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The veterinarian's role in and attitude to the disposal of unwanted pharmaceuticals

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ABSTRACT

A wide range of pharmaceutical chemicals have been documented in rivers, streams, lakes, coastal waters, groundwater, sewage sludge, landfill leachate, soils, air, and plant and animal tissues nationwide and around the world. Veterinarians' unique relationship with pharmaceuticals compared to other health professionals provide a wide breath of potential pathways. Given the role that veterinarians can play as both a source of new pharmaceuticals to the environment and a method of drug disposal, as well as their role as trusted professionals, the veterinarian is key to keeping unused and unwanted medicine out of the environment. However, little is known about their behaviors. The objectives were to: learn about the drug disposal practices of the veterinarian and their clients from the veterinarian's perspective; learn about the importance of the topic of drug disposal to veterinarians; and determine the outreach needs and preferences of veterinarians and how best to educate about this issue. This research was conducted through a cross-sectional online survey of licensed veterinarians in states within the Great Lakes region working with those states' veterinary medical associations or licensing boards. The 587 respondents were 72% female, 81% small animal practice, and 52% practicing in suburban geographic areas. Legal disposal requirements were the biggest factor influencing veterinarians to change pharmaceutical disposal behaviors followed by avoiding misuse and abuse. Veterinarians discussed disposal with clients in only 11% of appointments with clients. The most notable barriers include not remembering to mention, not enough time, not high enough priority, or not enough information known by the veterinarian. Continuing education opportunities need to be provided across the spectrum of practicing veterinarians so they can have a greater understanding of the problem of pharmaceutical waste and potential avenues they can implement to mitigate.

1. Introduction

1.1. Pharmaceuticals in the environment

A wide range of pharmaceutical chemicals have been documented in rivers, streams, lakes, coastal waters, groundwater, sewage sludge, landfill leachate, soils, air, and plant and animal tissues nationwide and around the world (Masoner et al., 2020; Meador et al., 2016; Schultz et al., 2010; Boxall et al., 2006; Kolpin et al., 2002). This includes prescription and over-the-counter pharmaceuticals used in human and veterinary medicine, including antibiotics (e.g., cephalosporins, fluoroquinolones, tetracyclines), painkillers (e.g., non-steroidal anti-inflammatory drugs, opioids, ibuprofen, acetaminophen), antidepressants (e.g., carbamazepine, fluoxetine), anti-fungals (e.g., azoles), synthetic estrogens (e.g., estradiol), and bactericides (e.g., triclosan, triclocarban) (Daughton and Ternes, 1999). Even though the chemicals occur at very low levels, typically parts per billion or trillion, they have been shown to cause changes in aquatic food webs, as well as to the behavior, reproduction, and growth in frogs, fish, mussels, and other aquatic animals (Richmond et al., 2018; Gaw et al., 2014; Ericson et al., 2010; Conners et al., 2009; Schwaiger et al., 2004). Most alarmingly, aquatic organisms are exposed to pharmaceutical mixtures that pose unknown and potentially greater ecological risks (Wilkinson et al., 2022).

This is further complicated by the breadth of ways veterinary medicines can make their way into the environment. Pharmaceuticals enter the environment when people dispose of them via the trash or toilet or after use when they are excreted or rinsed off the skin (i.e., through the municipal waste stream), when they enter the industrial waste stream, or through runoff from intensive livestock and farming practices (Pérez Solsona et al., 2021; Kaczala and Blum S, 2016; Gaw et al., 2014; Daughton and Ternes, 1999). Excretion plays a large

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role in discharging veterinary pharmaceuticals to the environment, as the waste products of large animal feeding operations are often a commodity that is re-introduced into the environment. Spreading manure from medicated animals on farmland as a fertilizer is a major pathway for veterinary pharmaceuticals to enter the environment, directly impacting soils and running off into nearby bodies of water (Pérez Solsona et al., 2021; Kaczala and Blum S, 2016). Exposure to manure and runoff to natural waters from large animal feeding operations have the potential to promote antibiotic resistance, cause nontarget impacts to invertebrates and soil organisms, and serve as a source of endocrine disruptors (Topp et al., 2013; Floate et al., 2005; Orlando et al., 2004; Römbke et al., 2010).

