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Field Leaching of Bricks and Concrete Containing Coal Fly Ash

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SUMMARY

In the Netherlands building materials must comply with leaching limits as laid down in the Buildings Materials Decree. The leaching behaviour of the building materials has to be determined by standardised tests at the laboratory. The results of these tests are used as input in formulas that calculate the cumulative emissions over 100 years. The question arises whether this approach is a good prediction of what will happen in the field. At KEMA a major research item is to investigate leaching behaviour under field conditions. This paper presents the results of field leaching of two types of bricks for five and a half years and of concrete for two years. For these three types of building material two forms are tested, one ordinary form and one in which 20% coal fly ash (CFA) is used. The results are compared between the different types of clay, between materials with and without CFA and between prolonged field tests and brief laboratory leaching tests.

The use of CFA as a raw material in bricks and concrete increases the leaching of As, Mo and sulphate. Vanadium also shows this increase of leaching in bricks, but not in concrete. The effect of using CFA in one type of brick is that the Cr leaching increases, while in another type of brick and in concrete it decreases. In all cases and for all elements the leaching stays well below the limits as laid down in the Building Materials Decree, so CFA can well be used in building materials without contaminating the soil or surface water.

Compared to the 5½ years field test, the extrapolation of the diffusion test to 5½ years gives a reasonable prediction of the leaching of molybdenum and vanadium; however, the diffusion test overestimates the leaching of arsenic and barium and it underestimates the leaching of chromium and sulphate.

Field leaching behaviour of building materials

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KEMA the Netherlands

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Dolmen or megalithic grave in the Netherlands

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Buildings Materials Decree

In order to prevent soil, groundwater and surface water pollution limits are set for immissions into the soil for use of primary, secondary and waste materials.

- two limits one for building materials in contact with rain, surface water and /or ground water and one for buildings materials isolated from water

- two type of limits one for moulded products and one for unmoulded products

Buildings Materials Decree

Gives maximum immission levels for the soil

the next step is

translation of emission levels, to be determined via column test for unmoulded materials, into immission levels according to the formula below:

$$I_{bN} = 1550 * (E_{mean(L/S\,=\,10)} - a) * h * f_{ext\,-\,N}$$

$$f_{ext\,-\,N} = \frac{1 - e^{-k \bullet \frac{t \bullet N_i}{1550 \bullet h}}}{1 - e^{-k \bullet 10}}$$

Characteristics of the various leaching tests for unmoulded materials

type of leaching test	Dutch column test	Dutch cascade test	EPA test [1)]	Dutch availability test
L/S ratio	10	5x20=100	20	2 x 50
time scale in years	5-50 short/medium	50-100/ 100-500 longterm		extreme long period worst case
demineralized water at pH: [1)]	initial pH=4 alkaline equilibrium-pH	initial pH=4 alkaline equilibrium pH	constant pH=5	constant pH=7 and pH=4
process	upward flow <2 cm•h^{-1}	shake test 5x refreshment	shake test	shake test 2x refreshment
time	3 weeks	5x23 hours	24 hours	2x3 hours

1) the pH is adjusted by adding HNO_3; for the EPA test this is a deviation from the prescribed acetic acid; for some ashes the equilibrium pH is acid, but those ashes are not taken into consideration in these experiments, because they are hardly produced any more.

