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Linking emerging contaminants to production and consumption practices

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Abstract

Emerging contaminants (ECs) associated with consumer products such as pharmaceuticals, personal care products, and plastics, are an issue of growing concern for water quality and human and environmental health. Growth in use of products associated with ECs is an outcome of growing populations, increased incomes and the emergence of new consumer products. Two examples are used illustrate the value of social science research in understanding patterns of consumption and sources of ECs, in order to identify potential interventions to reduce ECs in the environment—flushing inappropriate materials down the toilet, and antibiotic use in global livestock production. Antimicrobial resistance is a major policy driver to control the use of antibiotics in human healthcare and livestock production. Global antibiotic consumption increased 65% 2000–2015. Disposal of products, including unused pharmaceuticals and plastics, is influenced by regulation, consumer behavior, and infrastructure. This range of factors and trends demonstrates the complexity in understanding why ECs enter the aquatic environment and the extent that the issue can be tackled at the source rather than mitigated once in the environment.

This article is categorized under:

- Engineering Water > Water, Health, and Sanitation
- Human Water > Methods
- Science of Water > Water Quality

KEYWORDS

antibiotics, consumption, plastic, pollution

1 | INTRODUCTION

Emerging contaminants (ECs) are associated with consumer products such as pharmaceuticals, personal care products (PCPs) and plastics. The production, use and disposal of these products cause compounds of concern to enter the environment through wastewater, landfill leachate, and surface water runoff (Lapworth et al., 2012; Liu & Wong, 2013). The product types that generate ECs are ubiquitous, making management highly complex.

There is an increasing body of research that seeks to identify the occurrence, fate and effects of ECs in the environment making use of new analytical techniques. As evidence about the harmful effects of contaminants on human, animal and environmental health grows, strategies for controlling ECs are being developed for specific product types. For example, the threat of antimicrobial resistance (AMR) means that production, use and disposal of some antibiotics is subject to monitoring and control which has led to reductions in use in parts of the world. Evidence on endocrine disrupting compounds has also contributed a number of initiatives and campaigns to monitor and manage the use and disposal of some types of plastic, or compounds within them.

There is, however, comparatively little research that investigates how and why these products have become so ubiquitous in contemporary life in order to understand the occurrence of ECs and their distribution. Interpretive social sciences can provide critical analysis of broad societal trends and link product use to global production processes, consumer habits, and culture. This form of analysis provides a different lens to understand the problem of ECs and to look for points of intervention beyond the usual areas of waste management and product regulation. In this article, we outline the potential contribution of the social sciences to understanding the problem of ECs in order to identify barriers and opportunities to reduce their impact on the environment. Two case studies, antibiotics in livestock production and flushing inappropriate materials down the toilet, are presented to highlight how interpretive social science analysis creates knowledge that can inform policy and practice to improve management of ECs.

Pharmaceuticals, PCPs, and plastics are used to improve health and quality of life. Growth in use is an outcome of growing populations, increased incomes and the emergence of new consumer products marketed to improve lifestyles and convenience. The growth in pharmaceutical use also reflects improved access to healthcare by populations in low and middle income countries (LMICs), as well as aging and ailing populations and changing clinical practices in high income countries (González Peña et al., 2021). In addition to the increased human use of pharmaceuticals, there has been an increase in the use of pharmaceuticals for animal populations to intensify food production and increase productivity of agriculture. This range of factors demonstrates the complexity in understanding why ECs enter the aquatic environment and the extent that the issue can be tackled at the source and use, rather than mitigated once in the environment.

2 | SOCIAL SCIENCE INSIGHTS INTO ECs

Much literature on the source of contaminants takes a sectoral approach which identifies different sectors connected to the wastewater network (domestic, hospitals, industrial) and non-sewer sources such as landfill leachate and surface run off. This breakdown into source type does not typically provide analysis that links the broad drivers (e.g., population growth) to the more specific drivers governing a sector or context. Social science research can provide insight into of these more in depth "why" questions. For example, why do prescribing patterns differ within a country? Or, why do pharmaceutical industry standards not cover supply chains? These types of questions require understanding of the interplay between local context, global trends and the relative power and interests of institutions and end users. This also provides a different perspective on how the issue of ECs can be addressed at source by asking questions about the relative power of collective action of consumers, corporate interests and the status quo.

