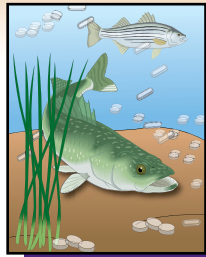


Disposal as a Source of Pharmaceuticals in the Environment

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INTRODUCTION



Active pharmaceutical ingredients (APIs) from a large and diverse spectrum of pharmaceuticals can enter the environment as trace contaminants, especially in waters, at individual concentrations generally less than a part per billion (µg/L) but sometimes more.

These trace residues may pose risks for aquatic life and cause concern with regard to human exposure, such as in drinking water supplies.

The predominate route by which APIs gain entry to the environment is via the discharge of raw and treated sewage contaminated with APIs as a result of their intended use in therapy or for lifestyle/cosmetic purposes.

Residues of APIs from parenteral and enteral drugs are excreted in feces and urine, and topically applied medications (plus APIs excreted in perspiration) are washed from skin during bathing.

For most APIs, the fraction of unchanged, parent API transferred to the environment is attenuated as a result of metabolic alteration in the body or transformation within a sewage treatment facility. For some APIs, only a small percentage of the total amount used is ever transported to the environment.

A secondary route of transfer of APIs to the environment is from the purposeful, direct disposal of medications to sewers and trash. The relative significance of this type of disposal with respect to excretion and bathing is poorly understood and subject to speculation. **Two major aspects of uncertainty exist. First, it is unknown what percentage of any particular API in the environment originates from disposal; the individual percentages probably vary dramatically among APIs. Second, disposal undoubtedly occurs from a variety of largely uncharacterized sources.**

Sources of disposal, along with the types and quantities of APIs resulting from each source, are important to understand so that effective pollution prevention approaches can be designed and implemented.

The accumulation of leftover, unwanted drugs can be used as an indicator of three major conditions:

- 1) Leftover drugs, when disposed to sewage or trash, represent a diverse source of potential chemical stressors in the environment.
- 2) Accumulated drugs represent increased potential for drug diversion, with its attendant accidental poisonings and purposeful addictive usage.
- 3) Leftover drugs represent wasted healthcare resources and lost opportunities for medical treatment.

OBJECTIVES

Summarized here is a project whose objectives were to:

- Catalog the diversity of locations where drugs are used and accumulate, eventually requiring disposal.
- Define the processes that control and drive the consumption, accumulation, and disposal of human pharmaceuticals.
- Identify opportunities for pollution prevention and source reduction.
- Develop an approach for accurately identifying the APIs (and their actual quantities) being disposed.

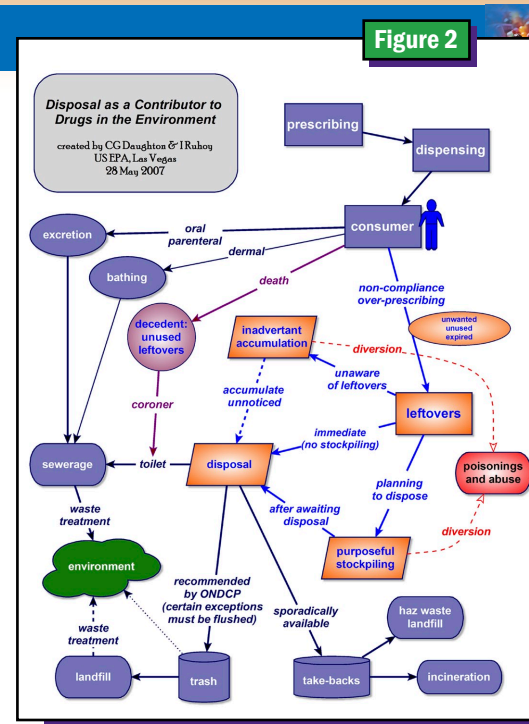
ACCOMPLISHMENTS

Identification of Sources: Probably more than for any other perishable, nonfood item consumed by humans, medications are used and stored at a vast array of locations throughout society. These products are frequently purchased in excess or not fully consumed as directed (e.g., patient non-compliance), leading to the accumulation of unwanted, leftover drugs. A broad spectrum of locations at which drugs are used and can accumulate, eventually leading to disposal, are shown in **Figure 1**. The relative significance of each of these sources with respect to disposal is currently unknown.