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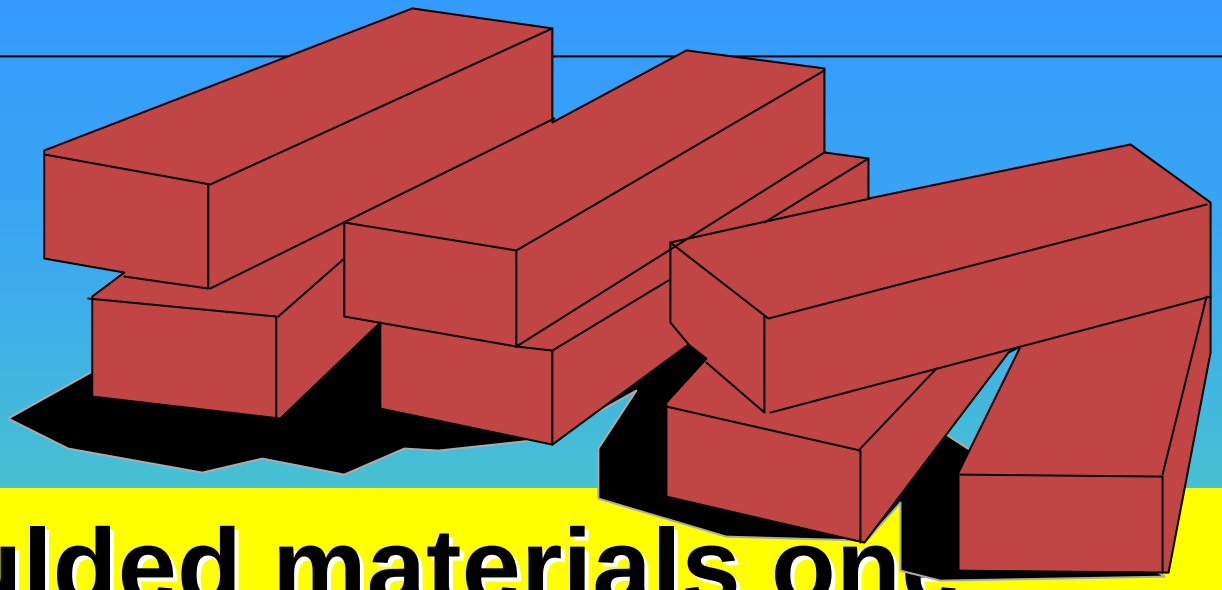

For moulded materials one have to perform a tank leaching test during 64 days and calculate the diffusion

Translation from laboratory test into emission

$$E_{(64d)} = d_b \cdot E_{bes} \cdot \ddot{O}(D_e/p) \cdot \ddot{O}t$$

$E_{(64d)}$	=	emission as determined by the diffusion test for 64 days
d_b	=	density of the material ($kg.m^{-3}$)
E_{bes}	=	emission as determined by the availability test ($mg.kg^{-1}$)
D_e	=	effective diffusion coefficient
t	=	contact time (s).

Translation from emission into immissions

$$I_{cal.}(Y) = E_{dif(64d)} \cdot f_{ext,v}(h, x\%, D_e) \cdot f_{tem}$$

$I_{cal.}(Y)$	=	calculated immissions after Y years in $mg.m^{-2}$
$E_{dif(64d)}$	=	calculated diffusion after 64 days in $mg.m^{-2}$
$f_{ext,v}(h,x\%,D_e)$	=	extrapolation factor of 64 days to Y years taking into consideration the size (high) of the building (h), wet periods (*x*%) and the possible change in D_e (see equation (1))
f_{tem}	=	correction factor for the temperature difference of the laboratory and field conditions

The composition of the building materials

code	type	mass (kg)	composition	PFA
			sand lime bricks	0-60% SDA
A	half-bricks	182	bronze fired clay	
B	half-bricks	178	bronze fired clay	20%
C	half-bricks	185	red fired clay	
D	half-bricks	178	red fired clay	20%
E	reference	178	trespa (plastic)	
F	hollow wall	2*178	bronze fired clay	20%
G	concrete		Portland cement CEM I 32,5	
H	concrete		Portland cement CEM I 32,5	20% + o.v. cement 320 kg/m^3
I	concrete		Portland cement CEM I 32,5, 20% recycled concrete granules as artificial gravel	20% + o.v. cement 320 kg/m^3
J	concrete		Portlandcement CEM I 32,5, 100% recycled concrete granules as artificial gravel	20% + o.v. cement 320 kg/m^3

