Indicating the parameters of the state of degradation of municipal solid waste

V. Francois [a], G. Feuillade [a,*], N. Skhiri [b], T. Lagier [b], G. Matejka [a]

[a] *Laboratoire des Sciences de l'Eau et de l'Environnement, ENSIL, 16 Rue Atlantis, 87060 Limoges Cedex, France*
[b] *CReeD, Zone Portuaire de Limay, 291 Avenue Dreyfous Ducas, 78520 Limay, France*

Abstract

This study related to the analysis of the physical (granulometry and composition) and chemical (organic matter, organic carbon and nitrogen contents) characteristics, as well as those relating to release (leaching tests and determining the methanogene potential) of several domestic wastes, with an aim of evaluating stabilization indicators. Values thresholds for a known stabilized waste were thus deduced by correlation (% paper-cardboard = 0–1; % volatile solid (VS) = 18–19; % OC = 5–6; % fines = 44–45; % degraded components = 75–76, COD of leachate = 141–155 mg O_2/L; DOC from leachate = 45–49 mg C/L and 0.9–1 m^3 CH_4/t of dry waste). However, these values thresholds remain specific to the method employed for the analyses. The results obtained represent a considerable advance in the definition of a waste stabilized state and propose the importance of certain parameters, such as the paper-cardboard content and the measurement of leachates by using the SUVA index for determining a stabilization state.
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1. Introduction

Landfilling is carried out in order to reduce environmental impacts to the minimum. Regulations (adopted on 9 September, 1997) impose, in particular, the recovery and the treatment of the leachate and the biogas produced during site exploitation and for the period of post-30-year exploitation. However, the end of the post-exploitation period does not inevitably mean that any risk of pollution has been isolated.

The final quality of waste thus becomes an indispensable criterion for ensuring that there is no risk of environmental pollution.

The definition of a waste stabilized state, and the ways of making it possible to reach this state quickly, are currently the highest priority. The stabilization criteria are mainly directed towards following-up leachates and biogas produced.

Morris et al. [1] indicated, for example, a stabilized state for a total gas production corresponding to 95% of the estimated theoretical gas production. However, the analysis of the pollution released by waste is not always representative of the potential waste pollution [2].

Recent studies [3–6] try to determine more relevant criteria to represent the state of waste degradation by analysing, for example, their biodegradability and their release potential. According to Kelly [4], the best parameters of waste stability are the organic matter content, the cellulose content and the measurement of waste methanogene potential. However, little data are available and it remains difficult to validate. The study described in this paper thus concentrates on the physicochemical characterization (granulometry, composition, organic matter content, organic carbon and nitrogen contents) of several domestic wastes of different ages, such as measuring total parameters of the leachate and biogas released in order to define the value thresholds of a stabilized state.

Table 1
Type of waste studied and analyses carried out

Age of wastes	3 Years	8 Years	8 Years	8 Years	20 Years	30 Years
Site	A	B	C	D	D	E
Name of wastes	A_3	B_8	C_8	D_8	D_{20}	E_{30}
Site surface cover	Clay layer	Clay layer	Clay layer	Clay composed of compost	Clay layer	Clay layer
Type of analysis carried out	Physical characteristics Chemical characteristics Release (leachate and biogas)	Physical characteristics	Physical characteristics	Physical characteristics Chemical characteristics Release (leachate and biogas)	Physical characteristics Chemical characteristics Release (leachate and biogas)	Physical characteristics Chemical characteristics Release (leachate and biogas)

2. Materials and methods

2.1. Choice of domestic wastes

The solid wastes were collected from sanitary landfill. In order to see a significant progression of the measured parameters, wastes of different ages were studied (Table 1).

These wastes were selected more because of their accessibility than their intrinsic characteristics. Their disparate sources make it difficult, however, to take the factor age in the results into account. For the 8-year-old wastes, study as been mainly carried out with D_8 (covered by clay composed of compost) because the mass of this waste was the more important and then the more significant. However, it will be necessary to realize the same study with B_8 and C_8 wastes to confirm the impact of the type of cover.

