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Mixed-methods approach to determine adherence, knowledge and behavioral determinants associated with medication wastage.

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1 **Mixed-methods approach to determine adherence, knowledge and behavioral determinants**
2 **associated with medication wastage**

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9

10 **Abstract**

11 **Background:** While literature quantifying medication wastage and assessing public's knowledge
12 and practices about medication disposal is substantial, less attention is given to the public's
13 knowledge and behavior pertaining to medication wastage prevention. This study aimed to
14 determine the public's knowledge of medication wastage, any association between knowledge
15 and adherence, and behavioral determinants potentially leading to wastage.

16 **Methods:** A mixed-method explanatory sequential approach was adopted with a quantitative
17 survey followed by qualitative semi-structured interviews. Maltese residents ≥ 18 years attending
18 social/ educational events were recruited in this mixed-methods study. Participants completed a
19 structured questionnaire comprising: 1) demographics; 2) medication adherence using 'Tool for
20 Adherence Behaviour Screening' dichotomized into 'good adherence'/'suboptimal adherence';
21 3) eight knowledge statements each carrying one point (total, 0=lowest; 8=highest); 4) and
22 whether they had unused medication at home. Chi-square analysis determined associations
23 between demographics and adherence, and having unused medication. Multiple regression was
24 performed to predict knowledge based on demographics, adherence, having regular medication
25 and having unused medication, $p \leq 0.05$. Questionnaire respondents expressing interest in
26 participating in semi-structured face-to-face interviews, based on the Theoretical Domains
27 Framework (TDF), were recruited consecutively until data saturation. Interviews were audio-
28 recorded, transcribed and analyzed using the Framework Approach.

29 **Results:** Of the 524 individuals attending 14 events, 80.5% completed the questionnaire (mean
30 age \pm standard deviation (SD): 65 \pm 13 years). Thirty-one percent (n=130/422) of respondents
31 reported having unused medication and 18.8% (58/309 taking chronic medication) classified as

32 'optimal' adherence. Mean±SD knowledge score was 4.7±1.5. Knowledge and adherence were
33 not significantly related. Most prevalent TDF domains influencing wastage emerging from 15
34 interviews were knowledge, beliefs about consequences and behavioral regulation.

35 **Conclusion:** Public's knowledge about medication wastage and adherence were inadequate,
36 necessitating implementation of tailored educational interventions based on behavioral
37 determinants recognized within this study. Identified inadequate behavior around disposal
38 mandates inclusion of environmental/ social planning issues when developing policies.

39

40

41 **Key words:** adherence; behavioral determinants; community; knowledge; theoretical domains
42 framework; medication wastage.

43

44 **Mixed-methods approach to determine adherence, knowledge and behavioral determinants**
45 **associated with medication wastage**

46 **Introduction**

47 Wastage reduction, including that of medication, is a priority which has been recognized by the
48 Commission of the European Communities.¹ A systematic review of published literature reported
49 discrepancy in the definition of medication wastage across different studies.² Abou-Auda
50 (p.1277)³ provided a general definition of medication wastage and stated that medication
51 wastage refers to *“any drug product, either dispensed by a prescription or purchased over-the-*
52 *counter (OTC) that is never fully consumed.”* A Delphi study carried out in Malta amongst a
53 panel of stakeholders including academics, practitioners, government officials, professional
54 organizations and patients, defined medication wastage as *“any medication which expires or*
55 *remains unused throughout the whole medicines supply chain”*.⁴ The definition further highlights
56 medication non-adherence by patients: *“the unnecessary or inappropriate consumption of*
57 *medications by patients, or the unjustified non-adherence to treatment guidelines by healthcare*
58 *professionals”*.⁴ Thus, the Delphi expert panel considered non-adherence is at par with
59 medication wastage. The definition also stated that *“medication wastage poses a financial*
60 *burden on patients themselves and the state's economy and requires adequate education of all*
61 *people concerned”*.⁴

62

63 Published literature largely focused on quantifying medication wastage using a variety of
64 methodological approaches and outcome measures. The majority of studies were conducted in
65 community pharmacies or participants' households.² Quantities ranged from 65 unused
66 medications collected from 73 households in Papua New Guinea⁵ to over 20,000 medications
67 gathered from 100 pharmacies in Sweden.⁶ A web-based survey conducted in a health institution
68 followed by a paper-based survey to collect data at medication take-back events found that two
69 out of every three prescribed medication were unused. Medication wastage amongst
70 communities is of public health concern due to its financial, environmental as well as societal
71 consequences. Direct cost of unused medication, when using average retail price of brand
72 medications, was estimated to be over 59,000 United States (US) dollars for the proportion of US
73 adults who are on at least one chronic prescription medication daily. If extrapolated to a national
74 level, the direct cost of unused prescribed chronic medication in the US would amount to \$5.8
75 billion in the US.⁷ Direct cost of unused prescribed medication in England was estimated to be
76 300 million English pounds annually.⁸

77
78 Environmental implications of inappropriate medical disposal have been reported;⁹ yet,
79 inappropriate disposal is still common practice amongst several countries. A systematic review
80 about knowledge and behavior in relation to disposal practices of unused medication globally
81 found that the most common disposal method is the garbage, with lack of inadequate information
82 being reported as an important factor leading to inappropriate disposal.¹⁰ A recent study which
83 analyzed contents of household garbage in Vienna confirmed the presence of unused medication
84 which, when extrapolated for Vienna, amounted to approximately 37 million euro of wasted
85 medication.¹¹ Therefore, while the literature presents quantification of medication wastage and
86 its contributory factors, as well as public's knowledge regarding medication disposal, there
87 remains a need for robust and rigorous mixed-methods research to allow quantification of key
88 influences on medication wastage, extent of knowledge about medication wastage rather than
89 just about disposal, followed by in-depth exploration of behavioral determinants leading to
90 medication wastage.

91
92 Research grounded in behaviour change theory is warranted to strengthen the research derived
93 evidence providing a basis for further intervention development.¹² Determinant frameworks are

94 composed of a number of domains which portray determinants that could act as facilitators or
95 barriers to implement behavior change.¹³ The Theoretical Domains Framework (TDF) is a
96 synthesis of 33 behavior change theories described initially as 12 domains,¹⁴ later refined to 14
97 domains.¹⁵ The TDF was chosen as a theoretical framework to guide the development of the
98 interview guide within this study due to its composition of a wide-range of theories and
99 theoretical constructs as well as the simplicity of each domain being specified by component
100 constructs. The 14 domains of the TDF are: knowledge; skills; social/professional role and
101 identity; beliefs about capabilities; optimism; beliefs about consequences; reinforcement;
102 intentions; goals; memory, attention and decision processes; environmental context and
103 resources; social influences; emotion; and behavioral regulation.¹⁵

104
105 The amount of unused medication and its cost, the extent of medication non-adherence by
106 patients, and education (knowledge) were three pillars in the definition of medication wastage by
107 West *et al.*⁴ that were addressed during this study. The overall aim of the study was to determine
108 adherence, knowledge and behavioral determinants associated with medication wastage. The
109 specific objectives of the study were to determine the knowledge of the general public
110 surrounding issues of medication wastage and to determine any association between knowledge
111 and adherence. The authors hypothesized that knowledge scores increase if adherence scores
112 based on validated tools increase, assuming that the higher the knowledge surrounding issues of
113 medication wastage, the higher the medication adherence. The third objective was to explore
114 behavioral determinants potentially leading to medication wastage.

115

116 **Methods**

117 *Setting*

118 The study was conducted in February and March 2018 during the morning hours. To ensure
119 participation of individuals with different educational and social backgrounds from the
120 community, participants were recruited from social and educational centres across Malta and
121 Gozo, the two inhabited islands of the Republic of Malta.