When considering the source of ECs, critical social research has the capacity to go beyond use and disposal of types of products to reflect on:

1. Ideology, which shapes understandings of progress, modernity, what makes a good life and how it should be achieved.
2. Governance, which defines the responsibilities of public sector, private sector, and civil society actors, without necessarily addressing the issue of which entities have the power or inclination to act in accordance.
3. Markets, which extend from shaping global production processes, scientific innovation as well as prescribing practices on community GPs and pharmacists.
4. Infrastructure, the technical systems that sustain the production and consumption, for example waste collection or antibiotics enabled agricultural intensification.
5. Affluence and lifestyle which impacts the volume, type and way that products used covering the trivial (increased use of shampoo for example) to the life changing (access to medicine for example).

Social science analysis may focus on one specific factor, such as markets, or the interactions between different elements, such as how infrastructures influence lifestyles. Social research may also provide different entry points to the complex system of ECs. Starting with a particular contaminant, say antibiotics, analysis can follow the social systems and relationships from production to consumption and disposal, identifying points of potential intervention. Starting with a social practice, for example medical prescribing, allows detailed analysis of a particular sub-system within the EC system, that may lead to knowledge that is relevant to several ECs (Kotwani et al., 2010; Morales et al., 2020).

Two examples help to illustrate the value of social science research in understanding patterns of consumption and sources of ECs, in order to identify potential interventions to reduce ECs in the environment. Focusing on a contaminant, analysis of the use of antibiotics in livestock production shows how politics, governance and markets interact to lead to undesirable and unintended outcomes (Kirchhelle, 2018). Analyzing a practice, the case of flushing inappropriate materials down the toilet demonstrates the value of detailed understanding of everyday cultures and practices of hygiene, health, and cleanliness, within wider systems of product marketing and waste and water infrastructure (Alda-Vidal et al., 2020).

The case studies also highlight the importance of understanding the power dynamics at different scales, covering the micro scale of gender relations in the home which affect the use and disposal of PCPs, to the international scale of global supply chains and the efficacy of intergovernmental regulatory action on antibiotics. They point to a range of methodologies that can be used to better understand the routes into the environment from observational studies of social practices shaping the use and disposal of certain products to comparative analysis and historical critiques.

3 | CONTAMINANT: ANTIBIOTICS FOR LIVESTOCK PRODUCTION

Antibiotics make up the most studied group of ECs due to concerns about global AMR. AMR stewardship emphasizes a "One Health" approach, recognizing the connections between animal and human health. The World Health Organization (WHO) Access, Watch and Reserve (AWaRe) antibiotic classification framework aims to balance the use of antibiotics with the need to reduce the impacts of AMR (WHO, 2018).

3.1 | Livestock trends

Globally, livestock production is expected to grow through a combination of intensification, technical changes to breeding processes, improved disease control and management which raises the productivity of each animal. An increase in animal numbers is also expected "especially in low income and emerging countries, which are expected to account for the majority of output growth over the next decade" (OECD & FAO, 2020). OECD–FAO (2020) predicts that India will have the fastest growth in livestock production between now and 2029, at around 25%. In contrast, Europe, Central Asia and North America will have slower growth (under 10%) due in part to already existing high productivity levels, but also due to constraints from environmental and animal welfare policies. The Asia Pacific region, which currently accounts for almost half of the world's agricultural output will continue to grow at around 15%.

In terms of consumption, the OECD–FAO (2020) report estimates that there will be a 15% increase in consumption of food commodities driven predominantly by the expected 11% increase in the global population, but with rising income levels playing a contributing factor. There is expected to be growing demand for meat protein, driven in particular by the increase in affluence of China's population (Tiseo et al., 2020). The OECD–FAO report notes (2020, p. 32) "Consumers' growing environmental and health-consciousness, on the other hand, is expected to support a transition from animal-based protein toward alternative sources of protein (e.g. plant-based and insect protein), as well as the more immediate substitution away from red meat, notably beef, mainly toward poultry and fish, which consumers perceive as healthier alternatives."

The relative use of antibiotics for livestock production or human health varies widely between countries. In the United Kingdom, in 2017, 26% of antibiotics were used in food production, and in 2015, it was estimated that in the US food production was approximately 80% of antimicrobial consumption (HM Government, 2019; Van Boeckel et al., 2014). In terms of relative mass, global use of antimicrobials is similar in humans and livestock per kilogram, but there are many more livestock animals than humans, so total use is much higher for livestock (Van Boeckel et al., 2014). Antibiotic use in livestock production is a key concern for agricultural standards in international trade, and also accounts for relative differences in national proportions of use in livestock. For example, in 2019 the United Kingdom was a net importer of meat, while the United States was a net exporter (OECD-FAO, 2020), partly explaining the relatively lower proportional use of antibiotic for livestock in the United Kingdom.

