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Article

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

Creators: Caniato, M., Tudor, T. L. and Vaccari, M.

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Abstract

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

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

**Keywords**
Palestine, Gaza Strip, Healthcare waste, Medical waste, Stakeholders engagement, Sustainability, Humanitarian context, Assessment methods.

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

**1. Introduction**
Palestine is divided into two geographical entities, the West Bank and the Gaza Strip. Although theoretically managed by the same government and regulated by the same
legislative framework, they are de facto autonomous entities, and administered respectively by the Palestinian Authority (Fatah), and Hamas. In the Gaza Strip the situation is quite different from the West Bank. For example, the management of waste differs between the two regions (Caniato et al., 2015a).

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

Since Hamas reinforced its power in Gaza in 2007, there have been three large-scale conflicts with Israel. However, the 2014 war was the most deadly and devastating, with more than 2,200 Palestinians (mostly civilians) killed, and 11,231 Palestinians injured. On the Israeli side, 67 soldiers and six civilians were killed, and 1,600 people wounded. About 170,000 homes and 360 factories in Gaza were damaged or lost, key
infrastructure hit, and thousands of acres of farmland were ruined (Schabas et al., 2015). In a similar context access to and quality of health-care are a particularly critical issue, as well as the management of by-products, like the waste generated. Therefore, a study focused on the Gaza Strip is important and timely. Similar contexts are usually characterized by shortage of accurate and coherent data, and information is even conflicting or based on the personal opinion of different stakeholders. Using health-care waste management (HCWM) as the key focus, this study aimed to understand the management of waste during a humanitarian crisis and to develop effective recommendations to address the issues identified. It aims to show that is possible to overcome such challenges with a combination of different qualitative and quantitative methods in order to draw evidenced-based conclusions.

2. Methods

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

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

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

2.1. Regulation, legislative framework and guidelines

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

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

In the Gaza Strip, hazardous HCW were either incinerated or disposed of in a dedicated landfill. Qualitative and quantitative data about incinerators were collected with a simple form during field visits. All of the three incinerators in the Gaza Strip were
visited several times, in order to understand the practices discussed with operators and the responsible officers. The hazardous waste landfill was visited as well, and its manager interviewed.

2.3. HCWM at the health-care facility level

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

2.4. Estimation of waste production and quality of HCW segregation

In January-February 2012, COOPI staff carried out a rapid weighing campaign in four HCFs (two hospitals and two clinics), for six consecutive days (from Saturday to Thursday). This analysis aimed to quantitatively estimate waste production and waste...
segregation. Moreover, direct observation gave some qualitative indication of onsite collection and storage practices. Clinics had an internal collection shift (7.00–14:30) only, thus the analysis, carried out in the morning, covered the entire HCW production. Hospitals were operative 24/7 and had three waste internal collection shifts (6:00–14:00, 14:00–22:00, 22:00–6:00), and COOPI staff could only weigh the first shift. However, the majority of waste was collected during this shift, which meant that this was representative of the overall quantities of waste. COOPI staff assessed the volume occupied by the waste by evaluating the percentage of filling of containers in use. The day after, COOPI staff assessed the volume of the total HCW produced in the previous day before it was transported out of the hospital. This estimated volume was then used to determine the waste quantities, using sample weights of the waste for the conversion. Therefore, COOPI staff could estimate the total HCW daily production. Safety boxes were collected just once a day, thus this generation was the actual value, not an estimation. Also UNRWA kindly agreed to participate, and their staff weighed the waste produced by the Rimal clinic for eight days (19 October – 27 October, 2011, excluding Friday 21 October), without the presence of COOPI staff. The effectiveness of waste segregation was assessed directly in both producer (HCF) and treatment/disposal site (incinerator, hazardous waste landfill and MSW landfill).
Only two waste streams could be identified, namely: (1) waste managed by MSW service providers, and (2) hazardous waste treated by MoH with incinerators. In all the assessed HCFs, after interviews, some wards were visited, as well as the temporary storage sites in use for non-hazardous (i.e. similar to MSW) and hazardous waste. In the incinerator at Al Shifa hospital (the biggest HCF in Palestine), some bags and safety boxes were opened in order to qualitatively observe the contents before incineration. Mixture of hazardous and non-hazardous waste was observed in both the streams during all the field activities, and was confirmed by all the interviews.