122

123 Localities that hold nation-wide known social group community events during the study data
124 collection time frame were listed. Two localities from each of the six regions of the Maltese

125 Islands that were listed were chosen randomly to act as sampling sites and include individuals
126 from all six geographical regions of Malta. Therefore, twelve public or private-run social group
127 centres holding social community events were selected. Since data collection was conducted in
128 the morning, all social groups that were listed held social community events for individuals ≥ 60
129 years. Considering that ageing increases prevalence of chronic conditions and need for
130 medication, participants were recruited from these centres.

131
132 With regards to educational centres, recruitment was conducted in two major public-run
133 educational centres. The first one offers lifelong educational courses for residents of Malta ≥ 16
134 years. Since, the above-mentioned social groups included participants who were mainly ≥ 60
135 years, another major public-run educational centre offering lectures for people > 60 years was
136 also included to mirror participants within this age bracket. As stated above, ageing increases
137 prevalence of chronic conditions and, therefore, elderly are known to be the major consumers of
138 medication. Therefore, recruiting participants within this age bracket from both social and
139 educational functions was considered by the research team to be necessary.

140
141 *Ethical approval*
142 Following receipt of approval from the individual in charge of each centre, ethical approval was
143 granted by University of Malta Research Ethics Committee (UREC Reference Number:
144 50/2017). Participants gave verbal informed consent to complete the questionnaire and written
145 informed consent to participate in the interview.

146
147 *Study design*
148 A mixed-method explanatory sequential approach was adopted with a quantitative survey
149 followed by qualitative semi-structured interviews to provide greater understanding and depth to
150 questionnaire responses.¹⁶ Individuals residing in Malta ≥ 18 years were included while those
151 unable to communicate in Maltese or English were excluded. Participants were recruited during
152 the social/ educational events described above. Event organizers were given an information letter
153 containing details regarding aim of the study, sampling, confidential nature and funding source.

154
155 *Cross-sectional survey*

156 Questionnaire comprised sections of: 1) demographics, 2) medication adherence, 3) knowledge
157 about medication wastage and disposal, and 4) unused medication.

158
159 The following demographic data were collected: age, gender, nationality and locality, whether
160 they live alone, level of education, occupation, whether the respondent has a condition which
161 requires daily medication and if so which condition. In view of the small size of the Maltese
162 Islands with families and extended families living in close proximity, respondents were also
163 asked whether they have a healthcare professional as a close family member. The following
164 information was also collected: whether the respondent 1) collects his/her own medication or
165 someone else collects them on his/her behalf from the pharmacy, 2) remembers to take his/her
166 medication or is reminded by someone else, and 3) prepares his/her own medication or someone
167 else prepares them for him/her for self-administration.

168
169 Medication adherence was determined using 'Tool for Adherence Behaviour Screening' (TABS)
170 scale. TABS is an eight-item validated scale composed of two four-item sub-scales named
171 'adherence' and 'non-adherence'. Each statement is answered on a five-point Likert-type scale
172 ranging from 'Never' to 'Always', with the final score determined by calculating the difference
173 between the two sub-scales and scores dichotomized into 'good adherence' for differential scores
174 of ≥ 15 or 'suboptimal adherence' for differential scores ≤ 14 .^{17,18} Translation and cultural
175 adaptation of TABS followed the report by International Society for Pharmacoeconomics and
176 Outcomes Research (ISPOR) on principles of good practice. For practicality reasons which were
177 also acknowledged by the ISPOR report, the Maltese translation was not compared to other
178 languages.¹⁹ However, it is important that further studies using TABS start harmonizing
179 translations of the different languages in relation to the original.¹⁹

180
181 Eight knowledge statements about medication wastage and disposal, which are presented in the
182 Results section, were derived from a Delphi study which defined medication wastage and
183 identified factors which give rise to wastage.⁴ The knowledge statements were also based on
184 medication disposal information provided by US Food & Drug Administration²⁰ and by
185 WasteServ Malta,²¹ a company responsible for Malta's waste management. Participants selected

186 either 'Yes' or 'No', with each correct response assigned one point, giving a total knowledge
187 score ranging from 0-8.

188
189 Respondents were also asked if they had any unused medication at home from the previous six
190 months, and if so to list these and the quantity left unused, the reason and who had recommended
191 use.

192
193 An estimated sample size of 385 survey responses would give 95% confidence intervals with a
194 5% margin of error.²² The principal researcher attended the events and invited attendees to
195 complete a paper-based questionnaire during the first 30 minutes of the event and return to the
196 event organizer on completion.

197
198 The questionnaire was designed by a professional graphic design house to ensure readability and
199 respondents' understanding. The questionnaire was presented to respondents in both Maltese and
200 English, and they could complete it in their preferred language. Prior to data collection, the
201 questionnaire was assessed for face validity, to ensure that visually the questionnaire measures
202 what it intended to measure, and for content validity to ensure that the items in the questionnaire
203 covered the aspects being assessed.²³ Validity was assessed by two academics, two pharmacists
204 and two lay persons. An internal pilot study amongst the first 100 event attendees was carried
205 out. Since there were no changes in the questionnaire content following the pilot study, results of
206 this were included in the main study.

207
208 *Qualitative interviews*

209 Semi-structured, face-to-face ten-minute interviews, informed by the TDF, were conducted.
210 Soon after questionnaire completion, the principal researcher invited respondents to participate in
211 the interview. If more than four individuals from each centre expressed interest to participate, the
212 first four consecutive participants were interviewed separately in a private room. The interviews,
213 which could be conducted in either Maltese or English, were audiorecorded and transcribed
214 verbatim, with Maltese statements translated into English.

215

216 Sample size for the interviews was based on the proposition by Francis *et al.*²⁴ for theory-based
217 interview studies. All questionnaire respondents showing interest to participate in the interview
218 were recruited consecutively until at least 13 participants (maximum of 4 participants per centre)
219 were interviewed and data saturation achieved. The interview guide was reviewed for credibility
220 by two academics and two pharmacists. It was also piloted on the first respondent that expressed
221 interest who also gave feedback on clarity of questions and was excluded from the analysis.

222

223 *Data analysis, cross-sectional survey*

224 Data were inputted into IBM® SPSS® Version 24 (IBM Corp. Released 2016. IBM SPSS
225 Statistics for Windows, Version 24.0. Armonk, NY: IBM Corp). Chi-square was used to
226 determine: associations between respondents' demographics with adherence and with possessing
227 unused medication; and association between adherence and possessing unused medication.
228 Multiple regression analysis was performed to predict knowledge based on demographics, and to
229 predict knowledge in relation to adherence, being on regular medication and having unused
230 medication.²⁵ One-way analysis of variance (ANOVA) was used to assess differences in the
231 mean knowledge score between the different regions of Malta. Level of significance was taken at
232 $p \leq 0.05$. Cost of unused medication was calculated based on: brand of medication or price of
233 generic; community pharmacy retail value at the time of data collection; and quantity listed by
234 respondents.

235

236 *Data analysis for interviews*

237 Thematic analysis, employing the framework method,²⁶ was carried out and findings described
238 narratively.

239

240 **Results**

241 *Survey study*

242 *Response rate*

243 Of the 524 individuals attending 14 events, 80.5% (422) completed the questionnaire (74.5%,
244 n=178/239 attendees from 12 social groups; 85.6%, n=244/285 attendees from two educational
245 centres).

246

247 *Demographics*

248 Table 1 describes participants' demographics. The majority were female (87.7%, n=370). Mean
249 age \pm standard deviation (SD) was 65 \pm 13 years. Seventy-three percent (n=306) suffered from \geq
250 one chronic condition and 73.2% (n=309) were on chronic medication.

