Cornell University College of Engineering

AguaClara

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Download Design Tool & More aguaclara.cee.cornell.edu

The AguaClara Process

The AguaClara Program was launched in 2005 as a collaborative venture between Cornell University and Agua Para el Pueblo, a non-governmental organization (NGO) in Honduras. On a global level, AguaClara provides a novel, scalable approach to infrastructure design, integrating education, innovation and invention with sustainable implementation and empowerment. Partners include multiple non-governmental organizations, towns with AguaClara facilities, donor organizations, Cornell students, and Cornell University. Together these partners are working to create a lasting solution to the problem of how to provide safe drinking water to the estimated 884 million people who lack access to this most basic of life's necessities.

Background: The Purpose of Water Treatment

In 1854, English physician John Snow halted a deadly outbreak of cholera by simply removing the handle from the water pump of the affected London neighborhood. In doing so, he proved that cholera, like many other diseases, is easily transmitted through water sources contaminated with what we now know to be microscopic organisms (bacteria and viruses). Denying the people of Broad Street access to the contaminated water was an effective way for Snow to stop the spread of Vibrio cholerae, but such drastic measures are usually not necessary today. Instead, water can be treated to remove the suspended bacteria before it is passed along to the general population. Though there are many different ways to build a water treatment plant, they all rely on the same general process:

The Water Treatment Process

1. Combine all of the suspended particles (including clay, dirt, and organisms such as bacteria) into larger bunches of particles. This process is called *flocculation* and uses a coagulant to bond the dissolved particles into *flocs*.

2. Allow the heavier, flocculated particles to settle out of the mixture. This process typical takes place in a *sedimentation tank* designed to

maximize the range of particle speeds & sizes it can capture.

3. Filter the water to remove any of the lighter flocs that escaped sedimentation.

4. Dose the water with chlorine to kill any remaining disease-spreading organisms.

The AguaClara Difference

Despite functioning on the same basic process, there are major differences in design between what is effective in the developed world and what is feasible in the Global South. Almost all of the plants in the developed world rely on large amounts of electricity to monitor and operate. However, in the developing world, access to a reliable source of electricity is both doubtful and prohibitively expensive. AguaClara plants use gravity instead of pumps, and mechanical devices instead of electrical monitors, to run the plant. Since the plants are designed to be constructed using almost exclusively locally-available materials and labor, AguaClara communities also avoid the risks of failure or shut-down that plague other projects dependent upon overseas expertise and supplies. Furthermore, up-to-date plant designs are freely -available and -customizable using the AguaClara Automated Design Tool, available for (free) download on the project website, aguaclara.cee.cornell.edu.

The next section of this document will explain the AguaClara process in detail: where our designs come from, how the Automated Design Tool works, how the plants in general work, and finally, what a community needs to do in order to construct an AguaClara plant.

AguaClara Designs

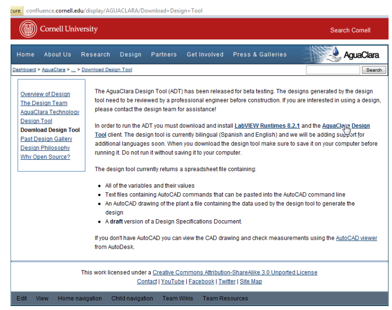
The market value of a small municipal-scale water treatment plant design is approximately $10,000; fully-customized AguaClara designs can be obtained for a few clicks of a button and a five-minute wait. This means that if an AguaClara server was running full-time, it could save nearly $3 million in a single day—striking even without including the construction and maintenance savings associated with the design. That said, AguaClara research teams innovate year-round to improve the designs' cost-effectiveness, ease-of-use, and efficiency. Once findings have been finalized, a research team can then work with the structural design team to evaluate the constructibility of a proposal and, finally, submit it for inclusion in the next release of the Automated Design Tool.

The Automated Design Tool

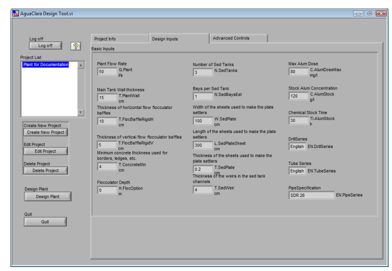
AguaClara's design tool is the lynch-pin of the program's scalability. Using the concept of design constraints as interrelated variables has allowed the automated program to replace many hours of human calculations and drafting with the few seconds it takes to run a script. Instead of repeating tasks, AguaClara team members can concentrate on research and improving the design tool itself.

