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Title: Assessment of health-care waste management in a humanitarian crisis: a case study of the Gaza Strip

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1 **Abstract**

2 Health-care waste management requires technical, financial and human resources, and
3 it is a challenge for low- and middle income countries, while it is often neglected in
4 protracted crisis or emergency situations. Indeed, when health, safety, security or
5 wellbeing of a community is threatened, solid waste management usually receives
6 limited attention.

7 Using the Gaza Strip as the case study region, this manuscript reports on health-care
8 waste management within the context of a humanitarian crisis. The study employed a
9 range of methods including content analyses of policies and legislation, audits of waste
10 arisings, field visits, stakeholder interviews and evaluation of treatment systems. The
11 study estimated a production from clinics and hospitals of 683 kg/day of hazardous
12 waste in the Gaza Strip, while the total health-care waste production was 3,357
13 kg/day. A number of challenges was identified including lack of clear definitions and
14 regulations, limited accurate data on which to base decisions and strategies and poor
15 coordination amongst key stakeholders. Hazardous and non-hazardous waste was
16 partially segregated and treatment facilities hardly used, and 75% of the hazardous
17 waste was left untreated. Recommendations for mitigating these challenges posed to
18 patients, staff and the community in general are suggested. The outputs are
19 particularly useful to support decision makers, and re-organize the system according to

20 reliable data and sound assumptions. The methodology can be replicated in other
21 humanitarian settings, also to other waste flows, and other sectors of environmental
22 sanitation.

23

24 **Keywords**

25 Palestine, Gaza Strip, Healthcare waste, Medical waste, Stakeholders engagement,
26 Sustainability, Humanitarian context, Assessment methods.

27

28 **Abbreviations**

29 BOR: bed occupancy rate; EQA: Environmental Quality Authority; ER: emergency room;
30 HCF: health-care facility; HCWM: health-care waste management; IPC: infection
31 prevention and control; LMIC: low- and middle-income country; MoH: Ministry of
32 Health; MSW: municipal solid waste; PMMS: Palestinian Military Medical Services;
33 UNRWA: United Nations Relief and Works Agency for Palestine Refugees; WHO: World
34 Health Organization; w/w: % weight per weight.

35

36 **1. Introduction**

37 Palestine is divided into two geographical entities, the West Bank and the Gaza Strip.

38 Although theoretically managed by the same government and regulated by the same

39 legislative framework, they are de facto autonomous entities, and administered
40 respectively by the Palestinian Authority (Fatah), and Hamas. In the Gaza Strip the
41 situation is quite different from the West Bank. For example, the management of
42 waste differs between the two regions (Caniato et al., 2015a).

43 A number of studies have been conducted across the Middle East on waste
44 management (Abd El-Salam, 2010; Aghapour et al., 2013; Alhumoud and Alhumoud,
45 2007; Askarian et al., 2012; Bdour et al., 2007; Ciplak and Barton, 2012). More
46 specifically, research has examined waste management in the West Bank (Al-Khatib,
47 2008; Al-Khatib et al., 2009; Al-Khatib and Sato, 2009), some of which are focused on
48 social factors such as the opinions of staff from health-care facilities (HCF) (Massrouje,
49 2001; Sarsour et al., 2014). However, there are various limitations of these studies,
50 including the fact that in some cases they refer to Palestine in general, some are based
51 on quite old data, and there has been limited large scale study of the Gaza Strip
52 specifically.

53 Since Hamas reinforced its power in Gaza in 2007, there have been three large-scale
54 conflicts with Israel. However, the 2014 war was the most deadly and devastating, with
55 more than 2,200 Palestinians (mostly civilians) killed, and 11,231 Palestinians injured.
56 On the Israeli side, 67 soldiers and six civilians were killed, and 1,600 people wounded.
57 About 170,000 homes and 360 factories in Gaza were damaged or lost, key

58 infrastructure hit, and thousands of acres of farmland were ruined (Schabas et al.,
59 2015). In a similar context access to and quality of health-care are a particularly critical
60 issue, as well as the management of by-products, like the waste generated.
61 Therefore, a study focused on the Gaza Strip is important and timely. Similar contexts
62 are usually characterized by shortage of accurate and coherent data, and information
63 is even conflicting or based on the personal opinion of different stakeholders. Using
64 health-care waste management (HCWM) as the key focus, this study aimed to
65 understand the management of waste during a humanitarian crisis and to develop
66 effective recommendations to address the issues identified. It aims to show that is
67 possible to overcome such challenges with a combination of different qualitative and
68 quantitative methods in order to draw evidenced-based conclusions.

69

70 **2. Methods**

71 The Gaza Strip is such a small area that the national and local administrative levels are
72 almost overlapping. The governorates and municipalities are very small and do not
73 play an important role concerning HCWM. Thus the study was focused on the entire
74 Gaza Strip.

75 The analysis included the following topics:

- 76 - Regulation, legislative framework and guidelines;

- 77 - Background information at the Gaza Strip level (e.g. identification of available
- 78 treatment options, market opportunities);
- 79 - HCWM at the health-care facility level (rapid assessment);
- 80 - Quality of HCW segregation and estimation of waste production;
- 81 - Identification of stakeholders (role, importance, relationships, and
- 82 communication networks);
- 83 - Identification of challenges and evaluation of stakeholder priorities.

84 Some methods were often applied together. For example, while assessing a HCF, staff
85 were also interviewed, and questions about different topics submitted.

86

87 *2.1. Regulation, legislative framework and guidelines*

88 Some thirty officers from departments of the Ministry of Health (MoH), municipal solid
89 waste (MSW) service providers, and staff from HCFs were interviewed to examine the
90 regulations concerning HCWM. The research was extended to the guidelines and laws
91 concerning public health and infection prevention and control (IPC), in order to have a
92 picture of all the pieces of regulation potentially of interest. Some laws were officially
93 available also in English, while the other documents were translated by COOPI –
94 COOPERAZIONE INTERNAZIONALE (COOPI) staff. COOPI is an international NGO which
95 acted as partners in the study.

