U.R. GERE

Supply of methods and data to optimize, to rationalize and to evaluate the operation of local composting in collective home or collective restaurant

PRODUCTION DE METHODES ET DE DONNEES POUR OPTIMISER, RATIONALISER ET EVALUER LES OPERATIONS DE COMPOSTAGE DE PROXIMITE EN HABITAT VERTICAL OU EN RESTAURATION COLLECTIVE

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Pour mieux affirmer ses missions, le Cemagref devient Irstea

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Introduction

Miniwaste project was initiated to design, implement and assess an innovative and sustainable strategic plan to minimize municipal organic waste in EU States. Two ways for waste reduction were selected i.e. reduce food wasting and promote in-situ composting. The productions of this project will be in particular tools like methods or software and data to manage locally these types of operation for wastes reductions.

Five partners take part to this project. These are three European municipalities i.e. Rennes Métropole, leader of this project, LIPOR and Brno, all wishing to reduce waste production through the reduction of food wasting and/or the promotion of composting. The fourth partner, ACR +, must permit to compile the various experiments as regards of local composting and reducing of waste in Europe on one hand and on the other hand must take part in the dissemination of work carried out within the framework of the project. Finally, Irstea-Cemagref takes part to this project as a scientific expert in the field of waste and especially composting. It is indeed charged to develop methods and to obtain data about the local composting operations.

Many municipalities wishing to develop operations of in-situ composting come up against the difficulty that there is a lack of data and methods to implement and optimize the operations and further to evaluate their interests and limits. Three research orientations were defined by Irstea - Cemagref. We sought to know specificities of individual composting, collective composting and the quality of the compost obtained for each of the two types of local composting.

This part of the Miniwaste project is focused on collective home composting and on operations of composting at communities producing high amounts of organic wastes as for instance collective restaurants at schools and universities. It aims to provide methods and data to rationalize and assess the collective composting operations.

Data required at first concern the amount of biowaste produced by a site for which the municipality wishes to develop a local collective composting operation. Indeed, the quantity of waste produced by the municipality may be known. For example, the residual household waste production of Rennes Métropole was estimated in 2010 at 211 kg/inbt/year (Rennes Métropole, Rapport Annuel 2010). However, it does not exist data about the production of residual household wastes by collective homes neither about the part of biowaste contained inside. It is thus necessary to determine these data and provide methods which allow their measure. This development of method and the acquisition of corresponding data were only carried out at collective homes.

Second, the existing data do not make it possible to know the quantity of organic waste which will be really diverted from the household waste by the installation of a composter. It is thus necessary to develop methods which permit to know the participation rate to the composting operation and the diverting rate i.e. the quantity of biowaste composted. Once again, this development of method and the acquisition of corresponding data were only carried out at collective homes.

Other types of methods and data are required by a municipality wishing to set-up a composting operation. These are methods or data allowing to i) choose the types of composters (ergonomy, treatment capacity, behaviour in composting etc), ii) apply the “best” composting process (bulking agent to waste ratio, residence time in fermentation then maturation etc), iii) dimension composters as function of waste diversion awaited, iv) be able to monitor composting treatment (measurement of temperature, odours, compost quality etc), v) evaluate satisfaction of people taking part to the composting operation, vi) provide to the municipality elements which allow the evaluation of the operation (costs, inhabitants satisfaction…). The data and the methods about these last parts being in progress, this report gives only an account of the methods developed and the results obtained on the quantity of organic waste produced at collective homes and the rate of diversion of organic waste by the setting up of a collective composter in foot of apartments building.

Chapter 1: Methods and data about the quantification of organic waste produced on a territory

1 Introduction

Currently, the quantity of waste produced by the municipality is known. For example, the residual household waste production of Rennes Métropole was estimated in 2010 at 211 kg/inhbt/year *(Rennes Métropole, Rapport Annuel 2010)*. However, data relating to the production for a special type of home and especially vertical buildings are unknown. More, an accurate characterization of the waste produced i.e. its content in biowaste is also necessary. The development of method and the acquisition of results were only carried out on collective home i.e. it did not include the development of a method for collective restoration.

2 Materials and methods

The method developed aimed to quantify organic wastes produced in collective homes in a defined area. The method was inspired by the one given by Fangeat (2005) and Ademe (2005). Sampling was applied in agreement with standard methods XP X30-413, XP X30-422. Characterization was practised on moistened household wastes in agreement with standard method XP X30-408.

.2.1 Sample constitution

Considering all inhabitants of collective homes on a territory, stratification may be applied on basis of, for instance, salary of inhabitants, height of buildings, people origins… This stratification has to be accurately legitimated on one hand and may be difficult to establish on the other. Thus, one way to stratify based on salary and height of buildings was abandoned. A global approach, without stratification, seemed more relevant at a first step. Indeed, it was difficult to choose one criterion of stratification over another because we did not know their relevance. Then, the inhabitants of collective homes at Rennes Métropole were considered without any layer meaning all people living in collective buildings on a defined territory constituted the studied population.

Measure annual biowastes production of a people sample imposes to follow this production enough time during the year on one hand and to take into account seasonality on the other. This led us to decide to sample wastes presented for collection at least four weeks per year, one week per season. At Rennes Métropole territory, there is no separate collection of biowaste meaning these are collected in the same bin as household wastes. In contrast there is a separate collection of papers, cardboards and plastics. Finally residual household waste collection for individual homes is separated from residual household waste collection for collective homes. For collective homes, the household collections are divided in 3 areas, the first one occurring two days per week on Monday and Thursday, the second one on Tuesday and Friday and the third one, corresponding to town center, and occurring three times a week. This last was excluded since it included wastes produced by economic activities and not only wastes produced by inhabitants of collective homes. Then, we decided to focus on the territory collected on Monday and Thursday (assumed similar to the second type). Due to the frequency of waste collection, 2 times per week, the measurement of the production during one week imposes to collect two samples per week (on Monday and Thursday) i.e. 8 samples per year. On this area, people living in collective homes are estimated to 69000 inhabitants (calculate based on Rennes Métropole and Insee data).

The list of buildings on the selected area accounted nearly 2500 places. A representative sample of buildings should be extracted from this list of addresses, which wastes would be collected twice a week and four weeks per year. In agreement with Fangeat (2005), the sample of household wastes collected should be at least of 2 tons. Taking into account household waste production data at Rennes Métropole (211 kg/inhbt/year in 2010), it leads to a population sample # 1100 inhabitants and, assuming a mean value of # 1,8 inhabitants per apartment, the sample of buildings should account for # 600 apartments. For a mean value assumed of # 15,6 apartments per buildings, it would lead to sample # 39 addresses.

In many buildings, establish a reliable correspondence between bins presented for collection and inhabitants in buildings is difficult and even impossible which was mainly due to the fact that these bins remain outside buildings i.e. they are supplied by inhabitants who do not live in the dedicated area. This should lead to abandon these places. For similar reasons, areas in which collection of wastes consisted in a collective bin for many people living around should be excluded due to the fact that, in these cases, correspondence between wastes in bins and people bringing was impossible. In order to prevent these abandons, 200 addresses were sampled randomly from the list. For 155, the correspondence mentioned previously was clearly impossible which led to their exclusion. 45 were kept.

For the residual 45 addresses, each was investigated, by requests to syndics, doorkeepers, representatives of owners or cleaners, to identify if its wastes storage organisation allowed to establish the correspondence between bins and apartments providing in bins. As just mentioned, the addresses, which did not allow the correspondence, were excluded. For certain addresses, the adjacent numbers of street at the selected building were included in the sample due to the frequent exchanges of dustbins between these buildings. The investigation was stopped as soon as # 600 apartments were accounted in the list. It led to a sample constituted by 21 sites of collection constituted of 41 addresses and 610 apartments. Further requests to syndics were made to determine the distribution of apartments –types at each address i.e. how many apartments of every type (T1, T2, T3, T4, T5, T6). Then, INSEE data (June 2007) were used to estimate as accurate as possible the number of inhabitants in each apartment then at every address. Thus, INSEE data consider that inhabitants living in T1, T2, T3, T4, T5, T6 are respectively 1,06, 1,26, 1,71, 2,31, 2,82, 3,11. Then, the sample was found accounting for 1123 inhabitants. A map of the studied and collected area is given in Annex 1.

.2.2 *Sampling method*

This sampling collection imposed to use a specific truck (similar to the ones used for waste collection but immobilized for sampling at every sampling day) on one hand and on the other, to impede that, at the day we collected wastes, the bins of the buildings selected were collected by the usual collection. Then, the bins of selected buildings were equipped with identification labels allowing to exclude them from usual collection. However, due to errors of the collection service, some bins which should not have been collected by usual collect were collected. These errors do not seem to damage or false our quantification.

Trucks were also equipped with weigh sensors which should allow to know exactly the mass of biowaste produced at each place. Since bins used for collection were equipped with identification sensors and trucks were equipped with weight sensors, the mass of wastes, produced by the studied sample, will be followed in continue for 12 months or more. Without this technology, the usual method is to measure the quantity of waste produced on 3 consecutive weeks. The halfway week is devoted also to the characterization of the sample. In our case, we completely relied on the weigh sensors for measuring quantity outside the week of characterization. However, in March 2011, some weigh sensors were still out of service meaning only masses measured at every sampling-collection for characterization could be used.

Finally the estimation of the production of wastes was also estimated by a rough estimation of the volume of wastes in every bin collected to constitute the sample. Indeed, sum the volumes and then multiply the total volume by the density of wastes in bins could lead to estimate the mass produced. Since this density may vary with season and territory, its determination through measurements is recommended.

One day was necessary to collect each sample (5 buildings were collected every hour - 1 every 12 mn - and the collection lasted around 8 hours per day). The mass collected was obtained by the measurements of the mass of the truck before and after collection. The sub-sample (500 kg household waste) was obtained by quartering in series of the amount of waste loaded in the truck at each collect (from 1 to 2 tons). Quartering was practiced after the unloading of the truck, by mixing the sample thanks to a loader, then choose and sample one area-fraction to 500 kg sub-sample. One day more was necessary for characterization of each sub-sample. The sub-samples were characterized in agreement with MODECOM procedure.

Four campaigns including collection, sampling and characterization were practised corresponding roughly to autumn, winter, spring and summer: September 2010, December 2010, March 2011 and June 2011.

.2.3 *Results*

.2.3.1 Residual household waste composition

Data on waste characterization including variation with season are given in Table 1. About the composition of residual wastes, we do not observe really a difference between the seasons for the whole of organic waste. We observe variations superior to 30% for non consumed food, garden waste, other papers, cardboard, EED, textiles, combustibles, other glass, other ferrous metal waste, other metal waste and special wastes. Such variations should be due to the small quantities of wastes in these categories. Thus, the part of fermentable waste in RHW does not vary significantly during the year.