Waste masses, ranged from 40 to 150 kg and were collected from 2 to 3 m depth.

Waste samples were preserved on plastic bags, and then they were studied in the following 48 h.

Fresh waste, reconstituted according to ADEME specifications, was called F and was also characterized. It is used as a reference. This waste composition is given in Table 2.

Table 2
Composition of reconstituted fresh waste F [19]

Waste category	National average of reference (in % of wet mass)
Putrescible waste	28.6
Papers	16.1
Cardboards	9.3
Packaged papers	1.4
Textiles	2.6
Medical textiles	3.1
Plastics	11.1
Wood	3.3
Glass	13.1
Metals	4.1
Inert material	6.8
Special waste	0.8
Total	100

2.2. Physical characteristics of waste

Wastes were characterized in a wet state so as to be closer to the characteristics of the waste in the landfill.

2.2.1. Granulometry
The MODECOM ADEME Method (1993) was applied to each rough waste:

$$\textbf{COARSE} - /10\,\text{cm}/ \rightarrow \textbf{MIDDLE} - /2\,\text{cm}/ \rightarrow \textbf{FINE}$$

2.2.2. Composition
Middle and coarse fractions were sorted according to the waste categories given in MODECOM [7]: paper-cardboards, plastics, wood, inert material, metals, special waste (batteries, cigarette butts, dirty sponges, medicines), textile, glass and a form of degraded wastes. The form of degraded wastes represent wastes in a state of degradation, so that it is not possible to associate them with a specific waste family.

This sorting stage proves to be difficult for the rather wet fractions, like degraded compounds, which tend to be linked to other waste categories.

2.3. Chemical characteristics

To be representative, the analysis to determine the chemical characteristics must be carried out on a homogeneous and fine sample. The grinded waste is thus necessary for these measurements. It is necessary to carry it out as a dry waste, in order to facilitate the operation. Therefore, a drying stage must be carried out before the grinding operation.

2.3.1. Waste preparation before analysis
2.3.1.1. Drying. The waste was dried under a stream of nitrogen (micronitrogen generator 90) in a glove box, in order to limit their oxidation.

This drying operation lasts approximately 3 weeks for a 50 kg quantity of waste.

2.3.1.2. Grinding of all sorted and dried fractions. The sorted and dried waste fractions were grinded to an approximate size

of 2 mm in diameter. This size is often taken as the reference for analysis of natural solid samples ([8] AFNOR [9,4]).

However, certain waste categories (plastics, metals and special wastes) could not be grinded and they were thus removed from the waste sample. However, because of their low biodegradability over time, this modification of the waste composition should not modify the waste intrinsic characteristics.

Taking these fractions into account, in particular plastics, can cause certain measurements to be overestimated, such as the organic waste content during its burning [4].

2.3.1.3. Reconstitution of dried and grinded waste, without plastics, metals and special waste.
Each powder of each dried and grinded sorted fraction is mixed by respecting the various category proportions contained in the initial waste composition.

2.3.2. Analysis carried out on the waste powders

All the analyses were doubled:

- measurement of the waste organic matter by burning it at 550 °C for 4 h [7]; the organic matter or volatile solids content is obtained by the difference between the weight of dry waste and the weight of calcined waste;
- measurement of the organic carbon which can be oxidized by the bichromate (Walkley and Black method (1934) [10];
- measurement of the waste nitrogen content by the Kjeldalh Method (NF U44-050).

2.4. Waste release estimation

2.4.1. Release in leachate

2.4.1.1. Leaching tests protocol.
Tests were carried out with a liquid to solid ratio (L/S) of 8. Before the standard test creation, pre-tests were carried out with various L/S, which highlighted significant results for the tests used. In continuing the study and in order to be able to compare all the results, this ratio of 8 was preserved, even if it is not that of leaching tests standard applied in France (standard X31-110 [11]). Agitation was carried out

Table 3
Characteristics of the Crézin leachate (Haute–Vienne)

