Ten Element Stack model - passive

Gas and leachate emission results.

The purpose of this note is to extend the presentation of the example results from the Ten Element Stack model – passive. The note focusses on the gas and leachate emissions, which are two key areas of interest in the context of landfill management.

The results have been analysed and plotted in the **Template: 10_el_stack template – passive gas and leachate emission**, which may be downloaded from the LDAT website page Help\Get Started\Some results.

The results may be compared to the transient characteristics of key parameter values that have been observed in real landfills. See **Transient characteristics of gas and liquid components in real landfills,** which may also be downloaded by clicking on the links in the LDAT website page Help\Get Started\Some results.

Note that further information about the initial and boundary conditions that have been applied to configure the model that produced these results are given in the note **Initial and Boundary Condition parameter values for LDAT landfill models**. Most of these data values are accessible to the user through the data editor. The values for the built in configuration parameters that have yet to be made accessible are also provided here. The note can be downloaded by clicking on the link in the LDAT website page Help\Get Started\Some results.

The sources of emitted landfill gas components, and the dissolved quantities in leachate, are the products derived from the chemical degradation reactions of the complex solid and liquid waste compounds. In the LDAT model these degradable compounds are assumed to be primarily the solid phase Protein, Fat, Carbohydrates and Glucose compounds found in waste.

The products of waste degradation are estimated by starting with a simple specification of the solid waste in terms of the characteristic percentage content of: Green waste and wood; Food; Paper card and cartons; Textiles and carpets; and Inert material. This specification is then converted into the initial values for the Protein, Fat, Carbohydrates and Glucose chemical compounds.

The initial leachate chemistry also needs to be specified. The main compound in the leachate is water, but initially the leachate may also contain dissolved compounds. These dissolved compounds may have the potential to degrade and eventually contribute to the gas and leachate emissions.

The emissions that leave the landfill are collected and accounted for in the boundary elements of the LDAT model. In the case of the Ten Element Stack model the Upper and Lower boundary elements of the 10 Active element Stack, elements 0 and 11, are therefore of particular interest. The overall content of the Active elements are also of interest as the results of field measurements of gas and leachate sample concentrations from this zone are also likely to be available for comparison with the model results. The Active element data is also required to check the mass balance of the calculations.

A list of the compounds used in the LDAT model is shown in Table 1.

The compounds are grouped into the five 'phases' used by LDAT – Liquid, Gas, Degradable Solids, Bacteria, and Inert. The value of the mass of each compound in each phase changes in response to the various landfill bio-chemical and physical processes that are taking place. The parameter values have a naming convention which is the pattern <compound name><rate><ion><phase index>. Thus dissolved mass value of the Protein compound with the highest degradation rate in the liquid phase is named 'ProteinFast_ion_1.

LDAT tracks and records the mass of each compound and the constitutive equations that model the changes in mass ensure that the total mass of the overall group of compounds is conserved. This means that the sum of the changes in mass between any two points in time will be zero.

LIQUID PHASE	GAS PHASE	BACTERIA PHASE
Water	**Water vapour**	**Total bacteria**
Water_1	Water_2	BiomassProteinS_4
		BiomassProteinM_4
Total dissolved solids ions	**Total primary gases**	BiomassProteinF_4
		BiomassFatS_4
ProteinSlow_ion_1	CarbonDioxide_2	BiomassFatM_4
ProteinMedium_ion_1	AmmoniaGas_2	BiomassFatF_4
ProteinFast_ion_1	Methane_2	BiomassCarbohydrateS_4
FatSlow_ion_1	Nitrogen_2	BiomassCarbohydrateM_4
FatMedium_ion_1	OxygenGas_2	BiomassCarbohydrateF_4
FatFast_ion_1		BiomassGlucoseS_4
CarbohydrateSlow_ion_1		BiomassGlucoseM_4
CarbohydrateMedium_ion_1	**Other gases**	BiomassGlucoseF_4
CarbohydrateFast_ion_1		BiomassMethaneOxidation_4
GlucoseSlow_ion_1	HydrogenSulphide_2	
GlucoseMedium_ion_1	Sulphate_2	BiomassAerobicProteinS_4
GlucoseFast_ion_1	HydrogenGas_2	BiomassAerobicProteinM_4
		BiomassAerobicProteinF_4
Total Acids	**DEGRADABLE SOLIDS PHASE**	BiomassAerobicFatS_4
		BiomassAerobicFatM_4
AqueousAcid_1	**Total degradable solids**	BiomassAerobicFatF_4
AqueousAcidIon_1		BiomassAerobicCarbohydrateS_4
AceticAcid_1	ProteinSlow_3	BiomassAerobicCarbohydrateM_4
AceticAcidIon_1	ProteinMedium_3	BiomassAerobicCarbohydrateF_4
BicarbonateIon_1	ProteinFast_3	BiomassAerobicGlucoseS_4
CarbonateIon_1	FatSlow_3	BiomassAerobicGlucoseM_4
CarbonicAcid_1	FatMedium_3	BiomassAerobicGlucoseF_4
	FatFast_3	
Dissolved Ammonia	CarbohydrateSlow_3	BiomassDenitroA_4
	CarbohydrateMedium_3	BiomassDenitroB_4
AmmoniumIon_1	CarbohydrateFast_3	BiomassAqueous_4
AmmoniaGas_1	GlucoseSlow_3	BiomassAceticAcid_4
	GlucoseMedium_3	
Other dissolved compounds	GlucoseFast_3	**Inert biomass**
Methane_1	**Solid CaCO3 buffer**	Inert_Glucose_ion_1
Nitrogen_1		
OxygenGas_1	CalciumCarbonate_5	**INERT PHASE**
HydrogenSulphide_1		
Sulphate_1		**Inert material**
CalciumIon_1		
NitriteIon_1		Inert_5
NitrateIon_1		
IronA_1		**Inert waste compounds**
IronB_1		
HydrogenIon_1		ProteinSlow_5
HydroxideIon_1		ProteinMedium_5
HydrogenGas_1		ProteinFast_5
		FatSlow_5
		FatMedium_5
		FatFast_5
		CarbohydrateSlow_5
		CarbohydrateMedium_5
		CarbohydrateFast_5
		GlucoseSlow_5
		GlucoseMedium_5
		GlucoseFast_5

