

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

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

3

4 **Abstract**

5 Environmental contamination caused by active pharmaceutical ingredients is an
6 emerging global concern. Unfortunately, China, including the Hong Kong Special
7 Administrative Region (HKSAR), lacks information on the quantities of
8 pharmaceutical products consumed and disposed. Thus, an in-street survey using
9 systematic sampling was conducted in 2015-16 to capture 1865 respondents from
10 seven sites for their practices in handling and disposing unused pharmaceuticals in the
11 household. Three-quarters of the population has unwanted medicines at home and on
12 average, each household is storing 138.4 gm, of which the major drug type is
13 medicines for cold. Middle class populations in HKSAR are more likely to have
14 larger quantities of unused medicines stored at home and slightly more than half
15 (53.9%) of people dispose unwanted drugs in garbage cans along with normal solid
16 waste. Our observations also suggest appreciable noncompliance and consumption of
17 unused medicines following self-diagnosis of symptoms. The level of support for a
18 future waste medicine take back scheme was less than 40% being wholehearted
19 supporters. The most preferred location to return unwanted drugs was out-patient
20 clinics, followed by convenience stores. While HKSAR is a developed world city by
21 income level, survey results show that it is more similar to the developing world in
22 terms of pharmaceutical resource management, especially due to lack of consumption
23 data, pharmaceutical waste handling infrastructure and medication compliance.
24 Insights gained from this survey can help public health and waste management
25 authorities in other cities to improve pharmaceutical resource management in urban
26 areas.

27

28 Key words: pharmaceutical waste management; unused medicine take back;
29 medication noncompliance; self-diagnosis; urbanization

30

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

33

34 **1. Introduction**

35 Advancement and growing consumption of pharmaceutical products have greatly
36 extended human life span. Given a total global gross domestic product (GDP) of
37 US\$51.307 trillion in 2006 (The World Bank, 2017), the amount of financial
38 resources committed to medicine procurement has ranged from US\$720,000 –
39 840,000 million per year. The latest World Health Organization (WHO) (2011) report
40 showed that per capita consumption of medicines in the non-hospital sector (84
41 countries studied in 2008) have increased by 18.6% in high income countries and
42 29.3% in low income countries compared to 2000. Unfortunately, these WHO data do
43 not include medicines consumption of the most populous country in the world, the
44 People’s Republic of China (PRC). Although accurate data on associated spending on
45 medicines are lacking (WHO, 2011), an increasing amount of financial resources is
46 being spent on medicines and healthcare. On a global scale, using up to 2006 data,
47 WHO (2011) calculated that about 24.9% of the total health expenditure or 1.4% to
48 1.63% of GDP in the world was spent on medicines. In comparison, in 1980, health
49 and medicine expenses accounted for 3.15% of the GDP of PRC, but in 2016, this
50 percentage climbed to 6.22%, an increase of more than 320 times over the same
51 period (The Statistical Yearbook on Health and Family Planning in China, 2017).
52 Such observations indicate that the level of resources spent on health and medicine in
53 PRC exceeds the world average. WHO (2011) identified that increases in medicines
54 consumption by volume would have a significant impact on the public and private
55 healthcare budget. A logical question to ask then is whether current practices in the
56 use of medicines are effective to minimize wastage and adverse environmental side
57 effects. Unfortunately, both issues have been largely neglected in environment and
58 health policy research (Blair et al., 2017).

59

60 ***1.1. Pharmaceutical residues and environmental sustainability***

61 Environmental contamination by pharmaceutical residues (PRs) has become a
62 global concern, and are indicators of an urbanizing water cycle (Brooks 2018). While
63 the concentration of active pharmaceutical ingredients in many natural water bodies is
64 often reported to be ng/L to low µg/L in developed countries, the actual health and
65 environmental consequences of their continuous introduction is unknown in many
66 parts of the world (Kookana et al., 2014; Kristofoco and Brooks, 2017; Blair et al.,
67 2017) and thus present diverse risks to wildlife (Brooks and Steele, 2018). For
68 example, direct influences of endocrine active medicines in the aquatic environment

69 includes feminization of male fish (Sanchez et al., 2011; WHO, 2002), and can lead to
70 population level adverse outcomes at environmentally relevant concentrations (Kidd
71 et al., 2007). Indirect influences of medicines were recently highlighted by Chung et
72 al. (2018), who found that the levels of some antibiotics in leachate plumes of both
73 active and closed landfills (>20 years) exceeded predicted no effect concentrations for
74 the development of antibiotic resistance in surface waters. Further, Kelly and Brooks
75 (2018) recently identified that 58% of municipal effluent discharges exceeded
76 predicted no effect concentration for development of antibiotic resistance to
77 ciprofloxacin, a critically important antibiotic designated by the WHO. Though the
78 Basel Convention on the Control of Transboundary Movements of Hazardous Wastes
79 and their Disposal imposes restrictions on the transboundary movement of hazardous
80 waste, including waste from pharmaceutical industries, it does not cover the discharge
81 of PRs to the environment. We are not aware of any international solid waste
82 regulation that covers specifically pharmaceutical waste (PW) management and
83 handling.

84 Though discharges from PR manufacturing facilities have received attention,
85 there are two major sources of PRs in the environment. The first is as by-products of
86 medicines consumption. This source of PRs includes the non-metabolized parent
87 compounds and their metabolite residues, which are introduced through municipal
88 and industrial effluent discharges, and land application of biosolids. The second
89 source is from the disposal of unused/unwanted medicines, i.e., waste from industrial,
90 domestic and other human activities. PW includes a wide range of unwanted or
91 unused prescription and non-prescription, human and veterinary drugs. While PW is
92 not generally considered the largest source of PRs in the environment, it has the
93 greatest potential to be prevented at source without incurring significant cost to public
94 health or the environment. As with other types of solid waste, PW comes from both
95 pre- & post-consumer sources. Between the two, post-consumer PW is considered to
96 be the main contributor to this waste stream (Ternes et al., 2004) and thus it represents
97 the focus of the current study. Post-consumer PW is generated by people during day-
98 to-day personal use. Municipal wastewater, sludge disposal and landfill discharges are
99 the most common media for post-consumer PW because it has been commonplace to
100 dispose of unwanted/unused drugs in the sewage system or the municipal waste
101 stream (Institute for Social-Ecological Research GmbH [ISRG], 2008; Kheir et al.,
102 2011; Musson et al., 2007; Thompson, 2010). Municipal wastewater collection
103 systems receive PW and their metabolites primarily through excretion from normal
104 course of treatment.

105 It is controversial to strictly apply the waste management hierarchy (WMH)
106 principle in PW management. The environmentally most desirable approach,

107 according to the WMH, is waste avoidance. Given the indispensable role of medicines
108 in human health protection, meticulous planning is needed to avoid the over use of
109 medicines. Although according to WMH, reuse should be considered before recovery
110 and treatment, to reuse PW is generally not advisable due to the unintended side
111 effects of perpetuating the self-medication culture, particularly in developed regions.
112 Self-medication occurs in developing countries where prescribed pharmaceuticals can
113 be purchased over the counter or even on the black market, and inadvertent
114 consumption of contaminated, improperly stored or unsuitable drugs can occur.
115 Further, if superfluous or expired unwanted drugs are diverted to people using them
116 without knowledge of their undesirable effects, there may be adverse consequences
117 for public health. Thus, unwanted medicines take-back represents one of the few
118 feasible solutions to reduce pharmaceutical discharges (Stoddard and Huggett, 2012;
119 Massoud et al., 2016, Stoddard et al., 2017). In fact, some New York hospitals have
120 permanently prohibited disposal of pharmaceuticals through the wastewater systems
121 and has implemented take-back schemes to collect unwanted drugs (Thompson,
122 2010). Since 1995, a take-back system of PW has been established in Germany using
123 local pharmacies as collection points (ISRG, 2008; Roig, 2010). Later, art. 127b of the
124 European Union (EU) Directive on the Creation of a Community Code Relating to
125 Medicinal Products for Human Use (2004/27/EC) stipulated the establishment of
126 collection systems for unwanted drugs in EU. While drug take-back schemes in
127 Europe were found to have had variable effectiveness (Roig, 2010), similar initiatives
128 are rarely observed in Asia, including PRC.

