

APPENDICE 4

Parametri per la caratterizzazione del biogas di discarica

Il biogas di discarica è costituito in prevalenza da metano (CH_4), in percentuale variabile dal 40 al 50% in volume, anidride carbonica (CO_2), 35 - 40% in volume della miscela, e piccole quantità di altri gas come acido solfidrico (H_2S), idrogeno (H_2), azoto (N_2) e composti in tracce, responsabili della formazione degli odori sgradevoli, quali mercaptani, ammoniaca, composti alogenati, ecc..

Nella tabella A4_1 è riportata una lista, abbastanza esaustiva, di composti in traccia identificati nel biogas prodotto dalla discarica, mentre nella tabella A4_2 si elencano alcuni gas contenuti tipicamente nelle emissioni delle torce e dei motori.

Si osserva che, nella elaborazione di un'analisi di rischio di livello 2, è essenziale utilizzare parametri sito-specifici determinati mediante prove di laboratorio.

Nella tabella A4_3 si indicano delle distribuzioni probabilistiche di alcuni composti in traccia presenti nel biogas prodotto che possono essere impiegate per confrontare i dati sperimentali.

Tabella A4_1. Composti in traccia presenti nel biogas prodotto [Environment Agency, *Guidance on the Management of Landfill Gas*; November 2002]

n°	composto in traccia	n°	composto in traccia
		50	1,2,4-trimethylbenzene
1	2-methyl-1-pentene	51	1,2,4-trimethylcyclohexane
2	3-methyl- 2-butanone	52	1,2,4-trimethylcyclopentane
3	p-cresol	53	1,2-dichloro-1,1,2,2-tetrafluoroethane
4	tert-butylbenzene	54	1,2-dichloro-1-fluoroethane
5	tetrahydro-2-furanmethanol	55	1,2-dichlorobenzene
6	(1-methylethyl)benzene	56	1,2-dichloroethane
7	(1-methylethyl)cyclohexane	57	1,2-dichloroethene
8	1-(ethenyloxy)-butane	58	1,2-dichlorotetrafluoroethane
9	1-(ethylthio)-butane	59	1,2-dimethyl-3-(1-methylethyl) cyclohexane
10	1,1,1,2-tetrachloroethane	60	1,2-dimethylcyclohexane (2,3)
11	1,1,1,2-tetrafluorochloroethane	61	1,2-Dimethylcyclopentane
12	1,1,1-trichloroethane	62	1,2-dimethylcyclopropane
13	1,1,1-trichlorotrifluoroethane	63	1,3,5-trimethyl cyclohexane
14	1,1,1-trifluoro-2-chloroethane	64	1,3,5-trimethylbenzene
15	1,1,1-trifluorochloroethane	65	1,3,5-trimethylcyclohexane
16	1,1,2,2-tetrachloroethane	66	1,3-butadiene
17	1,1,2,2-tetrafluoroethane	67	1,3-dichlorobenzene
18	1,1,2-trichloro-1,2,2-trifluoroethane	68	1,3-dimethylcyclohexane
19	1,1,2-trichloroethane	69	1,3-dimethylcyclohexane (cis)
20	1,1,2-trifluoro-1,2,2-trichloroethane	70	1,3-dimethylcyclohexane (trans)
21	1,1,2-trifluoro-1,2-dichloroethane	71	1,3-dimethylcyclopentane
22	1,1,2-trifluoro-1-chloroethane	72	1,3-dimethylcyclopentane (trans)
23	1,1,3-trimethylcyclohexane	73	1,3-dioxolane
24	1,10-undecadiene	74	1,3-pentadiene
25	1,11-dodecadiene	75	1,4-dichlorobenzene
26	1,1-chlorofluoroethane	76	1,4-dimethylcyclohexane
27	1,1-dichloroethane	77	1,4-pentadiene
28	1,1-dichloroethene	78	1,6-dimethylnaphthalene
29	1,1-dichlorotetrafluoroethane	79	1,6-heptadiene
30	1,1-difluoro-1-chloroethane	80	1,8-nonadiene
31	1,1-dimethylcyclopropane	81	1,9-decadiene
32	1,1-thiobispropane	82	1-butanethiol
33	1,1-trichloroethane	83	1-butanol
34	1,2 dichlorobenzene	84	1-butene
35	1,2,3 trichlorobenzene	85	1-chloro-1,1-difluoroethane
36	1,2,3,4 tetrachlorobenzene	86	1-chloro-1-fluoroethane
37	1,2,3,4,6,7,8-hpcdd	87	1-chloropropane
38	1,2,3,4,6,7,8-hpcdf	88	1-decene
39	1,2,3,4,7,8,9-hpcdf	89	1-ethenyl-3-ethylbenzene
40	1,2,3,4,7,8-hxcdd	90	1-ethyl-2,3-dimethylbenzene
41	1,2,3,4,7,8-hxcdf	91	1-ethyl-2-methylbenzene
42	1,2,3,6,7,8-hxcdd	92	1-ethyl-2-methyl-benzene
43	1,2,3,6,7,8-hxcdf	93	1-ethyl-2-methylcyclohexane
44	1,2,3,7,8,9-hxcdd	94	1-ethyl-2-methylcyclopentane
45	1,2,3,7,8,9-hxcdf	95	1-ethyl-3-ethylbenzene
46	1,2,3,7,8-pecdd	96	1-ethyl-3-methylcyclohexane
47	1,2,3,7,8-pecdf	97	1-ethyl-3-methylcyclopentane
48	1,2,3-trimethylbenzene	98	1-ethyl-4-methylcyclohexane
49	1,2,4-trichlorobenzene	99	1-heptene

