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Identifying household pharmaceutical waste characteristics and population behaviors in one of the most densely populated global cities

Shan-shan Chung[a,*], Bryan W. Brooks[b,c]

[a] Department of Biology, Hong Kong Baptist University, Kowloon Tong, Kowloon, Hong Kong, China
[b] Department of Environmental Science, Center for Reservoir and Aquatic Systems Research, Baylor University, Waco, TX, USA
[c] Institute of Biomedical Studies, Baylor University, Waco, TX, USA

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ABSTRACT

Environmental contamination caused by active pharmaceutical ingredients is an emerging global concern. Unfortunately, China, including the Hong Kong Special Administrative Region (HKSAR), lacks information on the quantities of pharmaceutical products consumed and disposed. Thus, an in-street survey using systematic sampling was conducted in 2015-16 to capture 1865 respondents from seven sites for their practices in handling and disposing unused pharmaceuticals in the household. Three-quarters of the population has unwanted medicines at home and on average, each household is storing 138.4 g, of which the major drug type is medicines for cold. Middle class populations in HKSAR are more likely to have larger quantities of unused medicines stored at home and slightly more than half (53.9%) of people dispose unwanted drugs in garbage cans along with normal solid waste. Our observations also suggest appreciable noncompliance and consumption of unused medicines following self-diagnosis of symptoms. The level of support for a future waste medicine take back scheme was less than 40% being wholehearted supporters. The most preferred location to return unwanted drugs was out-patient clinics, followed by convenience stores. While HKSAR is a developed world city by income level, survey results show that it is more similar to the developing world in terms of pharmaceutical resource management, especially due to lack of consumption data, pharmaceutical waste handling infrastructure and medication compliance. Insights gained from this survey can help public health and waste management authorities in other cities to improve pharmaceutical resource management in urban areas.

1. Introduction

Advancement and growing consumption of pharmaceutical products have greatly extended human life span. Given a total global gross domestic product (GDP) of US$51.307 trillion in 2006 ([dataset] The World Bank, 2017), the amount of financial resources committed to medicine procurement has ranged from US$720,000–840,000 million per year. The latest World Health Organization World Health Organization, (2011) report showed that per capita consumption of medicines in the non-hospital sector (84 countries studied in 2008) have increased by 18.6% in high income countries and 29.3% in low income countries compared to 2000. Unfortunately, these WHO data do not include medicines consumption of the most populous country in the world, the People's Republic of China (PRC). Although accurate data on associated spending on medicines are lacking (World Health Organization, 2011), an increasing amount of financial resources is being spent on medicines and healthcare. On a global scale, using up to 2006 data, World Health Organization, (2011) calculated that about 24.9% of the total health expenditure or 1.4% to 1.63% of GDP in the world was spent on medicines. In comparison, in 1980, health and medicine expenses accounted for 3.15% of the GDP of PRC, but in 2016, this percentage climbed to 6.22%, an increase of more than 320 times over the same period (The Statistical Yearbook on Health and Family Planning in China, 2017). Such observations indicate that the level of resources spent on health and medicine in PRC exceeds the world average. World Health Organization, (2011) identified that increases in medicines consumption by volume would have a significant impact on the public and private healthcare budget. A logical question to ask then is whether current practices in the use of medicines are effective to minimize wastage and adverse environmental side effects. Unfortunately, both issues have been largely neglected in environment and health policy research (Blair et al., 2017).

* Corresponding author at: SCT 703, Cha Chi-Ming Science Tower, Ho Sin Hang Campus, 224 Waterloo Road Kowloon, Hong Kong, China.
E-mail addresses: sschung@hkbu.edu.hk (S.-s. Chung), Bryan_Brooks@baylor.edu (B.W. Brooks).

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1.1. Pharmaceutical residues and environmental sustainability

Environmental contamination by pharmaceutical residues (PRs) has become a global concern, and are indicators of an urbanizing water cycle (Brooks, 2018). While the concentration of active pharmaceutical ingredients in many natural water bodies is often reported to be ng/L to low μg/L in developed countries, the actual health and environmental consequences of their continuous introduction is unknown in many parts of the world (Kookana et al., 2014; Kristofco and Brooks, 2017; Blair et al., 2017) and thus present diverse risks to wildlife (Brooks and Steele, 2018). For example, direct influences of endocrine active medicines in the aquatic environment includes feminization of male fish (Sanchez et al., 2011; World Health Organization et al., 2002), and can lead to population level adverse outcomes at environmentally relevant concentrations (Kidd et al., 2007). Indirect influences of medicines were recently highlighted by Chung et al. (2018), who found that the levels of some antibiotics in leachate plumes of both active and closed landfills (> 20 years) exceeded predicted no effect concentrations for the development of antibiotic resistance in surface waters. Further, Kelly and Brooks (in press) recently identified that 58% of municipal effluent discharges exceeded predicted no effect concentration for development of antibiotic resistance to ciprofloxacin, a critically important antibiotic designated by the WHO. Though the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal (1989) imposes restrictions on the transboundary movement of hazardous waste, including waste from pharmaceutical industries, it does not cover the discharge of PRs to the environment. We are not aware of any international solid waste regulation that covers specifically pharmaceutical waste (PW) management and handling.

