CE 3060: Water Treatment (B Term 2015)

Term Project

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1. Introduction

1.1. Drinking Water Regulations

There are regulations in place to ensure that people has access to clean drinking water. The main piece of legislation in place for this is the Safe Drinking Water Act (SDWA). The SDWA gives the EPA the authority to regulate drinking water. The EPA does this by setting maximum contaminant levels (MCL's) for contaminants in drinking water. Public water systems are then required to develop a plan to meet the MCL's. When developing the MCL's, the EPA attempts to balance public health risk and cost to meet the MCL. The EPA starts by developing a maximum contaminant level goal (MCLG), which is solely based on health risk (Nash, 2010). The MCLG for a contaminant is defined as "the level at which no known or anticipated adverse effects on the health of persons occur and which allows an adequate margin of safety" (Nash, 2010). The EPA then takes this value, considers the cost of meeting it, and develops the MCL (Nash, 2010). There are also secondary maximum contaminant limits (SMCL's) that are recommendations for water suppliers. In contrast with MCL's, public water systems are not required to meet SMCL's.

Drinking water regulations shape design of water treatment plants. When designing a plant, one must consider what is required to make sure the finished water meets the MCL's. More details on drinking water treatment plant design will be covered in the following sections.

1.2. Drinking Water Treatment Plant

A drinking water treatment plant is a critical part of water usage. Its overall purpose is to ensure that residents of the town it services have a clean water source. Without it, many parts of our daily lives that we do not think twice about would become difficult, such as cooking and washing dishes.

Drinking water treatment plants remove pathogens, bacteria, particles, and minerals from the water. Some of the matter removed would be harmful if consumed, and some may cause non-harmful color and odor issues. Each step in the treatment process plays a different and critical role. **Error! Reference source not found.** below shows a schematic of drinking water plant for surface water. There are also short descriptions of each part of the process below the schematics.

