Variations in the properties of leachate according to landfill age

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Naxos, 15th June 2018

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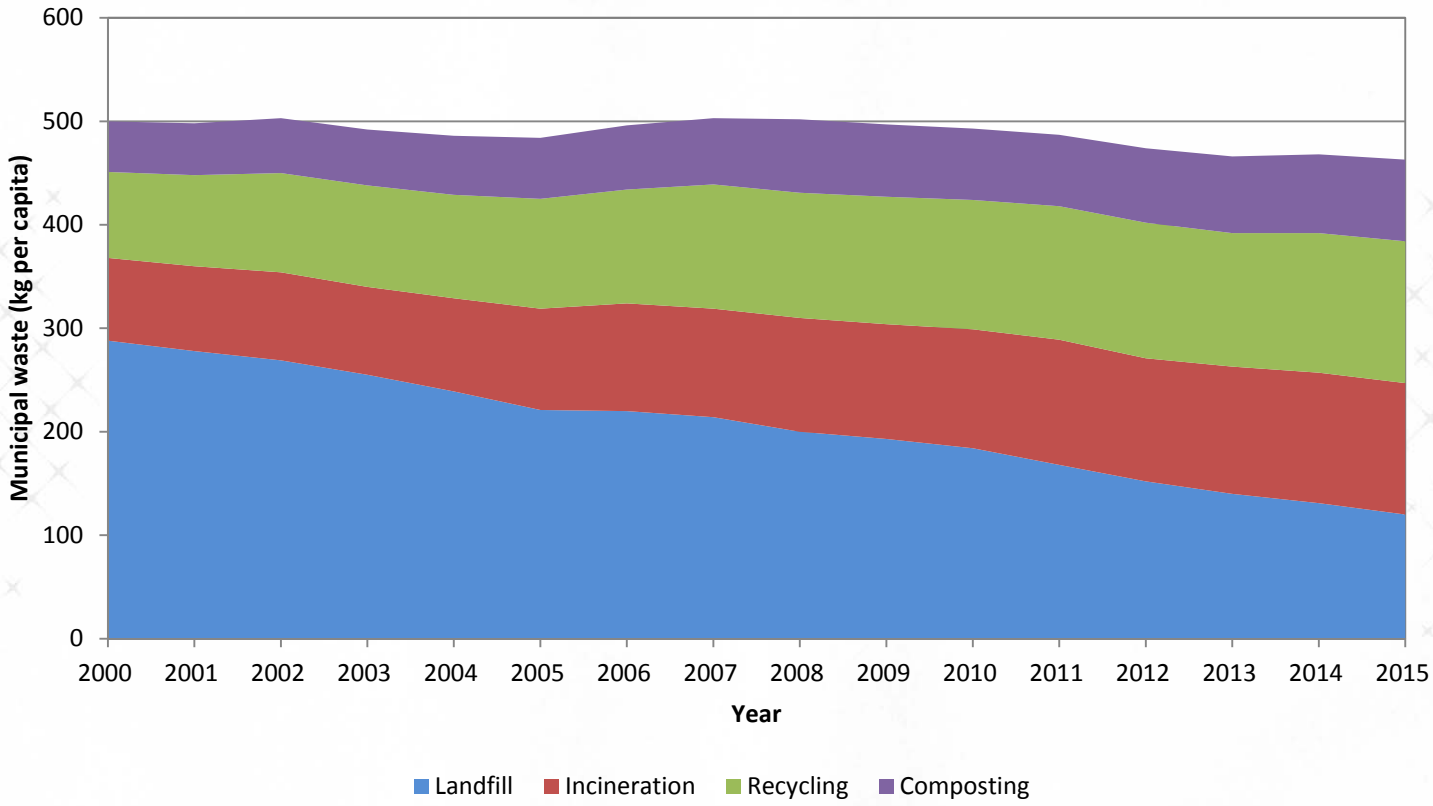
Background

- In the EU, annually 16 tonnes of materials are used by each person and 6 tonnes of it are converted into waste.
- Solid waste can be disposed in various ways:
  - Incineration.
  - Landfilling.
  - Recycling.
  - Composting.

- Landfilling has been the most commonly used solid waste disposal, especially in the Mediterranean and Eastern Europe countries.
- Landfills present long-term threats to soil, air, groundwater and surface water due formation of greenhouse gases (methane gas and carbon dioxide from decomposing garbage) and leachate.

