future challenges include the tackling logistics of providing the best recommendation possible, while continuing to make the website's recommendations scalable to new languages and technologies.

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Introduction

Web and mobile applications can act as important conduits of information, allowing users to transcend the limits of geography in gaining access to knowledge and resources. Now, in this data-driven age, websites are increasingly tasked with providing dynamic, tailored user experiences to each of their many users. Personalization figures particularly heavily in the provision of online recommendation services. Myriad algorithms process user preferences and constraints in order to suggest an album, book, or product that a consumer might enjoy. This concept of recommendation can be extended to provide technological recommendations to entities seeking information about various water treatment options.

Inspired by this capacity of web technologies, the project team AguaClara has begun the implementation of a Water Treatment Technology Selection Guide (WTTSG), a tool that will provide the feedback that organizations require in order to make an informed decision about which treatment options best suit their needs. By taking in information about the target population and source water of a potential plant, the tool can describe which treatments are most appropriate while simultaneously providing an estimate of plant cost. The WTTSG also will help serve in an outreach capacity, raising awareness of AguaClara technological solutions while providing thoughtful recommendations to the organizations and municipalities that need them. The tool will empower its users to make informed decisions as they pursue the implementation of a water treatment solution.

Literature Review

Point of Use Systems

Point of use systems are decentralized approaches to water treatment which may be implemented rapidly and without extensive resource requirements (Mintz, 2001). However, they may require behavioral changes of their users, who must invest more time and effort to disinfect and store their water (ibid). One such type of point-of-use technology is the LifeStraw family of filters and filter straws. These popular filters have demonstrated in a laboratory setting that they can exceed World Health Organization criteria for “High Protective” status against waterborne microbes (Naranjo, 2011). When deployed in households, these technologies may work to prevent diseases like diarrhea (Clasen, 2009). Their lifetime adequacy can range up to nearly 20,000 L (ibid). Still, they are limited in the ranges of turbidities that they can treat, and are not equipped to remove heavy metals and other contaminants from the water.

AguaClara Plants

AguaClara is an electricity-free technology for removing turbidity from contaminated surface water sources, scalable to fit the needs of many communities. AguaClara plants currently provide clean drinking water to over 45,000 people in Honduras.

AguaClara plants use no electricity or mechanization for low cost, long lifetime, and sustainable operation by local service providers. They feature an innovative use of geometry and hydraulics to practically eliminate moving parts. Simple parts and materials are used, enabling local empowerment, and the plants feature an operator-friendly design. Furthermore, AguaClara plants boast exceptional performance for particle removal, achieving high quality standards and effective disinfection. AguaClara plants can treat a wide range of turbidities; plants in Honduras have successfully treated turbidity over 1000 NTU to below 1 NTU with no interruption in service. AguaClara plants are not currently able to treat arsenic or heavy metals present in water, but as various team members continue to investigate the removal of these substances, this belief should be monitored in years to come.

AguaClara EStaRS

The AguaClara EStaRS (Enclosed STAcked Rapid Sand Filter) is a municipal-scale filter designed for communities of about 500 people. These filters are designed to treat water at low flow rates, often in the range of 1 L/s. They can be cleaned of any accumulated dirt through a simple backwash process. EStaRS filters can be used in areas where full-scale plants are not feasible, and may treat water from a variety of sources, even including well water.

EStaRS filters are simply constructed and straightforward to operate. To account for fluctuations in community size, the filters are designed so they can be easily added and run in parallel to an already existing set of functioning filters.

EStaRS filters are still relatively untested in the field, so further research will be needed to ensure they continue to deliver high-quality water even during the rainy season. The EStaRS filter is limited in the turbidity it can treat before it begins to clog much more quickly. AguaClara engineers estimate that this maximum bound on turbidity might be around 10 NTU when sand filtration is used as a standalone treatment.

Multistage Filtration (FIME)

Multistage filtration (FIME) produces filtered water with low turbidity, free of impurities and of pathogenic organisms. The process takes place in two stages: coarse gravel filtration (CGF) and slow sand filtration (SSF). The two processes working together allow FIME to be an effective treatment option for severely contaminated water (Alberto et al., 1998). The first stage, called pre-treatment, involves the separation of suspended solids by sand filters. The next stage consists of removing fine particles and microorganisms. Slow filtration and chlorination are common processes for the second stage (Veras et al., 2008).

FIME is robust, reliable, and simple in maintenance of operation. It involves low-cost infrastructure and is especially appropriate for rural areas and smaller cities. It may also be combined with pre-processing via simple sedimentation, sand taps, or screens. FIME is more appropriate than chemical water treatment technologies in small-community contexts (Alberto et al., 1998). Terminal disinfection is an important component that should be included after FIME.

In general, FIME should be used when influent water contains impure substances of different sizes, and treatment should be comprised of at least two stages (Veras et al., 2008). In these cases, FIME yields water with low turbidity and coliform levels.

Biosand Filters and Iron-Amended Biosand Filters

Biosand filters are adaptations of slow sand filters which are relatively small and do not treat continuous flow. They are comprised of layers of sand and gravel. A thin layer at the top of the filter is known as the bio layer or biofilm, which aids in the capture of various kinds of particles. Biosand filters may be iron-augmented in order to treat arsenic if it is present, with iron introduced uniformly throughout the sand layers (Bradley et al., 2011). Iron-amended biosand filters have also been shown to be effective at removing viruses from water (ibid), though their success at this endeavor depends upon both the characteristics of the iron and the influent water.

Previous Work

Fall 2014 WTTSG Team Report

This report details the most recent progress made in the creation of the WTTSG, including the design of the site, the creation of its navigation structure, efforts to pass data between pages, and some preliminary work in creating MySQL databases. The report also explains the mechanics of the Plant Cost Calculator, providing the equations and regressions that will allow the WTTSG to provide an estimate of total plant cost. Some preliminary literature review is provided differentiating various water treatment options, but since the collected information lacks sufficient citation, much of this data will have to be recollected.

Spring 2014 WTTSG Team Report

This report documents the efforts of the Spring 2014 WTTSG team, who developed a rudimentary PHP-based tool capable of providing recommendations between several treatment options. The site presented recommendation data in the form of a table, using green and red to highlight good and bad solutions, respectively. This version of the WTTSG did not provide a pleasing user experience, and, moreover, was not robust, breaking easily when subjected to various inappropriate inputs. While this version of the website was abandoned by the subsequent subteam, it still may prove useful to the current team as a source for the control flow logic necessary in providing recommendations.

Methods

Interaction Design Work

In order to provide a high-quality recommendation, the WTTSG must communicate information to users in a clear and cogent way, referencing key sources and supplying thoughtful cost-benefit analysis. This information must be easy to interpret, well-substantiated, and visually stimulating. Thus, the team dedicated a significant amount of attention to the design of the results page, the final page of the tool responsible for imparting a user with their personalized recommendation. The design of this page has been informed by various principles of human computer interaction design, including the value of medium-fidelity prototyping and user testing.

First, the team began by brainstorming the various features necessary to supply a recommendation. These included the statement of the overall recommendation, provision of a target flow rate, summary description of considered treatment options, enumeration of “dealbreakers” shaping the final recommendation, results of plant cost calculations, and opportunity to pursue further information. Also important was the capacity to edit previous inputs, enabling users to tweak their answers and receive updated information on the fly. The team then assembled these components into a low-fidelity prototype, drawn in marker on a whiteboard (see Figure 1).