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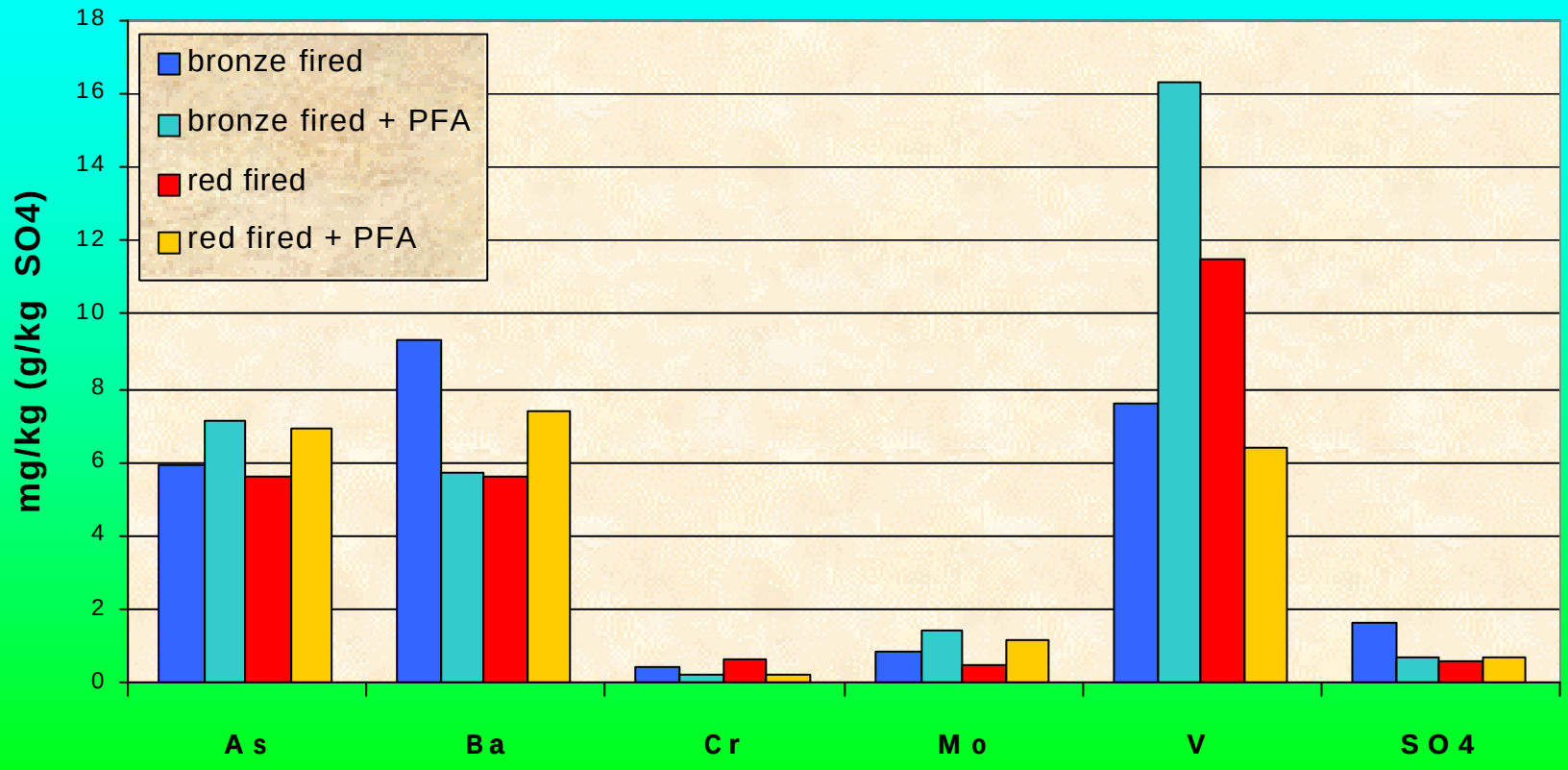
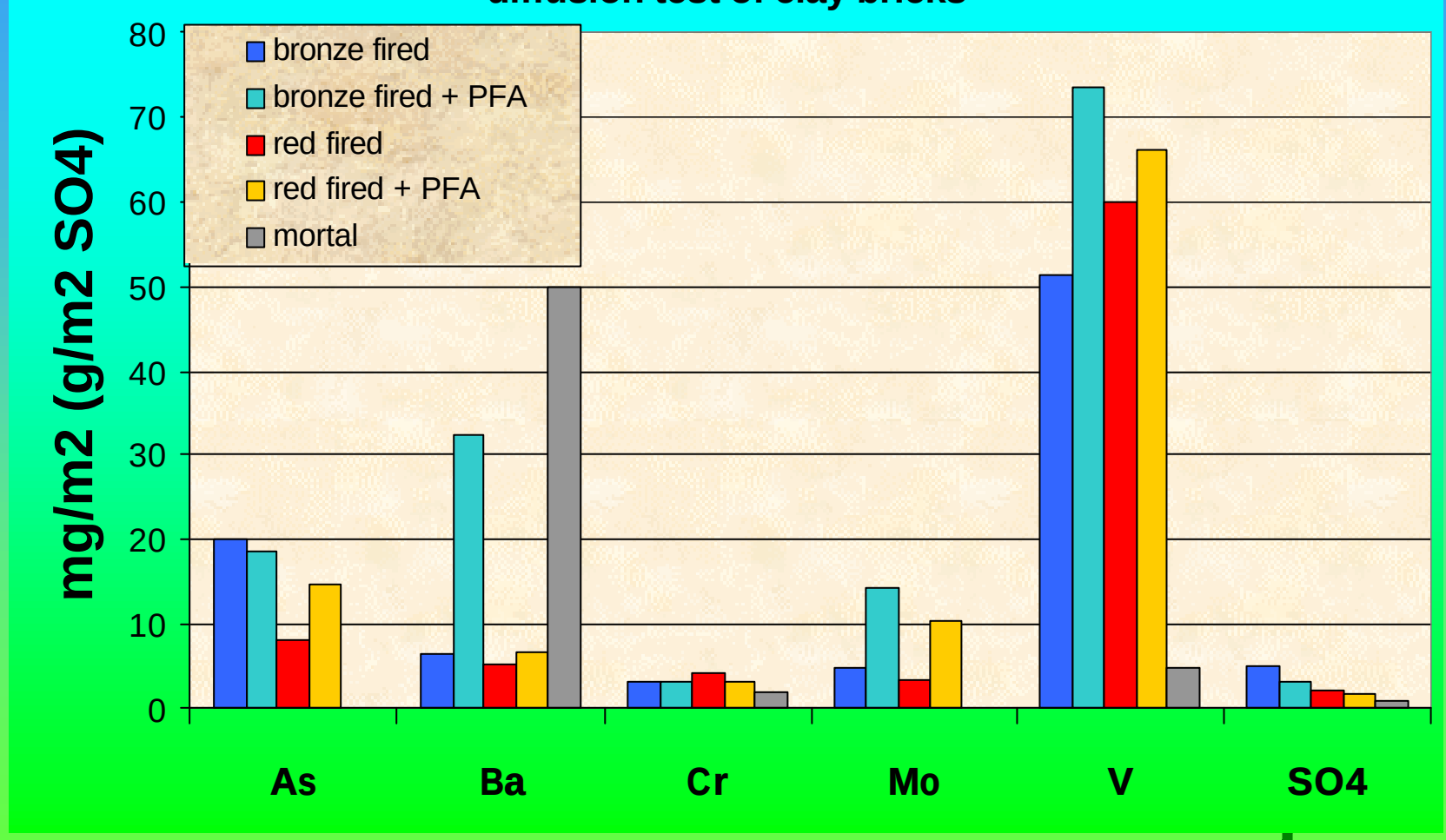
Availability test of clay bricks