Table 1 Compound list grouped by phase and plotting group.

In Table 1 the compounds in each phase are further divided into groups for plotting purposes. A summary of this grouping is shown in Table2.

Phase	Group name
Liquid	Water
	Dissolved degradable solids
	Acids
	Dissolved Ammonia
	Other dissolved compounds
Gas	Water vapour
	Total Primary gases
	Other gases
Degradable solids	Degradable waste solids
	Solid CaCO3 buffer
Bacteria	Total bacteria
	Inert biomass
Inert	Inert material
	Inert waste compounds

Table 2 Summary of Plotting Groups

The plots of the transient behaviour of selected parameter groups are shown in the sections that follow. The behaviour for the active (waste) zone are shown for the selected groups. In addition parameter group plots are also shown for the upper and lower boundaries, if this is relevant for the group concerned (parameter values may not change for some groups in one or other of the boundaries).

The plots are generated in the **Template: 10_el_stack template – passive gas and leachate emission**, which may be downloaded from the LDAT website page Help\Get Started\Some results.

The changes in mass calculated by the model over the first 100 days for each parameter group in each location are shown in Table 3 – see 'Mass balance Tables' tab in the Template. Note that the sum of the changes is 50.0, verifying the mass balance after the rainfall input of 0.5 kg/day over a period of 100 days is taken into account.

	Upper boundary		Active zone		Lower boundary		Upper boundary (change)	Active zone (change)	Lower boundary (change)
Plotting group	0 days	100 days	0 days	100 days	0 days	100 days			
Degradable waste solids			291.30	14.43				-276.87	
Solid CaCO3 buffer			180.98	202.49				21.51	
Dissolved degradable solids			0.00	0.76	0.00	32.15		0.76	32.15
Acids			52.06	18.89	0.00	17.17		-33.17	17.17
Water	0.00	9.97	5964.55	2934.43	100.00	3152.44	9.97	-3030.13	3052.44
Other dissolved compounds	0.00	2.05E-07	14.63	0.61	0.00	6.13	2.05E-07	-14.01	6.13
Dissolved Ammonia			0.00	5.99	0.00	0.86	0.00	5.99	0.86
Primary gases	100.00	270.72	0.50	3.40	10.00	10.00	170.72	2.90	
Water vapour	0.00	17.42	0.01	0.09			17.42	0.08	
Other gases	0.00	0.50	0.00	0.03			0.50	0.03	
Total bacteria			43.82	27.06				-16.76	
Inert biomass			0.00	74.31	0.00	7.99		74.31	7.99
Inert material	1000.00	403.34	3438.56	4035.22			-596.66	596.66	
Inert waste compounds			427.06	427.06				0.00	

Table 3 Mass changes in the plotting group parameters

These changes in values can be used in conjunction with the bio-chemical degradation pathways to construct a source-destination map for the groups of components. See Figure 1.