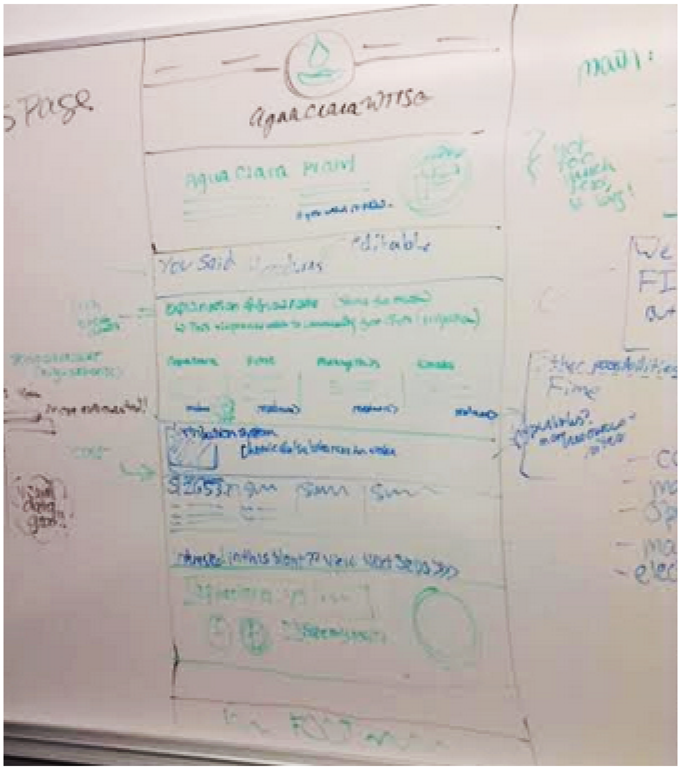
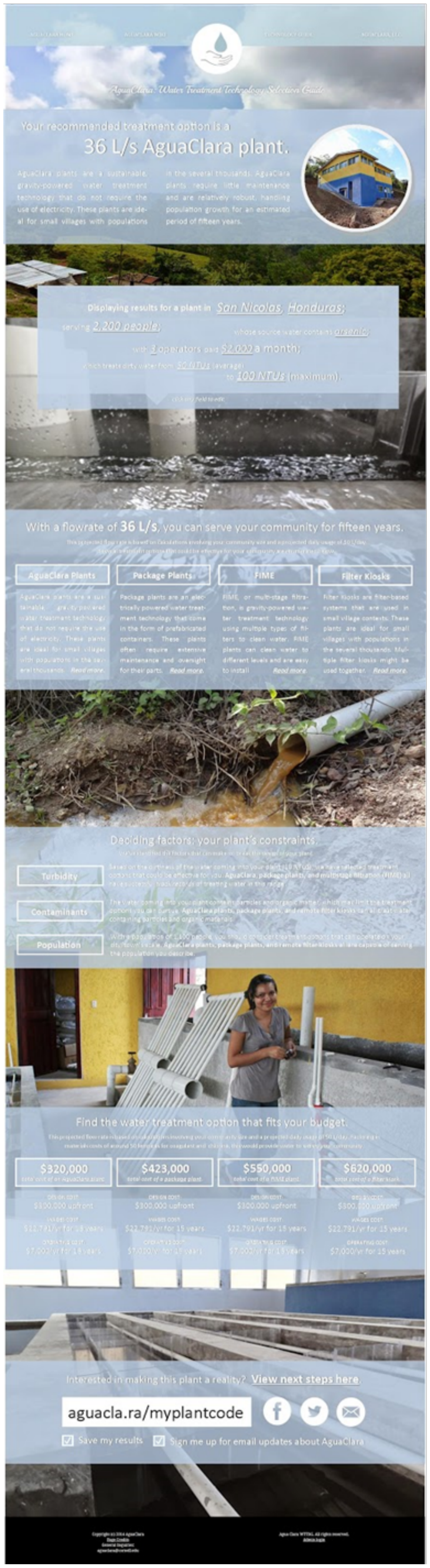


Figure 1: Low-fidelity prototype version of results page.

Next, the team worked to translate the low-fidelity version of the results page into a high-fidelity model, featuring more complete content and visually consistent with the rest of the WTTSG tool. This high-fidelity prototype was developed in Microsoft Publisher, using basic autoshapes and images taken from the AguaClara Picasa. This design features an overall recommendation at the top of the page, accompanied by a brief description of that technology. Next, the user’s inputs are displayed so that any previously completed field may be updated. A brief explanation of the target flow rate of the plant is provided, with a summary of the considered treatment options. These short summaries feature hyperlinks encouraging the user to read more if they are curious. “Dealbreakers” are discussed next--factors that could prevent a certain treatment option from being appropriate. These are subdivided into categories of population, turbidity, and contaminants (e.g. arsenic). A plant cost estimate is provided next, with a detailed breakdown of figures based on design, wages, and operating cost.

Multiple screens were created (Figure 2), so that an interactive version of the site could be implemented in InVision, a web prototyping tool. The screens were imported into InVision and then linked with clickable hotspots, so a user testing the site can navigate it as though certain fields are clickable. In particular, the wireframes explored the use of the mechanism dedicated to tweaking previously input fields to generate a new recommendation. The completed prototype can be found here: http://invis.io/UH29ZLSXB

Once the wireframes were fully implemented in InVision, some preliminary user testing was conducted. The results of this investigation are detailed more fully in the Analysis section.



Your recommended treatment option is a
36 L/s AguaClara plant.

AguaClara plants are a sustainable, gravity-powered water treatment technology that do not require the use of electricity. These plants are ideal for small villages with populations in the several thousands. AguaClara plants require little maintenance and are relatively robust, handling population growth for an estimated period of fifteen years.

Displaying results for a plant in San Nicolas, Honduras;
serving 2,200 people;
whose source water contains arsenic;
with 3 operators paid $2,000 a month;
which treats dirty water from 50 NTUs (average)
to 100 NTUs (maximum).

Click any field to edit.

With a flowrate of **36 L/s**, you can serve your community for fifteen years.

This projected flow rate is based on calculations involving your community size and a projected daily usage of 50 L/day.
Below are [illegible] options that could be effective for your community [illegible]

AguaClara Plants

AguaClara plants are a sustainable, gravity-powered water treatment technology that do not require the use of electricity. These plants are ideal for small villages with populations in the several thousands. *Read more.*

Package Plants

Package plants are an electrically powered water treatment technology that come in the form of prefabricated containers. These plants often require extensive maintenance and oversight for their parts. *Read more.*

FIME

FIME, or multi-stage filtration, is gravity-powered water treatment technology using multiple types of filters to clean water. FIME plants can clean water to different levels and are easy to install. *Read more.*

Filter Kiosks

Filter Kiosks are filter-based systems that are used in small village contexts. These plants are ideal for small villages with populations in the several thousands. Multiple filter kiosks might be used together. *Read more.*

Deciding factors: your plant's constraints.

We've identified the factors that [illegible] the [illegible] of your plant.

Turbidity

Based on the dirtiness of the water coming into your plant (10 NTUs), we have selected treatment options that could be effective for you. **AguaClara, package plants, and multistage filtration (FIME)** all have successful track records of treating water in this range.

Contaminants

The water coming into your plant contains particles and organic matter, which may limit the treatment options you can pursue. **AguaClara plants, package plants, and remote filter kiosks** can all treat water containing particles and organic materials.

Population

With a population of 1,100 people, you should consider treatment options that can operate on your city/town's scale. **AguaClara plants, package plants, and remote filter kiosks** all are capable of serving the population you describe.

Find the water treatment option that fits your budget.

This projected flow rate is based on calculations involving your community size and a projected daily usage of 50 L/day. Factoring in materials costs of around 50 lempiras for coagulant and chlorine, this would provide water to [illegible] community.