251

252 *Insert Table 1 here*

253

254 *Adherence*

255 Optimal adherence was reported by 18.8% (58/309) of respondents on chronic medication. The
256 mean \pm SD adherence score was 9.1 \pm 5.3 (possible scores -16 to 16).

257

258 Table 2 provides associations between demographic variables and adherence by using Chi square
259 for the combined total of both social and educational group. Adherence was categorized into
260 'good adherence' and 'suboptimal adherence' as described in the Methods section and this
261 dichotomization was applied when carrying out Chi square calculations. Whilst there was a
262 significant difference in adherence between Maltese nationals and others ($\chi^2=5.644$, $p=0.012$,
263 $df=1$), this result was excluded as the expected frequencies were less than 5.

264

265 *Insert Table 2 here*

266

267 *Having unused medication in household during previous 6 months*

268 Under a third of respondents (30.8%, n=130/422) reported having unused medication, 8.5%
269 (n=36/422) were unsure and 13.3% (n=56/422) did not respond. Table 3 provides associations
270 between demographic variables and having unused medications by applying Chi square for the
271 combined total of both social and educational group. There was a significant association between
272 adherence and having unused medication ($\chi^2=5.344$, $p=0.025$, $df=1$). Respondents who had
273 unused medication were more likely to self-report being non-adherent.

274

275 *Insert Table 3 here*

276

277 *Knowledge about medication wastage*

278 The mean \pm SD knowledge score was 4.7 ± 1.5 (possible scores 0 -8).

279

280 Table 4 gives the results of the knowledge statements. When asked whether ‘taking the
281 medication twice a day when you are supposed to take it three times a day is considered as
282 wastage’, less than half of respondents (41.0%, n=173) were aware that non-adherence is
283 considered as wastage. Keeping some emergency medication (such as a salbutamol inhaler) is
284 imperative, even if it expires, to ensure availability if an urgent need arises. However, the
285 majority of respondents (67.3%, n=284) considered this as wastage. On the other hand, the
286 majority of respondents (86.0%, n=363) were correct in their response that antibiotics should not
287 be stopped once the patient feels better even if the full amount that was prescribed has not been
288 administered. Stopping a course of antibiotics leads to leftover medication, which is also
289 considered as wastage.

290

291 Statements within the questionnaire that were related to medication disposal indicated inadequate
292 knowledge about appropriate disposal methods. Less than a third (31.0%, n=131) of respondents
293 knew whether medication should be crushed or not prior to disposal. Only slightly more than half
294 of respondents (54.7%, n=231) knew that medication that remains unused should not be thrown
295 away down the toilet.

296

297 *Insert Table 4 here*

298

299 Table S1 in the supplementary file demonstrates the mean knowledge scores amongst
300 respondents from different Maltese regions.

301

302 Multiple regression was performed to predict knowledge from demographics (gender,
303 educational/ social group, age, level of education, employment, close family member being a
304 healthcare professional, living alone, nationality). Some variables statistically significantly
305 predicted knowledge, $F(8, 368) = 4.203$, $p < .005$, $R^2 = .084$. The variables which statistically
306 significantly predicted knowledge were age ($p = .048$) and employment ($p = .025$). ANOVA
307 testing identified significantly higher mean knowledge scores amongst respondents from the < 65 years
308 group compared to the ≥ 65 years group ($p < .005$). ANOVA testing identified significantly higher

309 mean knowledge scores amongst respondents in the employment group compared to the ‘unemployed’
310 group that included respondents not in employment, pensioners and students ($p < .005$).

311

312 A further multiple regression was performed to predict knowledge from ‘being on regular
313 medication’, ‘adherence’ and ‘having unused medication’. Some variables statistically
314 significantly predicted knowledge, $F(3, 260) = 3.499, p < .016, R^2 = .039$. The variable which
315 statistically significantly predicted knowledge was ‘having unused medication’ ($p = .007$).

316 ANOVA testing identified significantly higher mean knowledge scores amongst respondents having
317 unused medication ($p = .005$).

318

319

320 *Cost of unused medication*

321 Overall, the amount of unused medication as reported by respondents, was estimated to be
322 507.52 euro based on medication retail value. Table S2 in the supplementary file describes the
323 type and amount of unused medication, who originally recommended the medication, the reason
324 for leftover medication and respective cost.

325

326 *Interview study*

327 *Response rate*

328 All 15 questionnaire respondents who expressed interest were interviewed. Table S3 in the
329 supplementary file describes participants’ demographics. The majority were females and
330 pensioners ($n=13/15$). All, except one, had \geq one chronic condition.

331

332 *Behavioral determinants based on the TDF leading to medication wastage*

333 Table S4 in the supplementary file describes the 14 TDF domains, with emergent key themes and
334 illustrative quotes.

335

336 Participants frequently discussed the medication that they take and how they take it and store it
337 (TDF domain: Knowledge). Some participants described the skill they require to use some of
338 their medication (TDF domain: Skills). Some participants reported being regularly confused
339 when taking their medication, especially if they are dispensed with different generics of the same

340 medication (TDF domain: Beliefs about capabilities). Embarrassment to inject the medication at
341 appropriate time schedules was brought up by one of the participants, who stated that, if she is
342 out of the house, she would skip her insulin dose as she is embarrassed to take it in public (TDF
343 domain: Beliefs about capabilities). Other participants reported intentionally missing doses of
344 their medication for various reasons, such as side-effects or feeling better (TDF domain:
345 Intentions). The issue of whether they knew the retail cost of all their medication was raised.
346 None of the participants were aware of the cost of medication that they obtain through the NHS
347 for free (TDF domain: Knowledge). Fear of remaining without medication was indicated as a
348 reason for having extra medication at home (TDF domain: Emotion). Participants mentioned a
349 number of practices they carry out which gives rise to or prevents medication wastage. Some of
350 these practices are discussed further below under the behavioral regulation TDF domain.

351
352 Participants felt that there is a scope not to waste medication, especially if it can be used by
353 others (TDF domain: Goals). However, some never thought about the issue of medication
354 wastage (TDF domain: Memory, attention and decision processes). A number of consequences in
355 relation to medication wastage were discussed, such as lack of medication for others who would
356 need it, abuse of unused medication and the effect of medication wastage on environment (TDF
357 domain: Beliefs about consequences). Participants felt that incentives, especially economic
358 incentives, could act as reinforcement to the public to prevent medication wastage and to dispose
359 unused medication adequately (TDF domain: Reinforcement). Knowledge about medication
360 disposal was lacking amongst some participants. Most of those who were aware of the
361 appropriate medication disposal system stated that they still do not use the current system as it is
362 impractical. Participants made a few propositions to enhance the current disposal system, such as
363 the provision of specific bins within households which are then collected on a regular basis.
364 Another proposition was to offer the disposal service through community pharmacies, with such
365 service being mandatory and part of the pharmacy's license to operate (TDF domain:
366 Reinforcement).

367
368 While some participants felt that their pharmacist offered them significant support to prevent
369 wastage, others felt that the pharmacist did not provide any information or explanation about
370 medication wastage (TDF domain: Environmental context and resources). Some participants felt

371 that through effective communication, medication wastage can be prevented (TDF domain:
372 Optimism). Some participants mentioned the information they received about medication storage
373 and disposal, while others said they never received such information (TDF domain: Social
374 influences). The importance of education about prevention of medication wastage through
375 various means, such as provision of seminar and leaflets was raised (TDF domain:
376 Social/professional role and identity).

377

378 *TDF domains with the most emerging themes*

379 Domains with the most emerging themes were knowledge, beliefs about consequences and
380 behavioral regulation and are presented below.