Tabella A4_1. Composti in traccia presenti nel biogas prodotto
[Environment Agency, *Guidance on the Management of Landfill Gas*; November 2002]

n°	composto in traccia	n°	composto in traccia
100	1-hexene	150	2-chloro-1,1,1-trifluoroethane
101	1-methyl-2-propylbenzene	151	2-ethyl-1,3-dimethylbenzene
102	1-methyl-2-propylcyclopentane	152	2-ethyl-1,3-dimethylbenzene
103	1-methyl-3-propylbenzene	153	2-ethyl-1-butanol
104	1-methyl-4-(1-methylethyl) benzene	154	2-ethyl-1-hexanol
105	1-methyl-4-(1-methylethyl)-benzene	155	2-ethyl-cycloheptanone
106	1-methyl-4-(1-methylethyl)cyclopentane	156	2-furanmethanol
107	1-methyl-4-1 (1-methylethyl) benzene	157	2-hexanone
108	1-methyl-4-propylbenzene	158	2-methyl-1,3-butadiene
109	1-methylpropylbenzene	159	2-methyl-1-butane
110	1-octene	160	2-methyl-1-butene
111	1-pentanethiol	161	2-methyl-1-propanethiol
112	1-pentene	162	2-methyl-1-propanol
113	1-phenyl-1-propanone	163	2-methyl-1-propene
114	1-propanethiol	164	2-methyl-2-propenoic acid
115	1-propanol	165	2-methylbutane
116	1-undecene	166	2-methyldecane
117	2 ethynyl phenol	167	2-methylheptane
118	2(2-hydropropoxy)propan-1-ol	168	2-methylhexane
119	2(methylthio)propane	169	2-methylnonane
120	2,2-difluoropropane	170	2-methyloctane
121	2,2-dimethylbutane	171	2-methylpentane
122	2,2-dimethylpentane	172	2-methylpropane
123	2,2-dimethylpropanoic acid	173	2-methylpropylbenzene
124	2,2-dimethyl-propanoic acid	174	2-methylpropylcyclohexane
125	2,3,3-trimethylpentane	175	2-pentanone
126	2,3,4,6,7,8-hxcdf	176	2-pentene
127	2,3,4,7,8-pecdf	177	2-propanethiol
128	2,3,4-trimethylhexane	178	2-propanol
129	2,3,4-trimethylpentane	179	2-propenal
130	2,3,7,8-tcdd	180	2-propene-1-thiol
131	2,3,7,8-tcdf	181	2-propyl thiophene
132	2,3-dimethylheptane	182	3 ethynyl phenol
133	2,3-dimethylpentane	183	3-(ethylthio)propanal
134	2,4,4-trimethylpentane	184	3,3-dimethylpentane
135	2,4,6-trimethylheptane	185	3,5-dimethyloctane
136	2,4-dimethylheptane	186	3-carene
137	2,4-dimethylhexane	187	3-ethyl-4-methylheptane
138	2,5-dimethylheptane	188	3-ethylhexane
139	2,5-dimethylhexane	189	3-ethylpentane
140	2,5-dimethylpentene	190	3-ethyl-pentane
141	2,6-dimethylheptane	191	3-methyl pentan-2-ol
142	2,6-dimethylnonane	192	3-methyl-1-butanol
143	2,6-dimethyloctane	193	3-methyl-2-butanone
144	2,6-dimethynonane	194	3-methyl-butan-2-ol
145	2-butanethiol	195	3-methyldecane
146	2-butanol	196	3-methylheptane
147	2-butanone	197	3-methylhexane
148	2-butene	198	3-methylnonane
149	2-butoxy ethanol	199	3-methyloctane