$320,000 total cost of an AguaClara plant	**$423,000** total cost of a package plant	**$550,000** total cost of a FIME plant	**$620,000** total cost of a filter kiosk
DESIGN COST $300,000 upfront	DESIGN COST $300,000 upfront	DESIGN COST $300,000 upfront	DESIGN COST $300,000 upfront
WAGES COST $22,791/yr for 15 years	WAGES COST $22,791/yr for 15 years	WAGES COST $22,791/yr for 15 years	WAGES COST $22,791/yr for 15 years
OPERATING COST $7,000/yr for 15 years	OPERATING COST $7,000/yr for 15 years	OPERATING COST $7,000/yr for 15 years	OPERATING COST $7,000/yr for 15 years

Interested in making this plant a reality? **View next steps here.**

aguacla.ra/myplantcode

☑ Save my results ☑ Sign me up for email updates about AguaClara

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Page Credits
General Inquiries:
aguaclara@cornell.edu

Agua Clara WTTSG. All rights reserved.
Admin login

Figure 2: High-fidelity wireframes of the website's results page.

With preliminary design work for the results page completed, it became apparent that the team would need to delve more extensively into available treatment options and their defining characteristics In order to present “dealbreakers,” for example, the turbidities, populations, and contaminants appropriate for each option must be rigorously defined. The team must also be more vigilant about collecting citations, so that any claims made within the context of the tool can be substantiated. This has been a weak point of previous semesters. The team has created a Google Spreadsheet that they will use to amass citations and other necessary information pertaining to each treatment option. In coming weeks, the team will continue to gather data and organize it for eventual integration within the site.

Initial Web Development Work

The team has continued work begun in previous semesters in expanding the features and functionality of the site. To facilitate the implementation process, the team is using a public Bitbucket Git repository for version control. This provides a backup of previous versions of the site and allows both team members to easily work on the same set of files. The repository is made public in the spirit of open-source engineering. (Future team members may request administrator permissions to the repository from Sarah Sinclair or Andrew Mullen.)

The data-passing functionality of the site was improved, with the left and right navigation arrows from each page turned into submission buttons. This allowed data to be passed from page to page, even if the user is traversing the site backwards. All inputs were saved in session variables, prepared for later storage in a MySQL database. The team also built out the site’s capacity to pre-populate previously selected inputs, maintaining selections of turbidity samples and checkboxes from page to page.

Attention was also paid to cosmetic matters. First, the left and right navigation arrows were given a consistent placement from page to page, drastically improving the look of the site and bettering user experience. Various features of the site were tweaked to increase legibility and make the design more aesthetically appealing--for example, certain margin sizes were increased. Other features were retooled for better cross-browser compatibility, including the range slider. Also, the decision was made to load smaller versions of images within the site, rather than the full-size versions that had been loaded previously. This will work to prevent unnecessarily slow loading.

Configuring the Server

With the help of Cameron Wilikens, the WTTSG team obtained access to a new server, which was unaffected by the permissions problems that had plagued the beta server in previous semesters. On the new server, a MySQL database “wttsg” was created using the .sql files created by the previous team. The MySQL database was configured for remote access, adding a new user, ROOT, with permission to interact with the database from the server’s IP address. Next, a configuration file was created for the webpage, giving it the necessary credentials to access the MySQL database. (Future team members can request necessary passwords from Sarah Sinclair, Andrew Mullen, or Cameron Wilikens.

In order to upload files to the web, team members can follow this simple protocol. First, they should connect to the Cornell VPN (virtual private network) at cuvpn.cuvpn.cornell.edu, connecting with username <insert netid here>@cee.ceevpn and their normal netid password. Those who do not already have access to the CEE VPN can email Cameron (cw2@cornell.edu) to be added to the private pool able to access the server. Next, using (Microsoft's) Remote Desktop Connection, connect to aguaclaraserver.cee.cornell.edu; under options > local resources > more, select OS (C:). The team recommends granting the remote connection access to the local hard drive, which will enable the simple transfer of files between a local machine and the server. Simply accept the settings and click connect, and a remote desktop connection will be opened. Files can be dragged and dropped from the local machine to the server, and should be placed in the C:\inetpub\wwwroot directory to be pushed live onto the web. Within this directory, supplementary files are included in folders named assets, css, js, and required, which contain images, stylesheets, JavaScript, and necessary files, including the database configuration file and files featuring arrays of countries. This organization is consistent with that of the WTTSG bitbucket repository.

Finally, a page redirect was added so that aguaclaraserver.cornell.edu would be rerouted to aguaclaraserver.cornell.edu/index.php, the first page of the WTTSG tool. Without this file, called iisstart.php, aguaclaraserver.cornell.edu displays (incorrectly) an empty page.

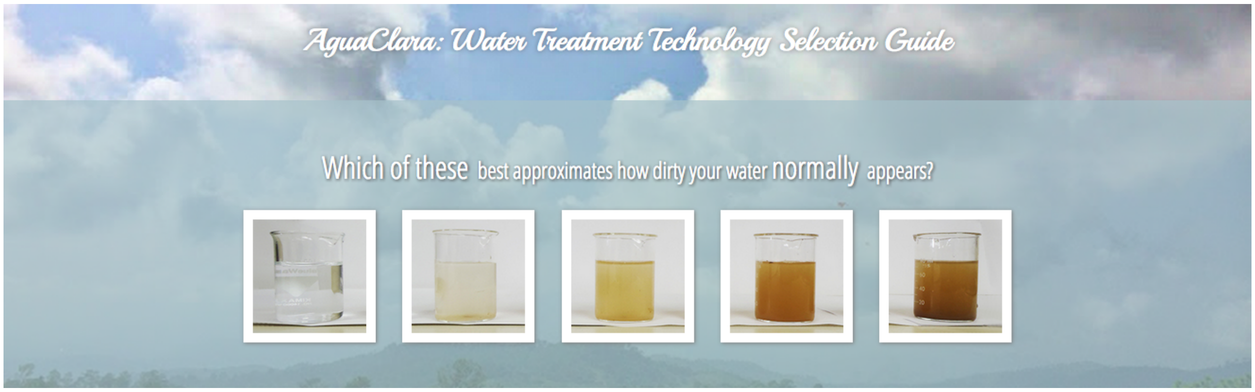
Regression

According to the work of the Fall 2014 WTTSG team, the best-fit regression equation that relates cost and flow rate is a power curve of the form $C = \alpha f^{\beta}$, where C is cost per flow rate, f is flow rate, and α, β are constants. Using the most current data available, these constants are α= 61077 and β=-0.599. However, as AguaClara technologies continue to evolve, these regression constants will most likely change. To accommodate this continued progress, the team has implemented a function to find the power regression of two arrays. This complicated problem can be broken down quite simply into a much easier to solve least squares regression; to solve this problem, simply take the least squares regression of $log(C)$ and $log(f)$.

The next step for this regression equation is to pull the recorded *C*s and *f*s from the database so that if the database is updated, the regression equation will reflect the contents of the database. However, from a perspective of computational expense, it does not make sense to force the server to re-perform the regression equation every time the site is loaded if the database hasn't been updated. Therefore, the team decided to store α and β in the database, and only perform the regression when the database is updated.