129 In PRC, PW is a type of hazardous waste (National List of Hazardous Waste,
130 2016) and is covered by the Medical Waste Management Regulation (2003), which
131 stipulates broad management principles of medical waste such as proper packaging
132 and centralized treatment. Incineration or disinfection before landfilling are the two
133 prescribed treatment approaches. In art. 33 of this Regulation, all cities and towns are
134 to establish centralized medical waste facilities within one and two years respectively
135 of the enactment of the Regulation. However, by 2012, total capacities of all licensed
136 hazardous waste treatment facilities in PRC could only handle 50% of the hazardous
137 waste generated in the country. In general, environmentally sound centralized storage
138 and treatment of medical waste is still lacking in the PRC (Ministry of Environment
139 Protection, National Development and Reform Commission, Ministry of Industry and
140 Information Technology and Ministry of Health, 2012). In domestic settings of the
141 PRC, unused medicines are likely being discarded indiscriminately with domestic
142 waste. While exact figures are lacking, by far, landfilling is still the most predominant
143 method in handling domestic waste in PRC (Mian et al., 2017), though the
144 environmental loading of pharmaceutical ingredients in landfill leachate is largely

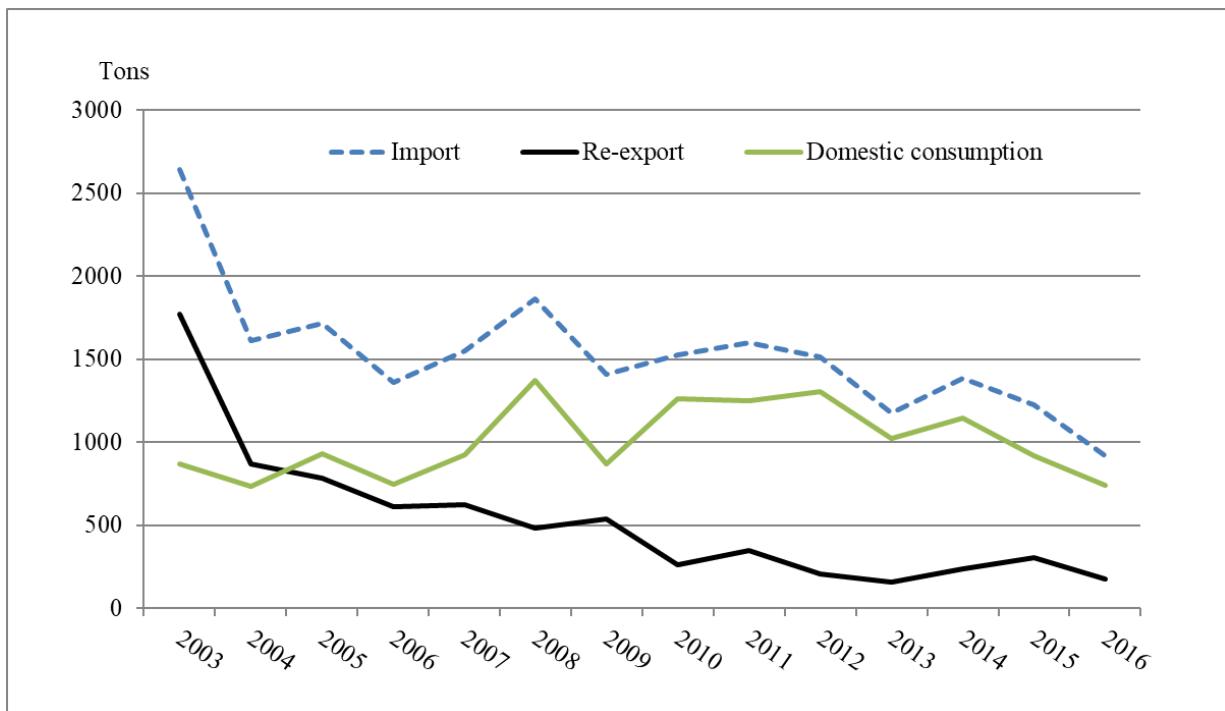
145 unknown (Chung et al., 2018). PW take-back approaches are rare in PRC and even if
146 such a scheme is present, the ultimate purpose is to reduce inappropriate medicine
147 consumption and not necessarily to reduce environmental pollution from improper
148 drug disposal. While Hong Kong Special Administrative Region (HKSAR) is an
149 affluent and the most developed city in the PRC, it does not have an unused medicine
150 take back scheme.

151

152 ***1.2. Medicine use and pharmaceutical waste management in HKSAR***

153 With the absence of medicines consumption data in China, it may be useful to
154 consider the data of HKSAR in an initial effort because this information may be
155 indicative of the broader situation in Chinese or other Asian cities. HKSAR has an
156 area of 1106.3 km² and a population of 7.35 million as of mid-2016 (Census and
157 Statistics Department, 2016a). It can be geographically divided into three main areas
158 (Kowloon, Hong Kong Island, and the New Territories) and 18 administrative
159 districts. Our direct communication with the Drug Office of HKSAR confirmed that
160 the government does not have data of consumption of registered pharmaceutical
161 products in the city (Chan, P., 2013, personal communication on 16th September).
162 Thus, external trade statistics of human medicines and other pharmaceutical products
163 (veterinary) regularly released by the government represents the most complete source
164 of data for drug consumption in HKSAR. Trade data show that HKSAR generally
165 does not export vitamins, raw materials for penicillin, other antibiotics and other
166 drugs. In 2016, domestic consumption (i.e., total imports less exports and re-exports)
167 of medicinal and pharmaceutical products (including veterinary medicines) amounted
168 to at least 743.3 tons.¹ However, this excluded several types of pharmaceutical
169 products for which the quantities were not reported in the government trade statistics.
170 In addition, such aggregated data do not provide information on the mass of
171 consumption by various drug-using sectors in the society, which represents essential
172 information for planning a drug take-back scheme. Figure 1 shows consumption
173 trends for 2003 – 2016. These apparent trends indicate that quantitative imports of
174 medicinal products have been at around 1000 tons per year over the last decade
175 (except for 2016) and domestic consumption of medicinal products has exceeded re-
176 exports since 2005. This indicates, for the past decade, the majority of imported
177 medicinal products have been consumed in HKSAR.

¹ The trade figures of Group 542, namely Medicaments (including veterinary medicaments) are not included because for the majority of the products in this group, only values and not the quantities traded are reported. Raw materials for medicines or medicines in ready to use form are categorized under group 541 in Hong Kong Merchandise Trade Statistics.



178

179 Fig. 1. Import, re-export and domestic consumption of medicine in Hong Kong
 180 (2003-2016).

181

182 Figures from the Environmental Protection Department (EPD) showed that
 183 healthcare institutes in HKSAR sent 58-73 tons of PW to the government owned
 184 Chemical Waste Treatment Facility (CWTF) for disposal in 2011-2013 (Li, 2014).
 185 However, similar figures for household PW are unavailable because these waste
 186 streams are largely unregulated in HKSAR [s.35 of The Waste Disposal (Chemical
 187 Waste) (General) Regulation, Chapter 354C, *Laws of HKSAR*]. As a result, there is a
 188 lack of information on the flow of PW in a household context in HKSAR. A survey
 189 was therefore conducted to fill this information gap. Unwanted medicines situations in
 190 the non-hospital sector were targeted in this study because it typically constitutes a
 191 larger volume compared to hospital use (WHO, 2011). Specifically, the key variables
 192 of concern included unwanted stocks of medicines in the domestic setting, common
 193 ways of medicines disposal and preferences of the general public on the prospects of
 194 implementing a drug take-back scheme in the future.

