Health Care Waste production: measures and estimates in "V. Cervello" Hospital, Palermo, Italy.

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ABSTRACT

A monitoring work was carried out in May/June 2007 in one large hospital located in Palermo. The monitoring consisted in weighing the infectious waste containers filled in some Departments purposely chosen. As a second stage of the work a comparison was attempted between the results obtained from the waste production monitoring and the Hospital's purchases recorded in the same time. A restricted list of purchased products out of the general one was extracted. Such list allows one to calculate approximately the mass of medical devices purchased and their composition. To these materials a reasonable change in humidity after use was attributed. It was possible in this deductive way to draw a probable amount and composition of waste materials really arising from health care activities (commonly – though not rigorously – considered all *infectious*), whose characters is forbidden to ascertain by direct inspection.

INTRODUCTION

Sanitary Wastes – also called Medical, or Health Care Wastes (HCWs) – are a classical topic in sanitary engineering and perhaps the oldest. Broad surveys are undertaken and published in successive stages, at every scale: national, regional and world-wide.

At the international level a comprehensive Report has been fairly recently published by WHO – World Health Organization [1]. Although many of the concepts are common knowledge, the figures gathered and criticized by its Authors are most useful. They have therefore been arranged in the Table 1 below for easier consultation.

Of course, **surveys at the national level** can be more frequently made and more easily updated. In Italy the most general among the recent official Reports is the one published by *APAT – Agenzia per la Protezione dell'ambiente ed i Servizi Tecnici* in 2008 [2]. Therefore it will be extensively quoted in this Introduction.

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Table 1. Figures of medical waste generation rates.
From WHO [1], rearranged by the Authors.

Criterion / Object	According to national income level (kg/head of population x yr)			According to source size (high income Countries) (kg/bed x d)				By world region (kg/bed x d)						
	HIGH	MEDIUM	LOW	UNIVERSITY HOSPITAL	GENERAL HOSPITAL	DISTRICT HOSPITAL	PRIMARY HEALTH-CARE CENTRE	North America	Western Europe	Latin America	Eastern Asia - high-income	Eastern Asia — middle-inc.	Eastern Europe	Eastern Mediterranean
all health-care waste	1.1 – 12	0.8 – 6	0.5 – 3	4.1 – 8.7	2.1 – 4.2	0.5 – 1.8	0.05 – 0.2	7– 10	3 – 6	3	2.5 – 4	1.8 – 2.2	1.4 – 2	1.3 – 3
hazardous health-care waste	0.4 – 5.5	0.3 – 0.4	n.d.											

For this paper's purposes, the most interesting figures in APAT 2008 Report are the following.

- When referred to resident people, the nationwide generation rate of HCW in Italy (2001 – 2004) is steady about 2.4 (kg / capita x yr) if wastes of the whole EWC Under-class 18 01 (see Appendix) are dealt with.
- The amount per bed and day in Italy is close to 1.4 kg. The amount per conventional day of stay is over 1.7; the two figures do not coincide because the number of beds taken for the ratio is the *total available* in the hospitals, whereas the days of stay are *actual*, that is somewhat less. Incidentally, the statistics are complicated by the fact that a bed featured by a Department of Day Hospital / Day Surgery can accommodate for more than one patient the same day; so, that bed will apparently generate twice the waste of an *ordinary* one.
- About public Hospitals in Italy, the APAT Report confirms the general knowledge, that larger facilities exhibit higher waste generation rates. Figures from Italy, however, appear lower than the ones assessed by WHO (see Figure 1).