96

97 *2.2. Background information at the Gaza Strip level*

98 One of the most complete databases about HCFs was developed by the World Health
99 Organization (WHO) in April 2009 (WHO and EMRO, 2010). It provides information
100 about each HCF, including utilization statistics, GPS coordinates, and health services.
101 This information was used as the main baseline (Table 1). The data were checked as
102 much as possible during meetings and visits, to confirm that they were still
103 representative of the Gaza Strip situation. However, in some facilities, utilization
104 statistics and other information were not easily available, and staff did not have the
105 data. Therefore, it is possible that they were either collected with different definitions,
106 or some facilities simply were not used to have a data recording system. It is important
107 to note that official documents report different numbers of beds and bed occupancy
108 rates (BOR) in MoH hospitals (Home Engineering Unltd et al., 2005a; Ministry of
109 Health, 2011a; WHO et al., 2011; WHO and EMRO, 2010). Other information was
110 collected from online documents, the MoH website, and interviews with MoH and
111 WHO officers, HCF staff and local experts in 2011 and 2012.

112 In the Gaza Strip, hazardous HCW were either incinerated or disposed of in a dedicated
113 landfill. Qualitative and quantitative data about incinerators were collected with a
114 simple form during field visits. All of the three incinerators in the Gaza Strip were

115 visited several times, in order to understand the practices discussed with operators
116 and the responsible officers. The hazardous waste landfill was visited as well, and its
117 manager interviewed.

118

119 *2.3. HCWM at the health-care facility level*

120 HCFs were assessed adapting the 1st version of the rapid assessment tool developed by
121 WHO & UNEP/SBC (2011). The 2nd edition was published in November 2011 only, after
122 the first field mission in the Gaza Strip. Waste segregation was surveyed in different
123 departments/wards in each HCF visited. Some 16 HCFs were assessed, 10 public and 6
124 non-governmental respectively. Non-governmental HCFs were managed by private
125 companies, NGOs or the United Nations Relief and Works Agency for Palestine
126 Refugees (UNRWA). The 16 HCFs were a representative sample from different
127 governorates, and represent the vast majority of both bed capacity and patients
128 treated in the Gaza Strip.

129

130 *2.4. Estimation of waste production and quality of HCW segregation*

131 In January-February 2012, COOPI staff carried out a rapid weighing campaign in four
132 HCFs (two hospitals and two clinics), for six consecutive days (from Saturday to
133 Thursday). This analysis aimed to quantitatively estimate waste production and waste

134 segregation. Moreover, direct observation gave some qualitative indication of onsite
135 collection and storage practices. Clinics had an internal collection shift (7.00–14:30)
136 only, thus the analysis, carried out in the morning, covered the entire HCW production.
137 Hospitals were operative 24/7 and had three waste internal collection shifts (6:00–
138 14:00, 14:00–22:00, 22:00–6:00), and COOPI staff could only weigh the first shift.
139 However, the majority of waste was collected during this shift, which meant that this
140 was representative of the overall quantities of waste. COOPI staff assessed the volume
141 occupied by the waste by evaluating the percentage of filling of containers in use. The
142 day after, COOPI staff assessed the volume of the total HCW produced in the previous
143 day before it was transported out of the hospital. This estimated volume was then
144 used to determine the waste quantities, using sample weights of the waste for the
145 conversion. Therefore, COOPI staff could estimate the total HCW daily production.
146 Safety boxes were collected just once a day, thus this generation was the actual value,
147 not an estimation.

148 Also UNRWA kindly agreed to participate, and their staff weighed the waste produced
149 by the Rimal clinic for eight days (19 October – 27 October, 2011, excluding Friday 21
150 October), without the presence of COOPI staff.

151 The effectiveness of waste segregation was assessed directly in both producer (HCF)
152 and treatment/disposal site (incinerator, hazardous waste landfill and MSW landfill).

153 Only two waste streams could be identified, namely: (1) waste managed by MSW
154 service providers, and (2) hazardous waste treated by MoH with incinerators. In all the
155 assessed HCFs, after interviews, some wards were visited, as well as the temporary
156 storage sites in use for non-hazardous (i.e. similar to MSW) and hazardous waste. In
157 the incinerator at Al Shifa hospital (the biggest HCF in Palestine), some bags and safety
158 boxes were opened in order to qualitatively observe the contents before incineration.
159 Mixture of hazardous and non-hazardous waste was observed in both the streams
160 during all the field activities, and was confirmed by all the interviews.

161 *2.5. Identification of stakeholders*

162 Stakeholders and social networks were analysed based on Caniato et al. (2014b).

163

164 *2.6. Identification of challenges and evaluation of stakeholder priorities*

165 During meetings and interviews, stakeholders were asked to give their opinions about
166 HCWM in the Gaza Strip, to state the challenges and the suggestions to improve the
167 situation. A set of challenges was identified, and a possible way forward for each one
168 was suggested, integrating requests from the field with indications from guidelines and
169 literature. Stakeholders stated their priorities about HCWM, as described in Caniato et
170 al. (2014b). A program of intervention was developed through the triangulation of
171 challenges, possible way forward, and priorities.

172

173 *2.7. Site surveys and data triangulation*

174 Some 39 stakeholders were engaged with, covering all the categories, and providing an
175 overview of the region, in particular general indications about organizational, logistical
176 and legislative factors. Visits, direct observation and field discussion with operators
177 contributed to investigation of practices. MSW management was previously assessed
178 with a specific methodology (Caniato and Vaccari, 2014), thus the presence of
179 hazardous HCW in street containers, transfer stations and disposal sites had already
180 been detected.

181 About hospitals, the main hazardous HCW sources, 12 out of 28 facilities (43%) were
182 assessed, covering 70% of the bed capacity (1,886 out of 2,697) and 81% of patients in
183 the Gaza Strip, according to WHO et al. (2011) (1,358,381 out of 1,685,265). This
184 number of patients refers to the sum of admissions, outpatients and emergency room
185 (ER) visits. Thus considering the number of beds, all the governorates, except Rafah,
186 were well represented in the sample.