Turbidity Pictures

Previous versions of the WTTSG utilize stock images of various turbidity samples for the parts of the tool requiring users to gauge the dirtiness of their water. Below is a webpage featuring the old turbidity pictures (Figure 3):

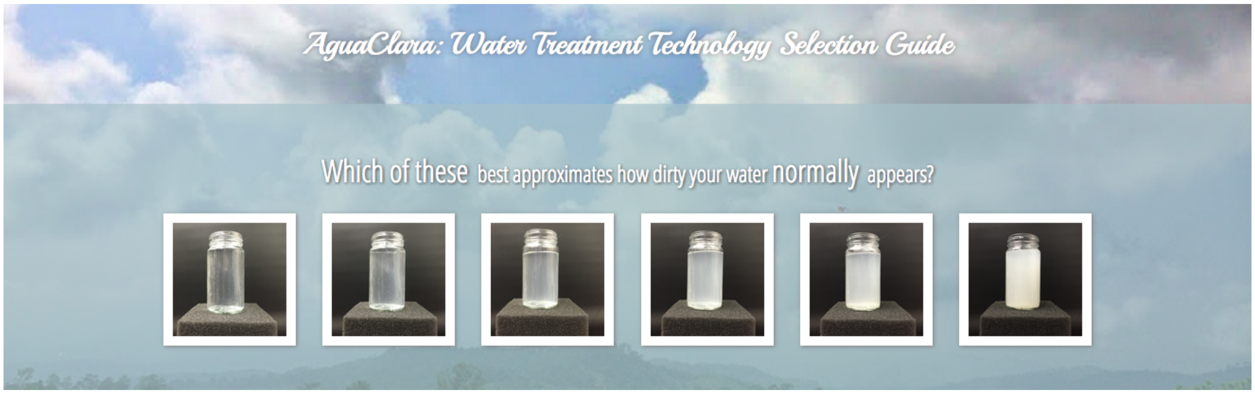


AguaClara: Water Treatment Technology Selection Guide

Which of these best approximates how dirty your water normally appears?

Figure 3: Turbidity pictures from left to right: 0NTU, 25NTU, 50NTU, 250NTU, 500NTU

However, the current subteam was concerned that these images do not represent an appropriate range of values for making recommendation decisions based on turbidity. For example, it does not seem prudent to have an option of 0 NTU, and the gap between 50 NTU and 250 NTU is too extreme. To resolve this problem, the team took its own photographs of water representing a more appropriate range of values, which would feature visually distinctive increments. Below is the same page updated with these new images (Figure 4):



AguaClara: Water Treatment Technology Selection Guide

Which of these best approximates how dirty your water normally appears?

Figure 4: Turbidity pictures from left to right: 15 NTU, 30 NTU, 60 NTU, 100 NTU, 200 NTU, 500 NTU

The team must consider whether it is productive to perform some post-processing to increase the clarity of the images. Some preliminary editing was done, in which the team decreased the processed images' size so that large images are not sent only to be downscaled client-side.

Exchange Rate

To aid in the illusion that this website was created specifically for the user's region, the tool checks Yahoo Finance to access the conversion rate from USD (the unit used in all of the site's cost calculations) to the currency of the country that the user chose on the first page. Although it may not quite be accurate to say that the estimated cost of a plant is equal to the exchange rate times the price in USD, as goods and services may cost different amounts based on the availability of resources within the nation, the team believes that this is a good starting point. Given team members' limited knowledge of foreign exchange rates, the site is using the Fx (about midway between the Bid and Ask) while estimating costs. Small deviations in exchange rate are acceptable when estimating the cost.

Translation

The WTTSG subteam has increased the site's international usability by including a simple Google Translate plugin. This plugin shares the limitations of any online translator, but as Google increases the reliability and accuracy of its translations, the WTTSG web tool is sure to benefit from better quality translations over time. This functionality is also quite scalable--Google Translate currently provides translations for up to eighty languages, so individuals from all over the world are likely to find a translation to a language they speak.

Structure of Recommendation Data

In order to make the tool as scalable as possible, it is necessary to construct a back-end that can be updated frequently to accommodate any changes in information that would affect the recommendation. For example, the team may want to add a new treatment option to the tool, or to update parameters like the maximum turbidity a certain technology can handle. If all of the recommendation logic is expressed solely through PHP code, updating technologies and critical parameters alike will be very difficult. Consequently, the team has resolved to keep critical values for all technologies in a SQL database.

Queries to the database can be used to select from any number of potential treatment options as new technologies are added to the database, and all conditional logic can be expressed in terms of database query results. Thus, without changing the PHP code, the recommendations provided will change; this is a very important consideration, especially if future administrators of the tool are not familiar with PHP. With this structure, updating information (an act the team predicts may be frequent, given perceived current comfort levels regarding the data the team has obtained) will be far simpler and will not require changing any actual code. To begin this process of implementing scalable recommendations, the team has created a new SQL table and populated it with the fields currently being used in the provision of recommendations. Interactions with this table are described below. The team implemented a function that, given a fully completed form, lists the possible treatment options that are capable of treating the input water, and why all of the other options are incapable of treating that water.

Additional Question Pages

As the team solicits inputs from AguaClara stakeholders and other content experts, more and more necessary questions for the tool are being identified. (So, too, have additional outputs been suggested, such as providing users with an estimate of the total amount of land area their plant is expected to occupy.) By the request of team members both in Cornell and afield in Honduras and India, the following pages were added to the tool.

First, understanding the differences in treatment options between Honduras and India, the team realized it would be necessary to know what type of source water a community was dealing with. This considerably influences the kinds of technologies possible to implement in that region, as well as if additional technologies like solar-powered pumps will be necessary. Thus, a page was added to determine if a plant would treat surface or groundwater (Figure 5).

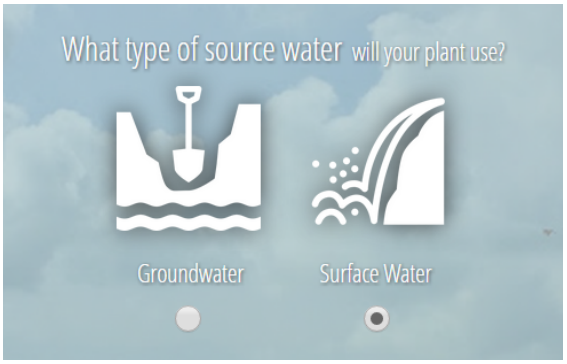


Figure 5: Types of water sources--groundwater and surface water. Radio buttons ensure only one of the two types of water sources can be selected at a time.

Next, as suggested by Walker Grimshaw, an AguaClara alumnus working for APP, the team added a page to capture whether the location in question already has a distribution system in place. Walker's suggested values were *Yes; No, but funds have been obtained for one;* and *No.* The team chose to directly port these questions into the site. As with the water source type page, these options were indicated with radio buttons, forcing the user to select exactly one answer.

For both new pages, the webtool's session variable was updated to log this input, data was saved when being passed both forwards and backwards, and default values were initiated on each page depending on the content saved in the session variable. This ensures that any data the user inputs are saved to be inserted in the userdata MySQL database, and that inputs are remembered from page to page for the duration of a user's browser session.

Administrator Page

As detailed previously in the report, many key functionalities of the WTTSG are implemented using SQL databases to allow for easy editing and scalability of the site. This meant that the team needed to allow an AguaClara administrator who does not know SQL to edit data in the databases.

- **Administrator Login.** In order to edit the WTTSG databases, first, the administrator must log in. The page for the administrator login was designed last semester (Figure 6a), so all that was left was to finish configuring the database for logging in as the administrator. In this implementation, the site takes a user's password and prepends a "salt," a short random string. Next a hash is taken of the "salted" password. A hash function applied to any object that has a binary representation (like the binary form of a string) finds an arbitrary string representation. The reason that hash functions are used for securing passwords is that, even if someone was able to read the hash of a password from the database, it is very hard to find the original password from this information.

  In fact, the only known way to crack a hash is to construct a hash dictionary, created by applying hash functions to every possible password. Hackers then enter the contents of these dictionaries as passwords to find login credentials. This can be easily prevented, however, by prepending a random string of several characters (the previously mentioned "salt") before taking the hash of the password. Thus, even if the user has a password that would be easily breakable from a dictionary attack, the effective password is much longer and more random, and therefore much more time intensive to crack.