A clear link between drinking and using water containing very low levels of certain pharmaceuticals and negative human health impacts has not been established (Rahman et al., 2009; de et al., 2015; Benotti et al., 2009; Kostich and Lazorchak, 2008; Jones et al., 2005), and there remain questions about the impacts of pharmaceutical mixtures and transformation products in the environment on humans (de et al., 2015). However, races of pharmaceuticals have been found in the drinking water sources of millions of Americans (Benotti et al., 2009), and analysis by U.S. EPA scientists showed that people would need to drink at least two liters of water a day for months or even years to consume even one dose of medication when considering monotoxic effects (Kostich and Lazorchak, 2008).

1.2. Disposal of unwanted pharmaceuticals

Much attention in recent years has been paid to the disposal of pharmaceuticals. While most pharmaceuticals are consumed and excreted (Gaw et al., 2014), a suite of recent surveys has found that between 28 and 63% of respondents throw medicine in the trash and 8–31% flush drugs down the toilet or sink (Ehrhart et al., 2020; Lam et al., 2018; Law et al., 2015; Wieczorkiewicz et al., 2013; Kotchen et al., 2009). In fact, research has found that over $100 billion worth of prescription drugs are disposed of every year in the U.S. (Law et al., 2015) However, research has also demonstrated that if respondents are aware of the potential problems caused by unwanted or expired pharmaceuticals, they are more likely to utilize a pharmaceutical collection program (Kotchen et al., 2009).

Pharmaceutical collection (or take-back) programs are one option for safe disposal of unused or unwanted prescription and over-the-counter medication. Many state and local governments have established either permanent collection programs or sponsor single-day events either independently or with the involvement of the U.S. Drug Enforcement Administration (DEA) National Prescription Drug Take Back Day (Take Back Day 2022). Drug take-back programs can be extremely effective at removing pharmaceuticals from the waste stream, as evidenced by the 360 tons of medication collected at the DEA's most recent take-back event in April 2022 (Take Back Day 2022). Research shows, however, that the public is often unaware of these opportunities. In a telephone survey of residents in Cook County, IL, more than 80% of respondents reported never having received information about proper disposal of medicines from either their health care provider or through the media (Wieczorkiewicz et al., 2013). Most alarmingly, the majority of clinicians and pharmacists are not educating their clients and patients about proper disposal of pharmaceuticals. Up to 78% of physicians, 76% of pharmacists, and between 61 and 55% of veterinarians currently do not provide information about pharmaceutical disposal (Vatovec et al., 2021; Lam et al., 2018).

1.3. The role of the veterinarian

Approximately 70% of U.S. households own a pet, with dogs found in 69 million households and cats living in 45.3 million households in 2021 (Pet Industry Market Size, Trends and Ownership Statistics. Accessed July 22, 2022). Pet industry spending in 2021 was a record-breaking $123.6 billion in the United States–with $34.3 billion of that figure spent on veterinary care and product sales, including pharmaceuticals (Pet Industry Market Size, Trends and Ownership Statistics. Accessed July 22, 2022). The American Veterinary Medical Association (AVMA) estimates that 83% of dog-owning households sought out a veterinarian at least once per year (American Veterinary Medical Association 2018). The profession is consistently highly respected and trusted; veterinarians are viewed as more approachable, sensitive, sympathetic, patient, and understanding compared to physicians (Kedrowicz and Royal, 2020).

