

Pharmaceuticals in Water

An Interactive Qualifying Project Report

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I. Introduction

Even with all of today's water treatment methods, there are still large amounts of chemicals in what is referred to as "clean" water. This is an ever growing problem especially with the amount of pharmaceutical compounds found in water. For the past twenty-five years there have been various attempts to determine the concentration of pharmaceutical compounds in drinking water (Webb et al., 2003). This problem was first brought to light in the 1990's in Europe when pharmaceutical compounds were found not only in drinking water but in greater abundance in wastewaters, streams, and ground-water resources across Europe. Though pharmaceutical compounds had been found in landfills and sewage-treatment plants these new discoveries showed that some of these compounds are getting into the water and then are not treated in the water treatment plants.

Since then the problem has grown, especially in the United States. It is not a very well-known or discussed problem and even though there has been a large amount of research on this topic there is still little known on the effects that these compounds have in the water and ways of getting rid of these increasing levels. Researchers have formed organizations to work on the problem of increasing levels of pharmaceutical compounds in water. One of the major organizations is known as Silent Spring, named after the book Silent Spring by Rachel Carson. The organization was formed in 1994 and its major cause is to study the environment in an attempt to discover environmental causes of cancer. The research focus of this group includes looking at pharmaceuticals in streams, lakes, underground reserves and wells, and in drinking water (Schaidler et al., 2010).

The greatest danger from the presence of pharmaceuticals in the water isn't so much the single types of pharmaceuticals but it's when different chemicals are consumed together and

produce a magnified effect which is known as synergism. On top of this, researchers do not know what the effects of these combined pharmaceuticals are. The main types or categories of pharmaceuticals in the water are antibiotics, pain killers, muscle relaxants and hormonal drugs (Xu et al., 2009). Each one of these has a different impact on people and the environment, and with ever growing levels these problems are getting worse. Through many tests researchers have collected various pieces of data on the effects these pharmaceuticals have, but because of the large number of variables in the different chemicals they cannot accurately estimate the full threat (Xu et al., 2009). Another reason for the lack of data is when pharmaceuticals go through the treatment process they may be changed or chemically modified to form a new product that can be potentially harmful.

Waste water treatment plants (WWTP) have been used for many years to help make waste water acceptable for discharge to the environment. The methods that are employed to treat the water are aimed at removing and reducing overall groups of contaminants to a government specified, safe level. This does not seem to be fixing the pharmaceutical problem though, because scientists are finding rising levels of pharmaceuticals in what was thought to be “clean” drinking water. These pharmaceuticals are not only found in public water, but are also found in wells, rivers, and other bodies of water (Webb et al., 2003).

There are a number of different ways these pharmaceuticals get into the water. One way is through incorrect disposal methods, which is recurrent everywhere from single homes to college campuses and hotels (Stackelber et al., 2004). They are used in larger quantities in hospitals and pharmacies. There are a few proper disposal practices performed by medical establishments, though these are not always followed and large amounts of pharmaceuticals may get thrown out with the trash or flushed down drains or toilets (Webb et al., 2003). This also

occurs on a smaller level with private and public housing because it used to be common practice to tell people to flush their unused medicine down the toilet or pour it down the sink drain. They then become part of the waste water but are not necessarily removed when the waste water is passed through treatment plants (Zhou et al., 2009).

There are no federal regulations for the disposal of pharmaceuticals but some states have started to create what they call “recommendations” for proper disposal, but these are not required by law to be followed. States have also tried to help reduce the amount of pharmaceuticals that need to be disposed of. They are starting to make places for people to recycle certain pharmaceuticals that can be reused or broken down and parts of them used. Also states are trying to get people to buy the minimum amount of medicine possible, and have doctors prescribe only the needed dosage and that the patient takes all that are prescribed so that there is a decrease in pharmaceuticals which need to be disposed of (Focazio et al., 2008).

Another major way that these pharmaceuticals get into the water is through excretion. When a person or animal is given a drug or medicine not all of the ingredients are digested, many of the chemicals end up passing right through their system. (Webb et al., 2003). While human excretion is flushed through to WWTP’s, animals are not, and it is excreted straight on the ground where it seeps into the ground and into groundwater sources or becomes runoff. Runoff is when the excretion is washed away with rain and this runoff usually ends up in streams, rivers and lakes. This is a major problem at chicken and cattle farms because these animals are given large amounts of hormones and antibiotics some of which is leftover in their excretion (Stackelber et al., 2004).

Even though this problem has only been really brought forth recently it is very similar to the problem of pesticides and their effect on the environment. Pesticides are chemicals used by

farmers to keep their crops free of insects. The problem with this that some of these chemicals are washed off with rain and become runoff which has led to growing amounts of pesticides to be in our waters. So now pharmaceuticals, just like pesticides, are not being treated in water treatment plants.

II. Background

A. History

Methods for treating water were primitive until the 1700's, when the first water filters for domestic application were introduced (Lenntech Water Treatment and Purification, 2009). About a hundred years later, the first municipal water treatment plant was built in Scotland in 1804 (Lenntech Water Treatment and Purification, 2009). This facility utilized slow sand filters as the primary method of treatment. These filters were large and required constant cleaning and maintenance. By the mid 1800's it was found that diseases traveled easily through water, when large cholera outbreaks were determined to be spread through water (Lenntech Water Treatment and Purification, 2009). At this time, producing clean water to drink was largely important; however it is likely that much of the earth was still drinking dirty water because of the lack of technological advances in treatment processes.

The 1900s brought increased technology and new methods for treating water. Scientists in the United States designed a rapid sand filter in the late nineteenth century (History of Water Filters, 2010). This new rapid sand filter was cleaned by powerful jet streams of water, which helped to greatly increase the efficiency and capacity of the water filter. During this time period, the government created water standards and published acceptable levels for trace chemicals in water. Today, water treatment in developed countries is very efficient, and most of the contaminants found in water can be removed through water cleaning processes.

WWTPs don't typically test for pharmaceuticals and personal care products. Not until recently was it discovered that they are present in our environment and therefore our drinking water. Several studies done across Europe in the early 1990's showed the presence of pharmaceuticals in lakes and streams. The health effects results from consumption of any level of these chemicals are still unknown. Some believe that since these chemicals are found at such low levels, their effect is negligible.

Over the past decade, many researchers and organizations have begun to study the effect these pharmaceuticals have once they become present in the water supply and how they enter the environment. The effects on the human body, as well as the effect on the environment, have been the two main points of study. However, there is still a lack of detailed information on the effects pharmaceuticals in water have on the human body. This issue is quickly becoming so widespread that it is likely that pharmaceuticals will be present in almost all water supplies across the world. Many people are still unaware of the increased levels of these chemicals. If the problem continues to be overlooked and understudied, then our society may suffer ill-effects from these chemicals. The bacteria found in water may also be building up a resistance to our current medicines due to the low levels of pharmaceuticals being found in the water alongside these bacteria. This is due to the fact that the bacteria are able to survive these low doses of pharmaceuticals and therefore are slowly building up immunity to them.

B. Studies

It is difficult to have testing methods that detects in its range Nano grams per liter and this is the case with low levels of pharmaceuticals in the water. The countless experiments that are being done in the pharmaceutical field use a variety of testing equipment and methods, so

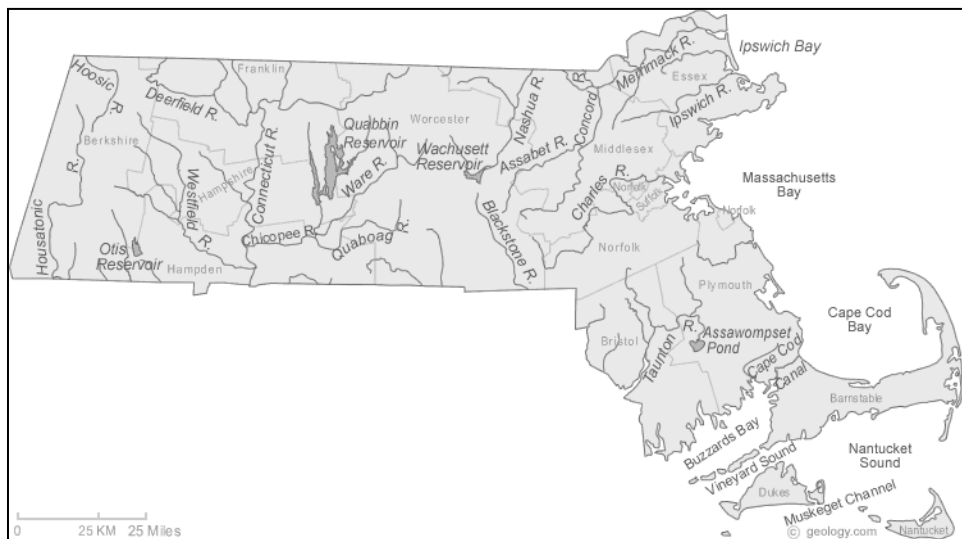
accuracy can be a factor in receiving correct results. When an experiment has a reaction that is significant, the analytical signal must be able to be picked up and properly observe the reaction for the experiment to be worthwhile. During many actual experiments, many original forms of a pharmaceutical will change into another form or makeup, known as an intermediate form. Intermediate forms are harder to detect than the original form because there has not been enough research conducted to know what that intermediate form is comprised of. Because of the complexity of the experiments and the unknown reactions that take place, the need to have the analytical technology to provide accurate services is needed. Many experimenters say that we need to advance our methods and technologies to stay ahead of this problem (Council, 2010).

The Silent Spring organization investigates how chemicals in our everyday life may affect the likelihood of being diagnosed with breast cancer or develop tumors. They recently performed a study which began in 2009 and was published in May 2010, which tested water from many different locations in the Cape Cod area for the presence of certain pharmaceuticals. In their report titled: “Emerging Contaminants in Cape Cod Drinking Water” they explained that, “Samples of untreated water from 20 wells and treated water from 2 distribution systems were tested for over 90 emerging contaminants altogether” (Schaidler et al., 2010). They found that 75% of all the test sites contained at least one emerging contaminant, and the most common contaminants found were, sulfamethoxazole an antibiotic, and a perfluorinated chemical (Schaidler et al., 2010). This study was completed recently which suggests that the odds of having at least one type of pharmaceutical contaminant present in a person’s drinking water are quite high. Since a large number of the contaminants they tested for showed up in at least one well in spread out locations, this implies that there are multiple different points of entry for these contaminants to enter the environment. The Silent Spring report made a suggestion to reduce the

level at which pharmaceuticals are entering the environment that included a better protection of supply wells and proper disposal of unused/unwanted medications (Schaidler et al., 2010). It is likely that one of the main points of entry into the environment is by releasing medications down the toilet. This is not the proper method for disposal; however there are no standards for the disposal of pharmaceuticals; which is most likely why they end up in our landfills or flushed down toilets. This study helps to confirm the widespread presence of pharmaceuticals in the environment, while identifying the ways in which these chemicals can enter the groundwater. This study also attempts to link the presence of the chemicals in the environment to the Cape's elevated instances of breast cancer. While no information could directly link these two, it is something Silent Spring looks to build a case on.

Pharmaceuticals have the potential to harm the environment while they are present in the groundwater, streams, or rivers. Not much is known about the specific concentrations of pharmaceutical compounds in Massachusetts Rivers due to the lack of testing and published tests.

Figure 1. Massachusetts Rivers



Source: Geology.com

Massachusetts Rivers Shown on the Map: Assabet River, Blackstone River, Cape Cod Canal, Charles River, Chicopee River, Concord River, Connecticut River, Deerfield River, Hoosic River, Housatonic River, Ipswich River, Merrimack River, Nashua River, Quaboag River, Taunton River, Ware River and Westfield River.

Massachusetts Lakes Shown on the Map: Assawompset Pond, Otis Reservoir, Quabbin Reservoir and Wachusett Reservoir.

On a National level, research is underway for new technologies and removal methods for pharmaceutical compounds. However, there is no standard for removing these contaminants yet, and some of these methods are still in their beginning phases of development.

In Massachusetts, “MassDEP is participating in a study with the University of Massachusetts (Amherst) and AECOM to examine twelve PPCPs and EDCs to determine treatment efficiency as well as whether treatment produces potentially harmful "daughter" compounds. This study will also examine the potential of these chemicals, and any daughter products, to interfere with the endocrine system.”(MassDEP).