- **Administrator Navigation.** Once the administrator is logged in, they need a way to navigate through their administrative options. The team implemented a basic navigation bar for choosing which table to view (Figure 6b). This navigation breaks from the basic visual theme of the rest of the site to allow for more readable text at smaller sizes.

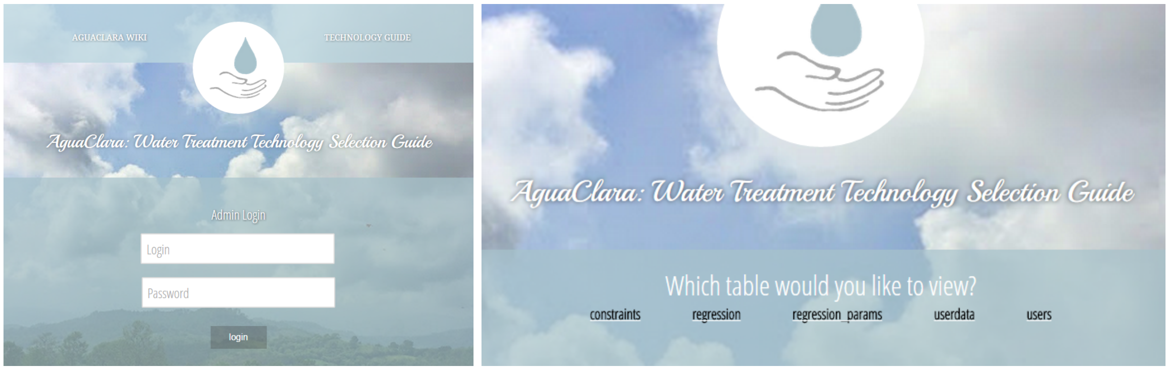
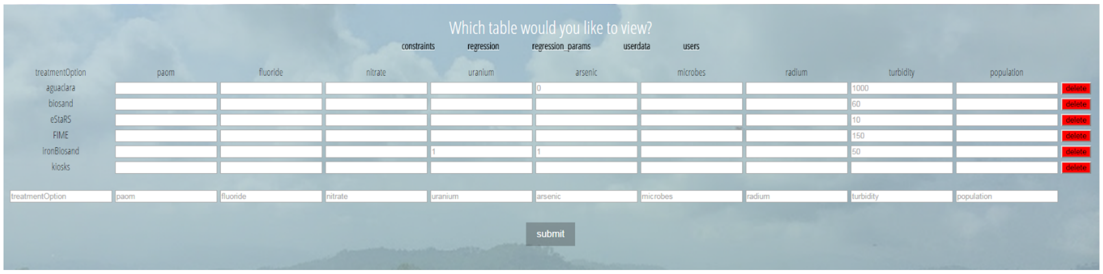

AGUACLARA WIKI
TECHNOLOGY GUIDE
AguaClara: Water Treatment Technology Selection Guide
Admin Login
Login
Password
login
AguaClara: Water Treatment Technology Selection Guide
Which table would you like to view?
constraints
regression
regression_params
userdata
users

Figure 6a (left) and 6b (right): Admin Login General Table Navigation: Once an administrator has logged in (left), they may view several options for viewing and editing tables(right).

- **Constraints Table.** Viewing the "constraints" table brings up the page pictured below (Figure 7). Each field, except for the name of the treatment option (the primary key of the table), is displayed as an editable field, with the current value in the database as placeholder text. There is also an extra row at the bottom of the page, with column names entered as placeholder text; this enables the adding of new technologies to the database.

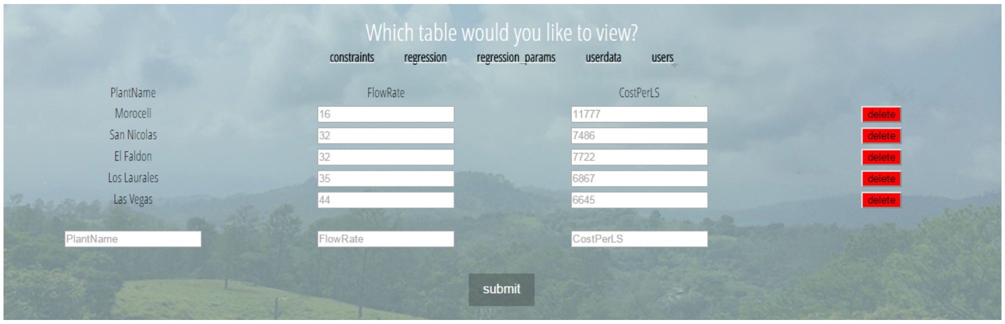
The delete buttons on the right hand side will remove all information about a technology from the database, and it will therefore no longer be recommended. The delete buttons break from the overall theme of the site to attract the user’s attention to an otherwise often overlooked part of a website. The color also represents the importance of the button, unlike every other button and option on the site, a deletion cannot be undone without going into the database log (manually or through phpMyAdmin) and restoring the table state from before the DELETE query was run. Note that the treatment options are not editable fields. This is a consequence of the setup of the SQL database. To rename a treatment option, an administrator can add a new treatment option with the new name, and then delete the old treatment option.



treatmentOption	paom	fluoride	nitrate	uranium	arsenic	microbes	radium	turbidity	population	
aguaclara					0			1000		delete
biosand								60		delete
eStaRS								10		delete
FIME								150		delete
ironBiosand				1	1			50		delete
kiosks										delete
treatmentOption	paom	fluoride	nitrate	uranium	arsenic	microbes	radium	turbidity	population	

Figure 7: Editing the Constraints Table

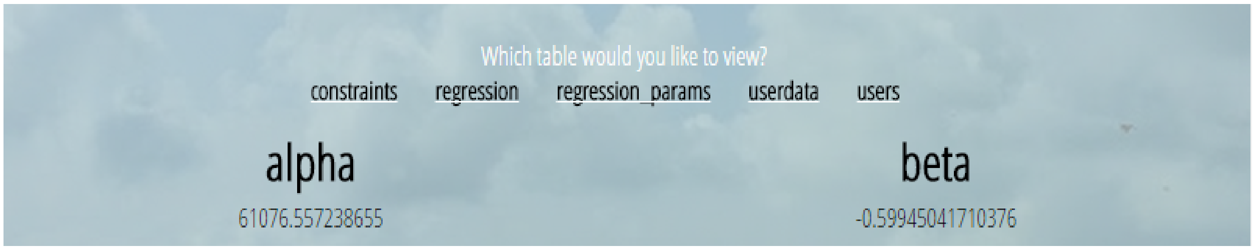
- **The Regression Table.** Viewing the regression table brings up the page pictured below (Figure 8). Each field, except for the name of the plant location (the primary key of the table), is displayed as an editable field, with the current value in the database as placeholder text. There is an extra row at the bottom, with the column names entered as placeholder text, to allow adding data for new plants. On submission, not only is the value updated in the regression table, but the entire regression is done to find the α and β values for the regression equation, as explained in regression section above. This way the regression is re-calculated when the database is updated by an administrator. As explained more in the previous section, the delete buttons on the right hand side will remove all information about a location and their plant cost data from the database, and it will therefore no longer influence the regression parameters or the estimation AguaClara plant cost.


Which table would you like to view?

PlantName	FlowRate	CostPerLS	
Moroceli	16	11777	delete
San Nicolas	32	7486	delete
El Faldon	32	7722	delete
Los Laurales	35	6867	delete
Las Vegas	44	6645	delete
PlantName	FlowRate	CostPerLS	

Figure 8: Editing the gathered AguaClara plant costs for AguaClara cost estimation.