Veterinarians have a unique relationship with pharmaceuticals because they can prescribe, administer, stock, dispense, and take back prescription medications (Mason et al., 2018). In addition, the ability of many veterinary clinics to serve as surgery centers increases the likelihood that veterinary clinics are using, storing, and ultimately disposing of a greater quantity and variety of veterinary pharmaceuticals, including special categories of pharmaceuticals like those for euthanasia, those that are mixed into animal feed, and many veterinary formulations that are not tested for human safety or approved for human use (Ruhoy and Daughton, 2008; Anand and Hosanagar, 2021). The Veterinary Feed Directive Final Rule (VFD), issued in 2017, increased veterinary control of antibiotics in food-producing animals – banning producers' indiscriminate use in feed for growth promotion, and making sure that veterinarians oversee therapeutic uses of antibiotics (Dillon and Jackson-Smith, 2021). This ensures veterinary oversight in the use of antibiotics and other prescription medications added to animal feed, marking a shift away from animal producers purchasing and administering prescription medications. Although the prescribing practices of veterinarians vary by state and from clinic to clinic, many veterinary clinics dispense their own prescriptions and have the ability to take drugs back from clients. However, many are unwilling to take back pharmaceuticals because of the cost to reverse distribute for the clinic, the logistics of disposing of medicated feed, and the time and resources needed to facilitate this process. As a result, veterinary medicines may represent a large portion of unused, unwanted, or expired pharmaceuticals that require proper disposal (Vatovec et al., 2021). To that end, the AVMA has committed resources to address this issue (Disposal of Unwanted Medications 2022). In 2016, the AVMA renewed a Memorandum of Understanding with the NOAA National Sea Grant College Program (NSGO) to collaborate on outreach to veterinarians and veterinary clients. The present study will help the AVMA and NSGO to appropriately tailor their outreach messaging to and will provide a baseline to evaluate their efforts going forward.

1.4. Research objectives

Given the role that veterinarians can play as both a source of new pharmaceuticals to the environment and a method of drug disposal, as well as their role as trusted professionals, the veterinarian is an important factor in the effort to keep unused and unwanted medicine out of the environment. However, little is known about veterinarians' medicine disposal habits and outreach needs on this important topic. To learn about the veterinarian's beliefs and attitudes, we focused on the following objectives:

1. Learn about the drug disposal practices of the veterinarian and their clients from the veterinarian's perspective.
2. Learn about the importance of the topic of drug disposal to veterinarians.
3. Determine the outreach needs and preferences of veterinarians and how best to educate about this issue.

Specifically, we hypothesized that:

1. Veterinarians do not prioritize discussing pharmaceutical disposal with their clients.
2. Veterinarians are not well informed on how best to dispose of pharmaceuticals.

3. Practicing proper human pharmaceutical disposal may be more frequent than proper veterinary pharmaceutical disposal.
4. Disposal of veterinary pharmaceuticals happens primarily in the garbage and secondarily through reverse distributors.
5. Drivers of pharmaceutical disposal in practice likely include what is financially feasible and legally required.

2. Methods

2.1. Study area

This research was conducted in states within the Great Lakes region—Illinois, Wisconsin, Minnesota, Indiana, Michigan, Ohio, Pennsylvania, and New York. In most states (IL, WI, MN, MI, NY, OH), we partnered with the State Veterinary Medical Association (VMA) or public health agency to distribute the survey to licensed veterinarians on our behalf. In some cases, this was via direct email (MN, WI) or via newsletter request to membership (OH, MI, NY, PA, IL, WI, Chicago). Freedom of Information Act (FOIA) requests were also filed for a subset of states where the survey received either a low response rate or there was difficulty in collaborating with the State VMA. State laws regarding the privacy of email addresses used or freely given in licensing applications varied. As such, FOIA requests in some states were rejected or did not contain the necessary information (IL, IN, PA) while in other states, requests were granted (MI, MN, OH, NY, WI). In total, the potential audience receiving the survey was 25,000 veterinarians across seven states as no solicitation went to Indiana.

2.2. Survey research

This research was approved by the University of Illinois at Urbana-Champaign Institutional Review Board (IRB #19731). From May to December 2019, we conducted a cross-sectional online survey of licensed veterinarians utilizing Qualtrics (Qualtrics, LLC, Provo, UT). Electronic informed consent was obtained from all survey respondents. The survey consisted of 24 questions including items on demographics, awareness, behavior, and role of veterinarians in pharmaceutical environmental concerns, and was estimated to take 15 min to complete (Appendix 1). Of the 735 respondents who completed the entire survey (3% response rate), 587 were clinically practicing veterinarians.