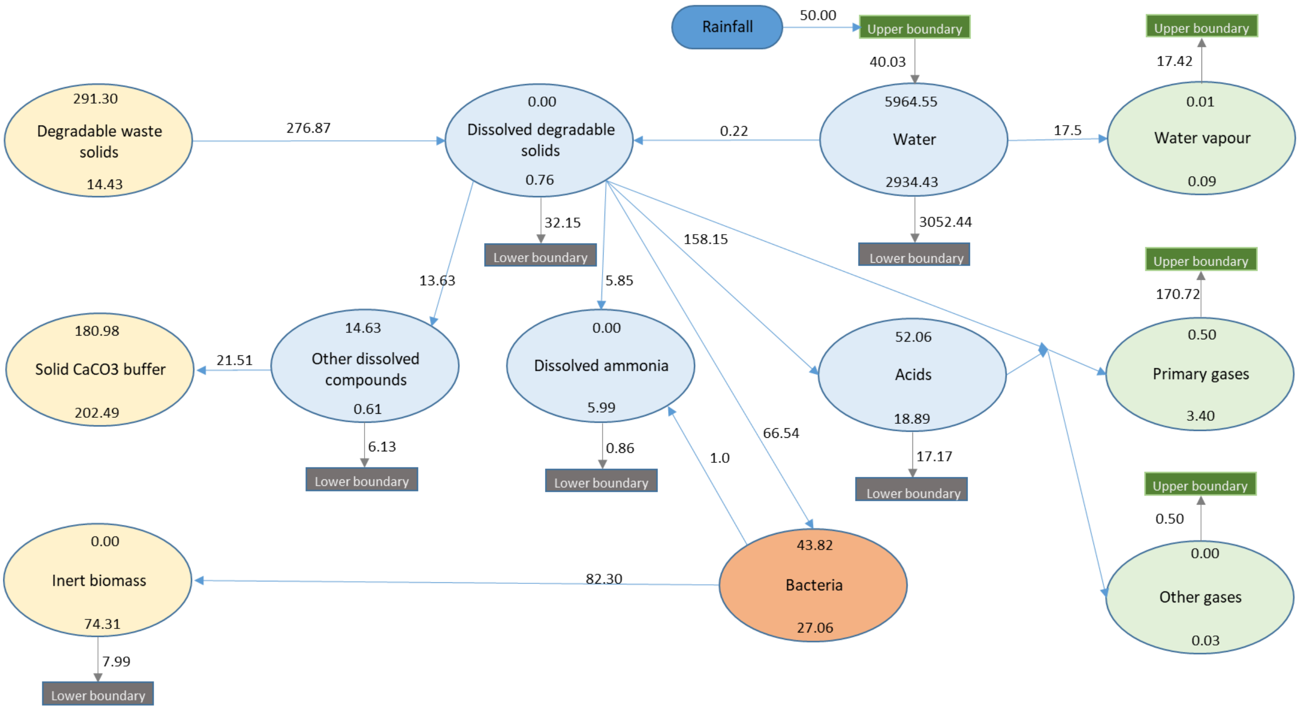

Figure 1 Component Source-Destination Map

The values inside each component group in the Map correspond to the 0 day and 100 day mass of the group in kg. These values can be found in the first grid of Table 3. Note that the Inert material and Inert waste compounds are not included in the Map as their mass balance is self-evident.

Solids in the Active elements

Dissolution of solid waste components– see Figure 2.

The initial values of the Degradable Solids compounds (ProteinSlow_3 etc – see Table 1) are derived from the Compound waste converter Table (converts Green waste etc into Protein etc) and the UK Environment Agency waste partition Table (partitions Protein etc into Slow, Medium, Fast and Inert categories).

The dominant ingredient is Glucose Fast_3. See 'Deg solids' and 'Waste to compounds' tabs in the Template. The rate of dissolution of each compound depends on values set for dissolution rate, and saturation concentration. The built in values for these parameters are given in the note **Initial and Boundary Condition parameter values for LDAT landfill models** which can be downloaded by clicking on the link in the LDAT website page Help\Get Started\Some results.