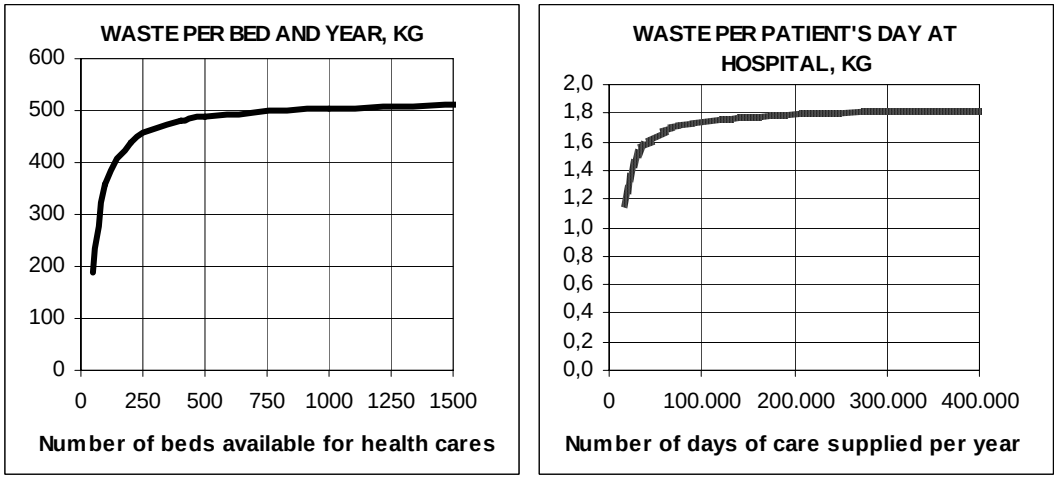

Figure 1. HCW unit generation rates in Italy, after APAT 2008 (redrawn).
According with (a) the Institution's size; (b) the days of care supplied.

Actually, the statistical correlation between the data shows that even in the largest Italian hospitals the production does not exceed 1.4 kg per bed and day, that is the figure attributed by WHO to plain "District Hospitals".

At local level, special attention deserves a broad and thorough survey carried out in Italy by Liberti and co-workers in 1991-92, published in 1994 and 1996 [3, 4]. Liberti's investigation included 2 public and 1 private hospital, with 164 Departments and 2.500 beds total; the monitoring was carried out for 50 weeks with 100 people of various duties and ranks.

The object of their sampling and measuring were the boxes defined - and used by the staff - as "Infectious Waste Containers". Exceptionally, the researchers were allowed to open 120 boxes and the bags inside, and to sort the content into 7 components for following analysis (physical and chemical). During the survey no modification of the hospital's operating rules was made.

The main findings of Liberti and co-workers appear the following.

- The overall generation rate of Infectious Healthcare Waste (IHW) in the 3 hospitals was 0.44 kg/(bed on duty × day). Non-hazardous waste did not exceed 2.5 kg.
- The average composition of IHW determined by Liberti has been expressed as a graph in Figure 2. Plastics and paper content appears dominant in the whole mass of waste: they account for around 80 % of the total. Note that "Liquids" component includes those contained in the drainage bags.
- Gross specific gravity of waste was 0.11; the Authors remarked that in some hospitals it appeared customary to close and seal the containers well before they were really filled up. Staff in a private institution, however, looked like behaving more carefully, achieving specific gravities as high as 3 times [4]. The Authors' suggestion was to replace the 60-dm^3 boxes with smaller and more practical 40-dm^3 ones.
- The analytical laboratories contributed to the generation of IHW by 23% of the entire mass (besides the possible production of chemical risk waste).

It was not our aim to replicate the survey, indeed unique, made by Liberti and co-workers. Instead, it was investigated the possible correlation between the results from the monitoring of waste production in 4 selected Departments and the purchases of remedies made and recorded by the Hospital in the same time span. This research entailed a direct monitoring work which consisted in weighing for 15 days the containers for infectious waste filled by the personnel.