381

382 1. Knowledge

383 Participants discussed how they take their medication. In Malta, patients are supplied medication
384 from their pharmacy, through the National Health System (NHS), without paying for it if they
385 fulfil entitlement criteria; otherwise against payment from their own pockets.²⁷ Participants knew
386 prices of medication that they purchase but had no knowledge of medication price collected
387 through the NHS.

388

389 Medication storage locations varied with one participant stating that she stores medication in the
390 kitchen to remind herself to take them,

391 *“I have a cupboard where I store coffee in the kitchen to make sure I remember.”* Participant 1,
392 76 years old, female

393

394 While only one participant stated that she goes to civic amenity sites to dispose of unused
395 medication, the majority still dispose of them inappropriately.

396

397 2. Beliefs about consequences

398 Participants felt that if people collect medication unnecessarily, this leads to medication
399 shortages. However, some participants added that they had never thought about the issue of
400 medication wastage,

401 *“I do not really stay thinking about it but that is what happens if you collect extra medicines.*
402 *There is not enough for everyone.”* Participant 1, 76 years old, female

403
404 One of the participants strongly emphasised the risk of medication abuse by other family
405 members as an important consequence of hoarding,
406 *“... A lot of suicides due to bullying are carried out by taking medicines. The tablets my daughter*
407 *took, we had tablets at home but they were not the same. We found stored boxes in her drawer...*
408 *we think she took them from her grandmother.”* Participant 13, 60 years old, female

409
410 Environmental consequences of inappropriate medication disposal were also raised,
411 *“I do not like the fact that I throw them down the toilet because I think it will end up in the sea.”*
412 Participant 4, 73 years old, female

413
414 3. Behavioral regulation

415 Some participants emphasized that they collect exact amounts of medication from pharmacies.
416 However, they still had unused medication for various reasons, including dose and medication
417 changes due to adverse effects.

418
419 Some affirmed that prescriptions for medication supplied through the NHS are left at the
420 pharmacy and prepared a few days before they have to collect them. Therefore, one participant
421 stated that the pharmacist prepares beforehand all prescribed medications and dispenses them to
422 her, irrespective of whether the patient still has supply at home,
423 *“The medicines would have already been prepared from beforehand. I end up with a lot...”*
424 Participant 7, 63 years old, female

425
426 There was the belief amongst some participants that if a patient fails to collect the prescribed
427 medication when they already have a sufficient supply, the person will lose the medication
428 entitlement to obtain their medication through the NHS,
429 *“I have extra stock. If you tell the pharmacist ‘No’, you’ve had it, as they will delete them from*
430 *the system for you.”* Participant 9, 59 years old, female

431

432 Lifestyle was a contributing factor leading to non-adherence and subsequent accumulation of
433 unused medication within households,
434 “... Sometimes he (husband) does not take them, those remain extra. He does not take them
435 because he would want to drink alcohol... he does not take the evening ones as he is afraid to
436 take them with alcohol.” Participant 7, 63 years old, female

437

438 Some participants tried to prevent wastage by not collecting unnecessary medication and by
439 raising awareness with relatives. However, one participant felt that for acute medication, smaller
440 packages should be available,

441 “... If boxes were smaller, if you need for one week why do you need to buy 30?” Participant 9,
442 59 years old, female

443

444 **Discussion**

445 The mixed-methods design provided quantitative evidence surrounding the public’s knowledge
446 about medication wastage, and an in-depth understanding of public’s behavior. Thorough
447 understanding of public’s behavior based on a theoretical framework enhances the possibility of
448 developing successful interventions.²⁸ Interviews identified key behavioral determinants based
449 on TDF leading to medication wastage, and substantiates the findings of a previous study in
450 Malta.²⁹ Dominant TDF domains (‘knowledge’, ‘beliefs about consequences’ and ‘behavioral
451 regulation’) are essential to the development of interventions and strategies to minimize
452 medication wastage.

453

454 *Knowledge of medication wastage and disposal*

455 Survey findings indicate that respondents’ knowledge of medication wastage is inadequate.
456 Inadequate knowledge also strongly emerged during interviews, providing depth and explanation
457 of the survey results of poor knowledge. Knowledge scores differed significantly between some
458 demographical groups. While this study aimed to address a lacuna in the literature around
459 exploration of public’s knowledge specifically pertaining to medication wastage rather than
460 solely on disposal, the identified lack of knowledge is in line with published literature reporting
461 inadequate public knowledge of medication disposal¹⁰ and domestic waste management in
462 general.³⁰

463

464 This recognized lack of knowledge reiterates the importance of education as mandated by the
465 European Commission to attain a sustainable future.³¹ Moreover, educating through public health
466 campaigns to improve medication use, reduce wastage and educate about appropriate disposal
467 have been advocated in the literature.³² There is evidence that educational seminars promote
468 knowledge in relation to many public health issues, including wastage. A door-to-door campaign
469 to enhance knowledge about domestic waste disposal in Italy, translated into significantly
470 improved waste management practices.³³ While this indicates the benefits of education to
471 enhance public health knowledge, there is currently no evidence relating to medication wastage
472 prevention.

473

474 The present study found that respondents having a chronic condition and being on regular
475 medication were more likely to self-report being adherent and having less unused medication
476 than those not having a chronic condition. Respondents who were 65 years or older were also
477 more likely to self-report having less unused medication than their younger counterparts. A
478 possible explanation for this is that individuals who have a chronic condition, which is more
479 prevalent in older patients³⁴, would require regular medication and, therefore, may become more
480 familiar with the management of their condition and their medication. Thus, they could
481 consequently adhere to their medication more appropriately with subsequent less wastage.
482 Despite younger respondents reporting more unused medication, this study found significantly
483 higher knowledge about medication wastage within this group. Similarly, respondents in
484 employment reported a higher likelihood of having unused medication despite obtaining higher
485 knowledge score. It is unclear why these two groups had a higher knowledge and yet reported to
486 have more unused medication. Therefore, further studies could address these demographical
487 groups to better understand this phenomenon. A possible explanation could be that individuals
488 possessing unused medication may need to dispose of it, hence, may seek information on
489 disposal, thus, enhancing their knowledge about disposal specifically rather than about
490 prevention of medication wastage in general. It is, therefore, essential to implement educational
491 interventions designed to target specific groups at individual and community level, as well as
492 within specific settings.³⁵ Patients should be involved in every stage of tailored educational

493 interventions, including the design, development and assessment, to enhance the likelihood of
494 success.³⁶

495
496 Knowledge, within this study, was found to differ significantly even between different regions of
497 Malta with higher mean knowledge score amongst respondents from the Gozo region and lowest
498 scores from the Northern region. Conversely, a health literacy study carried out by the Office of
499 the Commissioner for Mental Health in 2014 amongst the Maltese public found the health
500 literacy level amongst participants from Gozo to be more ‘problematic’ than that of other
501 regions.³⁷ However, in line with the health literacy study which showed that the total percentage
502 of respondents who rated ‘sufficient’ or ‘excellent’ health literacy within the Northern Harbour
503 region was higher when compared to the other regions,³⁷ the current study also indicated a higher
504 knowledge about wastage within the Northern Harbour region. Further research needs to explore
505 these similarities and differences, especially in view of the difference in recruitment strategies
506 between the two studies. The small sample size amongst Gozo respondents and largest sample
507 size amongst the Northern Harbour respondents within this study reflect national demographics
508 of population size by district for 2015, the last publicly available regional statistic of Malta.³⁸
509 Difference in knowledge could reflect a difference in health behaviors and, as stated above,
510 imply a need for targeted educational measures for different localities.