187 Clinics produce a smaller quantity of waste per patient than hospitals (Pruss-Ustun et
188 al., 2013), and hazardous wastes are mainly composed by sharps and infectious. Only
189 four clinics, two owned by the MoH and two by UNRWA, were visited. Information
190 about other clinics was directly or indirectly collected by the stakeholders met.

191 Therefore, the sample was not completely representative of all the clinics, but
192 information was consistent, and results were deemed reliable. Finally, the overview of
193 HCWM was obtained through information triangulation from both meetings and
194 stakeholder analysis.

195

196 **3. Results**

197 *National level: analysis of regulation, legislative framework and guidelines*

198 At the time of the study there was no clear regulation about HCWM in the Gaza Strip.
199 Only a few definitions (e.g. “hazardous substance” and “hazardous waste”) were
200 provided by the *Palestinian Environmental Law* (President of the Palestinian Authority,
201 1999), while specific terms like “medical waste” were left undefined. The
202 Environmental Quality Authority (EQA) had the responsibility to define the activities
203 and procedures for waste management in coordination with the specialized agencies,
204 and to monitor law enforcement. In the *National Strategy for SWM in the Palestinian*
205 *Territory 2010-2014* (Palestinian National Authority, 2010), Strategic Objective Five
206 dealt with medical, hazardous, and special wastes. In particular, the Authority aimed at
207 creating an inventory and tracking system, and establishing suitable treatment plants
208 for medical waste, though “... there are no Palestinian standards for dealing with
209 special, hazardous, and medical wastes...” (Palestinian National Authority 2010, p. 5).

210 Although not clearly defined, responsibility to manage hazardous HCW was generally
211 attributed to MoH, while Municipalities and Solid Waste Management Councils were in
212 charge of the non-hazardous waste, based on the *Public Health Law* (Palestinian
213 Legislative Council, 2004).

214 The law prepared in 2009 “*Concerning the management and the handling of medical*
215 *waste*” (Palestinian National Authority, 2009) was still under approval in 2013. It
216 included definitions, including “medical waste”, and “general waste”, a list of main and
217 secondary sources, and responsibilities. Medical waste categories were defined
218 similarly to the first edition of the WHO’s Blue Book (Pruss et al., 1999). Finally, the law
219 gave general indications about segregation, collection and temporary storage, and
220 onsite and offsite transport, while little was written about treatment and disposal.

221 Due to the internal Palestinian political conflict, officers from the same Ministry (e.g.
222 Ministry of Health) in the Gaza Strip and West Bank had little interaction, and
223 practically were independent structures, with specific regulations, recommendations
224 and plans. At the Gaza Strip level, *Recommendations of the committee of the*
225 *directorate of the medical wastes in the Ministry of Health, October 2010* (Ministry of
226 Health, 2010) required the establishment of a committee to classify waste, to
227 introduce an appropriate segregation system and to monitor its application. *Medical*
228 *waste incinerator situation in Ministry Of Health of Gaza, 5 October 2011* (Ministry of

229 Health, 2011b) reported the existing situation concerning incineration in the Gaza
230 Strip, and certified the lack of a segregation system, the old and poor condition of
231 incinerators, and their risks to public health. *Incineration run protocol* (Ministry of
232 Health, 2011c) set some general incineration procedures. Finally, some documents
233 about IPC were officially present, like “*Infection Prevention and Control Protocols*”
234 (Ministry of Health, 2004), but they were not being implemented at the time of the
235 study.

236

237 *3.1. National level: collection and analysis of data and useful information at the Gaza*

238 *Strip level*

239 Health-care was provided by both public and nongovernmental actors. Public HCFs
240 were owned and managed by either MoH or military services in Palestine (MSP, also
241 called Palestinian Military Medical Services PMMS), while non-governmental HCFs
242 were managed by private companies and local or international NGOs. UNRWA ran its
243 own facilities, providing primary health-care to refugees. In 2010, some 1,002,329
244 people accessed UNRWA health services (UNRWA, 2011).

245 HCFs were divided into clinics, which provided mainly primary services and dealt with
246 outpatients only, and hospitals, which provided secondary and tertiary services. Public
247 clinics had four levels according to the health services provided. Non-governmental

248 facilities did not follow specific rules (Regional Health Systems Observatory and EMRO,
249 2006). Table 1 presents the number of HCFs and main available statistics for each. The
250 Ministry of Health (2011a) reported a different number of non-governmental hospitals,
251 clinics and beds available. The lack of an univocal recording system, in particular
252 regarding non-governmental HCFs is evident.

253 TABLE 1 HERE

254 The most recent data estimated a HCW production of 730 tonne/month in the Gaza
255 Strip, but it was actually based on 2004-2008 surveys (PCBS, 2009). In 2011, the MoH
256 estimated that incinerators burnt about 4.5 – 5 tonnes/month (Ministry of Health,
257 2011b), but no weighing or reliable estimations were available about general HCW
258 production and composition. The *Master Plan for Healthcare Waste Management*
259 *West Bank/Gaza Strip* was the most up to date study and was still considered valid by
260 all the stakeholders. It estimated a production of 2,003 kg/day (400 kg/day of
261 hazardous waste) in 2004, considering 1.306 kg/bed/day and a BOR of 80% (1,534
262 occupied beds out of 1,917) (Home Engineering Unltd et al., 2005a). The *Feasibility*
263 *Study for the Implementation of Healthcare Waste Master Plan in West Bank/Gaza*
264 *Strip* reported slight differences, but the estimation of hazardous waste production
265 was similar (Home Engineering Unltd et al., 2005b). HCW was composed mainly of
266 domestic waste (80%), while infectious waste was the main fraction of hazardous