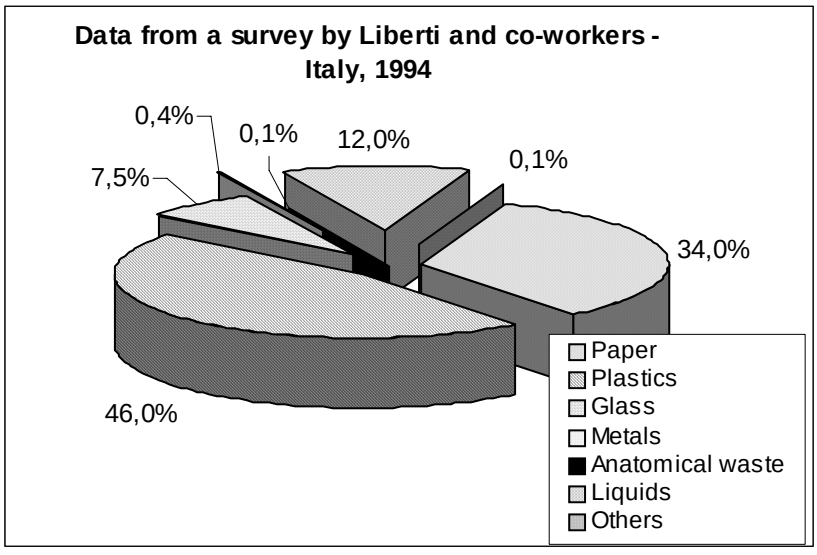

Figure 2. Average composition of IHW in Policlinic Hospital, Bari, Italy [3].

METHODS AND MATERIALS

The survey plan

Several are the daily questions arising in managing medical waste. In Europe, referring to the EWC (see APPENDIX), they can be expressed in this way.

- Do the wastes that are dropped and sealed in the special bins really belong all to the type 18 01 03* *(Waste whose collection and disposal is subject to special requirements in view of the prevention of infection)*?
- Is it sure that it is not being added any non-infectious waste such as type 18 01 04 *(Waste … not subject to special requirements …, e.g. dressings, plaster casts, linen, disposable clothing, diapers)* or 18 01 09 *(Medicines other than those mentioned in 18 01 08)* and even leftover meals?
- Maybe also types 15 01 02 (Plastic packaging) and 15 01 07 (Glass packaging) are being un-necessarily associated to supposed infectious waste?
- How much do the wastes really weigh?

Methods for gathering and relating data in hospitals and – generally – in health care facilities have been published for instance by UNEP - WHO [5]. The aim of the Authors here was to verify the possible consistence between the amounts of remedies purchased by the Institution - coming from official records - and the amounts of waste produced.

A difficulty in the research stayed in that, hospital staff hardly ever get directions to weigh the waste containers at their exit from the hospital. Most of situations, the daily weight is *presumed* from the number of containers consigned to the collection Firm.

A purposeful monitoring work was therefore carried out in May 2007 in one large Italian health care facility: *Vincenzo Cervello* Hospital located in Palermo. In details, this Hospital, with its 34 Departments and 418 sleeping accommodations, provides services of diagnosis and care of different specialities, either in admission system or in day hospital (DH).

The monitoring consisted in weighing for 15 days the containers for infectious waste filled by the personnel in some Departments purposely chosen.