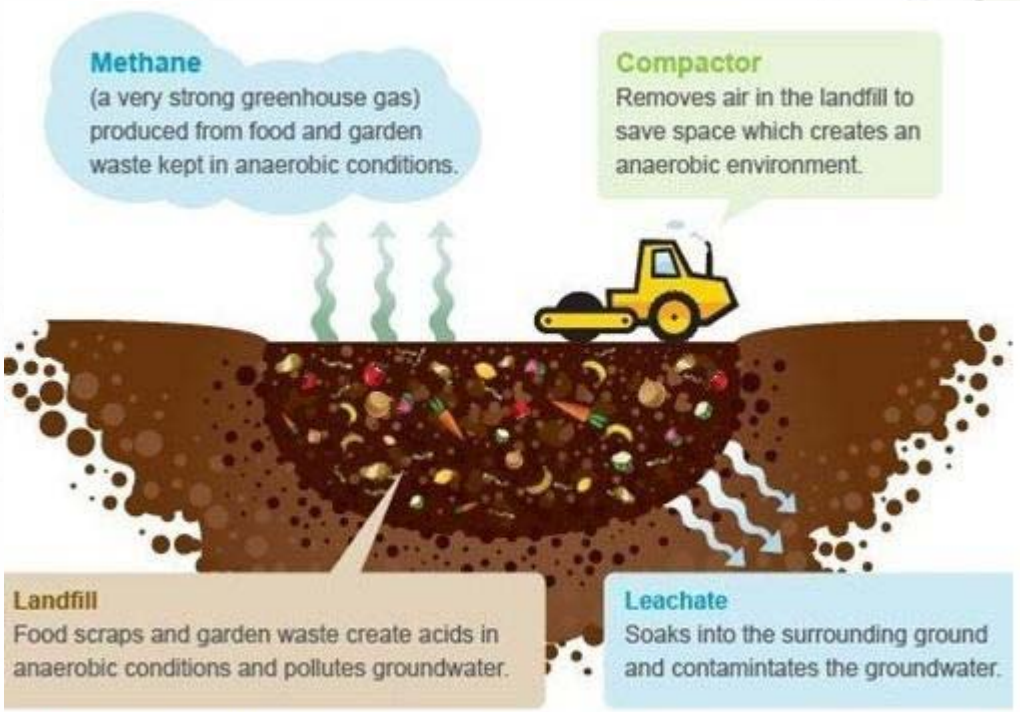
Background



Municipal waste generation and treatment, EU-27 (Source: Eurostat, 2017)

Leachate

- Leachate is the **liquid fraction** of the already existing moisture/liquid within the **solid waste** and the continuously formed liquid with dissolved and suspended solids extracted from the waste while rainfall percolates through it.
- Not only during their useful life, but also **fifty years after their closure**, landfills keep on producing leachate.
- Approximately, **10 m^3** of leachate is generated per **115 tonnes** of solid waste.
- The **composition** of leachate **differs** from site to site and also within the landfill, the composition of the leachate alters with time (from weeks to years).



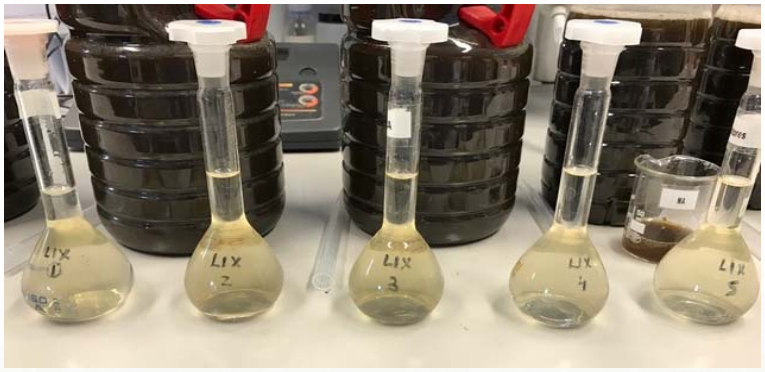
Leachate

- The **composition** of the leachate depends on **factors** such as:
  - waste characteristics.
  - moisture content.
  - climatic conditions.
  - degree of compaction.
  - age of the landfill.

- Therefore, the leachate composition cannot be generalised and an **unique treatment option cannot be suggested.**

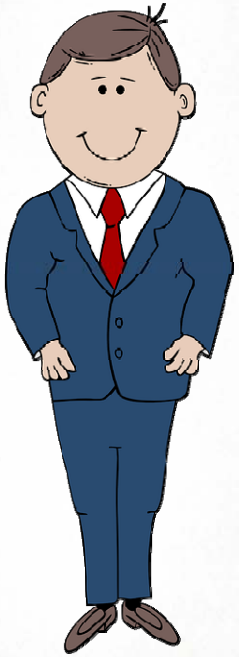
Leachate

- Although leachate composition varies from one to the other, what they have in common is **hazardous constituents** and their **potential ecotoxicological effects** on human and on terrestrial ecosystems.
- The main leachate **components** are:
  - Dissolved Organic Compounds.
  - Inorganic components.
  - Heavy Metals.
  - Xenobiotic organic compounds.



Leachate

- The age of a landfill can be classified according to the characteristics of its leachates in:
  - Young.
  - Intermediate.
  - Old.



Leachate

General leachate composition with respect to leachate age (Source: Stegmann et al., 2005)

Parameter	Acid phase (younger)	Methanogenic phase (older)
pH	6.2-7.8	7.0-8.3
BOD_5 (mg/L)	600-27,000	20-700
COD (mg/L)	950-40,000	460-8,300
TOC (mg/L)	350-12,000	150-1,600
NH_4-N(mg/L)	17-1,650	17-1,650
TKN	250-2,000	250-2,000
SO_4 (mg/L)	35-925	25-2,500
Total P (mg/L)	0.3-54	0.3-54
Na (mg/L)	1-6,800	1-6,800
K (mg/L)	170-1,750	170-1,750
Mg (mg/L)	30-600	25-300
Ca (mg/L)	80-2,300	50-1,100
Fe (mg/L)	3-500	4-125
Zn (mg/L)	0.05-16	0.09-3.5
Cr (mg/L)	0.002-0.52	0.002-0.52
Cl^-(mg/L)	315-12,400	315-12,400
Ni (mg/L)	0.01-1	0.01-1
Cu (mg/L)	0.005-0.56	0.005-0.56
As (mg/L)	0.0053-0.11	0.0053-0.11
Hg (mg/L)	0.00002-0.025	0.00002-0.025
Pb (mg/L)	0.008-0.4	0.008-0.4
Cd (mg/L)	0.0007-0.525	0.0007-0.525

Leachate

- In the absence of treatment, leachate is:
  - Recycled back to the waste to maintain the biological activity in the composting solid waste by keeping it moist.
  - Send it to sewer or to a wastewater treatment plant (WWTP) in case they do not treat it on site.