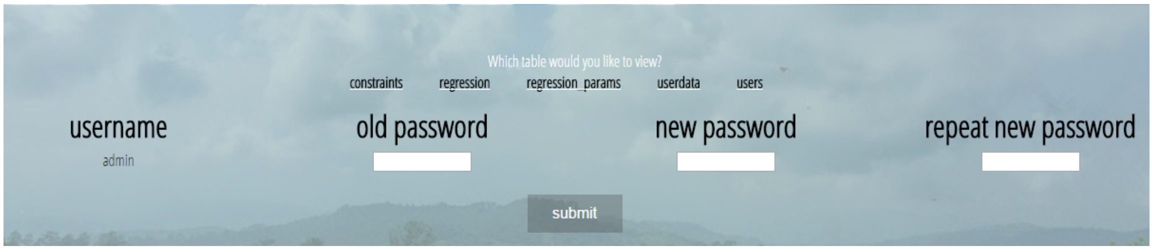
- **The Regression Parameters.** In case a future administrator wishes to view the regression parameters, the regression_params table contains the α and β values. It would not make sense to edit these directly, so they are only viewable (Figure 9). Instead, they are editable by updating the regression information. They are used in the estimation of the cost of an AguaClara plant as discussed above.


Which table would you like to view?

alpha	beta
61076.557238655	-0.59945041710376

Figure 9: Viewing the regression parameters. Note the lack of editable text fields.

- **The Users Table.** To allow the administrator to change their account's password, the team implemented an editable users table (Figure 10). For increased security, the page requires re-entry of the current password, as well as two versions of the new password, to proceed. If the two new passwords don't match, or if the old password is entered incorrectly, the password is not updated, and an error is shown to the user. If the old password is correct and the two new passwords match, then a new salt is randomly generated, and the salt and the hash of the new salted password is stored in the users table in the database. For more of a discussion of security and salts, see admin login above.



username
admin

old password

new password

repeat new password

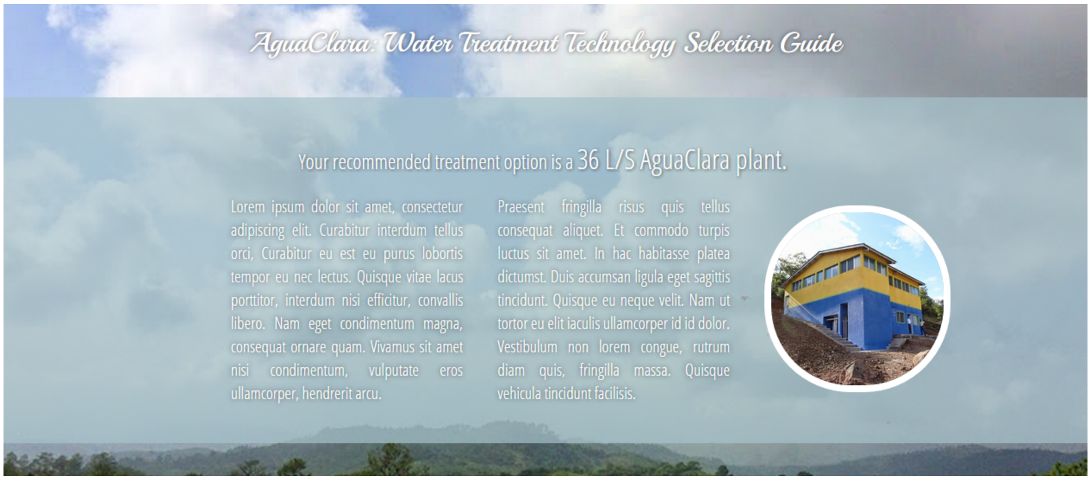
Figure 10: Editing the Administrator Password

- **The User Data Table.** The user data is represented by a very wide matrix, so working with it in Excel or some other spreadsheet editor may make the data more consumable for review . Therefore the team linked to a page that initiates a download of the user data in csv format.
- **Admin Logout.** Finally, the logout was made functional, so that when the administrator is logged in, the logout option in the footer logs out the administrator and returns the user to the admin login page.

Results Page Implementation

The results page was built out over the course of the semester, with components from the previous wireframe design translated into PHP and CSS. To reflect the larger size of the results page, as well as to keep the site visually interesting, background images for the page were compiled into a single photo, which is dynamically added to the site via JavaScript.

With progress still being made in amassing information to quantify the tool's recommendations, the actual control logic of the results page has not yet been implemented. Still, the foundation has been set for logical parameters to be saved in the database and used to conditionally display recommendations. The text of these recommendations can similarly be stored in the database and presented within the HTML/CSS skeleton (Figure 11) currently set forth in the code.



AguaClara: Water Treatment Technology Selection Guide

Your recommended treatment option is a 36 L/S AguaClara plant.

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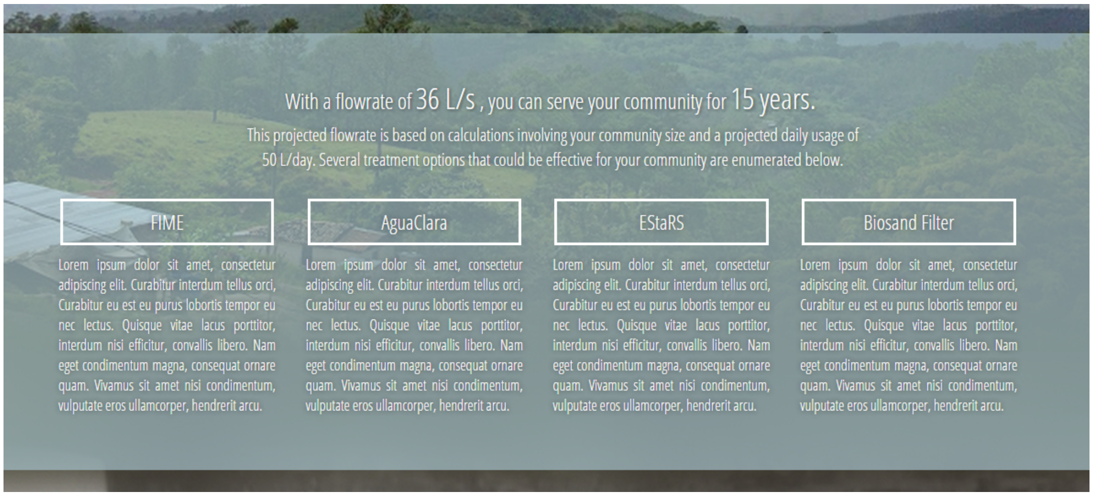

With a flowrate of 36 L/s , you can serve your community for 15 years.

This projected flowrate is based on calculations involving your community size and a projected daily usage of 50 L/day. Several treatment options that could be effective for your community are enumerated below.

FIME

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AguaClara

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Biosand Filter

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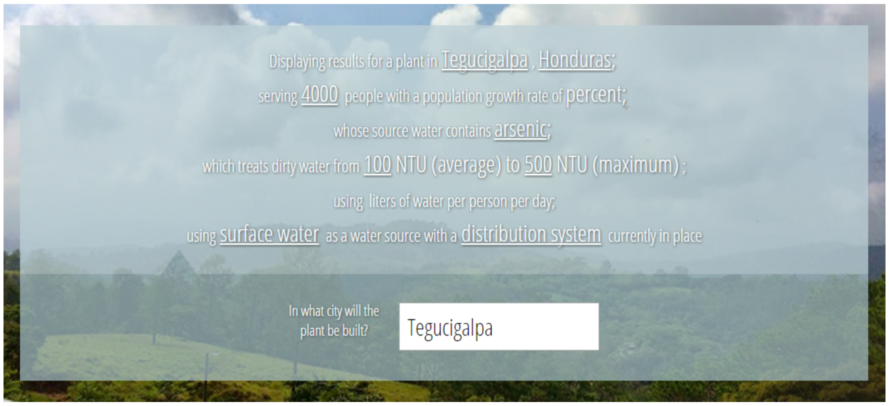
Figure 11: Example of placeholder text in the site. The layout is finalized, while the content may easily be swapped in once more data is collected..

