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Pharmaceutical Waste in Vermont: Results from a Survey on Purchasing, Use & Disposal

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PHARMACEUTICAL WASTE IN VERMONT:
RESULTS FROM A SURVEY ON PURCHASING, USE & DISPOSAL

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ABSTRACT

Pharmaceutical waste is an emerging form of waste with significant impacts on the environment. This study reports the results of a state-wide phone survey on pharmaceutical purchasing, use and disposal behavior among Vermont residents (n = 421). The objectives of this study were: 1) to compare the demographic nature of populations who purchase and use medicaton to those associated with leftover medication, and 2) to evaluate the impact of disposal behavior in Vermont and to recommend strategies to minimize pollution. The findings of this study showed that approximately 93% of survey participants reported purchasing of medication, 60% reported leftover medication and 25% reported disposing of medications down-the-drain or via municipal trash, both of which are known pathways leading to environmental pollution. Results indicate that pharmaceutical waste is common in Vermont and that disposal behavior may be contributing towards pollution. The conclusion of this study is that better management of pharmaceutical waste is needed to protect the environment and public health.

ACKNOWLEDGEMENTS

For Mother Earth.

and my Dad

who took me camping,

and for my Mom

who gave me a home,

and for my Brother

whose diagnosis

led to my awareness

of pollution

in the Environment.

And for my Committee,

Thank you.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1: INTRODUCTION

Pharmaceuticals are an emerging form of pollution with significant impacts on the environment. Increasing levels of pollution in the environment pose significant risks to ecological health (EPA, 2017b). Pharmaceutical compounds in the environment can be extremely toxic at extremely low levels. Some fish species may be at risk for population collapse from exposure to pharmaceutical levels equivalent to one drop of a medication in a lake (Kidd, 2015). The level of risk varies substantially according to each compound, however some studies show ecological risks may occur with concentrations as low as 5ppt (Kidd, 2015). Previous research shows that the level of risk can be very close to the median levels detected in the environment (Kolpin et al., 2002). The loss of fish populations is an example of one of a potentially infinite number of possible effects on ecosystems (Daughton & Ternes, 1999). The Environmental Protection Agency now considers pharmaceuticals "contaminants of emerging concern" (EPA, 2017a).

Pharmaceuticals enter the environment primarily through wastewater. In national reconnaissance studies, pharmaceuticals have been detected in 100% of wastewater samples (Loos et al., 2013), which is then discharged into rivers, lakes and streams, where the compounds remain persistent and ubiquitous, with serious potential effects. According to national statistics, detectable levels are present in over 80% of groundwater (Barnes et al., 2008), 80% of surface-water (Kolpin et al., 2002), and up to 100% of drinking water sampled in highly urbanized areas in the United States (Furlong et al., 2017). Drinking water technology, like wastewater technology, was never designed to remove chemicals (Caban et al., 2015; Ternes et al., 2002).

Increasing levels in drinking water and wastewater imposes a significant burden on water providers (American Chemical Society, 2008). The costs of updating water systems, primarily designed for water treatment, for purposes of water purification, is financially and technologically out of reach for most communities (Shannon et al., 2008).

Pharmaceutical pollution is expected to increase, due to increasing use of medication (Kantor et al., 2015). According to national statistics, 25% of children, 50% of adults, and 90% of older adults age 65+ use prescription medications each month in the U.S. (CDC, 2013). Pharmaceutical use contributes towards the relatively constant level of pollution seen in wastewater (Roberts et al., 2016). In 2014, a pilot study in Burlington, VT detected 51 pharmaceutical compounds in wastewater and identified the consumer population as the source (Vatovec et al., 2016). Several findings suggest that disposal of leftover medication may be a significant source of pollution in the environment (Bound & Voulvoulis, 2005; Law et al., 2015).

Previous research on lifecycle assessements have found that different strategies for disposal are each associated with their own set of socio-ecological consequences, depending on the method (Cook, 2012). Disposal impacts the health of the environment, as well as the health of communities, through various forms of pollution.

One of the proposed solutions: The National Prescription Takeback Initiative is intended to minimize the impact of disposal on the environment (DEA, 2017). Consumers are encouraged to “takeback” medication, rather than dispose down-the-drain, which contributes towards pollution in wastewater, or dispose through the trash, which contributes towards groundwater pollution surrounding landfills (Daughton, 2003).

Greater research is needed on pharmaceutical purchasing, use and disposal behavior, in order to develop intervention strategies to minimize pharmaceutical pollution, such as encouraging proper disposal through takeback programs. Greater research is needed on leftover medication specifically, in order to develop strategies to prevent waste, minimize disposal and therefore minimize pollution in the environment. This study will address this need by examining the results of a statewide survey on consumer purchasing, use and disposal behavior. The first objective of this study was to compare the demographic nature of populations who purchase and use medicaton, to those associated with leftover medication. The second objective was to evaluate the impact of disposal behavior in Vermont, and to recommend strategies to minimize pollution.

CHAPTER 2: LITERATURE REVIEW

2.1 Pharmaceuticals in the Environment

Pharmaceuticals are an emerging form of water pollution. Hundreds of studies have evaluated the occurrence, fate and effects of pharmaceuticals on many different kinds of aquatic and terrestrial species (Boxall et al., 2012). Pharmaceuticals have been shown to effect aquatic species including bacteria, plankton, insects, crustaceans, amphibians, fish, as well as terrestrial species such as worms, waterfowl and birds (EPA, 2017). Adverse effects include behavioral changes (Macikova et al., 2014), genetic, biochemical, or endocrine disruption (Hotchkiss et al., 2008), retardation of growth (Brausch et al., 2012), deformation, physical mutation (Brooks, 2014), bioaccumulation among tissues and organs (van der Oost et al., 2003), effects on reproduction, morphological intersex changes (Neimuth & Klaper, 2015), developmental abnormalities among offspring (Overturf et al., 2015), sterility and mortality (EPA, 2017a), and eventually, population collapse (Kidd, 2015).

Some pharmaceuticals are extremely toxic to aquatic life at extremely “low” concentrations. One of the most prescribed antidepressants, Prozac (fluoxetine), produces severe toxicity as low as 100ppt (Brooks, 2014). The most common diabetes medication, Metformin can change the sex of fish, as low as 40ppt (Neimuth & Klaper, 2015). Carbamazepine, an antiepileptic medication, produces morbidity and mortality, as low as 18ppt (Ferrari et al., 2004). Zoloft, a popular antidepressant, as low as 5ppt (Schultz et al., 2011). At this scale, pharmaceutical pollution is like one drop in lake. Pharmaceuticals are present in the environment in trace amounts, typically in the parts per trillion range. At this scale, pharmaceuticals may pose significant risks to ecological health (Brooks, 2014; Fent et al., 2006; Khetan & Collins, 2007).