Leachate treatment processes comparative costs (Source: Adapted from Giraldo, 2001)

Treatment technology	Cost (€/m^3)
Aerobic process with nitrogen removing	15.00
Two steps reverse osmosis	7.50
Biologic process + carbon activated + precipitation	18.75-26.25
Biologic process + reverse osmosis + concentrate evaporation	26.25-30.00
LIFE LEACHLESS technology (solar evaporation/condensation + forward osmosis)	**4.75**

LIFE LEACHLESS Project

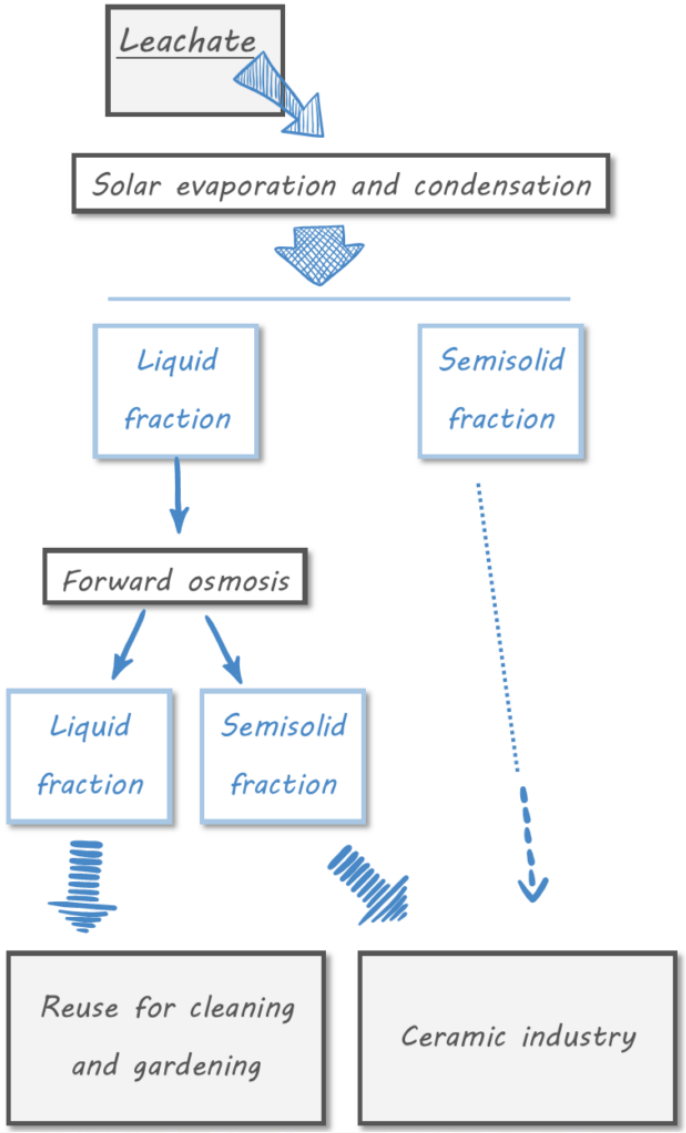
- The **leachate analyses** carried out in this work are part of the Preparatory Actions of the LIFE LEACHLESS project.
- The leachate samples come from 13 **solid waste landfills** managed by one of the most important waste managers in Spain.
- LIFE LEACHLESS project demonstrates the **feasibility of an innovative in-situ treatment process** for leachates generated in landfills and waste treatment plants.
- The project LIFE LEACHLESS proposes a **sustainable management** composed of specially designed solar panels, which reach to very high temperatures to evaporate the leachate.
- Then the vapour is condensed to follow its path through **forward osmosis** (FO) step.
- The proposed system is a **universal solution** independent of the leachate composition.

The figures of the project

LIFE 15 ENV/ES/00530

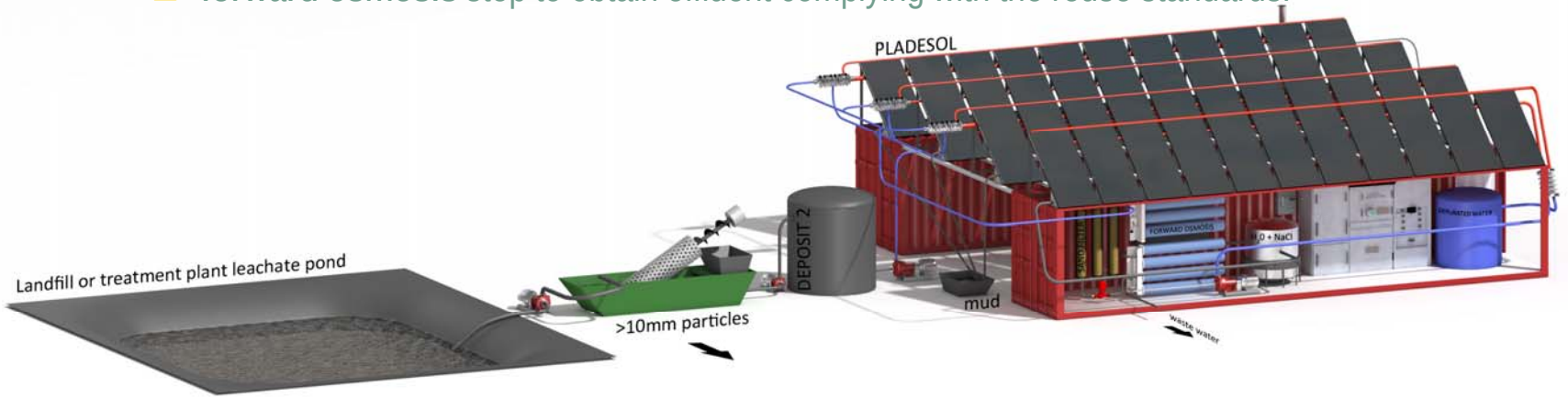
	Start: 01/10/2016		Total budget: 1,775,805 €
Dates	End: 31/12/2019	**Figures**	EU contribution: 1,041,237 € (60% of eligible budget)
	Duration: 39 months		4 partners