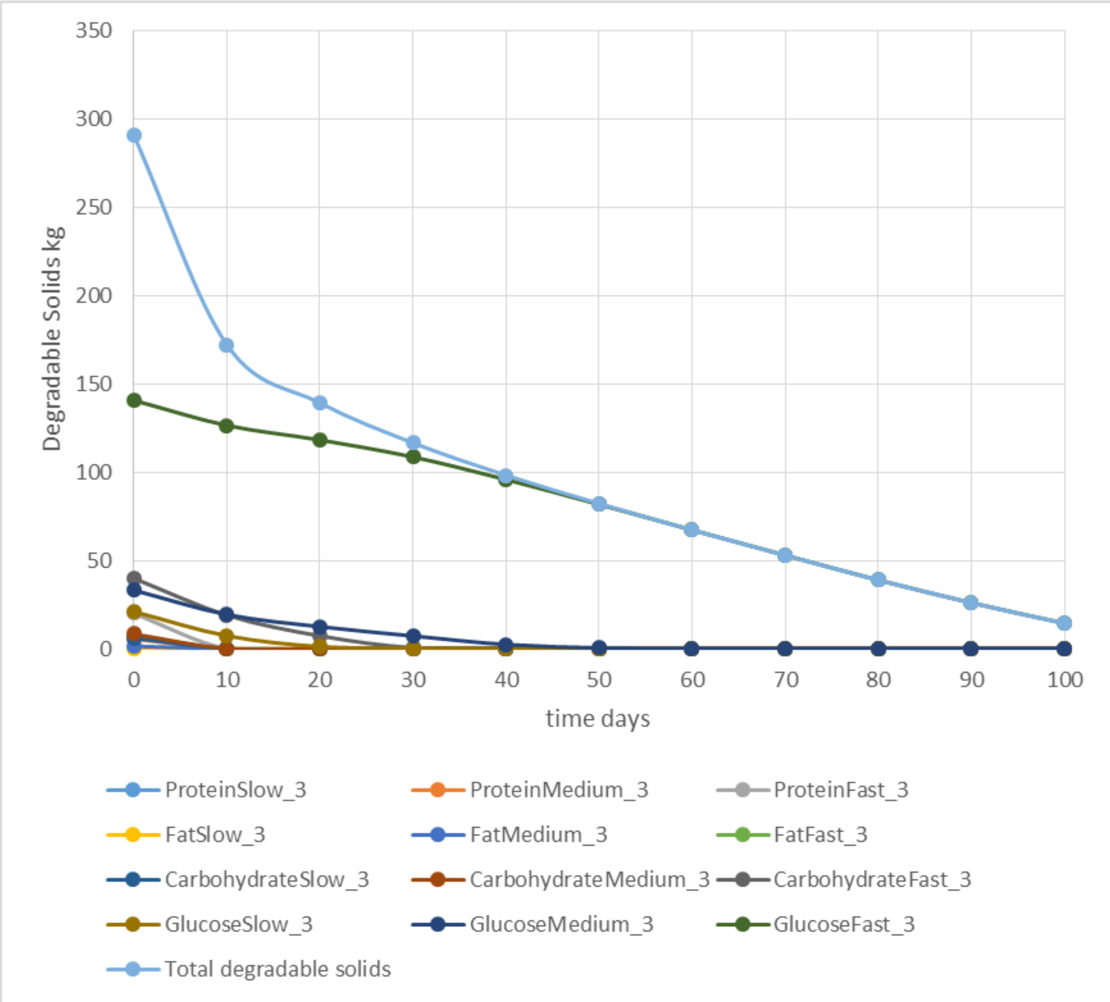

Figure 2 Degradable waste solids dissolution Active elements

Liquid in active elements

Generation of dissolved degradable solids – see Figure 3 and 'Deg solids' tab. This is the response to the dissolution of the degradable solids in Figure 2. Some of these compounds appear in the Lower boundary, having been convected and diffused there by the overall drainage and diffusion taking place in the liquid phase.

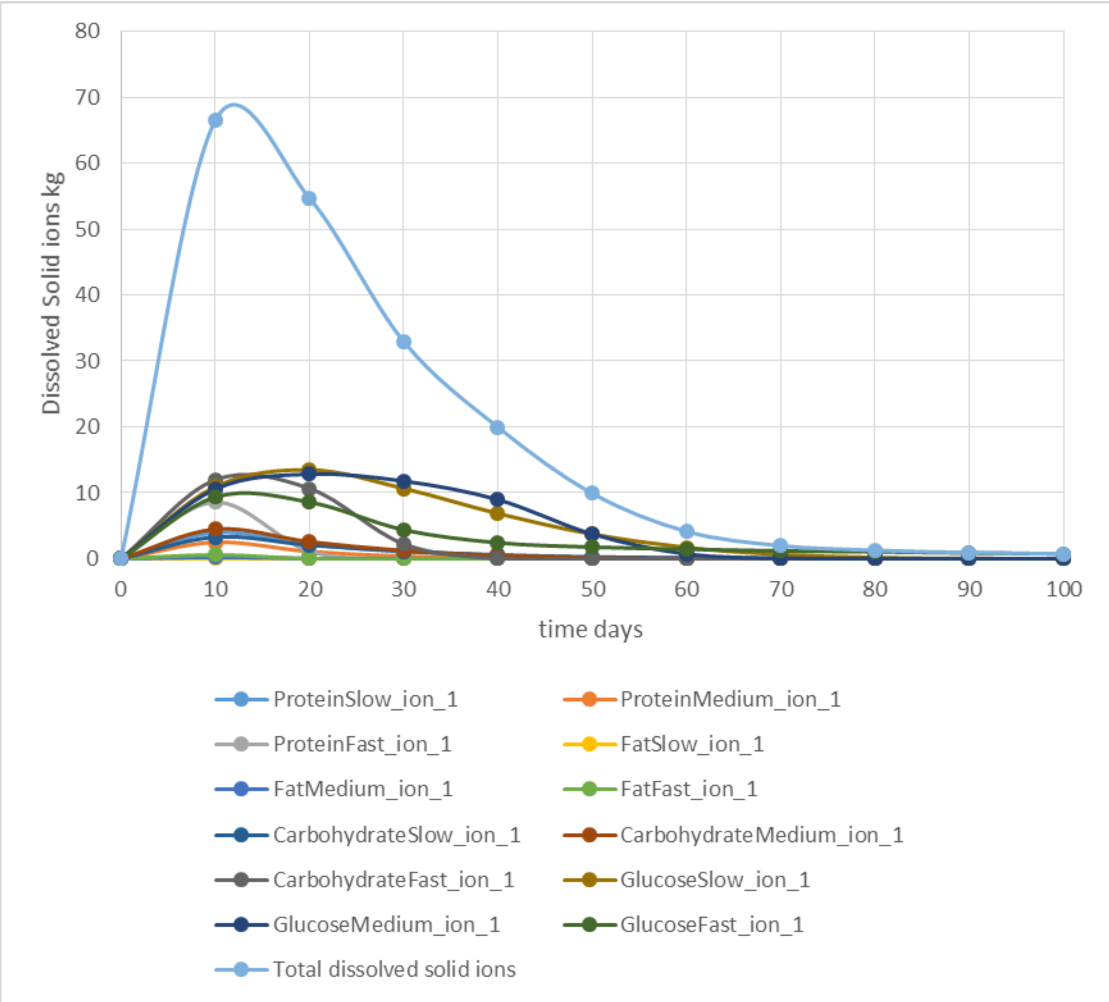

Figure 3 Dissolved waste solids ions in Active elements

The dissolved solids that remain in the Active zone become available to take part in the degradation bio-chemical reactions and become converted to acids and dissolved gases. In turn, the acids breakdown and the dissolved gases find their way out of the liquid phase into the gas phase as shown in the Component Source-Destination Map, Figure 1.