Very little is known about the full spectrum of potential risks to ecological health. Pharmaceuticals are introduced into the environment through continuous discharge of wastewater, which leads to a relatively constant level of pollution in rivers, lakes and streams (Roberts et al., 2016). Continuous use by the consumer population leads to continuous discharge into wastewater, which creates a “pseudo-persistence” to the levels of pollution in rivers (Daughton, 2003). Therefore, the levels in the environment, although relatively “low” due to dilution, are nevertheless constant and continuous. Aquatic life is therefore exposed to pharmaceuticals constantly and continuously. The constant discharge into the environment, combined with the actual persistence of the compounds further complicates the scale of the effects (Stackelberg et al., 2004). If a compound has ecotoxic properties, or endocrine disrupting properties, or bioaccumulation potential, the risks may go on for signficant periods of time (Halling-Sorensen et al., 1998). Aquatic life is exposed to a potentially infinite number of possible pollutants in rivers, leading to a potentially infinite number of possible bio-chemical reactions and interactions, which may catalyze significant, cascading effects throughout ecosystems (Daughton, 2003).

The lifespan of persistent compounds can measure in years, decades, or centuries and degradation of pharmaceuticals does not necessarily lead to less risk (Yamamoto et al., 2009). Pharmaceutical compounds may “degrade” into different compounds, or transform into “metabolites,” however these derivate compounds can be equally toxic, and sometimes more toxic than the parent compound (Donner et al., 2013). Very little can be known about the full spectrum of risks, primarily due to the inherent limitations to studying and predicting such effects, both from a methodological as well as an epistemological standpoint (Daughton & Ternes, 1999). Ecosystems are an open system, where multiple organisms can be exposed to multiple chemicals simultaneously, at multiple points in their lifetime, at different stages of life, leading to a multiplicity of effects across time and space. Effects from long term, continuous lifecycle and multigenerational exposure to multiple chemicals, from constant exposure to "low" concentrations in water may produce "subtle" effects that are not easily detectable or measurable (Daughton & Ternes, 1999).

2.2 Pharmaceuticals in Drinking Water

As stated previously, pharmaceuticals enter the environment primarily through discharge of wastewater into the environment (Ashton et al., 2004; Nikolaou et al., 2007; Roberts et al., 2016). Many municipalities rely on the same water body as a point of discharge for wastewater, but they also rely on the water body as the source of the community's drinking water.

Therefore, pollution in wastewater contributes towards pollution in rivers, which may increase potential pollution entering the drinking water cycle (Conley et al., 2017). Pharmaceuticals are introduced into the wastewater cycle through consumer use of medication, which results in excretion down-the-drain, as well as direct disposal down-the-drain (Daughton, 2003a, 2003b). Conventional water technology does not fully remove pharmaceuticals (Luo et al., 2014; Y. Yang et al., 2017). Hundreds of studies document pharmaceuticals in wastewater. For example, a survey of contaminants in wastewater at 90 wastewater facilities across 16 countries in the EU found pharmaceutical compounds in 100% of samples (Loos et al., 2013). Wastewater (along with pharmaceuticals, and other contaminants) is then discharged into surface waters or groundwater, where the pharmaceutical become a form of water pollution. Similarly, drinking water treatment does not fully remove pharmaceuticals (Caban et al., 2015; Ternes et al., 2002).

Pharmaceutical contamination of drinking water has been documented in some of the largest cities in the world (American Chemical Society, 2008). In the US, recent reconnaissance surveys have found pharmaceuticals may be present in up to 50% of drinking water on a national scale (Focazio et al., 2008) and potentially up to 100% in highly urbanized areas (Furlong et al., 2017). Pharmaceuticals in drinking water has catalyzed growing concern about the potential risks to public health. Human health risk assessments often produce conflicting results (Williams & Brooks, 2012). The World Health Organization has concluded the potential risks to human health are inconclusive, primarily due to the lack of occurrence data, therefore, without data on the levels in drinking water, comprehensive risk assessments were not possible (WHO, 2011). Nevertheless, the WHO concluded that the evidence supports precaution and recommended measures to minimize pharmaceutical pollution in the environment. One proposed measure was to minimize consumer disposal of medication.

2.3 Consumer Disposal as a Source of Environmental Pollution

Pharmaceutical excretion and disposal are the two primary source-pathways by which the consumer population transfers pharmaceuticals into the environment (Daughton & Ruhoy, 2007). Currently, it is unknown whether pharmaceutical pollution of water is caused primarily by consumer excretion or by consumer disposal

(Glassmeyer et al., 2009; Ruhoy & Daughton, 2008). Each of these sources needs greater research, however some studies are emerging to give us a sense of the relative contribution of each source (Ruhoy & Daughton, 2007; Vatovec et al., 2016).

Consumer disposal takes two forms. Disposal of leftover medication down-the-drain directly contaminates the wastewater cycle (Bound & Voulvoulis, 2005), while disposal through municipal trash transfers pharmaceuticals to landfills, where compounds are known to leach into surrounding groundwater (Eggen et al., 2010). Previous research on disposal behavior has often been framed within greater efforts to encourage proper disposal through a governmental program called The National Prescription Drug Takeback initiative (DEA, 2017). Takeback programs are the official, recommended method of disposal. Since the program began in 2010, over 9 million pounds of pharmaceutical waste has been turned into the program (DEA, 2017). However, this may represent only a fraction all pharmaceutical waste.

Surveys find that leftover medication is commonly reported among surveyed populations. For example, in southern California 66% of respondents report leftover medication (Law et al., 2015), with up to 45% of survey respondents reporting disposal (Kotchen, Kallaos, Wheeler, Wong, & Zahller, 2009). Reviews on disposal behavior find a minority of consumers dispose of medication through takeback programs and the majority of consumers dispose of medication through the household, a known pathway leading to environmental pollution (Kusturica et al., 2017; Tong et al., 2011). This indicates that consumer disposal may be a significant source of environmental pollution.

2.4 Takeback Programs, a Strategy to Minimize Environmental Pollution

Takeback programs were established to safely and securely collect medication from consumers, transfer the pharmaceutical waste to hazardous waste facilities, where the waste is disposed through incineration (EPA, 2017c). Although incineration may degrade chemicals, the potential of this method to reduce impacts on the environment remains unclear. Incineration, in general, is known to emit significant quantities of air pollution, which is known to adversely impact the health of surrounding communities (Rushton, 2003). Although the recommendation continues to be debated (Cook et al., 2012; Daughton, 2012), takeback programs are increasingly regarded as an effective solution to address the need for proper disposal of pharmaceutical waste (Glassmeyer et al., 2009).

2.5 Disposal Behavior and Participation in Takeback Programs

Several studies have examined drug disposal behavior in the U.S. and internationally. Reviews of surveys on disposal behavior find that leftover medication generally has two fates: either it is kept or disposed (Kusturica et al., 2017; Tong et al., 2011). A survey of 1,005 residents in southern California found most respondents dispose of medication through the trash (45%), flushing down the drain (28%), or takeback programs (10%) (Kotchen et al., 2009). Therefore, the primary method of disposal in the California study was through the trash and through flushing (73%).