The components of the survey included questions on awareness and actions of veterinarians and what outreach would assist them. Survey questions allowed participants to pick up to three options in many questions to capture the possible decisions and end points of the participants as one method or approach does not always occur. A three-point Likert-type scale was utilized for one question because the effect looked at was unidirectional in that the influence of certain actions on protecting the environment wanted to be attained. A traditional five-point Likert scale was utilized to capture factors affecting disposal of animal pharmaceuticals in practice.

2.3. Data analysis

All responses were imported from Qualtrics into Microsoft Excel (Microsoft 365, 2000). Descriptive analysis was performed in Excel or in SAS Studio (2020). Due to the nature of the study and the hypotheses proposed, descriptive analyses were predominately performed on the data. Any statistical differences in responses utilized ANOVA in SAS to differentiate behaviors between different types of practicing veterinarians. All analyses utilized a 95% confidence interval with a significance identified at $p<0.05$. Normal distribution of responses for ANOVA was determined using the Shapiro Wilk test. Survey responses were typically on a Likert scale or multiple choices providing a greater capture of behaviors in this environmental scan of the profession as it relates to pharmaceutical disposal. Frequency counts, means, median, and standard deviations were utilized to provide quantitative measures of survey responses.

3. Results

Of the 587 clinical veterinarians that completed the survey, the demographics represented the professions with 72% female, 81% small animal practice, and 52% practicing in suburban geographic areas. The age distribution of those who responded was relatively equal from age 27 through 64, however, a large majority had been in practice for greater than 10 years (Table 1). Over half (55%) of all practices allow clients to return unused medications and veterinarians rely most often on their professional organizations to provide information about pharmaceutical disposal (Table 2). While veterinarians are aware of the risk of pharmaceuticals in the environment, most believe that improper human pharmaceutical disposal is the greatest risk.

Veterinarians felt informed about the environmental issues with their state (Table 3). There are several factors that influence veterinarians to modify their behaviors in pharmaceutical disposal. The biggest influence is following legal disposal requirements for pharmaceuticals (both controlled and prescription) followed by avoiding misuse and abuse. For environmental protection, scientific studies have the greatest influence on veterinarians, followed by recommendations from professional organizations. Overall, veterinarians are most likely to dispose of pharmaceuticals in the garbage, followed by reverse distribution, but they felt a large percentage of clients disposed of pharmaceuticals primarily in the garbage (Fig. 1). Veterinarians typically do not discuss disposal with clients during appointments, with only 11% saying they cover the topic. The most notable barriers include not remembering to mention, not enough time, not high enough priority, or not enough information known by the veterinarian.

Between veterinary types of practice, there are different drivers and behaviors noted. Small and mixed animal practitioners are significantly influenced to dispose properly by legislation compared to food animal veterinarians ($p = 0.01$). Food animal veterinarians were more likely to think it better to flush pharmaceuticals than small animal or mixed animal veterinarians ($p = 0.01$) which may be influenced by their desire to avoid risk of misuse and abuse. A one-way between groups ANOVA was conducted to compare the percentage of appointments where pharmaceuticals were discussed among small animal, food animal, and mixed animal practitioners. There was a significant effect of percentage of appointments discussing pharmaceutical disposal among practice types at the $p<0.05$ level for the three groups [$F = 8.03$, $p = 0.0004$]. Notably, food animal practitioners discussed pharmaceutical disposal in a greater percentage of appointments (20%) compared to small and mixed animal (9–12%) ($p<0.001$).

The survey results indicated some of the best ways to address clients about this issue are to add directions to discharge instructions, to provide an information card with any prescription, or stock educational materials in the client waiting area (Fig. 2). Surveyed veterinarians felt the best way to reach them with additional information is primarily through recommendations from their professional organizations followed by product information and then government outreach (Fig. 3). The biggest aide for veterinarians to help them in clinics would be to provide additional outreach and education tools followed by regulations specific to the issue and then retailer and manufacturer collection.

4. Discussion

As one of the first comprehensive assessments of veterinarians' behaviors, attitudes, and knowledge around pharmaceutical disposal, this survey provides important insight moving forward. The survey provides a clearer understanding of some of the drivers and perceptions for drug disposal among these health professionals and helps guide future outreach efforts through what they feel would be most helpful. The veterinary profession has been under-targeted around the issue of phar-

Table 1
Demographics of survey respondents by predominant practice type.

