Examining Potential Effects of the Pharmaceutical Disposal Process on Water Sources in Colorado Through Current Federal and State Policies

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Abstract

As water scarcity in the United States and Colorado increases, the importance of research into the potential risks that depleting water levels can have on our environment as pollutants concentrate will be instrumental in strengthening public and environmental health. This thesis explores the potential effects the pharmaceutical disposal process has on water sources in Colorado through a multi-goal policy analysis approach that examines both state and federal policies in the United States and Colorado using an extensive literature review. Water Treatment plants and current technologies were explored to investigate current practices in Colorado and the United States. While current water treatment processes are extensive, they are unable to filter out pharmaceutical traces, which poses a risk to the environment when considering prescribed medications such as birth control, containing 17a-ethinylestradiol (estrogen), can be a biohazard for local wildlife and a potential threat to agriculture. Primary research was conducted through a Survey Study using the online platform Qualtrics, with a total of 107 participants answering survey questions regarding individual pharmaceutical disposal habits. Although there are many state and federal regulations and policies such as DEA Take Back programs, survey responses showed that 67.29% of participants were not aware of Take Back programs before participating. The lack of public awareness for safe disposal habits defeats the purpose of these programs, and more public outreach should be a top priority for stakeholders, as well as considering implementation of new water treatment technologies that specifically target pharmaceutically active compounds (PhACs).

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Introduction

Human caused activity is one of the main roots that lead to the growth of numerous environmental issues. It is often the small effects that continuously build and fall under the radar that can often present themselves as the most harmful when they finally emerge in front of society. Micropollutants and pharmaceutical traces that continuously build are invisible and easy to ignore, until they are not. My research question asks: what are the potential effects of pharmaceutical traces concentrating in water sources as a result of depleting water levels in Colorado, and how can these effects be minimized?

The 21st century is about convenience. Today, we are constantly searching for ways to make things more efficient in daily life, without realizing the impact those efficiencies might create. The current policies in place to mitigate pharmaceutical traces in the environment do not coincide with the present societal need for convenience and efficiency. This lack of a complementary relationship increases the likelihood of pharmaceutical buildup in the environment. This thesis explores the potential effects the pharmaceutical disposal process has on water sources in Colorado, dive into current policies regarding the disposal process on both the state and federal level through a policy analysis, and examine individual pharmaceutical disposal habits from a survey study.

Background

Introduction into Background Information

In this section I will be discussing background information relating to the pharmaceutical disposal process to give readers a better understanding of the scope of this thesis. First, I will discuss the differences between hazardous and non hazardous waste materials in the United States and in Colorado, as well as the contextual differences and similarities of a pharmaceutical and a drug. I will then highlight the different types of water such as gray water, black water, and wastewater that are mentioned in existing literature. A brief overview will be given of the private tour I was given of the Robert W. Hite Treatment Facility, a water treatment plant located in Denver, Colorado, along with a breakdown of the current treatment process utilized within the facility. Then, a diagram of the life cycle of a pharmaceutical will be provided, as well as percentages of drought in regions of Colorado and a quick summary of two major Colorado water resources. Lastly, stakeholders involved in all parts of the pharmaceutical disposal process will be mentioned to provide clarity for readers while going forward in this thesis.

Hazardous vs. Non Hazardous Waste

The United States Environmental Protection Agency defines hazardous waste as “waste with properties that make it dangerous or capable of having a harmful effect on human health or the environment” (United States Environmental Protection Agency [U.S. EPA], 2022). In order to be considered a hazardous waste, the material being examined must be a solid waste (U.S. EPA, 2022). Under this definition, prescribed pharmaceuticals are considered hazardous in the United States, and therefore are required to be disposed of properly and in accordance with federal and state regulations, which will be discussed in later sections. According to Jaseem et al.

(2017), pharmaceutical waste can include expired pharmaceuticals, discarded personal medications, or open containers of drugs that cannot be used; once a seal of a container is broken, it is considered contaminated and therefore must be disposed of. Pharmaceutical waste is considered hazardous in Colorado specifically, with the Colorado Department of Public Health and Environment stating, "Long-term exposure to pharmaceuticals in water supplies is a concern because it may harm animals and plants that live in the water, as well as humans." (Colorado Department of Public Health and Environment [CDPHE], 2023). Pharmaceuticals are considered both hazardous and classified as a pollutant in the United States. Major source facilities that produce pharmaceutical products are listed as hazardous air pollutants under the National Emission Standards for Hazardous Air Pollutants (NESHAP), specifically methylene chloride, methanol, toluene, and hydrogen chloride (U.S. EPA, 2023). Pharmaceuticals being recognized as hazardous in both the state and federal level raises the importance of pharmaceutical contamination prevention because there is little dispute between these levels that might cause hindrance in the significance of proper pharmaceutical disposal.

Pharmaceutical vs. Drug

It is important to distinguish that the terms 'pharmaceutical' and 'drug' can be used as two separate entities. While these terms are often used interchangeably, it appears as though the main difference between the two terms is the context of which government agency they are being used by. Pines and Smith (2022) discuss the contextual differences between a drug and pharmaceutical when stating the following:

> It's important to note the common confusion between hazardous waste pharmaceuticals from an EPA perspective and hazardous drugs from a NIOSH perspective. NIOSH is a

> research institution within the Department of Health and Human Services' (HHS) Center for Disease Control (CDC). EPA's primary responsibility is protection of human health and the environment, while the primary responsibility of NIOSH is to develop recommendations to protect employees. (p. 11)

For the purpose of this research, I will be discussing pharmaceuticals in the broad context of human consumption. The pharmaceuticals discussed will refer to those listed on the FDA Flush List, birth control prescriptions, pain medications, and prescribed pharmaceutical drugs. For this research, using words that contain 'pharmaceutical', 'drug', 'medicine', or 'prescription' may be used interchangeably in this paper and are dependent upon and followed in the context in which referred sources have used them.

Different Types of Water

Various types of water are important to be aware of because they all can signify a different route pharmaceutical traces can take when entering the environment. Gray water refers to waste water used for cleaning, bathing, or washing, while blackwater refers to any waste that has originated from a urinal or toilet. Wastewater is both gray water and black water (South Australia Environmental Protection Agency [S.A. EPA], 2021). Metro Water Recovery (n.d.) defines wastewater as "used water that flows through communities" such as water from sinks, toilets, showers, hospitals, food processing plants, and more broadly from homes, businesses, industries, and schools. By clarifying different types of water, we can begin to understand the types of water that are most likely to be affected or contaminated by pharmaceutical traces.

Metro Water Recovery

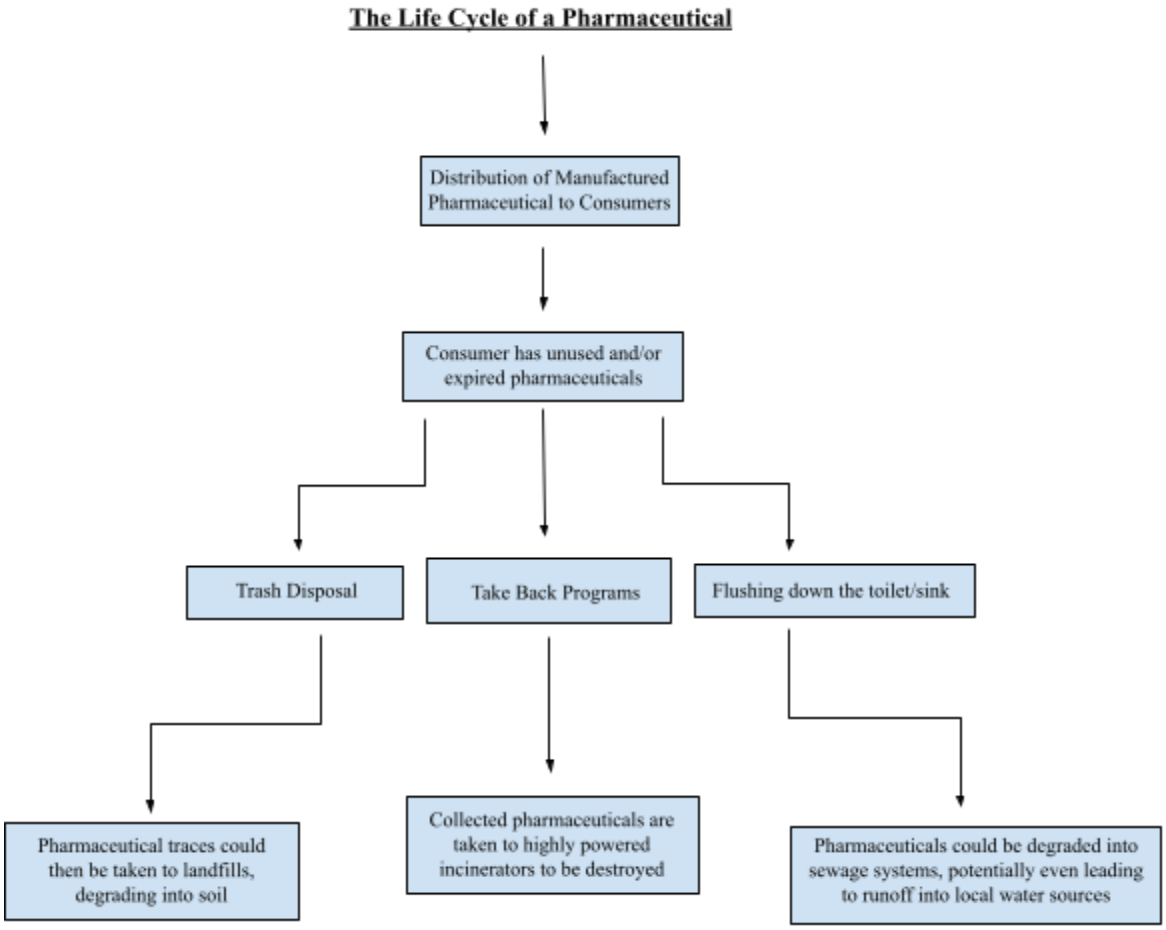
In August of 2022 I took a private tour of the Robert W. Hite Treatment Facility (RWHTF), a water treatment plant that is part of Metro Water Recovery, located in Denver, Colorado. The water treatment plant, which presently serves over 2.9 million people, has been in operation since 1961 (Metro Water Recovery, *We Get Your Water*, n.d.). Recently, the plant has taken a more progressive approach in recycling water, conserving energy when possible, and donating materials such as phosphorus to composters such as A1 Organics (C. Miller, personal communication, August 10, 2022).