In Sweden, the primary method is to keep medication (55%) or to takeback medication (45%) (Persson et al., 2009). Significantly, this study found no participants had reported disposal down-the-drain or through the trash. A review of surveys on disposal behavior found that Sweden has the highest rate of participation in takeback programs at 45% (Persson et al., 2009). Takeback programs have been more or less accessible in pharmacies for half a century in Sweden, which may account for distinctly different disposal behavior, compared to other countries such as the US, where takeback programs are beginning to be established. In Sweden, participation in takeback programs was 45%, as stated, however in the US, participation ranges from 1% to 10% in communities with newly established programs (Kotchen et al., 2009; Vatovec et al., 2017), however participation may be up to 20% in more established programs (Zero Waste Washington, 2006; Ekedahl, 2006).

The availability, accessibility, as well as the convenience of takeback programs are necessary conditions for participation, however other factors beyond the accessibility of the program itself, are likely more influential on disposal behavior, specifically participation in the program. Takeback programs are available in both communities in California and in Sweden, however household disposal is favored in the California study, and storage is favored in the Swedish study. Collectively, these findings suggest that the availability of a takeback program is not the only factor effecting consumer disposal behavior.

Participation in takeback programs is strongly correlated with education, information, and consultation about proper disposal from a healthcare provider, as well environmental awareness of the potential impacts from improper disposal (Abahussain et al., 2006; Bashaar et al., 2017; Kotchen et al., 2009; Seehusen & Edwards, 2006). Therefore, this study sought to identify populations who may benefit from takeback programs and to develop strategies increase participation through education based policies.

CHAPTER 3: METHODS

3.1 Survey Design, Participant Recruitment and Data Collection

Data were collected through a phone survey administered at the University of Vermont between October and November of 2016. Trained interviewers recruited participants by calling a random sample of phone numbers with the Vermont area code 802. Interviewers dialed each phone number at different points of the day on both weekdays and weekends, provided an overview of the survey content, read the confidentiality statement, asked for voluntary consent to participate in the survey and then proceeded to ask 27 questions while recording responses into an online survey database (Limesurvey, 2017). Questions included purchasing of medication, whether respondents ever have unused medication leftover, reasons why medication may be leftover, what they do with leftover medication, including methods of disposal and participation in takeback programs. Survey questions were designed to understand the demographic, geographic and behavioral nature of consumer pharmaceutical purchasing, use and disposal. This study was approved by the University of Vermont Institutional Review Board.

3.2 Data Analysis

Data were analyzed using SPSS social science statistical software (SPSS, 2017). Descriptive statistics were based on cross-tabulations to compare frequencies of different responses to questions, such as the percentage responding Yes or No to a question on pharmaceutical use. Pearson’s chi-square tests of significance were used to determine differences between groups associated with response variables that were categorical in nature, independent samples t-tests, for differences between the ages of two response groups, and Anova tests, for the ages of three or more response groups.

3.3 Framework for Assessing Environmental Impact of Disposal Behavior

The Framework (Figure 1) defined and characterized disposal behavior into high, uncertain and low impact groups. Data on disposal were derived from a question: "in general, what do you do with leftover medication?" Multiple responses were possible, therefore some respondents reported multiple disposal methods with mixed impact. For example, one individual may report flushing (high impact) as well as taking back medication (low impact). Respondents with mixed behavior involving two or more disposal methods with different impact were categorized into the "higher" impact category. If a respondent reported at least one high impact method, they were grouped into high impact behavior. If a respondent only reported low impact methods, they were grouped into the low impact behavioral group. For the uncertain group, respondents reported at least one uncertain method, and reported no high impact methods, but may have reported additional, low impact behavior. This criteria was used to categorize the disposal behavior of the survey population into three mutually exclusive groups, which enabled statistical and comparative analyses.

CHAPTER 4: ARTICLE

Abstract

Pharmaceutical waste is an emerging form of waste with significant impacts on the environment. This study reports the results of a state-wide phone survey on pharmaceutical purchasing, use and disposal behavior among Vermont residents (n = 421). The purpose of this study was to identify populations associated with leftover medication, evaluate the environmental impact of disposal behavior, and to recommend strategies to minimize environmental pollution. Results indicate that leftover medication is common in Vermont (60% of the sample reported leftover medication), leftover medication is associated with higher income populations (43% of those with <$25,000 had leftover medication, compared to 78% of those with >$100,000, p=0.0002), and that disposal may be contributing towards environmental pollution (25% of the sample reported disposal behavior associated with high environmental impact). Participants whose physician or pharmacist recommended takeback programs for disposal were more likely to return leftover medications. The findings of this study suggest that public campaigns seeking to increase participation in takeback programs would likely be effective coming from a doctor or pharmacist.

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4.1 Introduction & Literature Review

Pharmaceuticals are an emerging form of waste with significant impacts on the environment. According to national statistics, 25% of children, 50% of adults, and 90% of older adults age 65+ use prescription medications each month in the U.S. (CDC, 2013). A significant amount of medication is prescribed to the consumer population each year, however a significant amount of medication may go unused. Between 40% and 66% of consumers report leftover medication (Banwat et al., 2016; Kreisberg & Zheng, 2011; Kusturica et al., 2016; Law et al., 2015; Vatovec et al., 2017). The fate of medication that may become "leftover" due to partial or non-use is largely unstudied. Excess medication may become a risk factor for abuse (Birnbaum et al., 2011), childhood poisoning (Warner et al., 2011), adult overdose (Bohnert et al., 2011), or illicit diversion (Dart et al., 2015). In particular, excess prescription of opioids is gaining increasing attention (Bicket et al., 2017). Leftover medication is an emerging form of waste, with several unintended consequences. Generally, literature shows that leftover medication has two fates: either it is kept or disposed of (Tong et al., 2011). If medication is kept in the household, excess medication may impact public health in a variety of ways, otherwise if medication is disposed, the medication may enter the environment and contribute towards the increasing levels of pharmaceutical pollution detected in the environment. Greater research is needed on leftover medication and disposal, in order to develop intervention strategies to minimize the potential public health impacts of leftover medication, and to minimize the potential environmental impacts of pharmaceutical disposal.

Pharmaceuticals are found in virtually all wastewater (Loos et al., 2013), between 50% to 80% of groundwater (Barnes et al., 2008), over 80% of surface-water in the U.S., (Kolpin et al., 2002), and up to 100% of drinking water in highly urbanized areas (Furlong et al., 2017). Pharmaceuticals in the environment pose significant risks to ecological health (EPA, 2017b) and may pose risks to public health (WHO, 2011). The Environmental Protection Agency now considers pharmaceuticals “contaminants of emerging concern” (EPA, 2017a).