Amounts of pharmaceuticals and their strength are increasing due to the increase of the human population and their reliance on medications (Maggon, 2005). The pharmaceutical industry has to try and sell its products to people and “a customer-oriented culture allows a firm to achieve customer satisfaction, increase customer loyalty, and attract new customers.” (Gabriele et al., 2009). The attraction of new customers through advertisements and word of mouth allow for higher sales of pharmaceuticals and this in effect has a greater mass of them entering the environment. Not only has there been an increase in the use of prescription drugs

nationwide, but there has been an increase in the abuse of these drugs. Data from the National Drug Intelligence Center indicates that the abuse of pharmaceutical products is relatively high when compared to other drugs in this category. Pharmaceuticals were second highest on the list, and out of those that scored lower, were cocaine and heroin. The fact that there is a higher percentage of prescription drugs being abused than of cocaine and heroin, demonstrates an increasing problem. This situation adds to the problem of pharmaceuticals getting into our environment and water supply, because of the quantity that is being consumed and then transferring into the environment (justice.gov, 2004).

A study performed in England tested the bodies of water surrounding five WWTP's, to learn about the effects that the discharge from these plants had on the environment and the levels at which they were present in the water. The article entitled: "Pharmaceutical residues in wastewater treatment works effluents and their impact on receiving river water" states that, "the main route to the environment for pharmaceuticals is through discharged effluent from WTWs, a result of excretion from humans and animals, as well as from domestic disposal of medicinal products" (Zhou et al., 2009). The article's introduction describes a population collapse of vultures in India and Pakistan. These vultures were consuming the anti-inflammatory drug, diclofenac, that is regularly used for veterinary medication to livestock, which the vultures fed on. While the reaction to the exposure of certain chemicals is not completely known for animals and humans, this particular case shows how dangerous some chemicals may be to the health of animals and for that reason, humans as well.

In addition to the effects on animals, many researchers conducted their tests and experiments through the use of fish as the receiver of the pharmaceuticals. Due to their size they are affected to a greater degree by a smaller amount of pharmaceuticals than humans are. This

allows researchers to observe effects that are not noticeable on humans. Since fish live in water they are directly impacted by waste water discharge. They are also the first ones to be affected by the chemicals that result from pharmaceutical insertion into our water sources. Rebecca Klaper, a researcher at University of Wisconsin-Milwaukee's Great Lakes Water Institute, did an experiment on fish to see what the effects of the pharmaceuticals were. The experiment was supposed to be conducted over a week's time but had to be halted after twenty four hours because the fish started to die. The stress of the antibiotics present made the fish dispense a milky mucous and it was determined that the continuation of the experiment would kill them (Savransky et al., 98).

J. L. Parrott and D. T. Bennie conducted a similar experiment where they had a combination of different pharmaceuticals present in the experiment. They combined six pharmaceuticals; naproxen, gemfibrozil, diclofenac, ibuprophen, triclosan and acetaminophen as well as one personal care product, salicylic acid, to experiment with fathead minnows and see what the results were. Unlike Rebecca Klapers' experiment, Parrot and Bennies' experiment did not produce significant results relating to results others have received (Parrott & Bennie, 2009). Others, who conducted experiments focusing on single concentrations of pharmaceuticals found effects such as reduced egg fertilization, reduced male characteristics, histological changes in liver and gills and increased deformities. However, Parrott and Bennies' experiment showed no such results (Parrott et al., 2009). Another experiment was conducted with Zebrafish which were introduced into ecological relevant levels of pharmaceuticals. The fishes' genetic structure as well as ability to function was affected, similar to the other studies conducted on fish. One notable result was the fact that when the pharmaceutical was introduced in waves the effects were significantly higher (Pomati et al., 2007). The effects of these experiments show the

potential for harmful effects on humans and other animals in our environment. There is controversial data from similar studies, so more research needs to be conducted to pinpoint the exact cause and effects with the experiments conducted.

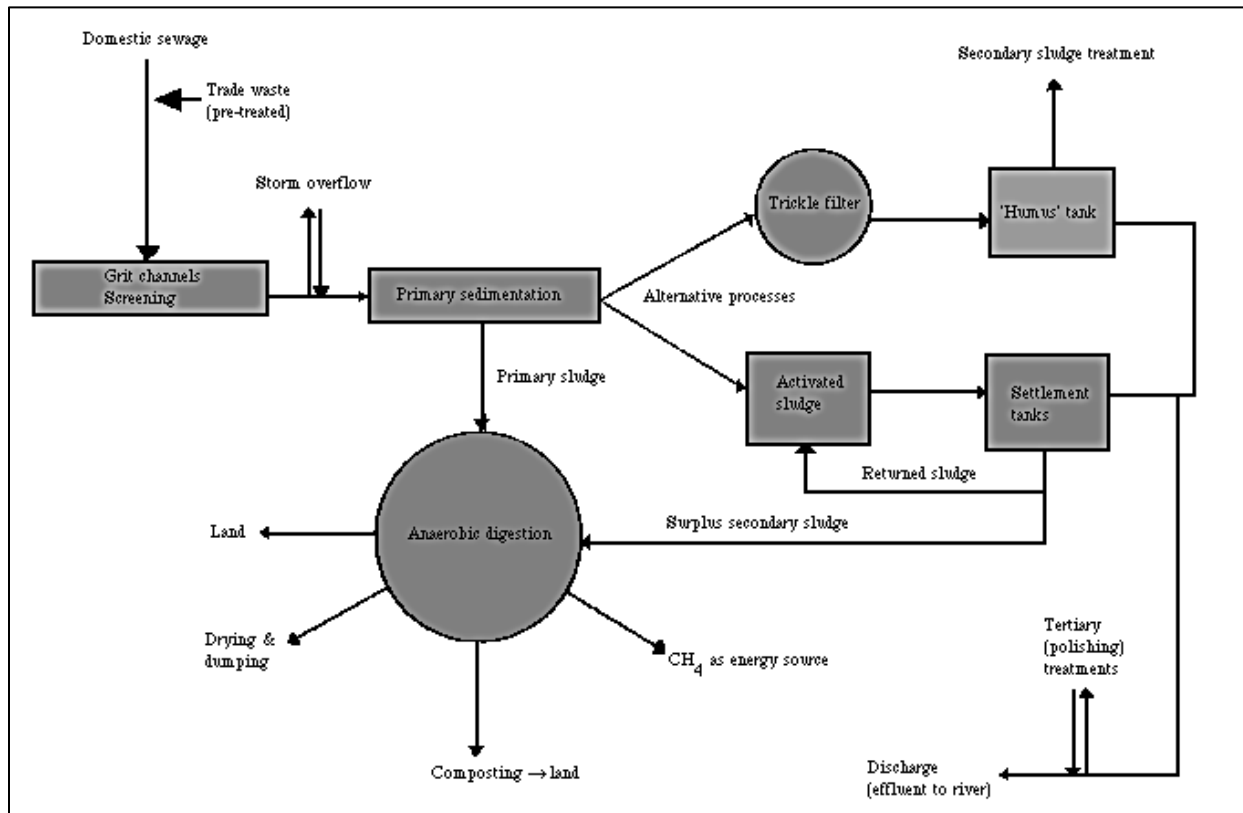
Another possible concern in the area of pharmaceuticals in the environment is the effect these various chemicals have on the surrounding soil. A study performed in the US in 2009 investigated the effect various pharmaceuticals had on four different agricultural soils. They looked at the absorption and degradation rates of these chemicals to determine whether or not their presence in the soil would cause problems. They found that: "...introduction of effluent-derived PPCPs into agricultural soils may cause potential soil pollution and thereby groundwater contamination, depending on soil type and chemical structures" (Xu et al., 2009). Not much is known for the effects pharmaceuticals have on the soil directly, or their effects on plant and animal life within the soil. This is an increasing point of study and should be focused on in the future, because these chemicals gain access into the soil as the first point of contact with the environment.

C. Water Treatment

WWTP's are relatively new. Many populations across the earth have understood since the 19th century that they had to reduce the amount of pollutants in their waste water. A movement to start cleaning up the water system began in the 1850's with large outbreaks of life-threatening diseases, which were traced to bacteria which was found in the polluted water (USGS, 2010). Nowadays most business's, hotels, schools, private homes, and most other establishments wastewater collection and treatment system. There is a difference between a WWTP and a Water Treatment Plant. Water Treatment Plants treat water before the consumption

by humans and the water is usually drawn from reservoirs or natural locations. WWTP's treat water after it has been used by humans. It is then is entered back into a stream or river.

Figure 2. Waste Water Treatment Plant Components Diagram



Source: weather.nmsu.edu

Large WWTP's may treat several million gallons of wastewater daily. The process which the water goes through to be 'cleaned' is similar to the process which happens naturally in a stream or lake but at an accelerated rate. WWTP's use a series of treatment steps to cleanse the water so that it can be released back into streams and rivers and eventually back into our drinking water (Friedman, 2000). This process includes three main stages, a preliminary, primary, and secondary stage for the water treatment. There is also the process of

tertiary/chemical addition which includes phosphorus removal, gravity filtration, granular activated carbon adsorption and disinfection in the form of chlorination. Sludge is then produced from the sediments and chemicals which are removed from the waste water (Friedman, 2000).

Before pharmaceuticals have the chance to enter any water supply, they may have the chance to affect the soil, bodies of water, and even animals that they may come into contact with. One way this is possible involves the effluent or sludge which is discharged from WWTP's. This liquid substance often contains trace levels of pharmaceuticals and has the potential to affect the environment, the discharge can percolate into the soil and often makes its way into streams and rivers.

Concentrations of pharmaceuticals in the water supply are not always obvious but are almost always prevalent; therefore techniques for treating these chemicals could help solve many problems. New methods for treating these chemicals are beginning to be developed and tested. Removal of such contaminants at trace levels makes this such a difficult task to complete. Typical treatment methods employed at WWTP's are not advanced enough to remove pharmaceutical or PCPP chemicals. A recent study titled: "Removal of Pharmaceuticals during Drinking Water Treatment", describes the various new treatment processes which were tested for their accuracy with five target pharmaceuticals. These methods included: biodegradation, flocculation, activated carbon adsorption, and ozonation (Ternes et al., 2002). It was found that: Slow sand filtration and flocculation by Iron(III) chloride were not effective, ozonation was very effective in oxidizing carbamazepine and diclofenac, and GAC filtration was very effective overall (Ternes et al., 2002).

As of right now WWTP's do not have treatment processes that solely target pharmaceuticals. But due to the realization of this problem, in recent years there have been many

different studies on how to treat wastewater that will target pharmaceuticals. Granular Activated Carbon, Powder Activated Carbon, Chlorination, Ozonation, Flocculation, Filtration, Adsorption, Biodegradation have all been looked into to try and solve the problem. A number of these methods are new ways of treatment and some have not been developed to their full extent yet. Several experiments use these methods as a way to test the possibility of treatment and have had varying degrees of success. In our methodology and results section we look more in depth on how these methods actually work and whether they are effective or not.

D. Legislation

Groups like the Ground Water Protection Council recognize pharmaceuticals as a threat to the quality of our ground water and are taking actions to try and monitor the situation for further evaluation (Council, 2010). Currently the EPA controls regulations related to clean drinking water. “Under the Clean Water Act (CWA), EPA establishes national regulations (called effluent limitations guidelines and standards) to reduce discharges of pollutants from industries to surface waters and publicly owned treatment works” (EPA, Management and Disposal of Unused Pharmaceuticals, 2008). Under this act the EPA is required to update it every two years and in 2006 looked into the health services industry. While the “EPA regulates the generation, storage, transportation, treatment, and disposal of any pharmaceutical waste defined as hazardous waste “ (EPA, Management and Disposal of Unused Pharmaceuticals, 2008) not all pharmaceuticals fall into this category. The pharmaceuticals not in this category are disposed of in ways that enter the water supply. One group; The Center for Medicare & Medicaid Services

“require LTCFs (long term care facilities) to return unused medications to pharmacies and to ensure that Medicaid is repaid for unused treatments when nursing home patients die, are discharged, or have their prescriptions changed...However, LTC (long term care) pharmacies typically receive little payment for these return services and have not found them to be cost effective. For example, when a pharmacy takes back a previously dispensed medication for disposal, it must pay to have the medication destroyed, but is not compensated for this service” (EPA, Management and Disposal of Unused Pharmaceuticals, 2008)

Also the Drug Enforcement Administration (DEA) makes regulations that affect the amount of pharmaceuticals entering the water due to the following acts: The Controlled Substances Act (CSA), The Resource Conservation and Recovery Act (RCRA), and The Health Insurance Portability and Accountability Act (HIPAA). Another factor into the dispersion of pharmaceuticals into water is the reuse or redistribution of pharmaceuticals. A few states prohibit this action and most have strict regulations such as making sure they are uncontaminated. Other states that require the destruction of unused pharmaceuticals do not specify the process to actually get rid of the product. This is obviously a problem that may be causing elevated amounts of pharmaceuticals in the water.