The formation and degradation of acids calculated by LDAT is shown in Figure 4 and may be found in the 'Deg solids' tab.

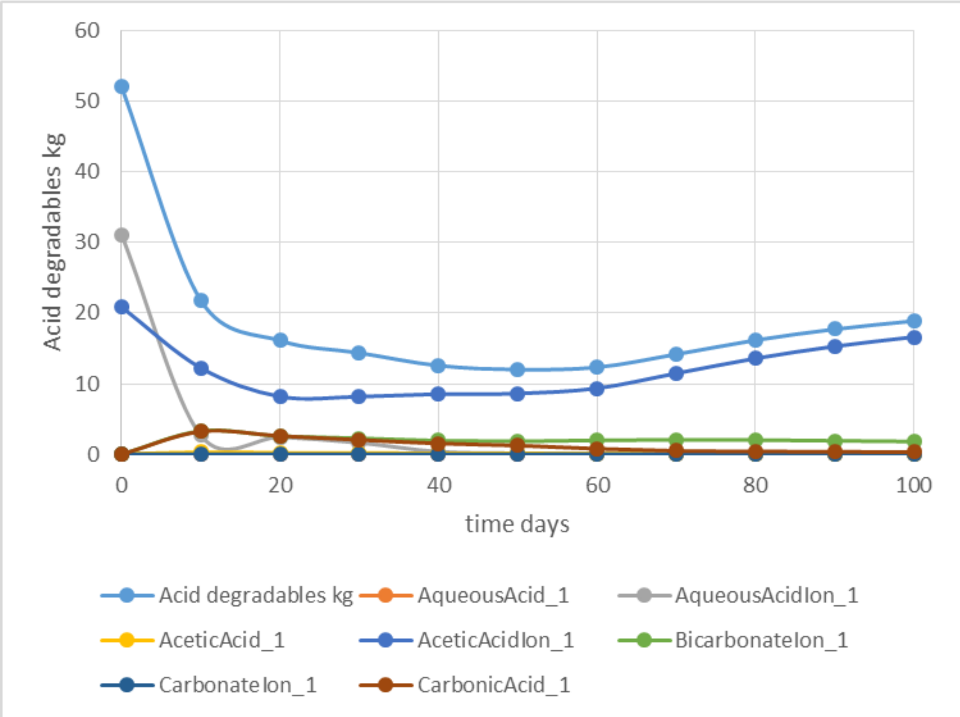

Figure 4 Formation/degradation of Acids in Active elements

Liquid in lower boundary

The transient behaviour of the Acids that drain into the lower boundary are shown in Figure 5 and are found in the 'Liquid in lower boundary' tab.

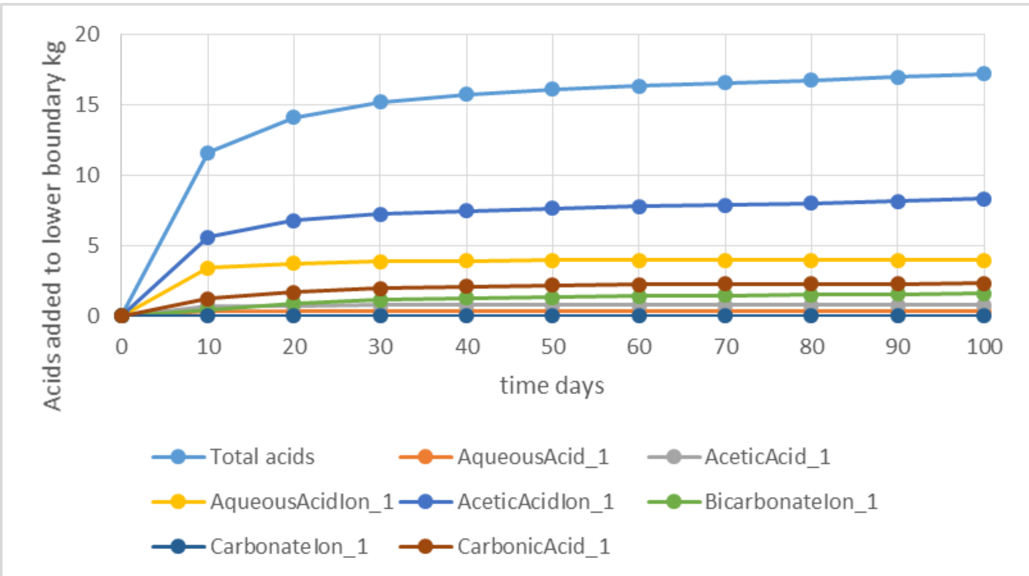

Figure 5 Acids arriving in the lower boundary.

The tab ‘Water and other liquids contains the plots for Figures 6 and 7 below.