In 2014, a pilot study in Burlington, VT detected 51 pharmaceutical compounds in wastewater and identified the consumer population as the source (Vatovec et al., 2016). Disposal of leftover medication is a known source of pharmaceuticals in wastewater (Daughton, 2003). In November 2016, researchers conducted a statewide survey of Vermont residents to collect data on pharmaceutical purchasing, use and disposal behavior, to assess the consumer population as a source of pollution. The purpose of this study was to identify populations associated with leftover medication, evaluate the environmental impact of disposal behavior, and to recommend strategies to minimize environmental pollution. The findings of this study are intended to provide a greater understanding of disposal behavior, in order to assist efforts to minimize pollution in the environment.

Currently, the preferred method for minimizing pharmaceutical pollution from leftover medication is to encourage participation in drug takeback programs. The National Prescription Takeback Initiative is the official, recommended form of disposal of pharmaceutical waste (DEA, 2017). Public education campaigns have been initiated to encourage disposal through takeback programs (Product Stewardship Council, 2017).

This study assessed the disposal behavior of populations with leftover medication in Vermont, in order to evaluate whether behavior may differ systematically in terms of demographic characteristics. If this is the case, a campaign to increase participation in takeback programs may require different strategies, in order to increase participation across the whole target population. Therefore, understanding purchasing, use and disposal behavior is needed, in order to better understand how to utilize takeback programs as a strategy to reduce pharmaceutical pollution in the environment.

4.2 Methods

4.2.1 Survey Design, Participant Recruitment and Data Collection

Data were collected through a phone survey administered at the University of Vermont between October and November of 2016. Trained interviewers recruited participants by calling a random sample of phone numbers with the Vermont area code 802. Interviewers dialed each phone number at different points of the day on both weekdays and weekends, provided an overview of the survey content, read the confidentiality statement, asked for voluntary consent to participate in the survey and then proceeded to ask 27 questions while recording responses into an online survey database (Limesurvey, 2017). Questions included purchasing of medication, whether respondents ever have unused medication leftover, reasons why medication may be leftover, and what they do with leftover medication, including methods of disposal and participation in takeback programs. Survey questions were designed to understand the demographic, geographic and behavioral nature of consumer pharmaceutical purchasing, use and disposal. This study was approved by the University of Vermont Institutional Review Board.

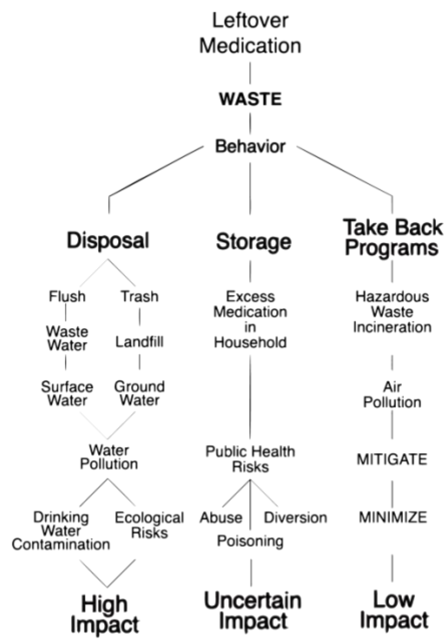
4.2.2 Data Analysis

Data were analyzed using SPSS social science statistical software (SPSS, 2017). Descriptive statistics were based on cross-tabulations to compare frequencies of different responses to questions, such as the percentage responding Yes or No to a question on pharmaceutical use. Pearson's chi-square tests of significance were used to determine differences between groups associated with response variables that were categorical in nature, independent samples t-tests, for differences between the ages of two response groups, and Anova tests, for the ages of three or more response groups.

4.2.3 Framework for Assessing Environmental Impact of Disposal Behavior

The Framework (Figure 1) defined and characterized disposal behavior into high, uncertain and low impact groups. Participants were assigned to high, uncertain, or low impact behavioral categories, based on their reported method: dispose, keep, or return. Flushing and trash methods were defined as high impact behavior because flushing and trash methods introduce pharmaceuticals directly into the environment (Daughton, 2003), where the compounds are known to remain persistent (Yamamoto et al., 2009). Keeping medication was classified as having uncertain impact because the impact on the environment is uncertain. Finally, returning medication to takeback programs was defined as low impact because takeback programs are recommended for low environmental impact (EPA, 2017c).

Figure 1. Framework for Assessing Impact of Disposal Behavior



Data on disposal were derived from a question: "In general, what do you do with leftover medication?" Multiple responses were possible, therefore some respondents reported multiple disposal methods with mixed impact. For example, one individual may report flushing (high impact) as well as taking back medication (low impact). Respondents with mixed behavior involving two or more disposal methods with different impact were categorized into the "higher" impact category. This criterion was used to categorize the disposal behavior of the survey population into three mutually exclusive groups.

4.3 Results

4.3.1 Demographics of the Survey Sample Population

The survey sample included a total of 421 participants. This sample size provides a 95% confidence interval of +/- 5%, for estimated proportions. Overall, demographics of the survey population were representative of the Vermont population in terms of gender, income, and locality, however the sample is slightly skewed towards older populations with more formal education (Table 1). The sample included slightly more females (54%) than males (46%) and the vast majority of respondents identified as white (98%). The sample was equally distributed above and below the state's median household income ($55,000); with 37% below and 41% above median income. The age of the sample population was moderately skewed towards older populations with 60% of the sample being 51 or older, compared to 40% of the Vermont general population, of the same age. The educational distribution of the sample was also moderately skewed towards higher formal education with 54% of the sample reporting a college education or higher, compared with 36% of the Vermont population. In terms of geographic locality: rural, urban and suburban, the sample population was similar to the Vermont population.

Table 1. Demographics of Sample vs. Vermont Population.

Demographics	Survey Sample n (%)		Vermont Population[1] (%)
Gender	**N = 419**		
Female	221 (54%)		(54%)
Male	192 (46%)		(46%)
Income	**N = 360**		
<$25,000	58 (16%)	(37%)	
$25 to $50,000	75 (21%)		
$50 to $75,000	81 (23%)		$55,000 (median)
$75 to $100,000	67 (19%)	(41%)	
>$100,000	79 (22%)		
Age	**N = 401**		
18 to 30	52 (13%)		(13%)
31 to 40	40 (10%)		(11%)
41 to 50	69 (17%)		(13%)
51 to 60	84 (21%)		(16%)
61 to 70	79 (20%)		(13%)
71 to 80	60 (15%)		(7%)
81 to 90	22 (6%)		(4%)
Education	**N = 402**		
<High School	11 (3%)		(8%)
High School	67 (17%)	(44%)	(56%)
Some College	71 (18%)		
Associates	38 (10%)		
Bachelor	108 (27%)	(53%)	(36%)
Post graduate	107 (27%)		
Locality	**N = 394**		
Rural	243 (61%)		(58%)
Urban	60 (15%)		(14%)
Suburban	91 (23%)		(22%)
Health Insurance	**N = 356**		
Uninsured	6 (2%)		(4%)
Medicare/aid	134 (38%)		(39%)
Private	216 (61%)		(55%)

Note. Percentages rounded to nearest whole number.