Parameters	Ranges of values from January 2002 to June 2003	Measuring accuracy
pH	7.0–7.2	±0.1
COD (mg O_2/L)	355–432	±20
BOD_5 (mg O_2/L)	85–125	±20
DOC (mg C/L)	85.0–130.0	±0.2
UV absorbance at 254 nm, dilution 1/10	0.189–0.246	±0.005
UV absorbance at 280 nm, dilution 1/10	0.157–0.206	±0.005
SUVA index	20–24	±1
Na^+ (mg/L)	249.0–320.6	±0.3
NH_4^+ (mg/L)	140.6–220.8	±0.3
K^+ (mg/L)	121.3–209.3	±0.3
Mg^{2+} (mg/L)	16.8–23.3	±0.3
Ca^{2+} (mg/L)	45.2–58.2	±0.3
Cl^- (mg/L)	243.3–500	±0.3
NO_3^- (mg/L)	0–2.6	±0.3
NO_2^- (mg/L)	0–8.8	±0.3
PO_4^3 (mg/L)	0–6.4	±0.3
SO_4^2 (mg/L)	4.0–8.8	±0.3

using a Jartest bench with stirrer blades (number of revolutions 155 rpm).

The elution solutions used are: ultrapure water and Crézin landfill leachate (Haute–Vienne) considered as a known stabilized leachate, according to the classification of Millot [12]. These leachate characteristics are provided (Table 3).

Tests in deionized water allow the pollution released by waste to be considered by simple washing out, whereas the tests with leachate allow the pollution likely to be released by this waste during possible recirculation tests to be understood.

Two types of tests were carried out:

(1) tests at various contact times (1 h, 6 h, 10 h, 24 h and 48 h) to consider the optimal concentration in released pollutant species,

Table 4
Analyses carried out on the leachates

Measured parameters	Method	Measuring accuracy	Information	Interest
COD	NFT 90-101 [20]	±20 mg O_2/L	Determination of the oxydable organic matter	Estimate of the risk of waste polluting the natural environment
DOC	COTmeter Phoenix 8000 (Dohrmann Instrument)	±10 mg C/L	Determination of dissolved organic carbon	
pH	pHmeter PH M210 "Meterlab"	±0.05	Determination of the pH of the medium	pH conditions favourable to the methanogenesis development
UV absorbance at 254 nm	UV–visible spectrophotometer mC^2 (SAFAS)	±0.005	Determination of aromatic organic compounds	Evaluation of humification, the maturation of leachate organic compounds
SUVA index	UV absorbance/DOC ratio	±1	Determination of the hydrophobic and aromatic character of the organic compounds	
Major ions (Ca^{2+} Mg^{2+}, Na^+, K^+, NH_4^+, SO_4^2, Cl^-, NO_3^-, NO_2^-, PO_4^3)	Ionic chromatography DIONEX DX 120	±0.3 mg/L	Determination of the mineral pollution released by waste	Some of these elements can inhibit the methanogenesis and/or support clogging if they are present in too significant quantities

(2) tests with successive liquid to solid ratios, the liquid being renewed every 24 h until reaching the maximum capacity of waste release.

All the leaching tests were repeated.

2.4.1.2. Leachate analysis. The leaching test juices were separated from the solid by centrifugation at 8000 rpm; the leachates were then filtered through acetate membranes with a porosity of 0.45 μm (Whatman) (Table 4).

2.5. Release of biogas

2.5.1. BMP tests protocol [13]

These tests allow the waste methanogene potential to be estimated and to envisage its state of degradation, and therefore its polluting potential.

The tests were carried out in CReeD and were repeated for each waste.

The tests were carried out in reactors, including three pickings of 30 g of dry waste, were mixed with an inoculum containing anaerobic digester sludge (0.1–0.2 g of inoculum VSS/g of waste VSS). 20 mL of nutritive solutions A (KH_2PO_4 and K_2HPO_4) and B (NH_4Cl, $CaCl_2$, $2H_2O$; $MgCl_2$, $6H_2O$ and $FeCl_3$, $6H_2O$) were added to the mixture. A solution of $NaHCO_3$ (0.3 g/g of dry waste) was also added to plug the medium. The mixture was supplemented with 600 mL of distilled water and the pH was adjusted with neutrality.