	Companion Animal (%)	Food Animal (%)	Mixed Animal (%)	Total (%)
Age				
22–26	12 (2.6)	0 (0)	1 (1.4)	13 (2.2)
27–34	75 (16.4)	10 (28.6)	11 (15.3)	100 (17.0)
35–44	123 (26.9)	7 (20.0)	19 (26.4)	156 (26.6)
45–54	104 (22.7)	3 (8.6)	17 (23.6)	127 (21.6)
55–64	96 (21.0)	11 (31.4)	9 (12.5)	122 (20.8)
65+	48 (10.5)	4 (11.4)	15 (20.8)	69 (11.8)
Total	458	35	72	587 (100)
Gender				
Male	113 (24.7))	18 (51.4)	22 (30.1)	160 (27.3)
Female	333 (72.7)	16 (45.7)	50 (69.4)	413 (70.4)
Prefer not to say/Other	12 (2.6)	1 (2.9)	0 (0)	14 (2.4)
Total	458	35	72	587 (100)
Practice Location (can count more than one)				
Urban	85 (17.0)	3 (7.7)	2 (2.7)	90
Suburban	300 (60.0)	4 (10.3)	11 (14.9)	315
Rural	115 (23.0)	32 (82.1)	61 (82.4)	208
Practice State				
Illinois	114 (24.9)	5 (14.3)	19 (26.4)	140 (23.9)
Indiana	3 (0.7)	1 (2.9)	0 (0)	5 (0.9)
Michigan	86 (18.8)	4 (11.4)	9 (12.5)	101 (17.2)
Minnesota	46 (10.0)	6 (17.1)	6 (8.3)	59 (10.1)
New York	38 (8.3)	2 (5.7)	3 (4.2)	45 (7.7)
Ohio	65 (14.2)	3 (8.6)	12 (16.7)	87 (14.8)
Pennsylvania	13 (2.8)	0 (0)	0 (0)	15 (2.6)
Wisconsin	58 (12.7)	9 (25.7)	14 (19.4)	87 (14.8)
Other	33 (7.2)	5 (14.3)	7 (9.7)	48 (8.2)
Total	458	35	72	587 (100)
Years in Practice				
<4 years	35 (7.6)	6 (17.1)	7 (9.7)	49 (8.3)
4–6 years	42 (9.2)	3 (8.6)	6 (8.3)	56 (9.5)
6–10 years	56 (12.2)	1 (2.9)	6 (8.3)	65 (11.1)
>10 years	325 (71.0)	25 (71.4)	53 (73.6)	417 (71.0)
Total	458	35	72	587 (100)