511
512 Lack of knowledge relating to safe medication disposal was evident despite availability of six
513 civic amenity sites around Malta for disposing medication.²¹ These results concur with a
514 previous survey in Malta, that only 6.6% of respondents disposed of expired medication at
515 medication disposal bring-in sites, while almost half of the respondents (47%) disposed of
516 expired medication in the trash and another third of respondents (34%) disposed of expired
517 medication through the drain.³⁹ Similar findings of inadequate knowledge about medication
518 disposal were found in a study which was conducted in Indiana (US) in 2014. The study found
519 that less than half of respondents (40%) were given information about unused medication take-
520 back locations within their community.⁴⁰ However, the lack of information was not the only
521 contributing factor leading to inadequate disposal since only 15% of those who were aware of
522 the unused medication take-back locations made use of them.⁴⁰ This is in line with the present
523 study, which found that within the TDF ‘reinforcement’ domain it also transpired that

524 participants did not have any incentive to dispose unused medication safely as they found this
525 system impractical. Inappropriate disposal is of public health concern due to environmental and
526 safety implications.⁹ Therefore, while a legal framework is available in relation to medication
527 disposal, macro-level interventions are also required. Since the current disposal service is
528 underutilized and considered impractical, policies need to be developed in relation to service
529 provision. The public is an important stakeholder in policy development, to ensure successful
530 and sustainable implementation of policies. Whilst service provision is the hallmark for policy
531 development, barriers identified through this study highlight the need to include also
532 environmental and social planning issues when developing policies on disposal.

533

534 *Adherence and wastage and their association with knowledge*

535 While a significant association between knowledge and adherence was not identified, there was a
536 low rate of ‘optimal’ adherence to chronic medication (18.8%). This is in line with a previous
537 study on adherence conducted in Malta.³⁹ Interviewees highlighted non-adherence as a key
538 behavioral determinant contributing to wastage, also noting that intentional non-adherence was
539 attributed to patients’ lifestyles, a similar finding to Bae *et al.*⁴¹ Patients may not always disclose
540 mundane private life particulars and misunderstandings about medication to healthcare
541 professionals out of fear of being judged.⁴² Therefore, while this study highlights the need for
542 educational interventions targeting patients, such interventions should support healthcare
543 professionals to encourage patients to feel comfortable to discuss their lifestyle and related
544 issues.^{43,44} This study also found that knowledge was significantly associated with having unused
545 medication. An important finding within this study is that, while almost a third of respondents
546 reported having unused medication (30.8%), another 22% of respondents were unsure or did not
547 respond. This latter group could also have unused medication which needs to be explored in
548 further research.

549

550 *Beliefs about medication as a key behavioral determinant potentially leading to wastage*

551 Another key behavioral determinant based on the TDF potentially leading to wastage is the
552 public’s beliefs about medication, especially about medication consequences. Beliefs about
553 health⁴⁵ and medication⁴⁶ are significantly related to adherence and can impact medication
554 wastage. Interviewees also raised behaviors in which they engaged leading to medication

555 wastage. Enhancing knowledge and awareness may help to inform both beliefs, as well as
556 behaviour.⁴⁷ This study, therefore, shows that micro-level interventions targeting individuals to
557 enhance patients' knowledge and overcome inadequate patients' beliefs, especially about
558 consequences, are required. This knowledge gap mandates the development of interventions
559 which need to be constructed in the context of demographical differences within a community
560 that were identified during the survey.

561

562 *Study limitations*

563 While the mixed methods approach and the use of a theoretical framework are study strengths,
564 there are a number of limitations. There may have been selection, recruitment and response
565 biases associated with the cross-sectional survey. Notably, the majority of respondents were
566 female and elderly pensioners, highlighting the gender and age bias of those attending these
567 events. Moreover, the study was conducted in the morning, thus, excluding individuals who
568 attend evening social or educational events and limiting generalizability of study findings.
569 Questionnaire data were self-reported, hence, may lack validity; responses to items of knowledge
570 and adherence may have been influenced by social desirability and recall biases. While data
571 saturation was achieved for the qualitative interviews, the number of questionnaire respondents
572 expressing interest was relatively low, hence may be biased towards those most interested. Since
573 pharmacy retail price were included to calculate the costs of wasted medication, the price could
574 be inaccurate for those medications that were obtained through the NHS scheme. Therefore, cost
575 of wastage within this study is an estimate. While chi square analysis was performed and
576 presented for all demographical groups, some groups (e.g. nationality and employment status
577 groups) had a small sample size and, thus, statistical interpretation of these groups needs to be
578 exercised with caution.

579

580 *Future research*

581 Future research should be aimed at addressing biases of the current research. Since in this study,
582 participants were recruited from social and educational groups, future research should be
583 directed towards the working population. Adherence and quantification of medication wastage
584 should be based on objective measures, such as pill counts and electronic monitoring, rather
585 than on self-reporting only. The knowledge section of the questionnaire could be adapted and

586 possibly used by other countries. On completion of data collection, a seminar was delivered 22
587 times to different groups who attended the events to enhance awareness in the community about
588 medication wastage. Attendees who did not participate in the study could also attend the seminar,
589 which was a fifteen-minute talk by the principal researcher on the prevention of medication
590 wastage, as well as appropriate medication storage and disposal. Future research **could** focus on
591 refining the seminar’s content and measuring the impact of the seminar in relation to adequate
592 medication wastage prevention behavior and adequate disposal in community.

593

594 **Conclusions**

595 This study identified a deficiency surrounding public’s knowledge about medication wastage, as
596 well as disposal, and a high level of self-reported medication non-adherence amongst the public.
597 While knowledge and adherence were not significantly related, higher knowledge (especially in
598 respondents who had less than 65 years and in employment) and non-adherence were
599 significantly associated with having unused medication. Therefore, in order to mitigate non-
600 adherence and medication wastage, the implementation of tailored educational interventions is
601 essential. These should be designed to target specific groups at individual and community level,
602 as well as within specific settings. Behavioral determinants recognized within the study also
603 provide a theoretical basis for the design and implementation of policies and individual tailored
604 interventions to address medication wastage. The inadequate knowledge around medication
605 disposal mandates the inclusion of environmental and social planning issues when developing
606 policies on disposal.

607

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613

614 **Conflicts of interest**

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617

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622

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773 Table 1: Respondents characteristics

Characteristic	Social group (n=178) % (n)	Educational group (n=244) % (n)	Total (n=422) % (n)
Gender			
Female	96.1 (171)	81.6 (199)	87.7 (370)
Male	3.9 (7)	18.4 (45)	12.3 (52)
Age (Mean \pm SD years)	72 \pm 9 years	59 \pm 13	65 \pm 13 years
Age category (years)			
18-24	--	0.4 (1)	0.2 (1)
25-34	--	4.9 (12)	2.8 (12)
35-44	0.6 (1)	11.9 (29)	7.1 (30)
45-54	1.7 (3)	11.5 (28)	7.3 (31)
55-64	14.6 (26)	31.6 (77)	24.4 (103)
65-74	42.7 (76)	32.4 (79)	36.7 (155)
75-84	32.6 (58)	6.6 (16)	17.5 (74)
85 and over	7.3 (13)	0.8 (2)	3.6 (15)
Missing data	0.6 (1)	--	0.2 (1)
Nationality			
Maltese	98.3 (175)	85.7 (209)	91.0 (384)
Other	1.7 (3)	14.3 (35)	9.0 (38)
Region			
Southern Harbour	20.8 (37)	8.2 (20)	13.5 (57)
Northern Harbour	11.8 (21)	39.3 (96)	27.2 (117)
South Eastern	15.2 (27)	13.5 (33)	14.2 (60)
Western	15.2 (27)	17.2 (42)	16.4 (69)
Northern	23.6 (42)	16.8 (41)	19.7 (83)
Gozo	12.4 (22)	--	5.2 (22)
Missing data	1.1 (2)	4.9 (12)	
Lives alone			
Yes	42.7 (76)	15.6 (38)	27.0 (114)
No	56.2 (100)	84.4 (206)	72.5 (306)
Missing data	1.1 (2)	--	0.5 (2)