Table 1

Composition of residual household waste of Rennes Métropole

	%		September		December		March		June		Average %	CV%
			Monday 20th	Thursday 30th	Monday 13th	Thursday 16th	Monday 14th	Thursday 17th	Monday 27th	Thursday 30th		
1	**Fermentable waste**	**Food waste**	**18,2**	**19,4**	**21,3**	**25,0**	**19,1**	**23,2**	**22,0**	**22,5**	**21,3**	**10,8**
		Non consumed food	**1,3**	**1,2**	**1,0**	**2,0**	**2,0**	**2,4**	**2,2**	**3,2**	**1,9**	**38,8**
		Yard and garden rubbish	**2,1**	**0,9**	**3,6**	**1,6**	**2,9**	**2,0**	**1,9**	**2,7**	**2,2**	**37,2**
		MO < 8mm	**4,7**	**3,6**	**6,3**	**4,6**	**3,5**	**3,8**	**2,8**	**2,5**	**4,0**	**30,2**
		Total fermentable waste	**26,2**	**25,2**	**32,2**	**33,2**	**27,5**	**31,4**	**28,9**	**30,9**	**29,4**	**10,1**
2	Papers	Packaging	0,8	1,5	0,6	0,8	1,1	0,9	1,1	0,9	1,0	28,6
		Newspapers-brochures	7,0	11,0	9,9	9,5	8,3	10,5	7,6	10,0	9,2	15,6
		Other papers	4,7	2,1	1,1	2,1	3,9	2,6	2,0	1,1	2,4	52,1
3	Cardboard	Flat packaging cardboard	3,5	3,5	3,1	2,9	3,6	2,8	3,7	2,6	3,2	12,8
		Corrugated packaging cardboard	2,4	3,1	2,7	4,0	2,6	2,2	1,8	1,3	2,5	32,0
		Other cardboards	1,0	0,3	0,4	0,2	0,7	0,6	0,5	0,9	0,6	48,4
4	Composites	Recycling packaging	0,5	0,5	0,6	0,9	0,6	0,9	0,6	0,4	0,6	28,9
		Other packaging	1,3	1,5	1,2	1,2	1,5	1,5	1,5	1,4	1,4	9,5
		Electrical and Electronical Device	0,1	0,2	0,1	0,1	0,7	0,4	0,2	0,2	0,3	75,8
5	Textiles		7,1	1,8	1,1	1,7	1,2	0,8	2,5	2,0	2,3	89,1
6	Health Care textile et papier souillé		6,7	13,8	11,7	10,7	8,5	10,5	14,5	11,5	11,0	23,3
7	Plastics	Films	6,6	6,2	5,8	5,6	7,7	5,6	6,6	5,6	6,2	11,8
		Bottles	1,6	1,4	1,5	1,6	1,8	1,7	1,9	2,3	1,7	15,3
		Other packagings	4,4	4,7	5,6	3,9	5,2	4,3	5,8	4,4	4,8	14,0
		Other plastics	1,8	2,2	0,9	1,9	2,3	3,0	1,9	2,5	2,1	28,6
8	Combustibles		3,2	4,2	1,6	3,4	4,3	3,9	2,9	5,2	3,6	30,0
9	Glass	Recycling packaging	5,0	4,6	5,3	5,4	4,6	4,8	6,0	5,8	5,2	10,1
		Other glass	0,6	1,0	0,9	0,8	0,7	0,3	0,1	0,7	0,6	45,2
10	Metals	Ferous metal packaging	1,7	2,4	1,8	1,6	2,4	1,5	1,4	2,0	1,9	21,5
		Aluminium packaging	0,1	0,2	0,3	0,2	0,2	0,2	0,3	0,3	0,2	30,6
		Other ferrous metal waste	0,3	0,5	1,3	0,6	0,7	0,8	0,3	0,2	0,6	61,5
		Other metal waste	0,5	1,2	1,1	0,7	0,6	0,7	0,6	0,8	0,8	32,7
11	Incombustibles		12,5	6,3	9,0	6,8	8,7	7,8	7,1	6,6	8,1	25,3
12	Special wastes		0,2	0,7	0,1	0,2	0,7	0,0	0,1	0,3	0,3	87,0

.2.3.2 Quantity of residual household waste and fermentable waste collected

Results about waste production obtained by the application of MODECOM procedure

Data on waste production including variation with season are given in Tables 2 and 3. The results of collected quantity are expressed at more or less 50kg due to the precision of the weighing machine used for the trucks. The mean production of residual household waste is 145 kg/inhbt/year. Although we do not observe a significant influence of the season (CV=12,6%), we note that the minimal and maximal production corresponding to respectively autumn and summer are quite different. On the other hand, the Figure 1 shows that there exists a difference in quantity collected between Monday and Thursday meaning we have to conserve 2 samples per week if there are 2 collections per week. The mean production of biowaste in collective home of Rennes Metropole is 42 kg/inhbt/year (Table 3). This quantity does not seem to vary during the year. We can observe that it still remains nearly 36 kg/inhbt/y. of wastes which can be recycled i.e. paper, packaging and glass in the residual household waste in spite of the collection for recycling waste set up by the municipality of Rennes Métropole.

Table 2
Quantity collected of residual household waste

	September		December		March		June			
	Monday 20th	Thursday 30th	Monday 13th	Thursday 16th	Monday 14th	Thursday 17th	Monday 27th	Thursday 30th	Average	CV%
Sample weight (kg)	2 080	1 180	1 880	880	1 840	1 060	1 600	1 080	1 450	31,3
Nb collected inhabitant	1071	920	1071	843	1090	1028	1123	1123	1 034	9,8

Table 3
Quantity collected per category in kg/inhbt/year

kg/inhbt/year	Automn	Winter	Spring	Summer	Average kg/inhbt/y.	CV%
Fermentable waste	**43,2**	**47,4**	**40,9**	**36,9**	**42,11**	**10,45**
Recycling Paper	14,5	14,2	12,9	10,6	13,03	13,49
Recycling packaging	17,4	15,2	14,9	11,6	14,76	16,27
Recycling Glass	8,1	7,7	6,6	7,0	7,36	9,49
Other wastes	84,4	61,0	66,1	57,6	67,28	17,75
Total kg/inhbt/year	**167,6**	**145,4**	**141,5**	**123,6**	**144,54**	**12,49**

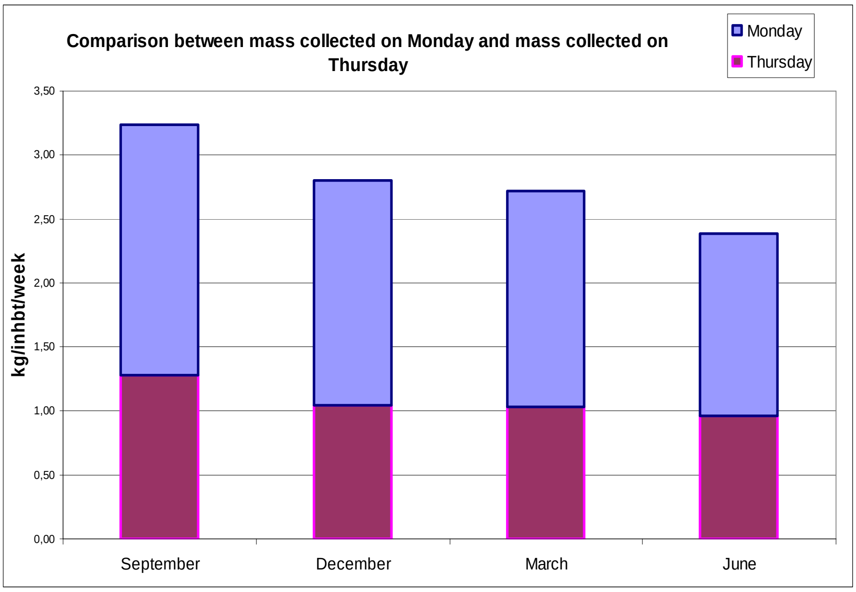

Fig. 1: Comparison between mass collected on Monday and mass collected on Thursday

Measurement of the quantity by the weigh sensors

Weigh sensors on the trucks coupled with identification sensors on every bin allowed to measure the mass collected at every address as illustrated in Table 4 for the sample collected the 20th of September. The total mass was calculated by adding all the masses measured at every address (1753 kg the 20th of September). This last can be compared with the total mass really collected (2080 kg) meaning the error was calculated as 15,75%. Table 5 summarizes such data for every collection practised. Discards between the mass really collected and measured thanks to sensors ranged between 0,28 and 23,6 % with a mean value of 6 %. Figure 2 shows that the data obtained by the weighing of the truck and those measured by the weigh sensors are similar for 75% of the data.

The follow-up of the quantities of waste by the means of a system of weigh sensors is valid on the condition of checking before the follow-up that the transmission of the data is effective for the studied sample.

The system of weigh sensor allowed to follow the quantities of waste produced during 52 weeks for the 20 addresses of our sample. The Figure 3 presents these variations. The winter season is not representative because for much of addresses, the transmission of the electronic data did not function correctly. We observe that apart from the periods of holidays (spring and summer) the quantity of waste produces per week does not vary significantly (CV=12,1%).

Table 4

Mass of residual waste measured addresses per addresses thanks to the weigh sensors. Example with the 20th of September.

Typology of the bins used in the sampled territory: 240L, 360L, 660L

Levels used to estimate the filled volume in a bin: 0,25 ; 0,5 ; 0,75 ; 1; 1,25

	20-sept			
Adress	Mass measured by weigh sensors (kg)	Filled volume estimated (L)	Mass obtained by multiplying the estimated volume by the volumic mass (kg)	Estimated mass*100/mass measured by weigh sensors
Cucillé	67,50	1080	123,79	183,39
G Berger	33,50	420	48,14	143,70
F Roosevelt	174,50	1800	206,31	118,23
G Palante	150,00	1348	154,45	102,96
Massouah	57,00	630	72,21	126,68
Recipon / Keranflech	320,00	2970	340,41	106,38
C Bernard	29,00	540	61,89	213,42
J Lallemand	40,00	330	37,82	94,56
Mabilais / Malakoff	191,00	1800	206,31	108,02
Sebastopol	66,50	840	96,28	144,78
Voltaire	71,50	990	113,47	158,70
Marbeuf	19,50	270	30,95	158,70
Mitterrand	102,50	900	103,15	100,64
Papu	71,00	720	82,52	116,23
Saint Cyr	81,50	900	103,15	126,57
Liothaud	42,00	360	41,26	98,24
Morand	144,00	1440	165,05	114,62
Louvigné	91,50	810	92,84	101,46
Total	**1753**	**18148**	**2080**	
Total mass of waste collected obtained by subtracting the mass of the truck before collection from the mass of the truck after collection (kg)	**2080**			
Discard between the mass measured by weighing the truck and the mass obtained by adding all the masses registered by weigh sensor placed on every bin (%)	**15,75**			
Volumic mass (kg/m3)	**115**			
mean				**128,74**
cv				**25,4**
min				**94,56**
max				**213,42**

Table 5

Summary of the discards between mass measured by weigh sensors and mass measured by weighing the truck

Typology of the bins used in the sapmpled territorry: 240L, 360L, 660L Levels used to estimate the filled volume in a bin: 0,25 ; 0,5 ; 0,75 ; 1; 1,25	Monday, the 20th of september	Thursday, the 30th of september	Monday, the 13th of december	Thursday, the 16th of december	Monday, the 14th of march	Thursday, the 17th of march	Monday, the 27th of june	Thursday , the 30th of june	Mean	CV%	MIN	MAX
Estimated volume (L)	18148	13220	20366	4002	21236	11456	16877	11125				
Mass measured by weigh sensors (kg)	1753	1214	1858	673	1740	1052	1605	1063				
Total mass of waste collected obtained by subtracting the mass of the truck before collection from the mass of the truck after collection (kg)	2080	1180	1880	880	1840	1060	1600	1080				
Discard between the mass measured by weighing the truck and the mass obtained by adding all the masses registered by weigh sensor placed on every bin (%)	15,75	2,88	1,20	23,58	5,46	0,75	0,28	1,62	6	133	0,28	23,58
Volumic mass (kg/m3)	115	89	92	220	87	93	95	97	95	10	86,64	114,62
Estimation of the collected mass by based on the mean of the volumics mass (kg)	1730	1260	1941	381	2024	1092	1609	1060				