Using the Design Tool

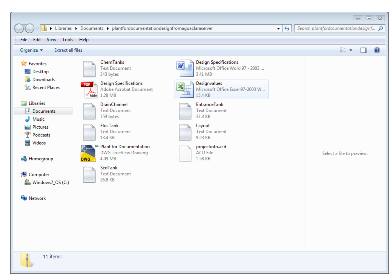
A simple LabVIEW program provides the front-end for the Automated Design Tool. Downloading this program lets an interested party change design inputs like flow rate and number of sedimentation tank bays to suit their constraints. Clicking "Design Plant" sends these variables to the AguaClara server, which has all of the necessary programs installed to create and email the design to the user. No specialized software besides updated LabVIEW runtimes and the free AutoCAD viewer are required to use the tool. The four steps are explained graphically to the right.



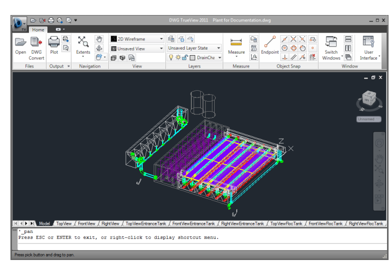
1. Downloading the Design Tool



2. Running the Design Tool



3. Unzipping the design files



4. Viewing the CAD design

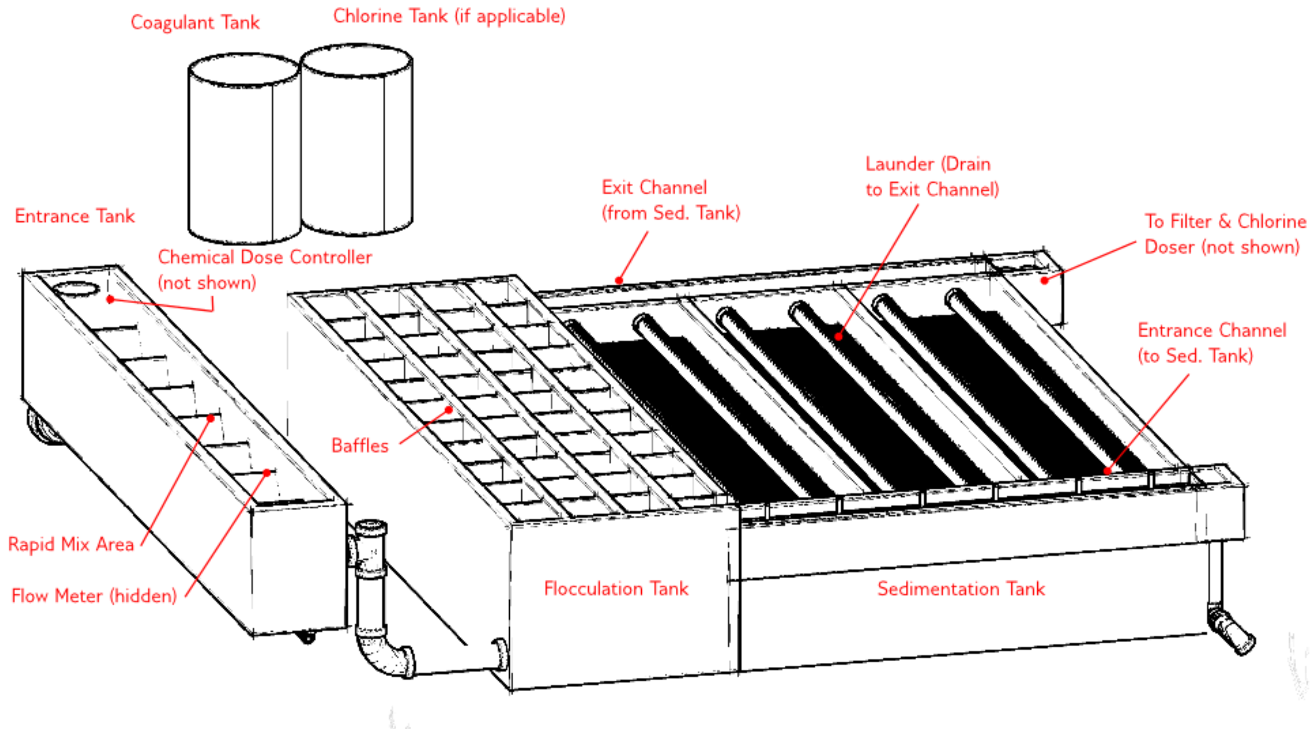
How the Design Tool Works

Once a design request has been submitted to the AguaClara server, LabVIEW uses ActiveX controls to input the user's design variables into MathCAD programs. These programs calculate design parameters that are used to populate AutoCAD scripts, which are then pasted into the AutoCAD command line to create the design. LabVIEW then creates a .ZIP file containing:

- the CAD drawing (.dwg),
- a spreadsheet of the design variables (.xls),
- text files (.txt) of the AutoCAD commands used for the design,
- two versions of the plant manual,
- a description of how the plant operates.