Though pharmaceuticals in water are a relatively new concern the government has been putting regulations into effect to help keep water clean of what they consider “hazardous” waste. When these regulations were put into effect there was little known and little concern of the possible effects of the drugs that were being disposed of on the environment. The few regulations

that are out there dealing with drugs deal mainly with what is considered “hazardous” waste which includes only a small amount of pharmaceuticals. Today though, with the increase of knowledge of the rising levels of pharmaceuticals in water, there is a growing concern for the way that these pharmaceuticals are being disposed of (Pharmaceutical Waste Solutions).

One of the first major acts that congress passed was the Resource Conservation and Recovery Act (RCRA) which, was brought into effect in 1976 and gave the EPA the authority to control hazardous waste. They had control of not only the disposal but also the generation, transportation, treatment, and storage of hazardous waste. In 1984 amendments were added to the RCRA, these were known as the Federal Hazardous and Solid Waste Amendments. These amendments increased the authority of the EPA and also focused on waste minimization and setting up a more stringent program for land disposal of hazardous waste. Under this act though only a few pharmaceuticals are covered. Common pharmaceuticals which are considered hazardous waste are nicotine, warfarin, any used sharp (needle), and also a number of chemotherapeutic agents (Resource Conservation and Recovery Act (RCRA), 1976).

Then in 1988 the EPA got congress to pass the Medical Waste Tracking Act which amended the Solid Waste Disposal Act. This act defined and established which medical wastes would be subject to regulations. Also it established a “cradle-to-grave tracking system which tracked the medical waste from generation all the way to disposal. This act also set standards for segregation, packaging, labeling and marking, and storage of medical waste. This act went to effect in 1989 and expired in 1991. Over this two year period the MWTA allowed the EPA to gather information and perform several studies related to medical waste management. This act also required the EPA to look into the various treatment technologies available at the time which

included incinerators and autoclaves, microwave units, and various chemical and mechanical systems (Medical Waste Tracking Act of 1988).

This act defined medical waste as “any solid waste that is generated in the diagnosis, treatment, or immunization of human beings or animals, in research pertaining thereto, or in the production or testing of biologicals.” This includes blood-soaked bandages, culture dishes and other glassware, discarded surgical gloves, discarded surgical instruments, discarded needles used to give shots or draw blood (e.g., medical sharps), cultures, stocks, swabs used to inoculate cultures, removed body organs (e.g., tonsils, appendices, limbs) and discarded lancets (Medical Waste).

As you can see the RCRA only covers a few pharmaceuticals and the MMTA covers almost none in their regulations. However these acts set a precedent for the EPA to follow for setting regulations for the proper disposal of pharmaceuticals. At this point the EPA is working on the finalization of the rulemaking to add hazardous pharmaceutical wastes to the federal universal waste program. This proposed addition will make it easier for the collection and proper disposal of these pharmaceuticals as hazardous waste to help protect public health and the environment. These rules will apply to pharmacies, hospitals, physicians’ offices, dentists’ offices, outpatient care centers, ambulatory health care services, residential care facilities, veterinary clinics, and other facilities that generate hazardous pharmaceutical wastes (Proposed Universal Waste Rule for Pharmaceuticals).

The Universal Waste regulations govern the collection and management of hazardous waste. As of now universal waste includes batteries, pesticides, mercury-containing equipment and light bulbs. These regulations also ease the regulatory burden on retail stores and others that wish to collect these wastes. They also encourage the development of municipal and commercial

programs to help to reduce the quantity of these wastes going to municipal solid waste landfills or combustors. The Universal Waste regulations also help to ensure that these hazardous wastes go to the proper treatment or recycling facilities (Universal Wastes).

All of these acts were put into effect a few years before there was any concern of pharmaceuticals in water but they do set a precedent for newer acts and any future acts that are enacted to help keep pharmaceuticals out of water.

Because of the quantity and complexity of the pharmaceuticals being placed into the water, there is no clear direction in which we should be moving forward. There are many treatment methods that have been looked at but there has not been a huge success. Is improving our regulations the best way to fight the problem or is finding a treatment method the avenue of approach? We look at these questions in our Methodology and Results section.

III. Methodology

A. How pharmaceuticals are being discharged

The first thing that we want to address is to determine how pharmaceuticals are being discharged into water. To find this we first looked through studies which were done on how pharmaceuticals were being discharged. We also researched where large amounts of pharmaceuticals were commonly being used with both people and with manufacturing. After we found where most of the pharmaceuticals were coming from with respect to humans and manufacturing plants we looked into what pharmaceuticals and in what quantity they were being given to animals.

B. Which pharmaceuticals are being discharged and found

Which pharmaceuticals are being discharged and found was another thing that we wanted to find out. We checked out different studies on which pharmaceuticals were being found. We found that different studies found different amounts and types of pharmaceuticals so we cross-referenced a few of these studies to find the most common pharmaceuticals found. With this info we made a table of the 114 pharmaceuticals and their byproducts. We then looked into the concentrations of pharmaceuticals found in different types of water systems.

C. Effects

Studies have been conducted towards finding the effects that pharmaceuticals have on people and animals. We took a look at this data to find if there is a correlation between pharmaceuticals and adverse effects.

D. Bacteria Resistance

A pressing issue that we believed to be important was an increase in bacteria resistance. To find how this was happening and to what extent we looked into what types of antibiotics were being found in water. Once we had some of the major types we looked into what effects they have on bacteria. Then we looked through some studies on antibiotic resistant bacteria found at fish farms and the causes for it.

E. Treatment Plants and how they work

Waste Water Treatment Plants are the main way of treating water, so we wanted to look into what types of plants there are then focus it more on plants in Massachusetts and how they work. To do this we looked into the three main types of WWTPs and how each one worked. We then looked through the Mass Department of Environmental Protection (DEP) to find how many of each type of plant there are in Massachusetts. Through the Mass DEP we were able to obtain a

list of the plants in Massachusetts and make a figure and table showing where some of the large major WWTPs are located.

F. Which treatments are effective

To find a solution to the pharmaceutical problem there needs to be a treatment method involved. We looked at all the available methods to find which ones were most effective. To do this we looked at studies conducted with many types of treatment methods.

G. Worcester TP and Hospital

To gain a better understanding about the average amounts discharged from hospitals as well as the effectiveness of ozonation as a treatment method, Worcester was analyzed. The analysis of the cost effectiveness of ozonation consisted of a comparison of the old system of chlorine vs. the new system of ozonation.

AA. Legislation

Legislation could potentially be a very effective way to combat pharmaceuticals. Our report looks at current legislation and is supplemented by our own suggestions.

BB. Disposal solutions

Looks at current disposal methods and tries to provide a few recommended solutions based off of other solutions found elsewhere and data found.

CC. Awareness

One of the big problems with pharmaceuticals in water is that the general public do not know or understand the problems present. Raising awareness is one of the steps that should be taken next.

A. Results

A. How pharmaceuticals are being discharged

The presence of pharmaceutical compounds in our environment is undeniable, and their potential to contaminate the water supply adds to the concern. The four ways in which these chemicals find their way, through sewage, into the groundwater is via pharmaceutical manufacturing plants, hospitals, private households, and landfills. Pollution from manufacturing plants is believed to contain only small levels, however further research may be required to determine whether or not these low levels are negligible. Another point of entry into the water supply is at hospitals. Since so many people staying in hospitals use medications it is said that: “The concentrations of pharmaceuticals in hospital wastewater are higher than in municipal sewage” (Webb et al., 2003). Private households add to the problem when individuals dispose of unused or unwanted medications via the sink, toilet or trash. All of these disposal methods are incorrect; however there are no current regulations for disposing of medications correctly. When these chemicals are disposed of in the trash, they will eventually end up in the landfill. Once in the landfill, it is possible for the pharmaceuticals to enter the landfill effluent; if there is no collection of this liquid it can easily enter the groundwater.

The first source, and possibly most obvious, is Pharmaceutical Manufacturing Plants. Chemicals which leach into surface or ground water from this source are said to contain the most concentrated form of the chemicals (Buxton). However, these pharmaceutical plants may not represent the biggest threat to the environment, “the amount of emissions occurring during manufacturing has been thought to be negligible” (Kummerer, 2009). The emission levels are thought to be low for both European and North American plants and not much is known about the discharge levels in other countries. But it can be concluded that although discharged

chemicals from these facilities are extremely potent, they may only rarely be exposed to the environment. Not much data is known about any country's manufacturing facilities, since manufacturers refuse to publish these types of statistics. Providing discharge levels may reflect their company in a negative light if the concentrations were high, or even moderately high. So instead, these companies refuse to provide this type of data, and deem it to be negligible, even when it might not be. Not publishing this data may suggest that pharmaceutical levels could be very high in some bodies of water.

One of the more obvious entrances into the water source for these contaminants is occurring at hospitals. Hospitals provide medications to patients and also have large quantities of medications, some of which may go outdated or unused, therefore either way they are entering the water supply. Pharmaceutical concentrations in the wastewater of hospitals are not only higher than private households, but there is wider range of contaminants.

All drugs are eventually eliminated or removed from the body. While inside the body, these drugs may metabolize, which alters the form of these chemicals, or they may remain unmetabolized until they leave the body. What it takes for a substance to metabolize depends largely upon the reactions inside the body. Also, the various body parts which come into contact with the drugs affect their make-up.

Characteristics of different drugs which enter the body affect the kidneys' ability to excrete them. The kidneys' ability to excrete drugs also depends on urine flow, blood flow through the kidneys, and the condition of the kidneys (Kopacek, 2007). Generally, older human beings excrete drugs less efficiently than younger human beings.

Drugs must also pass through the liver, and some of which remain unchanged at this stage and are excreted in the bile. The bile then enters the digestive tract and from there are then

either eliminated in feces or reabsorbed back into the bloodstream (Kopacek, 2007). However, some drugs are converted to metabolites when they pass through the liver and are then excreted into the bile and digestive tract to be eliminated.

“After swallowing and digesting medicines, our bodies excrete metabolized versions of them through urine and feces. Often, people flush unwanted or unused pills as well, without thinking about where the drugs will end up” (Sohn, 2010). Most drugs are excreted through urine and feces; however, some are excreted in saliva, sweat, breast milk, and even exhaled air (Kopacek, 2007). However, some studies suggest many of these medicines may remain unmetabolized. “Buhner (2002) states that high percentages of many pharmaceuticals can be excreted from the body unmetabolized and enter wastewater as biologically active substances” (Roth, 2003). “A specific example that supports this claim is provided in a study published in the scientific journal, *Chemosphere*, by Klaus Kummerer (2001), which states that 90% of the drug, propofol found in anesthesia, is excreted unmetabolized” (Roth, 2003). But contrary to this data is that “treated biosolids have the highest concentration of pharmaceuticals while drinking water has the lowest concentration. (Smith. 2005)” (Savransky et al., 98).

As mentioned earlier animals receive and consume a hefty amount of pharmaceuticals too. When a recent survey was conducted it was found that “the country used 4,800,000 kg of antibiotics just for humans. This was roughly two thirds the amount of antibiotics that was procured for farm animals (7,234,000 kg) that same year.” (Savransky et al., 98). Animal waste goes directly into the environment, which essentially goes into our ground water. And while it is filtered through the ground many pharmaceuticals do not get properly treated through this process and it has been proven through sand filtration tests. Even if we find a way to solve the

treatment side of the human problem, a bigger portion of the problem will not be solved and will be brought directly into our drinking water.

Both metabolized and unmetabolized forms of drugs and medicines excreted from the body have potential to be harmful. Once they reach the environment, they have the potential to react to synthetic chemicals in the environment, causing even more complex compounds.

B. Which pharmaceuticals are being discharged and found

Recent studies show a wide variety of pharmaceuticals and personal care products that are being found at low levels in the environment. The various types of compounds are listed in the table below.