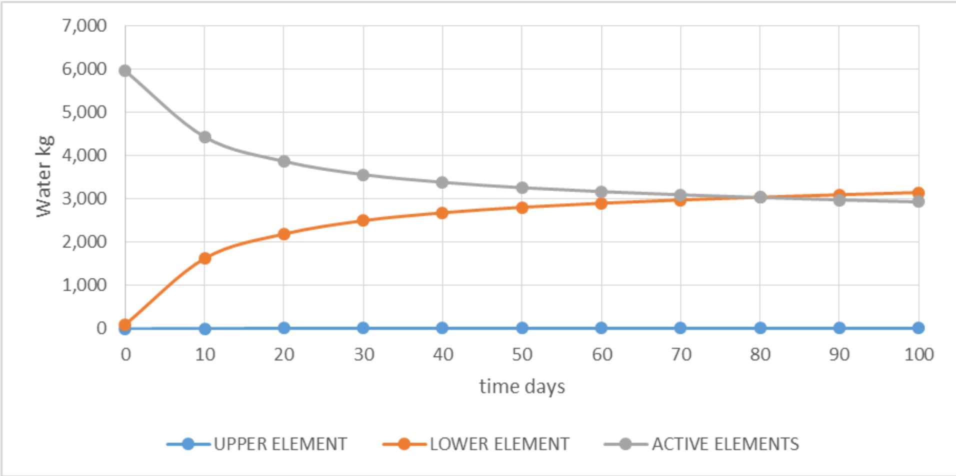

Figure 6 Transient behaviour of Water in the model

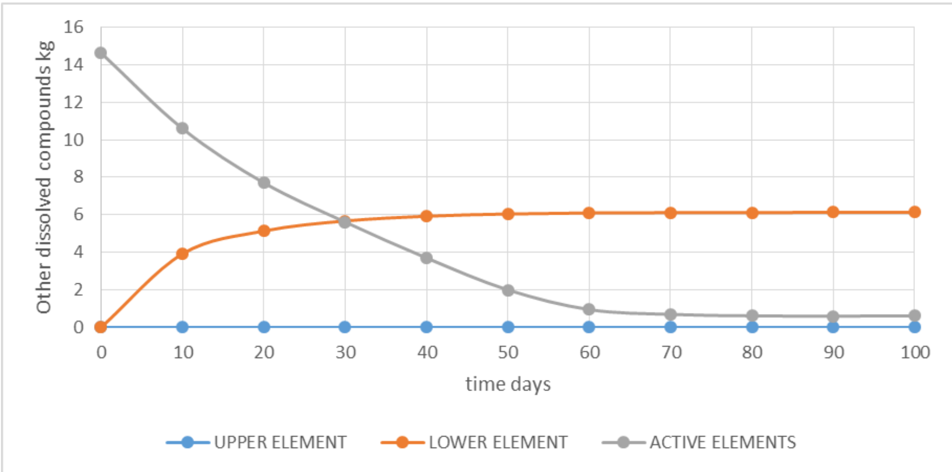

Figure 7 Transient behaviour of other dissolved compounds.

Gas in active elements

Figure 8 shows the transients for the relatively small amount of gas present in the waste Active element zone. See 'Gas in Active zone' tab.