195

196 2. Material and Methods

197 It has been our experience that in-street questionnaire surveys are able to collect data
 198 from a group of respondents with representative socio-demographic background
 199 despite the relatively high rate of non-responses (Chung et al., 2011). Though
 200 measurement of the PW content in household waste represents another approach,
 201 estimation of specific PW is challenging due to its relatively infrequent appearance in

202 the waste stream and being obscured by other waste and contaminants. Thus, fully
203 administered systematic sampling at seven sites (3 – New Territories, 2 – Hong Kong
204 Island, 2 – Kowloon Peninsular) was adopted to collect ~1800 samples. Based on a
205 commonly used sample size determining formula (Grimm and Wozniak, 1990) this is
206 sufficient for an error of less than 2.3% at 95% confidence assuming maximum
207 variability in variables for the situations in HKSAR. Among the probability-based
208 sampling methods, systematic sampling is the most straightforward to perform in-
209 street survey.

210

211 ***2.1. Quality Control***

212 A draft of the questionnaire was pilot-tested in April and May 2015 on ~70 adult
213 citizens of HKSAR and minor changes were made thereafter. The finalized
214 questionnaire was prepared in two languages, Chinese and English. While English is
215 commonly spoken in HKSAR, Chinese is still the first language of the majority of
216 people. Thus, >85% of the questionnaires completed were in the Chinese version. The
217 questionnaire consists of two parts. The first part included variables such as unused
218 medicine quantities and types at home, unused medicine disposal and storage
219 preferences and practices, sources of surplus drugs, preferences on an unused
220 medicine take back scheme and factors that would affect the attitudes towards such a
221 scheme. The second part consisted of questions on personal characteristics and other
222 socio-demographic data.

223 Data entry errors were reduced in two steps. First, after all the data were entered
224 in a computer, data distributions were reviewed to identify values that do not exist.
225 Second, about 10% of the questionnaires were randomly selected to cross-check for
226 data entry mistakes. If a mistake was found, an additional 5% of the questionnaires
227 were randomly selected, checked and corrected until no data entry errors were found.
228 About 20% of the questionnaires were cross-checked.

229 Two other quality control features were also introduced. First, rather than simply
230 asking the respondents to estimate the amount of unwanted pharmaceuticals stored at
231 their homes, enumerators would carry with them one 50-gm “dummy drug pack”
232 during the survey to show to the respondents. This provided a visual prompt to the
233 respondents and helped them to recall the quantities of drug stored at home more
234 accurately. The dummy drug packs contained tablets and capsules of the 30 most
235 dispensed medicines by public hospitals including public outpatient clinics in HKSAR
236 in 2013. Since the public healthcare sector is the predominant provider of secondary
237 and tertiary healthcare services in HKSAR (Food and Health Bureau, 2014), it was
238 anticipated that these 30 most dispensed medicines were also the most commonly
239 used drugs. This was developed so that the respondents would find the drugs in the

240 pack “familiar” or similar to what they have been using.

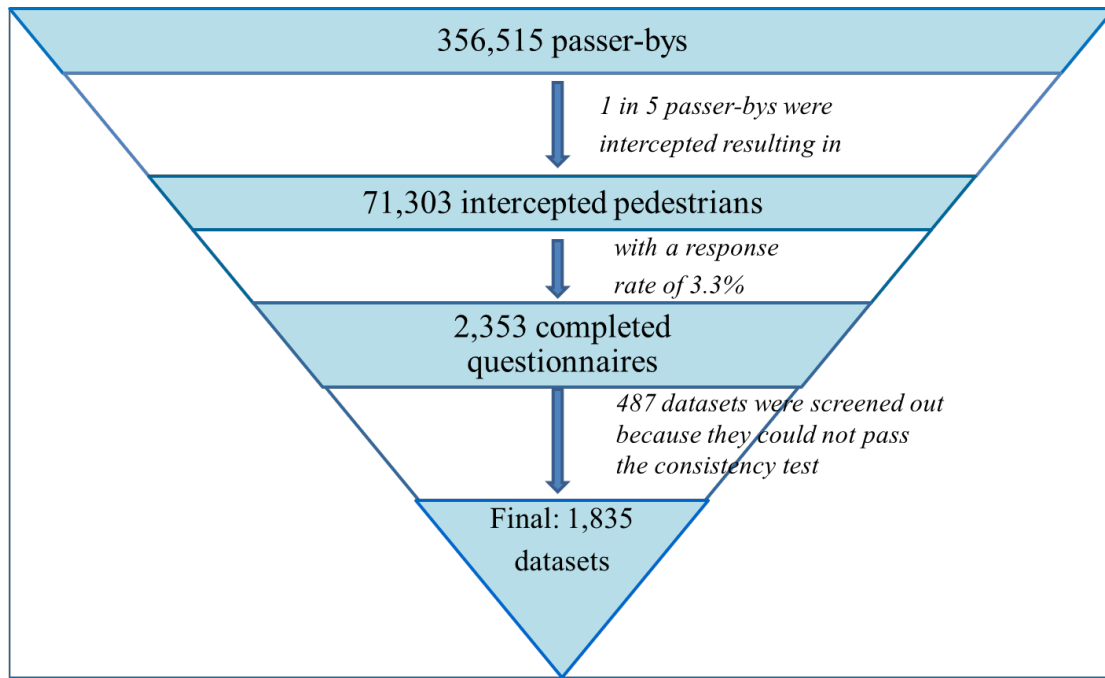
241 Second, a consistency test was introduced. Two questions (Q7 and Q12B of
242 section A) related to the same type of medication compliance behavior of the
243 respondent were asked. A dataset was discarded if the respondent provided
244 inconsistent answers to these two questions. A total of 487 datasets (nearly 21% of the
245 2353 questionnaires completed, Figure 2) were discarded as a result. This served to
246 screen out inconsistent responses, and to exclude those respondents who did not
247 answer the survey seriously, in order to ensure quality of the data.

248

249 ***2.2 Sample selection at survey sites and response rate***

250 Two questions (aged over 18 and being a HKSAR citizen) were used to screen people
251 intercepted. All the 7 sites chosen for in-street survey were roof-covered busy transit
252 points or areas outside shopping centers. Enumerators intercepted every fifth person
253 crossing a specific mark on the site. If the potential respondent passed the two
254 screening questions and consented to continue the dialogue with the enumerator, then
255 the enumerator showed to him/her a study information sheet (approved by the Human
256 Research Ethics Committee of the HKSAR Baptist University, HASC/13-14/0070),
257 which stated the rights of the respondents and the contact information of the project
258 leader. The survey formally began if the respondents showed willingness to take part
259 in the survey after presentation of the content stated in the study information sheet. A
260 total of 2352 questionnaires were completed with a response rate of 3.3%. Collected
261 data were entered and analyzed with IBM SPSS release 24. Figure 2 shows the flow
262 of respondent interception, questionnaire completion and consistency check for this
263 survey.

264 The response rate of 3.3% is lower than expected. In another study using the
265 same in-street fully supervised survey method in HKSAR on electronic and electrical
266 waste in 2009, the response rate was 8% (Chung et al., 2011). In a telephone survey
267 on home medications in Qatar, Kheir et al. (2011) could only achieve a response rate
268 of 11%. Thus, it appears that owing to reasons such as survey fatigue, selling under
269 the guise of research, growing popularity of use of e-means in communication, it is
270 becoming increasingly difficult to attain satisfactory response rates for surveys using
271 traditional instruments (Brennan, 1992; Pecoraro, 2012). Thus, having a “low
272 response rate” will remain a challenge for academic research using questionnaire
273 survey as the main data collection instrument. In view of the low response rate, the
274 discrepancies between our sample and the population of HKSAR are discussed in the
275 next section relative to the representativeness of the survey results.



