LEACHATE TREATMENT

- What do we need in order to design and operate leachate treatment facilities?
- How do the needs change in the future?

- Long term nitrogen management in bioreactor landfills
- Constructed wetlands treatment system for landfill leachate in cold climates
- Leachate treatment by direct capillary nanofiltration

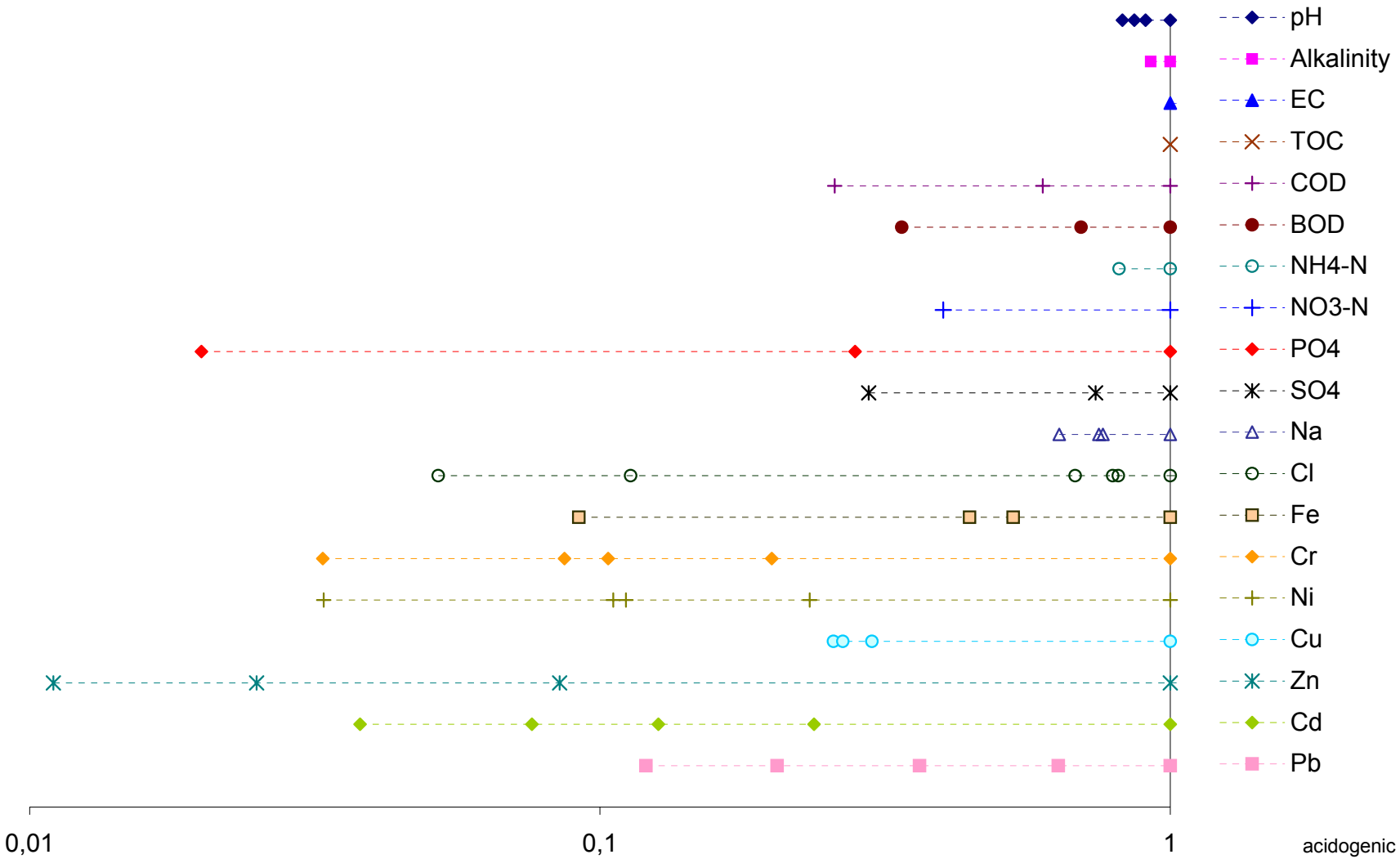
Range of concentrations in leachate from acidogenic and methanogenic landfills [mg/l if not otherwise given]