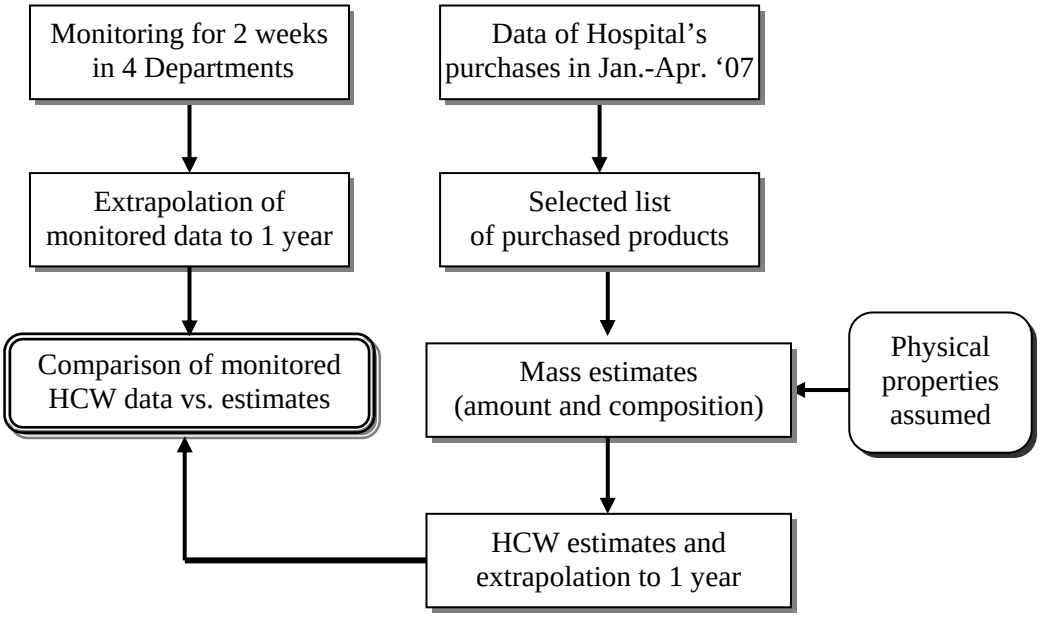

Figure 3. Procedure followed in this work for HCW production for year 2007

The Departments selected for the monitoring were four, namely: General and Emergency Surgery; 1st Resuscitation; Emergency Room; and Haematology. These Departments were selected for this study because they were expected to exhibit markedly different composition and production rates of waste material.
The results of this stage of work have already been published elsewhere [6].
As a second stage of the work a comparison was attempted between the results obtained from the waste production monitoring - extrapolated to one year - and the purchases of remedies of the Health Care Facility recorded in the same time.
Of course most of the medical devices undergo deep modifications when are used, mainly in humidity content, and the Authors made reasonable assumptions to take it into account.
From Hospital Pharmacy's orders a restricted list of products out of the general one - that includes more than 70 items - was extracted. Such list allows one to calculate the approximate mass of medical devices purchased and their "clean" composition, distinguished into cellulose, plastics, glass and steel. The "dirty" composition was then calculated.
It was possible in this deductive way to draw a probable composition of health care waste materials, which is forbidden to ascertain by direct inspection.
The procedure followed in this study is depicted in the flow sheet in Figure 3 above.

Waste measures: data from monitoring

Monitoring consisted in weighing the 60-dm^3 waste containers as they were – i.e. hermetically sealed and ready to be taken away for disposal – for fifteen days in the four Departments selected. This work was carried out in May/June 2007; monthly and annual waste production were then deduced [7]. The results are arranged in Table 2 below.

Pharmacy's records: a whole year's set of data and their elaboration

The orders of the Hospital's Pharmacy are the basis for analysing the uses of medicines and medical devices by the institution. Data concerning products purchased for the whole year 2006 and for the early four months of 2007 were made available to Authors.
The selected list of remedies purchased is reported in Table 3: for each item dry and wet mass were calculated.
For absorbent products it was supposed that:
a – they were dropped into infectious waste bag;
b – the mass increase due to liquids absorption by dry mass was the following: under-pads, 50 %; adult diapers, 50 %.
For bottles, bags and similar, it was assumed that bottles and bags bought full (such as glucose and physiological solution bottles) were disposed of completely empty; the other hand, that drainage bags - bought empty - were discarded full of organic liquids. [7, 8]

Table 2. HCW production arising from monitoring of the 4 Departments

Departments	HCW production (kg/month)	HCW production (kg/year)	Production per bed on duty (kg/day)	Specific gravity (kg/dm^3)
General and Emergency Surgery	622	7.464	1.43	0.133
1st Resuscitation	500	6.000	3.10	0.078
Emergency Room	290	3.480	----	0.110
Haematology	518	6.216	0.78	0.114

Table 3. Selected list of products purchased and relative presumed discarded mass at "V. Cervello" Hospital (year 2006)

Type of product or device	Material	Number purch. / yr	Mass purch. / yr (kg)	Assumed dry mass / yr (kg)	Discarded mass / yr (kg)
Vial (10 ml)	Glass	55 000	770	220	**220**
Bottle (250 and 500 ml)	Glass	120 000	69 300	24 300	**24 300**
Enema set	Plastics	4 800	600	24	**24**
Physiological Bag	Plastics	19 000	10 640	1 140	**1 140**
Drainage Bag	Plastics	3 456	622	622	**2 696**
Bladder and Venous Catheter	Plastics	77 100	2 191	2 191	**2 191**
Disposable infusion set	Plastics	140 000	3 500	3 500	**3 500**
Drainage, diverse	Plastics	720	72	72	**72**
Latex Gloves [a pair]	Latex	60 000	360	360	**360**
Syringe needle	Steel	111 000	444	444	**444**
Syringe	Plastics	500 000	2 500	2 500	**2 500**
Test Tube	Plastics	600 000	6 000	6 000	**6 000**
Under-pads	Cell+Pla	120 000	13 560	13 560	**20 340**
Adult diapers	Cell+Pla	60 200	8 670	8 670	**13 005**
Fringed and non-Fringed Lint	Cotton	9 500	475	475	**475**
Total		***( )***	***119 704***	***64 078***	***77 267***