3.2 | Antibiotic manufacturing

Antibiotics are part of a global pharmaceutical industry with international supply chains that respond to geographic differences in resource and labor availability as well as environmental regulations which can push up the cost of production. When considering how demand for the products leads to ECs, the manufacturing process can be included, even though it may be developed in a different time and place, and be implemented in a region far from where the act of product use occurs.

In 2016, the AMR Industry Alliance launched in response to the UN's call for international government action. The alliance has developed a "predicted no-effect concentrations (PNECs), which can be used to establish discharge targets for antibiotic manufacturing sites." A 2020 survey of members estimated that by 2023 "56% of products made at member-owned sites are expected to be made in accordance with discharge targets. The estimate for supplier sites was lower, 24% of products expected to be made in accordance with discharge targets" (AMR Industry Alliance, 2020). Other sources argue that more can be done to incentivize "green chemistry" and the development of drugs which do not produce environmental contaminants when they are disposed (González Peña et al., 2021).

India and China are global centers of manufacturing, and most active pharmaceutical ingredients for pharmaceutical products (including antibiotics) are made in these two countries (Maghear & Milkowska, 2018). "Evidence shows that uncontrolled discharges from pharmaceutical manufacturing have devastating impacts on water systems as well as on people and animals coming into contact with the resulting resistant bacteria" (Maghear & Milkowska, 2018).

3.3 | Why is the use of antibiotics in food-producing animals so widespread?

The use of antibiotics in food-producing animals has contributed to the rise of AMR threatening the future effectiveness of antibiotics and risking the global gains made in life expectancy and access to healthcare. Approaching the issue through historical analysis Kirchhelle (2018) provides a compelling account of how livestock production has come to depend on antibiotic use, how this history helps to understand the current failure to tackle this dependency and what can be done. Kirchhelle's work focuses on the industry producing the product to be consumed and looks at the interplay between scientific progress, national development agendas, and intergovernmental regulatory regimes.

The rise in per capita meat consumption which happened at pace in the 20th century, was enabled through the industrialization of animal production. By the 1960s, intensified livestock rearing processes were being exported throughout the capitalist and communist worlds. Kirchhelle argues that antibiotic use was fundamental to these processes, becoming itself a form of infrastructure within industrial agriculture systems globally. Antibiotics could be used to treat and reduce disease, but also used as a prophylactic to raise productivity while "reducing the expensive labour spent caring for individual animals." Research had found that antibiotics could promote growth in animals when added to feed, and reduce spoilage when used as a preservative after slaughter or in the preparation of fish and seafood. Kirchhelle charts the spread of these treatments and processes across the United States, Europe, Japan, the Soviet Bloc, South Africa, and China driven by commercial opportunity as well as national ambitions to deliver progress and affluence to their citizens.

Concern about antibiotics in agriculture has a history almost as long as their use. The first public concern and regulatory actions were initiated over antibiotic residues in milk and food in the 1950s. This was in the United States and western Germany and tied to concerns about increasing human exposure to chemicals and risks of cancer. In the United Kingdom, the main concern was AMR driven in part Kirchhelle argues, by the capacity of the state public health laboratory service's capacity to detect it. This led, by 1971, to Britain restricting the use of some forms of antibiotics in agriculture and the restrictions being adopted by EEC member states. Public concern meant some countries took action, but once national concerns had been confronted, public pressure reduced. "With no broader consensus on reform emerging, the increasingly kaleidoscopic nature of international regulations further diminished the prospect of sustained collective action against the growing global threat posed by AMR" (p. 5).

By the 1980s, consumer concern had led to a new market for organic food, which is produced without the use of synthetic antibiotics, in the United States and Europe, and to a lesser extent in Japan. However, this was "responsible for only a small fraction of overall food sales, organic farming offered a way for often wealthier consumers to opt out of conventional agriculture and a mode of antibiotic-intensive production that was still gathering steam" (p. 7). The 1980s in China marked the start of a dramatic increase in intensive, antibiotic dependent farming that grew through both legal and illegal antibiotic use. In contrast rising public concern over antibiotic residue and AMR in Scandinavian countries resulted in their agricultural producers voluntarily phasing out antibiotic growth promoters. In the 1990s, these states lobbied for EU restrictions to bring EU agriculture in line with Scandinavian standards, and were successful in part due to the Bovine spongiform encephalitis (BSE) crisis in the United Kingdom. Regulatory reform has occurred in other high income countries like the United States and Japan and today low and middle income countries also support reform in the use of antibiotics.