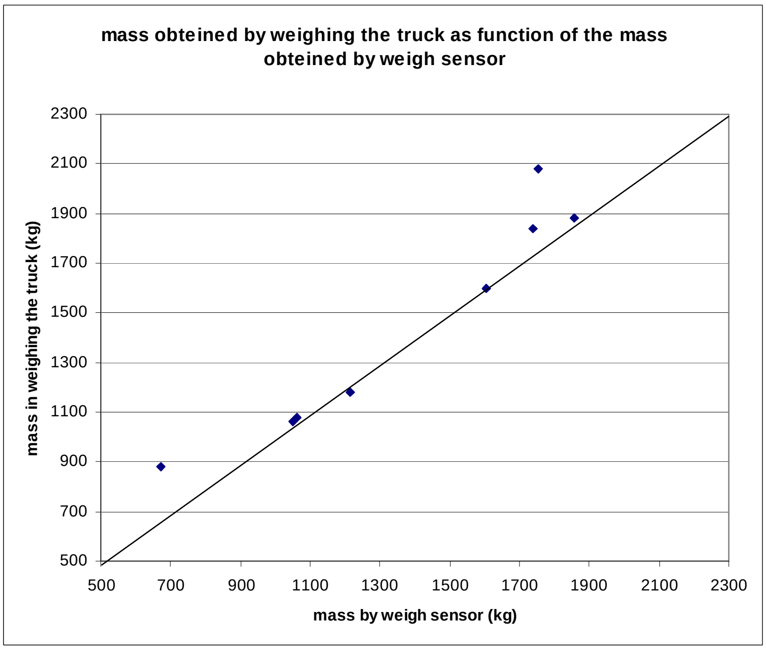

Fig. 2: Comparison between the data obtained by the weighing of the truck and those measured by the weigh sensors

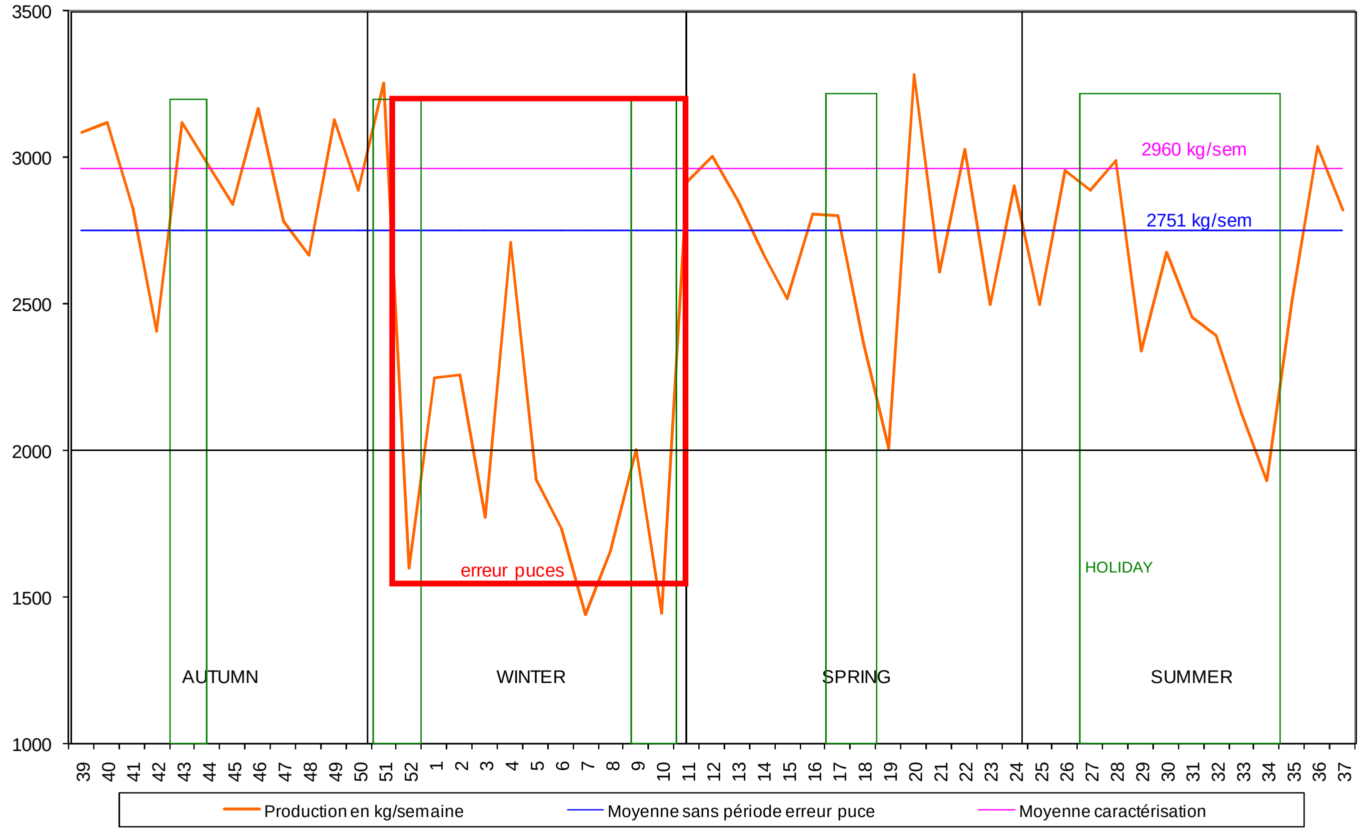

Fig. 3: Measure of the quantity of residual waste by the weigh sensors

.2.3.2.1 Measurement of the quantity thanks to an estimated density

Finally, masses were also calculated by estimation of the level of filled volume in each bin and then by multiply the total volume by the volumic mass (obtained by dividing the mass really collected by the previous total volume). On table 4, the mean discard between the mass measured by weigh sensors and the mass measured by the estimation of the volume is about 128%. The method by the estimation of the filled volume overestimate the collected mass regards to the results of the method by weigh sensors. This observation is right for a measure on a low number of bin. Figure 4 shows the comparison between the data obtained by the weighing of the truck and those measured by considering that the volumic mass was constant. We observe that with a mean density of 95kg/m3, the estimate of the mass collected by the measurement of volume is correct: the variation between electronic measurement and the evaluation by volume is to the maximum of 10%. We have checked that the density has not varied during the year but not if this data varies from a territory to the other. Moreover, Figure 5 shows that starting from 12 dustbins the difference between electronic measurement and the estimate becomes lower than 10%. The evaluation of the collected mass by a mean density is relevant on a sample of at least 12 bins.

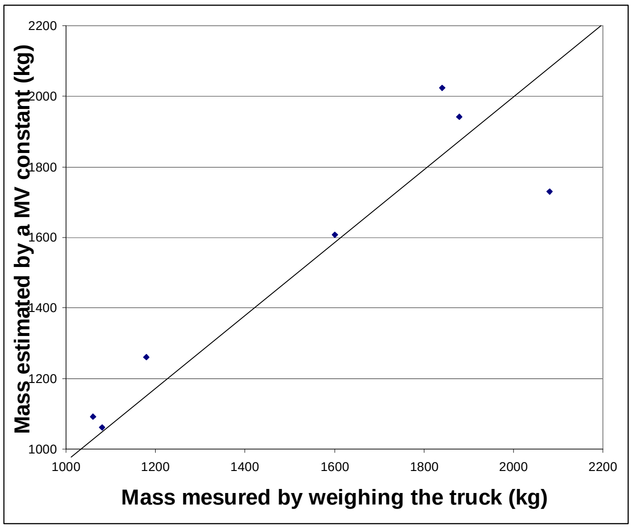

Fig. 4: Comparison between the data obtained by the weighing of the truck and those measured by considering volumic mass constant

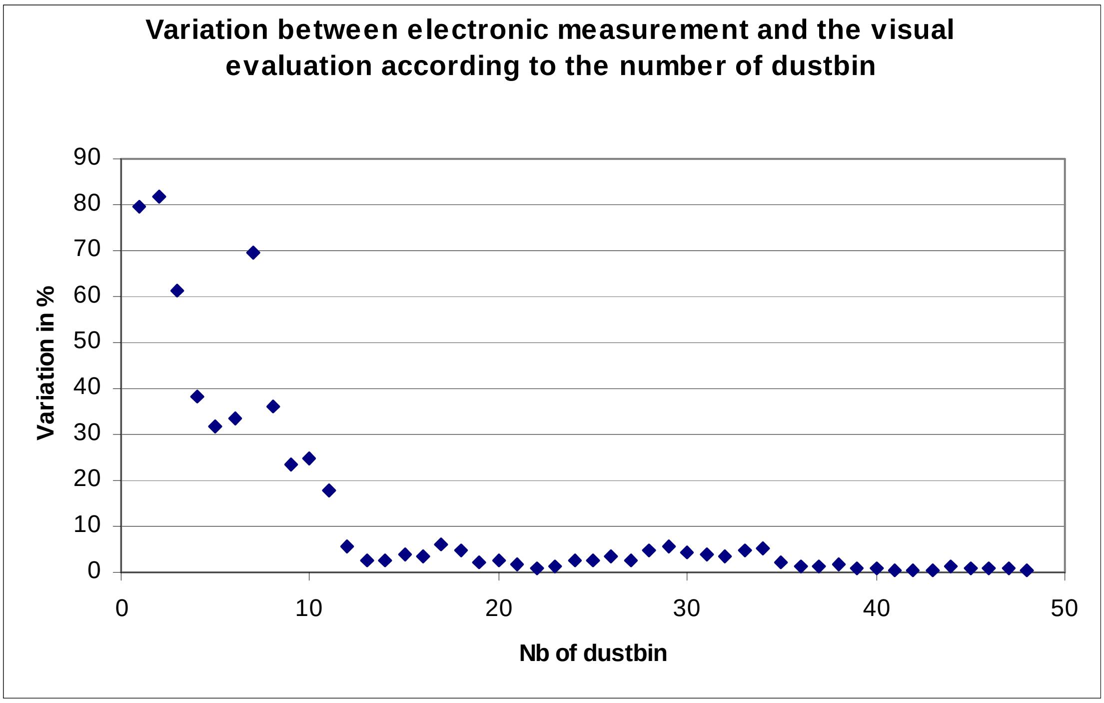

Fig. 5: Variation between electronic measurement and the visual evaluation according to the number of dustbin

3 Results

.3.1 *Proposal of a protocol for the quantification of organic waste produced on a territory*

.3.1.1 Objective of the protocol of study

In order to know the quantity of organic waste produced in collective homes in a defined area.

.3.1.2 Application

For the municipalities wishing to estimate the quantity of organic waste which could be diverted of the residual household waste (RHW) and follow-up the quantity of RHW produced.