Table 1. Pharmaceutical Compound Groups

Sub-Group	Common Use	Compound
analgesics	antipyretic, pain reliever	acetaminophen
	pain reliever	acetylsalicylic acid
anti-epileptic drugs (AEDs)	anticonvulsant	carbamazepine
anti-hyper-lipidemics	lipid regulator	fenofibric acid
	lipid regulator	clofibric acid
	lipid regulator	gemfibrozil
antimicrobials	antibiotic	erythromycin
	antibiotic	roxithromycin
	antibiotic	sulfamethoxazole
	antibiotic	tetracycline
	antiseptic	triclosan
	antibiotic	trimethoprim
polycyclic musks (PCMs)	fragrance	acetyl-hexamethyl-tetrahydro-naphthalene (AHTN)
	fragrance	hexahydrohexamethyl-cyclopentabenzopyran (HHCB)
non-steroidal anti-inflammatory drugs (NSAIDs)	anti-inflammatory	diclofenac
	anti-inflammatory	ibuprofen
	anti-inflammatory	ketoprofen
	anti-inflammatory	naproxen

Analgesics consist of the group of drugs used to relieve pain. These types of medications are sold in large quantities to the public at drug stores and grocery stores, and can also be prescribed by a doctor. Antimicrobials represent another large portion of these pharmaceutical compounds being found. Antimicrobial drugs either kill or prevent the growth of microbes. These drugs are also commonly used and can be purchased or received in a prescription. Chemicals from synthetic hormones are also present in our environment. A push for the increased use of natural hormones over synthetic has gained strength lately. The adverse effects they potentially have on the body and their exposure in the environment are two reasons for concern. These three groups of drugs represent the most widely used and most widely available out of all the chemicals listed. Mean concentrations for the chemicals in these three groups range from 0.001 to 0.1 micrograms per liter.

Analgesics, antimicrobials, and synthetic hormones are widely used and easily obtained after which the excess medications are very often disposed of improperly. Releasing medications down the toilet is one popular method the public uses for disposal. This is a direct cause of pharmaceuticals being present in our water supply, because currently WWTP's do not employ methods for removing trace level pharmaceuticals.

Throughout our research we found that there were many different cited numbers of pharmaceuticals in the water, some cited 35 and others claimed there were 95 and still others in the middle. There are not many ranking systems out in the known literature. While there was already a few ranking systems, they vary so much that it is hard to determine a real list (Arun Kumar, 2010). So we wanted to make our own list and we did so by cross referencing many different sources to see which ones were being tested for, which ones were recurrent throughout

the literature and then used this data to compile our own list. After compiling the list we had to make sure that each item was indeed a pharmaceutical byproduct and not a different byproduct that some of these authors are focusing on, such as detergents and other personal care products. Our final list ended up coming to 114 pharmaceuticals and their byproducts. This leads us to believe that there are an ever increasing number of pharmaceuticals entering our water systems due to many different factors, mainly because there are more and more pharmaceuticals being produced every year and more people consuming them which also tells us that there is never going to be a complete list. As you can see this would lead to a huge problem when trying to figure out treatment options because of the number of different chemicals and the huge variance of levels per site. This further leads to our conclusion that one of the best ways to solve this problem is by prevention.

Table 2 List of Known Pharmaceuticals In Our Water (114)

1, 7-Dimethylxanthine	Dehydrato-crythromycin	Iopamidol	Ranitidine
Acetaminophen	Dehydronifedipine	Iopromide	Roxithromycin
Acetyl Salicylic acid	Demeclocycline	Iothalamic acid	Salbutamol
Albuterol	Diatrizoate	Ketoprofen	Salinomycin
Androstenedione	Diazepam	Lasalocid	Sarafloxacin
Antipyrine	Diclofenac	Levothyroxine	Simvastatin
Atenolol	Dicloxacillin	Lincomycin	Sotalol
Azithromycin	Digoxigenin	Meprobamate	Sulfachloropyridazine
Bacitracin	Dilantin	Methicillin	Sulfadiazine
Benzylpenicillin	Diltiazem	Methotrexate	Sulfadimethoxine
Betaxolol	Diphenhydramine	Metoprolol	Sulfamerazine
Bezafibrate	Doxycycline	Miconazole	Sulfamethazine
Bisoprolol	Enrofloxacin	Minocycline	Sulfamethizole
Caffeine	Erythromycin	Monensin	Sulfamethoxazole
Carazolol	Estradiol	Nadolol	Sulfathiazole
Carbamazepine	Estriol	Nafcillin	Tamoxifen
Carbadox	Estrone	Naproxen	Terbutaline
Celiprolol	Ethynyl estradiol	Narasin	Testosterone
Chloramphenicol	Etofibrate	Norfloxacin	Tetracycline
Chlortetracycline	Fenofibrate	Oleandomycin	Theobromine
Cimetidine	Fenofibric acid	Oxacillin	Theophylline
Ciprofloxacin	Fenoprofen	Oxytetracycline	Timolol
Clarithromycin	Fenoterol	Penicillin	Triclosan
Clen buterol	Fluoxetine	Pentoxifylline	Trimethoprim
Clofibrate	Furosemide	Phenazone	Tylosin
Clofibric acid	Gemfibrozil	Phenoxymethylpenicillin	Virginiamycin
Cloxacillin	Ibuprofen	Prednisone	Warfarin
Codeine	Ifosfamide	Progesterone	
Cyclophosphamide	Indometacine	Propranolol	

Sources: All pharmaceuticals are pulled from all of our sources. Everything found in article tables to experiments. All cross referenced with: National Institute of Health, MedicineNet, The Free Dictionary and Encyclopedia.com to make sure that each one is a pharmaceutical or a byproduct of one.

Concentrations of pharmaceuticals in various places are small, but as seen by the studies on fish and other animals, these small concentrations are causing large effects (Savransky et al., 98).

Table 3. Environmental concentrations of Pharmaceuticals

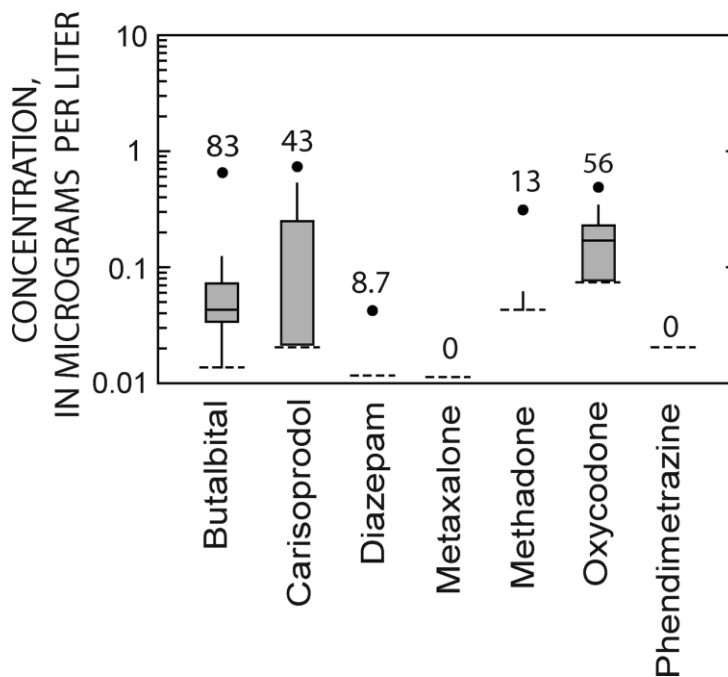
Drinking water	0.3 ug/L
Surface water	2 ug/L
Groundwater	1 ug/L
Municipal sewage (treated)	10 ug/L
Biosolids (treated)	10,000 ug/kg
Agricultural soils	10 ug/kg

Source: Savransky, et al., 98

“Concentration of pharmaceuticals in various environments as of 2005. Treated biosolids have the highest concentration of pharmaceuticals while drinking water has the lowest concentration. (Smith. 2005)” (Savransky et al., 98).

“Concentrations of seven pharmaceuticals analyzed in effluent from 23 wastewater treatment plants sampled across the United States between 2006 and 2009.” (Phillips et al., 2010). The levels show us that some pharmaceuticals are in high concentrations in the water supply while others are not as prevalent. This is just 23 random WWTP samples that are not near each other. Every one has different factors that affect the amount of pharmaceuticals in its effluent. WWTP’s downstream from a large number of hospitals will have higher concentrations than those that don’t.

Figure 3. Concentrations of Pharmaceuticals



Source: Phillips, et al., 2010

The above box plots depict range of concentrations, with top whisker equal to 90th percentile of concentrations, bar at the top of box equal to the 75th percentile, bar at the middle of the box equal to the 50th percentile, bar at the bottom of the box equal to the 25th percentile, bottom whisker equal to the 10th percentile. Dots above the top of the whisker represent maximum concentrations, number above boxplot refers to percent of samples with a positive detection. Dashed line at bottom of boxplot or whisker denotes method detection limit (Phillips et al., 2010).

The data shows us that there are large concentrations and a large number of pharmaceuticals in our environment. But it's not as much the amounts of pharmaceuticals, but rather the effects of these are the real concern.

C. Effects

There have been many experiments conducted on fish to connect the effects shown to what humans would experience. Many experiments show that fish are effected by concentrations of pharmaceuticals. Based on one experiment, one piece of data that we would like to bring forward is something that has not been touched on in any of the research that we have gone through. If fish are affected by waves of pharmaceuticals more than steady levels (Pomati et al., 2007), then the possibility of humans having the same reaction is possible. The levels of pharmaceuticals in water sources that fish would be found in would not be perfectly spread out, instead it would be present in pockets because that is how they are introduced into the water: by flushing of toilets and excretion from manufacturing companies. Not only is this how fish come into contact with this, humans would also come into contact this way in our drinking water; different pharmaceuticals present in different samples of water that comes out of the faucet.

Researchers such as J. L. Parrott and D. T. Bennie have conducted experiments showing that fish are not heavily effected by pharmaceuticals. Others such as Rebecca Klaper have conducted experiments proving the opposite. There are still many unknown variables and effects on animals and plants. The fact is that there is not enough complete data or research conducted to prove either that pharmaceuticals do effect animals and plants or that pharmaceuticals do not effect animals and plants significantly.

D. Bacteria Resistance

One issue that may be of pressing concern is the effect that pharmaceuticals in water are having on bacteria. Many medications have the purpose to attack bacteria and viruses and are effective at high concentrations, but if the levels are lower as they are in drinking water, bacteria

could have a better chance at combating the medication and build up resistance and immunities to it.

“Antibiotics, which are widely used in human and veterinary medicine as well as in agriculture, lead to the selection of antibiotic-resistant microorganisms” (Kemper, 2008). One example, “Tetracycline, is used to treat bacterial infections, including pneumonia and other respiratory tract infections; acne; infections of skin, genital and urinary systems; and the infection that causes stomach ulcers. It also may be used as an alternative to other medications for the treatment of Lyme disease and for the treatment and prevention of anthrax” (National Institute of Health). This antibiotic hinders and stops the growth of bacteria, just like many other pharmaceuticals in both markets and the water. In a study conducted by Harnisz, Gołaś and Pietruk, they found that fish farms heavily use this pharmaceutical to combat bacterial diseases (Miranda et al., 2002). They concluded that this pharmaceutical made “bacteria quickly respond to environmental changes, as demonstrated by the high level of resistance to tetracycline” (Harnisz et al., 2011).

Another study on fish farms shows that bacteria have resistance to such pharmaceuticals as Trimethoprim, Sulfamethoxazole, Erythromycin and Chloramphenicol. Although this type of bacterial resistance to a number of other pharmaceuticals was limited (Miranda et al., 2002). Of the studied bacteria “strains were also resistant to ampicillin in 100% and to amoxicillin in 98%, implying that all of the studied isolates were resistant to multiple drugs (tetracycline and the other tested classes of antibiotics)” (Harnisz et al., 2011).

“These results suggest that Chilean salmon farms might play a role as reservoirs of antibacterial multiresistant bacteria, thus prompting the necessity for a more restrictive attitude towards the intensive use of antibacterial in salmon farming” (Miranda et al., 2002). Because of

the high concentrations of certain pharmaceuticals in fish farms around the world, they are a main focus of study in this subject area because of the amplified results. Pharmaceuticals are also introduced from other sources at lower concentrations but the same effects can be inferred to result from these other sources just as they have proven at fish farms. So bacterial resistance to pharmaceuticals is a problem with many types of pharmaceuticals, but based on these studies, not all are as heavily affected as others or affected at all.