The wastewater treatment process in Metro Water Recovery facilities goes through a variation of thirteen steps. The first three steps of the water treatment process include collecting raw wastewater from over 805 square miles of service area, divided into seven drainage basins within the Denver Metro area and analyzing samples from the wastewater influent. The fourth step in the process is Preliminary Treatment, which removes large debris, trash, and other large materials. After Preliminary Treatment, Primary Treatment occurs; using gravity separation in a large tank, organic material and settleable solids are removed and transferred to a secondary treatment process. Next, a secondary treatment is performed that "biologically removes carbon, nitrogen, and phosphorus". While Metro Water Recovery's Northern Treatment Plant (NTP) does have Tertiary Treatment –a polishing treatment for removing "solids, nutrients, pathogens, and thermal pollution"– the RWHTF does not. Instead, water flow goes directly from secondary treatment to the disinfection process, which uses peracetic acid (PAA) as a primary disinfectant to "damage the biological processes of bacteria and make them unable to reproduce". To complete the water treatment process, newly recovered water enters the South Platte River, which is an "effluent location that is monitored carefully to meet permit requirements" (Metro Water Recovery, *How We Transform Wastewater*, n.d.).

Although the water reclamation process is lengthy and detail oriented, representatives of the plant confirmed that local treatment plants, including Metro Water Recovery, do not have access to current technology that allow the removal of pharmaceuticals such as those known as “forever chemicals”. ‘Forever chemicals’ (PFAs for short), are chemicals that do not break down in the environment. These chemicals are especially dangerous in the environment due to an increased usage of these chemicals but a lack of removal to combat the issue.

Life Cycle of a Pharmaceutical

Water sources are not the only way pharmaceutical traces can potentially impact the environment. The figure below provides an overview of the different potential processes that can lead to these traces being found.



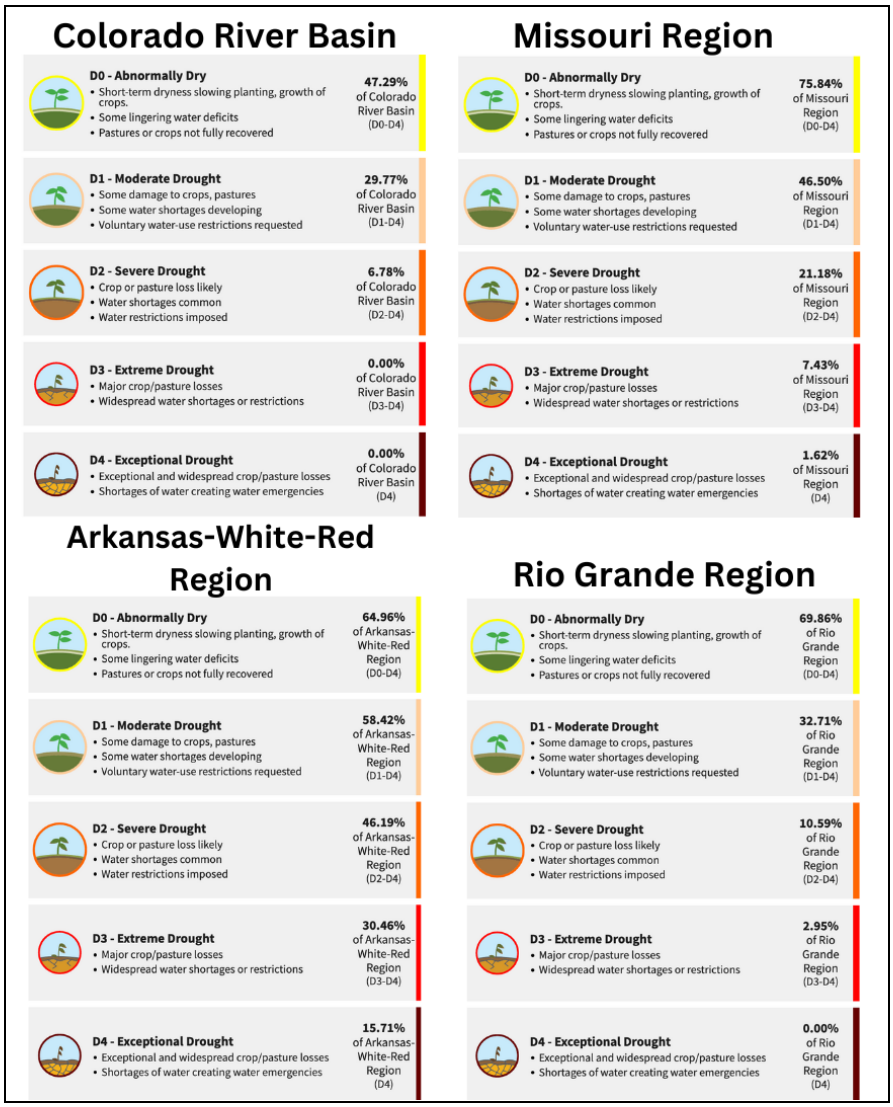
Colorado Water Sources

Water is becoming increasingly scarce as the climate changes. Changes in water levels can dramatically impact the quality of life and the integrity of ecosystems as a whole. For the state of Colorado, and parts of the Western half of the United States such as Arizona, California, Wyoming, Utah, Nevada, and New Mexico, the Colorado River is an integral water resource.

According to the Water Resources Mission Area (2018), it also supplies areas outside of the basin, such as Denver for example, and provides water to almost 40 million people and irrigates around 5.5 million acres of agricultural land.

The South Platte River and its tributaries are smaller than the Colorado River, but still hold the same weight when it comes to important water sources. As mentioned previously, the South Platte River flows through Water Metro Recovery, and is used heavily for drinking water, agricultural irrigation, and outdoor recreation (Metro Water Recovery, *South Platte River*, n.d.).

The United States Drought Monitor shows the location and intensity of drought across the country and is updated every Thursday. The state of Colorado falls under four separate regions: the Colorado River Basin (Upper and Lower Colorado Regions), the Missouri Region, Arkansas-White-Red Region, and a small portion of the Rio Grande Region (National Integrated Drought Information System, 2023).



This figure shows the different regions' drought intensities in Colorado as of Thursday March 30, 2023 (National Integrated Drought Information System, 2023).

Stakeholders

Due to the pharmaceutical disposal process having various stages, there are a wide range of stakeholders involved. The first stakeholders involved are pharmaceutical manufacturing companies who produce pharmaceuticals for distribution. According to Global Data (2022), the top ten leading pharmaceutical companies (listed in order from one through ten) are Johnson &

Johnson, Eli Lilly & Co, Pfizer Inc, AbbVie Inc, Merck & Co Inc, Bristol-Myers Squibb Co, Amgen Inc, Gilead Sciences Inc, Regeneron Pharmaceuticals Inc, and Vertex Pharmaceuticals Inc. All of these companies are headquartered in the United States, with a market capitalization ranging from $461,849 million (Johnson & Johnson) to $74,127 million (Vertex Pharmaceuticals) (Global Data, 2022). Prescription users are another stakeholder; according to ClinCalc (2021) which references a 2020 Medical Expenditure Panel Survey (MEPS), there were a total of 3 billion prescriptions in the United States, with about 500 of those prescriptions containing active ingredients. It is important to note that these amounts of prescriptions can be underrepresented due to either not being recorded by a third party insurance or other medications not being prescribed such as vitamins or other alternative medicines (ClinCalc, 2021).

Other stakeholders include tax payers in the United States, who may be put in the position to vote on the country's budget and expenses, and/or pay for additional expenses through taxation. Another stakeholder that would be involved in this process would be water treatment plant engineers and other personnel; water treatment plants are directly involved in any adaptation to the wastewater treatment process whether it be implementing new technology, tighter regulations, or simply improving current treatment processes. Lastly, a final stakeholder would be government agencies who are ultimately able to either push new policies and regulations into the government system, or adjust the policies and regulations that are already in place. More specifically, the United States Environmental Protection Agency (EPA), the United States Food and Drug Administration (FDA), and the United States Drug Enforcement Agency (DEA) are all major government agencies that are stakeholders.

Methodology

Individual Pharmaceutical Disposal Habit Survey

The purposes of this study are to determine the ways in which individuals most commonly dispose of their unused or expired pharmaceuticals and whether different demographics such as region, age, gender, or race have a role in types of disposal. Whereas there is quite a lot of data collected surrounding pharmaceutical waste from medical centers such as hospice care, clinics, hospitals, etc. there is very little research conducted surrounding household pharmaceutical waste. Medical centers such as hospice care or coroner offices record leftover medicines that are disposed of, whereas individuals within their home, cleaning out their cabinets per say, do not record their waste habits. The gap in current knowledge and data can lead to a lack of urgency and corrective action. If more data is collected surrounding household pharmaceutical waste, then it is possible that the data could show faults in current policy regarding pharmaceutical disposal procedures.

A small study was conducted using a survey that questions the correlation, if any, between pharmaceutical disposal habits of individuals within their households, and knowledge of United States disposal policies. Survey participants were asked no more than fourteen questions using Skip logic, regarding demographics, unused or expired medicine disposal preferences, and lastly knowledge of disposal policies within the United States and whether these policies are utilized by individuals.

The survey was conducted through the online platform Qualtrics. Subjects were able to reach the platform via a link provided through social media posts, which they accessed on a phone, tablet, or computer. Data responses were collected in March of 2023 through a ten day distribution period, and will be stored through the online platform Qualtrics until June 1, 2023

when the survey and data will be deleted. Due to subjects being able to access the Qualtrics survey link from social media, via a personal tablet, phone, or computer, exactly *where* subject participation occurred was not able to be determined. While Qualtrics can typically collect IP addresses, settings were adjusted in the Qualtrics platform to "Anonymize Responses", which prevents collection of specific location data to ensure subject privacy. A subject's participation and personal experience of data collection is not involved, due to adjusted "Anonymized" privacy settings for data collection in Qualtrics settings.

Policy Analysis Approach

A multi-goal policy analysis approach is best suited for examining pharmaceutical disposal efficacy because there are many different stages and stakeholders involved in the disposal process. This approach is designed for situations where there are multiple potential policy goals that cannot be quantified.