[1]Vermont population statistics obtained through state census (Census, 2017).

4.3.2 Populations associated with Purchasing, Use & Leftover Medication

The vast majority of the survey population reported purchasing medication (93%), the majority reported leftover medication (60%), and of those with leftover medication, approximately half kept the medication (48%), while the other half reported disposal (52%) (Table 2).

Table 2. Survey Population reporting Purchasing, Use & Leftover Medication.

<table>
<tr><td colspan="3">Purchasing of Medication
N = 421
n = 392
(93%)</td></tr>
<tr><td colspan="3">Leftover Medication
n = 254
(60%)</td></tr>
<tr><td colspan="3">Fate of Medication
What do you do with leftover medication?</td></tr>
<tr><td colspan="2">Disposal
n = 133
(52% of leftover population)
(32% of total population)</td><td>Keep
n = 121
(48%)
(29%)</td></tr>
<tr><td>Disposal Methods*</td><td>n (%)</td><td rowspan="2">Fate Unknown</td></tr>
<tr><td>Takeback
Trash
Flush</td><td>96 (72%)
81 (61%)
32 (25%)</td></tr>
<tr><td colspan="2">Environmental Impacts</td><td>Public Health Impacts</td></tr>
</table>

Note. Total Sample Population: N = 421.
*Multiple responses possible.

4.3.3 Populations associated with Disposal Behavior

The findings of this study indicates that disposal behavior varies according to the method of disposal. Of those who reported disposal of medication (n = 113), 72% reported participating in takeback programs, 61% reported trash disposal, and 25% reported flushing down-the-drain (Table 2). Participation in takeback programs was often reported alongside other behaviors. The majority of those who reported participation also reported multiple, additional methods, often with higher impact, and therefore were categorized into higher impact behavior, based on the criteria outlined in the Framework (Figure 1). For example, 72% reported participation (Table 2), but only 26% reported participation as their only disposal method and therefore only 26% were categorized as having exclusively low impact behavior (Table 3).

4.3.4 Evaluating Environmental Impact of Disposal Behavior

According to the results of this study, 60% of the sample population reported leftover medication (Table 2), and of those with leftover medication, disposal behavior was distributed among high (42%), uncertain (32%), and low impact behavior (26%) (Table 3).

Table 3. Disposal Behavior in the Survey Population based on High, Uncertain and Low Impact Behavioral Groups.

Disposal Method	Behavioral Groups based on Environmental Impact	n	% of Sample with Leftover Medication (n = 254)	% of Total Sample (n = 421)
Flush, Trash	High	107	42%	25%
Storage	Uncertain	80	32%	19%
Takeback	Low	67	26%	16%

Respondents who disposed of medication either disposed through the trash or through flushing (42%), or exclusively through takeback programs (26%) (Table 3). Therefore, disposal behavior produced mixed results, which suggests that participation in takeback programs can be improved. The total percentage of respondents who reported trash and flushing was 25% (Table 3), keeping was 29% (Table 2), and takeback was 23% (96 of 421) (Table 2).

4.3.5 Demographics of Populations associated with Leftover Medication

Populations associated with leftover medication differ significantly based on income and health insurance. Income (p = 0.002) and health insurance (p = 0.053) were the only demographics statistically related to leftover medication (Table 5). Participants with higher income and those with private insurance reported significantly higher prevalence of leftover medication, compared to lower income groups, with public insurance through Medicare/aid. No significant differences were found between populations who disposed of medication or kept medication, except for gender (p = 0.012) (Table 5). Women were more likely than men to report disposal of medication, and men were more likely than women to report keeping medication, and therefore keeping vs. disposal differed based on gender, however there were no significant demographic differences when disposal behavior was grouped into high, uncertain and low impact groups. All demographic populations were distributed approximately equally across high, uncertain, and low impact behavioral groups. Overall, disposal vs. keeping behavior differed based on gender, however disposal behavior (high, uncertain, low environmental impact) did not show any significant differences in terms of demographics.

Table 4. Demographics of Populations associated with Leftover Medication.

	Medication N = 412	
Demographics	Leftover n = 254 (60%)	None Leftover n = 158 (39%)
Gender	p = 0.188	
Female	141 (64%)	78 (36%)
Male	109 (59%)	77 (41%)
Income	***p = 0.002**	
<$25,000	25 (43%)	33 (57%)
$25 to $50,000	41 (55%)	34 (45%)
$50 to $75,000	45 (70%)	25 (30%)
$75 to $100,000	55 (72%)	22 (28%)
>$100,000	58 (78%)	21 (22%)
Age	p = 0.494	
Mean	54	54
18 – 30	28 (54%)	24 (46%)
31 – 40	29 (74%)	10 (26%)
41 – 50	46 (68%)	22 (32%)
51 – 60	53 (63%)	31 (37%)
61 – 70	47 (60%)	31 (40%)
71 – 80	35 (58%)	25 (42%)
> 80	10 (63%)	6 (37%)
Education	p = 0.252	
≤ High School	46 (59%)	32 (41%)
Some College	64 (60%)	43 (40%)
Bachelor	63 (59%)	45 (41%)
Post graduate	75 (70%)	32 (30%)
Locality	p = 0.154	
Rural	159 (66%)	82 (34%)
Suburban	54 (59%)	37 (41%)
Urban	32 (53%)	28 (47%)
Health Insurance	***p = 0.053**	
Medicare/aid	76 (57%)	58 (43%)
Private	144 (67%)	71 (33%)

Table 5. Demographics of Populations associated with Disposal & Environmental Impact.