Process diagram



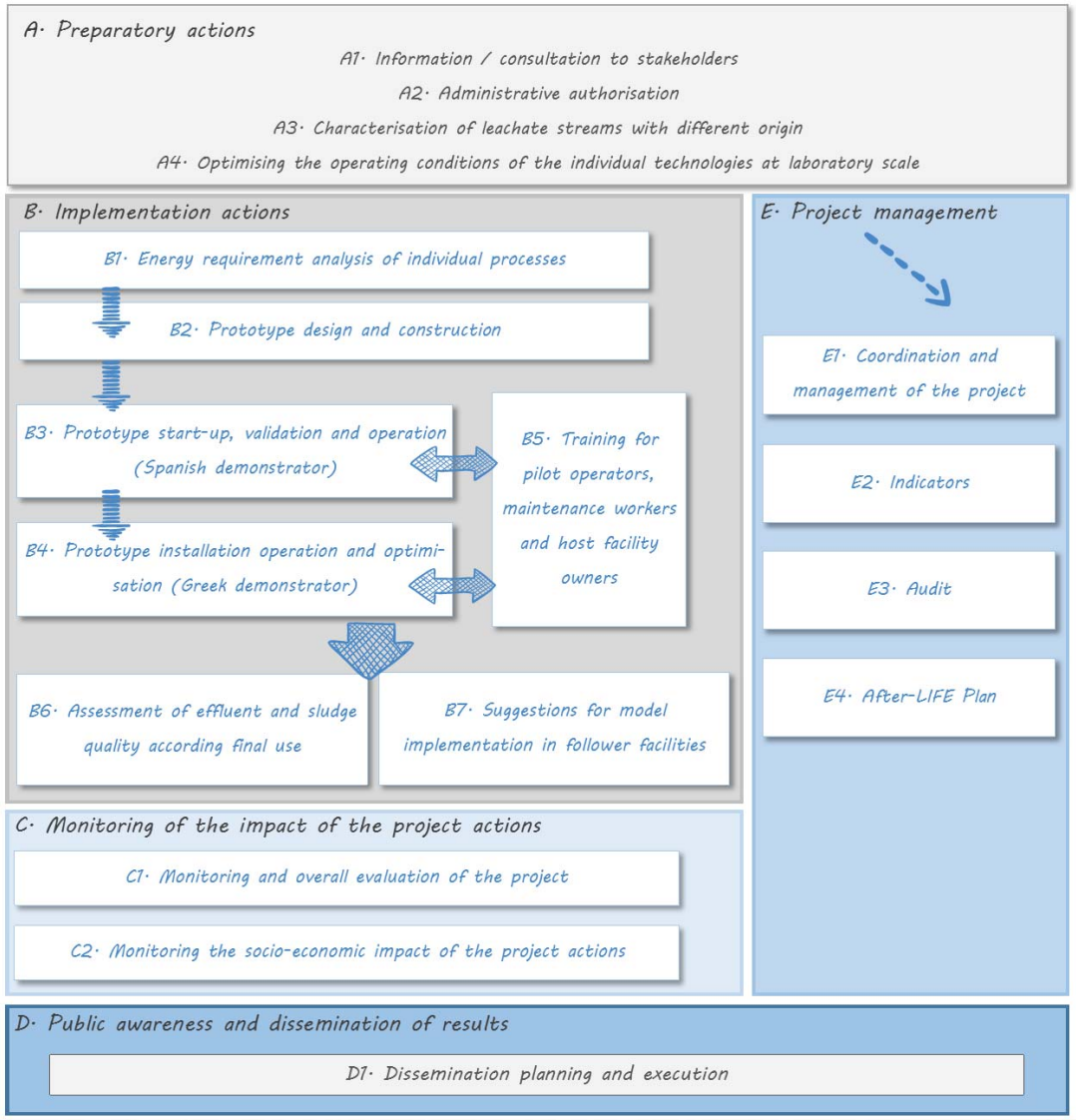
LIFE LEACHLESS Prototype

- The proposed treatment system is composed of two main separation processes:
  - a **novel solar panel**, which evaporates and condenses the leachate in the first step.
  - **forward osmosis** step to obtain effluent complying with the reuse standards.