.3.1.3 Material and method

In order to know the quantity of biowaste in the RHW, it is necessary to constitute a representative sample of the studied area. The sample will be representative to the sector containing the addresses list where the random selection will be carried out. In the same time, we need to reach the following data:

- Part of organic waste in the RHW
- Quantity of produced waste
- Number of inhabitant composing the studied sample

.3.1.3.1 Sample constitution

The number of inhabitant who will be collected during the study depends primarily on the mean quantity of waste produced on the studied territory, in the way in which the bins are presented to the collection and of the presence or not of a composter.

According to French standard XP X30-413, so that it is representative, the sample of RHW must be at least of 2 tons. Thus, by consulting the annual report of the municipality on the production of waste per year and per inhabitant, we obtain the necessary number of inhabitants. In cases where this data would take into account the waste of small industries, it is necessary to take a leeway to be sure to get a sample of at least two tons at each collection. To go back to the number of housing constituting a building and thus the number of address, we can consult the most recent reports on the population census and obtain a mean number of housing per building. It is then necessary to be able to have a list of buildings not-equipped with a composter. Then, by a random selection, we select sufficient addresses to be able to eliminate thereafter, those which would not make it possible to go back to the number of inhabitant producing waste. Indeed, the quantities of waste produced are expressed in kg/inhbt/year.

Then, on a small number of addresses, it is necessary to contact the syndics and lessors, to move on the sites to specify the number of apartment or inhabitant constituting these addresses and to understand how the bins are managed within the building. Thus, we can discover that certain dustbins are regularly exchanged between several addresses or that the dustbins of the building are accessible to external people. On Rennes Métropole territory that step of the sample constitution was carried out on less than 40 addresses.

The names and the telephone numbers of the syndics and the personnel charged to take out the dustbins must be kept because they are very useful at the time of the method implementation.

It is necessary to obtain the number of inhabitant per address the most precise as possible. Indeed, in the case of problem, for example “collection of the address by an other truck during the day of sampling”, the residents of the building could be deducted of the producers.

Once the sample is defined, it is necessary to establish a sampling plan in the perspective of the RHW characterization.

.3.1.3.2 Composition of Residual Household Waste

The characterization of the waste presented to the collection informs about the percentage of waste by category according to a standardized method. It was shown during our study that the part of organic waste did not vary significantly during the year. In the Rennes Metropole territory, it is thus not necessary to carry out a sampling per season as that was done. For Rennes Metropole, only one sampling is enough and it can be realized preferably in autumn. However, if the municipality has any doubt about the influence on waste composition, for example of tourism or garden waste, a second characterization must be carried out. That sampling must be conducted on the scale of the week i.e. it is necessary to realize the same number of sampling than there is collection in the week. The characterization of waste is carried out according to French standard XP X30-408, on wet waste in order to better identify organic waste or a standard method developed in the studied territory.

<u>*Procedure to carry out the composition of the RHW :*</u>

Sampling:

The sampling is carried out preferably with a vehicle of collection rented with crew near the company in charge to collect waste. The press of the collection truck must be cut down to the minimum to avoid compacting the sample too much. It is recommended to carry out the sampling of waste before the passage of the usual collection in order to avoid the collecting of the sample by another truck. At the end of the collection, the two tons of waste must be sub-sampled according to a standardized method. Two processes can be used for sub-sampling. French standard XP X30-413 recommends to entirely move the heap of waste with a bucket loader and with a random selection to keep 10 buckets of 50kg to constitute the sample of 500kg. For that, we calculate the number of bucket by dividing the total weight of the sample by 50kg, and then we draw with the fate the numbers of bucket. The second solution is to mix the heap then to equalize it using a bucket loader. Then, we keep half of this heap by taking the opposite halves and by rejecting the others. The operation should be repeated as much than necessary to obtain 500kg. The sample of 500kg can be then placed in bags to facilitate the weighing and the sorting. The bags are weighed before the characterization. The sampling and the sub-sampling require one day of work.

Characterization:
The French standardized method (XP X 30-408) is used to characterize the sample. The nature of waste is established according to 12 principal categories and subcategories which identify reusable wastes. The characterization is carried out on a sort table equipped with grids making it possible to dissociate waste according to following granulometry: >100mm, 20 à 100 mm, <20mm. To carry out the sorting, it is necessary to have forty bins, a lot of bags of dustbins, shovels, a balance and the sorting table. The superiors to 100 mm are sorted on the whole of the sample. Each of sorting categories issued from the superior to 100 mm is weighed. Then the sorting on the round-mesh of 20 mm is carried out only on the 1/8ème from the totality of waste lower than 100 mm. For that, we use the method of quartering. Quartering each time makes it possible to take half of the sample. It must be repeated 3 times successively to obtain the 1/8 of the initial sample. The sample must be weighed before its sorting. Each of sorting categories issued from the superior to 20 mm is weighed. The sample lower than 20mm, is dried before being sorted. The category “fermentable” higher than 8 mm is dissociated in kitchen waste and garden waste. Each of sorting categories issued from the superior to 8 mm is weighed. For the fraction in lower part of 8 mm, a calcination is carried out. It gives two fractions which are the ashes, comparable with “incombustibles” and the losses of mass called “MO<8mm”. The characterization of a sample of 500kg requires one day of work.

.3.1.3.3 *Quantity of produced waste*

The characterization of waste gives a composition in %. It is necessary to transform this % into quantities to have a technical assessment of the local composting operation. The follow-up of the collected quantities should not be limited to the only characterization of waste because to use only one data as reference can be dangerous i.e. it is important to confirm the value measured on the characterization week by two measurements before and after this characterization week. It is therefore necessary to choose three consecutive weeks in the year to follow-up the production of waste and to reserve one of it for the characterization of the sample. The studied weeks must be consecutives to avoid uncertainties on the waste production (shift of collection, bin not presented to the collection…). A second measure can be realized on another period of the year on three consecutive weeks to check the impact of some specificities of the studied territory (e.g. tourism, garden waste…).

The follow-up of the quantities of waste can be done according to three processes: the weighing of the truck at the end of the collect, a system of weigh sensors making it possible to identify the bin and to record the weigh numerically for each address or on the estimation of the filled volume.

.3.1.3.3.1 *Waste quantification based on weighing the truck*

This method requires to rent a truck of collection to carry out a specific collection on the addresses being part of sampling. It has the advantage of requiring only little of personal but requires a good organization to prepare the collection. It does not make it possible to carry out a follow-up by address.

.3.1.3.3.2 *Waste quantification based on weigh sensor utilisation*

Some municipalities equip the bins of collection of electronic systems of identification. In the same way the vehicles of collection are equipped with systems able to recognize the dustbins and to record the corresponding weight for each one of them. This method can be used throughout the year and makes it possible to obtain a precise and complete follow-up quantities produced on the studied sector. It is however necessary to make sure, prior to the study, of the effective transmission of the data and the correspondence bins/addresses.

.3.1.3.3.3 *Waste quantification based on the estimation of the filled volume*

This method requires to measure a mean density. Our study showed that starting from a dozen of bins, the variations obtained between an electronic measurement and a visual evaluation were lower than 10%. The density can thus be measured by weighing at least 20 bins and by noting the filled volume (25%, 50%, 75%, 100%, overflow). Then we must weigh the content of each bin to define a mean density.

The mean density can also be calculated on the day of the characterization since we know the total mass collected for the studied sample (provided volume was estimated in every bin collected and by adding every volume measured).

Then, to carry out a follow-up of the produced quantities, we have to note the rate of filling of each bin before its collecting by the usual collection and to apply the mean density calculated. This method is precise only starting from a sample of 20 bins. This requires human resources but little material.

.3.1.3.4 *Number of inhabitant composing the studied sample*

This data is very important because it makes it possible to express the quantities of waste produced in kg/inhabitant. This can be obtained by visits at the addresses, while counting, for example, the number of letterbox, or by contacting the syndics and lessors. We must be able to obtain at least the precise number of housing occupied in the building.

.3.2 *Transferable data with another territory*

To estimate the quantity of organic waste produced on its territory, a municipality can also directly apply the results obtained during this study. However our result of 42 kg/inhbt/year seem very specific to the Rennes Metropole territory. In the same way, we have not checked if the mass volumic of 95 kg/m^3 could vary from a territory to the other. That obliges the municipality to estimate its own density.

Thus, the municipalities must apply the protocol to know the quantity of OW in the Residual Household Waste of collective homes. A second solution could consist to take the national or local mean of the part of organic waste in the RHW with a measure of the quantity of RHW produced specifically in collective homes.

4 Conclusion

The combined use of the measurement of the collected quantities and procedure MODECOM made it possible to evaluate the quantity of organic waste at collective home in Rennes Métropole territory. The constitution of the studied sample takes much time. It depends on the quantities of waste produced on the territory, of the mode of presentation of the dustbins to the collection and the presence or not of a composter. In the implementation of the method, to obtain the telephone number of the syndics and personnel charged to leave the dustbins is very important. In the same way this method requires a regular contact with the society of waste collection to avoid the collect of the sample by another truck.

For the municipalities, it is necessary to better know the part of supplies by the small economic activities. Indeed, our data show a discard between the RHW measured specifically in collective homes and the quantity announced by Rennes Métropole in 2010 at Rennes i.e. 230 kg/inhbt/year. Regards to these data, the part of the contribution in RHW from the small economic activities may be significant.

Chapter 2: Method and data relating to the quantification of biowaste composted at home in case of a collective home composting operation (i.e. diverted from waste collection)

1 Introduction

The existing data do not make it possible to know the quantity of organic waste which will be really diverted from the household waste by the installation of a collective composter. It is thus necessary to develop methods which permit to know the participation rate to the composting operation and the diverting rate i.e. the quantity of biowaste composted. It is thus necessary to develop methods which permit to know the participation rate to the composting operation and the percentage of organic waste (OW). composted i.e. diverted from the usual collection. Determine the percentage of OW diverted requires to know the quantity of o.w. supplied to the composter and the residual amount of OW put in the Residual Household Waste (RHW). The determination of OW put in the RHW was performed for individual homes. It is difficult at collective homes since in a collective bin it is impossible to distinguish the wastes supplied by households who compost from the wastes supplied by households who do not compost. Thus, other methods have been developed to approximate the amount of organic waste really diverted by the installation of a collective composter.

2 Material and methods

In order to set-up the method to quantify organic waste diversion and to implement methods associated with composters monitoring and evaluation, 3 buildings, among 160 equipped at Rennes Métropole with collective composters, were selected.

.2.1 *Abandoned methods*

One method which was envisaged consisted to equip the composters with weigh sensors which would measure their mass in continue. This method was estimated too expensive on one hand and it was suspected to lead to safety problems (since it required connect composters to an electricity source) on the other. This method was abandoned.

.2.2 *Method based on the collective weighing of the organic wastes by a volunteer*

A first method (method 1) consisting to ask people to bring their wastes in a first container and find a volunteer to weigh the wastes brought in the container and displace them into the composter, every 3 or 4 days, was set-up. The main drawback of this method lies in the change of practise usually applied by inhabitants taking part to the composting operation (since they do not directly bring their wastes into the composter but into a transit container). The second drawback of this method is to know precisely the number of inhabitant taking part to composting. The third is to find volunteers to make transfer from transient bin to the composter.

Annex 2 shows the fitting-out of the composting site. Next to the composter, the inhabitants insert their wastes in a bin used as a transient container. Every three or four days, the wastes loaded by inhabitants in the transient tank are weighed by the volunteer who transfers them into the composter.