The analysis was conducted by first examining the current literature regarding pharmaceutical disposal habits, on an individual household level as well as an industry wide level. The literature review examines both state and federal responses to potential posed risks associated with pharmaceutical traces. Current technological advances were also researched as to the capabilities of water treatment, and the related costs and benefits. An environmental scan that evaluates the strengths and weaknesses of stakeholders, policies, and technology will be taken into consideration for the analysis (Centers for Disease Control and Prevention, 2022).

Review of Existing Literature

Disposal Methods

Disposal methods in waste management refer to the disposal of hazardous waste after it has been collected. For example, after pharmaceuticals are collected from Take Back Programs, they are then transferred to a waste collection site to be disposed of. The difference between disposing and discarding pharmaceutical waste is that when an individual "discards" expired or unused medicine, they are "throwing it away", whether that be through Take Back Programs, the trash, recycling, or down the toilet or sink. Disposing of pharmaceutical waste alludes to destroying it in its entirety. This section will go over some of the methods found in existing literature that are currently available to dispose of hazardous pharmaceutical waste.

The most common method used in the United States to dispose of pharmaceuticals is through incineration (also known as thermal treatment). Unused or expired pharmaceuticals are collected from Take Back Programs and transferred to thermal treatment facilities where "solid organic waste are subjected to combustion to convert them into residue and gaseous products". Pharmaceuticals which were once in a solid pill form, are heated up using high temperatures in a controlled environment to destroy their original form. Incineration is a widely accepted method but can be controversial due to the potential emissions released from incinerators (Jaseem et. al., 2017).

Other disposal methods include deep burial, which is where rural areas under specific conditions may allow bio-waste to be buried. Jaseem et al., (2017) also mentions two variations of waste immobilization such as inertization and encapsulation. Inertization is where pills are ground and formed into a homogeneous paste using a mix of water, cement, and lime. The paste then sets into a solid mass and is put into the municipal solid waste. Encapsulation is where

pharmaceuticals are immobilized into a solid block inside a plastic or steel drum, filled to 75% capacity and filled with a cement/lime mixture. The drums are then sealed and placed at the base of a landfill and covered with “fresh municipal solid waste” (Jaseem et al., 2017).

Pharmaceutical Trace Originations

Pharmaceuticals can be traced back from many different human sources, but the most common include medical offices, such as hospice care or coroners offices. It is more likely to have a record of these origins, as these centers are required to record their waste habits. These traces can also enter the environment unintentionally through everyday household waste, such as bathing or human excretion. However, household waste is much less reported due to individuals within the household not typically recording and submitting their waste habits for data reporting purposes (Bain, 2010).

Economic Burden/ Incentive

Complications surrounding pharmaceuticals arise when it comes to discussing them in an economic setting. Pharmaceuticals are in (and likely always will be) high demand, due to aging populations, new chemical combinations becoming available as pharmacology advances, as well as various conditions that require medication. Society has an increasing demand for pharmaceuticals, providing pharmaceutical companies a huge incentive to continue to supply. However, an economic burden comes into play when consumers are supplied with more medications than needed, or more than what ends up being used, leaving medication wasted. The burden is placed on the consumer, both financially, and potentially environmentally.

Potential Public Health Effects

Pharmaceutical traces can enter into water sources through human excretion, as well as flushing unused or expired medications down the toilet or sink. Flushing unused or expired pharmaceuticals is an extremely common way that traces can be found in water samples. In the United States, the FDA has a "flush list" of medicines that have been deemed safe for the public to be able to dispose of via the sink or toilet (United States Food and Drug Administration [U.S. FDA], 2020). The FDA first recommends disposal through Take Back Programs, but if none are available, they recommend flushing your expired or unused pharmaceuticals down to the toilet if they are listed on the flush list. If both of these disposal options do not fit for your specific pharmaceutical medicine, the FDA recommends to safely dispose of your medicine in the trash by removing all identifiable information and separating the medicine from its container, mixing the leftover medicine in coffee grounds or liquid, and placing the mixture in a sealed bag in the trash at home (U.S. FDA, 2018). Human excretion can also contribute to pharmaceutical presence unintentionally, as a result of daily prescription use exiting the body and ending up in sewage treatment and waste management facilities (Water Science School, 2018). Although sewage treatment and waste management facilities in the United States typically are thorough in filtering out waste, many of these facilities lack the proper infrastructure and/or filtration systems to filter out the chemical traces of pharmaceuticals, resulting in these traces being found in water sources. These traces may seem uncommon, but pharmaceutical mixtures were found to be common across all regions of the United States (Bradley et al., 2020). However, this issue is not limited to the United States, but spans internationally as well. Pharmaceutical presence has also been detected in various river waters in the Eastern Cape Province in South Africa, using samples from upstream, middle-stream, and lower-stream (Vumazonke et al., 2020).

In an effort to prevent pharmaceutical waste in water sources, take-back programs have been developed. Take back programs are programs that are designed to be a system or place where the public is able to drop off their unused or expired pharmaceuticals instead of throwing them in trash bins, flushing them, or discarding them down the drain. The United States Drug Enforcement Administration holds a national "Take Back Day" where the public can drop off their medications to a collection site such as a pharmacy or law enforcement office during set hours (United States Drug Enforcement Administration [U.S. DEA], n.d.). The United States leads in example, being one of the first countries to develop a take back program. According to Shwartz et al. (2021), Canada is recommended to develop a program as an alternative to flushing or throwing away pharmaceuticals. In Romania as well, there is a lack of pharmaceutical waste disposal procedures, resulting in "many deficiencies in waste management of medicines" (Bunguau et al., 2018). Bunguau et al. suggests that Romania looks to the United States as a "reference point" for developing pharmaceutical waste procedures (2018).

A recurring theme found in relation to pharmaceutical waste management were the potential public health risks, or rather recently, the lack thereof. Specifically, public health risks as a result of pharmaceutical traces found in water sources such as surface water and drinking water. According to Bain (2010), due to a lack of safety protocols and testing for pharmaceuticals, drinking water in the United States can include "increased risk of developing cancer, reproductive impairment, and the selection and development of antibiotic-resistant bacteria". However, more recently the United States Food and Drug Administration published a journal stating that studies have shown there are "negligible risks through ingestion of water and fish" that have been found with traces of the same pharmaceuticals listed on the FDA "flush list" (Khan et al., 2017). In a study taken from 50 wastewater treatment plants in the United States to

assess potential risks of pharmaceuticals, it was estimated that "potential risks to healthy human adults were greatest for six anti-hypertensive APIs, but nevertheless suggest risks of exposure to individual 32 APIs as well as their mixtures are generally very low" (Kostich et al., n.d.). However, in both studies, Khan et al. (2017) and Kostich et al. (n.d.), it was also determined that more detailed studies be conducted and that there is still a lack of data missing.

As is with most research, a solution to the issue is always the desired outcome or conclusion. In cases like pharmaceutical waste management, where new information is still readily flowing and becoming available, *potential* solutions are the next best option. One potential solution discussed by Suchomel et al. (2018) refers to a "rapid assessment method and screening values developed by MDH that provide information that can be used to respond to current detections and allow risk managers opportunities to be proactive in setting future priorities". Essentially, this method can be used to provide a quicker detection sample of pharmaceuticals, to maximize efficiency in risk assessments. Another potential solution is based on society instead of science or technology. As stated before, the result of the rapid increase in pharmaceutical use resulted in an increase in traces of pharmaceuticals in the environment. According to Thomas (2017), the key to decreasing pharmaceutical traces is to decrease societal dependence on pharmaceuticals as a whole. To do this, society must make a cultural shift in the way modern medicine is viewed.

Potential Environmental Effects of Birth Control

Birth control is a form of medication that is used commonly and has helped improve the lives of millions of both men and women (United Nations Department of Economic and Social Affairs, 2019). Contraceptive failure has been a common occurrence for women throughout

history, making the demand for effective birth control in the economic market a necessity. Previously, hormonal birth control such as the pill and IUD were difficult to take and needed to be modified to improve their efficacy (Watkins, 2012). New birth control methods were formed, but the disposal process for discarding these methods once they have been used appears to be discarded from mainstream research.

Currently, studies have been conducted to try and figure out the ways in which pharmaceutical waste is able to enter the environment. Studies have shown that there are multiple ways in which pharmaceuticals can enter, one of which is through human excretion, which was previously mentioned. Humans taking pharmaceutical medications can release traces of these medications into sewage systems via their feces and urine (Daughton & Ruhoy 2010). It could be plausible that women taking hormonal birth control medications could be releasing these hormones into sewage systems via their feces and urine as well. There have been pharmaceutically active compounds (PhACs) found in the surface waters and groundwaters since the mid 1990s in many countries after entering through wastewater treatment plants. Specifically, the active ingredient in the birth control pill, 17a-ethinylestradiol, has contributed to the feminization of fish populations after being exposed to low levels (Doerr-MacEwen, 2007). Not only have fish populations been feminized, 17a-ethinylestradiol can contribute to entire fish population collapses, such as the collapse of the fathead minnow population, showing that constant exposure to this ingredient can prove detrimental to marine wildlife (Blanchfield et al. 2015).

Exposure to estrogen levels is not limited to the United States. In Canada, many water samples from two riverbeds were found to have contained estrogen-like activity that include both

natural and synthetic estrogens, potentially affecting the longnose dace, a native species residing in Southern Alberta, Canada (Jeffries et al. 2010).

Although there are gaps in this research topic, one study shows that estrogen in pollutant levels have been found more commonly near wastewater treatment facilities (Adeel et al. 2017). The question to ponder is why these levels are found closer to these sites, and how this may pose risks for local wildlife and humans in the area. Another study found that most people disposing of birth control methods improperly were due to convenience and not being aware of other options of how to dispose of their birth control (Adashek, 2018). Many people often dispose of their medications through flushing them or improperly disposing them in the trash. The DEA, as mentioned previously, has developed semi annual take-back programs to help people to properly dispose of medications in a way to protect both the environment and the general public (United States Drug Enforcement Administration [U.S. DEA], n.d.). However, these take-back programs are often inconvenient for the average working person. According to the United Nations Population Fund [UNFPA] (2013), the most efficient and sustainable way to dispose of both hormonal and nonhormonal forms of birth control is through incineration or the landfill.