E. Treatment Plants and how they work

Most WWTP's have a three stage process for treating waste water. The preliminary stage occurs right when the waste water enters the plant. It is passed through a metal screen to remove large sediments, grit and scum. From there the water is sent to primary settling tanks. In these tanks the flow velocity is reduced to approximately one foot per second which allows for heavier solids to settle down to the bottom and also allows for grease and scum to collect on the surface for removal (Stackelber et al., 2004). The water is then sent to the secondary treatment system which uses aeration basins to remove bulk organic content nitrogen from the water to meet the discharge limits. These basins may use fine bubble diffusers in a series of aerated zones followed by anoxic zones to lower the nitrogen levels (USGS, 2010).

A possible following process begins with phosphorous removal which is a two stage process where each uses large reaction clarifiers which are usually arranged in series. Ferric chloride is then added at about a 34 percent concentration to achieve chemical precipitation of phosphorus (Friedman, 2000). In few of the larger WWTP's, water is may sent to rectangular basins whose beds of media consist of gravel, sand, and anthracite coal granules, through which

the water is filtered to remove additional solids and phosphorus. This process is known as gravity filtration, and though it is not a common process can be effective, which leads directly to granular activated carbon absorption basins. These basins are lined up either in series or parallel with the gravity filters to supplement them (USGS, 2010). A sodium hypochlorite solution may be added to the water for disinfection and then sodium bisulfate may be added to help neutralize any of the chlorine residues that are left over (Friedman, 2000).

When the sediments, grit, grease, and chemicals are removed, they become sludge and this sludge goes through a dewatering process. Through the first three stages of the treatment process this sludge is either collected straight out of the filters or is pumped into a dissolved air flotation thickener or gravity thickener before it is dewatered. The gravity thickener is used to increase the percentage of solids in the primary sludge and the flotation thickener processes the secondary waste activated sludge. Later the chemical sludge from the tertiary treatment is blended with the primary sludge (Friedman, 2000).

The combined thickened sludge from the mixture of the sludge from the different stages is then pumped into storage tanks or straight into a centrifuge. Polymer is mixed with the sludge that is pumped into the centrifuges which is then dewatered down to achieve about 23 to 28 percent solids. The sludge that is stored is processed by lime stabilization which uses hydrated lime to reduce pathogens and odors (Friedman, 2000). This process creates bio-solids which are then disposed of through incineration, for land application, or is sent to a landfill (USGS, 2010).

There are close to 3000 water treatment plants throughout Massachusetts. The different types can be categorized by three types. In Massachusetts there are groundwater plants, surface water plants (which is the type of plant which serves Worcester), and indirect discharge plants. There are also hundreds of thousands personal treatment systems and devices throughout

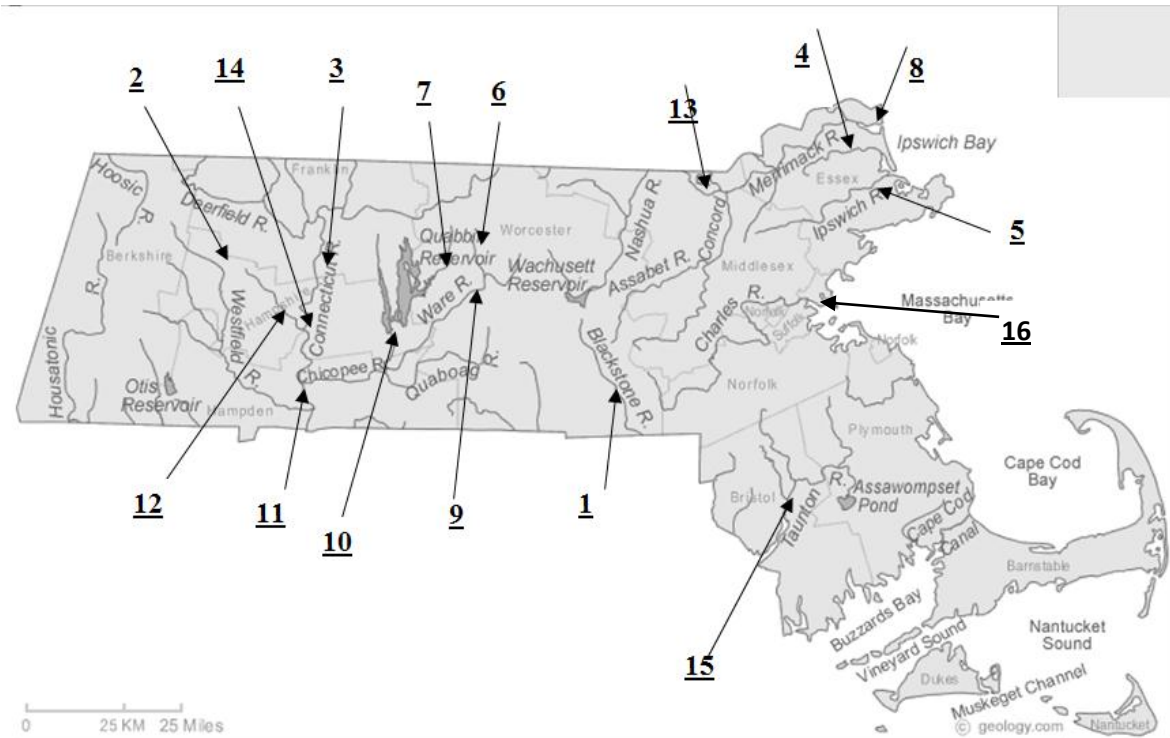
Massachusetts. Most modern day houses have their own system or have devices which treat and purify the water before consumption. Massachusetts also has a number of natural “systems” which purify water without any help from man made things (Wastewater Treatment Plants & Operators).

Ground water plants are usually smaller and will treat a smaller amount of water a day. The water collected by these plants may emerge as springs, artesian springs, or may be extracted from boreholes or wells. The water emerging from some of the deep ground water may have fallen as rain anywhere from tens to thousands of years ago. Soil and rock layers naturally filter the ground water to a high degree of clarity before the treatment plant. Deep ground water is generally of very high bacteriological quality, but the water typically is rich in dissolved solids, especially carbonates and sulfates of calcium and magnesium. Depending on the strata through which the water has flowed, other ions may also be present including chloride, and bicarbonate. There may be a requirement to reduce the iron or manganese content of this water to make it pleasant for drinking, cooking, and laundry use. Some of these treatment plants practice groundwater recharge. Ground water recharge is a process in which river water is injected into an aquifer to store the water in times of plenty so that it is available in times of drought. This process is equivalent to lowland surface waters for treatment purpose (Groundwater Discharge Permitting).

Surface water plants can treat several million gallons worth of water daily. There are two types of surface water plants: Waste Water Treatment plants and Water Treatment Plants. Water Treatment Plants are mainly located near large basins or bodies of water that resemble a reservoir. This is because they bring in the water from these sources to treat then distribute the clean water to communities and other populated areas (Surface Water Discharge Permitting

(NPDES)). WWTP's are generally located near rivers to allow for the treated water to be released back into the river.

Figure 4. Map of large Wastewater Treatment Plants in Massachusetts



Source: Massachusetts Facilities Online

Indirect discharge plants are the most numerous plants in Massachusetts. Indirect dischargers are different from other WWTP's in that they do not actually treat the water, they redirect wastewater and effluent from plants through shallow unsaturated soils or groundwater for additional polishing and diffusion before it is discharged to surface water. Some of the benefits of indirect discharge are that the wastewater temperature can be reduced in the groundwater or hyporheic to meet in-stream temperatures which would allow for stream flow volumes to be maintained. Also if a plant application is used in the design than the nutrients in

the water can be beneficially reused by plants and can reduce the nutrient load of the plant which the effluent is coming from (Lancaster, Haggerty, Gregory, Farthing, & Biorn-Hansen, 2007).

Table 4. Locations of large Waste Water Treatment Plants in Massachusetts

<u>Number</u>	<u>Name</u>	<u>Address</u>	<u>River</u>
1	Blackstone WWTP	13 Maple Ave, Upton, MA	Blackstone River
2	Deerfield WWTP	150 Sunderland Rd, South Deerfield, MA	Deerfield river
3	Erving Center WWTP	45 E Main St, Erving, MA	Conneticut
4	City of Haverhill WWTP	4 Summer St, Haverhill, MA	Merrimcak River
5	Earth Tech Gloucester WWTP	50 Essex Ave, Gloucester, MA	Ipswich River
6	Winchendon WWTP	637 River St, Winchendon, MA	Conneticut River
7	Templeton Town WWTP	33 Reservoir St, Baldwinville, MA	Conneticut River
8	Amesbury WWTP	19 Merrimac St, Amesbury, Ma	Merrimcak River
9	West Warren WWTP	2527 Main S, West Warren, MA	Ware River
10	Three Rivers WWTP	1 Norbell St, Three Rivers, MA	Chicopee River
11	Springfield WWTP	1550 Main St, Springfield, MA	Chicopee River
12	Hatfield WWTP	260 Main St, Hatfield, MA	Conneticut River
13	Fitchburg WWTP	24 Lanidies Ln, Fitchburg, MA	Concord River
14	Town of Sunderland WWTP	111 River Rd, Sunderland, MA	Conneticut River
15	City of New Bedford WWTP	100 S Rodney French Blvd, New Bedford, MA	Taunton River
16	Deer Island WWTP	190 Tafts Ave, Winthrop, MA	Massachusetts Bay

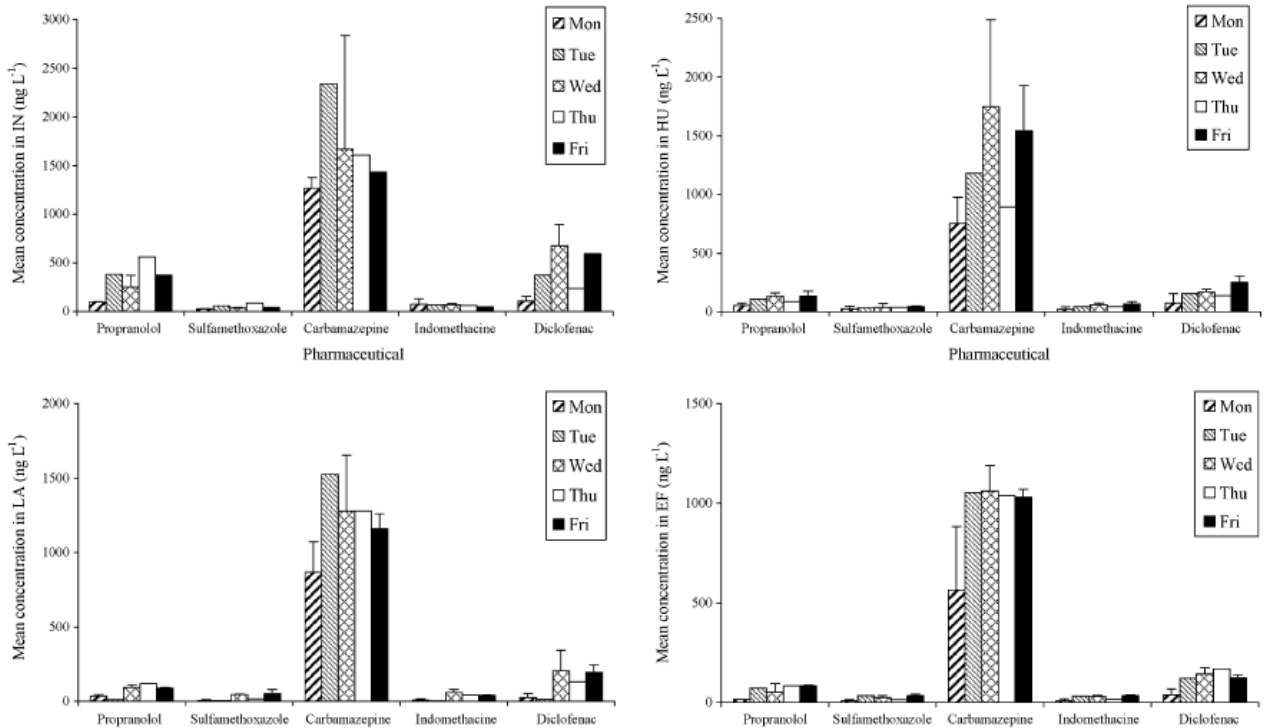
Source: Massachusetts Facilities Online

The map and table above shows the locations of the 15 larger WWTP's in Massachusetts. Private systems and devices that treat and purify water can be found across the state in nearly every household, community or public building. These systems and devices range from

household water purifiers to small water treatment systems which treat water for a community, a town, or even a city.