.2.3 *Method based on the individual weighing of the organic wastes by a volunteer*

A second method (method 2) was carried out with a panel of about thirty volunteers from various residences. The weighing of OW was done individually at the apartment before the transportation to the composter.

.2.4 *Method based on the mineral mass conservation*

A third method (method 3) funded on conservation of mineral matter (MM) was also set-up. This method consists to weigh initial waste in the composter, take a sample and measure its content in mineral matter. When turning of composting material or when compost is extracted, few weeks later, the mass of wastes is measured, a sample is extracted and its content in MM is measured. Assuming some mean values of moisture and MM content in biowaste, the increase of mass of MM allows to determine the mass of wastes brought to the composter. In case of addition of a bulking agent every time organic wastes is brought in the composter, the same procedure has to be applied to the bulking agent i.e. the mass of bulking agent has to be determined whereas its contents in moisture and mineral matter have to be determined at the beginning and every time compost is turned or extracted (this supposes to control bulking agent feeding in the container dedicated to its storage). The mass of bulking agents introduced is obtained by subtracting the mass in the storage container at the start of the cycle from the mass in the storage container at the end of the cycle. This method requires the determination of dry matter (DM) and organic matter (OM) contents of wastes and composts samples at a chemical laboratory. More, the method may be difficult to apply by inhabitants without any support (composting guide). It was proposed here mainly to check if it led to results similar to the ones obtained by method 1. The detail of this method is given in Annex 3.

.2.5 Results

As mentioned previously, 3 residences already equipped with composters have been identified: the methods 1 and 3 are applied simultaneously at the 3 residences. After a period of two months necessary to inform and make inhabitants and volunteers familiarize with the experiment performed, the acquisition of data started at the beginning of January 2011 and it last until January 2012. Then, the experiment lasted # 12 months. Since, composters are emptied every # 3 months, 9 cycles should be studied. However a volunteer did not wish any more to continue to weigh as from June 2011. These are thus 8 cycles of composting which were monitored.

The method 2, monitored by Rennes Metropole, lasted 8 months.

.2.5.1 Method based on the collective weighing of the organic wastes by a volunteer (Method 1)

The results about the quantity of organic waste diverted thanks to the collective composting are presented in Table 6. This table shows on one hand the quantity of OW composted per inhabitant resident in the building, whether or not they compost their OW and on the other hand the quantity of OW per inhabitant taking part of composting. The number of residents was obtained from the number of apartment multiplied by the mean number of habitant per apartment i.e. # 1.8 inhabitants per apartment. The number of inhabitant involved in the collective composting was obtained by request near the composting guides.

We obtained a mean composted quantity of OW of 43.53 kg/inhbt/year. This data is similar to the quantity of OW produced in collective homes (42 kg/inhbt/year). In that case, we could think that the rate of diversion is about 100% but this conclusion could be dangerous. Indeed, we do not know if we estimate correctly the composting population in the calculation of the diverted quantity. Moreover, it is possible that the composting population produces more OW than the non-composting population. A second calculation allows obtaining a rate of diversion at the scale of the residence to avoid the incertitude on the right number of composting people, i.e. OW composted per resident divided by the quantity of OW produced (42.14 hg/inhbt/y). Thus, we obtain a mean rate of diversion of 18.98%. This calculated rate of OW diversion is similar to the mean rate of participation calculated for the 3 composting sites (18.45%). That shows that the estimation of the number of inhabitants participating in composting thanks to the composting guides is rather correct.

Table 6
Organic wastes quantity measured by the volunteers

	Number of resident of the equipped building	Number of inhabitant taking part in composting (request)	Rate of participation (%)	OW composted per year (kg/y.)	OW composted per inhabitant participating (kg/inhbt/y.)	OW composted per resident (kg/resid./y.)	Rate of diversion per residence (%)
Method of calculation	D	E	D÷Ex100	G	G÷E	H=G÷D	H÷42.1x100
Alma	49	10	20,41	386,59	38,66	7,89	18,74
Rouerie	356	51	14,33	2326,91	45,63	6,54	15,53
Montand	97	20	20,62	926,38	46,32	9,55	22,68
Mean			**18,45**	1213,29	**43,53**	**7,99**	**18,98**

.2.5.2 Method based on the individual weighing of the organic wastes by a volunteer (Method 2)

The mean quantity of diverted OW obtained by this method is 47.4 kg/inhbt/year. All results are given in Annex 4.

.2.5.3 Comparison of the result between the Method 1 and the Method 2

Whatever the method used, we notice that the quantity of organic waste diverted obtained remains similar or even higher than the quantity of OW produced. This may be due to an underestimate of the number of participant to the composting in the case of method 1. However, the quantities of waste composted in the case of method 2 are higher than the other two values. The hypothesis that composting households produced more OW than those who do not is therefore true. This hypothesis has also been verified during the individual homes study. Table 7 compares the results of Method 1 and Method 2 regards to the results of the study carried out in individual homes. The values W, X, Y and Z were not measured and therefore remain unknown. Total of OW produced is an estimation calculated with two data collected separately. In this table we see that the households who compost all their OW (CI+) produce the largest quantity of waste. The composted part is about 85%. The CI- who compost only a part of their OW produce 61 kg/inhbt/y of which 73% are composted. The study conducted in individual homes (IH) showed that this group put in the composter very little quantities of meal wastes (meat, fish, shellfish…) unlike the CI+. Given that the instructions for collective composting are reduced to the OW resulting from meal preparation and green waste, we have assimilated the household of collective homes as the households of CI-. Moreover, Table 7 brings up the similarities between the diverted quantities from the CI-weighers at IH and collective homes (CH). We also note similarities in terms of production of OW between IH and CH non-composting households.

Table 7

Comparison of the results of Method 1 and Method 2 and the results of Individual home study

	Weigher or non-weigher	Diverted quantity of OW (kg/inhbt/year)	Quantity in RHW (kg/inhbt/year)	Total of OW produced (kg/inhbt/year)	Diversion rate (%)
		J	K	J+K	J/(J+K)*100
Individual homes (IH)					
Compost all their OW (CI+)	Weigher	70	12	82	85%
Compost a part of their OW (CI-)	Weigher	**45**	16	61	73%
CI+	Non-weigher	X	32	X+32	%<CI+ weigher
CI-	Non-weigher	Y	24	Y+24	%<CI- weigher
Non-composting people	Non-weigher	0	41	**41**	0
Collective homes (CH)					
Method 2	Weigher	**47**	W	47+W	%≈ CI- weigher
Method 1	Non-weigher	**43**	Z	43+Z	%≈ CI- non-weigher
Non-composting people	Non-weigher	0	42	**42**	0

These figures, put in connection with our experiments, allow to understand that households who are engaged in a study are often more aware of the reduction of their wastes. Without any other information, we can suppose also in our case that households who compost are likely to have different eating habits leading to higher production of organic waste.

On the other hand the central element to remember, without investigation, is as follows: at a quantified amount of OW thanks to a characterization, the potential of diverted quantity is at most 85% of OW produced. However, in the case of collective home, as the household category is similar to the CI-, thus we can consider that the maximal rate of diversion is around 75%.

Table 8 summarizes the different results obtained in Rennes Métropole by the two methods of weighing. It also provides a result obtained by applying the maximum diversion rate (75%) at the amount of OW produced. The discard between the result of 31.61 kg/inhbt/y and the result of the method 2 is significant.

Thus the two methods allow to estimate the quantity of organic waste diverted from the usual collection. In the method 2, we are in a case where the household are voluntary to do the weighing of their wastes. The data obtained gives an upper limit of compostable quantities and the method 2 the mean quantities. The last method, with the application of a maximal diversion rate gives a lower limit.

Table 8

Quantity of organic waste produced and composted

	OW produced non-composting people	OW composted Method 1	OW composted Method 2	Maximal diversion rate (75%)
Method	Characterization	Collective weighing	Individual weighing	OW produced x 75%
Data (kg/inhbt/year)	42,14	43,50	47,40	31,61

Then, the results showed that recruit volunteers to weigh can create a bias. In the case of R.M., an overestimation of the quantity potentially diverted becomes significant when the participation rate exceed 20%. It is confirmed by the study in individual i.e. the category CI+ produces the highest quantity of OW i.e. 80kg/inhbt/y. against nearly half for non-composters. Then, the assessment of the diverted quantity of OW by the method 2 named B must be corrected by a coefficient named C according to the general expression:

$$\text{Diverted quantity in kg/y.} = B \times C \times \text{number of inhabitant}$$

Let A be the amount of OW in the r.h.w. and y be the participation rate. The term "B × C" is framed as follows:

- $B \times C \approx B$ when y approaches 0 (0% of participation)
- $B \times C \approx 0.75 \times A$ when y approaches 1 (100% of participation)

The table 9 gives the framing of C as function of the participation rate named y.

TABLE 9

Framing of the coefficient C as function of the participation rate

When the participation rate (y) approaches	0	1
B × C =	B	0.75 × A
C =	1	(0.75 × A) ÷ B

As we do not know the specificities of the whole population, we expressed the coefficient C as a linear equation which can be posed as follows: $C = a \times y + b$

- When $y=0$ thus $C=1$ (Table 9). The equation $a \times y + b$ becomes $a \times 0 + b$, thus $b=C=1$.
- When $y=1$ thus $C=(0.75 \times A) \div B$. The equation becomes $a \times 1 + 1$, thus $a = C-1 = ((0.75 \times A) \div B) - 1$.

Thus, we can define C as function of the participation rate as follow:

$$C = a \times y + b = 1 + (((0.75 \times A) \div B) - 1) \times \text{participation rate}$$

The calculation of the diverted quantity becomes:

$$\text{Diverted quantity in kg/y.} = B \times (1 + (((0.75 \times A) \div B) - 1) \times \text{participation rate}) \times \text{number of inhabitant}$$

If the municipality does not want to implement weighing, it is also possible to rely on the waste characterization to estimate the amount of OW that can be diverted. Thus, the municipality considers that the behavior of the population is uniform i.e. there is no difference between a volunteer to compost and the rest of the population. The calculation of the diverted quantity becomes:

$$\text{Diverted quantity in kg/y.} = 75\% \times A \times \text{number of inhabitant}$$

.2.5.4 Monitoring duration of the methods 1 and 2

In Method 1, the monitoring of the 3 composting sites lasted from 6 to 12 months in order to be able to also monitor the maturation of the compost. In Method 2, the monitoring lasted 8 months. About the method 1, on Figure 6, we observe a homogenisation of the quantity produced in 6 months of monitoring. Moreover, at Alma site, we have observed a reduction in the participation in composting and especially after 6 months of monitoring. Thus, the method based on the weighing by a volunteer can sometimes generate some biases in the results because the inhabitants being less imply can cease composting or become neglecting. Given that the result of the weighing by a volunteer is an order of magnitude, we can limit monitoring to at least three months but not exceeding 6 months.