- This system will be placed in **two containers** (40 ft) for the easy portability between the demonstrations sites:
  - a **waste treatment centre** in Spain.
  - a **landfill** in Greece.
- The maximum **capacity** of the plant is 8 m^3/day.

Pert Diagram



Sampling and analytical method

- Leachate **samples** from 13 different **landfills** located in **Spain** were collected and analysed.
- After the sample collection, the leachate samples were transported to the laboratory. And **stored** at 4 ºC during the period required to complete all experimental analysis.
- **Physicochemical parameters** were measured in the leachate samples according to **Standard Methods**:
  - pH, conductivity, solids.
  - Biochemical Oxygen Demand (BOD_5), Chemical Oxygen Demand (COD).
  - Ammonia nitrogen, nitrate nitrogen, nitrite nitrogen, total nitrogen.
  - Total phosphorus, phosphate, sulphate, chloride, sodium, potassium, magnesium, calcium and heavy metals.

Results and discussion

- Composition of young leachates from different Spanish landfills.

Parameter	Units	Young leachate				
		Landfill 4	Landfill 5	Landfill 8	Landfill 9	Landfill 11
Ammonia nitrogen	mg N/l	4,238.7±386.9	5,245.5±465.8	2,302.1±227.4	3,990.8±367.1	2,702.2±261.4
Chloride	mg/l	7,870±1,180	6,310±946	10,300±1,545	7,640±1,146	9,360±1,404
Conductivity	mS/cm	42.8±2.4	44.7±2.5	44.8±2.5	43.2±2.4	40.5±2.2
BOD_5	mg O_2/l	12,250±2,205	12,690±2,284	11,912±2,144	4,874±877	2,310±416
COD	mg O_2/l	29,219±4,010	13,533±1,818	26,592±3,640	14,194±1,909	16,849±2,277
BOD_5/COD		0.42	0.94	0.45	0.34	0.14
Total phosphorus	mg P_T/l	148.4±17.4	74.0±9.3	75.4±9.4	97.1±11.8	148.7±17.4
Nitrate	mg/l	<3	<3	<30	<3	<3
Nitrite	mg/l	<4	<4	<40	<4	<4
Total nitrogen	mg/l	5,323.8±1,064.7	5,709.0±1,141.8	3,608.0±721.6	4,438.0±887.6	3,264.0±652.8
Phosphate	mg/l	23.1±4.6	24.1±4.8	56.7±11.3	29.2±5.8	58.7±11.7
pH	pH	8.24±0.39	8.17±0.38	7.63±0.36	8.03±0.38	8.69±0.41
Sulphate	mg/l	9.6±1.4	213.0±31.9	<60	2,250.0±337.5	511.0±76.6
Total suspended solids (TSS)	mg/l	3,104.6±392.2	159.0±24.7	639.0±90.0	398.6±58.0	185.5±28.5
Volatile suspended solids (VSS)	mg/l	1,815.0±237.9	126.0±19.9	430.0±62.3	229.3±34.7	116.0±18.4
Total dissolved solids (TDS)	mg/l	26,619±2899	25,235±2759	36,222±3863	28,217±3061	33,324±3574
Total solids (TS)	mg/l	29,724±2926	25,394±2759	36,861±3864	28,616±3062	33,509±3574
Calcium	mg/l	542.59±108.52	47.75±9.55	184.08±36.81	78.49±15.70	9.12±1.82
Magnesium	mg/l	161.35±32.27	194.66±38.93	113.33±22.66	161.70±32.34	13.18±2.64
Sodium	mg/l	5,617.84±1,123.57	4,832.05±966.41	6,869.45±1,373.89	4,694.29±938.86	5,511.10±1,102.22
Potassium	mg/l	3,172.96±634.59	2,513.91±502.78	2,959.91±591.98	3,129.35±625.87	4,853.65±970.73
Zinc	mg/l	0.99±0.20	1.27±0.25	2.68±0.54	1.16±0.23	1.58±0.32
Copper	mg/l	0.51±0.10	4.13±0.83	3.18±0.64	0.65±0.13	1.35±0.27
Chromium	mg/l	7.21±1.44	1.55±0.31	0.85±0.17	2.05±0.41	4.04±0.81
Manganese	mg/l	0.24±0.05	0.15±0.03	0.21±0.04	0.36±0.07	0.15±0.03
Lead	mg/l	0.11±0.02	0.10±0.02	0.07±0.01	0.15±0.03	0.13±0.03
Iron	mg/l	6.42±1.28	5.61±1.12	6.76±1.35	17.25±3.45	29.91±5.98
Nickel	mg/l	0.37±0.07	0.67±0.13	0.25±0.05	0.89±0.18	0.55±0.11
Cadmium	mg/l	0.004±0.001	0.003±0.001	0.029±0.006	0.076±0.015	0.075±0.015

Results and discussion

- Composition of intermediate leachates from different Spanish landfills.