International commitments on antibiotic stewardship have progressed today; however, Kichhelle raises concern about their effectiveness. Significant differences in use remain in high income countries and in general levels of use remain at levels higher than the 1960s when concerns were first acted on. For low and middle income countries stewardship is also patchy, China has banned Colistin for domestic use, but this has led to "thousands of tons" being exported to India, Vietnam and South Korea.

Kirchhelle offers a conclusion for the failure of international regulation on the use of antibiotics in agriculture and the continued rise in use and AMR. He suggests the primary reason is that

> the global history of agricultural antibiotics was initially one of immediate economic and political pressures as well as of ideological promises of plenty. Reacting to genuine agricultural demand and concerned about reducing imports, freeing agricultural labour, preventing communism, or sating the appetites of restive citizens, capitalist and communist planners alike licensed one antibiotic application after another. With the exception of early bans on antibiotic preservatives and residues in milk, the fiat of widening access to cheap food outweighed early warnings about antibiotic hazards. By around 1970, antibiotic infrastructures had become firmly entrenched in "Western" and "Eastern" food production. Once a system had become culturally and materially reliant on routine antibiotic use, further production increases were usually accompanied by rising drug use. (Kirchhelle, 2018, p. 10).

In addition, Kirchhelle points out that regulations have targeted some problematic outcomes of antibiotic use such as residues in milk, or AMR, without recognizing or challenging the systemic dependence on antibiotics within contemporary food production processes. This is something that must be tackled, because in Kirchhelle's analysis, even if the international commitments toward antibiotic stewardship turn into concrete action global regulations will not go far enough—"Without challenging the ideals of factory-like production and cheap protein that are still driving antibiotic use, current reforms will have limited success" (Kirchhelle, 2018, p. 10).

4 | PRACTICE: FLUSHING

Unsound disposal of plastics and PCPs is an area of concern in ECs research, with the image of a consumer flushing materials down the toilet used in a number of research papers in the field. Correct disposal—returning unused medication to a pharmacist or recycling for example—depends on a range of factors from the personal (educating and incentivizing individuals) to the infrastructural (e.g., adequately resourcing pharmacists, waste collection, or information campaigns).

Plastics and PCPs form part of a category of "unflushables"; solids that are flushed down toilets which the infrastructure is not designed to take. Unflushables comprise of many products and materials, including wet wipes, menstrual products, prophylactics, packaging and medical items. Flushing these not only contribute to the presence of ECs in aquatic environments, but also cause major infrastructural issues like blockages, flooding and increased water demand.

A study by Alda-Vidal et al. (2020) argues that to date most research on "unflushables" has focused on "end of pipe control and maintenance"; how to manage the problems of blockages like fatbergs and how to removed harmful compounds through WWT. The limited research on the source—the flushing—tends toward a narrow understanding of human behavior that assumes people flush things they should not due to a lack of understanding or care. This focuses solutions toward education campaigns, but fails to account to the broader material, cultural and political factors that affect flushing behavior.

Another way to approach the problem of unsound disposal of plastics and PCPs is to understand it as symptomatic of how sewage systems are used and to question why people use them to dispose of things other than human waste. The interpretive social sciences offer a number of theoretical and methodological approaches to provide detailed understandings of human behavior as well as broaden the scope for leverage points which could be used to tackle the problem of flushing “unflushables.” Alda-Vidal et al. (2020) provide a wide-ranging survey of the social factors that affect flushing and the social science approaches that help to understand them.

4.1 | Personal care products

PCPs cover a range of everyday household products used for cleaning, beauty and health purposes. Some of the most common compounds are used in disinfectants, fragrances, insect repellents, preservatives and sunscreen UV filters. Increasing incomes, product innovation and aging populations in the global are seen as increasing the market for PCPs, while cleaning products as seen as essential goods which maintain sales at times of economic downturns. In contrast to pharmaceuticals which are used internally, PCPs are for external use and are therefore not altered through metabolic processes. This means “large quantities of PCPs enter the environment unaltered through regular usage” (Brausch & Rand, 2011). Systematic reviews have shown chemicals are present in all continents, although lower income countries have had less studies conducted (Montes-Grajales et al., 2017). PCPs are some of the most commonly detected compounds in surface water globally, but less is known about the harmful effects in comparison to pharmaceuticals (Brausch & Rand, 2011). The main concerns are over the capacity for ECs from PCPs to bioaccumulate to higher levels, and the estrogenic and endocrine effects.