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n°	composto in traccia	n°	composto in traccia
200	3-methylpentane	250	butyl formate
201	3-methylpentane	251	butyl methyl trisulphide
202	3-pentanol	252	butyl propyl trisulphide
203	4-carene	253	butyl trisulphides
204	4-methyl-1-hexene	254	butylbenzene
205	4-methyl-2-pentene (e)	255	butylpropyldisulphide
206	4-methyldecane	256	butynes
207	4-methylheptane	257	butyric acid
208	4-methylnonane	258	camphene
209	4-methyloctane	259	camphor
210	5-methyldecane	260	carbon disulphide
211	acenaphthene	261	carbon monoxide
212	acetaldehyde	262	carbonyl sulphide
213	acetaphenone	263	carene
214	acetic acid	264	chlorobenzene
215	acetone	265	chlorodifluoromethane
216	acetonitrile	266	chloroethane
217	alpha-pinene	267	chloroethene
218	amyl acetate (mixed isomers)	268	chlorofluoromethane
219	amyl alcohol	269	chloromethane
220	amyl mercaptan	270	chloromethylbenzene
221	anthracene	271	chloropropene
222	arsenic	272	chlorotrifluoroethene
223	benzaldehyde	273	chlorotrifluoromethane
224	benzene	274	chlorotrifluoromethene
225	benzo(a)anthracene	275	chrysene
226	benzo(a)pyrene	276	cis-1,2-dichloroethene
227	benzo(b)fluoranthene	277	cyclobutane
228	benzo(ghi)perylene	278	cycloheptane
229	benzo(k)fluoranthene	279	cyclohexane
230	benzoic acid	280	cyclohexanone
231	benzothiazole	281	cyclopentane
232	beta-cymene	282	cyclopentanone
233	beta-pinene	283	cyclopentene
234	biphenylene	284	decahydro-4,8,8-trimethyl-9-methylene-,
235	bromochlorodifluoromethane	285	Decahydronaphthalene
236	bromochlorofluoromethane	286	Decamethylcyclopentasiloxane
237	bromodichloromethane	287	Decanal
238	bromoethane	288	Decanhydronaphthalene
239	butanal	289	Dibromochloromethane
240	butane mercaptan	290	dibutyl sulphide
241	butanoic ethyl ester	291	dibutyl trisulphide
242	butene	292	dichlorobenzene (mixed isomers)
243	butyl acetate	293	Dichlorobutene
244	butyl benzene	294	Dichlorodifluoromethane
245	butyl butyrate	295	Dichlorofluoromethane
246	butyl cyclohexane	296	Dichloromethane
247	butyl ester	297	diethyl disulfide
248	butyl ethanoate	298	diethyl disulphide
249	butyl ethyl trisulphide	299	diethyl phthalate