	Fate of Leftover Medication N = 254		**Environmental Impact of Disposal Behavior N = 254**		
Demographics	Disposal n = 133 (52%)	Keep n = 121 (48%)	Low n = 67 (26%)	Uncertain n = 80 (32%)	High n = 107 (42%)
Gender	***p = 0.012**		p = 0.077		
Female	75 (75%)	25 (25%)	43 (31%)	38 (27%)	60 (42%)
Male	41 (56%)	32 (44%)	22 (20%)	42 (39%)	45 (41%)
Income	p = 0.417		p = 0.674		
<$25,000	9 (56%)	7 (44%)	9 (37%)	8 (33%)	8 (29%)
$25 to $50,000	15 (60%)	10 (40%)	12 (29%)	14 (34%)	15 (36%)
$50 to $75,000	28 (74%)	10 (26%)	12 (22%)	14 (25%)	29 (53%)
$75 to $100,000	27 (77%)	8 (23%)	12 (27%)	14 (32%)	18 (41%)
>$100,000	27 (64%)	15 (36%)	15 (26%)	21 (36%)	22 (38%)
Age	p = 0.414		p = 0.091		
Mean	51	54	56	51	55
18 – 30	14 (64%)	8 (36%)	2 (7%)	12 (44%)	13 (49%)
31 – 40	18 (78%)	5 (22%)	9 (31%)	8 (28%)	12 (41%)
41 – 50	19 (65%)	10 (35%)	10 (22%)	11 (41%)	25 (54%)
51 – 60	28 (65%)	15 (35%)	13 (25%)	22 (25%)	18 (34%)
61 – 70	20 (69%)	9 (31%)s	14 (29%)	12 (35%)	21 (45%)
71 – 80	12 (57%)	9 (43%)	13 (28%)	12 (30%)	9 (26%)
> 80	2 (66%)	1 (33%)	5 (50%)	3 (30%)	2 (20%)
Education	p = 0.542		p = 0.227		
≤ High School	18 (72%)	7 (28%)	14 (30%)	11 (24%)	21 (45%)
Some College	29 (66%)	15 (34%)	18 (29%)	21 (33%)	24 (38%)
Bachelor	25 (58%)	18 (42%)	9 (15%)	26 (42%)	27 (44%)
Post graduate	41 (70%)	17 (29%)	24 (32%)	22 (29%)	29 (39%)
Locality	p = 0.687		p = 0.681		
Rural	72 (66%)	37 (34%)	42 (26%)	48 (30%)	68 (43%)
Suburban	27 (73%)	10 (27%)	11 (20%)	21 (39%)	22 (41%)
Urban	14 (64%)	8 (36%)	10 (32%)	9 (29%)	12 (39%)
Health Insurance	p = 0.659		p = 0.409		
Medicare/aid	36 (69%)	16 (31%)	21 (28%)	23 (31%)	30 (40%)
Private	69 (66%)	36 (34%)	30 (21%)	49 (34%)	65 (45%)

4.3.6 Disposal Behavior correlates with Education on Disposal, not Demographics

Although disposal behavior (high, uncertain and low impact) may not differ significantly among different demographic populations, the disposal behavior of participants in this study differed significantly based on whether a participant had been exposed to education, awareness and information about disposal (Table 6). Those who had lower impact behavior, namely those who had participated in takeback programs, were more likely be aware of environmental pollution, and to have received information on disposal from a doctor or pharmacist. Thus, awareness of environmental pollution, and information and education from a healthcare provider were both highly related to lower impact disposal behavior. Notably, awareness about takeback programs in and of itself, was not correlated with participation in takeback programs.

Table 6. Education, Awareness & Disposal Behavior.

	Environmental Impact of Disposal Behavior		
	Low	**Uncertain**	**High**
	Takeback Programs	Keep, Storage	Trash, Flush
Awareness of Takeback Programs, N = 157	p = 0.280		
Yes 77 (49%)	6 (5%)	47 (41%)	63 (54%)
No 80 (51%)	1 (2%)	12 (30%)	28 (68%)
Awareness of Pollution in Environment, N = 249	***p = 0.003**		
Yes 152 (61%)	72 (36%)	65 (33%)	61 (31%)
No 97 (39%)	6 (12%)	14 (27%)	31 (61%)
Information on Disposal Received, N = 252	***p = <0.001**		
Yes 204 (81%)	74 (36%)	66 (32%)	66 (32%)
No 48 (19%)	1 (2%)	14 (30%)	31 (67%)
from a Physician, N = 244	***p = 0.014**		
Yes 34 (14%)	15 (46%)	7 (22%)	11 (33%)
No 210 (86%)	52 (24%)	73 (33%)	94 (43%)
from a Pharmacist, N = 247	***p = 0.030**		
Yes 49 (20%)	23 (46%)	11 (22%)	16 (32%)
No 197 (80%)	44 (22%)	66 (33%)	87 (44%)

4.4 Discussion

Baseline results indicate that purchasing, use and leftover medication were commonly reported by the survey population. The vast majority of respondents had purchased medication within the last year (93%), which is consistent with national statistics (CDC, 2013). The majority of respondents reported partial or incomplete use of medication, as evidenced by 60% of the sample reporting leftover medication. This finding is consistent with other studies, which also find that leftover medication is common among surveyed populations. As stated previously, between 40% and 66% of populations report leftover medication (for example, Law et al., 2015).

Generally, the disposal behavior of the survey population appears to be similar to other surveyed populations (Tong et al., 2011). A significant finding of this study was that the total percentage of the survey population associated with high impact disposal behavior was 25%, thereby indicating that a potentially significant percentage of pharmaceutical waste in Vermont may be entering the environment through consumer disposal, either through landfills (via trash disposal) or through wastewater (via flushing).

Participation in takeback programs in Vermont was 72% among those who reported disposal of medication. Generally, the participation rate in Vermont appears to be substantially higher than other survey populations (Zero Waste Washington, 2006; Ekedahl, 2006; Persson, 2009; Braund et al., 2009). A significant finding of this study indicates that participation in takeback programs is often reported alongside other disposal behaviors associated with environmental pollution. Among those who disposed of medication, 72% reported participation, however only 26% reported participation as their only disposal method, which is equivalent to 16% of the total sample. Therefore, 16% of the total sample population reported participation as their only method of disposal. As stated previously, an additional 25% of the sample reported high impact disposal methods, namely down-the-drain or through the trash. The mixed nature of disposal behavior suggests that greater efforts are needed to encourage proper disposal through takeback programs.

Education and outreach-based campaigns could increase participation. Education and information, specifically on disposal has been shown to be an important variable influencing consumer disposal behavior (Abahussain et al., 2006; Bashaar et al., 2017; Kotchen et al., 2009; Seehusen & Edwards, 2006). Based on the results of this study, results support education as a potential intervention to increase participation in takeback programs. Those who had participated in takeback programs were highly associated with being aware of environmental pollution, and having previously received information on disposal from a doctor or pharmacist, however awareness of takeback programs in and of itself, showed no significant influence on disposal behavior.

The target population for takeback programs would be those with leftover medication, and more specifically, populations with high impact disposal behavior. The demographic characteristics of those with high impact disposal behavior were not significantly different from those with other disposal behavior. The only difference between participants associated with high impact behavior vs. low impact behavior was education on disposal. Those with high impact behavior were significantly less likely to be aware of the potential environmental impact of disposal, and significantly less likely to have received information on disposal.

Although there may have not been any patterns in terms of disposal behavior, the sample population reporting leftover medication had significantly higher income and was more likely to have private insurance. This suggests that pharmaceutical waste is likely a socio-economic issue. Initially, pharmaceutical waste was expected to be an issue related to age. Higher rates of leftover medication were expected among older populations, given the fact that older populations are prescribed more medication (CDC, 2013). The findings of this study suggest that waste is likely related to income, rather than age, and that disposal behavior is likely related to education on disposal, rather than demographics. Therefore, the results of this study support two potential strategies to increase participation in takeback programs: 1) incorporating socio-economic based strategies into public outreach and educational campaigns in clinics and pharmacies and 2) encouraging clinicians and pharmacists to educate and disseminate information on disposal to patients and consumers of medication.