Factors Governing Disposal: The processes leading to the disposal of drugs by the individual consumer are illustrated in **Figure 2**. A significant point is that accumulated, leftover medications pose several major problems for human health and safety and for the integrity of the environment. These problems result from the diversion of accumulated drugs to those for whom they were not intended (leading to accidental and purposeful poisonings of infants, children, adults, and pets) and from the disposal of accumulated drugs to trash and sewage. The latter promotes the entry of APIs to the ambient environment.

Factors Governing Consumption and Accumulation: Numerous factors affect the consumption of drugs by consumers (**Figure 3**). Most serve to increase use, although several are at work to reduce use. Most of these factors are amenable to measures that could be designed to reduce their influence on the consumer. But these measures, in general, are outside the purview of the EPA. The significance of these factors is that each is amenable to targeting by various actions or activities to actively and substantially reduce the potential for drugs to accumulate prior to their disposal.

Possible Outcomes from Pollution Prevention: Progress with pollution reduction/prevention activities could yield substantial benefits, including: (i) reductions in the types and quantities of drugs



CONCLUSIONS

While the disposal of leftover drugs adds to the environmental burden of drug residues, it is currently not known how significant it might be. By identifying which drugs accumulate (Ruhoy and Daughton 2007), and where they accumulate (Ruhoy and Daughton 2008), measures could be implemented that would not only reduce the consequent need for disposal, but also improve healthcare outcomes and reduce healthcare expenses. This would be done preferably not by focusing on ecologically prudent methods for disposing of leftover medications, but rather by changing the human and healthcare processes that lead to accumulation in the first place — to eliminate accumulation altogether.

If new approaches to medical care were developed that eliminated leftover drugs, the consequent environmental residues would be eliminated, therapeutic outcomes would improve, healthcare expenses would go down, and human morbidity and mortality (due to addictive usage and poisonings from diverted, leftover drugs) would decline. Reducing, minimizing, or eliminating leftover drugs represents a very significant opportunity to improve both ecological and human health.

PRODUCTS



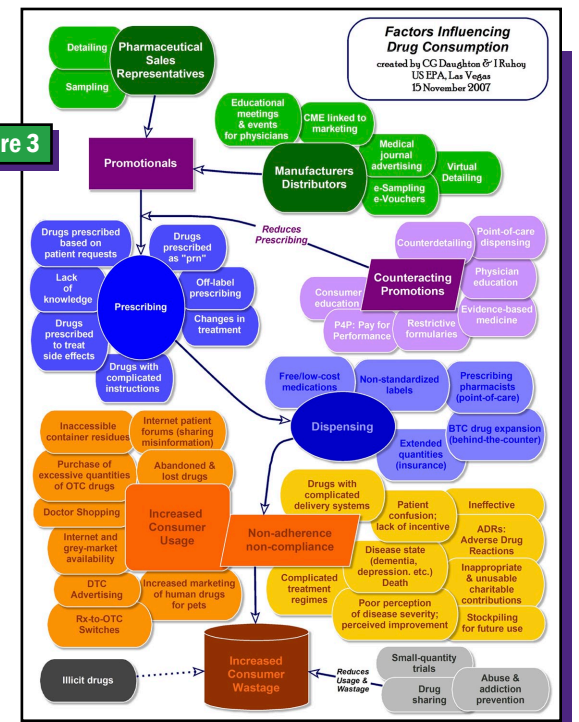
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Figure 3



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available from: <http://www.epa.gov/nerled1/chemistry/images/drug-disposal-1.pdf>