The reactors were placed in a thermostated box at 35 °C. Every 2 days, the pressure was measured by a pressure gauge via a picking; then the gas produced (CH_4 and CO_2) was analysed by gas chromatography (Micro GC VARIAN). The volume of gas produced was also measured by displacement of the water volume in a reversed test tube.

The duration of the tests varied according to waste samples, but on average lasted from 1 to 2 months.

3. Results and discussion

3.1. Waste granulometry

The size of the waste components seemed to progress with the age of the waste. A 3-year-old waste was made up mainly of coarse fractions (approximately 50%), whereas for a 30-year-old waste, in fact, the finest fractions prevailed. The granulometry of the 8-year-old waste and 20-year-old corresponded better in intermediate states. Moreover, the values found for waste D_8 were atypical, compared to those of other 8-year-old wastes. They are very close to those of a 20-year-old waste. The surface cover containing compost (of higher permeability) of this waste could be the reason for an acceleration in degradation (Fig. 1).

3.2. Waste composition

The evolution of the proportion of the waste-type present between 3 years and 30 years is an indicator of the state of
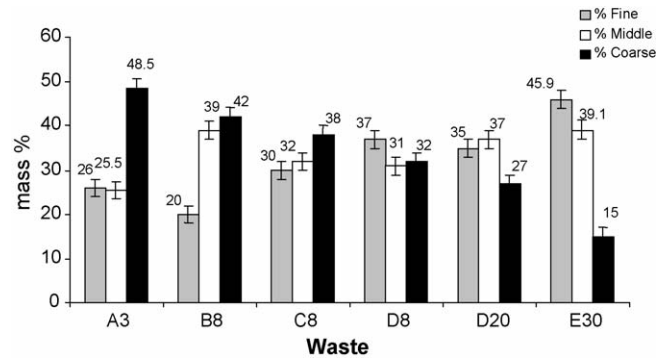

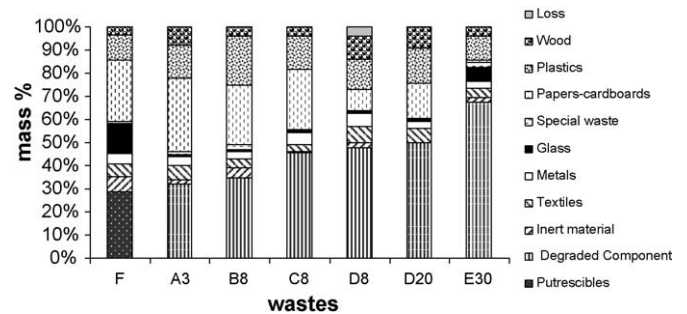Fig. 1. Waste granulometric distribution.
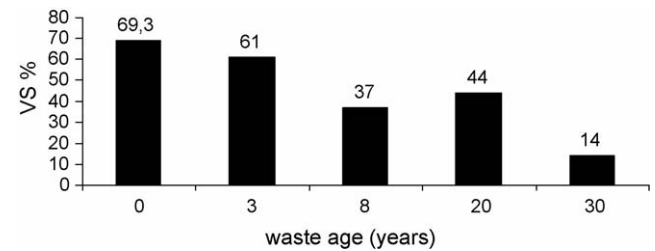

Fig. 2. Waste composition.

Fig. 3. Organic matter or volatile solids content contained in waste.

waste degradation. Indeed, the quantity of degradable components such as paper-cardboards decreased at the end of 30 years, whereas the quantity of degraded components increased up to 60%. No waste category (plastic, metals or glass) seemed very representative of the waste degradation state, because it remained constant between 3 years and 30 years. The proportion of glass found in this waste extracted from the site seemed weak compared to that provided in the fresh ADEME waste composition. Several assumptions can be made: either the waste
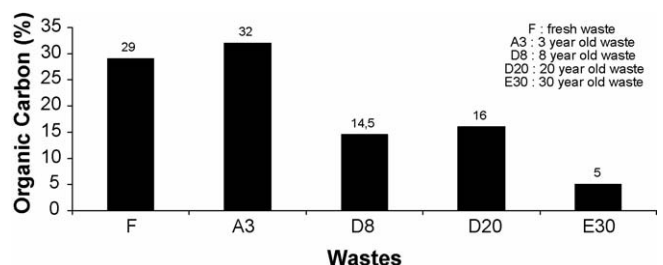

Fig. 4. Percentages of organic carbon waste.