267 waste. This estimation was based on a questionnaire, some visits to HCFs in the Gaza
268 Strip and a rapid sampling campaign. However, sampling probably was carried out for
269 only one day, analysing just one UNRWA clinic and one blood bank, and with an
270 unclear methodology (Home Engineering Unltd et al., 2005c). Therefore the data were
271 not completely reliable. Most of all, the final estimation considered only hospitals and
272 thus was based on waste production per occupied bed. Unfortunately, in the Gaza
273 Strip the number of clinics and visits cannot be accurately verified. In 2000, the *Quality*
274 *Improvement Project*, funded by the World Bank, estimated a waste production from
275 hospitals of 800 kg/day, out of a total HCW production in Gaza Strip of 3,800 kg/day
276 (DHV et al., 2012). Other studies, based on questionnaires or field activities, tried to
277 estimate HCW generation and composition (El-Hawi, 2004; Kamel, 2011; PCBS, 2000;
278 Qumboz, 2002; Zoarob, 1997), but did not provide a significant contribution to the
279 analysis.

280 Visits and meetings confirmed and integrated previous studies (DHV et al., 2012; El-
281 Hawi, 2004; Home Engineering Unltd et al., 2005b) about the poor HCWM standards.
282 Indeed, infectious waste and sharps management were not regulated by specific
283 procedures, while also those concerning pharmaceutical and anatomic waste were not
284 completely implemented (Table 2). Regarding pharmaceutical waste, for example, 200
285 m³ were collected and disposed in the only hazardous waste landfill of the Gaza Strip in 2010,

286 though encapsulation procedure was not fully respected. In 2012, about 250 m³ out of 6,500
287 m³ capacity of this landfill was filled (Solid Waste Director - Gaza Municipality, personal
288 communication, 16/02/2012). Assuming a 0.9 density conversion factor valid in UK for both EWC
289 code 180108 and 180109 – “cytotoxic and cytostatic medicines” and “medicines other than
290 those mentioned in 18 01 08” respectively – (UK Environment Agency, 2014) around 180
291 tonnes were disposed in 2010, and further 45 tonnes in the following two years.

292 TABLE 2 HERE

293 The three incinerators in the Gaza Strip were located in Al-Shifa hospital, in Gaza City,
294 Nasser hospital, and European hospital, both in Khan Younis. Their performances did
295 not meet international standards (Pruss-Ustun et al., 2013; SBC and UNEP, 2011; SSC
296 and UNEP, 2009) in terms of operations (e.g. temperature, retention time, emission of
297 pollutants) and staff safety (e.g. use of personal protective equipment, presence and
298 application of an accident monitoring system). In addition, operation and maintenance
299 procedures were neither written nor clearly defined.

300

301 *3.2. National level: rapid assessment of HCFs*

302 HCW management inside HCFs was often poor and potentially risky for patients,
303 visitors and health workers. Table 3 presents a detailed picture of the situation in HCFs
304 according to the health service provider.

305 TABLE 3 HERE

306 During the field visits, it was documented that in HCFs every HCWM step commonly
307 met neither international minimum requirement (Pruss-Ustun et al., 2013) nor
308 indications provided by local regulation. These non-compliances are reported in Table
309 4, and it was the key starting point to improve the entire HCWM system in the Gaza
310 Strip.

311 TABLE 4 HERE

312

313 *3.3. National level: estimated HCW generation and quality of HCW segregation*

314 The two MoH clinics provided 135,035 and 161,962 visits (i.e. general practitioner +
315 specialist visits) per year (WHO and EMRO, 2010). Their specific waste generation was
316 similar, 0.022 ± 0.012 and 0.027 ± 0.010 kg/visit, respectively. The two clinics segregated
317 safety boxes only, but the level of segregation was probably different. In the first clinic,
318 a segregation of 8.2% weight per weight (w/w) on the total HCW produced was
319 estimated, while in the latter it was 2.1% w/w only.

320 Two MoH hospitals were assessed, Kamal Edwan hospital in the North governorate,
321 and Al Shifa hospital in Gaza City. The first was a medium size hospital with 117 beds
322 and an average production of 2.64 ± 0.48 kg/occupied bed/day. The second was the
323 largest hospital in the Gaza Strip with 657 beds and a much smaller waste production,
324 0.91 ± 0.10 kg/occupied bed/day. Infectious waste, segregated exclusively in safety

325 boxes, on average was 2 kg/day (i.e. 0.8% w/w) and 10 kg/day (i.e. 2.0% w/w),
326 respectively. Therefore infectious waste segregation per occupied bed was very
327 limited, that is 0.025 and 0.018 kg/occupied bed/day, respectively.

328 UNRWA staff weighed two waste categories, namely sharps and non-sharps. However,
329 due to some confusion over the definition of “sharps”, all the infectious waste was
330 considered as segregated. Based on this hypothesis, the average infectious waste
331 production was 14.9 ± 5.1 kg/day out of a total production of 67.6 ± 11.3 kg/day, that is
332 22% w/w. Using a total of 415,356 visits/year (WHO and EMRO, 2010), the average
333 specific waste generation was 0.06 ± 0.01 kg/visit, which was much higher than in the
334 MoH clinics.