276

277 Fig. 2. The flow of respondent interception and sample selection for pharmaceutical
 278 practices in Hong Kong.

279

280

281 3. Results and Discussion

282

283 3.1. Profile of respondents

284 Demographic characteristics of the 1865 respondents are provided in Table 1. In terms
 285 of age, our study captured more younger citizens (aged 18-34) and our respondents
 286 were generally more educated and more wealthy (indicated by higher income and
 287 ownership of cars) than the typical situation in Hong Kong, although it is important to
 288 note that about one-third of the respondents did not want to disclose their incomes.
 289 These more wealthy respondents were likely residents of home ownership “court,”
 290 which was government-built housing for the lower middle class in HKSAR. In terms
 291 of living areas, the distribution of our samples was on par with the overall situation
 292 for Hong Kong in mid-2016 but with slight over-sampling of residents in the New
 293 Territories. The mean household size of the respondents was also slightly larger than
 294 average.

295

296 Table 1

297 Socio-demographic profiles of respondents in Hong Kong.

Socio-demographic characteristics	This study	Hong Kong (mid-2016)
Age		
18-34	55.6%	28.5% ^a

35-64	38.9%	53.6%
<64	5.5%	18.0%
Education		
No education/Pre-primary/Primary	8.1%	18.8%
Secondary	30.3%	49.2%
Matriculated	11.1%	
Tertiary	42.7%	31.9%
Post-graduate	7.8%	
Averaged per capita monthly income		
Below HK\$2500	2.1%	14.9% ^b
\$2501-5000	2.9%	14.0%
\$5001-10,000	7.0%	26.8%
\$10,001-15,000	14.0%	17.5%
\$15,001-30,000	23.7%	
\$30,001- 50,000	11.0%	26.7%
Over \$50000	5.6%	
I don't want to answer this question	33.7%	-
Vehicle ownership (no. per 1000 people)	90.7	71.2 (2015)
Household size (person)	3.4	2.9
Living area		
HKSAR Island	17.7%	17.1%
Kowloon	24.4%	30.2%
New Territories	57.9%	52.4%
Accommodation		
Public rental	22.8%	30.6%
Home ownership courts	23.3%	15.0%
Private (rental)	22.7%	53.6%
Private (owned)	30.7%	
Others (e.g., temporary housing)	0.6%	0.8%

298 ^a - The percentage of people in the age between 15 and 34 out of all people aged <15

299 ^b - Income distribution data for the City exactly matching the income ranges that are
300 used in this study are not available. The distributions of the closest ranges are
301 provided.

302 Sources: Census and Statistics Department, 2016a, 2016b; Transport Department,
303 2016.

304

305 ***3.2. Quantities and types of drugs at home and their relationship with demographic***
306 ***variables***

307 When investigating the quantities and types of unused (including expired and surplus)
 308 drugs at homes, enumerators unambiguously told the respondents that health
 309 supplements such as calcium tablets and medicines recently prescribed by medical
 310 doctors in the preceding 7 days were excluded from the survey. In addition, in the
 311 estimation of drug quantities stored at home, we also excluded more difficult-to-
 312 estimate dosage forms, such as asthma inhalers. Survey results from another study
 313 showed that only a very small proportion (e.g., 1%) of unused medicines was in such
 314 special forms (Gracia-Vásquez et al., 2015), perhaps because these maintenance
 315 medicines are more likely to be fully consumed.

316

317 Table 2

318 Percentage of people with unused medicine stored at home in Hong Kong and other
 319 locations reported in peer-reviewed literature.

	With some unused drugs at home	Not at the time of survey	Never
Hong Kong	75	12.8	12.2
USA	30		
Ghana	>50		
Serbia	96.3	n.a.	
Kabul	95		

320

321 Of the 1865 respondents, 75% indicated that at the time of the survey they had
 322 unused drugs at home and about 12.8% said they have previously kept medicines at
 323 home but were not doing so at the time of the survey (Table 2). The proportion of
 324 respondents having unused medicines at home was far higher in HKSAR than in
 325 Cook County, USA (Wieczorkiewicz et al., 2013) or in Ghana (Sasu et al., 2016) but
 326 lower than in urban Serbia (Kusturica et al., 2012) and Kabul in Afghanistan (95%,
 327 Bashaar et al., 2017). Such differences may partially be explained by the different
 328 emphases of these surveys. The 30% figure in the Cook County survey represented
 329 those with either prescription or non-prescription drugs at home but not taking any
 330 medication on a regular basis. On the other hand, our emphasis was on those who had
 331 kept unused drugs that were not dispensed by medical doctors in the last 7 days at the
 332 time of the survey, regardless of whether one was under constant medication. Despite
 333 this difference in emphasis, it is still likely that a greater proportion of HKSAR
 334 citizens is keeping unused medicines at home than in Cook County, USA.

335 We also invited the respondents to indicate the amount of drugs stored at home

336 by pre-set ranges² (Table 3). By using the mid-value of each range, an average citizen
 337 appears to be keeping 138.4 gm of drugs at home, or for each person who has
 338 excessive drugs stored at home, 182.4 gm. With a population of 7.35 million in mid-
 339 2016, this amount is equivalent to 1017 tons of stored medicines just in the domestic
 340 sector of Hong Kong. Remarkably, this quantity is greater than the total quantities of
 341 541 groups of drugs imported into HKSAR in 2016 (922.1 tons). The predominant
 342 majority of these 1017 tons of medicines found at homes were in tablet, capsule or
 343 powder forms. Cold medications represented the major type of medicine being stored
 344 by respondents, followed by anti-inflammatory and painkilling pharmaceuticals and
 345 drugs for stomach problems. These observations can likely be explained by the easy
 346 availability of most common cold drugs in HKSAR and the relatively high prevalence
 347 of common cold (among communicable diseases found in HKSAR) in a densely
 348 populated city.

349

350 Table 3

351 Amount of unused personal medicine stored at home in Hong Kong (N=1860).

Amount (mid value) (gm)	Percentage of respondents
<50 (25)	16.6
50-100 (75)	14.5
100-200 (150)	22.7
200-300 (250)	7.2
300-400 (350)	4.0
400-500 (450)	2.9
>500 (550)	8.1
no need to answer this question (0)	24.1

352

353 Our observation converges with similar findings elsewhere. In Qatar homes, the
 354 first and third groups of drugs kept at homes were analgesics (classified as a type of
 355 cold drugs in this study) and allergy, cough or cold drugs respectively. Also similar to
 356 our findings, their second most commonly stored drugs was nonsteroidal anti-
 357 inflammatory agents (Kheir et al., 2011). In Mexico, nonsteroidal anti-inflammatory
 358 drugs were the largest group of unwanted drugs, followed by cardiovascular and then
 359 gastrointestinal drugs (Gracia-Vásquez et al., 2015). In Cook County, the top three

² “Standard Unit” is the unit used by WHO and IMS to describe medicine volume. One SU equals one tablet/capsule/prefilled syringe/dose of inhaled medicine etc. SU was not used in the questionnaire as it cannot be readily translated into commonly used units in waste treatment, namely, kilogram or ton and neither would it be easy for respondents to indicate the amount of unwanted medicines stored up which can be a substantial amount, e.g. several hundreds of tablets.

360 types of medicines kept at home were, in order of quantities, over-the-counter (OTC)
361 pain medicines, vitamins and cold, cough or flu medicines (Wieczorkiewicz et al.,
362 2013). Since vitamins were excluded from our survey, it appeared that cold/flu and
363 pain medicines were the two most commonly kept medicines at home in various
364 societies.