In 2006 the National Health Service (NHS) did a study to determine the effectiveness of WWTP's on pharmaceuticals. They tested for the concentration of five pharmaceuticals in the four main stages of the Scaynes Hill waste water treatment plant. The five pharmaceuticals which were tested for were propranolol, sulfamethoxazole, carbamazepine, indomethacine and diclofenac and the four stages which they tested were the influent, the humus tank, the lagoon, and the effluent. The NHS took multiple water samples, from each of these stages, Monday through Friday and then took the concentrations they got of the 5 pharmaceuticals and averaged them out.

Figure 5. Waste Water Effluent Samples



Sources: Zhou et al., 2009

The study showed that in the influent, which is where the waste water first enters, the mean concentration of the pharmaceuticals ranged from about 100 ngL^{-1} to 2500 ngL^{-1} . These concentrations dropped by about 20% from the influent stage to the humus tank, which is the second stage. From the humus tank stage to the lagoon, the third stage, the mean concentration of the pharmaceuticals dropped another 15%. Then, from the humus tank to the effluent or end of the treatment process the concentrations dropped a final 15%. So the mean concentration dropped about a total of 50% which while is a high percentage is not a large amount of these pharmaceuticals being eliminated. So NHS concluded that, while pharmaceuticals were slightly reduced, the treatment process was not very effective in treating these pharmaceuticals (Zhou et al., 2009).

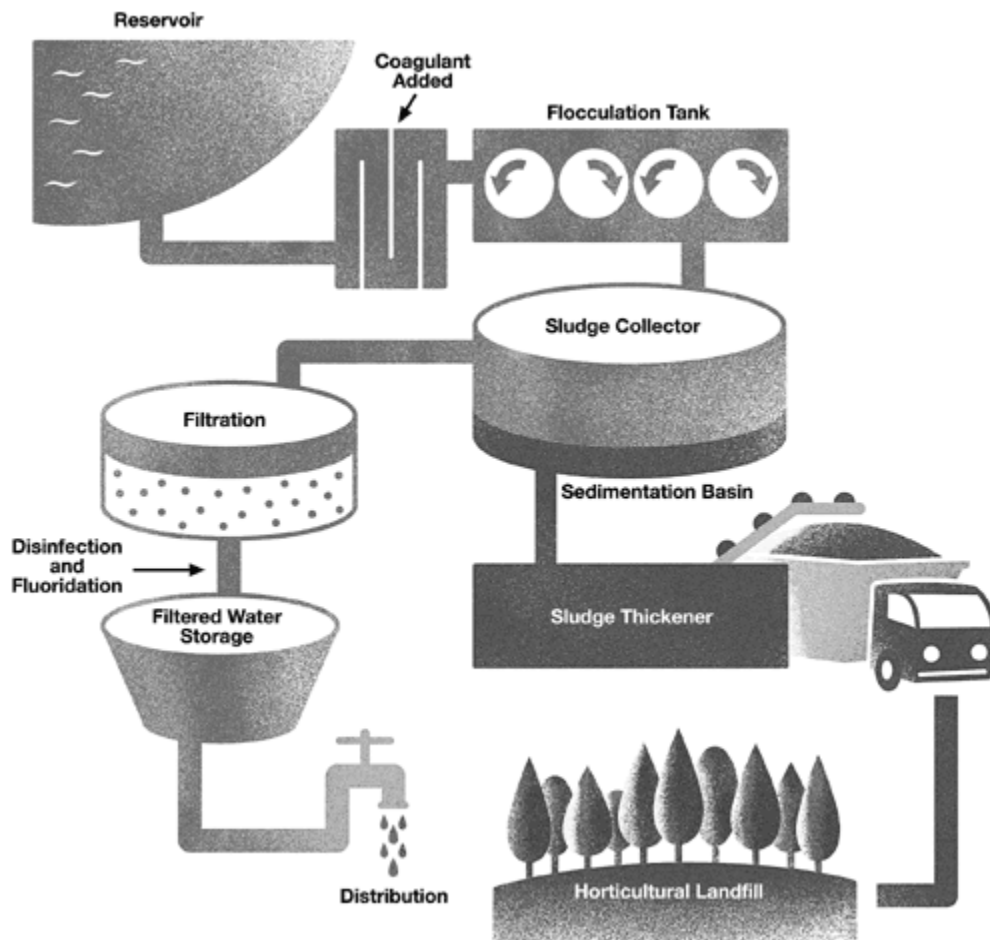
F. Which treatments are effective

The first type, Chlorination is one of the most common method of treatment for water around the world. Chlorine is added to the water to combat bacteria and viruses and a large portion of Massachusetts plants utilizes this system for treating water. When used as treatment there needs to be a certain level of free chlorine, which is the excess chlorine that didn't react with anything, to combat bacteria along the way to its final destination. The accepted level is a concentration of 0.3-0.5 mg/l (Wilkes University).

The method of flocculation is used for bringing out materials that were once dissolved in the water out so that a filter can grab ahold of them. While this was originally designed by Professor Wilfred F. Langelier for the use of heavy metals and solids (Hendricks, 2006), it has recently been experimented with to see how effective it is at removing pharmaceuticals. Coagulation is somewhat similar to flocculation in that the goal is to make larger particles that

will either settle to the bottom or be able to get filtered. The difference is that coagulation combines the particles using positive charges from iron or aluminum salts (Foundation). This step is usually what is done prior to flocculation and both methods are used in combination to be an effective step in the water purification process (University of Waterloo Canada). Ternes and a few colleagues conducted an experiment with Flocculation using Iron (III) chloride and the results showed no real effect on the pharmaceuticals present (Ternes et al., 2002). Also many other similar experiments have confirmed this data (Suarez et al., 2009) so flocculation and coagulation can be taken out of the list for methods to treat pharmaceuticals.

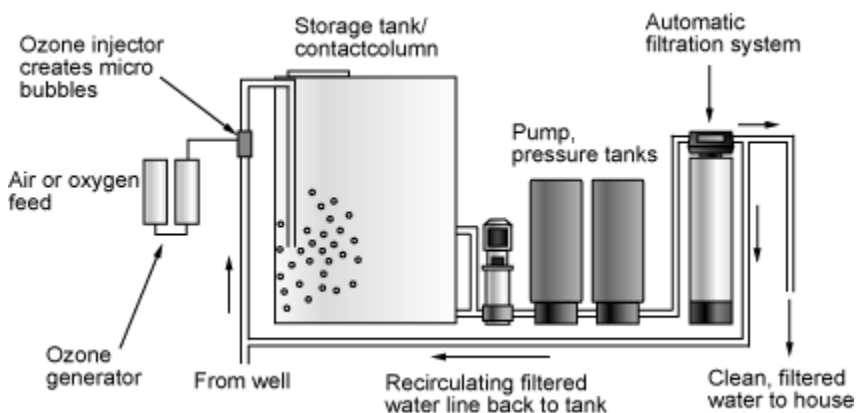
Figure 6. Flocculation and Coagulant Diagram



Source: <http://www.ogwa-hydrog.ca/en/node/39>, 2009

Many experiments have been conducted using ozonation in the hope of finding the method that will purify water of all pharmaceuticals. The way that ozonation works is that it oxidizes the organics that make up the pharmaceutical molecules (National Drinking Water Clearinghouse, 1999).

Figure 7. Ozonation filtration process



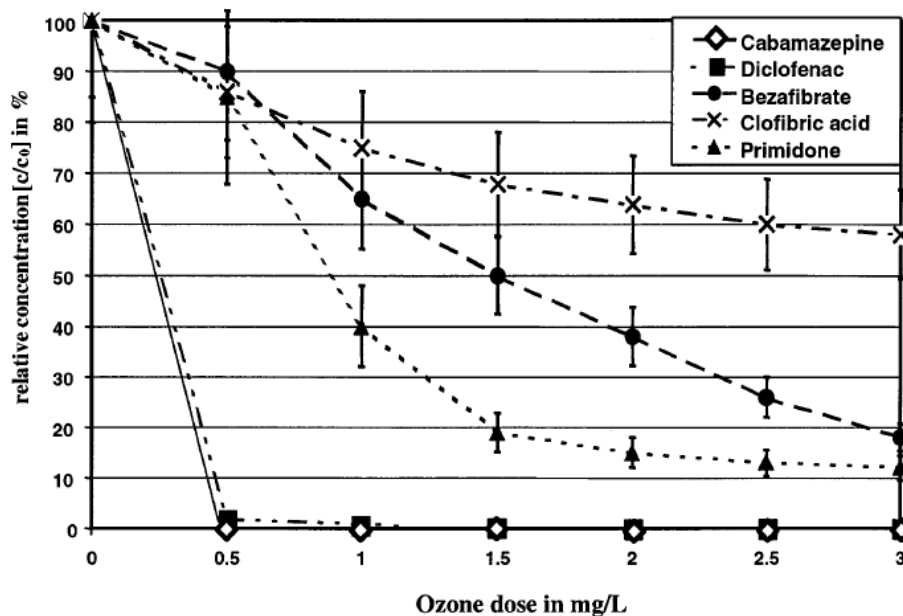
Source: Excel Water Technologies, INC., 2007

Through the many experiments conducted it has been found that there is no guarantee that ozonation will react with all the pharmaceutical compounds that are found in the water and is only effective in combating pharmaceuticals to a certain extent. It is believed to be a selective oxidant, which means that it only reacts with certain molecules easily. The experiments that have been conducted are in a stable and limited variable environment (Zwiener et al., 2000). Even the pharmaceuticals that ozonation does react with, experiments show the highest results reacting with 90% of the pharmaceuticals present but this result is not repeated with many experiments on pharmaceuticals (Ternes et al., 2002). After taking into consideration the many types of particles in the water that are in high quantities and the fact that pharmaceuticals are in low

concentrations, it can be inferred that in real scenarios less pharmaceuticals will be able to react with ozonation and then be filtered than was shown in experiments (Zwiener et al., 2000).

In the experiments Ternes conducted, he used different amounts of ozone to determine the different levels of effects. Using 0.5 mg/L it “was shown to reduce the concentrations of diclofenac and carbamazepine by more than 90%” (Ternes et al., 2002). The results for other pharmaceuticals showed less efficiency in reacting with ozonation. With an increase in ozone to 1.5mg/L, bezafibrate only decreased total concentration by 50%. With an increase of ozone to 3 mg/L, which is an extremely high level of ozone, there was only a 30% decrease in clofibric acid levels which is shown in the figure below (Ternes et al., 2002).

Figure 8. Amount of ozone required to treat select pharmaceuticals

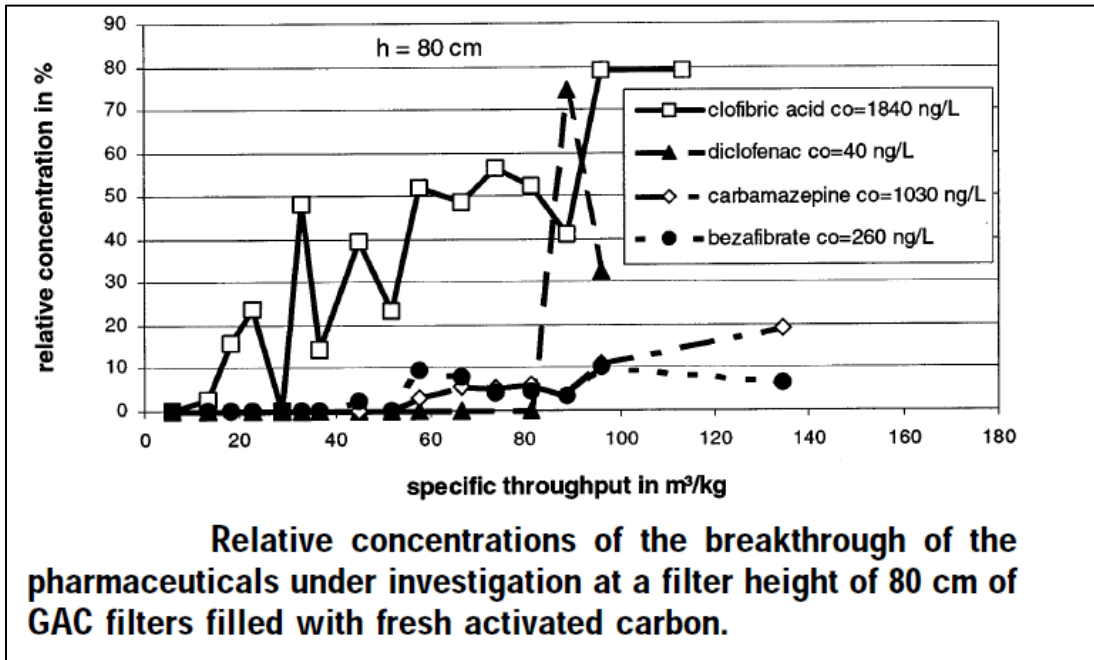


Source: Ternes, et al., 2002

Adsorption is another way to purify water. The process involves a solid or liquid surface that reacts with gases or liquids to form a film (Adsorption). There are two ways in which this can happen, physisorption and chemisorption. Physisorption is a reaction involving Van der Waal bonds that are weaker than the bonds that form through chemisorption (Chemisorption and physisorption , 2002).