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[Environment Agency, *Guidance on the Management of Landfill Gas*; November 2002]

n°	composto in traccia	n°	composto in traccia
300	diethyl sulphide	350	ethylisobutyl disulphide
301	diethylbenzene	351	ethylmethyl disulphide
302	di-isooctyl phthalate	352	ethylmethyl trisulphide
303	dimethoxy methyl propanoate	353	ethyl-methylcyclohexane
304	dimethyl cyclohexane	354	ethylpentane
305	dimethyl cyclopentane	355	ethylpropyl disulphide
306	dimethyl disulphide	356	ethylpropyltrisulphide
307	dimethyl ether	357	ethylvinyl benzene
308	dimethyl ethyl methanoate	358	ethyne
309	dimethyl furan	359	fluoranthene
310	dimethyl pentan-3-one	360	fluorene
311	dimethyl styrene	361	formic acid
312	dimethyl sulfide	362	furan
313	dimethyl sulphide	363	furfural
314	dimethyl tetrasulphide	364	gamma-terpinene
315	dimethyl trisulphide	365	h6cdd 123478
316	dimethylbutane	366	h6cdd 123678
317	dipropyl ether	367	h6cdd 123789
318	dipropyl sulphide	368	h6cdf 123478
319	dipropyl trisulphide	369	h6cdf 123678
320	dodecamethylcyclohexasiloxane	370	h6cdf 123789
321	dodecene	371	h6cdf 234678
322	eicosane	372	h7cdd 1234679
323	ethanal	373	h7cdf 1234678
324	ethane	374	h7cdf 1234789
325	ethanethiol	375	HA1334
326	ethanol	376	HA1335
327	ethene	377	HA1343
328	ether	378	HA1344
329	ethyl 2-methyl butyrate	379	HA1352
330	ethyl acetate	380	HA1353
331	ethyl alcohol	381	heneicosane
332	ethyl butyrate	382	heptachlorodibenzo-dioxin
333	ethyl caproate	383	heptadecane
334	ethyl cyclohexane	384	heptadibrodibenzo-furan
335	ethyl cyclopentane	385	heptyl mercaptan
336	ethyl dimethyl propanoate	386	hexachlorobenzene
337	ethyl ethanoate	387	hexachlorodibenzo-dioxin
338	ethyl isopropyl disulphide	388	hexadecane
339	ethyl isovalerate	389	hexadibrodibenzo-furan
340	ethyl methyl ether	390	hexadiene
341	ethyl n-propyl disulfide	391	hexamethylcyclotrisiloxane
342	ethyl pentanoate	392	hexamethyldisiloxane
343	ethyl propionate	393	hexanal
344	ethyl toluene	394	Hexane, 3-ethyl-
345	ethylbenzene	395	hexyl methanoates
346	ethylcyclohexane	396	hydrogen
347	ethylcyclopentane	397	hydrogen chloride
348	ethylcyclopropane	398	hydrogen cyanide
349	ethylene oxide	399	hydrogen fluoride

Tabella A4_1. Composti in traccia presenti nel biogas prodotto
[Environment Agency, *Guidance on the Management of Landfill Gas*; November 2002]