335 During the weighing campaign it was evident that MoH HCFs segregated and collected
336 only sharps, using almost exclusively carton safety boxes. Further field visits confirmed
337 that at least some private and NGO HCFs were in the same situation. UNRWA had
338 some infectious waste segregation procedures, but all the waste, both hazardous and
339 non-hazardous, was collected and transported by the same truck and sent to the
340 landfill together. However, official records at the Gaza Strip level were available
341 neither about HCW generation nor segregation in 2012 (DHV et al., 2012). Ministry of
342 Health (2011c) estimated that incinerators in Al Shifa, Nasser and European hospitals
343 regularly dealt with 2-2.5, 1.5 and 1 tonne/month, respectively. Only data about

344 incineration in Al Shifa hospital were confirmed by a record of waste burnt, with an
345 average of 77 kg/day. Unfortunately, the incinerators in both Al Shifa and European
346 hospitals were sometimes out of order. Therefore the Nasser hospital sometimes had
347 to manage hazardous waste from all the HCFs in the Gaza Strip. 2011 data about Al
348 Shifa hospital incinerator demonstrated that few HCFs sent hazardous waste for
349 treatment. Indeed, only 15 HCFs regularly sent waste, totalling an average of 73 ± 46
350 kg/day, while other 10 HCFs were considered periodic or irregular sources, with a total
351 supply of 4 kg/day (it was not possible to estimate the related standard deviation).
352 Thus in several HCFs waste segregation was either ineffective or even absent, and the
353 large majority of hazardous HCW was comingled with MSW. It resulted in more than
354 75% of hazardous waste generated in the Gaza Strip being left untreated. This share
355 was probably higher in reality because the overall production of hazardous waste was
356 probably underestimated.

357

358

359 *3.4. National level: stakeholders, their roles, and relationships*

360 There were a number of stakeholders involved in HCWM with a complex network of
361 relationships, as evaluated in Caniato et al. (2014b). Only MSW service providers had a
362 clear picture of HCWM, while other actors, like MoH HCFs, WHO, private contractors in

363 HCFs, EQA and health NGOs, had high interest but medium-low power. The MoH was
364 both a regulator and manager of public HCFs, and in such a position was the only
365 stakeholder with enough power to affect HCWM. However, it was also a very complex
366 institution and lacked financial resources.

367 The analysis evidently showed that technical staff dealing with HCWM suffered from
368 the lack of a discussion platform to share practices, and develop appropriate solutions.

369 Only official institution's managers and representatives were usually allowed to
370 communicate with other stakeholders, and it was particularly true especially for MoH
371 HCFs. Finally stakeholders did not feel well trained about HCWM. Indeed, they had to
372 rely on a few training opportunities, their initiative, and personal research using the
373 internet. Only UNRWA staff reported having been trained specifically about this topic.

374 However, guidance on HCWM, including training, experience sharing and pilot
375 activities, were requested by almost all the stakeholders. Finally, it is remarkable that
376 stakeholders gave little attention to the blockade imposed to the Gaza Strip since 2006
377 or to the difficult economic conditions due to it. However, a private hospital did report
378 that sometimes buying safety boxes was more difficult and importing treatment
379 technologies was difficult and limited.

380

381

382 *3.5. National level: identification of challenges and evaluation of priorities*

383 Stakeholders self-evaluated HCWM in their facility, and tried to identify challenges and
384 needs. Their indications were used to identify the global challenges of the HCWM
385 system, and develop a possible way forward, including both procedural and
386 infrastructural factors (Table 5).

387 The stated priorities reflected the stakeholders' knowledge and work. In particular,
388 waste segregation at the HCF level, appropriate material for first storage and cleaning,
389 and onsite storage were the most cited steps (Caniato et al., 2015b).

390

391 **4. Discussion**

392 *4.1. Evaluation of the key findings*

393 The results suggest that HCWM varied across the different HCFs in the Gaza Strip. A
394 number of challenges were identified including lack of clear definitions and
395 regulations, limited accurate data on which to base decisions and strategies, limited
396 coordination amongst key stakeholders, limited segregation of hazardous and non-
397 hazardous waste, limited training opportunities and treatment facilities that were not
398 fit for purpose (and hardly used). These challenges posed significant risks to patients,
399 staff and the community in general, as reported in several other low- and middle-

400 income countries (Caniato et al., 2015a; Liu et al., 2015; Ara et al., 2016; Thakur and
401 Ramesh, 2015).

402 Although regulation was lacking in several aspects, it was evident that existing laws
403 were not well-known by all the stakeholders, and they were confused about what
404 should be enforced and how. Regulations did not give clear indications about HCWM,
405 but practices did not apply even what was suggested. Indeed, standard procedures
406 applicable in the Gaza Strip for the management of each hazardous HCW, from the
407 segregation to final disposal, should be developed. There are already a number of
408 existing international guidelines which could be employed to provide definitions and
409 guidance (e.g. WHO, 2014; UNEP, 2012). Given that, there are already various policies
410 in place and, evidently, a key factor is also the effective implementation of any existing
411 and new guidelines. As the key agency, the MoH should probably take at least initial
412 responsibility for implementation and regulation.

413 Several studies tried to describe HCW generation and composition, but none was able
414 to give a reliable picture of the situation, and the gap of knowledge was still evident.
415 For this reason verification and triangulation of data and information were considered
416 so fundamental and received greatest attention. Nevertheless, all the hazardous waste
417 categories should be better analysed and tracked from production to final disposal.

418 Indeed, all the HCWM steps were not compliant with international standards and local
419 regulation (e.g. Pruss-Ustun et al. 2013; SBC & UNEP 2011; SSC & UNEP 2009).

420 Despite the limited data on HCW generation, a range of waste production of 0.9-2.7
421 kg/occ. bed/day looks acceptable for the Gaza Strip and similar with other countries in
422 similar economic conditions (Pruss-Ustun et al., 2013). However, there is a need for
423 more accurate data on which to develop evidence-based policies and strategies.

424 Moreover, data were largely estimated on the basis of data of other studies, like bed
425 capacity, BOR and number of patients (Ministry of Health, 2011a; WHO et al., 2011;
426 WHO and EMRO, 2010).

427 According to the findings, UNRWA segregated about 22% of the waste, but then it was
428 all transported and managed together. HCWM could be effective onsite with more
429 effective segregation, with good results in terms of IPC. However, it was ineffective
430 once the waste left the HCF, and was managed by the MSW service provider.