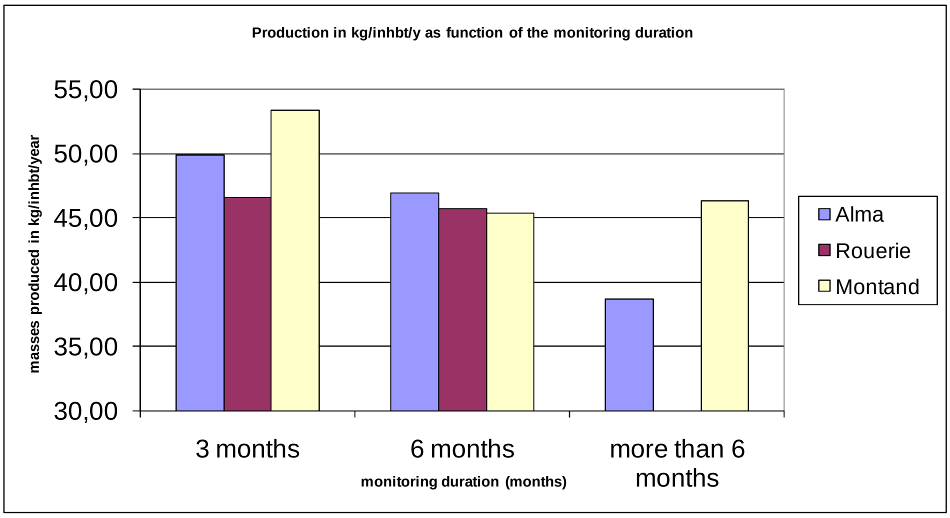

Fig. 6: Composted mass as function of the monitoring

.2.5.5 Method based on the mineral mass conservation (Method 3)

Masses and characteristics (moisture, H, and organic matter, OM, contents) of bulking agent and composting material at the starting and at the end of every cycle are filled in the calculation file (under Excel) which an example is given in Table 10. Then, the calculation allows to estimate the mass of organic waste introduced in the composter which can be compared to the mass measured by the volunteer. The details of this method are given in Annex 3.

Table 10
Worksheet of the mineral mass conservation method

		METHOF BASED ON THE CONSERVATION OF THE MASS OF MINERAL MATTER				METHOD BASED ON THE WEIGHING
		Masse (g)	**H %**	**MO %**	**Masse de MM (g)**	**Masse (g)**
07/01/2011 t=0 START cycle 1	**Mass of bulking agent in the storage container (g)**	116825,00	57,67	97,34	1313,97	
	Mass of compost placed in the composter as starter (g)	39140,00	76,32	68,18	2949,75	
	Mass of bulking agent placed in the composter as starter (g)	8840,00	57,67	97,34	99,43	
	Total mass of mineral matter in the composter (g)				3049,18	
			H %	**MO %**		
24/03/2011 t= 76 END cycle 1	**Mass of bulking agent in the storage container (g)**	52041,94	56,78	96,12	872,27	
	Mass of composting material in the composter (g)	320130,00	74,77	**82,75**	13927,27	
	Mass of mineral matter coming from organic wastes (g)				10436,40	
	Mass of organic wastes introduced in the composter (g)	**671821**	**75,35**	**93,70**		**477900**
	Mass of bulking agent introduced in the composter (g)	**64783**	57,22	96,73		**65190**
	Masse of bulking agent*100/Mass of organic wastes	**9,64**				

Massof organic wastes sampled in the transient container (g) **6286,00**

Cycle duration	Removal rate of organic matter (%)
76	63,3

Number of inhabitant	Organic waste production measured at collective homes (kg/inhbt/year)	Mass of organic wastes diverted from usual collection i.e. supplied in the transient container (kg)	Rate of participation to the composting oepration (%)	Rate of participation based on request (%)
356	42,1	678,11	0,022	14,31

Date of sampling waste in the transient container	Mass (g)	H %	OM %
28/01/2011	2611	75,59	91,02
25/02/2011	3675	75,10	96,38
Total /Mean	6286	75,35	93,70
CV (%)			

Data underligned in yellow are calculated, others have to be measured then inserted in the calculation file

.2.5.6 Comparisons between the Method 1 and the Method 3

The measured masses and the calculated masses (Table 11) were compared on the basis of graph given on Figure 7. Table 11 exhibits a high discard between the mass measured by the volunteers and the mass calculated on basis of conservation of mineral matter. On Figure 7, we observe that the method based on conservation of the mineral matter always gives results much higher than the method by the weighing. This difference is due to inaccuracy of the method 3. Indeed, this method imposes assumptions of moisture and organic matter contents of the waste supplied. Although, biowaste supplied were sampled and analysed once per month, their real characteristics remain unknown. If uncertainties for moisture do not lead to significant discards in the calculation of biowaste supplied thanks to Method 3, uncertainties for organic matter content lead to high under or over estimation compared to data obtained by applying method 1 (see example following).

Uncertainties in method based on Mineral Mass conservation:

In the case of the cycle 1 at Rouerie site (Table 11) a moisture to 65% instead of 75% (mean value from two measurements with CV=0.46%) would lead to a mass of biowaste composted similar to the one measured by volunteers. Such over-estimation of moisture seems almost impossible. In contrast, CV for OM contents was higher (4%) with a mean value of 93.7%. However, assume OM contents of biowaste supplied to 91.14% instead of 93.7%, i.e. only 2.5% inferior led to a calculated mass of biowaste composted equal to the one measured by volunteers i.e. 477.9 kg instead of 671.8 kg.

Then, the heterogeneity of biowaste and its variation in OM content, added to potential errors in OM analysis, do not allow to apply the method based on conservation of mineral matter.

For biowaste, the method by the weighing seems then more precise than the method based on the conservation of the mineral matter. More, the Figure 7 shows that the results obtained for the bulking agents are close. We can thus consider that the measurement by the volunteers is worthy of confidence. To determine the quantity of organic waste diverted of the usual collection by collective composting, it is more precise to use the method of the weighing.

Table 11

Comparison between Method 1 and Method 3

		Mass of organic waste calculated (kg)	Mass of organic waste measured by volunteers (kg)	Mass of bulking agent measured by Irstea (kg)	Mass of bulking agent measured by volunteers (kg)
Site Rouerie	Cycle 1	671,800	477,900	64,800	65,190
	Cycle 2	737,836	559,000	68,800	59,500
Site Alma	Cycle 1	316,700	136,800	143,400	130,500
	Cycle 2	223,381	68,000	89,300	71,400
	Cycle 3	In progress	129,280	8,815	13,380
Site Montand	Cycle 1	555,450	203,400	90,400	82,010
	Cycle 2	404,835	181,900	68,000	51,300
	Cycle 3	259,487	225,230	38,965	44,730

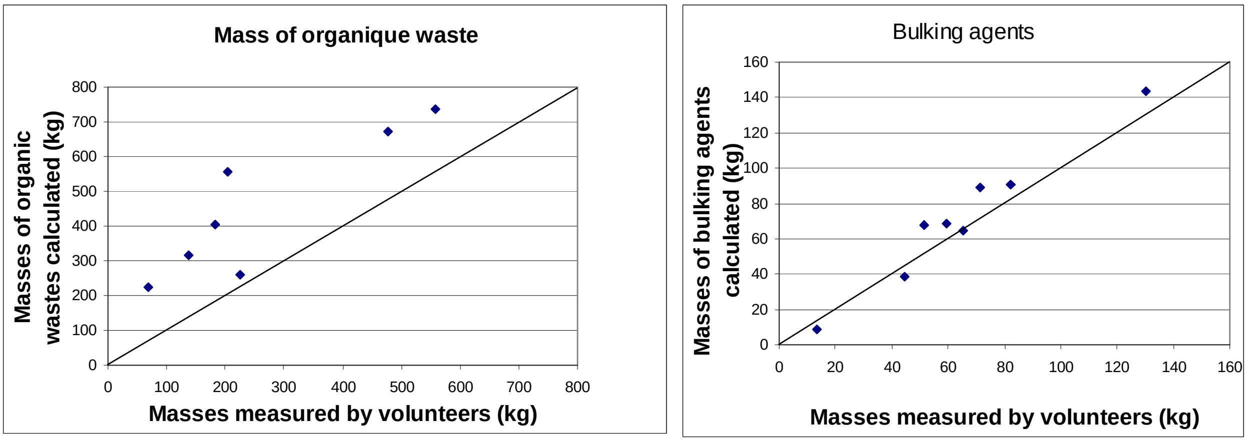

Fig. 7: Comparison between the calculated results and the weighed results

3 Results

.3.1 *Proposal of a protocol to the quantification of organic waste composted in case of an operation of collective composting*

.3.1.1 Objective of the protocol of study

In order to know the quantity of organic waste diverted from the usual collection of the household waste in the case of an operation of composting in collective home.

.3.1.2 Application

Intended for the municipalities wishing to estimate the quantity of organic waste diverted of the household waste, to determine a rate of diversion and to evaluate an operation of collective composting.

.3.1.3 Material and method

We demonstrated that the method based on conservation of the mineral matter can not be applied. It is therefore necessary to look for volunteers to weigh their organic waste. Two methods of weighing were tested. They are complementary but gives an order of magnitude of the amount of organic waste diverted. We thus present the material and the method to be applied in both cases and the advantages and disadvantages of each protocol.

To know the quantity of biowastes diverted by composting, the study must be carried out under real conditions, i.e. on pre-existent sites of collective composting. It is necessary to be able to reach the following data:

- Quantity of organic waste added in the collective composter
- Number of inhabitant in the residence
- Number of inhabitant taking part in composting on the studied site
- Quantity of organic waste produced in collective home (Chapter 1)

.3.1.3.1 *Comparison between a method with a collective weighing and a method with an individual weighing*

	Collective weighing	Individual weighing
Data to acquire	- Number of inhabitant in the residence - Number of inhabitant taking part in composting - Quantity of organic waste produced in collective home - Quantity of organic waste added in the collective composter	- Number of inhabitant in the household - Quantity of organic waste produced in collective home - Quantity of organic waste added in the collective composter
Sample constitution	3 composting sites where at least one user is ready to help the technician for the weighing of the organic waste brought to the composter	20-30 households from one or several residences
Material	- One or two scales per site - Four or five buckets per site - Monitoring sheets for the weighing of OW - An adapted composter (Annex 2) - Descriptive sheets on the composters	- One scale per household - One bucket per household - One monitoring sheet per household - Stamped envelopes for the return of the results
Monitoring	- Volunteer: weighing between one and three times per week - Technician: take part of the weighing at least once per week	- Explanation at each household of the weighing method and distribution of the material - Weighing by the household

	- Carry out meetings with the volunteers to inform them of the results and to motivate them - Limit the monitoring to 6 months	- Carry out meetings with the households to inform them of the results and to motivate them - Limit the monitoring to 6 months
Advantage	- The diverted quantity measured at the scale of a building is a surer data - Monitoring easier because of the low number of site and volunteer - If the estimation of the number of participant is correct thus the result expressed in kg/inhbt/y and calculated at the scale of the inhabitant participating is right	- The number of inhabitant is know in the household - Easier to find volunteers to weigh their own wastes - Know the type of waste added to the composter
Disadvantage	- Estimation of the inhabitant participating is difficult. That needs a survey near all the resident	- Bias in the measurement because volunteers are more vigilant in sorting out their wastes → to apply a factor at the result (Formula V) - Manage more people is more difficult

In the case of method 2, the bias due to the specific behaviour of the weighing volunteer requires to apply a corrective formula to the result. That formula, named V, allows to have a better approach of the quantity really diverted from the usual collection. V can be expressed as follows:

- Let A be the quantity of OW measured in the RHW (kg/inhbt/y.)
- Let B be the quantity of OW measured of the weighing method 2 (kg/inhbt/y.)
- Let y be the rate of participation measured or expected (expressed between 0 and 1)

Thus the formula V becomes:

$$V \text{ in kg/year} = B \times (1 + (((0.75 \times A) \div B) - 1) \times y) \times \text{number of inhabitant}$$

.3.1.3.2 Number of inhabitant in the residence

This data can be obtained by counting the number of letterbox of the selected building and multiplying by a mean number of inhabitants per apartment. It can also be obtained by request near the syndic, lessor or caretakers.