2.5. Identification of stakeholders

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

2.6. Identification of challenges and evaluation of stakeholder priorities

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

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

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

Clinics produce a smaller quantity of waste per patient than hospitals (Pruss-Ustun et al., 2013), and hazardous wastes are mainly composed by sharps and infectious. Only four clinics, two owned by the MoH and two by UNRWA, were visited. Information about other clinics was directly or indirectly collected by the stakeholders met.
Therefore, the sample was not completely representative of all the clinics, but information was consistent, and results were deemed reliable. Finally, the overview of HCWM was obtained through information triangulation from both meetings and stakeholder analysis.

3. Results

National level: analysis of regulation, legislative framework and guidelines

At the time of the study there was no clear regulation about HCWM in the Gaza Strip. Only a few definitions (e.g. “hazardous substance” and “hazardous waste”) were provided by the Palestinian Environmental Law (President of the Palestinian Authority, 1999), while specific terms like “medical waste” were left undefined. The Environmental Quality Authority (EQA) had the responsibility to define the activities and procedures for waste management in coordination with the specialized agencies, and to monitor law enforcement. In the National Strategy for SWM in the Palestinian Territory 2010-2014 (Palestinian National Authority, 2010), Strategic Objective Five dealt with medical, hazardous, and special wastes. In particular, the Authority aimed at creating an inventory and tracking system, and establishing suitable treatment plants for medical waste, though “... there are no Palestinian standards for dealing with special, hazardous, and medical wastes...” (Palestinian National Authority 2010, p. 5).
Although not clearly defined, responsibility to manage hazardous HCW was generally attributed to MoH, while Municipalities and Solid Waste Management Councils were in charge of the non-hazardous waste, based on the Public Health Law (Palestinian Legislative Council, 2004).

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

Due to the internal Palestinian political conflict, officers from the same Ministry (e.g. Ministry of Health) in the Gaza Strip and West Bank had little interaction, and practically were independent structures, with specific regulations, recommendations and plans. At the Gaza Strip level, Recommendations of the committee of the directorate of the medical wastes in the Ministry of Health, October 2010 (Ministry of Health, 2010) required the establishment of a committee to classify waste, to introduce an appropriate segregation system and to monitor its application. Medical waste incinerator situation in Ministry Of Health of Gaza, 5 October 2011 (Ministry of...
Health, 2011b) reported the existing situation concerning incineration in the Gaza Strip, and certified the lack of a segregation system, the old and poor condition of incinerators, and their risks to public health. *Incineration run protocol* (Ministry of Health, 2011c) set some general incineration procedures. Finally, some documents about IPC were officially present, like “*Infection Prevention and Control Protocols*” (Ministry of Health, 2004), but they were not being implemented at the time of the study.

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

Health-care was provided by both public and nongovernmental actors. Public HCFs were owned and managed by either MoH or military services in Palestine (MSP, also called Palestinian Military Medical Services PMMS), while non-governmental HCFs were managed by private companies and local or international NGOs. UNRWA ran its own facilities, providing primary health-care to refugees. In 2010, some 1,002,329 people accessed UNRWA health services (UNRWA, 2011). HCFs were divided into clinics, which provided mainly primary services and dealt with outpatients only, and hospitals, which provided secondary and tertiary services. Public clinics had four levels according to the health services provided. Non-governmental
facilities did not follow specific rules (Regional Health Systems Observatory and EMRO, 2006). Table 1 presents the number of HCFs and main available statistics for each. The Ministry of Health (2011a) reported a different number of non-governmental hospitals, clinics and beds available. The lack of an univocal recording system, in particular regarding non-governmental HCFs is evident.