The calculated diffusion coefficient D_e (10^{-12} m.s $^{-1}$) for the various types of bricks

code	composition	As	Ba	Cr	Mo	V	SO_4^{2-}
A	bronze-fired clay	2.3	0.1	8.8	6.5	9.1	2.0
B	idem + 20% CFA	1.5	6.8	40.8	22.0	4.3	3.9
C	red-fired clay	0.4	0.2	9.2	8.4	5.2	3.0
D	idem + 20% CFA	1.0	0.2	58.7	17.9	22.6	1.0

Diffusion test of clay bricks



$mg.m^{-2}$

time	64 days						
	BMD[1)]		test[2)]				
wall	U_{1a}	$U_{2,1b}$	A	B, F	C	D	mortal
As	41	140	20.1	18.6	8.2	14.8	<0.9
Ba	600	2000	6.5	32.3	5.2	6.6	50
Cd	1.1	3.8	0.1	<0.05	0.12	<0.05	<0.05
Co	29	95	<1.1	<1.1	<1.1	<1.1	<1.1
Cr	140	480	3	3.2	4.3	3	1.9
Cu	51	170	3	1.2	<1.1	<1.1	<1.1
Hg	0,4	1.4	<0.06	<0.06	<0.06	-	<0.06
Mo	14	48	4.7	14.3	3.3	10.3	<2.3
Ni	50	170	<1.7	<1.7	<1.7	<1.7	<1.7
Pb	120	400	15.6	6.9	9	3.8	<2.3
Sb	3.7	12	<1.7	<1.7	<1.7	<1.7	<1.7
Se	1,4	4.8	<1.1	<1.1	<1.1	<1.1	<1.1
Sn	29	95	<1.1	<1.1	<1.1	<1.1	<1.1
V	230	760	51.4	73.6	59.9	66.2	4.8
Zn	200	670	3.1	<2.9	8	<2.9	<2.9
SO_4^{2-}	27000	80000	5096	3184	2322	1603	793