365

366 An association between private rented housing dwellers and the amount of
367 medicines stored at home was observed. Specifically, there was a disproportionately
368 high percentage (34.0%) of private rented housing dwellers and a slightly higher than
369 average percentage of privately owned-housing dwellers (35.4%) storing more than
370 500 gm or more of medicines at home (compared with 15.3% for dwellers in the other
371 two types of public housing; $\chi^2=40.03$, $df= 18$, two-tailed $p=0.02$). Regarding the
372 relationship between the quantities of medicines stored at home and monthly per
373 capita personal income levels (ignoring those who did not reveal their income levels),
374 respondents with a monthly per capita income above HK\$15,000 (\approx US\$1930), in
375 particular the HK\$15,000 – 30,000 range, tended to have more unused medicines at
376 home ($\chi^2=73.56$, $df=25$, two-tailed $p=0.000$). Both associations appear to suggest that
377 the middle class in HKSAR is more likely to have greater quantities of unused
378 medicines at home. There is a paucity of literature on the association between income
379 levels and unused medicine storage in the domestic context. In Ethiopia and Iran, a
380 related finding reported middle to higher income families with a higher tendency to
381 keep medicines at home (Teni et al., 2017).

382

383 ***3.3. Reasons for having left over medicines***

384 Respondents identified that a medical doctor's prescription is the most common
385 channel to obtain medicines, followed by procurement from registered pharmacies.
386 Obtaining medicines from friends and relatives was only a minor source of
387 medication. When asked why there was excessive storage of drugs at home, reasons
388 cited in order of importance were: 1. recover before the medicine was finished; and 2.
389 saving medicine for future use. A change in prescription and occasional non-
390 compliance with medical prescription were the other two reasons with similar level of
391 importance. Saving medicine for future use suggests self-diagnosis practices is
392 commonly occurring.

393

394 ***3.4. Disposal of drugs***

395 Respondents were requested to indicate how the medicines stored at home would be
396 further handled. Regarding the fate of the stored medicines, about 53.9% of these
397 substances would later be disposed by the respondents at garbage cans with normal

398 solid waste. The use of other handling methods are provided in Table 4. Such a
 399 finding indicates that if a take-back scheme for unused drugs is to be introduced in
 400 HKSAR, the predominant majority of the citizens will need to be educated to change
 401 their usual way to handling surplus and unused drugs. In sum, about 60% of the
 402 medicines acquired by the households in HKSAR are disposed or wasted. This may
 403 represent an underestimation as it is doubtful if the respondents actually continue to
 404 use or apply the 35.3% leftover drugs as indicated.

405

406 Table 4

407 The fate of leftover medicines in Hong Kong (N=1837).

Method	%	Method	%
Toilet	4.1		
Sinks	1.3	Continue to ingest or apply	35.3
Waste bin	53.9	Sell to others	0.6
Burn at home	0.5	Give to the needy	3.1
Return to point of purchase ^a	0.9		
<i>To be disposed</i>	<i>60.7</i>	<i>May still be used</i>	<i>39.0</i>

408 ^a Medicines, even unused, if returned to pharmacies are usually destroyed (Hassali et
 409 al., 2012)

410

411 From Table 4, Hong Kong citizens most frequently dispose of unused medicines
 412 in ordinary trash bins. Waste bins are the usual places of disposal for unwanted
 413 medicines also in Qatar (Kheir et al., 2011), Cook County (Wieczorkiewicz et al.,
 414 2013), Ghana (Sasu et al., 2016), South Backa District of Serbia, Kabul of
 415 Afghanistan (Bashaar et al., 2017); and many other places (Kusturica et al., 2012). In
 416 contrast, discarding unwanted medicines along with normal solid waste (3%) and
 417 flushing them down the toilet/drain (0-1%) are rare in Sweden (Persson et al., 2009).

418

419 **3.5. Storage of drugs**

420 Where do people store surplus medicines? The majority in Hong Kong stored them in
 421 cupboard or drawers; this was followed by anywhere convenient and refrigerators
 422 (Table 5). In view of the previous findings that about one-third of the surplus drugs
 423 might still be ingested later following self-diagnosis, it is important to understand if
 424 these common storage approaches are appropriate. In general, excessive moisture,
 425 light and extreme temperatures may cause decomposition of active ingredients in
 426 drugs. In view of this issue, a small number of respondents (< 1%) are informed
 427 enough to further specify that such storage places should be dry, cool and dark or a
 428 medicine box. Contrary to the responses of the 16.4% of respondents, medicines

429 should be stored in refrigerators only if the labels say so. As a result, it appears that
430 while about 60% of the respondents are storing surplus drugs correctly, others may
431 not.

432

433 Table 5

434 Storage of unused medicine at Hong Kong homes (N=1862).

	<u>Percentage of response^a</u>
Cupboard or drawers	59.5
Refrigerators	16.4
Anywhere convenient	24
Within reach by young children	16.8
Others	1.9

435 ^a Multiple responses allowed.

436

437 In addition, about 16.8% of the respondents admitted that medicines were stored
438 at home in places that were within reach of young children (Table 5). The HKSAR
439 situation was found similar to that in urban Serbia where 19.6% of the families
440 admitted surplus medicines stored at home were highly accessible to children
441 (Kusturica et al., 2012). Thus, children are potentially exposed to medicines and are at
442 risk of accidental poisoning. It is therefore obvious that improving public education
443 on medicines handling in HKSAR is necessary.

444

445 **3.6. Compliance to medication instruction**

446 While 26.8% of the respondents reported strict compliance to all medication
447 instructions, the majority of respondents (73.2%) admitted that they did not always do
448 so for reasons such as forgetfulness, a medicine was not effective, or have
449 experienced undesirable side effects. But the top reason for noncompliance with
450 medication instructions was that the respondents used the discretion to stop
451 medication when they felt that they had “recovered” though no related medical
452 instructions were given (Table 6). This is concerning as poor medication adherence
453 can lead to many adverse consequences (see “Policy Implications”). The high
454 percentage of respondents admitting poor medication adherence in HKSAR puts the
455 City on par with developing countries for which, according to WHO (2011), only less
456 than half of patients adhered to treatment regimes. Thus, based on observations in the
457 present study, HKSAR is an affluent society with an apparent developing world
458 standard of medication instruction compliance.

459

460 Table 6

461 Reasons for not complying with medication instructions in Hong Kong (N=1356).

	Percentage of response ^a
Forgetfulness	36.7
Medicine not effective	23.8
Know of or experienced undesirable side effects	22.8
Thought to have recovered	50.4
Others	1.1

462 ^a Multiple responses allowed.

463

464 **3.7. Environmental awareness of respondents**

465 The survey requested respondents to indicate their levels of agreement with two
 466 statements, one on pharmaceutical waste handling (Statement 1 in Table 7) and one on
 467 general waste handling (Statement 2). It was found that 62.3% of respondents strongly
 468 disagreed or disagreed that disposing unwanted medicines in waste bins, through
 469 drains or in toilets would not significantly harm the environment (Table 7). While this
 470 compares favorably with Serbian (Kusturica, 2012) and even Sweden situations
 471 (Persson et al., 2009), this HKSAR finding also indicates that almost 40% of the
 472 people are ignorant of the environmental risks of uncontrolled discharge of active
 473 pharmaceutical ingredients. Clearly environmental education programs are needed in
 474 Hong Kong to raise awareness of water quality issues, including the urban water
 475 cycle.

476

477 Table 7

478 Percentage of people in Hong Kong who disagree or strongly disagree with two
 479 statements related to pharmaceutical waste disposal.

	Percentage of respondents	
	Statement 1	Statement 2
Hong Kong	62.3	17.4
Sweden	42	
Serbia	50	n.a.