| TABLE 1 HERE |

The most recent data estimated a HCW production of 730 tonne/month in the Gaza Strip, but it was actually based on 2004-2008 surveys (PCBS, 2009). In 2011, the MoH estimated that incinerators burnt about 4.5 – 5 tonnes/month (Ministry of Health, 2011b), but no weighing or reliable estimations were available about general HCW production and composition. The Master Plan for Healthcare Waste Management West Bank/Gaza Strip was the most up to date study and was still considered valid by all the stakeholders. It estimated a production of 2,003 kg/day (400 kg/day of hazardous waste) in 2004, considering 1.306 kg/bed/day and a BOR of 80% (1,534 occupied beds out of 1,917) (Home Engineering Unltd et al., 2005a). The Feasibility Study for the Implementation of Healthcare Waste Master Plan in West Bank/Gaza Strip reported slight differences, but the estimation of hazardous waste production was similar (Home Engineering Unltd et al., 2005b). HCW was composed mainly of domestic waste (80%), while infectious waste was the main fraction of hazardous
waste. This estimation was based on a questionnaire, some visits to HCFs in the Gaza Strip and a rapid sampling campaign. However, sampling probably was carried out for only one day, analysing just one UNRWA clinic and one blood bank, and with an unclear methodology (Home Engineering Unltd et al., 2005c). Therefore the data were not completely reliable. Most of all, the final estimation considered only hospitals and thus was based on waste production per occupied bed. Unfortunately, in the Gaza Strip the number of clinics and visits cannot be accurately verified. In 2000, the Quality Improvement Project, funded by the World Bank, estimated a waste production from hospitals of 800 kg/day, out of a total HCW production in Gaza Strip of 3,800 kg/day (DHV et al., 2012). Other studies, based on questionnaires or field activities, tried to estimate HCW generation and composition (El-Hawi, 2004; Kamel, 2011; PCBS, 2000; Qumboz, 2002; Zoarob, 1997), but did not provide a significant contribution to the analysis.

Visits and meetings confirmed and integrated previous studies (DHV et al., 2012; El-Hawi, 2004; Home Engineering Unltd et al., 2005b) about the poor HCWM standards. Indeed, infectious waste and sharps management were not regulated by specific procedures, while also those concerning pharmaceutical and anatomic waste were not completely implemented (Table 2). Regarding pharmaceutical waste, for example, 200 m³ were collected and disposed in the only hazardous waste landfill of the Gaza Strip in 2010,
though encapsulation procedure was not fully respected. In 2012, about 250 m$^3$ out of 6,500 m$^3$ capacity of this landfill was filled (Solid Waste Director - Gaza Municipality, personal communication, 16/02/2012). Assuming a 0.9 density conversion factor valid in UK for both EWC code 180108 and 180109 – “cytotoxic and cytostatic medicines” and “medicines other than those mentioned in 18 01 08” respectively – (UK Environment Agency, 2014) around 180 tonnes were disposed in 2010, and further 45 tonnes in the following two years.

TABLE 2 HERE

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

3.2. National level: rapid assessment of HCFs

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

TABLE 3 HERE
During the field visits, it was documented that in HCFs every HCWM step commonly
met neither international minimum requirement (Pruss-Ustun et al., 2013) nor
indications provided by local regulation. These non-compliances are reported in Table
4, and it was the key starting point to improve the entire HCWM system in the Gaza
Strip.

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

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

Two MoH hospitals were assessed, Kamal Edwan hospital in the North governorate,
and Al Shifa hospital in Gaza City. The first was a medium size hospital with 117 beds
and an average production of 2.64±0.48 kg/occupied bed/day. The second was the
largest hospital in the Gaza Strip with 657 beds and a much smaller waste production,
0.91±0.10 kg/occupied bed/day. Infectious waste, segregated exclusively in safety
boxes, on average was 2 kg/day (i.e. 0.8% w/w) and 10 kg/day (i.e. 2.0% w/w), respectively. Therefore infectious waste segregation per occupied bed was very limited, that is 0.025 and 0.018 kg/occupied bed/day, respectively.