Variable	Acidogenic	Methanogenic
pH [-]	4.5 - 7.8	6,4 - 9
Alkalinity as $CaCO_3$	160 - 15,870	100 - 11,500
EC [mS/m]	47 - 5,200	160 - 1,930
TOC	350 - 29,000	14 - 2,270
COD	400 - 152,000	<1 - 8,000
BOD	500 - 68,000	<0.5 - 1,770
NH_4-N	8,5 - 3,610[a]	<1 - 2040; <1 - 3,000[a]
NO_3-N	<0.2 - 18; 0.1 - 50[a]	<0.1 - 64; <0.1 - 64[a]
PO_4-P	<0.05 - 22.6	<0.01 - 18.4
SO_4	4 - 2,800[a]	<1 - 1,190; <1 - 2,500[a]
Na	29 - 3,000; 1 - 6,800[a]	4 - 3,650; 1 - 6,800[a]
Cl	8.5 - 5,000; <1 - 12,400[a]	<1 - 5,000; <1 - 12,400[a]
Fe	0.1 - 2,300	0.2 - 330
Zn	0.02 - 200	<0.005 - 9
Cd	<0.0002 - 0.1; <0.0002 - 0.525[a]	<0.00001 - 0.9; <0.00001 - 0.9[a]
Cr	<0.01 - 1.5; 0.002 - 1.6[a]	<0.00001 - 0.7; <0.00001 - 1.6[a]
Cu	0.003 - 1.1; 0.003 - 1.4[a]	<0.0007 - 0.6; <0.0007 - 1.4[a]
Ni	<0.01 - 1.8; <0.01 - 2.05[a]	0.0036 - 0.6; 0.0036 - 2.05[a]
Pb	<0.001 - 0.9; <0.001 - 1.02[a]	<0.0001 - 1.9; <0.0001 - 1.9[a]

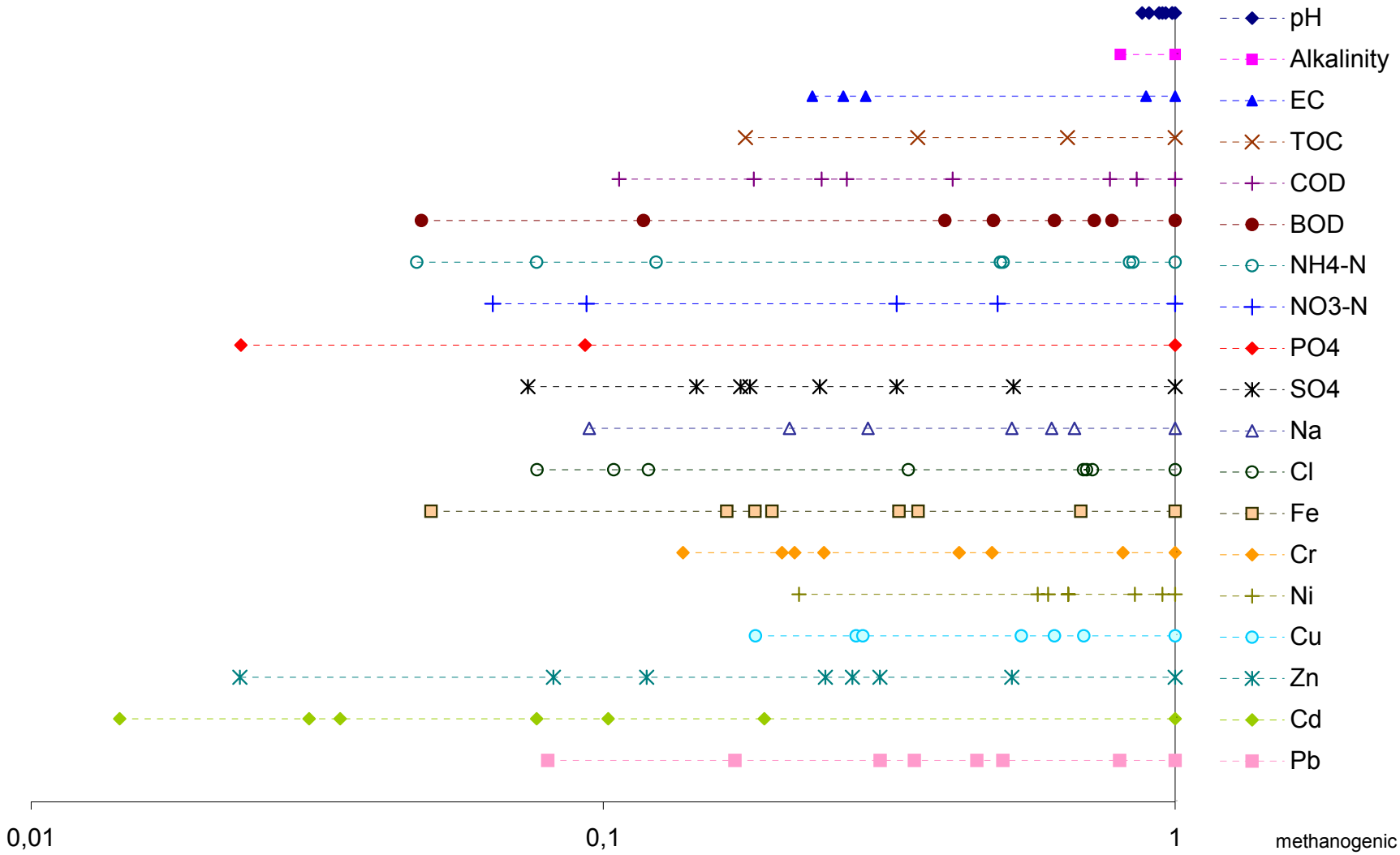
Based on data from: Ehrig (1989), Kettunen (1997), Krümpelbeck & Ehrig (1999), Kruse (1994), Marttinen *et.al.* (2001), Robinson (1995) and Tchobanoglous (1993).