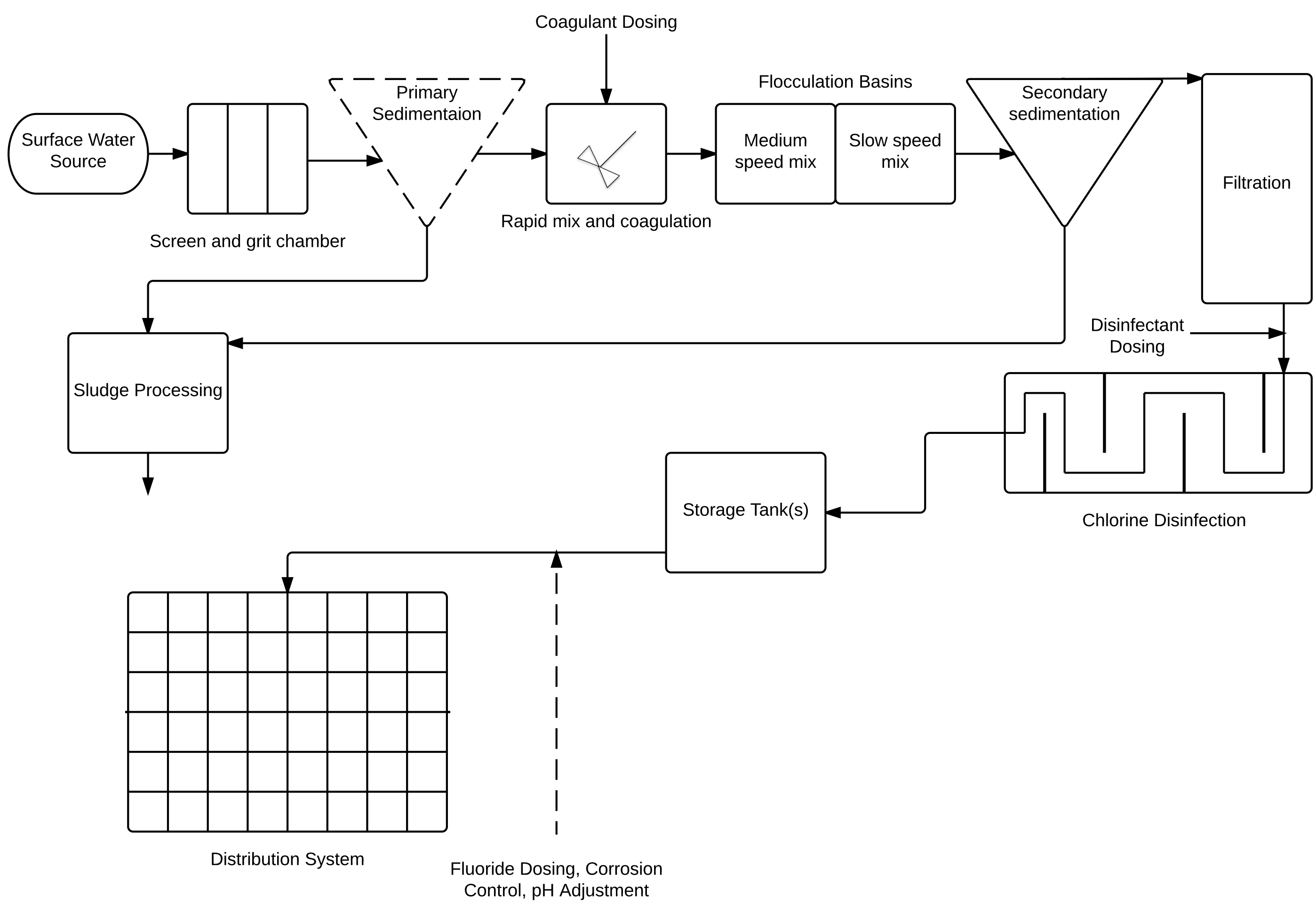

Figure 1: General Schematic of a Drinking Water Treatment Plant

Screening

The purpose of screening is to remove large particles in the water and to prevent any aquatic wildlife from entering the drinking water plant.

Pre-Sedimentation

Pre-sedimentation is an optional step that can be used instead of screens in some cases. The purpose of sedimentation is to remove sediment from the water. At this stage, it is used for larger particles.

Coagulation and Flocculation

Coagulation involves adding chemicals to the water in order to collect small particles into clusters. The process starts by adding a coagulant, which initiates the process while rapidly mixing the water. This drags the particles out of solution. Next the water moves to the flocculation basins where it is mixed at a medium speed and then a slow speed. This allows the particles to settle after the rapid mixing and start to clump together into larger groups called flocs.

Secondary Sedimentation

Secondary sedimentation happens after coagulation and flocculation. This step allows the flocs to settle from the water and fall to the bottom of the tank. Clean water is taken from the top of the settling tank, while the sediments are removed from the bottom and are processed as sludge.

Filtration

Filtration is a physical process in which water flows through a media (or several media) and particles and bacteria are removed from the water. Typical media are sand, anthracite coal and granular activated carbon.

Disinfection

Disinfection is used to kill and/or injure harmful pathogens and bacteria in the water. Typically chlorine is used. Effectiveness of disinfection depends on many factors, including water pH, water temperature and contact time. Serpentine structures in disinfection tanks are utilized to get the needed contact time.

Corrosion Control

Corrosion control is required for water systems to avoid stripping of metal pipes into the water supply. If pipes made of dangerous metals, such as lead, exist in the distribution system, corrosion control chemicals are used to coat the pipes. This ensures that metal on the pipe will not be stripped off.

Fluoridation

Fluorine is added in some systems for dental care purposes.

pH Adjustment

Depending on the water supply, some water systems may need to add chemicals to adjust the pH of the water. This may happen at the beginning of a treatment plant or before distribution.

Storage

Water systems generally have storage tanks where they store finished water before it enters the distribution system. Many water systems will make most of the water for the day in the early morning and store it before peak water usage hours occur.

Distribution

The distribution system is involved of a complex piping network that moves water from the treatment plant to homes, businesses and schools. Distribution will be further discussed in the next section.

1.3 Distribution Systems

The distribution system is a complex network of pipes that take finished water from a drinking water treatment plant and deliver it to locations throughout a town or city. Distribution systems are expected to provide clean water at an acceptable pressure and flow rate (Hart, n.d). Previously, distribution systems were not expected to provide clean water, and were only concerned with pressure and flow (Hart, n.d). Thus, many distribution systems in place were not designed with the goal of providing clean water in mind. For example, many distribution systems have lead pipes. If corrosion control is not in place at a drinking water plant, chlorine in the water may react with the lead and strip it off the pipes. This exact thing recently happened in Flint, Michigan when the city changed water supplies. The corrosive nature in conjunction with extra chlorination to decrease total coliform bacteria caused stripping of lead pipes in the distribution system (Carody, 2015). This created health issues, such as lead poisoning, throughout the city (Carody, 2015).

Distribution systems play a large role in providing clean water to citizens and a lot can happen to affect the water quality between the treatment plant and the point of use (POU), such as someone's tap. In addition to monitoring issues with dissolved metals in water, distribution systems need to be designed to eliminate bacteria, maintain detectable chlorine residuals, and keep disinfection byproducts below 50ppm (Hart, n.d). If any of these parameters are not managed correctly, water quality issues may arise. However, treatments are in place to prevent these water quality issues. Filtration and disinfection are used to eliminate bacteria, chlorination is used to maintain a chlorine residual, concentrations of disinfection byproducts are kept below 50 ppb by reducing organic materials that may react with chlorine and by ozonation and combined residuals, and metals (lead and copper) and kept out of the water with corrosion control (Hart, n.d).