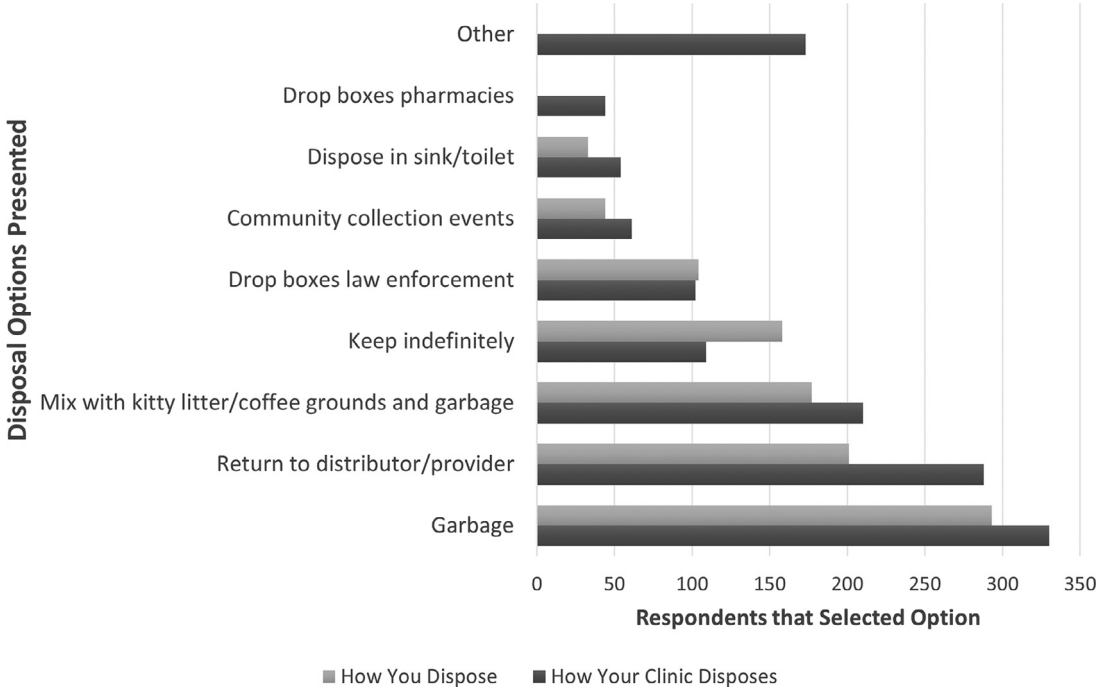

Fig. 1. How veterinarians dispose of pharmaceuticals individually and at their clinics (multiple selections were possible).

Table 2
Discussing pharmaceutical disposal with clients.

Percentage Appts Where Pharmaceutical Disposal Discussed	Percentage (±SE)
Overall	11.2 ± 1.5*
Companion Animal	9.3 ± 1.3
Food Animal	20.4 ± 9.9
Mixed Animal	12.1 ± 3.9
Barriers to Discussing with Clients (Multiple selection)	N (%)
Veterinarians forget to mention	312 (27.1)
Veterinarians do not have enough time	223 (19.4)
Veterinarians do not have enough information	223 (19.4)
Not a high priority	222 (19.3)
Clients do not want to hear	93 (8.1)
Other	77 (6.7)
Allow Clients to Return Meds to Clinic	N (%)
Yes	320 (54.5)
No	267 (45.5)

* ANOVA comparing companion animal, food animal, and mixed animal means p value = 0.0004, F value = 8.03. Food animal significant in pairwise comparisons to companion animal using a *t*-test assuming equal variances ($p<0.001$).

maceutical disposal (Lam et al., 2018). As a diverse profession, the licensed veterinarian has different needs and priorities in how they practice medicine but have a strong relationship with their clients and owners that provide an opportunity to influence drug disposal actions (Vatovec et al., 2021).

Veterinarians face unique challenges compared to many other health professions because they often serve as a pharmacy or dispensary as well as clinic. With the dispensing of pharmaceuticals, they also have to handle disposal of pharmaceuticals but yet are not included in disposal regulations applicable to most pharmacies (Davidson, 2017). This means their ability to take outside medications for disposal is limited. At the same time, there has been less guidance and regulations aimed at veterinarians so that they can follow the proper legal requirements at the state and national level. Although groups like Healthcare Environmental Resource Center and AVMA provide some guidance (Healthcare Environmental Resource Center (HERC) 2022; Disposal of Unwanted Medications 2022), veterinarians are often left confused of how best to deal with pharmaceuticals that may be left over. This was seen in responses to this survey. Many also have fewer resources to manage the overhead of reverse distribution or proper disposal which may influence their actions.

One of the biggest takeaways from this survey are potential next steps to help veterinarians be compliant and minimize improper pharmaceutical disposal. A key issue is how to communicate this information to their clients and owners without taking more of the already limited appointment time. Given that veterinarians typically discuss pharmaceutical disposal in only 11% of appointments, other preferred avenues like adding information to discharge instructions or labels on dispensed drugs should be explored (Fig. 1). Additionally, many veterinarians would like an information card or brochure in their lobby or website that clients can have that provides accurate guidance without spending time discussing during the appointment. Passive information sharing, like these preferences, can be beneficial in dealing with difficult subjects or to save time (Scott et al., 2016).