Parameter	Units	Intermediate leachate				
		Landfill 1	Landfill 3	Landfill 6	Landfill 12	Landfill 14
Ammonia nitrogen	mg N/l	1,385.8±146.1	3,084.1±293.3	3,568.1±333.0	1,999.9±201.1	2,216.9±220.0
Chloride	mg/l	3,140±471	7,240±1,086	4,940±741	5,780±867	8,970±1,345
Conductivity	mS/cm	16.2±0.9	36.9±2.0	32.2±1.8	29.4±29.4	39.3±2.2
BOD_5	mg O_2/l	5,550±999	4,100±738	1,184±438	2,307±415	2,450±441
COD	mg O_2/l	12,554±1,683	13,701±1,841	10,026±1,336	8,938±1,187	13,646±1,834
BOD_5/COD		0.44	0.30	0.12	0.26	0.18
Total phosphorus	mg P_T/l	45.4±5.9	94.4±11.5	64.2±8.1	56.9±7.3	90.2±11.1
Nitrate	mg/l	<3	<3	<30	<3	<3
Nitrite	mg/l	<4	<4	<40	<4	<4
Total nitrogen	mg/l	2,101.5±420.3	3,642.6±728.5	3,386±677.2	2,550.0±510.0	2,928.0±585.6
Phosphate	mg/l	10.7±2.1	48.6±9.7	25.1±5.0	29.3±5.9	20.2±4.0
pH	pH	7.73±0.36	7.81±0.37	8.25±0.39	7.96±0.37	8.43±0.40
Sulphate	mg/l	65.8±9.9	81.0±12.1	<60	7.6±1.1	824.0±123.6
Total suspended solids (TSS)	mg/l	595.0±84.2	117.5±18.6	197.5±30.2	153.5±23.9	257.0±38.6
Volatile suspended solids (VSS)	mg/l	446.7±64.5	79.0±12.9	142.5±22.3	120.5±19.0	175.0±26.9
Total dissolved solids (TDS)	mg/l	14,166±1,612	27,372±2,976	20,361±2,259	19,076±2,126	31,923±3,434
Total solids (TS)	mg/l	14,761±1,614	27,489±2,976	20,558±2,260	19,229±2,126	32,180±3,434
Calcium	mg/l	809.97±161.99	70.23±14.04	96.88±19.38	174.85±34.97	---
Magnesium	mg/l	186.56±37.31	65.81±13.16	90.46±18.09	98.88±19.78	222.71±44.54
Sodium	mg/l	1,435.18±287.04	4,802.39±960.48	3,451.17±690.23	2,541.10±508.22	4,846.64±969.33
Potassium	mg/l	1,430.39±286.08	3,196.61±639.32	1,932.08±386.42	2,763.94±552.79	4,891.99±978.40
Zinc	mg/l	10.69±2.14	1.74±0.35	1.61±0.32	0.86±0.17	0.38±0.08
Copper	mg/l	3.28±0.66	1.93±0.39	2.57±0.51	1.07±0.21	0.53±0.11
Chromium	mg/l	1.05±0.21	2.68±0.54	0.47±0.09	2.05±0.41	13.75±2.75
Manganese	mg/l	0.75±0.15	0.13±0.03	0.31±0.06	0.75±0.15	0.36±0.07
Lead	mg/l	0.09±0.02	0.13±0.03	0.04±0.01	0.09±0.02	0.08±0.02
Iron	mg/l	14.87±2.97	9.45±1.89	9.24±1.85	9.62±1.92	4.35±0.87
Nickel	mg/l	0.46±0.09	0.55±0.11	0.31±0.06	0.39±0.08	0.58±0.12
Cadmium	mg/l	0.003±0.001	0.002±0.000	0.028±0.006	0.075±0.015	0.072±0.014

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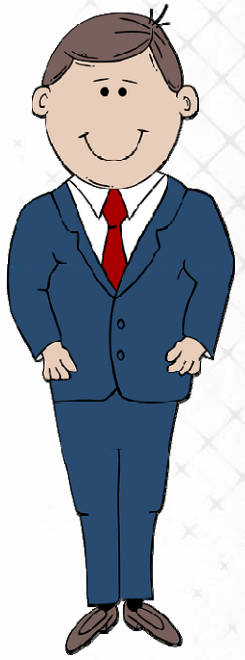


Results and discussion

- Composition of old leachates from different Spanish landfills.

Parameter	Units	Old leachate		
		Landfill 7	Landfill 10	Landfill 13
Ammonia nitrogen	mg N/l	757.3±86.3	486.0±58.7	377.5±47.1
Chloride	mg/l	2,440±366	2,480±372	4,740±711
Conductivity	mS/cm	15.0±0.8	17.1±0.9	17.7±1.0
BOD_5	mg O_2/l	632±234	164±29	443±163.9
COD	mg O_2/l	2,725±350	3,460±448	4,777±623
BOD_5/COD		0.23	0.05	0.09
Total phosphorus	mg P_T/l	38.7±5.1	37.8±5.0	50.4±6.5
Nitrate	mg/l	<30	<30	<3
Nitrite	mg/l	<40	<40	<4
Total nitrogen	mg/l	1,541.0±308.2	1,401.0±280.2	981.0±196.2
Phosphate	mg/l	19.6±3.9	55.8±11.1	18.1±3.6
pH	pH	8.05±0.38	8.22±0.39	8.36±0.39
Sulphate	mg/l	99.2±14.9	<60	627.0±94.1
Total suspended solids (TSS)	mg/l	96.5±15.5	106.0±16.9	110.5±17.6
Volatile suspended solids (VSS)	mg/l	68.5±11.3	64.5±10.6	69.5±11.4
Total dissolved solids (TDS)	mg/l	9,004±1,057	11,089±1,283	15,333±1,735
Total solids (TS)	mg/l	9,100±1,057	11,195±1,283	15,443±1,735
Calcium	mg/l	120.61±24.12	49.14±9.83	95.33±19.06
Magnesium	mg/l	65.95±13.19	---	39.30±7.86
Sodium	mg/l	1,624.57±324.91	1,900.12±380.02	2,327.95±465.4
Potassium	mg/l	714.54±142.91	1,601.03±320.21	2,262.17±452.43
Zinc	mg/l	1.13±0.23	2.17±0.43	1.77±0.35
Copper	mg/l	5.36±1.07	3.32±0.66	1.36±0.27
Chromium	mg/l	0.44±0.09	1.03±0.21	1.45±0.29
Manganese	mg/l	0.41±0.08	0.27±0.05	2.70±0.54
Lead	mg/l	0.05±0.01	0.11±0.02	0.15±0.03
Iron	mg/l	4.09±0.82	15.80±3.16	34.73±6.95
Nickel	mg/l	0.21±0.04	0.34±0.07	0.51±0.10
Cadmium	mg/l	0.029±0.006	0.079±0.016	0.076±0.015