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

During the weighing campaign it was evident that MoH HCFs segregated and collected only sharps, using almost exclusively carton safety boxes. Further field visits confirmed that at least some private and NGO HCFs were in the same situation. UNRWA had some infectious waste segregation procedures, but all the waste, both hazardous and non-hazardous, was collected and transported by the same truck and sent to the landfill together. However, official records at the Gaza Strip level were available neither about HCW generation nor segregation in 2012 (DHV et al., 2012). Ministry of Health (2011c) estimated that incinerators in Al Shifa, Nasser and European hospitals regularly dealt with 2-2.5, 1.5 and 1 tonne/month, respectively. Only data about
incineration in Al Shifa hospital were confirmed by a record of waste burnt, with an average of 77 kg/day. Unfortunately, the incinerators in both Al Shifa and European hospitals were sometimes out of order. Therefore the Nasser hospital sometimes had to manage hazardous waste from all the HCFs in the Gaza Strip. 2011 data about Al Shifa hospital incinerator demonstrated that few HCFs sent hazardous waste for treatment. Indeed, only 15 HCFs regularly sent waste, totalling an average of 73±46 kg/day, while other 10 HCFs were considered periodic or irregular sources, with a total supply of 4 kg/day (it was not possible to estimate the related standard deviation). Thus in several HCFs waste segregation was either ineffective or even absent, and the large majority of hazardous HCW was comingled with MSW. It resulted in more than 75% of hazardous waste generated in the Gaza Strip being left untreated. This share was probably higher in reality because the overall production of hazardous waste was probably underestimated.

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

There were a number of stakeholders involved in HCWM with a complex network of relationships, as evaluated in Caniato et al. (2014b). Only MSW service providers had a clear picture of HCWM, while other actors, like MoH HCFs, WHO, private contractors in
HCFs, EQA and health NGOs, had high interest but medium-low power. The MoH was both a regulator and manager of public HCFs, and in such a position was the only stakeholder with enough power to affect HCWM. However, it was also a very complex institution and lacked financial resources.

The analysis evidently showed that technical staff dealing with HCWM suffered from the lack of a discussion platform to share practices, and develop appropriate solutions. Only official institution’s managers and representatives were usually allowed to communicate with other stakeholders, and it was particularly true especially for MoH HCFs. Finally stakeholders did not feel well trained about HCWM. Indeed, they had to rely on a few training opportunities, their initiative, and personal research using the internet. Only UNRWA staff reported having been trained specifically about this topic. However, guidance on HCWM, including training, experience sharing and pilot activities, were requested by almost all the stakeholders. Finally, it is remarkable that stakeholders gave little attention to the blockade imposed to the Gaza Strip since 2006 or to the difficult economic conditions due to it. However, a private hospital did report that sometimes buying safety boxes was more difficult and importing treatment technologies was difficult and limited.
3.5. National level: identification of challenges and evaluation of priorities

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

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

4. Discussion

4.1. Evaluation of the key findings

The results suggest that HCWM varied across the different HCFs in the Gaza Strip. A number of challenges were identified including lack of clear definitions and regulations, limited accurate data on which to base decisions and strategies, limited coordination amongst key stakeholders, limited segregation of hazardous and non-hazardous waste, limited training opportunities and treatment facilities that were not fit for purpose (and hardly used). These challenges posed significant risks to patients, staff and the community in general, as reported in several other low- and middle-
income countries (Caniato et al., 2015a; Liu et al., 2015; Ara et al., 2016; Thakur and Ramesh, 2015).

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

Several studies tried to describe HCW generation and composition, but none was able to give a reliable picture of the situation, and the gap of knowledge was still evident. For this reason verification and triangulation of data and information were considered so fundamental and received greatest attention. Nevertheless, all the hazardous waste categories should be better analysed and tracked from production to final disposal.
Indeed, all the HCWM steps were not compliant with international standards and local regulation (e.g. Pruss-Ustun et al. 2013; SBC & UNEP 2011; SSC & UNEP 2009).

Despite the limited data on HCW generation, a range of waste production of 0.9-2.7 kg/occ. bed/day looks acceptable for the Gaza Strip and similar with other countries in similar economic conditions (Pruss-Ustun et al., 2013). However, there is a need for more accurate data on which to develop evidence-based policies and strategies. Moreover, data were largely estimated on the basis of data of other studies, like bed capacity, BOR and number of patients (Ministry of Health, 2011a; WHO et al., 2011; WHO and EMRO, 2010).