Table 5
OC/VS ratios of studied wastes

	OC/VS
Fresh waste	0.42
3-Year-old waste	0.52
8-Year-old waste	0.39
20-Year-old waste	0.36
30-Year-old waste	0.36

Table 6
OC/N values of studied waste

	OC/N
Fresh waste	71.8
3-Year-old waste	45.7
8-Year-old waste	20.7
20-Year-old waste	16
30-Year-old waste	28.9

initial composition landfilled on the various sites is very different from the composition of reconstituted domestic waste; or during the landfilling, glass becomes easily friable and was strongly dispersed on the site; or, even, the considerable presence of industrial wastes landfilled with domestic wastes caused a dilution phenomenon of this quantity (Fig. 2).

3.3. Waste organic matter or volatile solids (VS) content

Fresh and 3-year-old wastes had a strong organic matter content, which is a sign of a little degraded state; the 8-year-old and 20-year-old wastes had lower contents, characterizing a more advanced state of degradation (Fig. 3).

The 30-year-old waste had a low organic matter content, which could be associated in a stabilized state, if one referred to the values in volatile solids given by Kelly [4]. The organic matter content contained in waste D_8 was close to that of D_{20} waste which again validated the atypical character of this waste.

Organic matter analysis enabled the 60–80% of the organic matter to be measured in the studied waste, which comes from degraded components and from the paper-cardboards to be highlighted. Moreover, the greater the age of the waste, the greater the organic matter due to degraded compounds – and very little by paper-cardboards (only 0.3% of the organic matter is due to paper-cardboards at the end of 30 years).

3.4. Percentages of organic carbon waste

The percentages of organic carbon measured for various wastes follow the same evolution as the organic matter: strong contents were measured for fresh and 3-year-old wastes, whereas lower contents were obtained for the 8-year-old, 20-year-old and 30-year-old wastes (Fig. 4).

Organic carbon/volatile solids (OC/VS) ratio was calculated for various wastes (Table 5).

For wastes which were not very much degraded, this ratio was about 0.5, which was consistent with the data of the literature [14,15]. Lower values were obtained for the 20-year-old and 30-year-old wastes: about 0.35.

This slight reduction could be explained by the presence, therefore, of less oxydable components which were more resistant to degradation. Organic compounds of high molecular weight, such as the humic substances like compounds, which are famous for their refractory character, could be the reason for this bad oxidation of organic carbon present.

3.5. Waste nitrogen content

The evaluation of OC/N ratio could be further used to determine the intrinsic characteristics of wastes (Table 6).

This ratio increased for fresh and 3-year-old wastes, and was characteristic of a significant carbon content, containing a substrate of, therefore, a slightly degraded state. 8-year, 20-year and 30-year wastes presented a ratio close to that of compostable waste. However, the 30-year-old waste, with a very small quantity of nitrogen (approximately 0.2%), tended more towards the characteristics of soil [16].

3.6. Waste release potential

3.6.1. Tests in deionized water

Analysis of the leachates released by various wastes during leaching tests indicated:

- a significant progression of some pollution parameters, such as COD, DOC, UV absorbance and SUVA index with the state of waste degradation;
- a quantity in DOC and in COD released, which decreased with the age of waste (Table 7).