480 Statement 1: Disposing unwanted medicines in waste bins, through drains or in toilets
 481 would not significantly harm the environment

482 Statement 2: I will reuse or recycle waste as far as possible.

483

484 Regarding Statement 2, 82.6% of the respondents perceive themselves to be
 485 reusing or recycling other non-medicine materials as much as possible. This
 486 represents major progress when compared with the situation 26 years ago (in 1991)

487 when only 21% of the respondents sometimes recycled and 10% always did so (Hong
488 Kong Environment Centre, 1991). With years of extensive public education on waste
489 recycling and the increasing availability of recycling receptacles in HKSAR,
490 eventually changes in behavior have appeared. This observation is telling because
491 similar to the case of general waste recycling, with assiduous environment and health
492 education, eventually the public will also be able to properly handle pharmaceutical
493 products or waste.

494

495 ***3.8. Take back schemes***

496 At the top of the WMH, avoidance is still the best solution to reduce pharmaceutical
497 waste generation. However, it is doubtful whether in the case of PW, other waste
498 management options below “avoidance” in the traditional hierarchy should be in the
499 usual sequence of environmental desirability. For instance, reuse of drugs prescribed
500 to patient A by patient B represents self-diagnosis and medication behavior that is
501 understandably advised against by healthcare professionals. As a result, an
502 environmentally preferred way to manage PW is to centralize and properly treat all
503 unwanted drugs that would otherwise be disposed along with normal waste.
504 Pharmaceutical take-back schemes, periodic or permanent, serve to allow people to
505 bring unconsumed or unused medicines to an organized collection site such as a local
506 supermarket or a clinic for proper management and disposal (Bain, 2010). It is
507 considered an effective method to limit the dispersal of active pharmaceutical
508 ingredients to the environment and to safe guard public health. Unwanted drugs take
509 back programs are being implemented in the State of Washington in the US, Taipei
510 city, Sweden, Germany, Portugal, Hungary, Canada, New Zealand and other regions.
511 Some mainland Chinese cities (e.g., Shanghai) have also mandated expired drug take
512 back obligations on retail pharmacies. In Shanghai, this obligation is stated in the
513 operations standards for the trade; all retail pharmacies are required to provide
514 unwanted medicine collection boxes in prominent places at all times (Shanghai
515 Municipal Food and Drug Administration, 2007 & 2015). However, there is no such
516 requirement in HKSAR. Because of the lack of instituted procedures to channel
517 household PW for proper disposal, reluctantly even EPD officers have to advise
518 citizens to dispose PW with household waste (Li, 2014). But if an unwanted drugs
519 take-back scheme is established in HKSAR, will it be effective?

520 Results showed that there was only a mild degree of support from the HKSAR
521 general public for a waste medicines take back scheme. Only less than 40% were
522 wholehearted supporters, compared to 89.4% in Cook County (Wieczorkiewicz et al.,
523 2013). Another 8.1% in HKSAR professed that they would return some but not all
524 medicines through this scheme (partial supporters). At the same time, 23.3% of the

525 respondents would not participate in such a take-back scheme and another 28.8%
 526 would consider but were undecided at the time of survey (Table 8). As a result, it
 527 appears that a clear majority did not support an unused drugs take-back scheme in
 528 HKSAR, perhaps due to a lack of awareness of pharmaceutical contamination of the
 529 environment as a challenge of importance to Hong Kong and other urban areas (see
 530 s.3.9).

531

532 Table 8

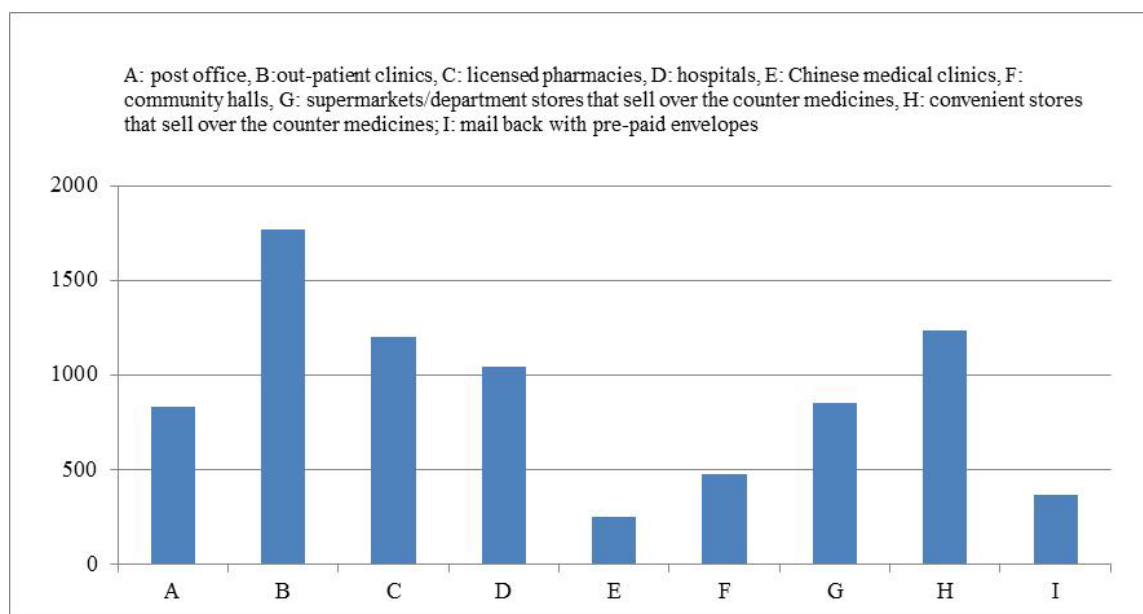
533 Percentage of people willing to participate in an unused drug take-back program in
 534 Hong Kong.

	Will join in principle (whole-hearted supporters)	Not Willing (non-supporters)	Will only return some medicines (partial supporters)	Will consider, but undecided yet (undeciders)
Hong Kong	39.8	23.3	8.1	28.8
Cook County, USA	89.4		n.a.	

535

536 The (wholehearted and partial) supporters of such a take back scheme were
 537 asked to indicate their top three preferred take back locations/approaches out of the
 538 nine options set out in the questionnaire. Respondents were also given the option to
 539 provide their own suggestions beyond the nine stated (A – I in Figure 3). As in the
 540 case of Chung and Poon (2001), we use real numbers to represent the ranks indicated
 541 by the respondents. By assigning three points to each most preferred vote, two points
 542 to the second best and one point to each third choice, each suggested
 543 location/approach was given a score. Figure 3 shows the scores of all the suggested
 544 locations. The top three most preferred take back locations are in the order of
 545 popularity: western outpatient clinics, convenient stores that sell over the counter
 546 medicines, and licensed pharmacies. One reason why hospitals were not included in
 547 the top three choices was likely due to the fewer number of hospitals in the City when
 548 compared to western outpatient clinics and licensed pharmacies. The fact that
 549 respondents preferred to return unused drugs at certain convenience stores indicated
 550 that just like other waste take-back schemes (Dahlén and Lagerkvist, 2010),
 551 convenience is an important consideration for return of unused medicines. However,
 552 if unused drug return boxes are set up in convenience stores, statutory exemptions to
 553 allow these stores to keep prescribed drugs will need to be granted and appropriate
 554 waste transport and disposal of such collected products will need to be implemented.

555 This would involve amendment of current laws.



556

557 Fig. 3. Surplus drug take-back scheme location preferences in Hong Kong.

558

559 The non-supporters or partial supporters of the take back scheme said that the
560 main reasons for their decision were: 1. cannot be bothered about returning the
561 medicines (18.3%); 2. want to retain the medicines to guard against scarcity (15.0%);
562 3. more convenient to dispose at home (9.3%); and 4. it is their right to use leftover
563 medicines (4.9%).

564 As a result, indifference and inconvenience appear to be the primary reasons
565 inhibiting people to join a drugs take back scheme. About 0.3% of the respondents
566 commented that they were physically disabled and therefore not in a position to return
567 unused medicines. While only a very small percentage of respondents said so, these
568 responses highlight the fact that people who are likely to possess a substantial
569 quantity of surplus medicines are usually those who have chronic or significant health
570 problems. As a result, to maximize participation and effectiveness, any drugs take
571 back scheme should be easy for them to use as well. If collection points can be set up
572 at clinics that they normally visit, unwanted medicines could be returned without
573 incurring extra travel.