This file is then sent by email to the user's specified address. If after reviewing the design, the user decides to change some parameters (or needs to correct an error or request a different AutoCAD filetype), they can simply return to the design tool, where a list of all their previous designs and their settings have been saved.

How Water Flows Through the Plant



Coagulant Dosing

After the influent water supply has been prefiltered slightly to remove leaves and other debris, a coagulant, typically alum or poly-aluminum chloride (PAC), is added to initiate the flocculation process. There are two factors determining the rate at which coagulant is delivered to the influent water supply: (1) A higher turbity means that more particles are dissolved in the water, so a higher *concentration* of coagulant must be used in order to bond these particles into flocs. (2) If the water level changes, the *rate* at which the coagulant is added must be adjusted in order to ensure a constant ratio of coagulant solution to influent flow. The first factor (coagulant concentration) is controlled by the plant operator, but the second is automated.

This is done by establishing a linear relationship between plant flow rate and the water level in the entrance tank, which adjusts the height of a float connected to a lever arm. The end of the hose delivering coagulant is connected to the other end of this lever, so as the height of the float varies (linearly), the height of the hose varies proportionately. The tank containing the coagulant is above the end of the hose at constant pressure, so lowering the end increases the flow or coagulant and

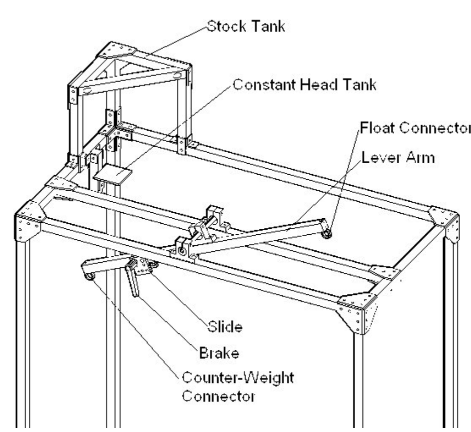


Diagram of Dose Controller

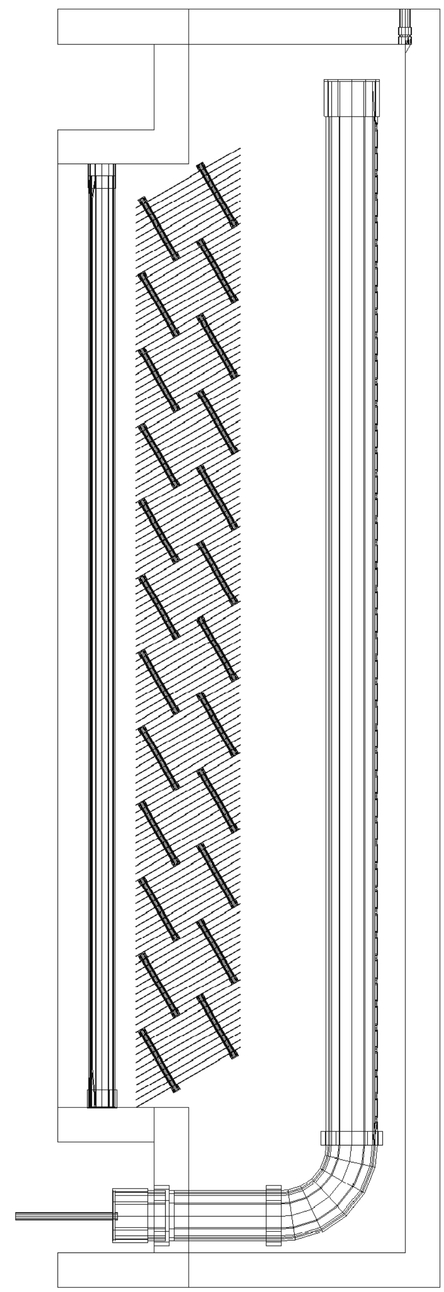
Turbity is measured in NTUs, or Nephalometric Turbity Units, which quanitify the degree of "cloudiness" in a water sample by measuring how much light is diffracted as it passes through the sample. The more light is diffracted, the more dissolved particles are present in the water. The EPA standard for drinking water turbidity in the US is 0.3 NTU.

raising the end decreases it. *In the end, a linear relationship between plant flow rate and the chemical dose is established.* The operator needs only to adjust the initial position of the coagulant orifice and it will respond automatically to changes in flow rate.