Current Technology in Water Treatment

There are many types of water treatments but to remain within the scope of this thesis only processes that relate to chemical contaminants will be discussed. Reverse Osmosis and Nanofiltration are similar treatment processes in that they physically remove contaminants from water through membrane separation. Both processes can be used to remove synthetic organic chemicals, and are beneficial because they can remove a large amount of contaminants and pollutants at once. However, one large disadvantage of using Nanofiltration or Reverse Osmosis

comes into play when water is scarce. Fifteen to thirty percent of the water flow that is treated using these processes are lost, and while many contaminants may be removed, energy consumption increases due to increased contaminants being collected (U.S. EPA, 2022, July 8).

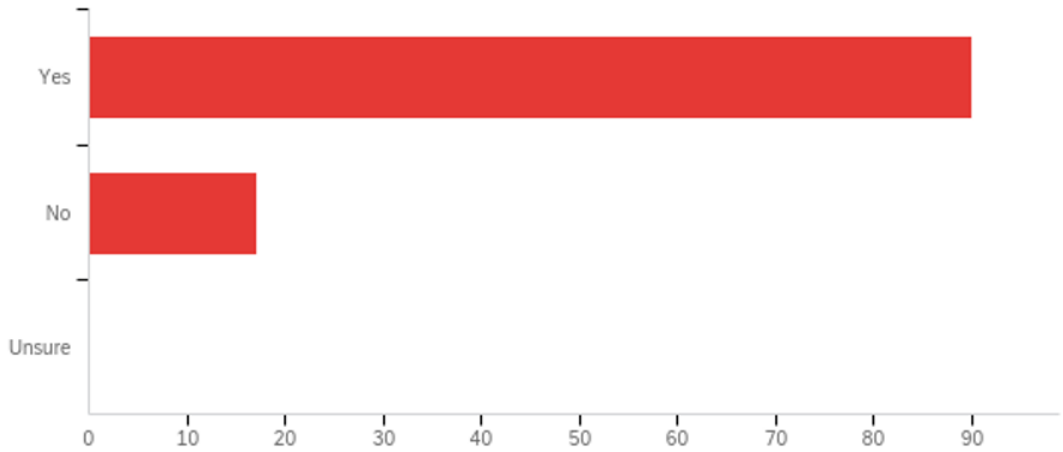
Beheading is a very new chemical process where the molecule is taken apart to form a different, less harmful substance. According to Pappas (2022) and Trang et al. (2022), beheading can potentially allow for the breakdown of PFAS, or 'forever chemicals' and reduce the negative longevity of these chemicals in the environment.

Other water treatments that target pharmaceutical chemicals in wastewater are Granular Activated Carbon (GAC) and Powdered Activated Carbon (PAC) treatments. These treatments are filtration processes, and differ only in particle size. Although the difference may seem small, a 2017 study compared pharmaceutical removal in municipal wastewater at three different wastewater treatment plants in Sweden. The study showed a success rate removal of 95% of pharmaceutically active compounds (PhACs) in wastewater using the PAC treatments, while GAC treatments were much broader in removal (Kårelid et al., 2017).

Survey Report Results

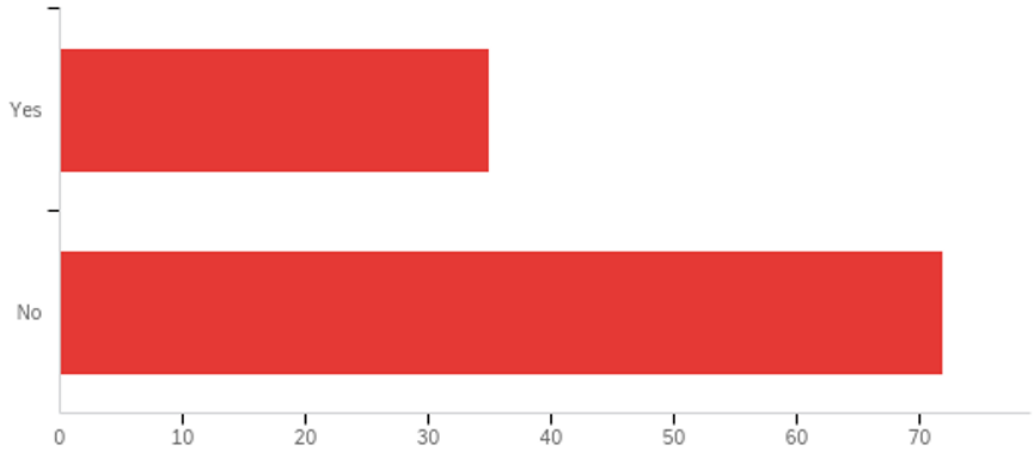
There were a total of 107 participants in this survey study. Of the participants, 27 identified as male, 75 identified as female, 4 identified as 'other', and 1 participant preferred not to disclose their gender. In total, 51 participants considered themselves a resident of the West Pacific region, 30 participants considered themselves residents of the Mountain West region, 4 for West South Central, 5 for South Atlantic, 1 for West North Central, 9 for East North Central, 5 for Middle Atlantic, and 2 for North East New England. Questions 1-3 asked participants to select demographics that relate to them, as mentioned above. Questions 1-5 are asked to every participant in the survey, but depending on individual responses to Question 5, skip logic is used. Survey questions, including skip logic, are available to view in Appendix B.

Q4 - Do you currently or have you previously taken prescribed medication? (Including but not limited to medication for an injury, surgery, and/or prolonged use for a condition, birth control, mental health, etc.)



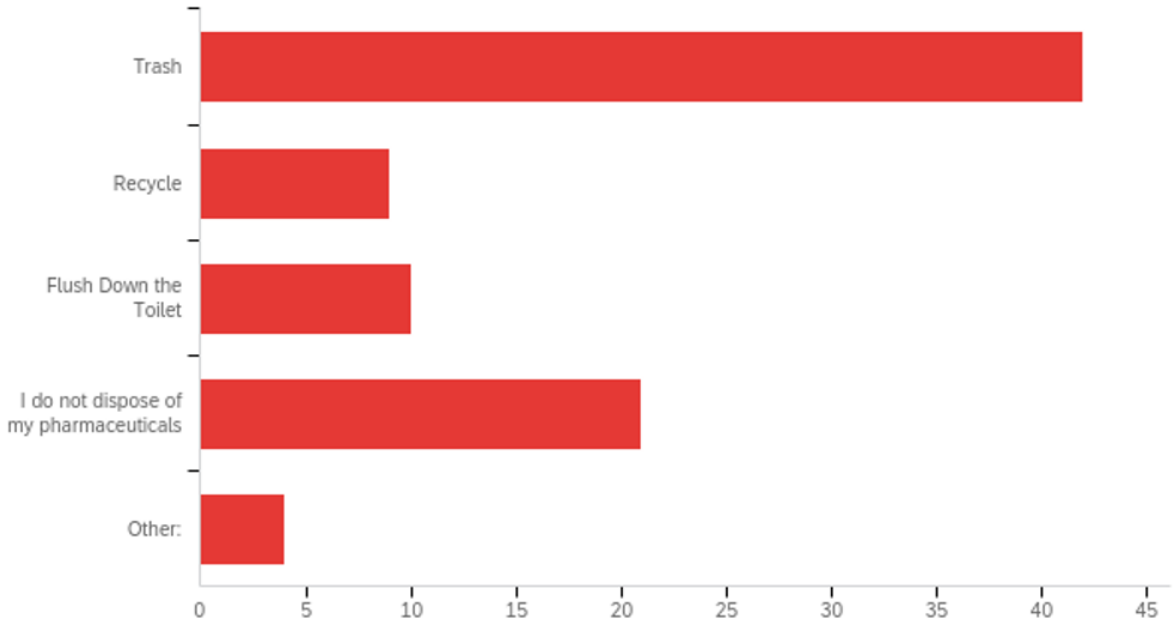
When asked Question 4, 90 participants said yes to currently or previously having taken medication, and 17 participants said no.

Q5 - Take Back Programs such as the DEA's National Take Back Day are programs sponsored by state and federal governments to collect unused or expired pharmaceuticals at various disposal sites such as local police departments and/or medical centers. Were you previously aware of Take Back Programs before participating in this survey?



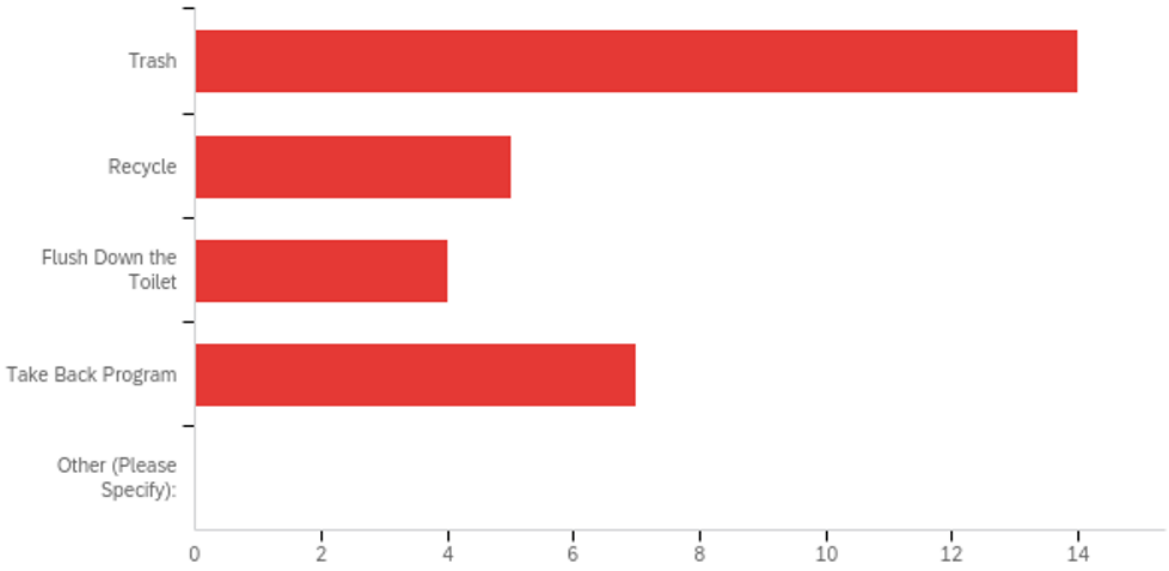
For question 5, 72 participants (67.29%) were not previously aware of Take Back Programs before participating in this survey. 35 participants (32.71%) were previously aware of Take Back Programs.

Q6 - How do you dispose of your expired and/or unused pharmaceuticals? Please check all that apply.