4.5 Conclusion

The findings of this study indicate that pharmaceutical waste may be a significant form of waste, and that consumer disposal behavior may be contributing towards environmental pollution. Public campaigns seeking to increase participation in takeback programs would likely be effective coming from a doctor or pharmacist who communicates awareness of the program itself, alongside awareness of the impact of improper disposal, specifically the environmental pollution associated improper disposal. Public campaigns directed towards higher income populations may be a useful strategy to increase participation in takeback programs. Greater research is needed on populations associated with leftover medication and consumer disposal behavior, in order to develop more comprehensive strategies to increase participation in takeback programs.

The limitation of this study is that it is based on data from one state, therefore results may not be easily generalizable. When variables were stratified, sample size became small in some categories, which reduces statistical power. This study did not measure the proportion or quantity of medication leftover, so the scale of pharmaceutical waste is unknown, nor did the study measure the levels of pollution resulting from disposal, so the actual impact of consumer disposal as a source of pollution is not known. The strength of this study is that it gives a first look at the prevalence of leftover medication and the potential environmental impact of consumer disposal behavior on a statewide basis.

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CHAPTER 5: ADDITIONAL RESULTS

5.1 Populations associated with Purchasing vs. Leftover Medication

The vast majority of the survey population had purchased medication (n = 392, 93%), while the majority had reported leftover medication (n = 254, 60%) (Table 7).

Table 7. Purchasing, Use & Leftover Medication.

Purchasing of Medication N = 421 n = 392 (93%)	
Partial Use **Some Leftover** n = 254 (60% of the Purchasing population)	**Full Use** **None Leftover** n = 138 (40%)

Several statistically significant demographic differences within the survey population were found regarding those who reported purchasing medication and those who reported having leftover medication. Purchasing of prescription medication was statistically associated with all demographics: age, income, education, locality and insurance, excluding gender. Significantly higher purchasing was reported by older populations, with lower income, lower education, suburban/urban status, and public insurance through Medicare/aid. Lower purchasing was reported by younger populations, and higher income populations, with higher education, rural status, and private insurance.

Leftover medication was statistically associated with income and health insurance (Table 8). Higher income populations with private insurance reported significantly more leftover medication, compared to lower populations who reported significantly less.

Income and health insurance were the only two demographics statistically associated with both purchasing and leftover. Income was negatively related to purchasing of prescription medication ($p = 0.009$) but positively related to leftover medication ($p = 0.002$) (Table 8). Insurance was also significantly related to purchasing of prescription medication ($p = 0.003$) and leftover medication ($p = 0.053$). Lower income groups with public insurance reported higher purchasing, but lower income groups with public insurance reported the least leftover. Higher income groups with private insurance reported lower purchasing, but more leftover. Age was also clearly related to purchasing and use of medication ($p = 0.009$), however the relationship between age and leftover medication was not statistically related (Table 8).

Table 8. Statistical Associations in the Demographics of Purchasing vs. Leftover Populations

	OTC Purchasing	**Prescription Purchasing**	**Leftover Medication**
Demographics	Average Quantity N = 421	Average Quantity N = 421	% of Population N = 254 (60%)
Gender	p = 0.345	p = 0.531	p = 0.188
Female	2.6	2.9	141 (64%)
Male	2.5	2.8	109 (59%)
Income	p = 0.236	***p = 0.009**	***p = 0.002**
<$25,000	2.9	4.3	25 (43%)
$25 to $50,000	2.4	3.8	41 (55%)
$50 to $75,000	2.7	3.1	45 (70%)
$75 to $100,000	2.4	2.5	55 (72%)
>$100,000	2.7	2.0	58 (78%)
Age	p = 0.525	***p = 0.021**	p = 0.494
18 – 30	2.5	1.8	28 (54%)
31 – 40	3.5	1.9	29 (74%)
41 – 50	2.8	2.7	46 (68%)
51 – 60	2.2	2.4	53 (63%)
61 – 70	2.2	3.6	47 (60%)
71 – 80	2.8	4.2	35 (58%)
> 80	2.5	4.9	10 (63%)
Education	p = 0.421	***p = 0.057**	p = 0.252
≤ High School	3.0	3.5	46 (59%)
Some College	2.4	3.2	64 (60%)
Bachelor	2.6	2.5	63 (59%)
Post graduate	2.6	2.6	75 (70%)
Locality	p = 0.095	***p = 0.058**	p = 0.154
Rural	2.3	2.5	159 (66%)
Suburban	2.9	3.8	54 (59%)
Urban	2.6	3.4	32 (53%)
Insurance	p = 0.398	***p = 0.003**	***p = 0.053**
Medicare/aid	3.0	4.3	76 (57%)
Private	2.5	2.0	144 (67%)

Note. Total sample population: N = 421.
* Designates statistical significance at $\alpha = 0.05$.

CHAPTER 6: DISCUSSION

6.1 Pharmaceutical Waste May be Significant

Prevalence: How common is leftover medication? The most important finding from this study is that 60% of the population in Vermont reported leftover medication. As stated previously, this finding is consistent with other studies, which find leftover medication is common among surveyed populations. An additional question is whether specific demographic populations are commonly associated with leftover medication.

Volume and Scale of Waste: How much is leftover?

Several studies have measured the amount, quantity and weight of pharmaceutical waste (Stewart et al., 2015), while other studies have calculated the proportion of waste, based on the amount disposed and the amount of medication returned unused to takeback programs (Yang et al., 2015). These studies provide ratios between use and non-use, a metric of proportion, which are often combined with quantity and weight measurements, to give us a sense of the scale, volume or magnitude of pharmaceuticals as a form of waste. For example, in the state of Maine, researchers estimated that 24% of dispensed medication had been used, and that 76% of medication had been wasted, based on calculations of how much was dispensed on the prescription bottle, and how much was returned unused to takeback programs (Stewart et al., 2015). A similar study from a one-day event in Lansing, Michigan estimated 34% of medication had been used, based on 66% of medication being returned unused (Yang et al., 2015). A more comprehensive study, across six states over five years, found less than 50% of medication had been used, and thus, greater than 50% had been wasted (Jaramillo et al., 2018).

From the results of this study, we conservatively estimate that, based on the volume of waste turned into the Vermont takeback programs in 2016 (Governor, 2017), combined with the participation rate from this survey, that approximately 8,400 pounds of pharmaceuticals may be wasted each year in Vermont. For example, in Vermont, 60% reported leftover, however only 16% participated and 2,500 pounds was received (Table 4). Thus, the fate of the leftover medication associated with the remaining 44% of the population is unknown, however based on reported disposal behavior, the remaining waste is likely either stored (19%) or disposed (25%) (Table 4).

However, as described, the waste turned into takeback programs is likely only a fraction of the total volume of pharmaceutical waste. Reviews on disposal behavior find a minority of consumers takeback medication, while the majority keep or dispose through other methods (Tong et al., 2011). Furthermore, the majority of surveyed population report leftover medication.