Flocculation

Once the coagulant has been thoroughly mixed into the influent water (e.g. the coagulant is distributed evenly throughout the solution), the sample passes into the flocculation tank, where it flows over a series of baffles. As the water flows alternately over and under the baffles, the 90° turns mix the various velocity gradients and cause collisions of the very positively-charged coagulant particles with the oppositely-charged particles in the water. Since there are many free positive charges on one alum or PAC molecule compared to the small charges on the pollutants, large flocs are formed around the coagulant. These flocs grow as the water flows through the flocculation tank and many more collisions occur.

Because heavier combinations of particles are slower-moving, they 'settle out' of the solution much faster than the lighter particles and require shallower sedimentation tanks to do so. This means that from the time the coagulant is added and until the purified water is discharged from the plant, it is critical to minimize the number of small orifices and sharp turns the water must pass through, as all of these things cause floc breakup and thus make the plant less effective.



Side view of sed tank interior. Rotate page clockwise to view correctly.

Sedimentation

The principle of sedimentation is simple: allow the flocculated water to enter the bottom of a large enough tank, and before the water reaches the other end of the tank, any particles will settle to the bottom where they can be drained away. The main design consideration, then, for a standard sedimentation tank, is the horizontal momentum (mass times velocity) of the incoming particles. Generally, sedimentation tanks are very long and relatively shallow, but these dimensions can be altered by the addition of tightly-spaced baffles called *lamella*, which are slanted at 60° to the horizontal and situated perpendicularly to the length-wise axis of the tank. Particles are discharged along the bottom of the tank and drift updwards until they collide with the lamella and stop, sliding down into the drain channel. Meanwhile, clean water is collected in perforated *launder* pipes along the surface and transported out of the sedimentation tank. Thus, using lamella makes it possible to build shorter, deeper 'sed tanks' with shorter hydraulic residence times than traditional designs—a more compact, more efficient, and cheaper solution to sedimentation.

Filtration

Although filtration is often the first thing that comes to mind when it comes to water treatment, this process is only effective with waters at relatively low turbidities already, and even then yields only small gains in water quality compared to the flocculation/sedimentation process. At the same time, filters incur costs in energy usage and head loss. For these reasons, many resource-poor communities choose to forgo filtration or wait to add one until additional funds are available. If filters are present, however, they are usually of the *rapid sand* variety.

Rapid sand filters operate by pushing water through a deep bed of material like sand (a fine substance) or anthracite coal (a coarse one), which through various molecular and fluid-dynamical effects trap most of the flocs left in the water. Over time, these trapped particles build up and clog the filter, so periodic *backwashing* (running clean water backwards through the filter) is necessary to clean it out. This process accounts for the high energy cost of rapid sand filtration, and explains why AguaClara plants cannot use this method in its traditional from. Instead, AguaClara's stacked rapid sand filters deliver water to five or six different positions along the vertical length of the filter. Each orifice acts to backwash the "stacks" on either side of it. In this way, backwash and filtration are accomplished at the same time, and the filters can be run using only gravity, as required by the design.

Chlorination & Storage

The final step before channelling the clean water into distribution tanks is chlorination. This is accomplished using the same principle as the coagulant doser, but instead of bonding particles, the added chlorine kills any remaining bacteria in the water. After this is done, the water is safe to drink.

Building an AguaClara Plant

Before deciding on a specific course of water treatment, AguaClara or otherwise, communities should always review the many options available to them. If a community does decide to use an AguaClara design, it should first be reviewed by a professional engineer. AguaClara also strongly encourages the formation of a community water board, with mandatory meeting attendance, in order to ensure that the plant has definite and continued support for construction, operation, and maintenance.

Engineering-in-Context

The AguaClara team at Cornell is also always happy to provide answers and assistance in site selection, plant design, or finding funding for a new plant or upgrade, but the goal of the Cornell team is *not* to manufacture the actual water treatment plants (this would not be cost-, resource-, skill-, or time-effective). Instead, students make an annual Engineering-in-Context trip to Honduras—a valuable chance to tour plants, test potential modifications, interact with AguaClara's two engineers 'on the ground' and make cross-cultural connections with the people of Honduras.

Further Reading

AguaClara "About Us" page: https://confluence.cornell.edu/display/AGUACLARA/About+Us
Agua Para el Pueblo (APP) Website: http://www.apphonduras.org/
World Health Organization/UNICEF Data Estimates: http://www.wssinfo.org/data-estimates/introduction/
WHO "What is Improved Sanitation": http://www.who.int/whosis/whostat2006ImprovedWaterImprovedSanitation.pdf

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