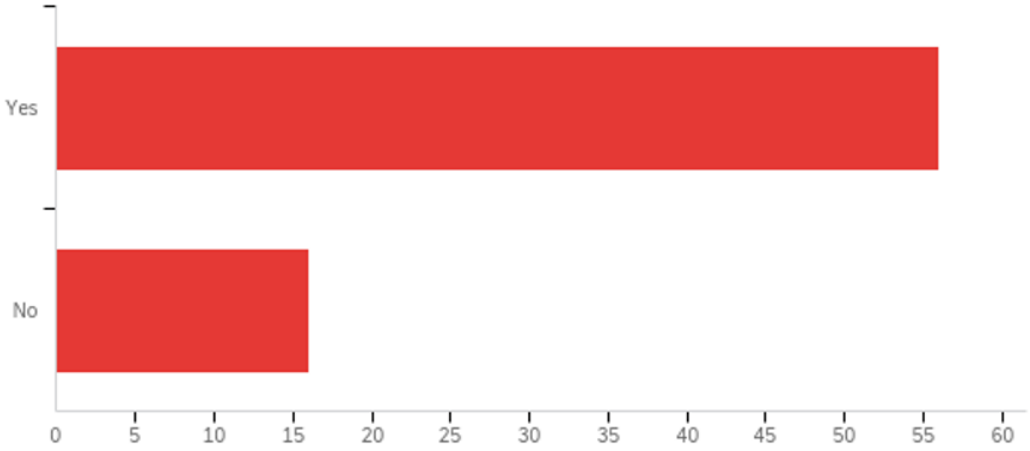
Question 6 requests participants to check all applicable ways that they dispose of their pharmaceuticals. Question 6 was applied to 86 responses after using skip logic on Question 5. Participants were shown Question 6 if they answered "No" to Question 5. Participants that selected 'Other' as another method of disposal, typed responses, saying "Take to pharmacy for disposal", "put in plastic bag, tied tightly, and trash", "often keep it if I don't know what to do with it", and "Junk Drawer".

Q7 - If you were to dispose of your pharmaceuticals, which disposal method would you use? Please mark all that apply.



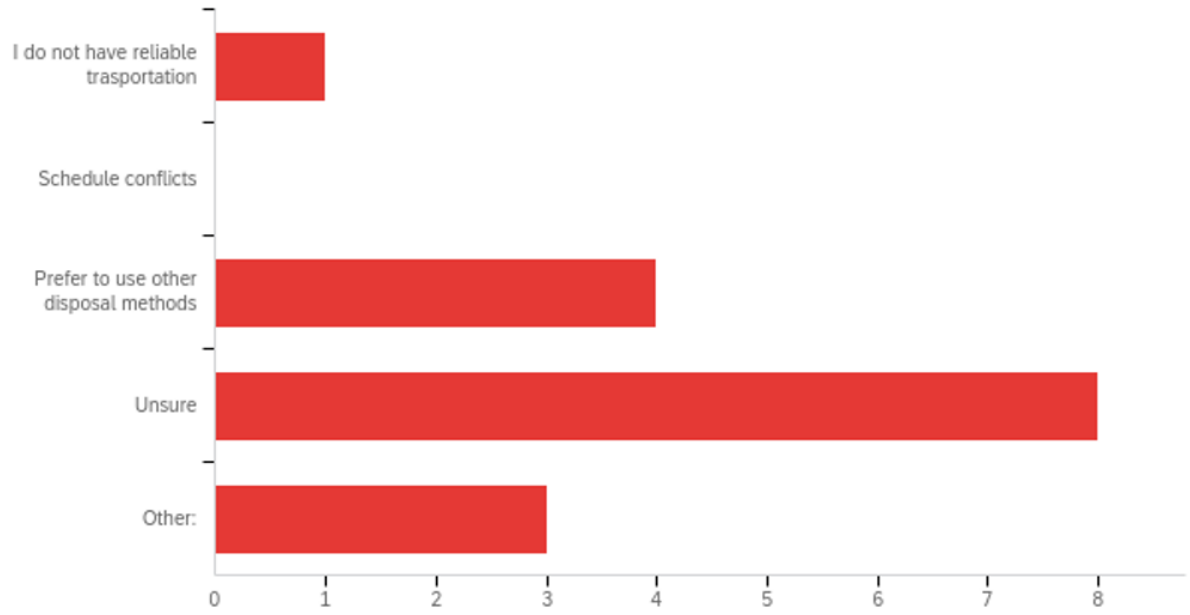
There were a total of 30 responses checked for Question 7, with 14 selecting ‘Trash’, 5 selections of ‘Recycle’, 4 selections of ‘Flush Down the Toilet’, and 7 selections of ‘Take Back Programs’.

Q8 - After being informed of what Take Back Programs are, would you use them as a pharmaceutical disposal method in the future?



For question 8, there were a total of 72 responses, with 56 participants answering ‘Yes’ and 16 participants answering ‘No’.

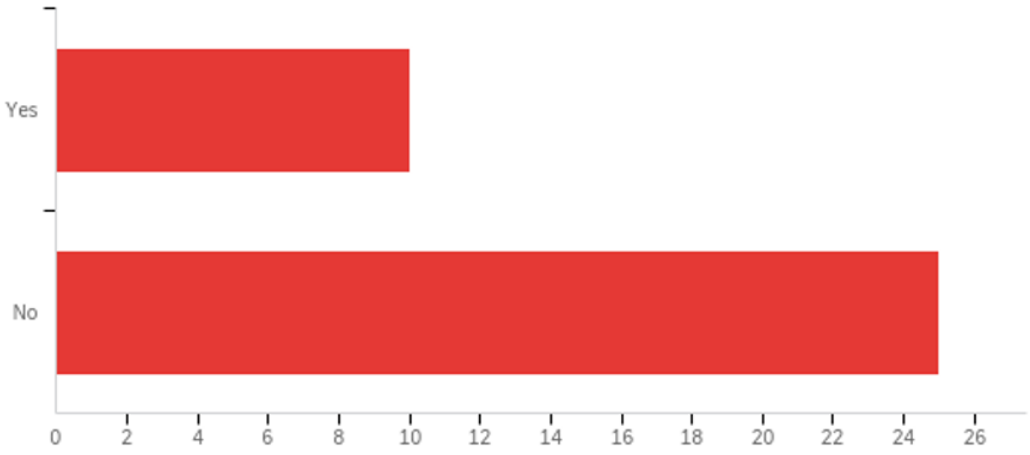
Q9 - Why would you choose to not use Take Back Programs as a disposal method in the future?



Question 9 had a total of 16 responses. Participants that chose ‘Other’ included these responses:

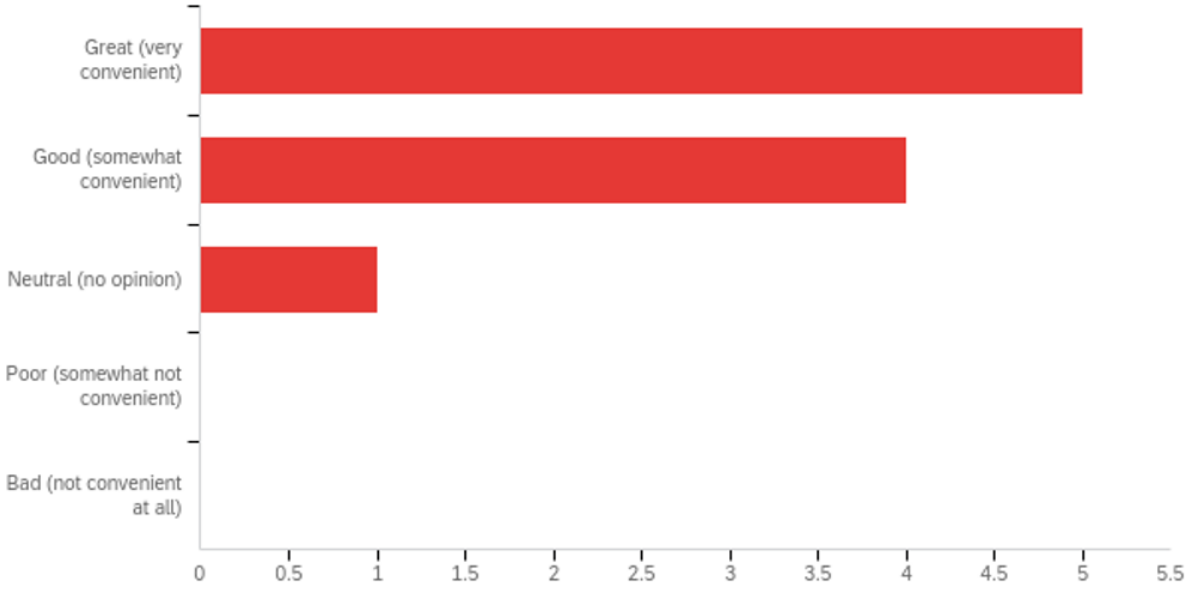
- “Too much effort”
- “Personal time it takes”
- “Effort on my part”

Q10 - Have you ever utilized a program for disposing of your unused/expired pharmaceuticals?



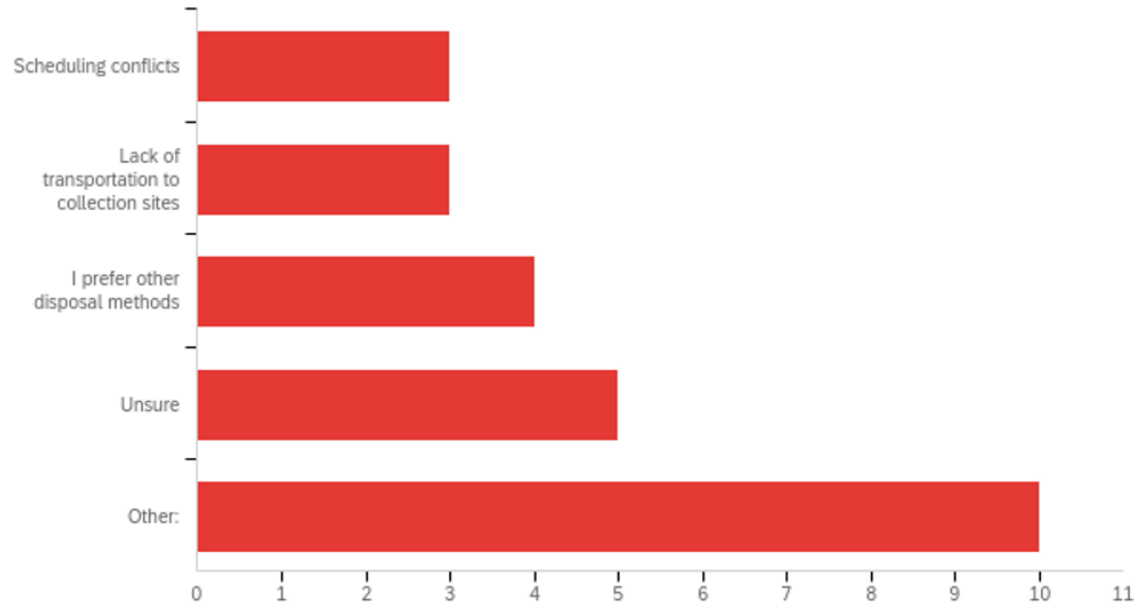
Question 10 had 35 total participant responses, with 10 participants answering ‘Yes’ and 25 participants answering ‘No’.