Table 7
Characteristics of the leachates released by waste after leaching in water

Wastes	F	A_3	D_8	D_{20}	E_{30}
pH	7.2	7.5	8	7.5	7.8
COD (mg O_2/L)	7000	4900	900	400	120
COD quantity released (g O_2/kg of dry waste)	62.6	42.9	6.7	5.2	1.3
DOC (mg C/L)	ND	1342	249	110	40
DOC quantity (g C/kg of dry waste)	ND	12.8	1.5	1.3	0.3
[Na^+] (mg/L)	456	350	460	240	31
[NH_4^+] (mg/L)	5.8	17	30	119	0.8
[K^+] (mg/L)	490	409	270	133	39
[Mg^{2+}] (mg/L)	21	47	43	18	16
[Ca^{2+}] (mg/L)	137	251	177	60	165
[Cl^-] (mg/L)	300	460	396	319	32
[NO_3^-] (mg/L)	0	3	10	6	15.2
[NO_2^-] (mg/L)	0	0	0	0	0.6
[PO_4^3] (mg/L)	230	0	0	0	0
[SO_4^2] (mg/L)	300	344	1000	500	274.1
Ion quantity released (mol/kg of dry waste)	0.7	0.5	0.8	0.3	0.03
UV absorbance at 254 nm	18	11.2	3	2	3.3
SUVA index (cm^{-1} g C^{-1} L)	ND	8.4	12.0	20.0	82.5

Fresh and 3-year-old wastes had a strong release potential, at the same time, in organic and mineral pollution. The 8-year-old waste had a rather weak potential, which was nonetheless higher than that of the 20-year-old and 30-year-old wastes, and there was a higher risk of pollution. The COD measured for these three wastes corresponded to that of a leachate known to be stabilized, according to Millot [12], to the values of UV absorbance and to the strong value of the SUVA index, which also indicated the presence of aromatic organic macromolecules in these leachates.

The SUVA index of a stabilized leachate of landfill was about 20 and 30 for humic and fulvic acid-like compounds [17].

The measurement of this parameter was significant, because it makes it possible to distinguish the strong differences between the 8-year, 20-year and 30-year-old wastes, which was not the case with the simple measurement of the COD.

Mineral pollution was significant for fresh and 3-year wastes. However, chloride and sulphate pollution, in particular, was also high for older wastes like the 8-year-old and 20-year-old wastes. The presence of industrial waste mixed with household waste could be the reason for this significant pollution. The leaching test conditions, which had a slightly oxidizing effect, could also be responsible for the strong sulphate release observed in all the waste.

3.6.2. Tests in a stabilized leachate (Crézin leachate)

The release results presented were obtained after subtracting the pollution caused by the Crézin leachate (Table 3).

The release of COD in fresh, 3-year, 8-year and 30-year wastes slightly increased during tests with the leachate, compared to the tests in water. On the other hand, it decreased for the 20-year-old waste. Equilibrium state phenomena created themselves between the pollution caused by the Crézin leachate and that likely to be released by the 20-year-old waste. If there was an equilibrium phenomenon state, it was because the molecule characteristics were certainly identical (Table 8).

The SUVA index was modified, compared to the tests in water: the differences between the 20-year-old waste and 30-year-old waste were less visible and the value strongly decreased for the 30-year-old waste leachate.

3.6.3. Organic carbon percentage released by waste after leaching in water and in leachate

If a waste was in contact with a leachate of DOC which was smaller than the DOC released by waste in water, then the quantity released in leachate was decreased in comparison with quantity released in deionized water. There was a transfer phenomenon between the solid phases and the liquid phases. It was the contrary when the DOC of leachate was higher (Table 9).

Table 8
Characteristics of the leachates released by waste after leaching in a stabilized leachate