Although consumer concern shapes both the regulation of compounds and the market for products that use them, the compounds used in products and the limited knowledge about main sources and effects of human exposure mean it is hard for consumers to avoid them (Huang et al., 2020; Karwacka et al., 2019; Wang et al., 2018). A study investigating the impact of PCP product selection on greywater characteristics examined 55 PCPs and found they produced a broad range of pollution load and toxicity characteristics which varied both within and between product types. However, the variations did not correlate with factors typically seen as affecting consumer choice such as brand, type (eco-friendly or not) or price. The authors concluded “it is not currently possible for consumers to actively manage the issue [of greywater quality] through choice” and stress that “products labelled as eco-friendly were not seen to be less polluting or indeed less toxic”(Kadewa et al., 2020).

The wet wipes market is growing, and is a source of concern. Production and use of “nonwoven materials” of which wet wipes is one of the fastest growing market segments is rising. They are used for baby wipes, personal hygiene and household cleaning. Made from synthetic materials they are a source of microplastics, but there is not much research on the specific ECs they release, nor on appropriate disposal and methods to recycle the difference plastic polymers used (Lee et al., 2021).

4.2 | Recycling and disposal

Flushing medication down the toilet is a disposal method that is a source of concern for the management of ECs in the environment. The correct disposal of pharmaceuticals is an area of research that implicates consumers as well as professionals and industry in the production of ECs. Globally, the infrastructure in place to support appropriate disposal of medication by returning unused or expired medication to the medical system differs. For example in the EU, it is standard for pharmacists to be paid to provide this collection service, but in Croatia pharmacists are mandated to provide the service without being paid (Jonjić & Vitale, 2014). There are also different levels in awareness of how to manage unused and expired medicines as well as different levels of compliance even when the correct disposal practices are known.

Plastic is “a ubiquitous pollutant” and the mismanagement of plastic waste is a large problem (Stanton et al., 2021). Once in the environment plastic debris acts as a dispersal vector for persistent organic pollutants, heavy metals and pharmaceuticals (Stanton et al., 2021), and when they breakdown they realize additional chemicals such as plasticizers and dyes (Rochman, 2015). Different polymers are used for different purposes with the additives defined by end use; however, other compounds can be introduced through the manufacturing process. A modeling exercise run in 2015, estimated that approximately 6300 Mt of plastic waste had been generated globally, around 9% of which had been recycled, 12% was incinerated, and 79% was accumulated in landfills or the natural environment (Geyer et al., 2017).

4.3 | Why do people flush "unflushables"?

Social practice theory can help investigate how flushing has come to be an unsustainable practice and how it can change. A social practice is an action shaped not only by personal motivation but also material circumstances and social norms all of which contribute to how people make sense of what they should do. In this case, norms around hygiene interact with consumerism and conventions of cleanliness. "Flushability" is a marketable feature that has evolved with the commodification of hygiene. Our understanding of how to keep clean is shaped by, as well as drives, an industry of single use hygiene products like tampons or antibacterial wipes. "The increasing demand for single-use hygiene products is intertwined with rising anxieties over the elimination of pathogenic germs and with widespread cultures of convenience" (Alda-Vidal et al., 2020). Alda-Vidal et al. explore how this creates expectations that certain types of products are meant to be flushed, and flushing becomes a common way of expelling waste from a bathroom. However, this approach also shows how trends change. Disposable menstruation products used to be the major source of sewer blockages, but their presence in sewers is falling and at the same time the presence of disposable wet wipes is rising and becoming a major area of concern.

Sensory experiences of dirt and the cultural differences toward waste provide another path of analysis. Anthropological research shows how disgust is culturally determined rather than a human universal, and is provoked in different contexts by different forms of waste. Alda-Vidal et al. (2020) explain that differences in knowledge types can explain some flushing culture, and the strongly held belief that exposing people to blood and feces is dangerous and therefore the safest way to manage it is to flush it. While scientific evidence can be used to explain that risk of harm is negligible, it can be hard to counter the visceral responses provoked by some forms of waste in some contexts.