n°	composto in traccia	n°	composto in traccia
400	hydrogen sulphide	450	n-butanol
401	indeno(123cd)pyrene	451	n-butyl disulphide
402	isobutane	452	n-butyl propionate
403	isobutyl formate	453	n-decane
404	limonene	454	n-decene
405	l-propanol	455	n-dodecane
406	m-cresol	456	n-heptane
407	mercury	457	n-hexane
408	methanal	458	n-hexanol
409	methanethiol	459	n-hexyl mercaptan
410	methanol	460	n-nonane
411	methyl 2-methyl butanoate	461	n-octane
412	methyl 2-methyl propenoate	462	nonadecane
413	methyl acetate	463	nonanal
414	methyl butyl disulphide	464	nonene
415	methyl butyrate	465	n-pentane
416	methyl caproate	466	n-propane
417	methyl cyanide	467	n-propyl acetate
418	methyl cycloheptane	468	n-propyl butyrate
419	methyl ether	469	n-tetradecane
420	methyl ethyl butanoate	470	n-tridecane
421	methyl ethyl disulphide	471	n-undecane
422	methyl ethyl ketone	472	n-undecene
423	methyl ethyl propanoate	473	ocdd
424	methyl furan	474	ocdf
425	methyl isobutyl carbinol	475	o-cresol
426	methyl isobutyl ketone	476	octachlorodibenzo-dioxin
427	methyl isobutyrate	477	octadecane
428	methyl isopropyl disulphide	478	octadibrodibenzo-furan
429	methyl isopropyl ketone	479	octadiene
430	methyl isovalerate	480	octamethylcyclotetrasiloxane
431	methyl naphthalene	481	octanal
432	methyl pentanoate	482	p5cdd 12379
433	methyl propanoate	483	p5cdf 12378
434	methyl propyl disulphide	484	p5cdf 23478
435	methyl propyl ethanoate	485	para-cymenyl
436	methyl vinyl ketone	486	pcb 101
437	methyl-4-isopropenylbenzene	487	pcb 118
438	methylal	488	pcb 126
439	methylcyclobutane	489	pcb 138
440	methylcyclohexane	490	pcb 153
441	methylcyclopentane	491	pcb 169
442	methylcyclopropane	492	pcb 180
443	methylenecyclohexane	493	pcb 28
444	methylethyl cyclohexane	494	pcb 52
445	methylethyl sulphide	495	pcb 77
446	methylpropyltrisulphide	496	pentachlorobenzene
447	methylthioethane	497	pentachlorodibenzo-dioxin
448	naphthalene	498	pentadecane
449	n-butane	499	pentadibrodibenzo-furan

Tabella A4_1 Composti in traccia presenti nel biogas prodotto
[Environment Agency, *Guidance on the Management of Landfill Gas*; November 2002]

n°	composto in traccia	n°	composto in traccia
500	pentanal	550	trichloromethane
501	pentene	551	trifluorobenzene
502	pentyl benzene	552	trimethyl cyclopentane
503	pentyl methanoates	553	trimethylhexane
504	pentyl trisulphide	554	trimethylsilanol
505	phellandrene	555	vinyl toluene
506	phenanthrene	556	xylene
507	phenol	557	a- chlorotoluene
508	pinene		
509	propadiene		
510	propan-2-one		
511	propanal		
512	propanoic acid		
513	propene		
514	propionic acid		
515	propyl butyl disulphide		
516	propyl cyclohexane		
517	propyl methyl propanoate		
518	propyl methyl trisulphide		
519	propyl propionate		
520	propylbenzene		
521	propylthiophene		
522	propyltoluene		
523	pyrene		
524	sec-butyl alcohol		
525	sec-butylbenzene		
526	styrene		
527	sulfuric acid		
528	sulphur dioxide		
529	t4cdd 2379		
530	t4cdf 2379		
531	t-butyl alcohol		
532	terpenes		
533	tetrachlorodibenzo-dioxin		
534	tetrachloroethane		
535	tetrachloroethene		
536	tetrachloromethane		
537	tetradecane		
538	tetradibrodibenzo-furan		
539	tetrafluorochloroethane		
540	tetrahydrofuran		
541	tetramethylbenzene		
542	tetramethylcyclohexane		
543	thiophene		
544	thujene		
545	Toluene		
546	trans-1,2-dichloroethene		
547	tribromomethane		
548	trichloroethene		
549	trichlorofluoromethane		

Tabella A4_2. Elenco di alcuni composti in traccia presenti nelle emissioni dalle torce e/o dai motori [Golder Associates, *GasSim v1.02 Manual Supplement*; October 2003]

<i>n°</i>	<i>composto in traccia</i>
1	Diossine e furani
2	Fluoruri totali (espressi come HF)
3	Composti organici volatili non metanigeni (NMVOCs)
4	Monossido di carbonio
5	Cloruri totali (espressi come HCl)
6	Ossidi di azoto
7	Solfuri ridotti (espressi come SO ₂)
8	Benzo(a)pyrene
9	PM10s (polveri con diametro inferiore a 10 mm)