Figure 4 shows the details of dry and wet mass calculation for four items chosen as example. In one line of the spreadsheet (e.g. line 3 for "glass bottle") formulae used by the Authors are specified and corresponding figures are shown in the line below (e.g., line 4 for "glass bottle"). Modification of liquid content after use plays in the calculations in column "I". This column represents the mass at the disposal. Among the 4 items listed, only for "glass bottle" dry and wet mass are the same.
Assumed wet mass calculated through the spreadsheet is the discarded mass of Table 3.

	A	B	C	D	E	F	G	H	I
1	**Item**	**Material**	**Nr. purchased / yr**	**Gross mass (g)**	**Contained mass (g)**	**Tare (g)**	**Mass purchased / yr (kg)**	**Assumed dry mass / yr (kg)**	**Assumed wet mass / yr (kg)**
2	……								
3	**Bottle 500 ml**	Glass	60000	755	500	=D3-E3	=C3*D3/1000	=C3*F3/1000	=H3
4			60000	755	500	255	45300	15300	15300
5	……								
6	**Drainage Bag**	Plastics	3456	=E6+F6	600	180	=C6*F6/1000	=C6*F6/1000	=H6+C6*E6/1000
7			3456	780	600	180	622	622	2696
8	……								
9	**Under-pads**	Cell+Pla	120000	113	113	0	=C9*D9/1000	=G9	=H9+0,5*$H9
10			120000	113	113	0	13560	13560	20340
11	**Adults diapers**	Cell+Pla	60200	144	144	0	=C11*D11/1000	=G11	=H11+0,5*$H11
12			60200	144	144	0	8670	8670	13005
13	…...								

Figure 4. Example of dry and wet mass calculation for some items in a spreadsheet

Elaboration of data from Table 3 leads to the probable material composition at the discarding moment of Table 4.

Table 4. Probable HCW material composition for "V. Cervello" Hospital (year 2006)

HCW Material composition	Mass (kg)	Fraction %
Cellulose	20.104	26,02
Glass	24.520	31,73
Latex	360	0,47
Plastics	18.650	24,14
Steel	444	0,57
Liquids	13.189	17,07
Total	***77.267***	***100,00***

Material composition including liquids (imbibed and/or contained) is graphically represented in Figure 5 a) and without liquids in Figure 5 b). Cellulose, glass and plastics represent the most consistent solid mass fractions, steel and latex being negligible.
Cellulose percentage coming from Table 4 is presumably lower than the actual value because for certain items (among which, sanitary napkins) purchase data were not available in pharmacy's files. This data blank affects mainly the percentage of cellulose in the waste.

Estimates: HCW production in year 2007

From Hospital's Pharmacy data for products and devices transferred to each of the four Departments – covering the time from January to April 2007 – the *presumed* HCW production was calculated. Calculations were carried out in the same way explained above.
The "selected list" of purchased products and relative presumed mass of wastes produced are shown in Table 5.
A basic hypothesis was that all purchased products were used in the same year of purchase. In other words, no products were assumed to be stored in stock, so that they contributed entirely to HCW production.
HCW production obtained in this manner was extrapolated to one year. These presumed HCW production figures – coming from Hospital's Pharmacy purchases data records and following transfer to Departments – were used for the comparisons with monitoring data for the same year 2007 presented below.