Veterinarians in this survey overwhelmingly get and prefer to get their information on topics like pharmaceutical disposal from their professional organizations (Fig. 3). This includes state and national veterinary medical associations as well as specialty professional organizations. As the survey was disseminated with assistance from many of the state veterinary medical associations in the Great Lakes region, these organizations have an interest in helping their members attain the correct information. By building this stronger information pathway, both sides will benefit in reducing environmental impacts from pharmaceuticals in the profession. This pathway is also more efficient that the top priori-

Table 3
Attitude and knowledge about pharmaceutical disposal of survey respondents listed from greatest to least.

Factors that Influence Actions to Protect the Environment (Scale 1–3, no influence to major influence)	Mean (CI)
Scientific evidence	2.75 (2.71, 2.79)
Encouragement from professional organization	2.61 (2.57, 2.66)
Financial penalty	2.53 (2.48, 2.58)
See people I know and trust doing it	2.31 (2.26, 2.36)
Encouragement from government agencies	2.29 (2.24, 2.34)
Encouragement from others	2.28 (2.22, 2.33)
Hear people discussing dangers of inaction	2.13 (2.08, 2.19)
News media coverage	2.05 (2.00, 2.10)
Public notices/ads	2.02 (1.96, 2.07)
Financial incentive/reward	2.01 (1.95, 2.06)
How Well Informed on Environmental Issues in Your State (Scale 1–4, not informed to very informed)	2.74 (2.68, 2.80)
Factors that Influence How You Dispose of Veterinary Pharmaceuticals (Scale 1–5 very unlikely to very likely)	
Legally required	4.56 (4.51, 4.62)
Avoid misuse/abuse	4.53 (4.46, 4.59)
Avoid accidental poisoning	4.37 (4.30, 4.44)
Minimize pharmaceuticals in water	4.36 (4.29, 4.43)
Utilize inventory control	4.34 (4.27, 4.40)
Minimize pharmaceuticals in landfills	4.04 (3.96, 4.12)
Convenience	3.96 (3.87, 4.05)
Financially affordable	3.51 (3.42, 3.59)
Acceptable to colleagues	3.04 (2.95, 3.13)
Go with what majority regards as acceptable	2.73 (2.64, 2.83)
Heard it is better to flush	1.72 (1.64, 1.80)
Pharmaceuticals Effect on Environment (Scale 1–5, strongly disagree to strongly agree)	
Improper disposal of human pharmaceuticals threatens the environment	4.74 (4.70, 4.79)
Improper disposal of animal pharmaceuticals threatens the environment	4.68 (4.63, 4.73)
Pharmaceuticals in the environment threaten plants/animals	4.67 (4.62, 4.73)
If evidence fish are affected, then would be concerned	4.62 (4.56, 4.68)
Personal obligation to take action to prevent pharmaceuticals in the environment	4.46 (4.40, 4.52)
Pharmaceuticals in the environment threaten me and my family	4.44 (4.37, 4.51)
I take positive steps to live an environmentally friendly life	4.39 (4.33, 4.44)
Domestic animal waste is a source of contamination in water	3.97 (3.88, 4.05)
Without others taking steps, my actions don't matter	2.91 (2.80, 3.02)