574 Another insight from the respondents was that without prompting (i.e., it is not
575 one of the standard options in the questionnaire), about 1.3% of the respondents
576 mentioned their concern over the security and handling of drugs surrendered to the
577 drug take-back program as a reason for not returning surplus drugs. Thus, similar to
578 other take-back or waste recycling programs, public confidence remains important
579 (Bragg, 2012) and program organizers must put in place measures and control
580 mechanisms to ensure that there is no leakage of returned drugs to any undesirable

581 channels.

582 In general, delivering reminders (e.g., “please support drug return”) when
583 acquiring medicines can be an effective means to boost participation with 55.1 –
584 60.6% of respondents indicating support. Since this was 7-12% higher than the
585 aggregate of wholehearted and partial supporters (39.8%+8.1%), it may be inferred
586 that if a drug take-back program is launched in Hong Kong, it is possible that some of
587 the undecided respondents and even non-supporters may also drop off their unwanted
588 medicines.

589

590 *3.9. Association with other behavioral and personal variables*

591 Who are the supporters and who are not? It was found that the willingness to take part
592 in a drug take-back scheme was associated with the respondents’ age, education,
593 accommodation and living district. Detail are shown in Table 9.

594

595 Table 9

596 Social and demographic characteristics of future unused medicine take-back scheme
597 supporters in Hong Kong.

Personal particular	Findings	Test statistics
Age	The mean age of non-supporters was about 3 to 4 years older than those who were undecided, willing to join or willing to join with conditions.	Welch=4.392, df=3, 513.411, $\rho=0.005$
Education	Greater proportion of respondents with tertiary education or above were willing to join the scheme.	$\chi^2= 59.303$, df=15, two-tailed $\rho=0.000$
Accommodation	Slightly greater proportion of public rental housing residents were not willing to join such a scheme.	$\chi^2= 18.457$, df=9, two-tailed $\rho=0.030$
Living district	Residents in the New Territories were more likely to be half-hearted participants; residents in Kowloon were least likely to be so.	$\chi^2=18.176$, df=6, two-tailed $\rho=0.006$
	Residents of the Tuen Mun district had the lowest support for such a scheme	$\chi^2= 137.966$, df=51, two-tailed $\rho=0.000$

598

599 A series of chi-square test results also showed that higher proportions of
600 wholehearted supporters of the drugs take back scheme agreed that disposing

601 unwanted medicines through toilets or drains would harm the environment
602 ($\chi^2=93.272$, $df=6$, two-tailed $p=0.000$), had greater self-perceived discipline in
603 handling prescription ($\chi^2= 152.278$, $df=6$, two-tailed $p=0.000$) and non-prescription
604 ($\chi^2= 85.342$, $df=6$, two-tailed $p=0.000$) drugs waste when prompted with a reminder
605 on the packaging of medicines, and had better self-perceived compliance to a drug
606 return scheme for both prescription ($\chi^2= 215.224$, $df=6$, two-tailed $p=0.000$) and non-
607 prescription ($\chi^2= 211.542$, $df=6$, two-tailed $p=0.000$) medicines.

608 On the other hand, those who rejected a drugs take-back scheme tended to be
609 neutral or overlooked the environmental impact of disposing unwanted medicines
610 through toilets or drains ($\chi^2=93.272$, $df=6$, two-tailed $p=0.000$), to assess themselves
611 having poorer compliance to a drug return scheme for both prescription ($\chi^2= 215.224$,
612 $df=6$, two-tailed $p=0.000$) and non-prescription ($\chi^2= 211.542$, $df=6$, two-tailed
613 $p=0.000$) drugs, had lower self-perceived discipline in handling prescription ($\chi^2=$
614 152.278 , $df=6$, two-tailed $p=0.000$) and non-prescription ($\chi^2= 85.342$, $df=6$, two-tailed
615 $p=0.000$) drugs waste even when prompted with a reminder on the packaging of
616 medicines and less of a diligent waste recycler ($\chi^2= 54.773$, $df=3$, two-tailed
617 $p=0.000$). These associations suggested high consistencies in the respondents'
618 reported behavior and their stance on a future potential drug take back scheme.
619 While this study was not designed to assess the effects of different information
620 sources on the degree of support of a drugs take-back scheme, Lim-Wavde et al.
621 (2017) remarked that information delivered through a more direct channel (e.g.,
622 delivered directly to the person) could more effectively influence people's behavior in
623 household hazardous waste consumption than dissemination through public or
624 indirect channels (e.g., newspaper). Thus, in the future, should a drugs take-back
625 scheme is put in place in Hong Kong or other regions, attaching an extra reminder
626 with the medicines acquired should be done in addition to extensive media publicity.
627

628 **4. Policy Implications and Limitations**

629 Teni et al. (2017) concluded that 82%-100% of households in Indonesia, Iran, Iraq,
630 Oman, Greece and USA have kept medicines at home. Kusturica et al. (2015) found
631 that among all drugs stored at Serbian homes, 82.2% were not being used at the time
632 of survey. Together with the data from the present study (section 3.2), keeping unused
633 medicines in the domestic setting is common in many countries and marked amounts
634 of unused drugs (main groups being cold/flu and pain medicines) can be found in the
635 residential setting worldwide. If drugs (including unwanted medicines) are improperly
636 ingested, handled or disposed, serious health and environmental consequences might
637 result. In order to efficiently use pharmaceutical resources, reduce improper self-
638 diagnosis and medication and other potentially serious environmental quality and

639 public health incidents, two policy measures are warranted. We thus focus our
640 subsequent discussion on how these two interrelated policy measures could develop in
641 HKSAR based on results from the current study.

642

643 *4.1. Drug return schemes*

644 A precondition for a successful drugs return scheme is to make available proper
645 treatment facilities for PW. With a designed capacity of 100,000 tons per year, the
646 CWTF in HKSAR is currently operating at only about 10% of its designed capacity
647 (EPD, 2016). As a result, even if all 1,000 tons of stored PW in the domestic sector
648 were collected in one event, this mass is well within the designed capacity of CWTF
649 to properly treat these wastes within a short period of time. A bigger hurdle for a
650 prospective drug return scheme, however, is the moderate level of support for such a
651 scheme in HKSAR. The lukewarm support can be explained by the lack of familiarity
652 of the general public with such a scheme (e.g., nearly 30% of the respondents were
653 undecided) and at the same time, a substantial proportion of the respondents (almost
654 40%) failed to see a direct link between their own personal action and the adverse
655 environment and public health effects of these contaminants of emerging concern.
656 Thus, to prepare for adoption of a successful drug return scheme in the future, it will
657 be important to educate the public on adverse environment and public health risks
658 from improper disposal of PW.

659 Despite the generally moderate level of support for the drugs return scheme, our
660 findings show that non-supporters tend to live in public rental housing, in the New
661 Territories and are older in age. Whole-hearted supporters tended to be better
662 educated. Thus, an improvement in the general education standard and income of the
663 society in the near future may lead to greater acceptance of such a scheme. Such
664 findings also pinpoint where and which social sector(s) should receive more health
665 education attention when a drug return scheme is designed and introduced in the
666 future.

667 While soliciting support for a future drugs take back scheme by reminders is
668 likely to boost participation, our data showed that such reminders might have better
669 effects on the wholehearted supporters of the scheme. In this regard, our data
670 indicated that the context in which such reminders were given did not matter -
671 compliance appeared equally positive whether the reminder was given during a
672 private purchase of medicines at the pharmacies or taking prescriptions directly from
673 a clinic. However, regarding the drop-off location for unused medicines, findings
674 suggested that outpatient clinics were preferred because this group of premises
675 fulfilled several important criteria related to compatibility with current law,
676 credibility, and convenience to most participants, including those who are

677 incapacitated by health conditions.