431 Moreover, any waste segregation was almost nullified by mixing as soon as the waste
432 was collected. In MoH clinics, waste segregation depended on the HCF size, and
433 health-care services provided. A more effective segregation could lead not only to a
434 reduction in public health incidences, but also to a reduced amount of waste to treat in
435 the incinerators. A key factor in effective waste segregation and management is the
436 provision of training, which was identified as a major concern by almost all staff. Given

437 its importance, the MoH should take lead responsibility for developing training
438 programmes for all relevant stakeholders. This could be done in conjunction with the
439 international agencies (e.g. NGOs), that operate in the Gaza Strip. Some of these
440 programmes should be made compulsory in order to improve the standards and
441 procedures across both the health-care and the treatment facilities.

442 It is particularly important to note that little attention was paid to the Gaza Strip
443 blockade and the difficult economic conditions. Indeed, 30% of the population is below
444 poverty line and unemployed rate is among the highest in the World (CIA, 2016).

445 Probably such a situation was considered as given, and all the stakeholders were used
446 to coping with it. Moreover the difficulty in the importation of items was only limitedly
447 reported. Indeed, health-care items are only partially affected by the blockade,
448 including those useful for HCWM. Access to suitable treatment technologies would
449 evidently be limited and constrained. However, during recent years none has tried to
450 import any systems to the best of the authors' knowledge. Finally the situation has an
451 evident impact on HCWM, as all the aspects of people life in the Gaza Strip but with an
452 indirect link, thus often neglected. For example, very few HCF staff can rarely attend
453 training sessions out of the Gaza Strip, and the presence of trainers coming from
454 abroad is strongly limited by the situation and depending on access permits. Therefore
455 it is very difficult for HCFs to have clear references for inspiration. In general it is

456 already hard to provide minimum standards of the service – especially during violence
457 escalations – thus a complex issue as HCWM is rarely a priority for health-care service
458 providers.

459 Table 5 outlines some recommendations for overcoming the procedural and
460 infrastructural barriers identified. These recommendations include the development of
461 protocols and procedures, definition of roles and responsibilities, improved availability
462 and conditions of consumables and vehicles, and identification of appropriate
463 treatments and final disposal of waste. Given the particular complexity of working on
464 HCWM in a humanitarian crisis, it is reasonable that only a few recommendations can
465 be implemented in the short term. In particular the reason behind a crisis and the
466 consequences cannot be affected by a waste management intervention and must be
467 considered as part of the context. However, a picture of the main challenges and a
468 clear way forward can support both local institutions and humanitarian organizations
469 to identify priorities for intervention and planning, and facilitate coordination of their
470 work.

471 TABLE 5 HERE

472

473 *4.2. Developing a programme of interventions*

474 The production coefficients calculated for both clinics and hospitals were applied to
475 utilization statistics. Indeed a production of 683 kg/day of hazardous waste out of
476 3,357 kg/day total HCW was estimated for the Gaza Strip (Table 6). However, the study
477 providing the unit production for hospitals did not give any error estimation (Home
478 Engineering Unltd et al., 2005b). Indeed, these quantities appeared to underestimate
479 production levels, because the number of beds in private HCFs was probably higher
480 and BOR considered was smaller than other documents (Ministry of Health 2011a).
481 Finally, none of the scattered sources was considered. According to these hypothesis,
482 the production of 683 kg/day of hazardous waste should be mainly composed of
483 infectious (80%, that is 16% of total HCW), sharps (15%, that is 3% of total HCW), blood
484 and bodily fluids, and others.

485 TABLE 6 HERE

486 Considering the spatial distribution of HCFs, HCW production was concentrated in the
487 Gaza City governorate, due to the presence of Al Shifa hospital. Hazardous HCW
488 production from clinics was instead more regularly distributed (Table 7).

489 TABLE 7 HERE

490 Finally, the analysis allowed the development of a program of intervention, based on
491 the field work and the system's needs (Table 8).

492 TABLE 8 HERE

493

494 *4.3. About the methodology*

495 The triangulation process of information from interviews, field visits, reports and other
496 documents was effective. The large set of primary sources considered served not only
497 to enable data reliability and validity, but also to provide background information to
498 better inform further investigations.

499 The approach to understanding regulation and HCWM at the Gaza Strip level enabled
500 definition of the required detail for the HCF rapid assessment, as well as an analysis of
501 key stakeholders. The rapid assessment gave a clear picture of public HCFs, and
502 informed judgments of non-governmental and private facilities. Indeed, HCWM in
503 these HCFs could potentially be different. However, the approach enabled an overview
504 of HCWM without the need to survey all the producers. The stakeholder analysis not
505 only helped identify challenges and priorities, but also completed the picture of HCWM
506 practices.

507 The estimation of HCW generation was difficult, due to the lack of adequate resources.
508 Indeed Kamal Edwan hospital presented a large production per occupied bed, while in
509 Al Shifa it looked more realistic. However, effective bed occupancy during any
510 weighing campaign should have been considered, as well as other factors like hospital
511 size, health-care services provided and specific level of management. Similar

512 considerations should be applied to the data from the clinics. Utilization statistics and
513 the estimations calculated were not particularly reliable due to the shortage and poor
514 quality of data, as is typical for similar situations (e.g. Manga et al., 2011; Caniato et al.,
515 2015a). However, estimations of HCW coefficients gave a rough indication of total
516 HCW production and hazardous component, and in particular demonstrated that a
517 large quantity of hazardous HCW was mismanaged. Moreover it was possible to
518 predict where the largest production of hazardous waste was concentrated. The
519 triangulation of this data with the HCFs segregating at least part of the waste allowed
520 identification of the main points of concern, and the development of the program of
521 intervention. Although it was not stated directly by HCWM stakeholders, the program
522 was based on their opinions and priorities. Therefore the process was implicitly
523 participated and experience-based. It did not only identify some humanitarian
524 responses, but suggested a holistic program of intervention which can address the
525 HCWM system improvement for a certain period. Keeping the focus on both the global
526 (i.e. the Gaza Strip) and the local (i.e. the HCF) level is the most appropriate strategy to
527 achieve an effective and sustainable improvement of HCWM.