The WTTSG's result page is intended to support users' ability to easily tweak their inputs on the fly and consequently see how various changes in input parameters affect their final recommendation. To enable this functionality, the team has engaged in the implementation of a toggle menu that allows users to review all of the inputs they have entered thus far and revise them accordingly. However, several specific challenges were encountered in this implementation, because the values of the user's previously input answers are saved within a PHP $_SESSION variable while the dropdown functionality of the toggle tool is implemented using JavaScript. PHP is a server-side language, while JavaScript is a client-side language, meaning that is nontrivial to pass information from one language to the other. Indeed, in order to translate the values in the $_SESSION variable into a form where they were usable in JavaScript requires the use of AJAX, or Asynchronous JavaScript and XML, a technique for asynchronously retrieving information from a server.

Once the session variable has been passed through to the JavaScript portions of the results page, the toggle tool is controlled by a variety of event handlers, which are triggered as various parts of the toggle are selected (Figure 12). Each piece of editable input is assigned a unique ID which allows the site to detect which of the available inputs was the one selected. Users may click between multiple fields to see their respective editable fields, or click a single field multiple times in a row to open and close the menu. The menu grows and shrinks as it dynamically adds and deleted page content.

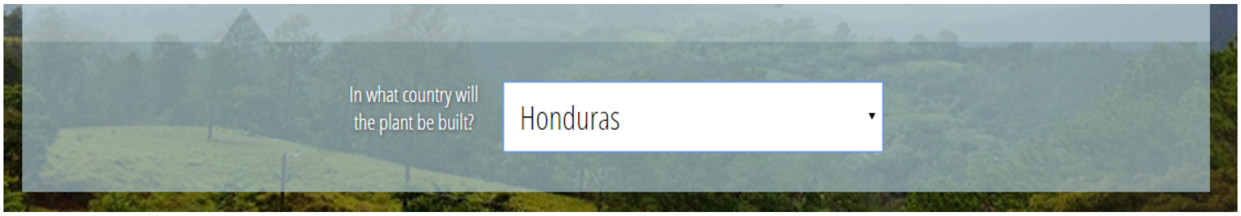


Displaying results for a plant in Tegucigalpa , Honduras;
serving 4000 people with a population growth rate of percent;
whose source water contains arsenic;
which treats dirty water from 100 NTU (average) to 500 NTU (maximum) ;
using liters of water per person per day;
using surface water as a water source with a distribution system currently in place

In what city will the plant be built? Tegucigalpa

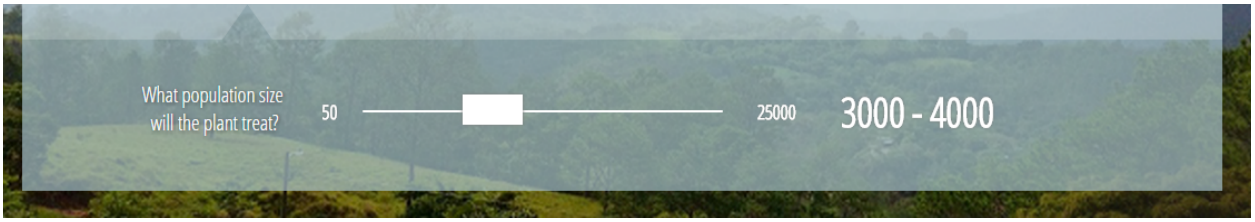
Figure 12: Menu for Updating User Inputs. Selecting an underlined term allows its value to be edited. The editable field shown here is a free text input. The contents of the box are sanitized and have tags stripped before they are saved into SESSION variables once more.

Since the user needs to be able to edit all inputs of the tool in their various types, the team decided to maintain the same interfaces here that were used in previous pages of the tool. Stylistically, this was also intended to ensure that operation of the tool is as seamless as can be, taking advantage of known mechanisms. As detailed in Figure 13, in addition to the editable textbox of Figure 12, this included the addition of a country dropdown menu (13a), a population range slider (13b), contaminant checkboxes (13c), selectable turbidity pictures (13d), and a list of radio buttons (13e). The implementation of each of these functionalities required translating the forms from the PHP of the index page into JavaScript, so content can be controlled dynamically.



In what country will the plant be built? Honduras

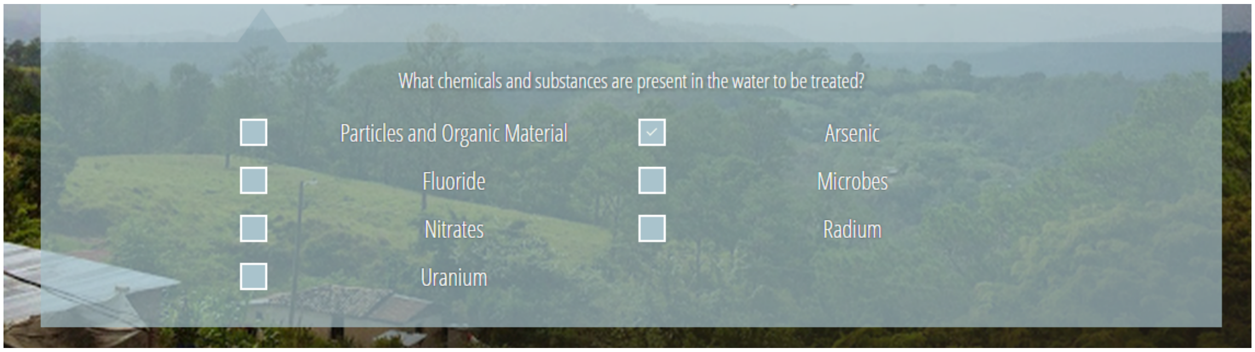
Figure 13a: Detail shot of country selection (dropdown menu).



What population size will the plant treat?

3000 - 4000

Figure 13b: Detail shot of population selection.


What chemicals and substances are present in the water to be treated?

□ Particles and Organic Material
□ Fluoride
□ Nitrates
□ Uranium
☑ Arsenic
□ Microbes
□ Radium

Figure 13c: Options used to change the list of contaminants present in the water.