Level of education			
No schooling	3.9 (7)	--	1.7 (7)
Primary	61.8 (110)	8.6 (21)	31.0 (131)
Secondary	21.3 (38)	31.6 (77)	27.3 (115)
Post-secondary	7.9 (14)	25.0 (61)	17.8 (75)
Tertiary	2.8 (5)	24.6 (60)	15.4 (65)
Post-graduate	0.6 (1)	9.0 (22)	5.5 (23)
Missing data	1.7 (3)	1.2 (3)	1.4 (6)
Occupation			
Employed	2.8 (5)	14.3 (35)	9.5 (40)
Unemployed	2.2 (4)	7.0 (17)	5.0 (21)
Self-employed	0.6 (1)	4.1 (10)	2.6 (11)
Pensioner	83.7 (149)	48.4 (118)	63.3 (267)
Student	0.0 (0)	1.6 (4)	0.9 (4)
Other (including housewife)	9.0 (16)	22.1 (54)	16.6 (70)
Missing data	1.7 (3)	2.5 (6)	2.1 (9)
Healthcare professional as a close family member			
Yes	22.5 (40)	34.0 (83)	29.1 (123)
No	68.5 (122)	64.8 (158)	66.4 (280)
Missing data	9.0 (16)	1.2 (3)	4.5 (19)
Suffers from chronic condition for which they required medication everyday			
Yes	88.2 (157)	61.1 (149)	72.5 (306)
No	10.7 (19)	36.1 (88)	25.4 (107)
Missing data	1.1 (2)	2.9 (7)	2.1 (9)

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781 Table 2: Associations between demographics and adherence determined by using Chi-square

Characteristic	Association
Gender: Male (n=46) Female (n=295)	$\chi^2=2.753, p=0.140, df=1$
Group: Social (n=142) Educational (n=199)	$\chi^2=3.488, p=0.081, df=1$
Age dichotomized at 65 years: < 65 years (n=134) ≥ 65 years (n=207)	$\chi^2=0.121, p=0.771, df=1$
Living alone: Yes (n=91) No (n=249)	$\chi^2=0.510, p=0.518, df=1$
Level of education: Less than tertiary (n=264) Tertiary or more (n=74)	$\chi^2=1.022, p=0.387, df=1$
Employment: Yes (n=42) No (n=291)	$\chi^2=0.920, p=0.390, df=1$
HCP close family member: Yes (n=105) No (n=223)	$\chi^2=0.018, p=0.878, df=1$
Chronic condition: ¹ Yes (n=279) No (n=57)	$\chi^2=11.274, p=<0.0005, df=1$
Medication regularly: ² Yes (n=280) No (n=50)	$\chi^2=10.120, p=<0.0005, df=1$

782 ¹Respondents not having a chronic condition were more likely to self-report being non-adherent
783 than those having a chronic condition.

784 ²Respondents not on regular medication were more likely to self-report being non-adherent than
785 those requiring regular medication.

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815 Table 3: Associations between demographics and having unused medications determined by
 816 using Chi-square

Characteristic	Association
Gender: Male (n=41) Female (n=289)	$\chi^2=1.728, p=0.232, df=1$
Group: ¹ Social (n=136) Educational (n=194)	$\chi^2=20.075, p=<0.0005, df=1$
Age dichotomized at 65 years: ² < 65 years (n=138) ≥ 65 years (n=192)	$\chi^2=5.902, p=0.017, df=1$
Nationality: ³ Maltese (n=296) Other (n=34)	$\chi^2=7.945, p=0.009, df=1$
Living alone: Yes (n=86) No (n=243)	$\chi^2=1.044, p=0.369, df=1$
Level of education: ⁴ Less than tertiary (n=251) Tertiary or more (n=75)	$\chi^2=19.895, p=<0.0005, df=1$
Employment: ⁵ Yes (n=45) No (n=277)	$\chi^2=4.430, p=0.047, df=1$
HCP close family member: Yes (n=97) No (n=221)	$\chi^2=0.152, p=0.710, df=1$
Chronic condition: ⁶ Yes (n=237) No (n=87)	$\chi^2=14.634, p=<0.0005, df=1$

Medication regularly: ⁷ Yes (n=236) No (n=84)	$\chi^2=8.916, p=0.004, df=1$
Adherence: ⁸ Yes (n=50) No (n=224)	$\chi^2=5.344, p=0.025, df=1$

817 ¹Respondents recruited from the educational group were more likely to self-report having unused
818 medication.

819 ²Respondents < 65 years were more likely to self-report having unused medication.

820 ³Non-Maltese respondents were more likely to self-report having unused medication than
821 Maltese respondents.

822 ⁴Respondents with a tertiary or higher level of education were more likely to self-report having
823 unused medication than respondents with a post-secondary or lower level of education.

824 ⁵Employed respondents were more likely to self-report having unused medication than
825 respondents who were unemployed or pensioners.

826 ⁶Respondents not having a chronic condition were more likely to self-report having unused
827 medication than those having a chronic condition.

828 ⁷Respondents not on regular medication were more likely to self-report having unused
829 medication than those requiring regular medication.

830 ⁸Respondents who indicated having unused medication were more likely to self-report being
831 non-adherent.

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841 Table 4: Knowledge statements about medication wastage presented to participants and the
 842 corresponding correct values

Statement	Correct responses % (n)
Taking the medication twice a day when you are supposed to take it three times a day is considered as wastage.	41.0 (173)
It is important to keep some emergency medication even if it expires.	32.7 (138)
If not disposed properly medication can be found by small children or animals who can eat/ingest the medication accidentally.	69.7 (294)
It is important to crush medication before putting it in the garbage.	31.0 (131)
When you are taking antibiotics, you should stop taking them as soon as you feel better even if you have not taken the full amount that the doctor has prescribed.	86.0 (363)
A medication should be stored on the window sill so that children will not be able to reach it.	70.4 (297)
Applying cream to the skin more often than is necessary is considered as refreshing.	70.4 (297)
Medication that remains unused should be thrown away down the toilet.	54.7 (231)

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Table S1: Mean \pm SD knowledge scores amongst respondents from the six different regions of Malta

Region	Mean \pm SD knowledge score
Gozo (n=22)	5.8 \pm 1.4 ^a
Northern Harbour (n=117)	5.0 \pm 1.4
South Eastern (n=60)	4.7 \pm 1.3
Southern Harbour (n=57)	4.7 \pm 1.2
Western (n=69)	4.5 \pm 1.6 ^a
Northern (n=83)	4.4 \pm 1.5 ^a

^a ANOVA testing identified, significantly higher mean knowledge scores amongst respondents from the Gozo region compared to the Northern region ($p = 0.011$, 95% Confidence Intervals of the mean knowledge difference [CI] 0.19–2.51), and compared to the Western region ($p = 0.023$, 95% CI 0.10–2.48). There were no other statistically significant differences in mean knowledge score between the other regions.