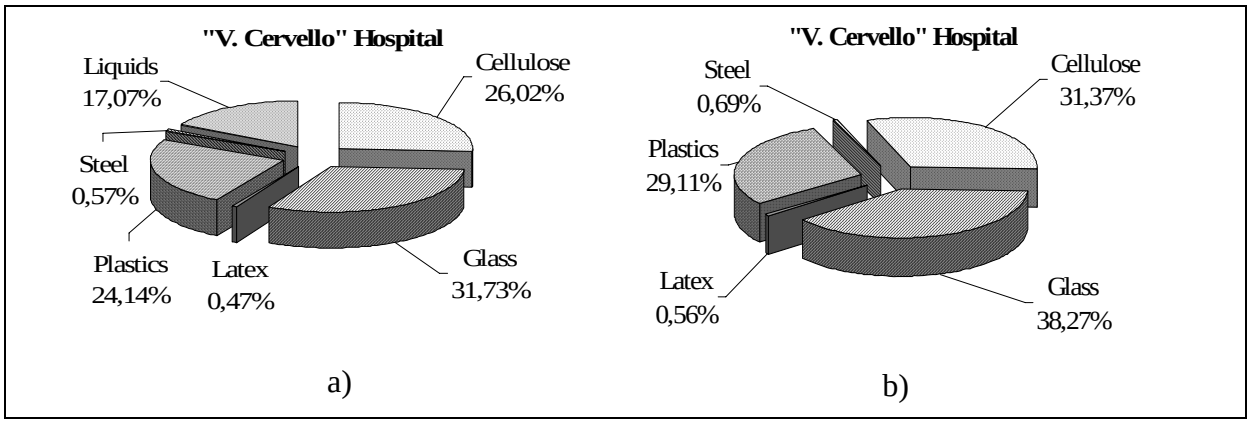

Figure 5. Probable waste material composition a) including liquids; b) without liquids. Year 2006.

Comparisons: measured amount of HCW versus presumed, year 2007

Procedure followed by Authors for comparisons can be resumed as follow:

- review of Hospital's Pharmacy purchases data records covering the period January – April 2007;
- selection of data concerning the four Departments of interest;
- selection of a list of purchased products;
- assumption for each item of percent mass increase or decrease from purchased device to waste after use (as mentioned above);
- calculation – under the hypothesis that all product were used – of HCW production in terms of mass of materials for items selected (Table 5);
- extrapolation to one year of HCW production calculated above.

The calculations that lead to figures in Table 5 are analogous to those illustrated in Table 3 and Figure 4. The last step of the procedure consists in extrapolating the total discarded mass for each Departments to one year. The last figures are those used in histograms of Figure 6 relative to the presumed HCW production coming from Pharmacy's purchases.

In short, elaboration of data, with the considerations made above, leads to histograms showed in Figure 6, where HCW mass production in one year – coming from monitoring – is compared with the one coming from pharmacy purchases in the same year.

Table 5. Selected list of products purchased and relative presumed discarded mass for the four Departments studied at "V. Cervello" Hospital (January – April 2007)

Type of product or device	**Material**	**Presumed discarded mass (kg)**			
		General and Emergency Surgery	***1st Resuscitation***	***Emergency Room***	***Haematology***
Vial (10 ml)	Glass	0,84	24,78	6,03	13,72
Bottle (250 and 500 ml)	Glass	470,40	633,59	2984,95	994,16
Physiological Bag	Plastics	722,40	327,04	100,80	506,80
Drainage Bag	Plastics	23,40	312,00	0,00	0,00
Bladder and Venous Catheter	Plastics	0,10	32,30	3,40	0,60
Disposable infusion set	Plastics	90,00	73,75	150,88	98,25
Latex Gloves [a pair]	Latex	64,02	124,95	139,11	72,57
Syringe needle	Steel	2,00	32,00	7,20	8,36
Syringe	Plastics	41,96	71,12	145,60	78,05
Test Tube	Plastics	25,49	17,50	209,08	102,60
Under-pads	Cell+Pla	315,27	155,94	249,17	254,25
Adult diapers	Cell+Pla	278,64	112,32	108,00	73,44
Lint	Cotton	103,10	569,50	213,00	64,00
Total		***2 137,62***	***2 486,79***	***4 317,22***	***2 266,80***

RESULTS AND DISCUSSION

Thanks to data provided by Hospital Management, for "V. Cervello" Hospital (Palermo, Italy) HCW material composition was estimated for year 2006. Main waste fractions are cellulose (26 % wet basis), plastics (24) and glass (32). The percentage of cellulose calculated could be slightly underestimated.