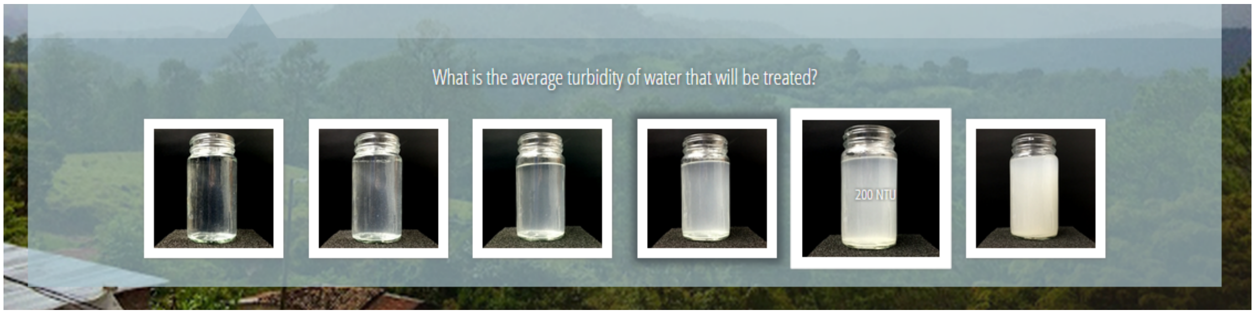
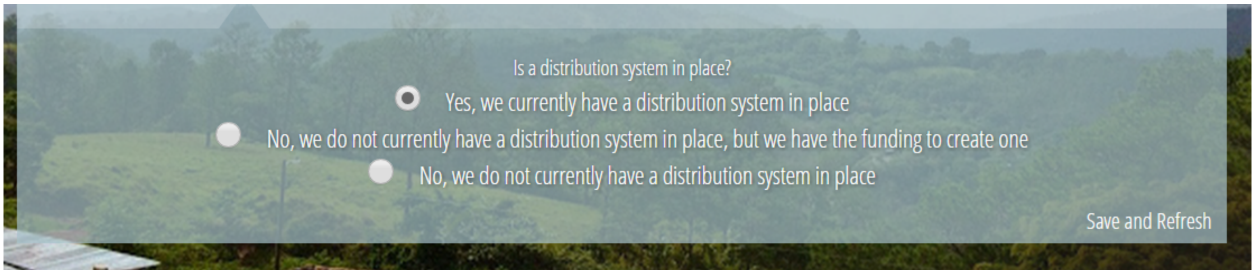

What is the average turbidity of water that will be treated?

Figure 13d: This figure is a detail shot demonstrating turbidity selection from the site toggle tool.


Is a distribution system in place?

● Yes, we currently have a distribution system in place
○ No, we do not currently have a distribution system in place, but we have the funding to create one
○ No, we do not currently have a distribution system in place

Figure 13e: This figure shows various options expressing the state of the user's distribution system.

A "Save and Refresh" button was added (Figure 13e, above) to each of these dropdowns which saves the current contents of the form to the SESSION variables and refreshes the page to provide a new recommendation. Furthermore, to provide a cohesive user experience, the user's scroll position is maintained upon refresh. This allows them to quickly toggle another field as well. The WTTSG team is optimistic that this toggle tool will allow users to better understand the factors that determine a plant recommendation by being able to play around with these values themselves.

Finally, the WTTSG ultimately hopes to produce a recommendation that a user can share with others, providing a unique way to return to the recommendation page for further review and consideration. Thus, the team has begun the implementation of a small sharing widget, placed at the bottom of the results page, which will allow users to share their recommendation through email or social media. These functionalities, as well as url-shortening service and the capacity to recall a user’s complete inputs based solely on their url, should continue to be developed in later semesters. Though the functionalities of this tool are forthcoming, the team has begun the implementation of its design, providing a framework for future work.

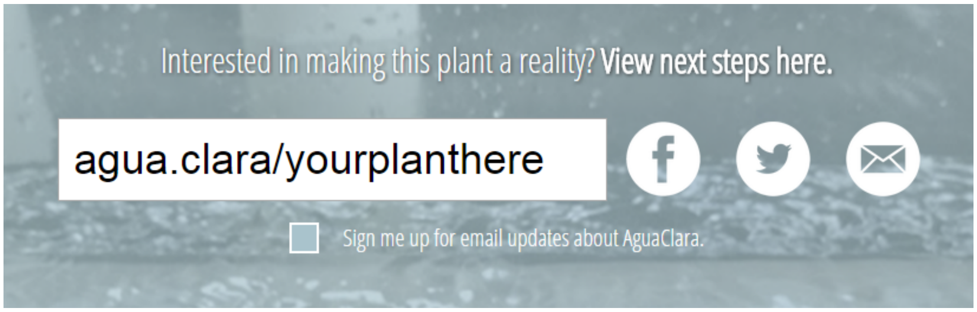

Interested in making this plant a reality? View next steps here.
agua.clara/yourplanthere
□ Sign me up for email updates about AguaClara.

Figure 14: Design of a tool to help users save and share their plant details, and to gain more information about AguaClara by signing up for email updates

Analysis

User testing was performed using the wireframes, harnessing the interactive power of InVision. Substantial feedback was collected from Drew Hart, an AguaClara engineer, about potential cultural barriers, the presented treatment options, and the layout and feel of the site. Drew alerted the team that disclosing financial information is taboo in Honduras, and that providing a default value for operator wages could inspire negative reactions in users. It is far better to allow organizations seeking plants, who will have firm conceptualizations of appropriate salaries, to input this feature into the WTTSG. Drew also advocated for removing the “number of operators” field from the tool, to discourage users from inputting “1” or “0” in an attempt to save costs. Instead, he suggested incorporating number of operators as a component of the the final recommendation. He also recommended that the population slider be scaled up to include inputs of at least 25,000, up from a previous maximum of 7,000.

Conclusions

The team has made significant progress in both the web development and the design of the Water Treatment Technology Selection Guide. Thanks to progress in web development, information is correctly passed between pages and automatically filled into previously updated fields, so that users can revisit pages without having to reenter information. The team has worked to increase consistency in layout between pages and across different web browsers, and has integrated Google Translate’s translation services into the site. The flow rate vs. cost regression equation has been implemented in code, allowing for a programmatic estimation of plant cost dependent on parameters stored within a database.

Additional content pages were integrated into the WTTSG, making new parameters available to the future recommendation algorithm. The administrator pages now represent a simplified way to interact with database contents, and the results page continues to be fleshed out with features like a toggle for updating user inputs. The server has been configured to enable the use of MySQL databases, and the site has been deployed live.

In terms of design progress, the team brainstormed the layout and functionality of the results page, creating wireframes in order to user-test and refine it before full implementation. Reception to this part of the tool was positive, and the design was implemented in HTML, PHP, and CSS.

Future Work

The team must continue to perform an extensive literature review, amassing the data that will be used to support recommendations made by the WTTSG tool. Through the collection and curation of hyperlinks and external references, the team can validate the legitimacy of the claims made by the site. The team will create and populate tables in the database with the regression logic, so that whenever new technologies emerge, or when new research finds new information on these technologies, to update the website, one must only update the database.

Population growth is an important factor that helps to determine the flow rate of a plant. However, prospective users of the WTTSG may not have the projected population growth rate for their region readily available. Users who feel ill-equipped to provide a growth rate may be discouraged from using the tool, so a thoughtful default value should be provided. The team plans to fetch the projected population growth rate of the country input by the user in order to prepopulate this field of the WTTSG. In case the user has more specific knowledge about the population growth rate of their region, this field will be made editable. Efforts have already been taken to ensure any default value in these fields is saved to the session variables upon page submission.

At many points throughout the development process, the team should reach out to stakeholders, engineers, project team members, and individuals with various cultural backgrounds to test the WTTSG and its components. It is particularly important to ensure that the tool will perform well across different cultures and regions. The team plans to specifically target users connected to India and Honduras, due to current AguaClara presence in these countries. Further user testing, especially of users in these target regions, is essential to ensure that all of the design decisions that we have made work across cultures. This will also lend tremendous insight as to the intuitiveness, usefulness, and efficacy of the tool.

Since the potential users of the WTTSG speak many different languages, the team has integrated Google Translate functionality into the tool. To ensure a high-quality translation is provided in AguaClara's four most important languages (English, Spanish, Tamil, and Hindi), the team plans to ask AguaClara team members or partners to help translate website content. The team should develop an infrastructure that will allow for the easy addition of more human-translated languages.

Along with list of plants that are capable of treating the input water, the team hopes to suggest the possible treatment types in order of increasing cost. The team also hopes to include explanations of how treatment types differ, as well as to explain why some treatment types would be incapable of treating the water, as well as why some water treatment types are less reliable in general.

Future work will need to include ensuring that the site works across platforms and every page adheres proper HTML by ensuring that the website validates with a service such as W3C's.

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