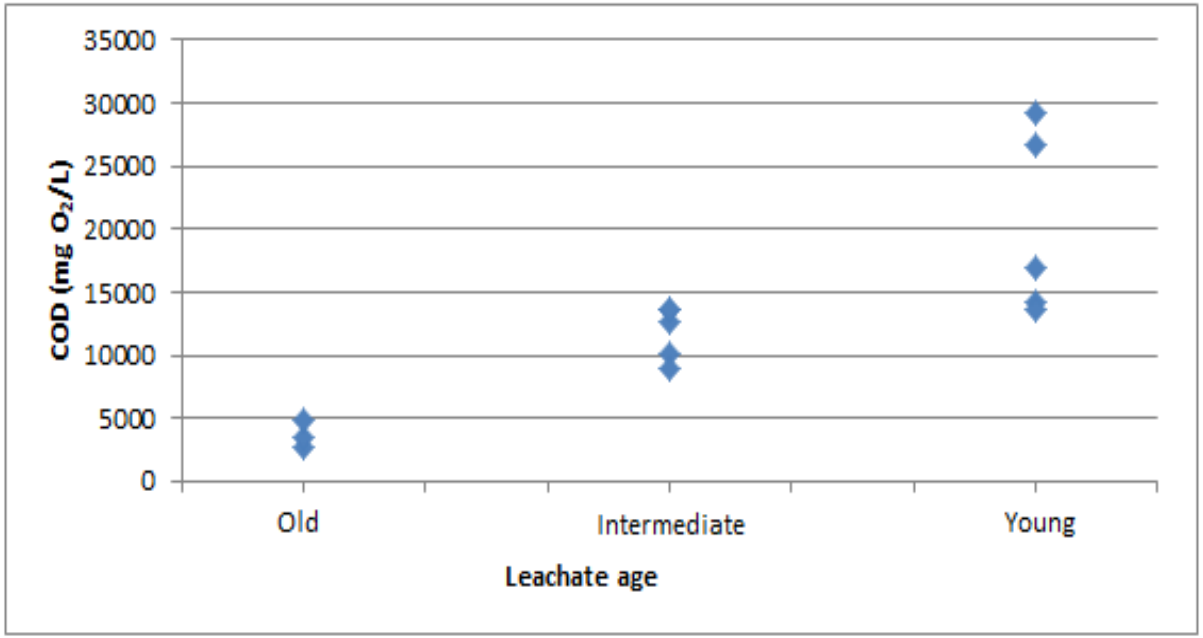
---not detected

Results and discussion

- According to the results, there are **significant differences** between the different ages of the leachate.
- **Leachate age** is one of the factors that **most affect** the leachate composition.
- As a **landfill increases** the **age**, the **constituents** of the leachate **decrease** their **concentration** due to the processes of stabilisation of the waste that occurs within the landfill.
- These differences are found in some parameters such as COD, BOD_5 and ammonia nitrogen.