Figure 2 below shows a general schematic of a distribution system. There are several elements involved in a distribution system. A list of these elements and their purposes is below **Error! Reference source not found.**.

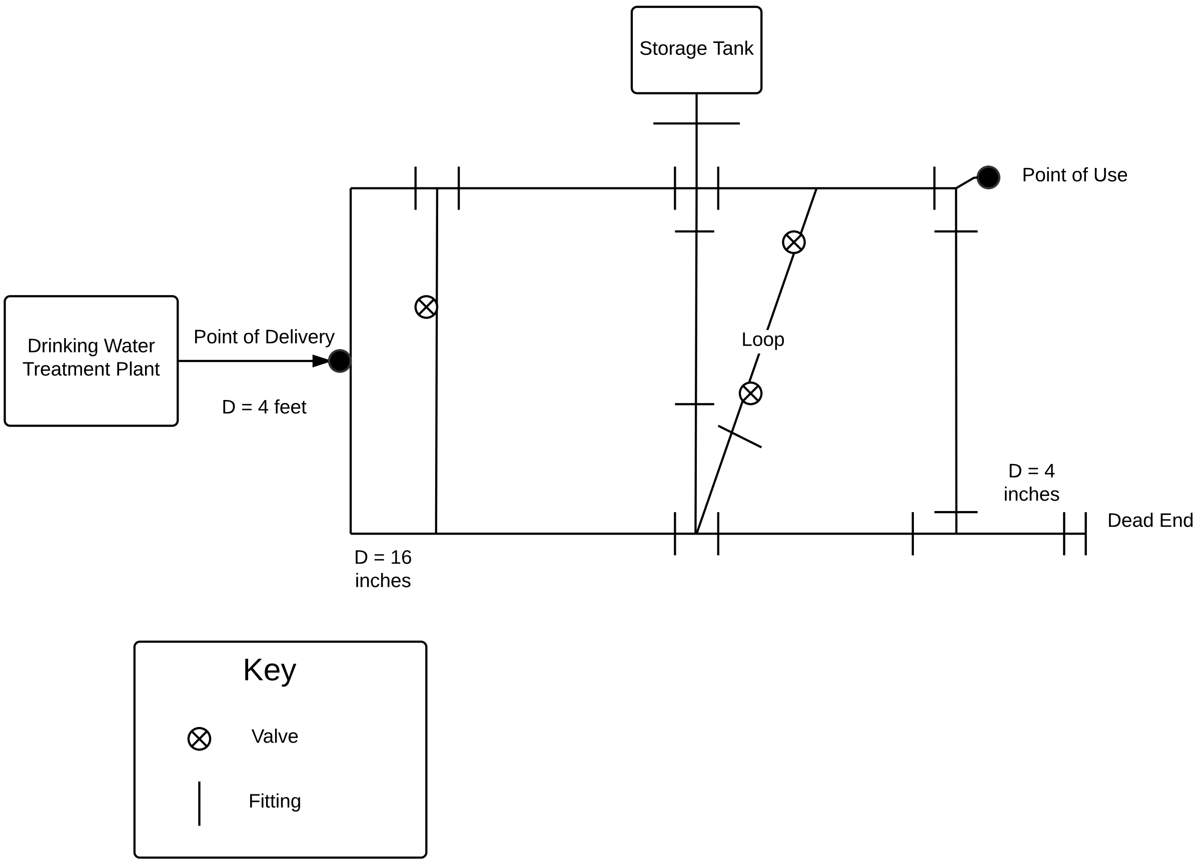

Figure 2: General Schematic of a Drinking Water Distribution System

Elements of a Distribution System

- Pipes
    - The material of pipe chosen is a key parameter in a distribution system, and material pros and cons need to be weighted. For example, a lead pipe may be very strong but it poses a health risk.
        - Materials used for pipes include iron, steel, concrete, asbestos concrete, and plastic (Lukin, 2004).
    - The diameter of a pipe has a direct effect on the velocity of the water via the following equation, where V = velocity [length/time], Q = flow rate [volume per time], and A = area [length X height]. In general, the diameter of a pipe should decrease as it gets closer to the point of use in order to decrease the time the water spends in the pipe.