According to the findings, UNRWA segregated about 22% of the waste, but then it was all transported and managed together. HCWM could be effective onsite with more effective segregation, with good results in terms of IPC. However, it was ineffective once the waste left the HCF, and was managed by the MSW service provider. Moreover, any waste segregation was almost nullified by mixing as soon as the waste was collected. In MoH clinics, waste segregation depended on the HCF size, and health-care services provided. A more effective segregation could lead not only to a reduction in public health incidences, but also to a reduced amount of waste to treat in the incinerators. A key factor in effective waste segregation and management is the provision of training, which was identified as a major concern by almost all staff. Given
its importance, the MoH should take lead responsibility for developing training programmes for all relevant stakeholders. This could be done in conjunction with the international agencies (e.g. NGOs), that operate in the Gaza Strip. Some of these programmes should be made compulsory in order to improve the standards and procedures across both the health-care and the treatment facilities.

It is particularly important to note that little attention was paid to the Gaza Strip blockade and the difficult economic conditions. Indeed, 30% of the population is below poverty line and unemployed rate is among the highest in the World (CIA, 2016). Probably such a situation was considered as given, and all the stakeholders were used to coping with it. Moreover the difficulty in the importation of items was only limitedly reported. Indeed, health-care items are only partially affected by the blockade, including those useful for HCWM. Access to suitable treatment technologies would evidently be limited and constrained. However, during recent years none has tried to import any systems to the best of the authors’ knowledge. Finally the situation has an evident impact on HCWM, as all the aspects of people life in the Gaza Strip but with an indirect link, thus often neglected. For example, very few HCF staff can rarely attend training sessions out of the Gaza Strip, and the presence of trainers coming from abroad is strongly limited by the situation and depending on access permits. Therefore it is very difficult for HCFs to have clear references for inspiration. In general it is
already hard to provide minimum standards of the service — especially during violence escalations — thus a complex issue as HCWM is rarely a priority for health-care service providers.

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

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

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

Finally, the analysis allowed the development of a program of intervention, based on the field work and the system’s needs (Table 8).
4.3. About the methodology

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

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

The estimation of HCW generation was difficult, due to the lack of adequate resources. Indeed Kamal Edwan hospital presented a large production per occupied bed, while in Al Shifa it looked more realistic. However, effective bed occupancy during any weighing campaign should have been considered, as well as other factors like hospital size, health-care services provided and specific level of management. Similar
considerations should be applied to the data from the clinics. Utilization statistics and the estimations calculated were not particularly reliable due to the shortage and poor quality of data, as is typical for similar situations (e.g. Manga et al., 2011; Caniato et al., 2015a). However, estimations of HCW coefficients gave a rough indication of total HCW production and hazardous component, and in particular demonstrated that a large quantity of hazardous HCW was mismanaged. Moreover it was possible to predict where the largest production of hazardous waste was concentrated. The triangulation of this data with the HCFs segregating at least part of the waste allowed identification of the main points of concern, and the development of the program of intervention. Although it was not stated directly by HCWM stakeholders, the program was based on their opinions and priorities. Therefore the process was implicitly participated and experience-based. It did not only identify some humanitarian responses, but suggested a holistic program of intervention which can address the HCWM system improvement for a certain period. Keeping the focus on both the global (i.e. the Gaza Strip) and the local (i.e. the HCF) level is the most appropriate strategy to achieve an effective and sustainable improvement of HCWM. Finally, such an in-depth data collection and triangulation process was necessary to draw a reasonably acceptable picture of the situation in the area of intervention, including some quantitative benchmarks. The extensive use of locally available reports
and documents was mandatory, due to the lack of more reliable data sources. Even in
the case of an intervention on a very limited area (e.g. a single hospital), such a process
should be undertaken in order to provide the analysis with an adequate
contextualization and set reasonable targets of improvements. In particular, the goal
of conservation of resources requires knowledge of the context, including barriers,
threats and opportunities.