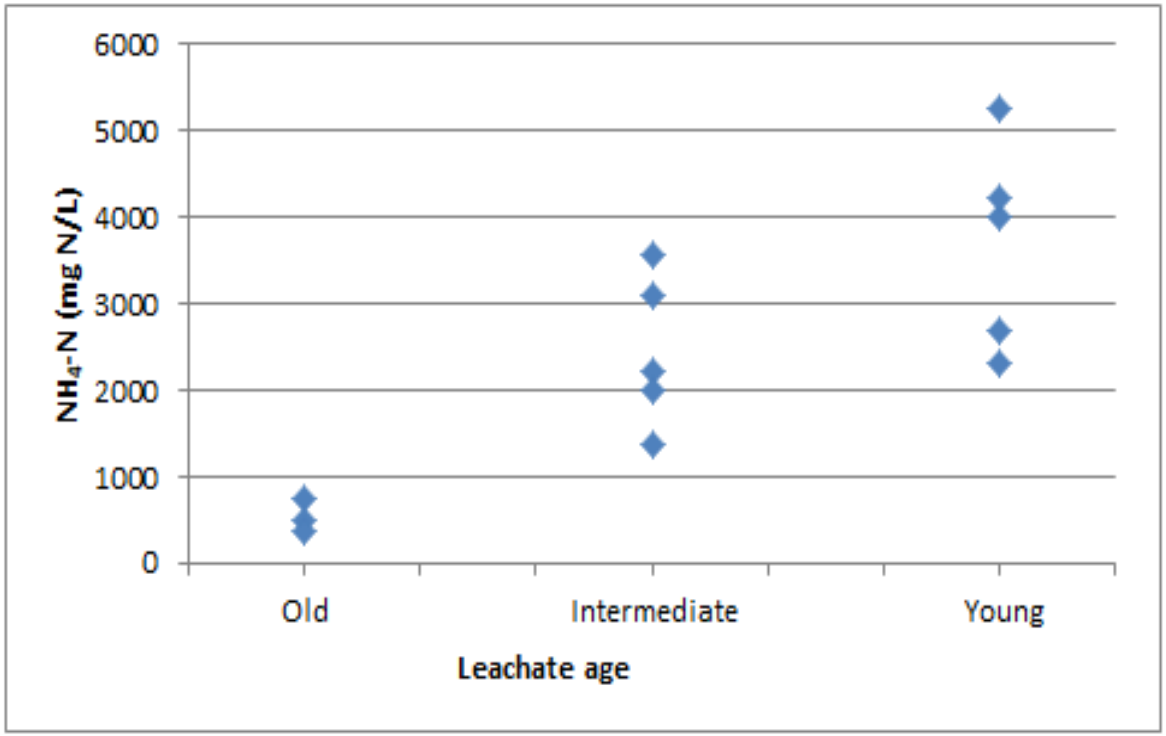
Results and discussion

- Organic compounds concentrations with respect to leachate age is decreasing.
- Because of biodegradable nature and washout.
- Old leachate samples show low COD values while intermediate and young leachates show higher COD values with a wider range.



Results and discussion

- Ammonia nitrogen concentration follows the same trend as organic compounds. Decreasing the concentration when the age of the leachate increases.
- That is due to the deamination of amino acids and destruction of organic compounds that occurs in young landfills.



Results and discussion

- pH:
  - The pH results are **all greater** than 7.5, which according to the characteristics of leachates all landfills would be old.
  - However it is known that this is not the case.
  - **Some leachates** that are exposed to the atmosphere could cause some **removal** of **carbon dioxide** from the leachate which increases the pH.

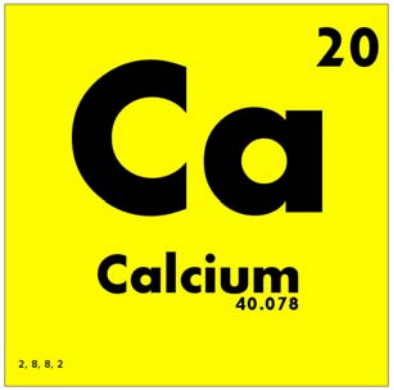
pH

Results and discussion

- Anions:
  - **Chlorides concentration decreases** as the **age** of the **landfill increases**, due to a washing phenomenon, but to get low chloride concentrations can last for years.
  - **High chloride content** in the leachate sample reflects the presence of significant amount of **soluble salts** in the municipal solid waste materials.

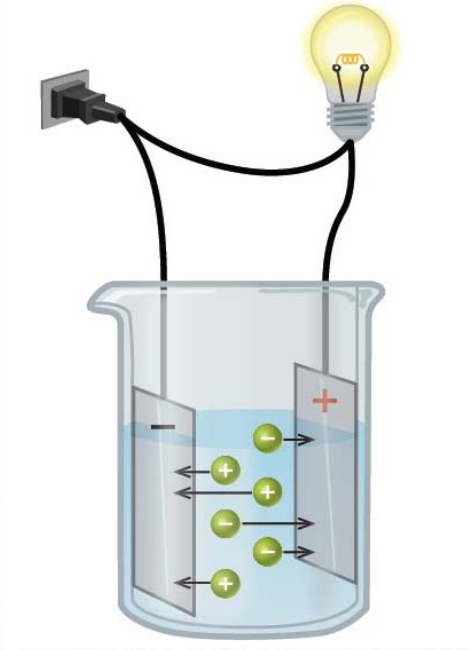
Results and discussion

- Cations:
  - **Cations** concentrations such as calcium, magnesium, iron and manganese depend on the **stabilisation** of the **landfill**.
  - The concentrations of these cations are **lower** in **methanogenic phase** due to **higher pH** and **lower organic matter** content.



Results and discussion

- Conductivity:
  - **Conductivity** of the leachate samples is mainly due to the **presence** of the **cations** such as sodium or potassium.
  - **High conductivity values** are observed in **young leachates**, due to a high presence of these cations, mainly sodium.



Results and discussion

- Heavy metals:
  - When the **landfill age increases**, the solubility of the metal decreases due to the increase in pH values, so **decreasing the metal concentrations**

- In general, **fluctuation of parameters** such as phosphorus, chlorides, calcium, magnesium, sulphates and heavy metals depends on **seasonal variations** rather than on landfill age.

Conclusions

- Leachate age has a **significant effect** on its characteristics and composition but **other factors**, such as type of waste that is mostly treated in landfills, also have an **important effect** on its composition.
- As a **landfill increases the age**, the **constituents** of the **leachate decrease** their **concentration** due to the processes of stabilisation of the waste that occurs within the landfill.
- The **leachate samples** from different Spanish landfills show the general tendencies of the **effect of the leachate age** on its composition and this effect is shown in several parameters for instance COD or ammonia nitrogen, being the lowest concentration as the leachate age increases.
- **Wastes** generated from **European Union countries** with regard to composition are basically **different**. The **composition** of the **leachate changes** because waste is piled for many years in layers that will be in different phases of decomposition.

Thank you for your attention

If you have any question, do not hesitate to contact me

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