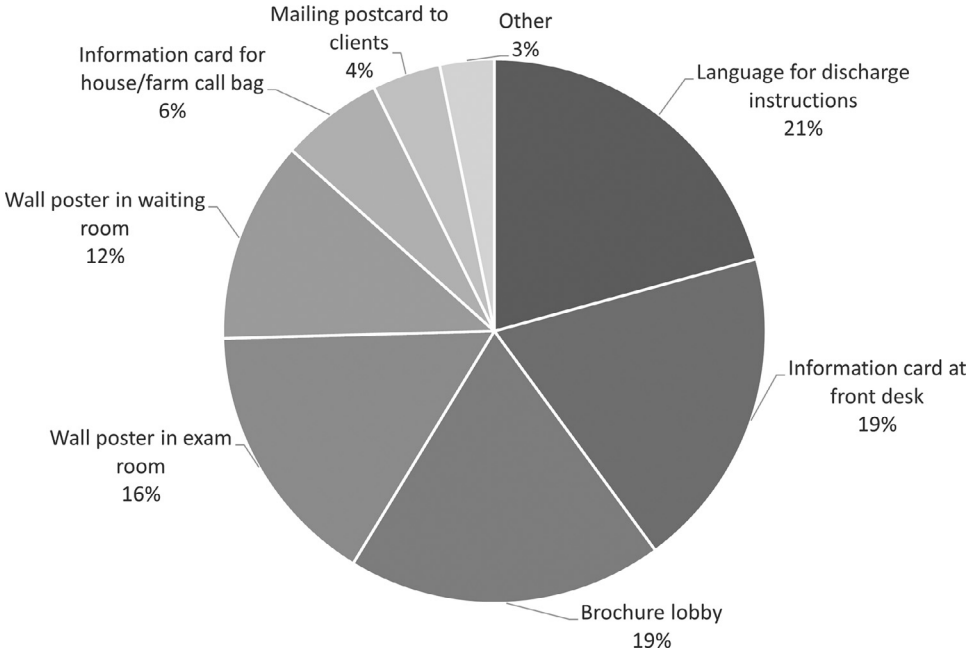

Fig. 2. Solutions veterinarians feel would help address pharmaceutical disposal with clients.

Fig. 3. Top Ways veterinarians learn about pharmaceutical disposal and how they would prefer to learn.

tized way to receive information for veterinarians – scientific literature. Veterinary medical associations can conveniently disseminate current literature without veterinarians spending the time keeping up with it themselves.

As a cross-sectional survey, this study had inherent limitations. The results represent a snapshot in time and only included seven states. While these states include some diverse populations, these results cannot be extrapolated to the country as a whole. Within those seven states, there were variable dissemination rates between veterinary medical associations and licensing boards and variable response rates between states. Partnering with state veterinary medical associations had challenges in how the survey could be disseminated, what percentage of licensed veterinarians in that state were part of the association, and the frequency with which the survey was sent out. With an overall response rate below 5%, this study suffered like many have recently from survey fatigue (de Koning et al., 2021). Other factors for the low response rate could include method of dissemination, interest in the subject area, and time available to complete the survey. Despite that, with over 700 responses, this still provides the biggest data set to date on this topic in veterinary medicine. Finally, in an effort to decrease survey questions, other factors tied to pharmaceutical disposal were not surveyed including antimicrobial resistance, prescribing practices, and types and quantities of drugs prescribed.

A key next step would be additional qualitative research involving focus groups perhaps working with each state's veterinary medical association. With the inherent limits of a cross sectional survey, qualitative research would provide additional insight into the themes from this study's results and provide more nuanced approaches and recommendations. With the MOU in place between Illinois-Indiana Sea Grant and the American Veterinary Medical Association, this may be a high prioritized next step in the coming five years.

5. Conclusions

This snapshot provides a baseline to build from moving forward in better understanding pharmaceutical disposal and waste from a sector that contributes up to half of it nationally (Kaczala and Blum S, 2016). Future studies should focus on causal and root analysis to figure out the true contribution of the veterinary profession to the problem and what medications could be targeted. Like the Stockholm model, which contains environmental hazard and risk information for pharmaceuticals (Ramström et al., 2020), an alternative formulary that not only provides pharmaceutical information but provides alternatives that may have a smaller environmental footprint could be an alternative way to approach this problem.

Continuing education opportunities need to be provided across the spectrum of practicing veterinarians so they can have a greater understanding of the problem of pharmaceutical waste and potential avenues they can implement to mitigate. Along with education, better and more consistent messaging from professional associations including the AVMA would reach many veterinarians. This is an opportunity to build off the work AVMA has already done over the past decade and the collaboration the association has with the National Sea Grant College Program and Illinois-Indiana Sea Grant College Program. For future veterinarians, colleges of veterinary medicine need to include this aspect of the pharmaceutical lifecycle in pharmacology and clinical medicine courses so the next generation (Abrons et al., 2010) can improve upon the steps taken today.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CRediT authorship contribution statement

William E. Sander: Conceptualization, Methodology, Formal analysis, Investigation, Writing – original draft, Writing – review & editing, Visualization, Project administration. **Sarah A. Zack:** Conceptualization, Methodology, Investigation, Writing – original draft, Writing – review & editing, Visualization, Project administration.

Data availability

Data will be made available on request.

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Supplementary materials

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