Waste	F	A_3	D_8	D_{20}	E_{30}
pH	8	8.2	8.1	8	7.9
ΔCOD (mg O_2/L)	8000	5300	905	130	236
COD quantity (g O_2/kg of dry waste)	68.9	36.7	5.3	0.8	2.5
ΔDOC (mg C/L)	ND	1235	266	40	70
DOC quantity (g C/kg of dry waste)	ND	9.8	1.05	0.5	0.8
$\Delta[Na^+]$ (mg/L)	450	311	600	0	9
$\Delta[NH_4^+]$ (mg/L)	5	7	110	0	114
$\Delta[K^+]$ (mg/L)	500	380	370	12	0
$\Delta[Mg^{2+}]$ (mg/L)	20	27	34	0	0
$\Delta[Ca^{2+}]$ (mg/L)	100	100	90	20	0
$\Delta[Cl^-]$ (mg/L)	300	215	750	80	17.5
$\Delta[NO_3^-]$ (mg/L)	0	0	7	2.8	12
$\Delta[NO_2^-]$ (mg/L)	7.8	0	0	0	0
$\Delta[PO_4^3]$ (mg/L)	180	0	0	0	0
$\Delta[SO_4^2]$ (mg/L)	200	360	960	500	267
Ion quantity released (mol/kg of dry waste)	0.6	0.2	1.1	0.08	0.08
UV absorbance at 254 nm of the mixture (leachate + waste)	18	15	5	2.5	3.2
SUVA index of the mixture (cm^{-1} g C^{-1} L)	ND	11.2	13.5	18.6	17.6

The proportion of organic carbon released by waste in leachate decreased with the age of the waste. A 3-year-old waste released approximately 4% of its carbon potential, whereas the 8-year-old waste and 20-year-old waste released approximately 1% of their potential. These differences could be explained by a more or less important humification state of organic matter. This release was more limited for the tests in Crézin leachate, which indicated an exhaustion of the waste pollution, which was more difficult with this type of test. However, in general, the carbon release in the leachate remained weak, compared to the potential of pollution contained.

3.7. Methanogene potential

Carrying out BMP tests provided the following results (Table 10).

A strong methane (or biogas) production potential was highlighted for fresh waste and 3-year-old waste with a composition in CH_4/CO_2, which was characteristic of putrescible waste [18].

Table 9
Proportions of organic carbon released by waste after leaching in water and in a stabilized leachate

	Fresh waste	3-Year-old waste	8-Year-old waste	20-Year-old waste	30-Year-old waste
Waste organic carbon (%)	29	31	14.5	16	5
DOC released in water/organic carbon of waste (%)	ND	4	1	0.8	0.7
DOC released in a stabilized leachate/organic carbon of waste (%)	ND	3	0.7	0.3	1.6

Table 10
Methane, carbon dioxide and biogas production

	Fresh waste	3-Year-old waste	8-Year-old waste	20-Year-old waste	30-Year-old waste
CH_4 production (m^3/t of dry waste)	170	73	2	2.3	9
CO_2 production (m^3/t of dry waste)	150	60	5	2.9	7.4
CH_4/CO_2	1.13	1.26	0.44	0.8	1.2
Percentage of biodegradation in comparison with its of fresh waste	0	59	98	98.4	95
Biogas production (m^3/t of dry waste)	320	133	7.6	5.2	16.4
VS (kg/t of dry waste)	693	610	370	440	140
Biogas production (m^3/t of VS)	464	218	18.9	11.8	117

The values obtained for the 8-year-old and 20-year-old wastes were low, compared to the values in the literature [4]. This low methanogene potential could be explained by the significant presence of sulphates, therefore of sulfato-reducing bacteria which could compete with methanogenic bacteria during degradation. The H_2S measurement during tests would have enabled these results to be validated. Experimental errors could take place and it would thus be advisable to validate these results; for this reason, new test are in progress.

The value of the potential methanogene of the 30-year-old waste was significant compared to the other wastes, especially if one is interested in the biogas produced and which is expressed in m^3/t of VS.

This waste made up the major part of degraded component. This category could be a substrate, which was much more quickly assimilable than the less degraded waste categories, such as paper-cardboards.

3.8. Correlations between the various parameters by PCA

The principal component analysis (PCA) was carried out using STATISTICA 5.0 software. The table of figures was generated starting from the various samples of waste and the measured parameters. The PCA makes it possible to highlight the principal groups of parameters directly connected to the state of waste degradation.

These groups consisted of: paper-cardboards, volatile solids, organic carbon, coarse fractions of waste, concentrations in COD and DOC of the leachate obtained after leaching tests and by the degraded component and fines of waste.