Tabella A4_3. Distribuzioni di probabilità di default per alcuni composti in traccia presenti nel biogas prodotto [Golder Associates, *GasSim v1.02 Manual Supplement*; October 2003]

<i>composto</i>	<i>distribuzione di probabilità</i>
1,1,1,2-Tetrafluorochloroethane	LOGTRIANGULAR(2e-3, 0.2, 2)
1,1,1-Trichlorotrifluoroethane	LOGTRIANGULAR(5e-3, 0.4, 8)
1,1,2-Trichloroethane	LOGTRIANGULAR(4e-3, 1, 10)
1,1-Dichloroethane	LOGTRIANGULAR(1e-3, 0.1, 61800)
1,1-Dichloroethene	LOGTRIANGULAR(1e-3, 0.01, 1516)
1,1-Dichlorotetrafluoroethane	LOGTRIANGULAR(0.05, 0.25, 6.4)
1,2-Dichlorotetrafluoroethane	LOGTRIANGULAR(0.01, 9.8, 300)
1-Chloro-1,1-difluoroethane	LOGTRIANGULAR(0.04, 0.57, 31)
2-Chloro-1,1,1-trifluoroethane	LOGUNIFORM(0.05, 1.5)

Tabella A4_3. Distribuzioni di probabilità di default per alcuni composti in traccia presenti nel biogas prodotto [Golder Associates, GasSim v1.02 Manual Supplement; October 2003]

<i>composto</i>	<i>distribuzione di probabilità</i>
Methyl ethyl ketone (2-butanone)	LOGTRIANGULAR(5e-3, 5e-3, 73)
Methyl isobutyl ketone	LOGTRIANGULAR(5e-3, 0.2, 9.9)
Odour Units (Predicted)	TRIANGULAR(50000, 125000, 250000)
PAH (reported as Naphthalene)	LOGTRIANGULAR(1e-3, 0.2, 17)
para-Dichlorobenzene (modelled as 1,4-Dichlorobenzene)	LOGTRIANGULAR(6e-3, 0.05, 2.7)
Pentane	LOGTRIANGULAR (0.02, 0.3, 105)
Pentene (all isomers)	LOGTRIANGULAR(1e-3, 0.2, 11)
Propane	LOGTRIANGULAR (1e-3, 1.9, 12.9)
Propanethiol	LOGTRIANGULAR(0.2, 0.2, 2.1)
Sulphide, total simulations with H2S	LOGTRIANGULAR(1e-3, 2.4, 5575)
Sulphide, total simulations without H2S	LOGTRIANGULAR(5e-4, 8e-3, 3.5)
Sulphur reduced (reported as SO2)	LOGUNIFORM(30.8, 430.5)
1,2-Dichloroethene	LOGTRIANGULAR (6e-3, 1.0, 41)
Tetrachloroethane (modelled as 1,1,2,2-Tetrachloroethane)	LOGUNIFORM(1e-3, 50)
Tetrachloroethylene (Tetrachloroethene)	LOGTRIANGULAR(1e-3, 0.01, 7700)
Toluene	LOGTRIANGULAR(0.01, 0.1, 1250)
Total chloride (reported as HCl)	LOGTRIANGULAR(14.7, 79.5, 850)
Total fluoride (reported as HF)	LOGTRIANGULAR(5.6, 251.2, 735)
Total non-methane volatile organic compounds (NMVOCs)	LOGUNIFORM(0.05, 1473)
Trichlorobenzene (all isomers)	LOGTRIANGULAR(0.01, 0.01, 0.13)
Trichloroethylene (trichloroethene)	LOGTRIANGULAR(0.01, 2.0, 608)
Trichlorofluoromethane	LOGTRIANGULAR(1e-3, 0.01, 1000)
Trichlorotrifluoroethane	LOGTRIANGULAR(1e-3, 4.8, 24)
Trimethylbenzene (all isomers)	LOGTRIANGULAR(1e-3, 0.01, 187)
Vinyl chloride (chloroethene, chloroethylene)	LOGTRIANGULAR(1e-3, 0.01, 7660)
Xylene (all isomers)	LOGTRIANGULAR(1e-3, 1e-3, 61784)