$$V = \frac{Q}{A}\ [length/time]$$

- Storage Tanks
  - Before, water enters a distribution system it is stored in a large tank. These tanks ensure that there is enough water at peak water usage times and allow disinfection contact time.
- Fittings
  - Fittings create bends and elbows in the piping system.
- Dead ends
  - Dead ends in distribution systems should be avoided as it creates a potential for old water to build up in a system. If a dead end is necessary it should be flushed frequently (Lukin, 2004).
- Valves
  - Valves are most commonly used to regulate flow, but can also be used to regulate pressure, provide air and vacuum relief and prevent backflow (Lukin, 2004).
  - Gate valves are a common valve used in public water systems to start and stop flow (Lukin, 2004).
- Water age
  - It is important that water does not stay in a distribution system for too long a time. If it stays in the piping for too long, issues such as bacteria contamination or metal stripping may occur.
- Point of use
  - This is the point where the water is used, such as a homeowner's tap.
- Point of delivery
  - This is the point where water is delivered from the treatment plant to the distribution system.

1.4 Water Resources

In the United States, 80% of water withdrawals are from surface waters and 20% are from groundwater (Hart & Sawyer, n.d). In 2005, water usage in the United States averaged at 410 billion gallons per day (Hart & Sawyer, n.d). Climate change and population growth are having effects on availability of water across the world, including the United States. Some areas, such as the southwestern United States, are quickly running out of water. It is expected that droughts will expand or persist to 90% of the land in the southwest (Hart & Sawyer, n.d). It is also anticipated that water supplies in the Colorado River, a major source of water for the southwest, will drop 20% this year (Hart & Sawyer, n.d).

In the Northeast, water scarcity is not as much a concern. It is predicted that more extreme weather events will occur, but water supplies will likely not be at risk (Hart & Sawyer, n.d). However, regions with compromised water supplies, such as the southern United States, may start to rely on the Northeast for water, which could create strain (Hart & Sawyer, n.d).

Although running out of water soon is not a huge concern in the northeast, old infrastructure is a concern. Old pipes could create water quality issues down the road. This could become particularly problematic if other regions need to start depending on the northeast for water as well.

The Massachusetts Water Resources Authority has data on average water demand from 2007-2014. Figure 3 below shows the average demand each year.

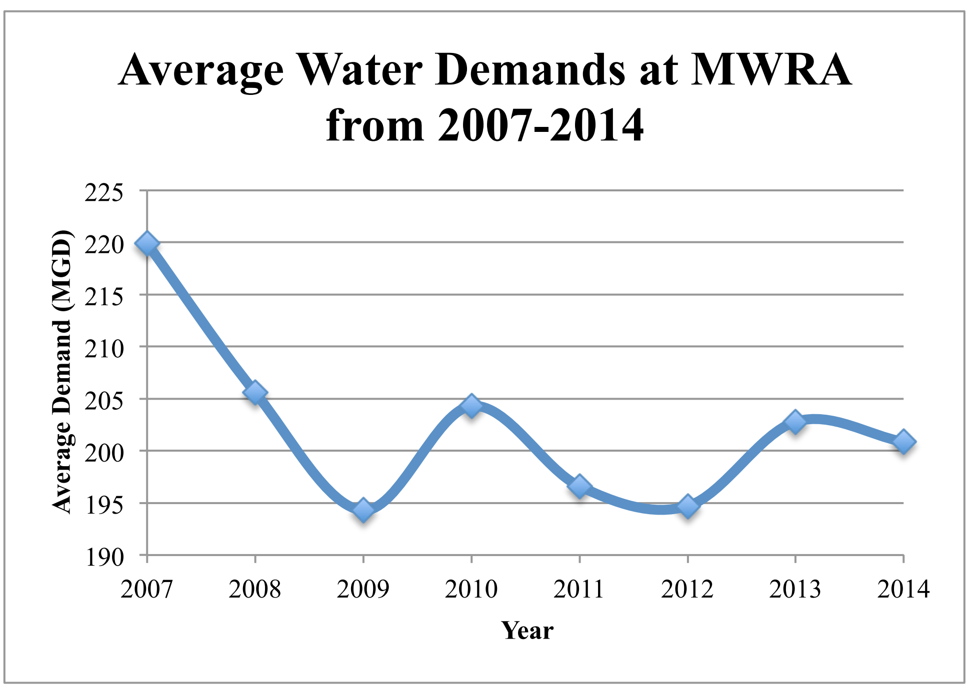

Figure 3: Average Water Demands at MWRA from 2007-2014 (MWRA, 2015)

Average water demand has decreased since 2007, and is fluctuating above and below 200MGD (MWRA, 2015). In the next 50 years, a water utility in the northeast may expect an increase in water usage due to continued population growth and the southern areas of the United States running out of water. However, this can be combatted with water conservation techniques, upgrades to infrastructure, and water reuse.

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