Q11 - How was your experience in terms of personal scheduling convenience?



There were a total of 10 participants that answered Question 11, with 5 participants answering ‘Great’, 4 participants answering ‘Good’, and 1 participant answering ‘Neutral’.

Q12 - Why have you not utilized Take Back Programs?



In total, there were 25 participants that answered Question 12. Question 12 allowed participants to type in 'other' explanations as to why they might not utilize Take Back Programs. Responses included:

- "Difficult to find in our area"
- "I haven't needed them. I haven't been in a situation where I had leftover medications"
- "I don't think about it. It'll just sit in a drawer for decades"
- "I take all prescribed medication."
- "Wasn't sure of where the take back programs were located/ normally go through entire prescriptions and don't have pharmaceuticals that need to be disposed of."
- "I personally have not but my dad did, which is why I know of these programs"
- "I do not know how to participate"
- "Lazy"
- "Procrastination"

Multi-Goal Policy Analysis Results

Federal and State Level Disposal Policies

Due to this approach being designed for situations with multiple potential policy goals, it is important to distinguish the different stages in which policies are applied. Individual/household disposal directly correlates to the FDA Flushlist and recommendations, as well as DEA Take Back programs. Federally, the specific policies explored were year round disposal locations, DEA sponsored Take Back Days, and FDA recommendations. As mentioned in the literature review, the FDA recommends safely disposing of expired or unused pharmaceutical medicine in the trash by removing identifiable information, separating the medicine from its container, mixing the leftover medicine in coffee grounds or liquid, and placing the mixture in the trash in a sealed bag (U.S. FDA, 2018). Also mentioned in the existing literature section are the Drug Enforcement Agency's semi-annual Take Back programs, which are designated days of the year in which you can take your unused or expired pharmaceuticals to a local police station or medical center to safely dispose of them (U.S. DEA, n.d.). Year round disposal locations are able to be searched using the DEA's Diversion Control Division website, which enables individuals to utilize safe disposal habits if they missed annual and/or semi-annual Take Back Days (Diversion Control Division, n.d.).

For the state of Colorado, the policies and recommendations researched were the Colorado Consortium for Prescription Drug Abuse Prevention and local drop boxes. More specifically, the Colorado Consortium for Prescription Drug Abuse Prevention promotes a resource titled "TakeMedsSeriously". The website guides individuals through safe disposal practices, by providing links to find safe disposal locations near you, the importance of safe

disposal, and what you can and cannot dispose of. The website even allows individuals to host an event or start a Take Back Box to promote awareness (TakeMedsSeriously, 2023).

Water Treatment Regulations

The United States Environmental Protection Agency (EPA) oversees regulations relating to water enforcement. The Clean Water Act (CWA) and the Safe Drinking Water Act (SDWA) are both enforced under the EPA. The enforcement of the CWA is to "ensure that remedies are resilient in the face of climate impacts, such as sea level rise, flooding, and drought" (U.S. EPA, 2022, June 29). The SDWA is monitored and enforced "to ensure that the nation's public drinking water supply and its sources (rivers, lakes, reservoirs, springs, and groundwater wells) are protected," (U.S. EPA 2022, June 29). Both of these acts are put in place to be able to monitor water sources and quality, and to set a standard for both waste management and water treatment.

The National Pollutant Discharge Elimination System (NPDES) is a type of permit program created by the CWA to help address water pollution by regulating sources that discharge pollutants into United States waters sources. This permit provides a license for a facility to be able to "discharge a specified amount of a pollutant under certain conditions into a receiving water". NPDES permits also allow authorization for certain facilities to incinerate or process sewage sludge (U.S. EPA, 2022, July 6).

Cost and Benefit Calculations

The National Association of Drug Diversion Investigators (NADDI) creates drop boxes for unused or expired pharmaceuticals to be sold and distributed across the United States. The

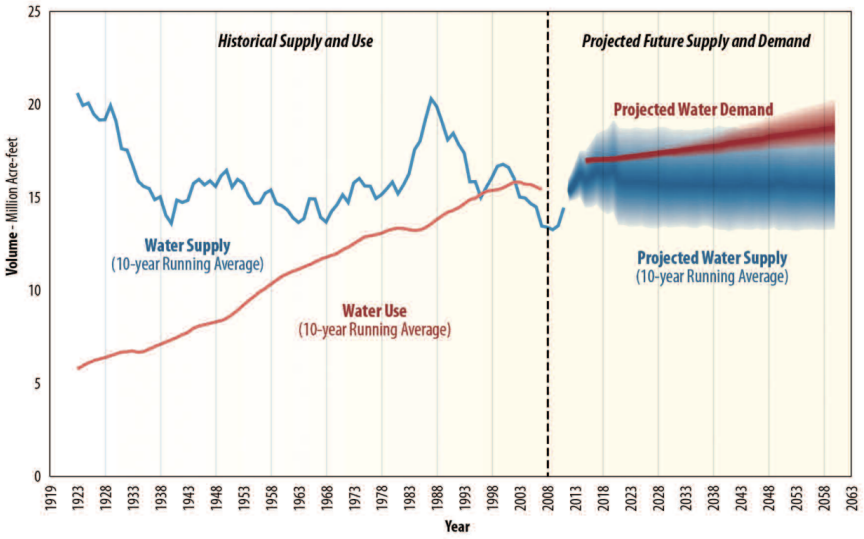
total cost is a one time payment of $1500 per drop off box, which includes shipping. Typically, drop boxes will be shipped within seven to ten business days (National Association of Drug Diversion Investigators, Inc., 2022). Through cooperation with local law enforcement, healthcare professionals, and other state government agencies, the NADDI is able to apply and share safe disposal practices to local agencies, companies, or even individuals at a low cost. By purchasing a drop box, local agencies and healthcare providers are able to not only limit pharmaceutical waste in the environment, but potentially reduce public health risks and medication getting into the wrong hands and injuring individuals. A question for further research is how might we be able to determine the cost of implementing new water treatment technologies such as beheading or PAC Treatment as common practice in United States water treatment plants?

Environmental Scan

An environmental scan is "a proactive, systematic collection of information about events, trends, and expectations of what you might encounter during the policy process." (Centers for Disease Control and Prevention, 2022). The United States Bureau of Reclamation created the 'Figure 2', which shows the range of the projected future water supply and demand of the Colorado River Basin. The figure stresses the importance of future water management actions, as it is plausible that water supply vs. water demand might begin to clash as years progress (United States Department of the Interior, Bureau of Reclamation, 2012).

FIGURE 2

Historical Supply and Use[1] and Projected Future Colorado River Basin Water Supply and Demand



Taking this projection into account, along with the current statistics of the Colorado River Basin in 2023, the projection appears to be generally on track for future projections. Water sources in Colorado, specifically the Colorado River Basin supply, are not able to consistently keep up with water usage demand. As water scarcity increases, the probability for pharmaceutical pollutants to concentrate in water sources shows potential.

Discussion

One of the first questions that comes to mind is: which stakeholder should be responsible for the cost? Arguably all stakeholders, whether it be pharmaceutical companies, prescription users, tax payers, water treatment personnel, and government agencies all hold some responsibility for the cost, both quantifiably or qualitatively. The main distinction between the type of cost goes into which stakeholder should represent and be responsible for which stage in the pharmaceutical disposal process. Pharmaceutical companies such as Johnson & Johnson, or pharmacies like Walgreens or CVS, might be deemed more reasonable when looking into implementing new water treatment technologies to prevent pharmaceuticals –that are supplied by their companies– from entering our local water sources. Government agencies should also step in to enforce new regulations or technologies, as well as potentially fund future research into investigating potential risks in the future. It is also the responsibility for healthcare facilities, local law enforcement agencies, and state agencies to front the cost for more disposal drop boxes in neighborhoods and cities. Individual prescription users and tax payers as a whole should consider safely disposing of their unused medications and practicing safe disposal habits, even if the process might be an inconvenience. Individuals are able to adjust personal habits once they are made aware of an issue, whereas implementing policy or regulations can take months or even years to be established in public practice.

While there are many regulations and disposal policies in place to mitigate pharmaceutical pollutants entering the environment, there is minimal existing literature on pharmaceutical trace risks in water sources, as a result of lowered water levels. Minimal knowledge in existing literature can pose a potential threat for the wellbeing of future generations and environmental sustainability. While the U.S. FDA's 2017 study suggests minimal

risk associated with pharmaceutical traces in the environment (Khan et al., 2017), estrogen leaking into water systems through human excretion can pose a biohazard risk. Due to many water treatment plants being unable to filter out pharmaceutical traces, water contaminated with traces of estrogen can potentially pose a risk for drinking water or agricultural irrigation. Based on literature mentioned in the *Potential Environmental Effects of Birth Control* section, even low levels of estrogen can completely disrupt fish local wildlife populations. If estrogen levels get into municipal water supplies, what is the potential impact on our agricultural industry?

Along with minimal existing research, comes little awareness of the many regulations and programs put in place for safe disposal habits of individuals. The survey results show that 67.29% of survey respondents were not aware of Take Back Programs before taking the survey. While buying and placing disposal drop boxes on the corner of every street would help accessibility of these take back programs, they will not be beneficial if individuals are not aware of what their purpose is. If individuals aren't aware of Take Back Programs, then the programs will not be utilized.