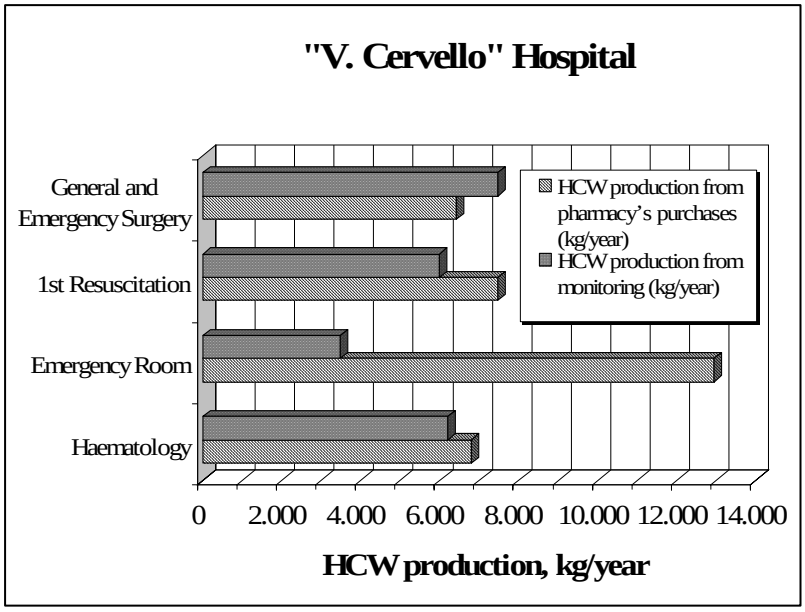

Figure 6. HCW production: comparison between monitoring results and those coming from Hospital's Pharmacy purchases

The amounts weighed in 4 Departments in 2007, extrapolated to the entire year, show that in 3 of them less waste is actually discarded than forecast from the amount of remedies supplied to them.

For Resuscitation and for Haematology the differences between the two HCW production figures are around -14 %, which is a satisfactory agreement. A higher estimate of the water content in waste would easily lead to the balance.

For "Emergency Room", however, Pharmacy purchases lead to a forecast HCW production value even three times that from monitoring.

Indeed, analyzing Pharmacy's data, the number of glass bottles transferred to Emergency Room in year 2007 (2.690 for 500 ml bottles and 2.385 for 250 ml ones in the first 4 months) appears high compared with that transferred to other Departments.

Probably for Emergency Room there was an occasional restoration of glass bottles stock, and this has led to an overestimated expectation of HCW production.

Only the General and Emergency Surgery Department generated more waste than expected: difference is around +16 %. The Authors suggest that the longer patients' stays for care may lead to *parasitic* waste dropping in the infectious waste bag.

The production rates calculated by Authors (Table 2) are greater than Infectious Waste average production determined by Liberti (0,44 kg/bed/day) [3, cit.]. Differences with APAT's figures however (national average 1,3 kg/bed/day) are smaller [2, cit.].

Also the waste composition determined in this work differs from that by Liberti. The most evident difference is for *glass*: the Authors' percentage is more than four times Liberti's one. This is probably due to insufficient care in source separation of materials before waste disposal in the case-study hospital. For *paper / cellulose*, accordance between the two percentages is acceptable; finally, for *plastics* Liberti's figure is double than ours.