5. Conclusions

At the time of the study, the Gaza Strip faced and continues to face significant social,
political and humanitarian challenges. These challenges placed a strain on the
availability of resources to provide effective services, including for HCWM. However, it
is evident that there was a link between the management of HCW (and indeed waste
in general), and the partial alleviation of some of these challenges. For example, more
effective management of HCW could lead to reduction in the public health and
environmental risks posed not only to staff employed in the provision of health-care
and management of waste, but also the community at large. A more sound
management of HCW could also lead to a better use of resources, with an impact on
financial performances of HCFs. The methodology proposed proved to be applicable in
a humanitarian crisis. It could collect a large quantity of information, evaluate its
quality and address specific analyses through integration of the data. In particular the
need for additional analyses is reduced because they entail particularly relevant costs
and risks for field staff in a humanitarian context. Recommendations were developed
starting from the challenges identified, considering opinions and priorities of all the
stakeholders involved and the resources actually available. While so many barriers
have been identified, given the resource-strained nature of the situation, some of the
recommendations suggested could be implemented at low or no costs (e.g.
introduction of technical specifications and guidelines, and provision of training). In
particular, in order for these benefits to be realised, it is important to improve the
governance structures and coordination amongst key stakeholders within the Gaza
Strip, including local and international organisations. Despite the major hurdles to be
overcome, effective management of waste and resources during a prolonged and
serious humanitarian crisis such as is the case in the Gaza Strip is possible, and can lead
to significant environmental and public health outcomes. However, effective, holistic
and coordinated strategies have to be put in place for these outcomes to be realised.

Acknowledgements

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Table 1 – Hospitals and clinics in the Gaza Strip
<table>
<thead>
<tr>
<th>Reference</th>
<th>WHO et al. 2011</th>
<th>WHO &amp; EMRO 2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>HCFs</td>
<td># of facilities</td>
<td># of beds</td>
</tr>
<tr>
<td><strong>Hospitals</strong></td>
<td>27</td>
<td>2,697</td>
</tr>
<tr>
<td>MoH</td>
<td>13</td>
<td>2,009</td>
</tr>
<tr>
<td>PMMS</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>NGOs</td>
<td>14</td>
<td>688</td>
</tr>
<tr>
<td>Private</td>
<td>13</td>
<td>63</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Clinics</th>
<th># of facilities</th>
<th>Facilities with buildings in bad conditions</th>
<th># of facilities</th>
<th># of visits**</th>
</tr>
</thead>
<tbody>
<tr>
<td>MoH</td>
<td>54</td>
<td>9</td>
<td>9</td>
<td>56</td>
</tr>
<tr>
<td>UNRWA</td>
<td>20</td>
<td>N.A.</td>
<td>20</td>
<td>N.A.</td>
</tr>
<tr>
<td>NGOs</td>
<td>57</td>
<td>N.A.</td>
<td>34</td>
<td>N.A.</td>
</tr>
</tbody>
</table>

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

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

<table>
<thead>
<tr>
<th>HCWM step</th>
<th>Pharmaceutical waste</th>
<th>Anatomic waste</th>
<th>Infectious and sharps waste</th>
</tr>
</thead>
<tbody>
<tr>
<td>Definition and segregation</td>
<td>MoH HCFs segregated parts of expired medicines or leftover without any clear criterion or specific procedures.</td>
<td>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.</td>
<td>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.</td>
</tr>
<tr>
<td>Collection and onsite storage</td>
<td>Pharmaceutical waste was stored without specific attention.</td>
<td>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, placetas could not be stocked properly, thus they were directly disposed in plastic bags with general MSW, sometimes with 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.</td>
<td>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).</td>
</tr>
<tr>
<td>Haulage</td>
<td>General Directorate for Pharmacy within the MoH periodically collects from MoH HCFs and sends to Johr al Deek landfill.</td>
<td>Hospitals and nongovernmental clinics had their own haulage system. MoH provided a monthly collection service, but without a fixed schedule.</td>
<td>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.</td>
</tr>
<tr>
<td>Treatment</td>
<td>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.</td>
<td>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.</td>
<td>Bottom ash was mixed with MSW. Incinerators were not provided with air pollution control devices, thus fly ash was not produced.</td>
</tr>
<tr>
<td>Residue disposal</td>
<td>No official data were available.</td>
<td>No data were available.</td>
<td>No clear data were available.</td>
</tr>
<tr>
<td>Quantity estimation</td>
<td>No official data were available.</td>
<td>No data were available.</td>
<td>No clear data were available.</td>
</tr>
<tr>
<td>Cost</td>
<td>Collection and transportation costs were not available. Disposal costs were 150 NIS/m³ (about 39 USD/m³).</td>
<td>No data were available.</td>
<td>No data were available.</td>
</tr>
</tbody>
</table>
Table 3 – HCWM in HCFs in 2012 according to the health service providers

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

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.