.3.1.3.3 Number of inhabitant taking part in composting on the studied site

Before starting the study, it is necessary to count the number of inhabitant taking part to composting on the selected sites. Three methods are possible:

- The composting users are already listed by the municipality and we consider that there are not new participants or stop

- The volunteer knows the participants well and can thus give this information

- Carry out a survey near the inhabitants with the support of the volunteer(s). It is more consuming in time but a surer method. It also makes possible to recover other related information about the composting practices or the acceptability of this type of operation and to communicate on the experimentation to come. A proposition of survey is given in Annex 5.

.3.1.3.4 Quantity of organic waste produced in collective home

In order to calculate a rate of diversion, it is necessary to know the quantity of organic waste found in the residual household waste. This work must be done before or in parallel of this protocol, on the same territory and by targeting buildings not equipped with composter. The detailed method is given in the protocol in chapter 1.

.3.2 *Transferable data with another territory*

A simplified protocol can be used by a municipality which do not want to implement the weighing. That method is based on the result of the characterization. With that method, the formula V becomes:

$$V = 75\% \times A \times \text{number of inhabitant}$$

4 Conclusion

The estimation of the quantity of diverted biowaste is not easy due to the difficulty to know precisely the number of inhabitant taking part of composting. It exists two possible methods to weigh the biowaste supplied to the composter: an individual weighing and a collective weighing. The collective weighing makes it possible to know a potential diversion to the scale of a building. This value once acquired may be applied on a set of building to approach the quantity of biowaste avoided in RHW. Moreover, if the number of participant is sure this method gives also a good data about the quantity of OW really diverted thanks to the collective composting site. This method makes it possible to obtain information on the evolution of the compost at the foot of the studied building and to monitor the maturation period i.e. we have a better knowledge about the processes in local composting.

The individual weighing can be used if it is not possible to find a volunteer ready to weigh all the biowaste of the building. The result found must be corrected by a factor due to the different behaviour of weighing volunteers in sorting their OW.

In the case where the weighing is not possible, we can rely to the data of the production of OW in the RHW measured by a characterization combined with a follow-up of the produced quantity to approach the quantity of OW diverted thanks to the installation of a collective composter.

CONLUSION

Thus, we have developed several methods to determine the amount of organic waste contained in the household wastes of collective homes on one hand and on the other hand to evaluate the quantity of waste really diverted by the practice of composting in case of an operation of collective composting.

The quantification of OW in RHW and the measurement of the quantities really diverted regards to the results of individual homes allowed us to note that, on the one hand, economic activities impact probably significantly the amount of total waste produced on the scale of the city of Rennes and on the other hand that the people involved in an operation of individual weighing have a different comportment regard to the average of the composting population. We have also noted that composting does not divert all of the quantities produced since it remains yet in the OMR.

The method used to evaluate the quantity of OW in the RHW is the MODECOM method added to a method of follow-up of the produced quantities. To be able to compare the data obtained, it is necessary to express them in kg/inhbt/year. Thus, the main difficulty in the application of these methods is the estimate of the population which composes the sample.

We find also this difficulty in the application of the method aiming to determinate the quantity of OW diverted from the usual collection thanks to the collective composting. Thus, it was for us a difficulty to determine a rate of diversion since, in the application of this method, we found results similar to the produced quantity of OW. If we are not sure about the number of inhabitanst participating, it is possible to define a rate of diversion per residence instead of per inhabitant.

We also have to make remark that if the methods can be partly transferred to the other European municipalities, provided adaptation due to specificities of the studied area, the data are less sure due to variation from one country to the others. For municipalities who are starting their composting operation it is possible to evaluate the potential for diversion only by the application of the protocol about the quantity of organic waste in the RHW.

Finally, these two chapters were only devoted to the collective homes whereas the municipalities may also be interested by the other producers of OW, in particular those whose production could also be treated thanks to in-situ composting like for school restoration. It is thus necessary to seek after tools able to treat productions higher than the collective homes with a product of quality at exit. This work is included within the framework of the Miniwaste project since as mentioned in the introduction, the seek of further methods, to choose a composter, define a composting process, monitor composting and finally evaluate the operation, is in progress and partly set-up at composting operations at collective restaurants.

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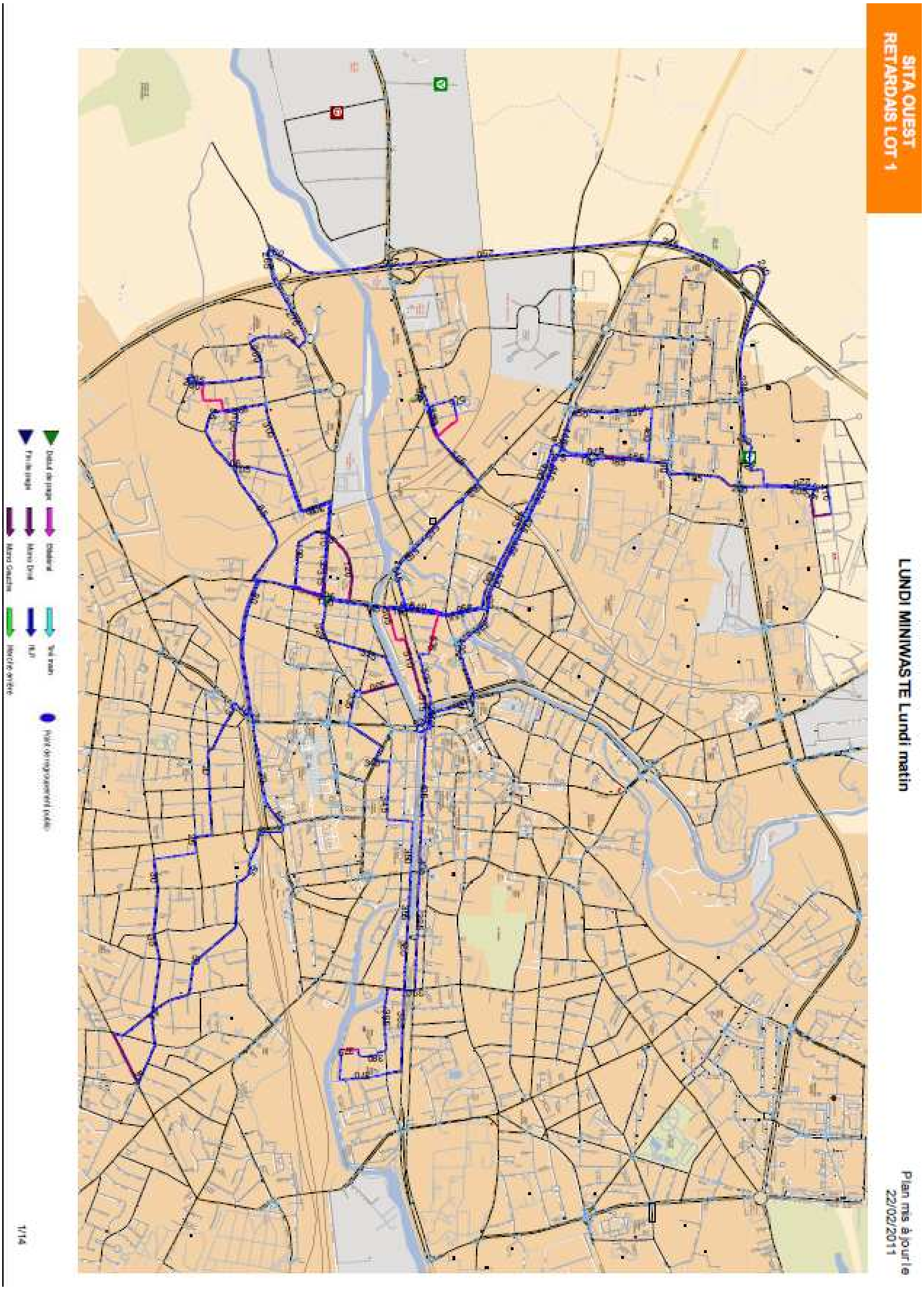
ANNEXES

ANNEX 1
Collection circuits



ANNEX 2
Detailed method:
Method based on the weighing of the organic wastes by a volunteer (Method 1): Fitting-out of the area dedicated to the experimentation

The area dedicated to composting of biowastes is constituted by 3 containers (Figure 1):

- the composter (A) which cover is locked and the key committed to the volunteer,

- a container similar to a composter (B) dedicated to storage of yard wastes i.e. the bulking agent which cover is locked and the key committed to the volunteer,

- a container similar to a composter (C) which contains:

  - a bin (a) where inhabitants insert their biowastes and a pencil and a form to register that they brought biowastes

  - a scale (b) given to the volunteer to weigh the wastes loaded in the bin (a) by inhabitants (and that after weighing the volunteer will load in the composter) and furniture to register the mass of wastes (a pencil and a form to register the mass).

  - a bracket (c) of which the upper part slips into the lower part in order to be able to withdraw and to put the upper part in the composter. This easy way makes it possible to preserve the usual aspect of the site of composting. Moreover, this bracket can turn on its axis and make it possible to pour the contents of the bucket when it is suspended at the bracket, in the composter of supply.

Yard wastes (also named "bulking agent") were added to wastes by the volunteer according three different ratios (one fixed ratio per site).

Each composter must be correctly closed (except the composter with the buckets) and signposted by a descriptive poster so that the inhabitants do not make error.