528 Finally, such an in-depth data collection and triangulation process was necessary to
529 draw a reasonably acceptable picture of the situation in the area of intervention,
530 including some quantitative benchmarks. The extensive use of locally available reports

531 and documents was mandatory, due to the lack of more reliable data sources. Even in
532 the case of an intervention on a very limited area (e.g. a single hospital), such a process
533 should be undertaken in order to provide the analysis with an adequate
534 contextualization and set reasonable targets of improvements. In particular, the goal
535 of conservation of resources requires knowledge of the context, including barriers,
536 threats and opportunities.

537

538 **5. Conclusions**

539 At the time of the study, the Gaza Strip faced and continues to face significant social,
540 political and humanitarian challenges. These challenges placed a strain on the
541 availability of resources to provide effective services, including for HCWM. However, it
542 is evident that there was a link between the management of HCW (and indeed waste
543 in general), and the partial alleviation of some of these challenges. For example, more
544 effective management of HCW could lead to reduction in the public health and
545 environmental risks posed not only to staff employed in the provision of health-care
546 and management of waste, but also the community at large. A more sound
547 management of HCW could also lead to a better use of resources, with an impact on
548 financial performances of HCFs. The methodology proposed proved to be applicable in
549 a humanitarian crisis. It could collect a large quantity of information, evaluate its

550 quality and address specific analyses through integration of the data. In particular the
551 need for additional analyses is reduced because they entail particularly relevant costs
552 and risks for field staff in a humanitarian context. Recommendations were developed
553 starting from the challenges identified, considering opinions and priorities of all the
554 stakeholders involved and the resources actually available. While so many barriers
555 have been identified, given the resource-strained nature of the situation, some of the
556 recommendations suggested could be implemented at low or no costs (e.g.
557 introduction of technical specifications and guidelines, and provision of training). In
558 particular, in order for these benefits to be realised, it is important to improve the
559 governance structures and coordination amongst key stakeholders within the Gaza
560 Strip, including local and international organisations. Despite the major hurdles to be
561 overcome, effective management of waste and resources during a prolonged and
562 serious humanitarian crisis such as is the case in the Gaza Strip is possible, and can lead
563 to significant environmental and public health outcomes. However, effective, holistic
564 and coordinated strategies have to be put in place for these outcomes to be realised.

565

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575

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|671 [Table 1 – Hospitals and clinics in the Gaza Strip](#)

673

<u>Reference</u>	<u>WHO et al. 2011</u>		<u>WHO & EMRO 2010</u>		
<u>HCFs</u>	<u># of facilities</u>	<u># of beds</u>	<u># of facilities</u>	<u># of beds</u>	<u># of patients*</u>
Hospitals	27	2,697	28	2,697	1,685,265
MoH	13	2,009	13	2,040	1,325,658
PMMS	-	-	1	45	56,720
NGOs	14	688	11	549	302,887
Private			3	63	N.A.
	<u># of facilities</u>	<u>Facilities with buildings in bad conditions</u>	<u># of facilities</u>	<u># of visits**</u>	
Clinics	131	9	110	6,493,704	
MoH	54	9	56	2,735,716	
UNRWA	20	N.A.	20	3,449,316+	
NGOs	57	N.A.	34	308,672++	

674 *N.A.: not available.*675 **: # of patients includes admissions, outpatient and ER visits.*676 *** : # of visits includes general practitioner and specialized visits.*677 *+: data from 3 clinics are missing.*678 *++: data from 8 clinics are missing.*

679

680 Table 2 – Management of hazardous health-care waste categories in the Gaza Strip

<u>HCWM step</u>	<u>Pharmaceutical waste</u>	<u>Anatomic waste</u>	<u>Infectious and sharps waste</u>
<u>Definition and segregation</u>	MoH HCFs segregated parts of expired medicines or leftover without any clear criterion or specific procedures.	Anatomic waste includes body parts and placenta and should be buried in accordance with Islamic practices. The waste was segregated, with different procedures according to the HCF.	Waste considered infectious by HCF were segregated. Only some nongovernmental HCFs used colour coding. Several HCFs did not segregate infectious waste, or did it for a very small quantity. Sharps should be segregated in a safety box.

<u>Collection and onsite storage</u>	<u>Pharmaceutical waste was stored without specific attention.</u>	<u>Anatomic waste was collected and temporary stored in the HCF. Then, patient's family collected it and provided for an adequate burial. In several HCFs,</u>	<u>Collection was usually carried out with the same trolleys for general waste and without specific routing. Safety boxes were temporary stored with infectious waste bags, frequently not in a dedicated room (e.g. generator house or entrance).</u>
<u>Haulage</u>	<u>General Directorate for Pharmacy within the MoH periodically collects from MoH HCFs and sends to Johr al Deek landfill.</u>	<u>placentas could not be stocked properly, thus they were directly disposed in plastic bags with general MSW, sometimes with</u>	<u>Hospitals and nongovernmental clinics had their own haulage system. MoH provided a monthly collection service, but without a fixed schedule.</u>
<u>Treatment</u>	<u>A small part of the waste was disposed in the hazardous waste section (it should be encapsulated in cement boxes, but they are simply stocked without proper closure), and the remaining was crushed and landfilled in the non-hazardous section. Separation criterion were not well defined.</u>	<u>chlorine. Animals regularly scavenged for it in MSW containers. Body parts uncollected by families should be buried by the MoH, but this practice did not follow a specific procedure.</u>	<u>3 small-scale incinerators were available, but a limited number of HCFs sent their infectious waste and sharps there. Others simply mixed such a waste stream with MSW.</u>
<u>Residue disposal</u>			<u>Bottom ash was mixed with MSW. Incinerators were not provided with air pollution control devices, thus fly ash was not produced.</u>
<u>Quantity estimation</u>	<u>No official data were available.</u>	<u>No data were available.</u>	<u>No clear data were available.</u>
<u>Cost</u>	<u>Collection and transportation costs were not available. Disposal costs were 150 NIS/m³ (about 39 USD/m³).</u>	<u>No data were available.</u>	<u>No data were available.</u>