This study appears to be the first study to evaluate disposal behavior on a state-wide basis. Although the findings are not easily generalizable, the 60% of the population in this study reporting leftover medication is consistent with other studies (Zero Waste Washington, 2006; Ekedahl, 2006; Persson, 2009; Braund et al., 2009).

Generally, leftover medication has two fates; either it is kept or disposed as a form of waste, based on the results of this study. If medication is kept, leftover medication may potentiate public health risks. A significant amount of research on patient use (and non-use) exists, particularly when non-use or over-use leads to adverse health effects (Horne, 2006). Both non-use as well as over-use indirectly relate to leftover medication; the first results in a portion of the prescription going unused, becoming “leftover,” while the latter is associated with issues related to abuse, poisoning, overdose and diversion.

If medication is disposed, disposal may potentiate various forms of environmental pollution. We found that 25% of Vermonters who participated in this study reported disposal behavior associated with high environmental impact (trash and flushing). What is known is that the volume of pharmaceutical waste appears to be substantial, and estimates suggest that pharmaceutical waste will continue to increase (Kantor, 2015). The volume of waste itself and the potential societal and environmental impacts of waste, combined with findings on disposal behavior justifies the need for takeback programs. The magnitude of disposal as a source remains unknown, in relation to the other known source: pharmaceutical use and excretion, which is likely the greater source (Vatovec et al., 2016), however surveys on disposal behavior have provided vital information to support disposal as a potential source of environmental pollution.

Environmental researchers concerned with waste and pollution have called for lower dose prescribing among healthcare providers, as well as greater collaboration with medical researchers, based on mutually-aligned interests (Daughton and Ruhoy, 2014). While there may not necessarily be a mutual interest in the issue, there is certainly a mutually-aligned interest. “Drug disposal has interested medical professionals primarily because of insights it can yield on issues related to patient compliance and economic costs to the consumer. The driving force has rarely emanted from the potential for environmental benefits, although progress towards one aim is often relevant to the other – they are intimately tied together… Protecting the health, safety, and pocketbook of the patient holds potential for protecting the environment – and vice versa" (Daughton, 2003b). Reducing wasted medication could further reduce the economic costs of medications (Fasola, 2014).

Therefore, pharmaceutical waste may be impacting public health, the environment, and the economy. The impact on the economy is largely unknown, however medication that may become "leftover" represents wasted consumer spending (Morgan, 2001). The financial costs of wasted medication are one aspect of the economic impacts of pharmaceutical waste. Additional costs are associated with the municipal costs of funding, establishing and managing takeback programs.

An estimated cost of operating three takeback programs in Washington state for one year was $500,000 (Zero Waste Washington, 2012). This takeback program appears to be funded by a public-private partnership between local governments and local pharmaceutical companies (MED-Project, 2017). This partnership, however, appears to be an anomaly. All takeback programs are managed by governments as a public service, and most appear to be funded exclusively with public funding, but some are funded through public-private partnerships, with additional funding from philanthropies and nonprofits, not pharmaceutical companies. Washington state, and more importantly, the case of Alameda, California, are two exceptions, which represent the future of funding for the programs. Alameda county was the first municipality to successfully pass legislation requiring pharmaceutical manufacturers to fund takeback programs (Alameda County, 2017). The pharmaceutical industry filed an appeal, which eventually led to a judgment by the Supreme Court in favor of Alameda Country ruling that the pharmaceutical industry is liable for funding these programs (Mukherjee, 2016). Since then, multiple states have successfully passed similar legislation to expand takeback programs in their states, despite heavy lobbying against these measures by the pharmaceutical industry (Massachusetts, 2017). In addition to funding the actual program itself, the industry is now required to fund the costs of disposal.

The costs of managing the waste may include the financial costs of funding, expanding and maintaining takeback programs, the logistical costs associated with planning and coordination needed to establish the programs between multiple stakeholders (government, pharmacy, police, waste management), as well as the costs of public education campaigns, to increase participation in takeback programs. These costs may represent a significant impact on the economy.

Takeback Programs as a Solution

Takeback programs may address some of the public health and environmental issues surrounding leftover medication. Takeback programs are recommended not only to remove medication from the home, but also based primarily on the comparatively low environmental impact of this disposal method (EPA, 2017d). Pharmaceutical waste is disposed through hazardous waste incineration, which is said to degrade the chemicals, release the waste into the air, and therefore minimize release into, and thus impact on the aquatic environment (EPA, 2017c). The impact of the air pollution on surrounding communities was acknowledged by the WHO in their recommendation for incineration of pharmaceutical waste (WHO, 1995). Although the recommendation continues to be debated (Cook et al., 2012; Daughton, 2012), takeback programs are increasingly regarded as an effective solution to address the need for proper disposal (Glassmeyer et al., 2009).

Takeback programs may be able to minimize the problems associated with pharmaceutical waste, however takeback programs do not prevent the waste itself. If a consumer "takes-back" medication, this removes the medication from the home, which may prevent abuse or diversion, and this may mitigate disposal behavior that would otherwise contribute toward environmental pollution, however the programs cannot redress the financial costs of the waste on the consumer population. Furthermore, the programs themselves, or more accurately the waste itself, imposes an economic burden on society, and on the environment. Pharmaceutical takeback programs involve significant costs needed for operation, and incineration of the waste is associated with additional environmental impacts associated with air pollution. While takeback programs are certainly part of the solution, the greater solution lies in prevention of the waste itself.

CHAPTER 7: CONCLUSION

This study evaluated purchasing, use and disposal behavior in order to recommend strategies to minimize environmental pollution. We found a large proportion of the surveyed population reported purchasing of medication, as well as leftover medication, and that a significant proportion reported disposal through the trash or through flushing, both known pathways leading to pollution in the environment. Given that leftover medication was common, this study sought to understand what happens to waste, or more generally, what consumers do with leftover medication. We found that disposal behavior varies based on the method of disposal, and that the impact of disposal behavior also varies. A large portion of the survey population reported participating in takeback programs, but our results indicate that participation is reported alongside other disposal behaviors associated with environmental pollution. Therefore, the findings of this study suggests that participation in takeback programs could be strengthened. One primary way to increase participation in takeback programs would be to incentivize clinicians and pharmacists to educate patients about proper disposal. Public campaigns in pharmacies could promote awareness of the program itself, along with the environmental impact of improper disposal. Future studies should consider focusing on the educational, informational and awareness factors that may influence disposal, as well as the logistic factors needed to incorporate disposal education into healthcare settings, namely clinics and pharmacies. The conclusion of this study is that disposal may be contributing towards environmental pollution downstream, which reinforces the need for greater research upstream, to minimize leftover medication, minimize disposal and thus, minimize pollution at its source. Future research should consider further study of consumer purchasing, use and disposal behavior, to better understand leftover medication, not only to develop strategies to increase participation in takeback programs, but also to identify strategies to minimize leftover medication, and therefore to minimize many of the associated impacts on public health and the environment.

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