Table S2: Type and amount of unused medication, who originally recommended it, reason to remain unused and the respective cost

Unused medication	Dosage form	Indication	Originally prescribed by:	Amount of unused medication	Reason for having unused medication	Cost/ Euro of unused medication
Alginic acid	Tab/cap	GI system	Pharmacist	50 tablets	I only take them occasionally	5.81
Angelica	Tab/cap	GU	Gynaecologist	1 box	-	52.51
Aspirin	Tab/cap	CV system	-	1 box	-	2.99
Aspirin	Tab/cap	CV system	OTC	10 doses	I store it	0.84
Aspirin	Tab/cap	CV system	Doctor	1 box	Difference from one doctor to the other	2.99
Betahistine	Tab/cap	Labyrinth	Doctor	12 tablets	I keep them just in case I get vertigo	4.08
Bromhexine	Syrup	Respiratory	Doctor	2ml	Leftover following the course I needed	0.08
Calcium	Tab/cap	Nutriton	-	1 box	-	10.39
Carbimazole	Tab/cap	Thyroidism	Doctor	1 box	-	6.90
Carbocisteine	Syrup	Respiratory	Paediatrician	Half a bottle	Child did not get sick	1.15
Carbocisteine	Tab/cap	Respiratory	Doctor	10 tablets	I felt better	3.95
Carbocisteine	Syrup	Respiratory	Paediatrician	Half a bottle	Child did not get sick	3.99
Carbocisteine	Syrup	Respiratory	Doctor	One-fourth	Did not need it any longer	2.00
Carbocisteine	Syrup	Respiratory	Doctor	Half a bottle	Changed medication	3.99
Carbocisteine	Syrup	Respiratory	Doctor	Half a bottle	Changed medication	3.48
Clarithromycin	Tab/cap	Infection	-	1 box	-	20.98

Co-amoxiclav	Tab/cap	Infection	-	1 box	Taken just in case on a long trip abroad	9.00
Co-amoxiclav	Tab/cap	Infection	Doctor	One-fourth	Felt better	2.25
Co-amoxiclav	Tab/cap	Infection	Doctor	4 packets	Expired	36.00
Co-amoxiclav	Tab/cap	Infection	Doctor	Leftovers	Dosage achieved	0.86
Co-amoxiclav	Tab/cap	Infection	Doctor	1 box	I don't need them and expired	9.00
Compound analgesic	Tab/cap	NS	Doctor	32 tablets	First aid box	4.95
Compound analgesic	Tab/cap	NS	Doctor	18 tablets	They caused nausea	2.93
Diclofenac	Cream	Musculo	Doctor	1 tube	-	10.00
Enalapril	Tab/cap	CV system	-	1 box	-	4.64
Flavonoids	Tab/cap	Vascular	-	1 box	-	8.94
Flupentixol	Tab/cap	NS	Psychiatrist	30 tablets	Change in medication	2.89
Flupentixol/melitracen	Tab/cap	NS	Doctor	3 tablets	Changed medication	0.27
Fusidic acid	Cream	Infection	Doctor	1 tube	Do not need it	6.36
Hydrocortisone	Cream	Skin	Doctor	2 tubes	Bought as precaution when abroad	7.50
Hyoscine butylbromide	Tab/cap	GI system	Doctor	1 box	Not required	2.31
Ibuprofen	Tab/cap	Musculo	Doctor	2 tablets	I don't need them and expired	0.46
Ibuprofen	Tab/cap	Musculo	-	20 tablets	Used only when necessary	3.67
Levocetirizine	Tab/cap	Allergic	Doctor	20 tablets	First aid box	9.0
Levocetirizine	Tab/cap	Allergic	Doctor	10 tablets	Hay fever attacks vary	4.5
Loperamide	Tab/cap	GI system	-	1 box	-	2.96
Metformin	Tab/cap	Endocrine	Doctor	50 tablets	Did not consume full dose	2.50
Paracetamol	Syrup	Fever	-	Bottle	-	4.3
Paracetamol	Syrup	Fever	Paediatrician	Half a bottle	Child did not get sick	2.15
Paracetamol	Tab/cap	NS	-	1 box	-	3.60

Paracetamol	Tab/cap	NS	OTC	Half a box	Did not need them	1.60
Paracetamol	Tab/cap	NS	OTC	1 box	I was not sick	3.60
Paracetamol	Tab/cap	NS	Doctor	1 box	First aid box	1.80
Paracetamol	Tab/cap	NS	-	1 box	No pain	3.60
Paracetamol	Tab/cap	NS	-	1 box	-	3.60
Paracetamol	Tab/cap	NS	Doctor	Half a box	For next time	0.75
Paracetamol	Tab/cap	NS	Pharmacist	10 tablets	Supply in case I get a cold	0.15
Paracetamol	Tab/cap	NS	-	1 box	-	1.50
Paracetamol/Pholcodine/Pseudoephedrine	Syrup	Respiratory	OTC	Half a bottle	Changed medication	2.90
Paracetamol/Promethazine/Dextromethorphan	Syrup	Respiratory	OTC	Half a bottle	Changed medication	1.90
Paroxetine	Tab/cap	NS	-	1 box	-	5.68
Povidone-iodine	Spray	Skin	Doctor	1 bottle	Side-effects	6.75
Pregabalin	Tab/cap	NS	Doctor	Half a box	Side-effects and doctor stopped them	23.46
Ranitidine	Tab/cap	GI system	-	1 box	-	9.95
Salbutamol	Inhaler	Respiratory	-	1 inhaler	-	3.19
Salbutamol	Inhaler	Respiratory	-	1 inhaler	-	3.19
Simvastatin	Tab/cap	CV system	Neurologist	2 boxes	Adverse reaction; stopped by specialist	3.96
Simvastatin	Tab/cap	CV system	Doctor	2 boxes	Side-effects	3.96
Simvastatin	Tab/cap	CV system	GP	3 boxes	Because of side-effects	42.66
Valsartan	Tab/cap	CV system	Consultant	3 boxes	Pills were double the dose so have extra	84.33
Valsartan	Tab/cap	CV system	Doctor	1 box	-	18.84
Zolmitriptan	Tab/cap	NS	GP	2 boxes	End of treatment	12.98

Total cost						507.52
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Allergic=Allergic conditions, CV= cardiovascular, GI=Gastro-intestinal, GU=Genito-urinary, Labyrinth=Labyrinth disorders,
 Musculo=Musculoskeletal system, NS=Nervous system, OTC=Over-the-counter, Tab/cap=Tablets/capsules, Thyroidism=Hyperthyroidism,
 Vascular=Vascular disease

Table S3: Demographics of individuals participating in interviews

Number	Gender	Age	Level of education	Occupation	Lives alone	In-charge of own medication	Family member is healthcare professional	Medical condition	Which chronic condition
1	F	76	Secondary	Pensioner	Yes	Yes	Yes	Yes	COPD, HC
2	F	69	Primary	Pensioner	No	Yes	No	Yes	Diabetes, HT, HC
3	F	62	Primary	Pensioner	No	Yes	No	Yes	Breast cancer, diabetes, HT, insomnia
4	F	73	Primary	Pensioner	No	Yes	No	Yes	Diabetes, HT, HC
5	F	83	Secondary	Pensioner	Yes	Yes	No	Yes	HT, HC, osteoporosis
6	F	74	Secondary	Pensioner	No	Yes	Yes	Yes	HT
7	F	63	Secondary	Pensioner	No	Yes	No	Yes	Diabetes, HT
8	F	68	Primary	Pensioner	No	Yes	No	Yes	HT, HC, GI reflux
9	F	59	Secondary	Employed	No	Yes	Doctor	Yes	HT
10	F	80	Primary	Pensioner	Yes	Yes	No	Yes	HT, HC, GI reflux, TIA
11	F	78	Secondary	Pensioner	No	Yes	No	Yes	HT, hypothyroidism
12	F	73	Secondary	Pensioner	Yes	Yes	No	Yes	HT, osteoporosis, depression
13	F	60	Secondary	Employed	No	Yes	No	No	--
14	M	73	Tertiary	Pensioner	No	Yes	Yes	Yes	Cardiac
15	M	71	Tertiary	Pensioner	No	Yes	Yes	Yes	HT, HC