Conclusion and Recommendations

This thesis explored the potential effects the pharmaceutical disposal process has on water sources in Colorado, while examining current policies and regulations regarding the disposal process on both the state and federal level through a policy analysis. Insight into individual pharmaceutical disposal habits were gained through a small survey study of 107 participants. While there are many federal and state policies and regulations in place to encourage individuals to dispose of unused or expired pharmaceutical medications safely, survey responses reflected that most individuals were not aware of programs for safe disposal. Current studies show that traces of estrogen can pose an extremely high risk, even at low quantities. While there is fairly limited research on pharmaceutical traces being shown to pose a negative effect on public and environmental health as a whole, the potential risks could increase as water scarcity and drought increase in Colorado and other regions of the United States. Pharmaceutical Manufacturers, Government Agencies, Water Treatment Personnel, and prescription users, must all work together to promote better disposal practices for the safety of our environment and future generations.

Recommendations

Going forward, it would be in stakeholders' best interest to push more publicity on Take Back programs, to make individuals more aware of safe disposal habits so they are utilized. Take Back programs appear to have the lowest cost with the potential for reducing pharmaceutical waste in local rivers, lakes, streams, and wastewater treatment plants. Awareness can be created by announcing semi-annual Take Back Days and pharmaceutical disposal drop off locations and resources on government agency social media sites or newsrooms. If more awareness is created,

purchasing drop off boxes and installing them in front of common or high traffic areas such as grocery stores or pharmacies for easy access, incentivizes individuals to utilize them, rather than improperly disposing of medications because it is more convenient. Lastly, federal and state governments, pharmaceutical companies, and water treatment plant personnel should consider investing in progressive water treatment technologies to filter out pharmaceutical traces such as estrogen in water treatment plants.

Bibliography

Adashek, J. (2018). *How Students at the University of Colorado at Boulder Dispose of User-disposed Contraceptives and Potential Implications for the Environment.* Retrieved from https://scholar.colorado.edu/concern/undergraduate_honors_theses/4q77fr800

Adeel, M., Song, X., Wang, Y., Francis, D., & Yang, Y. (2017). Environmental impact of estrogens on human, animal and plant life: A critical review. *Environmental International, Vol. 99,* 107-119. https://doi.org/10.1016/j.envint.2016.12.010

Bain, K. T. (2010). Public Health Complications of Household Pharmaceutical Waste in the United States. *International Journal of Offender Therapy and Comparative Criminology, 3,* 1079-1103. https://doi.org/10.4137/HSI.S4673

Blanchfield, P. J., Kidd, K. A., Docker, M. F., Palace, V. P., Park, B. J., & Postma, L. D. (2015). Recovery of a wild fish population from whole-lake additions of a synthetic estrogen. *Environmental Science & Technology, 49*(5), 3136. Retrieved from https://colorado.idm.oclc.org/login?url=https://www.proquest.com/scholarly-journals/recovery-wild-fish-population-whole-lake/docview/1661371550/se-2?accountid=14503

Bradley, P., Journey, C. A., Button, D. T., Carlisle, D., Huffman, B. J., Qi, S. L., Romanock, K., & Van Metre, P. C. (2020). Multi-region assessment of pharmaceutical exposures and predicted effects in USA wadeable urban-gradient streams [Abstract]. *PLoS, 1*(15), 1-25. https://doi.org/10.1371/journal.pone.0228214

Bungau, S., Tit, D., Fodor, K., Cioca, G., Agop, M., Iovan, C., Cseppento, D., Bumbu, A., & Bustea, C. (2018). Aspects Regarding the Pharmaceutical Waste Management in Romania. *Sustainability*, *10*(8), 2788. https://doi.org/10.3390/su10082788

Centers for Disease Control and Prevention, Office of the Associate Director for Policy and Strategy. (2022, September 27). *Policy Analysis*. https://www.cdc.gov/policy/polaris/policyprocess/policyanalysis/index.html

ClinCalc. (2021, September 12). *Drug Usage Statistics for the United States (2013 to 2020)*. https://clincalc.com/DrugStats/About.aspx#:~:text=Using%20the%202020%20year%20as,About%203%2C000%2C000%2C000%20total%20prescriptions

Colorado Department of Public Health and Environment [CDPHE]. (2023). *Medical and Pharmaceutical Waste.* https://cdphe.colorado.gov/medicalwaste

Daughton, C. J., & Ruhoy, I. S. (2010). Environmental footprint of pharmaceuticals: The significance of factors beyond direct excretion to sewers. *Environmental Toxicology and Chemistry, 28*(12), 2495-2521. https://doi.org/10.1897/08-382.1

Diversion Control Division. (n.d.). *Drug Disposal Information*. U.S. Department of Justice, Drug Enforcement Administration. https://www.deadiversion.usdoj.gov/drug_disposal/

Doerr-MacEwen, N. (2007). *The management of human pharmaceuticals in the environment* Retrieved from https://colorado.idm.oclc.org/login?url=https://www.proquest.com/books/management-human-pharmaceuticals-environment/docview/21010037/se-2?accountid=14503

Ehiri, J. E., & Birley, M. (2002). Environmental impact of contraceptive use: An overview of available evidence. *Environmental Management and Health, 13*(1), 55-65. Retrieved from https://colorado.idm.oclc.org/login?url=https://www.proquest.com/scholarly-journals/environmental-impact-contraceptive-use-overview/docview/204520207/se-2?accountid=14503

Geurts, M.G.J., De Boer, W., De Graaf, J.S., Van Ginkel, C.G. (2007). Environmental exposure assessment of ethinyl estradiol (EE) from a combined hormonal vaginal contraceptive ring after disposal; leaching from landfills. *Science of the Total Environment, 377*(2-3), 366-370. https://doi.org/10.1016/j.scitotenv.2007.02.007

Global Data. (2022, December). *Top 10 Pharma Companies in the US by Market Capitalization*. https://www.globaldata.com/companies/top-companies-by-sector/healthcare/us-companies-by-market-cap/#:~:text=Showing%2010%20out%20of%2024,of%20December%2031%2C%202022).

Henrique de Carvalho, R., Lacerda, P. D., Mendes, S. da S., Barbosa, B. C., Paschoalini, M., Prezoto, F., & Maria de Sousa, B. (2015). Marine debris ingestion by sea turtles (Testudines) on the Brazilian coast: an underestimated threat? *Marine Pollution Bulletin, 101*(2), 746-749. https://doi.org/10.1016/j.marpolbul.2015.10.002

Jaseem, M., Kumar, P., & John, R. M. (2017). An overview of waste management in pharmaceutical industry. *The Pharma Innovation Journal, 6*(3), 158-161. https://www.thepharmajournal.com/archives/2017/vol6issue3/PartC/6-2-9-174.pdf

Jeffries, K. M., Jackson, L. J., Ikonomou, M. G., & Habibi, H. R. (2010). Presence of natural and anthropogenic organic contaminants and potential fish health impacts along two river gradients in Alberta, Canada. *Environmental Toxicology and Chemistry*. https://doi-org.colorado.idm.oclc.org/10.1002/etc.265

Kårelid, V., Larsson, G., & Björlenius, B. (2017). Pilot-scale removal of pharmaceuticals in municipal wastewater: Comparison of granular and powdered activated carbon treatment at three wastewater treatment plants. *Journal of Environmental Management, 193*, 491-502. https://doi.org/10.1016/j.jenvman.2017.02.042

Khan, U., Bloom, R.A., Nicell, J.A., & Laurenson, J. P. (2017). Risks associated with the environmental release of pharmaceuticals on the U.S. Food and Drug Administration "flush list". *Science of The Total Environment, 609,* 1023-1040. 10.1016/j.scitotenv.2017.05.269

Kostich, M. S., Batt, A. L., & Lazorchak, J. M. (n.d.). *Concentrations of prioritized pharmaceuticals in effluents from 50 large wastewater treatment plants in the US and implications for risk estimation.* United States Environmental Protection Agency. https://www.epa.gov/sites/default/files/2014-09/documents/50_large_wwtp_effluent.pdf

Luo, Y., Guo, W., Ngo, H.H., Nghiem, L. D., Hai, F. I., Zhang, J., Liang, S., & Wang, X. C. (2014). A review on the occurrence of micropollutants in the aquatic environment and their fate and removal during wastewater treatment. *Science of the Total Environment, 473-474*(1), 619-641. https://doi.org/10.1016/j.scitotenv.2013.12.065

Metro Water Recovery. (n.d.). *How We Transform Wastewater*. https://treatment.metrowaterrecovery.com/

Metro Water Recovery. (n.d.). *South Platte River*. https://treatment.metrowaterrecovery.com/south-platte-river/

Metro Water Recovery. (n.d.). *We Get Your Water*. https://www.metrowaterrecovery.com/

National Association of Drug Diversion Investigators, Inc. (2022). *Get a Box*. RxDrugDropBox.org. https://www.rxdrugdropbox.org/get/

National Integrated Drought Information System. (2023). Drought.gov. https://www.drought.gov/watersheds/colorado

Pappas, S. (2022, August 24). *Scientists find a simple way to destroy 'forever chemicals' –by beheading them.* Live Science. https://www.livescience.com/pfas-forever-chemicals-broken-down

Pines, E., & Smith, C. (2022). *A 10 Step Blueprint for Managing Pharmaceutical Waste in U.S. Healthcare Facilities* (3rd ed., pp. 11). (C. Smith, Ed.). Colorado Department of Public Health and Environment. (Original work published April 15, 2006). https://hercenter.org/10_step_blueprint_guide_final_9-22.pdf

Planned Parenthood. (2015, December 7). *12 Types of Birth Control.* Planned Parenthood of the Pacific Southwest, Inc. https://www.plannedparenthood.org/planned-parenthood-pacific-southwest/blog/12-types-of-birth-control

Rudzinski, S. (2012). *Recommendation on the Disposal of Household Pharmaceuticals Collected by Take-Back Events, Mail-Back, and Other Collection Programs.* Office of Solid Waste and Emergency Response. https://rcrapublic.epa.gov/files/14833.pdf

Schwartz, H., Marushka, L., Chan, H. M., Batal, M., Sadik, T., Ing, A., Fediuk, K., & Tikhonov, C. (2021). Pharmaceuticals in source waters of 95 First Nations in Canada. *Canadian Journal of Public Health, 112*(Suppl 1), 133-153. https://doi.org/10.17269/s41997-021-00499-3

South Australia Environmental Protection Agency. (2021, June 1). *Black and Grey Water Management.* https://www.epa.sa.gov.au/environmental_info/water_quality/programs/grey_and_black_water_discharge