[a] Includes data where some of the authors did not separate data for the phases.

Scattering of average concentrations in acidogenic leachate



Scattering of average concentrations in methanogenic leachate



Examples for cleaning goals:

Different European limit values for direct discharge into recipients [Kylefors 2000]:

Substance	Unit	Germany (1989)	Switzerland (1988)	Italy (1976)	Austria (1981)	Netherlands (1987)
COD	mg/l	200*	(60)#	160	75-90	75-150
BOD_5	mg/l	20	20	40	20-25	7-20#
Susp. solids	mg/l	20	20	80	30	-
Cl^-	mg/l	-	#	1 200	#	-
SO_4^{2-}	mg/l	-	300	1 000	#	500
N_{Kj}	mg/l	-	-	-	-	18-15#
NH_4-N	mg/l	50	(5)#	12	#	4-8#
Pb	µg/l	500	500	200	1 000	50
Cd	µg/l	100	100	20	100	2.5
Cr(VI)	µg/l	-	100	200	100	75
Tot-Cr	µg/l	500	2 100	2 200	2 100	-
Cu	µg/l	500	500	100	1 000	50
Ni	µg/l	500	2 000	2 000	2 000	100
Hg	µg/l	50	10	5	10	0.5
Zn	µg/l	2 000	2 000	500	3 000	200
Sn	µg/l	-	2 000	10 000	2 000	-
Fe	mg/l	-	2	2	2	-
AOX	µg/l	500	-	-	-	-
Phenol	µg/l	-	50	500	100	-
Fish toxicity	class	2	0-5#	2	-	-

* Alternatively: a minimum of 95 % COD reduction during leachate treatment is required if COD > 4000 mg/l.

\# Depending on the quality and the size of the recipient.

Comparison of periods of time necessary to reach certain discharge limits in landfill leachate (I)

(limits: COD = 200 mg/l; TOC = 100 mg/l; N_{Kj}/NH_4-N/N_{tot} = 5 or 10 mg/l)

Substance	Reference	Time [years]
TOC	BELEVI, BACCINI (1989)	**500 - 1.700**
COD	KRUSE (1994)	**280**
	KYLEFORS, LAGERKVIST (1999)	**232**[3]
	KRÜMPELBECK, EHRIG (1999)	**65 - 320**
	HEYER, STEGMANN (1997)	**80 - 360**
	ANDREAS (2000)	**40 - 400**
N_{Kj}	BELEVI, BACCINI (1989)	**55 - 80**
NH_4	KRUSE (1994)	**815**
$N_{tot.}$	LAGERKVIST (1987)[1]	**700 (2.400)**[2]
	KRÜMPELBECK, EHRIG (199)	**decades to centuries**
	HEYER, STEGMANN (1997)	**120 - 450**
	ANDREAS (2000)	**150 - 560**

1 total N; limit N_{tot} = 10 mg/l

2 results of 100 l physical simulators; in brackets: 3 m^3 methanogenic field test cell

Comparison of periods of time necessary to reach certain discharge limits in landfill leachate (II)

(limits: Cl^- = 100 mg/l; AOX = 0,5 mg/l)

Substance	Reference	Time [years]
Cl^-	BELEVI, BACCINI (1989)	**100 - 150**
	KRUSE (1994)	**210**
	KRÜMPELBECK, EHRIG (1999)	**25 - 60 (130)[3]**
	HEYER, STEGMANN (1997)	**90 - 250**
	ANDREAS (2000)	**170 - 400**
AOX	KRÜMPELBECK, EHRIG (1999)	**40 - 100**
	KYLEFORS, LAGERKVIST (1999)	**208**
	HEYER, STEGMANN (1997)	**30 - 210**

[3] 130 years at above-average load