There are also expectations of the technical system that are investigated by Science and Technology Studies scholars. The focus of this type of work is how normative values shape the design and development of technology and are affected by technology. Alda-Vidal et al. (2020) point out that the United Kingdom has one of the highest rates of flushing solids in Europe which they attribute to the historical development of the large scale infrastructure hidden from view. In areas where the infrastructure is new, less robust or more visible there are different norms about what the infrastructure is designed to do and what can be flushed. Awareness campaigns are being run that seek to remind people of where toilet water goes and challenge the luxury of "flush and forget" infrastructure.

Product design and regulations also influence people's perceptions of flushability. Products like tampons have historically been marketed as flushable, creating associations that are hard to undo when new advice comes in and products are marked as unflushable. The growing problem of wet wipes in sewers has provoked a response from industry, and there has been a move to voluntary industry codes and standards. INDA, the Association of the Nonwoven Fabrics Industry, and EDANA, the International Association Serving the Nonwovens and Related Industries produced guidelines specifically about wipes which advised when to include "do not flush" labels. They recommend any product that is designed for use in the bathroom has a higher likelihood of being disposed of in the toilet, and therefore should carry a do not flush symbol. This symbol is recommended as mandatory for baby wipes. The guidance is, however, based on the potential to block and damage sewage infrastructure rather than the potential to introduce contaminants into the environment (INDA/EDANA, 2017). By suggesting that a do not flush label will mitigate the growing problem of wipes in sewers, the industry is not confronting the other environmental harms that could occur when wipes are disposed via solid waste management allowing the continued growth of single use disposable products.

The gender dimensions of flushing practices offer another analytical route. Hygiene and cleanliness are highly gendered issues that encompass the dominant association of women with cleaning the home as well as the standards of beauty and cleanliness that are linked to the performance of gender. Sydney Water, when investigating the problem of wet wipes in sewers found that "the major user group of flushable wipes were young males, 15–29" and not, as they had previously assumed, "young mums with babies." Perceptions and performance of gender roles are changing, with for example, a growing beauty industry targeted at men. Alda-Vidal et al. (2020) demonstrate that understanding gender also contributes to our understanding of EC routes into the environment and interventions that seek to reduce them.

The research into "unflushables" sketches out the diverse factors that affect the use of a toilet to dispose of products and packaging that cause environmental harm, blocked sewers and contribute to increasing water demand. It also signposts other areas, for example care and labor relations are not examined in detail as the assumption is that the flushing is carried out by the person who uses the product. However, PCPs and cleaning products or the household's waste management can be carried out by others such as cleaners, and paid or unpaid carers. It is therefore helpful to understand the division of labor and how this shapes where used products or packaging end up.

These types of research questions and approaches apply more broadly to other EC routes into the environment, and can be used to understand use of household cleaning products, recycling and waste disposal in domestic, hospital and industrial contexts. They show that the disposal practices cannot be separated from broader dynamics governing perceptions of hygiene, cultures of convenience and the political economy of resource production, use and disposal.

5 | CONCLUSION

The impact and management of ECs in the environment is likely to become more complex as the consumption of products that produce them continues to increase. Growing global population and affluence drives increasing total and per capital consumption of products that generate ECs, including meat, wet wipes, medications and PCPs.

Social science analysis is useful in identifying the underlying drivers for growth and potential interventions to improve management, including reducing sources of contamination. Interventions such as changing consumer behavior may be limited in effectiveness within powerful market dynamics and pervasive cultures of convenience. However, understanding the detail of how and why people use products of concern, including farmers and health care professionals, provides opportunities to design interventions to avoid or reduce use within wider constraints and systems. International efforts on antimicrobial stewardship demonstrate the value of integrated regulatory and policy responses. Regulation is constrained in its capacity to respond to growing consumer demand and the emergence of new products and markets. These dynamics emphasize the need to address the problem of ECs throughout the product lifecycle, including new formulations of drugs and products that are non-polluting, the use of cleaner production and more effective waste management processes, as well as supporting consumers to avoid polluting products.

AUTHOR CONTRIBUTIONS

Charlotte Johnson: Conceptualization (equal); investigation (lead); resources (supporting); writing – original draft (lead); writing – review and editing (supporting). **Sarah Bell:** Conceptualization (lead); project administration (lead); resources (lead); writing – original draft (supporting); writing – review and editing (lead).

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CONFLICT OF INTEREST

The authors have declared no conflicts of interest for this article.

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

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