CONCLUSION AND REMARKS

Forecasting HCW production starting from the recorded Pharmacy purchases demonstrated itself in our case-study hospital a useful first-approximation tool.
The rates determined in the case-study are, in general, higher than those monitored: differences can be considered acceptable, except when particulars events occur during the time span considered.
The composition calculated by Authors for year 2006 differs from others found in literature inasmuch is much richer in glass.
Since glass fraction in medical waste is made up mainly by empty containers of medicines; and, unless they are contaminated by cytotoxic and cytostatic substances, once the needle is detached these bottles are neither infectious nor dangerous; this glass could legally be collected separately and recycled.
Plastics are probably mixed: i.e., made up of emptied infusion bags + drainage bags full of organic liquids. Of course only the former are recyclable.
A closer inspection of data by the Hospital Management would yield the measure of the potential for recovery / recycle, so skipping unnecessary and indiscriminate incineration as waste.
From Author's grab survey, monitored data in year 2007, in terms of HCW mass produced in a year, are in good agreement with those deduced from Hospital Pharmacy's purchases for three of the four Departments studied. For "Emergency Room", probably there had been an occasional restoration of stock for some products (glass bottles): this resulted in a marked overestimation of HCW produced.
To improve the analysis carried out in this work some actions ought to be ordinarily undertaken in Hospitals. First, regular and longer surveys that would reduce errors or help in identifying them. Further, a monitoring of all Departments which would allow comparisons with global data available. Finally, handier information about the transfer of Pharmacy's purchases to Departments.
The efforts suggested here in this direction would yield more realistic estimates of waste to be collected; a systematic weighing of carts and vehicles would provide the objective confirm. The economical implications of such better knowledge appear obvious.
In investigations about hospital wastes attention must be paid to the fact that production, in quality and quantity, depends not only on types of Departments but also on sanitary services performed by the single one.
For instance, Day Hospital and Emergency Room (or First Aid), for their characteristics can provide significantly different figures respect to other Departments of similar size. Hence it is advisable to manage these data separately.

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ACKNOWLEDGMENTS

The Authors are glad to thank Dr. G. Filippazzo - Vice Chief, Health Services; and Dr. A. Guttadauro - Chief of Pharmacy Services of "V. Cervello" Hospital (Palermo) for their permission and help in consulting and interpreting the data records.

The Libraries of *Università degli Studi di Cagliari, Dipartimento di Ingegneria Chimica e Materiali* and of *Università degli Studi di Palermo, Dipartimento di Ingegneria Idraulica e Applicazioni Ambientali* were helpful in procuring less common papers necessary for this work.

APPENDIX

European Commission Decision of 3 May 2000 (…) establishing a list of wastes (…) (2000/532/EC)

EWC – European Waste Catalogue - Abstract

09	**WASTES FROM THE PHOTOGRAPHIC INDUSTRY**
09 01	**Wastes from the photographic industry**
09 01 01*	Water-based developer and activator solutions
09 01 02*	Water-based offset plate developer solutions
09 01 03*	Solvent-based developer solutions
09 01 04*	Fixer solutions
09 01 05*	Bleach solutions and bleach fixer solutions
15	**WASTE PACKAGING; ABSORBENTS, WIPING CLOTHS, FILTER MATERIALS AND PROTECTIVE CLOTHING NOT OTHERWISE SPECIFIED**
15 01	**Packaging**
15 01 02	Plastic packaging
15 01 03	Wooden packaging
15 01 04	Metallic packaging
15 01 05	Composite packaging
15 01 06	Mixed packaging
15 01 07	Glass packaging
15 01 08*	Packaging containing residues of - or contaminated by - dangerous substances
18	**WASTES FROM HUMAN OR ANIMAL HEALTH CARE AND/OR RELATED RESEARCH (except kitchen and restaurant wastes not arising from immediate health care)**
18 01	**Wastes from natal care, diagnosis, treatment or prevention of disease in humans**
18 01 01	Sharps (except 18 01 03)
18 01 02	Body parts and organs including blood bags and blood preserves (except 18 01 03)
18 01 03*	Waste whose collection and disposal is subject to special requirements in view of the prevention of infection
18 01 04	Waste whose collection and disposal is not subject to special requirements in view of the prevention of infection, (e.g. dressings, plaster casts, linen, disposable clothing, diapers)
18 01 06*	Chemicals consisting of or containing dangerous substances
18 01 07	Chemicals other than those mentioned in 18 01 06
18 01 08*	Cytotoxic and cytostatic medicines
18 01 09	Medicines other than those mentioned in 18 01 08
18 01 10*	Amalgam waste from dental care
18 02	**Wastes from research, diagnosis, treatment or prevention of disease involving animals**
18 02 01	Sharps (except 18 02 02)
18 02 02*	Waste whose collection and disposal is subject to special requirements in view of the prevention of infection
18 02 03	Waste whose collection and disposal is not subject to special requirements in view of the prevention of infection
18 02 05*	Chemicals consisting of or containing dangerous substances
18 02 06	Chemicals other than those mentioned in 18 02 05
18 02 07*	Cytotoxic and cytostatic medicines
18 02 08	Medicines other than those mentioned in 18 02 07.