Suchomel, A., Goeden, H., & Dady, J. (2018). A Method for Developing Rapid Screening Values for Active Pharmaceutical Ingredients (APIs) in Water and Results of Initial Application for 119 APIs. *International Journal of Environmental Research and Public Health, 15*(7), 1308. https://doi.org/10.3390/ijerph15071308

TakeMedsSeriously. (2023). *Safe Disposal*. https://takemedsseriously.org/safe-disposal/

Thomas, F. (2017). Pharmaceutical Waste in the Environment: A Cultural Perspective. *Public Health Panorama, 3*(1), 1-140. https://www.euro.who.int/__data/assets/pdf_file/0010/334396/10-Pharmaseutical-waste-environment.pdf

Trang, B., Li, Y., Xue, X., Ateia, M., Houk, K. N., & Dichtel, W. R. (2022). Low-temperature mineralization of perfluorocarboxylic acids. *Science. 377*(6608), 839-845. DOI: 10.1126/science.abm8868

United Nations Department of Economic and Social Affairs. (2019). *Contraceptive Use by Method* [Data Booklet]. Retrieved May 21, 2022 from https://www.un.org/development/desa/pd/sites/www.un.org.development.desa.pd/files/files/documents/2020/Jan/un_2019_contraceptiveusebymethod_databooklet.pdf

United Nations Population Fund [UNFPA]. (2013). *Safe Disposal and Management of Unused, Unwanted Contraceptives.* Retrieved from https://www.unfpa.org/resources/safe-disposal-and-management-unused-unwanted-contraceptives#:~:text=Unusable%20contraceptive%20waste%20can%20consist,derivatives%20included%20in%20hormonal%20contraceptives.

United States Census Bureau. (n.d.) *Census Regions and Divisions of the United States*. https://www2.census.gov/geo/pdfs/maps-data/maps/reference/us_regdiv.pdf

United States Department of the Interior, Bureau of Reclamation. (2012). *Reclamation: Managing Water in the West*. Colorado River Basin Water Supply and Demand Study. https://www.usbr.gov/watersmart/bsp/docs/finalreport/ColoradoRiver/CRBS_Executive_Summary_FINAL.pdf

United States Drug Enforcement Administration. (n.d.). *Take Back Day*. https://www.dea.gov/takebackday

United States Environmental Protection Agency. (2021, December 15). *Collecting and Disposing of Unwanted Medicines*. https://www.epa.gov/hwgenerators/collecting-and-disposing-unwanted-medicines

United States Environmental Protection Agency. (2022, June 29). *Water Enforcement*. https://www.epa.gov/enforcement/water-enforcement

United States Environmental Protection Agency. (2022, July 6). *National Pollutant Discharge Elimination System (NPDES)*. https://www.epa.gov/npdes/about-npdes

United States Environmental Protection Agency. (2022, July 6). *Learn the Basics of Hazardous Waste*. https://www.epa.gov/hw/learn-basics-hazardous-waste

United States Environmental Protection Agency. (2022, July 8). *Overview of Drinking Water Treatment Technologies.* https://www.epa.gov/sdwa/overview-drinking-water-treatment-technologies

United States Environmental Protection Agency. (2023, March 29). *Pharmaceuticals Production Industry: National Emission Standards for Hazardous Air Pollutants (NESHAP).*

https://www.epa.gov/stationary-sources-air-pollution/pharmaceuticals-production-industry-national-emission-standards

United States Food and Drug Administration. (2018, December 20). *Drug Disposal: Dispose "Non-Flush List" Medicine in Trash*. https://www.fda.gov/drugs/disposal-unused-medicines-what-you-should-know/drug-disposal-dispose-non-flush-list-medicine-trash

United States Food and Drug Administration. (2020, October 1). *Drug Disposal: FDA's Flush List for Certain Medicines.* *https://www.fda.gov/drugs/disposal-unused-medicines-what-you-should-know/drug-disposal-fdas-flush-list-certain-medicines*

Vumazonke, S., Khamanga, S. M., & Ngqwala, N.P. (2020). Detection of Pharmaceutical Residues in Surface Waters of the Eastern Cape Province. *International Journal of Environmental Research and Public Health, 17*(11), 4067. https://doi.org/10.3390/ijerph17114067

WACHS SOUTH WEST. (2019, March 18). *Handling of Expired Medicines, Excess Stock and Pharmaceutical Waste Disposal Procedure.* Government of Western Australia WA Health Country Health Service. https://www.wacountry.health.wa.gov.au/~/media/WACHS/Documents/About-us/Policies/Handling-of-Expired-Medicines-Excess-Stock-and-Pharmaceutical-Waste-Disposal-Procedure-WACHS-South-W.pdf?thn=0

Water Science School. (2018, June 6). *Pharmaceuticals in Water*. United States Geological Survey. https://www.usgs.gov/special-topics/water-science-school/science/pharmaceuticals-water

Watkins, E. S., PhD. (2012). How the PILL became a LIFESTYLE DRUG: The pharmaceutical industry and birth control in the United States since 1960. *American Journal of Public Health, 102*(8), 1462-72. Retrieved from https://colorado.idm.oclc.org/login?url=https://www.proquest.com/scholarly-journals/how-pill-became-lifestyle-drug-pharmaceutical/docview/1039281399/se-2

Appendix

Survey Questions

Individual Pharmaceutical Disposal Habit Survey

Survey Flow

Block: Survey Questions (15 Questions)

Page Break

Start of Block: Survey Questions

Consent Form Consent form Please read this form and then answer the following question.

- ○ Yes, I agree to participate in this study, and I am 18 years or older (1)
- ○ No, I do not agree to participate in this study, or I am not 18 years or older (2)

Skip To: End of Survey If Consent Form = No, I do not agree to participate in this study, or I am not 18 years or older

Skip To: End of Survey If Consent Form != Yes, I agree to participate in this study, and I am 18 years or older

Page Break

Q1 What age range best describes you?

- ○ 18-25 (1)
- ○ 26-35 (2)
- ○ 36-45 (3)
- ○ 46-55 (4)
- ○ 56-65 (5)
- ○ 66 and above (6)

Page Break

Q2 What gender best describes you?

- ○ Male (1)
- ○ Female (2)
- ○ Other: (3) _____
- ○ Prefer not to say (4)

Page Break

Q3 What region of the United States are you considered a resident?

○ North East, New England (Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont) (1)

○ North East, Middle Atlantic (New Jersey, New York, Pennsylvania) (2)

○ Midwest, East North Central (Indiana, Illinois, Michigan, Ohio, Wisconsin) (3)

○ Midwest, West North Central (Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, South Dakota) (4)

○ South, South Atlantic (Delaware, District of Columbia, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, West Virginia) (5)

○ South, West South Central (Arkansas, Louisiana, Oklahoma, Texas) (6)

○ South, East South Central (Alabama, Kentucky, Mississippi, Tennessee) (7)

○ West, Mountain West (Arizona, Colorado, Idaho, New Mexico, Montana, Utah, Nevada, Wyoming) (8)

○ West, Pacific (Alaska, California, Hawaii, Oregon, Washington) (9)

○ Prefer not to say (10)

Page Break

Q4 Do you currently or have you previously taken prescribed medication? (Including but not limited to medication for an injury, surgery, and/or prolonged use for a condition, birth control, mental health, etc.)

○ Yes (1)

- ○ No (2)
- ○ Unsure (3)

Page Break

Q5 Take Back Programs such as the DEA's National Take Back Day are programs sponsored by state and federal governments to collect unused or expired pharmaceuticals at various disposal sites such as local police departments and/or medical centers.
Were you previously aware of Take Back Programs before participating in this survey?

- ○ Yes (1)
- ○ No (2)

Page Break

Display This Question:

If Q5 = No

Q6 How do you dispose of your expired and/or unused pharmaceuticals? Please check all that apply.

- ☐ Trash (1)
- ☐ Recycle (2)
- ☐ Flush Down the Toilet (3)
- ☐ Other: (5) _____

☐ I do not dispose of my pharmaceuticals (4)

Page Break

Display This Question:

If Q6 = I do not dispose of my pharmaceuticals

Q7 If you were to dispose of your pharmaceuticals, which disposal method would you use? Please mark all that apply.

☐ Trash (1)

☐ Recycle (2)

☐ Flush Down the Toilet (3)

☐ Take Back Program (4)

☐ Other (Please Specify): (5)

_____

Page Break

Display This Question:

If Q5 = No

Q8 After being informed of what Take Back Programs are, would you use them as a pharmaceutical disposal method in the future?

○ Yes (1)

○ No (2)

Page Break

Display This Question:

If Q8 = No

Q9 Why would you choose to not use Take Back Programs as a disposal method in the future?

○ I do not have reliable trasportation (1)

○ Schedule conflicts (2)

○ Prefer to use other disposal methods (3)

○ Unsure (4)

○ Other: (5) _____

Page Break

Display This Question:

If Q5 = Yes

Q10 Have you ever utilized a program for disposing of your unused/expired pharmaceuticals?

○ Yes (1)

○ No (2)

Page Break

Display This Question:

If Q10 = Yes

Q11 How was your experience in terms of personal scheduling convenience?

- ○ Great (very convenient) (1)
- ○ Good (somewhat convenient) (2)
- ○ Neutral (no opinion) (3)
- ○ Poor (somewhat not convenient) (4)
- ○ Bad (not convenient at all) (5)

Page Break

Display This Question:

If Q10 = No

Q12 Why have you not utilized Take Back Programs?

- ○ Scheduling conflicts (1)
- ○ Lack of transportation to collection sites (2)
- ○ I prefer other disposal methods (3)
- ○ Unsure (4)

○ Other: (5) _____

Page Break

Display This Question:

If Q12 = Scheduling conflicts

And Q12 = Lack of transportation to collection sites

And Q12 = Unsure

And Q12 = Other:

Q13 What other disposal methods would/do you use?

☐ None, I prefer using only Take Back programs (1)

☐ Trash (2)

☐ Recycle (3)

☐ Flush Down the Toilet (4)

☐ Other: (5) _____

Page Break

Display This Question:

If Q12 = I prefer other disposal methods

And Q9 = Prefer to use other disposal methods

Q14 What disposal methods do you prefer that are not Take Back Programs?

- [ ] Trash (1)
- [ ] Recycle (2)
- [ ] Flush Down the Toilet (3)
- [ ] Other (Please Specify): (4)

_____

End of Block: Survey Questions