There are many different types of adsorption to include chromatography and activated carbon. Chromatography is a procedure that separates mixtures by passing through a membrane or dissolved mixture (medical-dictionary, 2011). Ternes concluded in one of his experiments that the pharmaceuticals had good results with Granular Activated Carbon (Ternes et al., 2002). Granular Activated Carbon is used as an adsorption technique. Due to its high surface area of 500 m² per gram it is very effective and is even used when a person swallows a toxic chemical (Chemisorption and physisorption, 2002). In water treatment the water moves through a thick bed of activated carbon for the water to be cleaned. Different particles and pharmaceuticals require a certain throughput or rate of entry for it to react efficiently with the activated carbon and each pharmaceutical is different. Ternes had positive results in one of his experiment and the “four selected pharmaceuticals can be removed efficiently under real conditions by activated carbon filtration in waterworks.” (Ternes et al., 2002). As you can see by the graph below, the different throughputs are what affect the percentage of pharmaceuticals that were taken out of the water.

Figure 9. Concentrations of pharmaceuticals using GAC filters



Source: Ternes, et al., 2002

As with ozonation, adsorption is only so effective against pharmaceuticals in real conditions due to the competition that the different particles have with reactants.

Ozonation and adsorption are the treatments that have shown to be effective, but only in perfect conditions. The actual effectiveness of these treatment methods under real circumstances still prove to be shown, but if any treatments are going to be effective, these two are the ones to work with.

G. Worcester Treatment Plant and Hospitals

G1. Hospital Data

The treatment of waste water that comes from hospitals, private households, and other facilities within Massachusetts fall under the duties of the MassDEP (Massachusetts Department of Environmental Protection). Similarly, in other states, the state's environmental health agency or department holds the responsibility of treating this waste. The MassDEP has regulations according to the type of business or facility, for which each is given a Standard Industrial Classification (SIC). Their regulations on hospitals are outlined below:

“Hospitals - Toilet waste and water from sinks, showers, and laundry is sanitary wastewater and can go to a septic system as long as it's less than 10,000 gallons per day. However, it is unlikely that a hospital would discharge less than 10,000 gallons per day. Any lab wastewater generated needs to be stored in an industrial wastewater holding tank permitted by MassDEP.” (Department of Environmental Protection).

These regulations are based on the amount of water discharged and have no regulations on pharmaceutical content or emerging contaminants. The MassDEP does not currently employ any alternative methods of removal for treating pharmaceuticals. However, they do evaluate potential risks of PPCPs and EDCs to human health and the environment.

With the number of complex procedures that take place in hospitals and the number of pharmaceuticals needed for post treatment, it is obvious that there are a large number of pharmaceuticals going through hospitals. At Worcester Memorial/State Hospital there are a large number of these types of procedures, just as an example see figure below.

Table 5. Common Procedures conducted at Worcester Memorial/State Hospital

Common Procedures	Volume
Coronary Artery Bypass Graft (CABG)	489
Valve Surgery	88
Percutaneous Coronary Intervention (PCI)	1,440
Abdominal Aortic Aneurysm Repair (AAA)	119
Carotid Endarterectomy (CEA)	157
Lower Extremity Bypass	156
Angioplasty/Stent	352
All Hip Replacements and Revisions	381
All Knee Replacements and Revisions	491
Bariatric Surgery	577

Source: Worcester Memorial Hospital, 2011

In Worcester there are four main hospitals that contribute to the pharmaceutical output into Worcester waste water.

1. At UMass Memorial Medical Center - University Campus there are 690 beds with 222,884 inpatient days. This includes both UMass Memorial Medical Center - Hahnemann Campus and UMass Memorial Medical Center - Memorial Campus (Revolution Health, 2011).
2. At Saint Vincent Hospital there are 321 beds with a total of 15, 995 inpatients last year (American Hospital Directory, 2010).
3. At Worcester State Hospital there are 126 beds with a total inpatient days of 42, 097 (American Hospital Directory, 2010).
4. At Fairlawn Rehabilitation Hospital there are 110 beds and a total of 28, 804 inpatient days (American Hospital Directory, 2010).

This data can be used in conjunction with the average amount of pharmaceuticals passed per bed to find the average amount of pharmaceuticals passed through Worcester’s hospital system. While there is a differentiation between general hospitals and psychiatric hospitals and this should be taken into consideration when calculating the Worcester excretion, the main hospitals in Worcester are all general hospitals. “The general and psychiatric hospitals showed very different pharmaceutical usage patterns in 2007. First, the total amount of pharmaceuticals differed substantially. In the general hospital, 779 kg were excreted, from which we can predict a load excreted from each “bed” of 2.3 kg per year. In the psychiatric hospital only 17 kg were excreted, which gives an excreted load of 0.08 kg per bed” (Escher et al., 2011). At Saint Vincent Hospital there is an average of 738.3 kg of pharmaceuticals excreted per year. Worcester State Hospital is 289.8 kg per year and 1587 kg per year for UMASS Memorial Medical Center. Fairlawn Rehabilitation Hospital has an average of 253kg per year. This totals 2, 868.1 kg of pharmaceuticals discharged by these four hospitals in the Worcester area per year.

Table 6. Summary of Worcester Hospital Data

Hospital	Number of Beds	Inpatient Days	Avg. pharmaceuticals per bed (kg)	Avg. pharmaceuticals per year (kg)
UMass Memorial Medical Center	690	222,884	2.3	1587
Saint Vincent Hospital	321	15,995	2.3	738.3
Worcester State Hospital	126	42,097	2.3	289.8
Fairlawn Rehabilitation Hospital	110	28,804	2.3	253
Total				2868.1

Utilizing the number of beds in Worcester and the amount of pharmaceuticals discharged in Worcester as well as the average flow per hospital bed, the total concentration of pharmaceuticals in the water can be calculated. Worcester has 1,247 beds and an average of 165 gallons per bed per day or 60,225 gallons in a year and a total of 2,868.1 kg of pharmaceuticals excreted per year (Metcalf & Eddy, 2003)

Calculations:

$$1247 \text{ beds} \times 165 \text{ gal per day/bed} = 205,755 \text{ gal per day}$$

$$205,755 \text{ gal per day} \times 365 \text{ days per year} = 75,100,575 \text{ gal per year}$$

$$\frac{2868.1 \text{ Kg per year}}{75,100,575 \text{ gal per year}} = 0.000038 \text{ Kg/gal}$$

$$0.000038 \text{ Kg/gal} \times 1000 = 0.038 \text{ g/gal}$$

$$0.038 \text{ g/gal} \times 1000000 = 38000 \text{ } \mu\text{g/gal}$$

$$\frac{38000 \text{ } \mu\text{g/gal}}{3.7854} = 10038.57 \text{ } \mu\text{g/L}$$

This shows us that 10038.57 $\mu\text{g/L}$ of pharmaceuticals are being discharged from the Worcester hospitals.

G2. Cost-Benefit Analysis For Implementing Ozonation As a Form of Treatment

Figure 10. Worcester's Water Treatment Basics

Plant Flow - 50 Million Gallons Per Day (MGD)

Reservoir System - The treatment plant utilizes a series of ten surface water reservoirs located in Leicester, Paxton, Rutland, Holden, and Princeton. The ten reservoirs combined, hold over 7 billion gallons of water.

Primary Disinfection - Ozone, generated by four ozone generators (one standby) from air with a system capacity of 834 pounds per day. The applied ozone averages 1 mg/L, with a design maximum of 2 mg/L.

Rapid Mixing/Coagulation - Two-stages, utilizing vertical shaft radial turbine mixers. Coagulant chemicals are aluminum sulfate (alum) and cationic polymer.

Flocculation - Three stages, having a total of 15 min. detention time and utilizing vertical- shaft, axial-flow flocculators. nonionic polymer is provided as a filtration aid.

Filtration - Eight filters having a design filtration rate of 8 gpm/sf. Filter media consists of 60 inches of anthracite coal over 12 inches of sand. The filters are designed to accept activated carbon media if needed in the future.

Corrosion Control - pH adjustment using lime, followed by an application of a blended orthophosphate corrosion inhibitor.

Final Disinfection - Chlorine

Treated Water Storage - Two, 2.75-million-gallon storage tanks.

Source: Water Treatment Plant, 2011

To determine the level of effectiveness to cost ratio of having ozonation as the treatment option we used the Worcester, Ma water treatment plant as an example. The Worcester water treatment plant is one of the few water treatment plants in Massachusetts that uses ozonation as part of the process for filtration. Recently built, the design included ozonation as its primary method because “The pilot testing revealed that pretreatment would best be achieved by pre-

ozonation, coagulation, and flocculation using alum and cationic polymer. Combined with direct filtration through a deep-bed anthracite filter, these processes were the most effective and economical water treatment process for Worcester.” (Water Treatment Plant, 2011). There are many different variables to the pilot test that may have affected the economical values of the decision and was conducted by professionals. When this was built it is very unlikely that pharmaceuticals were considered as one of the variables to bring reason to implement this as there are still currently many studies going on. So we will try to determine the cost to effectiveness ratio still.

Leaving out the overhead cost of implementing the initial machines and structure of the plant and solely looking at day to day activity we can compare the costs for ozonation based plants and other plants to see which is more cost effective as well as see if either one is more cost effective for treating pharmaceuticals. The average flow rate per day through the Worcester Water Treatment Plant is 23.2 Million Gallons Per Day (MGD) and the cost for ozone per Million Gallon (MG) is \$9.33/MG. The electric cost for treating 8,466,180,000 gallons was \$79,000 which gives us the \$9.33/MG. Based on these average numbers it cost \$216 per day of operation for ozonation. A major consideration for these results is that every plant is unique due to the flow rates and quality of water. Also the size of the Worcester Water Treatment Plant is larger than most other systems that would be implemented which likely dampens the unit costs (Interview, 2011).

In comparison of ozone and chlorine as treatment methods the numbers to look at is the amount of chlorine still used prior to the implementation of ozonation and the amount used currently. Prior to the implementation of ozonation, the average chlorine dose per million gallons was 28.45 pounds per million gallons. At the time this equaled 239,295 pounds of chlorine per

year which also shows us that 8,411,072,056 gallons was the flow rate per year at this time. This a 50,107,944 gallon difference lower than the current flow rate that goes through the ozonation process. With the current process there is an average of 24.92 pounds per million gallons for a total of 192,390 pounds of chlorine per year (Interview, 2011). This shows us that the amount of chlorine needed is not affected much by the implementation of an ozonation system as only 46,905 pounds of chlorine is saved from the process. It also potentially shows us that ozone reacts with chlorine and that is why so much is needed in the system.

Table 7: Summary of Ozonation vs. Chlorine Analysis

Factors	Ozonation Plant	Chlorine Plant	Ozone Difference
Plant flow rate per year	8,466,180,000 gallons	8,411,072,056 gallons	50,107,944 gallons
Cost of ozone	\$9.33/MG	\$0/MG	\$9.33/MG more
Cost of ozone per day	\$216	\$0	\$216/day more
Cost of ozone per year	\$79,000	\$0	\$79,000/year more
Chlorine used per MG	24.92 pounds	28.45 pounds	3.53 pounds/MG less
Chlorine used per year	192,390 pounds	239,295 pounds	46,905 pounds less

We were not able to obtain the cost per pound for chlorine, so we were not able to calculate the cost of the chlorine. Overall money is not saved from implementing an ozonation system although it is comparable. It is the only option of the two that really is effective in treating pharmaceuticals. The real analysis does not lie in cost but in the effectiveness of chlorine versus ozonation.

So based on these results we can infer that the Worcester Water Treatment plant which averages 1 mg/L ozonation, that some pharmaceuticals such as diclofenac and carbamazepine can be fully combated in Worcester's treatment plant, in optimal conditions.

Other pharmaceuticals such as bezafibrate are treated but they are not treated to the full extent because there is not enough ozone in the treatment process. Our data tells us that making ozonation treatment plants somewhat effective in combating pharmaceuticals primarily for the sake of combating pharmaceuticals.