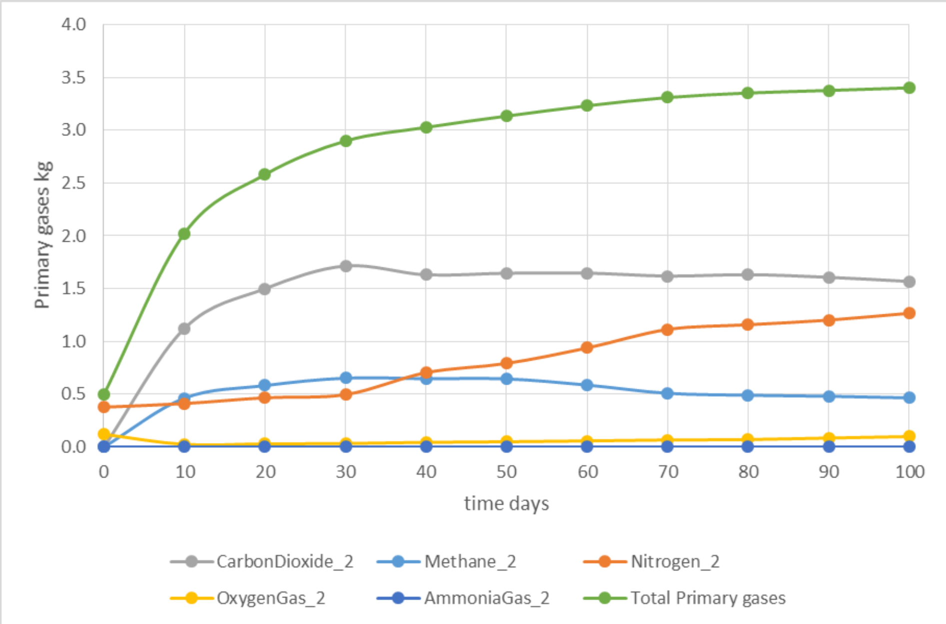

Figure 8 Gas transients in Active zone

See 'Gas in Active zone' tab

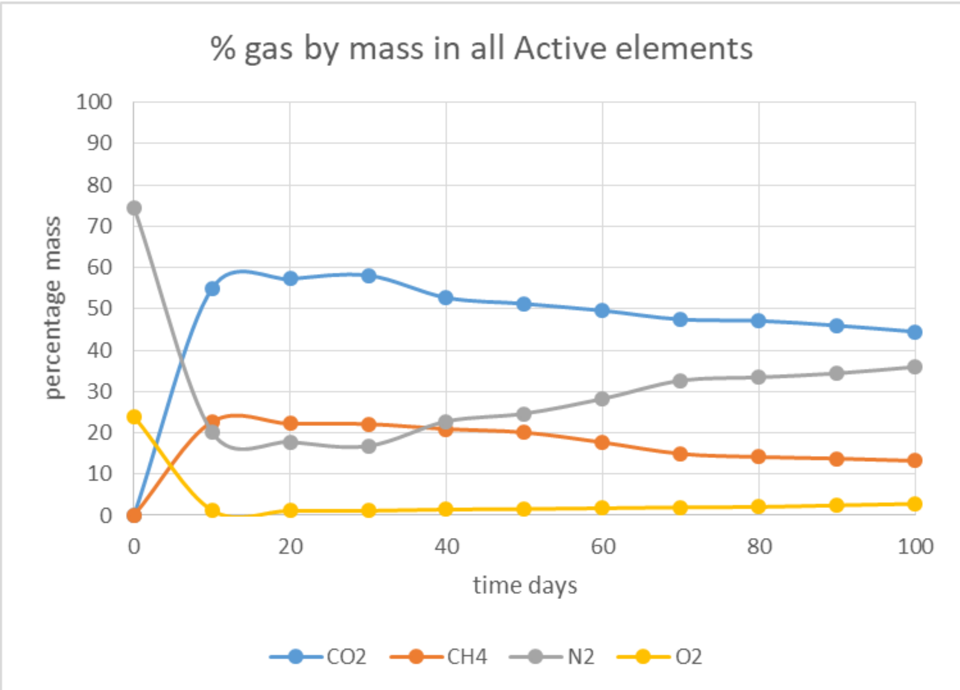

Figure 9 Gas concentrations in Active zone - % mass

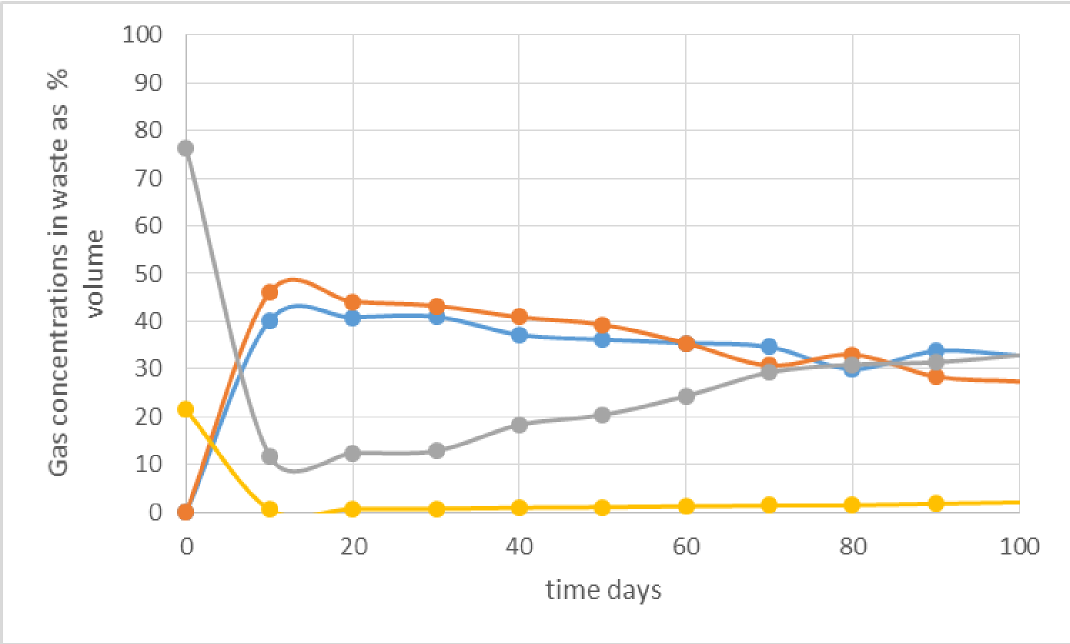

Figure 10 Gas concentrations in Active zone - % volume

This result is in the ‘Gas volumes’ tab.