On the contrary, parameters such as wood, textiles, waste nitrogen content (N), inert material and glass appeared not very representative of the state of waste degradation.

Paper-cardboards (PC) waste constituted the waste category which was correlated with granulometry, with the volatile solids content, organic carbon (OC) of waste and with the characteristics of the released leachate (COD and DOC).

The determination of this waste fraction seemed essential to evaluate quickly the state of waste degradation. By supposing that the 30-year-old waste studied was representative of a very degraded waste, which could be considered as the most stabilized state of all the studied wastes, according to the values of global parameters; its paper-cardboard content (approximately of 1%) used in relations obtained by PCA made it possible to estimate the stabilized waste characteristics. Paper-cardboard

Table 11
Relations between the quantity of paper-cardboards waste and its released leachate and biogas characteristics (valid for a range of % paper-cardboards between 0 and 32)

Leachate and biogas characteristics

Relations obtained by PCA	R^2	Values for a stabilized waste
DOC (mg C/L) = 45 exp (0.0774*% PC)	0.8	Leachate DOC = 45–49 mg C/L
COD (mg O_2/L) = 141.3 exp (0.0942*% PC)	0.8	Leachate COD = 141–155 mg O_2/L
BMP (m^3 CH_4/t of dry waste) = 0.9 exp (0.11*% PC)	0.76	BMP = 0.9–1 m^3 CH_4/t of dry waste

Table 12
Relations between the quantity of paper-cardboards of waste and its physical, chemical characteristics (valid for a range of % paper-cardboards between 0 and 32)

Waste characteristics

Relations obtained by PCA	R^2	Values for a stabilized waste
% OC = 4.7 + 0.64*% PC	0.98	% OC = 5–6
% VS = 18.43 + 1.08*% PC	0.96	% VS = 18–19
% Fines = 44.8 − 0.46*% PC	0.97	% Fines = 44–45
% Degraded component = 76.7 − % PC	0.99	% Degraded component = 75–76

content could be considered as an indicator only for wastes for which a part of the resource had not been recycled to reuse before a MSW landfill (Tables 11 and 12).

However, it is important to specify that the values obtained depended on the method used to determine each parameter.

4. Conclusion

This study made it possible to highlight the physico-chemical parameters representative of the state of degradation of a domestic waste landfilled in a sanitary landfill.

Other characterization analyses of other waste samples are nevertheless necessary to validate the importance of certain parameters in the stabilization state definition.

The quantity of paper-cardboards measured in a domestic waste seemed to be the most revealing parameter of the waste stabilization state and the easiest to determine onsite.

This study also showed that certain criteria, such as the measurement of a leachate COD, were not always a sufficient indicator to determine the waste stabilization state. On the other hand, another parameter, the SUVA index translating the presence of organic aromatic macromolecules in the leachates, proved a much more significant stage of waste degradation. Certain inconsistencies in the state of degradation and the age of the waste were highlighted: the composition of the site surface cover (as, for example, a cover containing compost) seemed to have a great influence on the waste degradation in particular, making it possible to imagine the characteristics of a 20-year-old waste at the end of 8 years.

The release potential of waste estimated by leaching tests was also significant in reaching a conclusion about the stabilized state of a waste. This type of tests made it possible to quantify the risk of pollution of waste under extreme release conditions.

However, the quality of the elution solution put in contact with wastes must be evaluated before reaching a conclusion: the tests with the Crézin leachate highlighted a release attenuation when the leachate characteristics were close to those likely to be released by waste.

The quantity of pollutants released after renewal of the leachate was also weaker than during the tests with water. The exhaustion of the waste pollution was greater when washing out was used. From these results, it is possible to assume certain effects of the leachate recirculation onsite, as, in particular, a favoured release of pollutants, if the recirculated leachate was different from that released by landfilled waste.

These assumptions will have to be validated onsite before concluding the application of such processes to support release during recirculation. Indeed, the results obtained with the leaching tests are not very close to the reality of what happens onsite, particularly in terms of biological phenomena and exchanges.

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