HC= hypercholesterolemia, HT=hypertension, TIA=transient ischemic accident

Table S4: Behavioral determinants leading to medication wastage from the perspectives of individuals within the community

TDF domains ¹⁵ (Examples of Constructs)	Themes	Illustrative quotes
Knowledge (Knowledge)	<p>Knowledge about medication taking</p> <p>Knowledge about cost of medication</p> <p>Knowledge about medication storage</p> <p>Knowledge about medication disposal</p>	<p><i>“Yes. I prepare them once a week, I have a box and I prepare them once a week.”</i> Participant 2, 69 years old, female</p> <p><i>“No because I get them from the Government.”</i> Participant 1, 76 years old, female</p> <p><i>“I buy my medicines, but my husband collects them for free. I buy all my medicines, so I know how much each medicine costs.”</i> Participant 2, 68 years old, female</p> <p><i>“I have a cupboard where I store coffee in the kitchen to make sure I remember.”</i> Participant 1, 76 years old, female</p> <p><i>“I have a bag which I store in the wardrobe away from heat.”</i> Participant 6, 74 years old, female</p> <p><i>“I put them in a first aid box on a high shelf in the bathroom.”</i> Participant 8, 68 years old, female</p> <p><i>“No. If I had to throw them away, I wouldn’t know how because I am afraid to throw them down the toilet as they might affect the fish. So, I would wrap them up in a paper and throw them in the dustbin.”</i> Participant 3, 62 years old, female</p> <p><i>“I sometimes give them to the pharmacist or to the hospital. Otherwise I throw them down the toilet.”</i> Participant 4, 73 years old, female</p> <p><i>“Sometimes we have my husband’s salbutamol, and we take them to WasterServ. Before I used to flush them down the toilet but now, I don’t do it anymore.”</i> Participant 9, 59 years old, female</p>
Skills	Skills	<i>“I take inhalers with spacer.”</i> Participant 1, 76 years old, female

(Competence, ability)		<i>"I take medicines but I forgot what they are."</i> Participant 11, 78 years old, female
Social/professional role and identity (Social identity)	Education	<i>"More education, maybe send leaflets in households. Some say the internet. Not everyone uses the internet, but if you receive a leaflet at home, I personally would read it...It is also important to teach in schools, if they are around 7-8 years. For example, my granddaughter tells my daughter which items are recyclable, because that's the nice thing about children, they learn from a young age."</i> Participant 9, 59 years old, female <i>"Seminars. And even in schools. Actually, in schools, on the subject we discussed (overdosing), start educating as soon as possible, as it is the student's right to know. The information should be suitable for their age."</i> Participant 13, 60 years old, female
Beliefs about capabilities (Self-confidence, self-esteem, perceived competence, beliefs, self-efficacy)	Confused how to take medication Embarrassed to take medication in front of others	<i>"No because you get used to them. Even if they change the brands, I do not get confused. I only confuse the name when I get to say it."</i> Participant 2, 69 years old, female <i>"Yes, to tell you the truth sometimes I get confused. When the brands change. For example, when Metformin has a different name. The leaflet would be the same. But it annoys me..."</i> Participant 3, 62 years old, female <i>"I do not forget them, but the insulin, sometimes I go to a coffee morning or I go out in the evening and I do not arrive home by 7, so I take it when I arrive home. Cause I do not like taking out the insulin in front of everyone, and I am disgusted to take insulin in a toilet."</i> Participant 4, 73 years old, female
Optimism (Optimism)	Effective communication	<i>"If I am speaking with someone and the topic (on how to prevent medication wastage) is brought up I will tell him my opinion."</i> Participant 1, 76 years old, female

<p>Beliefs about consequences (Beliefs, consequents)</p>	<p>Not enough medication for everyone</p> <p>Abuse of unused medication</p> <p>Effect of medication wastage on environment</p>	<p><i>“I do not really stay thinking about it but in fact that is what happens if you collect extra medicines. There is not enough for everyone then.”</i> Participant 1, 76 years old, female</p> <p><i>“My daughter was bullied at secondary school...My (other) daughter found her on the floor... A lot of suicides due to bullying are carried out by taking medicines. The tablets my daughter took, we had tablets at home but they were not the same. We found stored boxes in her drawer that were outdated for a long time. They were not expired 3 months ago or 6 months ago. So, she had been planning it out and hoarding them. And we think she took them from her grandmother.”</i> Participant 13, 60 years old, female</p> <p><i>“Of course, I do not like the fact that I throw them down the toilet because I think it will end up in the sea, and that is still wrong.”</i> Participant 4, 73 years old, female</p>
<p>Reinforcement (Rewards, incentives, contingencies)</p>	<p>Incentive not to waste medication</p>	<p><i>“Try with a lottery as an incentive, so if I go to throw them at WasteServ I participate.”</i> Participant 9, 59 years old, female</p> <p><i>“There should be economic incentives, such as plastic money incentives and fiscal incentive measures.”</i> Participant 15, 71 years old, male</p> <p><i>“Elderly people in our days are not the same elderly people that we will have in the near future... The elderly that we have now suffered times of poverty... But they lived hard times. So, even if they had to take the medicine and throw it away, but they take it because they are entitled to it. I do not think that the elderly in the future will have the same mentality. We are already teaching our elderly here, we teach them how to use a computer, we teach them how to access internet, they know how to read, so we are making them aware of these things. So, it is important that you continue teaching.”</i> Participant 13, 60 years old, female</p>

Goals (Autonomous goals)	Scope not to waste	<i>"Yes of course so that others can use those medicines."</i> Participant 7, 63 years old, female
Memory, attention and decision processes (Attention, decision making)	Consider prevention of medication wastage	<i>"No, it never crosses my mind."</i> Participant 5, 83 years old, female <i>"That's why I tell her not to give me the medicines if I still have left at home."</i> Participant 10, 80 years old, female
Environmental context and resources (Resources)	Pharmacist/doctor/nurse to help to prevent medication wastage	<i>"The pharmacist that we have is very helpful and very good. She does not help you not to waste, but for example, how to take them, she is very knowledgeable."</i> Participant 10, 80 years old, female <i>"They never told us (how to prevent medication wastage). Actually, do you know what is wrong sometimes? That they do not explain well to us (about the medication) and we have to read the leaflet."</i> Participant 11, 78 years old, female
Social influences (Social support)	Information about medication storage Information about medication disposal	<i>"My granddaughter gives me a lot of information but I get annoyed and do as I please."</i> Participant 6, 74 years old, female <i>"No one ever told me."</i> Participant 8, 68 years old, female <i>"Recently WasteServ told us and I told them that I flush them and they told me that it is wrong."</i> Participant 8, 68 years old, female <i>"No information at all."</i> Participant 14, 73 years old, male
Emotion (Fear)	Worried of remaining without medication	<i>"No because I do not leave my medicines until the last tablets before I collect a fresh supply."</i> Participant 5, 83 years old, female <i>"Some time ago my mother-in-law was at hospital. But we did not throw away any medicines as we were afraid that we would not find them if we need them. Even recently I told my daughter that I will buy a bottle of paracetamol syrup just in case for</i>

	What they do to prevent medication wastage	<p><i>“I used to speak about it with my sister. I used to tell her “if you already have stock for this month, why are you going to collect them?” Participant 2, 69 years old, female</i></p> <p><i>“I do not collect extra medicines. Sometimes I tell the pharmacist to give me less packs of medicines.” Participant 4, 73 years old, female</i></p> <p><i>“I try, last time I bought something from the pharmacist and I asked her if she can give me sheets instead of a whole box. I only needed a few. If boxes were smaller, if you need for one week why do you need to buy 30?” Participant 9, 59 years old, female</i></p>
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