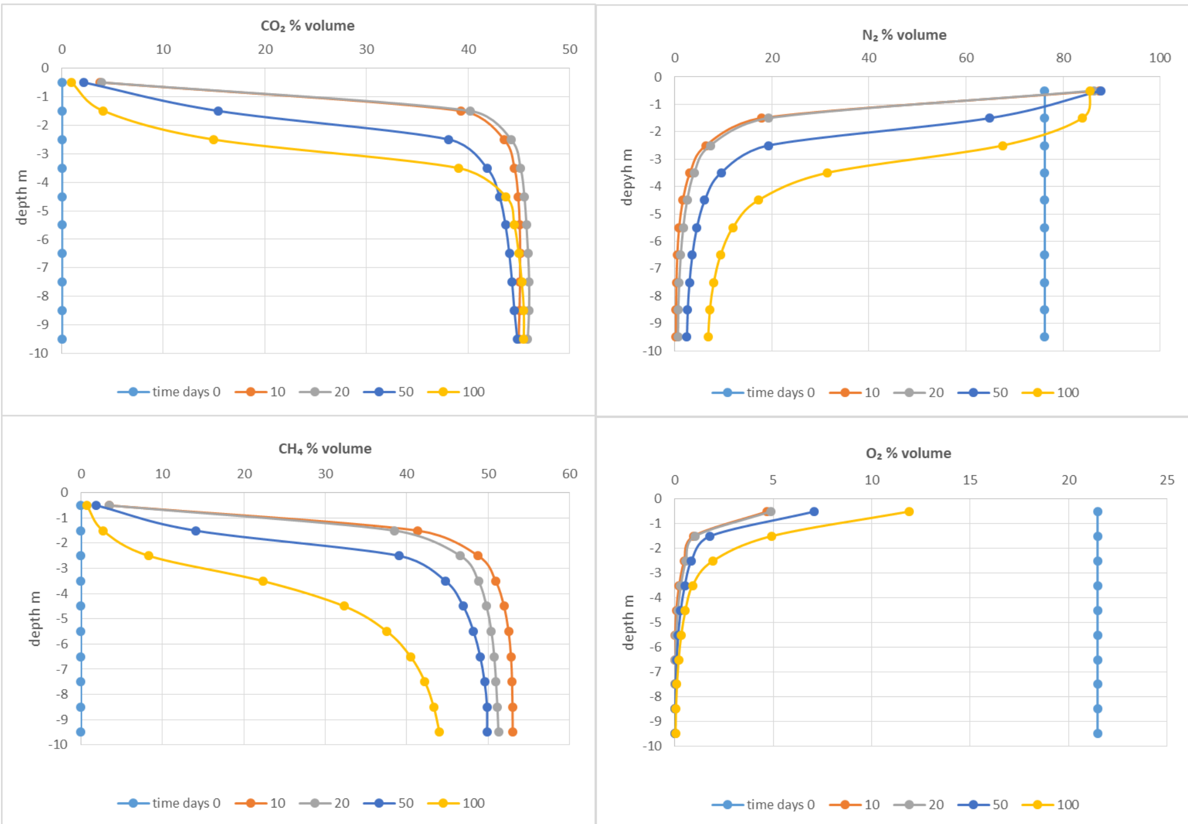

Figure 11 Gas concentration % volume – profiles in Active zone

This result is in the ‘Gas volumes’ tab.

Gas in upper boundary

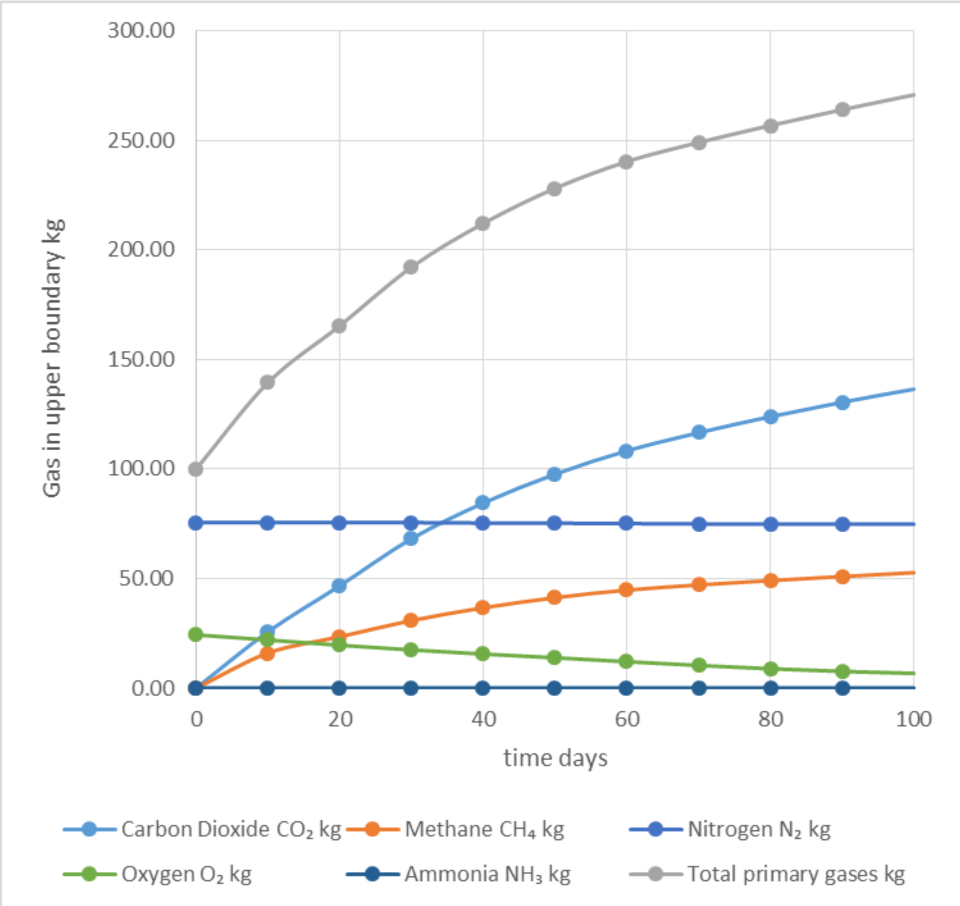

Figure 12 Gas mass emissions to upper boundary.

This result is in the 'Gas in upper boundary' tab.