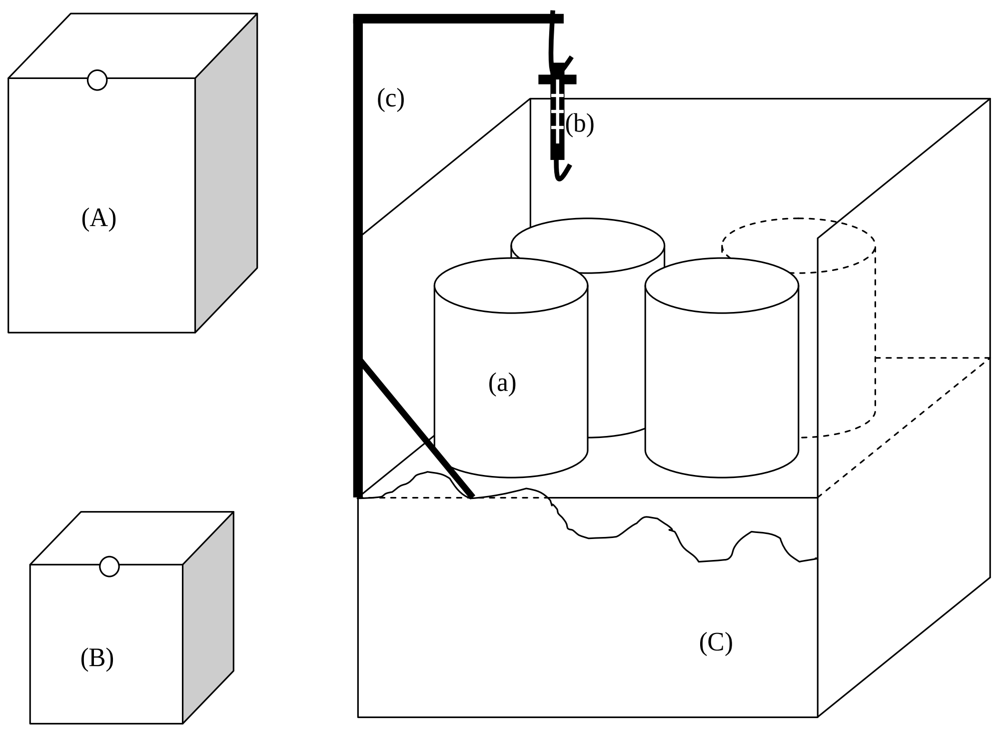


Fig. 1. Area for composter

ANNEX 3 (1/2)

Detailed method:
Method 3: Mineral mass conservation

The method is based on conservation of mineral matter along composting treatment. At every event (start of monitoring, turning, material or compost extraction, end of monitoring), the masses of composting material, bulking agent placed in a dedicated container, sample of composting material and material extracted have to be weighed and the samples have to be analysed for determination of their contents in dry matter and mineral matter. The mass of wastes supplied to the composter during the time dt, from t to t+dt, i.e. mWS(dt) can be calculated thanks to the following equations:

$mMM_{WS}(dt) = mMM_{CM}(t+dt) - mMM_{CM}(t) – mMM_{BA}(dt) + mMM_{ME}(dt)$ (1)

$mMM_{CM}(t+dt) = mCM(t+dt)*(DM_{CM}(t+dt)/100)*((100-OM_{CM}(t+dt))/100)$ (2)

$mMM_{CM}(t) = mCM(t)*(DM_{CM}(t)/100)*((100-OM_{CM}(t))/100)$ (3)

$mMM_{BA}(dt) = mMM_{BA}(t+dt) – mMM_{BA}(t)$ (4)

$mMM_{BA}(t+dt) = mBA(t+dt)*(DM_{BA}(t+dt)/100)*((100-OM_{BA}(t+dt))/100)$ (5)

$mMM_{BA}(t) = mBA(t)*(DM_{BA}(t)/100)*((100-OM_{BA}(t))/100)$ (6)

$mMM_{ME}(dt) = mME(dt)*(DM_{ME}(dt)/100)*((100-OM_{ME}(dt))/100)$ (7)

$mMM_{WS}(dt) = \mathbf{mWS(dt)}*(DM_{WS}(dt)/100)*((100-OM_{WS}(dt))/100)$ (8)

with:

$mMM_{CM}(t+dt)$ and $mMM_{CM}(t)$: masses of mineral matter (MM) in material in composting at t+dt and at t, obtained thanks to equations (2) and (3) with mCM(t+dt), mCM(t): the masses (kg) of composting material measured at t+dt and at t, $DM_{CM}(t+dt)$ and $DM_{CM}(t)$: dry matter content (%) of composting material at t+dt and at t (measured on the samples collected at t and t+dt), $OM_{CM}(t+dt)$ and $OM_{CM}(t)$, organic matter content (%) of composting material at t+dt and at t (measured on samples),

$mMM_{BA}(dt)$, the mass of mineral matter contained in bulking agent into the composter, calculated thanks to equation (4) with $mMM_{BA}(t+dt)$ and $mMM_{BA}(t)$, the masses of MM contained in bulking agent at t and t+dt, obtained thanks to respectively equations (5) and (6) with mBA(t+dt) and mBA(t), the masses of bulking agent (stored in a dedicated container) at t and t+dt, $DM_{BA}(t+dt)$ and $DM_{BA}(t)$, DM content of bulking agent at t and t+dt (measured on a sample collected at t and t+dt), $OM_{BA}(t+dt)$ and $OM_{BA}(t+dt)$, OM content of bulking agent at t and t+dt,

$mMM_{ME}(dt)$: mass of mineral matter contained in material (compost or other) extracted during dt obtained thanks to equation (7) with mME(dt), the mass of material extracted during dt (measured), $DM_{ME}(dt)$ the DM content of the material extracted (measured on a sample) and $OM_{ME}(dt)$, its content in OM (measured on the sample).

$mMM_{WS}(dt)$: mass of mineral matter contained in wastes supplied to the composter during dt calculated from equation (1) and which allows thanks to equation (8) to calculate **mWS(dt)** assuming mean values of DM and OM of wastes supplied (DM_{WS} and OM_{WS}) i.e. food wastes (which values will be estimated thanks to biowastes characterization practised through the set-up of a method to quantify biowaste production and also thanks to data found in literature).

ANNEX 3 (2/2)

<u>Procedure:</u>
In case inhabitants use bulking agent, a container has to be dedicated to their storage. When adding bulking agent in this container, mass supplied will be measured.

The inhabitants bring their wastes in the bin and the volunteer transfers them into the composter in agreement with the organization imposed by method 1.

At every event (start of monitoring, turning, material or compost extraction, end of monitoring), the masses of composting material, bulking agent in the dedicated container, sample of composting material and material extracted have to be weighed and the samples have to be analysed for determination of their contents in dry matter and mineral matter. Masses and DM and OM contents will be mentioned in the form below.

Date	Nature of event	Data on wastes	Symbol	Value	Data on bulking agent	Symbol	Value
xx/yy/zz	Starting of monitoring Or Turning Or Compost extraction Or Monitoring Or Feeding of yard wastes container	Mass of Composting Material in the composter Before Sampling	mCMbs (kg)		Mass of bulking agent in the dedicated container Before Sampling	mBAbs (kg)	
		Mass of Sample of CM extracted for analysis (# 50%)	mCMS (kg)		Mass of Sample of BA extracted for analysis (# 50%)	mBAS (kg)	
		Mass of Material Extracted for compost recover or any other reason (# 50%)	mME (kg)		Mass of BA extracted for analysis (# 50%)	mBAE (kg)	
		Mass of Composting Material let in the composter After Sampling (and/or extraction) (# 50%)	mCMas (kg)		Mass of bulking agentlet in the container After Sampling (and/or extraction) (# 50%)	mBAas (kg)	
		Content in Dry Matter of the sample of Composting Material	DM_{CM} (%)		Content in Dry Matter of the sample of bulking agent	DM_{BA} (%)	
		Content in Organic Matter of the Sample of Composting material	OM_{CM} (%)		Content in organic matter of the sample of bulking agent	OM_{BA} (%)	
		Content in Dry Matter of Material Extracted	DM_{ME} (%)		Content in Dry Matter of the bulking agent Extracted	DM_{BAE} (%)	
		Content in Organic Matter of Material Extracted	OM_{ME} (%)		Content in organic matter of the bulking agentExtracted	OM_{BAE} (%)	

ANNEX 4
Individual weighing of the quantity of organic waste diverted: Results about Rennes Metropole experimentation (Method 2)

The result about Household 27 was removed because it seems beyond the means of the studied sample. We obtain a mean quantity of composted waste of 47 kg/inhabitant/year.

			nov	dec	jan	feb	march	april	may	june	Composted waste per household
	Number of inhabitant	Number of month monitored	Quantity of composted waste (g)								kg/year
Household 1	5	7		2400	16100	18400	11800	6000	10550	8600	126,6
Household 2	2	7	17200	13500	6000	11000	7000	9500	3000		115,2
Household 3	2	8	4300	3100	4900	2200	1600	1200	1000	1100	29,1
Household 4	2	8	8000	5500	6400	800	7200	6000	8300	5500	71,6
Household 5	2	7	11900	8900	7600	10200	13200	7000	12900		122,9
Household 6	2	8	14200	23600	19200	14700	16400	14100	13700	9500	188,1
Household 7	1	5	410		580	590	6700	52000			144,7
Household 8	2	8	5300	7700	8400	8000	8400	9300	12700	9000	103,2
Household 9	2	8	5500	3700	6200	3600	3400	4300	4400	3000	51,2
Household 10	3	6		3300	3000	2600	2550	3200	5300		39,9
Household 11	2	8	4300	5300	4500	6200	6450	5700	5100	7250	67,2
Household 12	1	8	6700	7700	14300	5900	6400	4700	6000	7900	89,4
Household 13	2	7	18300	7500	16100	17900	12100	8500	9700		154,5
Household 14	5	8	9600	11500	14700	9100	7700	13900	16800	15700	148,5
Household 15	2	7	22000	9400	13300	11600	9200		14400	11200	156,2
Household 16	2	7	6800	4900	4100	6600	4800	6200	7200		69,6
Household 17	4	8	6700	9900	6500	12900	11700	12100	11000	14000	127,2
Household 18	2	7	20900	22000	17300	16400	20000	23900	23900		247,5
Household 19	4	6	13600	12600	20100	22800	12300	17000			196,8
Household 20	1	5	0	5000	3400	2600	2700				32,9
Household 21	3	8	56200	12100	11600	10600	10200	6300	9500	9600	189,2
Household 22	3	6	16100	16600	13800	10200	11300	7700			151,4
Household 23	2	4	17700	12500	5700	15800					155,1
Household 24	2	8	5500	14500	15700	11400	19600	12500	17200	17700	171,2
Household 25	2	8	8750	13700	14300	16300	5300	5700	8000	4400	114,7
Household 26	4	8	8390	6850	9750	9880	7700	10900	11500	8370	110,0
Household 27	1	7	2800	15500	24000	9000	9000	16000	16000		158,2
Household 28	4	6	6500	1600	5400	2700	5000	4600			51,6
										total	3225,2

Mean of composted waste:	**47,4**	kg/inhbt/year

ANNEX 5 (1/2)
Survey to know the opinion of the inhabitants about their acceptability of the operations of composting

1) How much person constitute your household?
   - Number of adults: ……………………………….
   - Number of children: …………………………....

2) Do you taking part of composting in your building?

Notch the box and read the corresponding comment		
Yes		Answer all the questions
I stopped		Answer all the questions
No		Answer only the questions in light (no concerned by the questions in gray)
I did not know there was a site of composting		Answer only the question n°3

2 bis) If yes: What it is the frequency of contribution of waste to the composter?

☐ When I think of it

☐1 time every 15 days

☐ 1-2 times per week

☐ 3 times per week

☐ More than 3 times per week

3) About the practice of composting :

	Yes	No	No opinion	Comments
Composting regularly is a difficult activity.				
Do you have the intention to begin/continue the practice of composting				
Do you think to be quite informed on the manner of composting your waste?				

4) The distance between your building and the site of composting appears to you:

		Comments
Too much large		
Too much small		
Satisfactory		

ANNEX 6 (2/2)

5) About the installation of the composting site of composting:

	Yes	No	No opinion	Comments
The number of composter is satisfactory				If it is no, which would be satisfactory? Number of desired composter: ………..
The configuration of the composter is satisfactory				
The aestheticism of the site is successful				

6) About the working of the composter:

	Yes	No	No opinion	Comments
The volume of the composter is satisfactory				
The tools are easy to use.				
In general way, the compost evolves well.				
The composter is regularly source of harmful effects				If yes, which harmful effects? ……………………………………. …………………………………….
The quality of the compost obtained is correct				

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