Table 6 – Estimation of HCW coefficients and total production

<table>
<thead>
<tr>
<th>SOURCE</th>
<th>ESTIMATION</th>
<th>TOTAL PRODUCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLINICS* Total visits/year</td>
<td>HCW (kg/visit)</td>
<td>Hazardous HCW (%)</td>
</tr>
</tbody>
</table>
### Table 7 – Estimation of hazardous HCW production in kg/day and distribution per governorate

<table>
<thead>
<tr>
<th>CLINICS</th>
<th>North Gaza (kg/day)</th>
<th>Gaza City (kg/day)</th>
<th>Middle Zone (kg/day)</th>
<th>Khan Younis (kg/day)</th>
<th>Rafah (kg/day)</th>
<th>TOT (kg/day)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>MoH</td>
<td>7±3.1</td>
<td>15±6.6</td>
<td>5±2.2</td>
<td>7±3.1</td>
<td>4±1.8</td>
<td>37±16.7</td>
<td>22%</td>
</tr>
<tr>
<td>UNRWA</td>
<td>21±3.5</td>
<td>43±7.2</td>
<td>29±4.8</td>
<td>8±1.3</td>
<td>24±4.0</td>
<td>125±20</td>
<td>72%</td>
</tr>
<tr>
<td>NGO</td>
<td>2±0.3</td>
<td>4±0.7</td>
<td>1±0.2</td>
<td>4±0.7</td>
<td>1±0.2</td>
<td>11±2.0</td>
<td>6%</td>
</tr>
<tr>
<td><strong>SUB TOTAL</strong></td>
<td>30±6.9</td>
<td>61±14.4</td>
<td>34±7.2</td>
<td>19±5.1</td>
<td>29±5.9</td>
<td>173±39</td>
<td>100 %</td>
</tr>
<tr>
<td></td>
<td>17%</td>
<td>35%</td>
<td>20%</td>
<td>11%</td>
<td>17%</td>
<td>100%</td>
<td></td>
</tr>
</tbody>
</table>

### HOSPITALS

<table>
<thead>
<tr>
<th>CLINICS</th>
<th>North Gaza (kg/day)</th>
<th>Gaza City (kg/day)</th>
<th>Middle Zone (kg/day)</th>
<th>Khan Younis (kg/day)</th>
<th>Rafah (kg/day)</th>
<th>TOT (kg/day)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>MoH</td>
<td>26</td>
<td>212</td>
<td>26</td>
<td>105</td>
<td>18</td>
<td>386</td>
<td>76%</td>
</tr>
</tbody>
</table>

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.
<table>
<thead>
<tr>
<th></th>
<th>9</th>
<th>0</th>
<th>0</th>
<th>0</th>
<th>0</th>
<th>9</th>
<th>2%</th>
</tr>
</thead>
<tbody>
<tr>
<td>NGO</td>
<td>13</td>
<td>57</td>
<td>9</td>
<td>24</td>
<td>0</td>
<td>104</td>
<td>20%</td>
</tr>
<tr>
<td>Private</td>
<td>0</td>
<td>12</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>12</td>
<td>2%</td>
</tr>
<tr>
<td><strong>SUB TOTAL</strong></td>
<td>48</td>
<td>280</td>
<td>35</td>
<td>129</td>
<td>18</td>
<td>510</td>
<td>100%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>North Gaza (kg/day)</th>
<th>Gaza City (kg/day)</th>
<th>Middle Zone (kg/day)</th>
<th>Khan Younis (kg/day)</th>
<th>Rafah (kg/day)</th>
<th><strong>TOT (kg/day)</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TOTAL PRODUCTION</strong></td>
<td>78</td>
<td>341</td>
<td>69</td>
<td>148</td>
<td>47</td>
<td><strong>683</strong></td>
</tr>
<tr>
<td>%</td>
<td>11%</td>
<td>50%</td>
<td>10%</td>
<td>22%</td>
<td>7%</td>
<td>100%</td>
</tr>
</tbody>
</table>

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