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Table 3 – HCWM in HCFs in 2012 according to the health service providers

Step	Aspect	MoH hospital	MoH clinic	UNRWA clinic	NGO clinic/hospital	Private hospital
<u>Segregation</u>	<u>Written procedure</u>	No	No	Yes	According to NGO	N.A.
	<u>Procedure in place</u>	Sharps segregation ⁴ theoretically infectious but rarely applied	Sharps segregation, theoretically infectious but not applied	3 categories: - Sharps - Infectious - General	According to NGO	N.A.
	<u>Colour coding</u>	No	No	Yes	According to NGO	N.A.
	<u>Bins</u>	Generally plastic	Generally plastic	Plastic	Generally plastic	N.A.
	<u>Bags</u>	Poor quality plastic, not always present	Poor quality plastic, not always present	Plastic, according to waste typology	According to NGO	N.A.
<u>Collection</u>	<u>Procedure</u>	3 times/day	1-2 times/day	1-2 times/day	According to NGO	N.A.
	<u>Workers</u>	Private company	Private company	Internal staff	Private company/internal staff	N.A.
	<u>PPE</u>	According to private company	According to private company	Good	N.A.	N.A.
<u>Onsite transport</u>	<u>Procedure</u>	No	No	No	N.A.	N.A.
	<u>Method</u>	Trolley, cart, hand	Trolley, cart, hand	Trolley	Trolley, cart, hand	Trolley, cart, hand
<u>Temporary storage</u>	<u>Hazardous (sharps)</u>	Various	Various	Various	Various	Various
	<u>To landfill</u>	Container	Container	Container	Container	Container

N.A. not available (information was not enough to determine a general practice)

NOTE: Liquid waste from all the HCFs was directly disposed into the sewage system. Only a fraction was partially treated.

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Table 6 – Estimation of HCW coefficients and total production

SOURCE		ESTIMATION		TOTAL PRODUCTION	
<u>CLINICS*</u>	<u>Total visits/year</u>	<u>HCW (kg/visit)</u>	<u>Hazardous HCW (%)</u>	<u>HCW (kg/day)</u>	<u>Hazardous HCW (kg/day)</u>

MoH	2,735,716	0.025±0.011	20%	187±82	37±16
UNRWA	3,449,316	0.060±0.010	22%	567±95	125±21
NGO	308,672	0.060±0.010	22%	51±8	11±2
-	-	-	SUB TOTAL	805±185	173±39
HOSPITALS**	Total beds	HCW (kg/bed/d)	Hazardous HCW (%)	HCW (kg/day)	Hazardous HCW (kg/day)
MoH/MSP	2,085	1.3	20%	1,973	395
Private	549	1.3	20%	520	104
NGO	63	1.3	20%	60	12
BOR (Bed Occupancy Rate) = 72.8%			SUB TOTAL	2,552	510
-	-	-	-	HCW (kg/day)	Hazardous HCW (kg/day)
-	-	TOTAL PRODUCTION		3,357	683

Scattered sources were not included.

Error estimation of total production not included due to the impossibility to estimate it for hospital production.

*: MoH unit production based on weighing campaign, and composition on Pruss-Ustun et al. (2013).

UNRWA estimation was applied for both UNRWA and NGO clinics. Number of visits is based on WHO & EMRO (2010).

** : Unit production and composition based on Home Engineering Unltd et al. (2005b). Number of beds based on WHO & EMRO (2010). BOR adapted from WHO et al. (2011); total BOR was calculated as the total beds occupied on the total beds available in MoH hospitals. Error estimation for hospital production was not available.

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Table 7 – Estimation of hazardous HCW production in kg/day and distribution per governorate

CLINICS	North Gaza (kg/day)	Gaza City (kg/day)	Middle Zone (kg/day)	Khan Younis (kg/day)	Rafah (kg/day)	TOT (kg/day)	%
MoH	7±3.1	15±6.6	5±2.2	7±3.1	4±1.8	37±16.7	22%
UNRWA	21±3.5	43±7.2	29±4.8	8±1.3	24±4.0	125±20. 8	72%
NGO	2±0.3	4±0.7	1±0.2	4±0.7	1±0.2	11±2.0	6%
SUB TOTAL	30±6.9	61±14.4	34±7.2	19±5.1	29±5.9	173±39. 6	100 %
-	17%	35%	20%	11%	17%	100%	-
HOSPITALS	North Gaza (kg/day)	Gaza City (kg/day)	Middle Zone (kg/day)	Khan Younis (kg/day)	Rafah (kg/day)	TOT (kg/day)	%
MoH	26	212	26	105	18	386	76%

<u>MSP</u>	<u>9</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>9</u>	<u>2%</u>
<u>NGO</u>	<u>13</u>	<u>57</u>	<u>9</u>	<u>24</u>	<u>0</u>	<u>104</u>	<u>20%</u>
<u>Private</u>	<u>0</u>	<u>12</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>12</u>	<u>2%</u>
<u>SUB TOTAL</u>	<u>48</u>	<u>280</u>	<u>35</u>	<u>129</u>	<u>18</u>	<u>510</u>	<u>100</u>
-	<u>9%</u>	<u>55%</u>	<u>7%</u>	<u>25%</u>	<u>3%</u>	<u>100%</u>	-
-	<u>North Gaza (kg/day)</u>	<u>Gaza City (kg/day)</u>	<u>Middle Zone (kg/day)</u>	<u>Khan Younis (kg/day)</u>	<u>Rafah (kg/day)</u>	<u>TOT (kg/day)</u>	-
<u>TOTAL PRODUCTION</u>	<u>78</u>	<u>341</u>	<u>69</u>	<u>148</u>	<u>47</u>	<u>683</u>	-
<u>%</u>	<u>11%</u>	<u>50%</u>	<u>10%</u>	<u>22%</u>	<u>7%</u>	<u>100%</u>	

689 Error estimation of total production not included due to the impossibility to estimate it for hospital

690 production

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692