678

679 ***4.2. Public education on the proper handling of pharmaceutical resources/waste***

680 In view of the findings on the association between wealth or accommodation types
681 with the amount of unused medicines at home, we further recommend that for greater
682 effectiveness, public should be educated on safe and appropriate use and handling of
683 pharmaceuticals more frequently in areas with private housing clusters and targeted
684 towards the middle to upper class communities that do not own cars, even though
685 these communities and housing settings generally have lower population densities
686 than those inhabited by the lower income groups.

687 The “saving up for future use” being the second most important reason for
688 holding on to old medicines is suggestive of some level of drug hoarding behavior in
689 HKSAR. Drug hoarding is discouraged because it will increase the chance of expired
690 medicines ingestion and substance abuse. In this study, we were not able to determine
691 the major type of drugs “hoarded” at homes in HKSAR. We also failed to detect any
692 associations between this drug hoarding tendency and socio-demographic
693 characteristics. As a result, future public education against drug hoarding should
694 equally be delivered to all HKSAR residents regardless of their age, housing types,
695 education and income levels.

696 Another aspect that should be included in a future pharmaceutical products
697 public education program is related to medication adherence. In this study, we found
698 that over half of the respondents thought that they knew when to stop medication even
699 without such instructions having been given by a health care professional. Feeling
700 better or recovered (as perceived by patients) and therefore stopping medication
701 appears to be a common practice not just in HKSAR but also globally (Engelkes et
702 al., 2015; Ho et al., 2006). For example, this was the major reason for not finishing
703 the full prescription for citizens in Cook County (Wieczorkiewicz et al., 2013). Other
704 reasons for medication non-compliance include unaffordable cost, forgetfulness and
705 undesirable side-effects. Regardless of the reason, pre-mature cessation of medication
706 is a behavior of concern from the professional perspective even in the case of
707 “instructed” medication cessation because patients and healthcare professionals are
708 likely to have different understandings on “recovery”. Uninstructed medication
709 cessation is a form of medication nonadherence and is associated with many possible
710 adverse health effects for the patients. It also leads to wastage of medical resources or
711 increase the likelihood of over-medication in subsequent treatments (Engelkes et al.,
712 2015; Ho et al., 2006). In the case that the medicine concerned is an antibiotic,
713 underdosage, a form of improper use, may additionally promote antibiotic resistance
714 (Hong Kong Government, 2017). As a result, there is a genuine need to educate the

715 HKSAR general public on the importance of medication adherence.

716 A preferred way to discard (most types of) unwanted drugs is to dispose of them
717 with normal solid waste but with extra steps to prevent unwanted diversion of the
718 discarded drugs (i.e., put and mix unwanted drugs with an undesirable substance such
719 as kitty litter in an impermeable bag) before disposal (Office of National Drug
720 Control Policy, 2007). Based on present data, while the majority of households are
721 disposing unwanted drugs through the proper channel (i.e. with normal solid waste),
722 the packaging and mixing precautions recommended are likely not followed. Further,
723 almost one-third of the respondents are continuing to consume left over drugs. While
724 this appears to be a resource saving behavior, without the supervision of health care
725 professionals such behavior will also raise the likelihood of expired drug ingestion
726 and risks of unintentional poisoning and thus should be discouraged. In short, safe
727 medicine disposal education in HKSAR is inadequate. Our findings can inform
728 relevant policy makers in HKSAR (e.g. the Department of Health and the EPD) where
729 the weaknesses in our current public education on the proper handling of unused
730 pharmaceuticals lie, in the hope to induce a safe and rational medicines disposal
731 culture in HKSAR. The effects of such public education and the drug return system
732 however may take time to establish based on lessons learned in Sweden (Persson et
733 al., 2009). Based on the literature reviewed, it appears that many of the undesirable
734 practices in household pharmaceutical handling prevail worldwide and the lessons
735 learned from this study are useful references for many other cities.

736

737 **4.3. Limitations**

738 This study has a number of limitations. First, all the data collected were self-reported
739 and although dummy medicine packs were used to help the respondents to more
740 accurately gauge the quantities of surplus medicine stored up at home, it was still
741 possible that the data collected do not fully reflect the true amounts of stored
742 medications. Second, the questionnaire is relatively long. Therefore, respondents may
743 have got impatient toward the end and provided imprecise answers to latter questions.
744 Such a concern, however, was overcome to some degree by the consistency checks
745 described in section 2.1. Third, the response rate is very low and response bias may
746 therefore be substantial. We also oversampled the younger, better educated and
747 middle to upper middle classes and under-sampled citizens with debilitating health
748 problems. The middle class respondents in this survey are more likely to have greater
749 quantities of unused medicines at home and so are the citizens with debilitating health
750 problems. However, the younger age group tended to use less medicine than the older
751 groups and our survey also excluded some medicines dosage forms (e.g., inhalers
752 possessed by the respondents). Therefore, it is likely that the effects of these

753 estimation errors on the total quantity of surplus medicine estimated will offset each
754 other and render the estimate on left over medicines in HKSAR homes of 1017 tons a
755 reasonable approximation, particularly in the absence of other information. Finally,
756 since our survey has covered HKSAR citizens only, inferences drawn from this
757 survey may not be directly generalized to other cities in PRC. However, HKSAR and
758 other cities in PRC have many relevant commonalities such as low awareness of this
759 emerging issue among local governments and common citizens, landfills serving as
760 the major form of domestic waste disposal method, lack of unused medicine take-
761 back schemes and increasing public expenses in health and medical expenses. Thus,
762 we anticipate lessons learned in this study will be useful to other cities in PRC, in
763 other parts of Asia and on other continents.

764

765 **5. Conclusion**

766 Unwanted pharmaceuticals are often kept at homes for a long period of time before
767 being disposed of improperly in HKSAR. In this study, 75% of the population has
768 unwanted drugs at home and on average, each has storing up 182.4 gm of medicines
769 with the major drug type being drugs for cold. Despite possible estimation errors, this
770 novel study provides crucial progress on this much neglected area of environmental
771 management.

772 The prevailing existence of unwanted medicines in HKSAR households poses
773 risks to the health of the households (especially children) and the environment.
774 Undesirable phenomena, such as hoarding unused medicines beyond the originally
775 prescribed time period and self-diagnosis and medication are common practices.
776 Children having access to surplus medicines at home is still greater than desirable and
777 most surplus medicines are improperly handled before disposal. The general public's
778 support on a drugs return scheme is lukewarm and their knowledge and awareness on
779 proper drug handling has room for improvement. This may be due to lack of public
780 education in this aspect. Persistent and extensive public education on unused
781 medicines handling is important and improvement with time is possible due to
782 familiarization and growing concerns on the environment.

783 Some of the drugs using and handling practices and preferences of HKSAR
784 people and the lack of systematic pharmaceutical waste management in HKSAR
785 make it more closely resemble a developing world city. Thus, even though most of the
786 study findings here are specific to HKSAR, they should also be of reference value to
787 many other Asian cities where pharmaceutical waste management is at its infancy.
788 With a per capita rate of 138.4 gm of drugs kept at home, and a total population of 4.4
789 billion in 2016 for all Asian countries (United Nations Department of Economic and
790 Social Affairs, 2017), the scale of the problem in Asia is notable – up to 0.6 million

791 tons of unused pharmaceutical products are kept in the domestic sector alone. Without
792 proper collection and treatment, active pharmaceutical ingredients associated with
793 these 0.6 million tons of drugs will eventually disperse to different environmental
794 media, particularly in regions with less developed sewage treatment infrastructure
795 (Kristofco and Brooks, 2017), and result in pollution of surface and possibly drinking
796 waters. It is thus hoped that this study can induce awareness and support efforts by
797 waste and public health policy makers to tackle this growing problem in urban areas.

798

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804

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