V. Solutions

AA. Legislation

In 1989 the state legislature of Massachusetts passed the Toxics Use Reduction Act (TURA). This act requires companies in Massachusetts that use large quantities of specified “toxic” chemicals to evaluate and plan pollution prevention practices. If these practices were deemed practical then the companies were to implement them, then measure and report the results of these practices (Toxics Use Reduction Act (TURA) Program Overview).

- Reduce the generation of toxic waste by 50 percent statewide (this was accomplished by 1998);
- Establish toxics use reduction (TUR) as the preferred means for achieving compliance with federal and state environmental, public health and work safety laws and regulations;
- Provide and maintain competitive advantages for Massachusetts businesses, both large and small, while advancing innovation in cleaner production techniques;
- Enhance and strengthen environmental law enforcement across the state; and
- Promote coordination and cooperation among all state agencies that administer toxics-related programs.

On July 28, 2006 Governor Mitt Romney signed into law major amendments to the Toxic Use Reduction Act. Some of the things these amendments did was help to streamline the

reporting and planning requirements for pollution prevention. They also established a categorization system for categorizing chemicals as high hazard and low hazard with different reporting thresholds (Toxics Use Reduction Act (TURA) Program Overview).

In 1970 Congress passed the Controlled Substances Act (CSA) as Title II of the Comprehensive Drug Abuse Prevention and Control Act of 1970. The CSA is the federal U.S. drug policy under which the manufacture, importation, possession, use and distribution of certain “controlled” substances (21 USC CHAPTER 13 - DRUG ABUSE PREVENTION AND CONTROL). In September of 2010 the CSA was amended with the implication of the Secure and Responsible Drug Disposal Act of 2010. This act allows a user of a controlled substance, who has lawfully attained the substance, to deliver that substance to another person, without being registered, for disposal. The person that is receiving the substance has to be authorized to dispose of the substance and also the substance has to be disposed of in accordance with regulations set by the Attorney General (Secure and Responsible Drug Disposal Act of 2010) .

Under the Secure and Responsible Drug Disposal Act the Attorney General is required to take into account a few different factors when developing regulations. They have to take into consideration the public health and safety, also the ease and cost of program implementation and participation by various communities. This act also gives the Attorney General power to, through regulations, authorize long-term care facilities to dispose of controlled substances on behalf of users who reside at these long-term care facilities in a manner which will provide effective controls against diversion and be consistent with public health and safety (Secure and Responsible Drug Disposal Act of 2010).

One alternative that MassDEP could look into to reduce the amount of pharmaceutical contaminants in wastewater is to apply treatment at the source. The type of treatment process

would depend upon the facility or location, and the levels at which pharmaceutical were present. For example, Hospitals, which have: high levels of PPCPs & EDCs, and a wider range of contaminants, would likely use multiple methods of treatment which could include: chlorination, carbon filtration, and ozonation. The high levels of PPCPs and EDCs found in hospital wastewater would require extensive treatment, whereas private households or other smaller facilities may require only one alternative treatment method.

BB. Disposal Solutions

Through our research we have come up with a couple solutions to help lower the concentration of pharmaceuticals getting into the water supply. A major problem we found was with the way that pharmaceuticals were being disposed of and that there were no regulations on their proper disposal. There are examples of how communities set up collection points to gather and then properly dispose of medications. This is a good idea and should be implemented everywhere.

Most prescription drugs and other medications can be legally discarded in the trash. However, to reduce the risk of these medications falling into the wrong hands after they are disposed, the FDA has guidelines for citizens to follow.

First, all medication should be removed from the prescription container, and any personal information should be removed from the prescription bottle. As long as the medication does not specify to flush down the toilet only, then it is ok to throw away. One suggestion when discarding is to mix any medication with substances such as kitty litter before being thrown in the trash. Another option is to take old medicine, if it is in pill form, and pulverize the pills before throwing them away. After they are crushed, return them to their container and place the

container inside several zip lock plastic bags or a thick plastic container. Once this has been completed, the package can now be tossed into the trash. There are a few problems with this method, however. Many people don't like to waste their plastic bags or a container by throwing them out with old medicine. Plastic does not degrade easily, if at all. In addition, there's still a chance that the medicine can leak out of the various bags and present a hazard (EPA, Take-Back Programs or Events for Unneeded or Expired Pharmaceuticals). These suggestions are in place to help reduce the risk of these chemicals reaching the environment. This does little to avoid the fact that everything thrown in the trash still reaches a landfill where it has the potential to enter the groundwater.

Some medications may instruct the user to discard in the toilet, if there is any leftover. This method may not be any safer than throwing in the trash, because it still is contaminating our water supply. The reason some drugs are supposed to be disposed this way is because of their high concentrations of certain ingredients. For example, prescription pain pills with large doses of pain reliever may have recommendations of disposing an unused medication by flushing them. This method is no longer preferred, because like disposing in the trash, this method still gives potential for the chemicals to enter our water supply.

The best collection methods we found are known as community take-back programs which not only keep chemicals and pharmaceuticals out of the water supply, but they keep unused medications from being illegally abused or sold. The first step is to contact the local pharmacy about their 'take-back' methods. Many pharmacies have drug recycling programs in place at their store. Some locations may take back these drugs at any time; others hold periodic drives to collect expired medicine. They will take back your expired or unused medication and make sure that it is disposed of correctly. If the local pharmacy doesn't take back your old drugs,

they may have alternate recommendations or can direct you to a pharmacy which has these capabilities.

This method represents the best way to dispose, properly, of any unused or unwanted medications. Every day, millions of people take prescription drugs or other drugs which pass through their bodies, and end up in the water anyway. "... The main way drug residues enter water systems is by people taking medications and then naturally passing them through their bodies, says Raanan Bloom, PhD" (U.S. Food and Drug Administration). Therefore, we must find a solution to limit the amount of chemicals which pass through our bodies. Or we must limit the chemicals in our wastes from entering our WWTP's, where they do not test for pharmaceutical and similar contaminants.

There have been a few community take back programs which can be used as precedents for creating a take back program for Worcester. The first one we looked at was the Colorado Medication Take-Back Pilot Project. The Colorado Medication Take-Back Pilot Project is a local program which stretches over several counties in the Denver area of Colorado. The article states: "The collection boxes can be found at eleven convenient locations - nine on the Front Range and two in Summit County" (Summit Water Quality Committee, 2011). Although this is only a small collection area, it gives many residents of Colorado the chance to properly dispose of certain unused medications. The DEA restricts anyone from collecting narcotics or any other controlled substances; therefore, there are restrictions on what may be dropped off. This project is intended to last through the year 2011 (Summit Water Quality Committee, 2011). Take back programs like this could find success on a small local level, but does not create much awareness on a national level.

We looked also at the Walgreens Mail-Back Program. Walgreens has launched the first ongoing, nationwide Safe Medication Disposal Program, a safe and environmentally responsible way to dispose of unused or expired medications” (Sharps Compliance Corp.). Walgreens launched this program in late 2010, and is expecting to take back millions of unused medications that would have otherwise been improperly discarded. The way this program works is through a mail-back envelope which can be purchased at any Walgreens location. The unused drugs/medications are loaded into the envelope and mailed to a facility which will properly dispose of the material. Another Program we looked at was Las Vegas PD Collection Sites. Nevada’s Bureau of Water Pollution Control States that some Police Stations in downtown Las Vegas began to take back old or unused medication in February 2011. Upon further reading, there are a total of nine police stations in the Las Vegas community that offer this program (Valley, 2011). Las Vegas Police and city officials hope this will prompt residents to check the expiration dates on all their medications, and dispose of them if needed.

In Washington State they created several Collection Areas to build the Take Back Network. The Take Back Network states that in Washington State: “Several pharmacies and law enforcement offices across the state offer medicine return programs.” It goes on to describe that Law enforcement officers usually take all medicines, including controlled substances. For all other medicines which are not controlled substances, “ ...can be returned to any Group Health Pharmacy locations in Washington State, and select Bartell Drugs pharmacies around Puget Sound” (Unwanted Medicine Return Program). After scanning through the pages of collection facilities, it is apparent that Washington State has the most collection facilities of any state so far. This in turn offers citizens across the state locations to drop their unused/unwanted medications without having to travel too far.

These various collection programs are all relatively small local projects. Currently, there are no state-wide programs which offer state mandated locations to drop off medicines. The Walgreens program comes at a cost; however it is available to a larger audience than any of the other programs. This option may be more successful than collecting unused medication on site, or inside a pharmacy. “The drawback associated with the pharmacy-as-collection-point model is that pharmacy employees are not permitted to collect and dispose of controlled substances” (Cotter, 2006).

Currently, there is at least one collection site which accepts medications, sharps, or old electronics in only 15 states in the US (Take Back Express Website). This shows that awareness is limited but growing around the country. Establishing large city or state take-back programs seems like the next necessary step.

Using these programs as precedents we decided on two possible solutions to implement in Worcester, MA. One possible solution to reduce the amount of drugs improperly disposed of in Worcester is to develop a curbside pickup program. Currently, Worcester uses a curbside trash and recycling program which has shown some success. Citizens must buy Worcester trash bags at any local grocery store and use them to dispose of their household trash in. Then they must be brought to curbside once a week, preferably in the early morning hours, right before pickup. Also, all recyclables must be put into a plastic bin and taken out to the curb as well. A similar program could be developed or added to this existing setup which would provide for medicine disposal.

A collection box or bag would have to be developed with security in mind. Although Federal Law restricts anyone from picking up or dropping off any controlled substances, many other medicines are abused and taken the same way. Therefore, leaving them on the curbside

may be an appealing place for them to be stolen or taken for misuse. With such a high crime rate in Worcester, this may not be the most viable option for collection.

The second and more viable solution that can be implemented in Worcester is to have its own collection program. This would be a three part program. The first part would be similar to the Walgreens project except instead of a mail-back program medication, users would be able to just bring their unused or out of date medication to their local pharmacy. This would be convenient because people who purchase or need medication usually go back to the same pharmacy again to get more medication and would be able to just drop off their used medication while they are there. In Worcester this would include Walgreens, Wal-mart, CVS, and local pharmacies (Local Pharmacies - Worcester MA.). This way of collection however while allowing for everyday collection of used medication could be costly. It would require these pharmacies to have a place to store the used medications until they are picked up for proper disposal. Also the amount of pick-ups for these medications would have to increase to cover all of the pharmacies.

The second part would be to have hospitals collect used medication. The way this would work is the same as with the pharmacies in that patients or any medication users would be able to just go to the hospital and drop off all of their unused medication for proper disposal. This is more efficient and less costly than dropping off medication at pharmacies because hospitals are used to handling large amounts of medication and disposing of them. In Worcester there are two main hospitals: Saint Vincent and UMass Memorial, which are two large hospitals and would be where the program could be implemented first.

CC. Awareness

Though there are no real regulations on the proper disposal of most pharmaceuticals, there are guidelines on both a state and a federal level. Unfortunately these guidelines are not well known to the public and go against some of the well-practiced disposal methods that are used today. The problem is that there is very little being done to educate the public on both proper disposal methods and the possible harm, if these guidelines are not followed, on the environment. Our group has worked to find ways of educating the public and have come up with some possible solutions.

We believe that one of the more efficient ways to educate the public would be to create a brochure that explains these guidelines. The optimal way of delivering this brochure would be to have a brochure to be given out with every pharmaceutical sold. It would either be handed out at the counter or included in the packaging or could even be added as a part of the instructions that come with the drug. This would ensure that everybody who purchased any type of pharmaceutical would have the guidelines to the proper disposal of their pharmaceuticals. This solution is very improbable because it would be very expensive to print out enough to give to every customer. Also if it were to be included in the packaging there would have to be regulations passed by the government requiring every pharmaceutical manufacturer to include this brochure in their packaging.

However, we believe a brochure is an effective way to educate the public. A good and attainable solution would be to have these brochures at pharmacies, doctors' offices, hospitals, and, anywhere else that pharmaceuticals are used or sold, for the customer or patient to pick up or just look at. This would not be nearly as expensive and also easily doable. These brochures would include but not be limited to correct and incorrect disposal methods of pharmaceuticals,

where local collection agencies are, effects pharmaceuticals have in the environment, and which pharmaceuticals are worse than others for the environment.

Having public service announcements through the proper outlets is another method for creating more awareness. This would allow for a large part of the population to be informed on why proper disposal methods are needed and what they are. Although many people will not retain all that is said in these announcements we believe the best way of creating awareness is through a combination of announcements and brochures.

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