Though discharges from PR manufacturing facilities have received attention, there are two major sources of PRs in the environment. The first is as by-products of medicines consumption. This source of PRs includes the non-metabolized parent compounds and their metabolite residues, which are introduced through municipal and industrial effluent discharges, and land application of biosolids. The second source is from the disposal of unused/unwanted medicines, i.e., waste from industrial, domestic and other human activities. PW includes a wide range of unwanted or unused prescription and non-prescription, human and veterinary drugs. While PW is not generally considered the largest source of PRs in the environment, it has the greatest potential to be prevented at source without incurring significant cost to public health or the environment. As with other types of solid waste, PW comes from both pre- & post-consumer sources. Between the two, post-consumer PW is considered to be the main contributor to this waste stream (Ternes et al., 2004) and thus it represents the focus of the current study. Post-consumer PW is generated by people during day-to-day personal use. Municipal wastewater, sludge disposal and landfill discharges are the most common media for post-consumer PW because it has been commonplace to dispose of unwanted/unused drugs in the sewage system or the municipal waste stream (Institute for Social-Ecological Research GmbH, 2008; Kheir et al., 2011; Musson et al., 2007; Thompson, 2010). Municipal wastewater collection systems receive PW and their metabolites primarily through excretion from normal course of treatment.

It is controversial to strictly apply the waste management hierarchy (WMH) principle in PW management. The environmentally most desirable approach, according to the WMH, is waste avoidance. Given the indispensable role of medicines in human health protection, meticulous planning is needed to avoid the over use of medicines. Although according to WMH, reuse should be considered before recovery and treatment, to reuse PW is generally not advisable due to the unintended side effects of perpetuating the self-medication culture, particularly in developed regions. Self-medication occurs in developing countries where prescribed pharmaceuticals can be purchased over the counter or even on the black market, and inadvertent consumption of contaminated, improperly stored or unsuitable drugs can occur. Further, if superfluous or expired unwanted drugs are diverted to people using them without knowledge of their undesirable effects, there may be adverse consequences for public health. Thus, unwanted medicines take-back represents one of the few feasible solutions to reduce pharmaceutical discharges (Stoddard and Huggett, 2012; Massoud et al., 2016; Stoddard et al., 2017). In fact, some New York hospitals have permanently prohibited disposal of pharmaceuticals through the wastewater systems and has implemented take-back schemes to collect unwanted drugs (Thompson, 2010). Since 1995, a take-back system of PW has been established in Germany using local pharmacies as collection points (Institute for Social-Ecological Research GmbH, 2008; Roig, 2010). Later, art. 127b of the European Union (EU) Directive on the Creation of a Community Code Relating to Medicinal Products for Human Use (2004/27/EC) stipulated the establishment of collection systems for unwanted drugs in EU. While drug take-back schemes in Europe were found to have had variable effectiveness (Roig, 2010), similar initiatives are rarely observed in Asia, including PRC.

In PRC, PW is a type of hazardous waste (National List of Hazardous Waste, 2016) and is covered by the Medical Waste Management Regulation (2003), which stipulates broad management principles of medical waste such as proper packaging and centralized treatment. Incineration or disinfection before landfilling are the two prescribed treatment approaches. In art. 33 of this Regulation, all cities and towns are to establish centralized medical waste facilities within one and two years respectively of the enactment of the Regulation. However, by 2012, total capacities of all licensed hazardous waste treatment facilities in PRC could only handle 50% of the hazardous waste generated in the country. In general, environmentally sound centralized storage and treatment of medical waste is still lacking in the PRC (Ministry of Environment Protection, National Development and Reform Commission, Ministry of Industry and Information Technology and Ministry of Health, 2012). In domestic settings of the PRC, unused medicines are likely being discarded indiscriminately with domestic waste. While exact figures are lacking, by far, landfilling is still the most predominant method in handling domestic waste in PRC (Mian et al., 2017), though the environmental loading of pharmaceutical ingredients in landfill leachate is largely unknown (Chung et al., 2018). PW take-back approaches are rare in PRC and even if such a scheme is present, the ultimate purpose is to reduce inappropriate medicine consumption and not necessarily to reduce environmental pollution from improper drug disposal. While Hong Kong Special Administrative Region (HKSAR) is an affluent and the most developed city in the PRC, it does not have an unused medicine take back scheme.

1.2. Medicine use and pharmaceutical waste management in HKSAR

With the absence of medicines consumption data in China, it may be useful to consider the data of HKSAR in an initial effort because this information may be indicative of the broader situation in Chinese or other Asian cities. HKSAR has an area of 1106.3 km^2 and a population of 7.35 million as of mid-2016 (Census and Statistics Department, 2016a; 2016b). It can be geographically divided into three main areas (Kowloon, Hong Kong Island, and the New Territories) and 18 administrative districts. Our direct communication with the Drug Office of HKSAR confirmed that the government does not have data of consumption of registered pharmaceutical products in the city (Chan, P., 2013, personal communication on 16th September). Thus, external trade statistics of human medicines and other pharmaceutical products (veterinary) regularly released by the government represents the most complete source of data for drug consumption in HKSAR. Trade data show that HKSAR generally does not export vitamins, raw materials for penicillin, other antibiotics and other drugs. In 2016, domestic consumption (i.e., total imports less exports and re-exports) of medicinal and pharmaceutical products (including veterinary medicines)