Limits according to the Buildings Materials Decree and lab. test results in $mg.m^{-2}$

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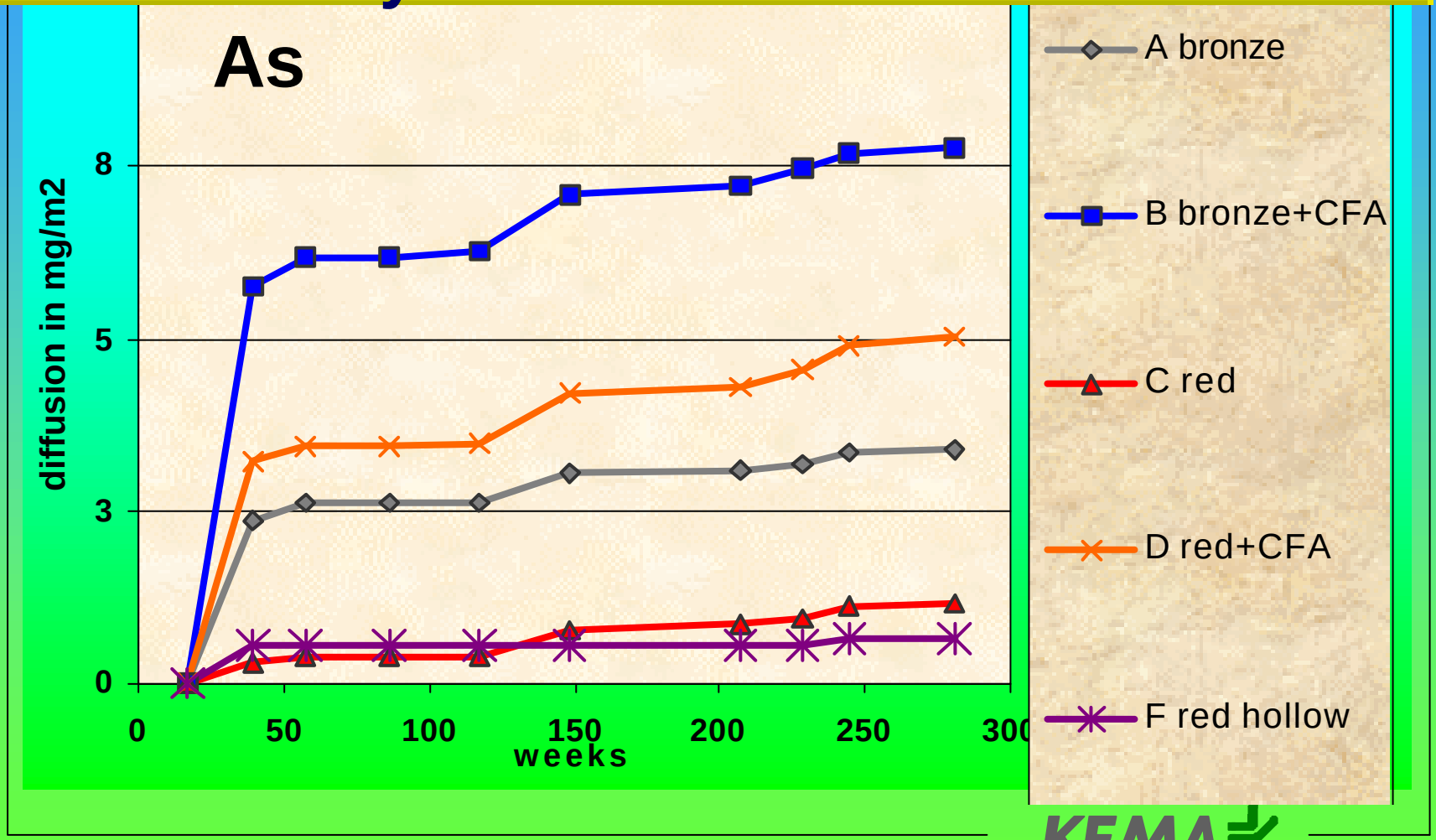
Hydrology of the walls

type of wall	amount of leachate	amount of evaporation
reference (plastic)	100%	0%
concrete	77%	23%
half-bricks	17%	83%
hollow wall	1.3%	90-94%

Cumulative Field leaching of bricks in 5½ years under field conditions



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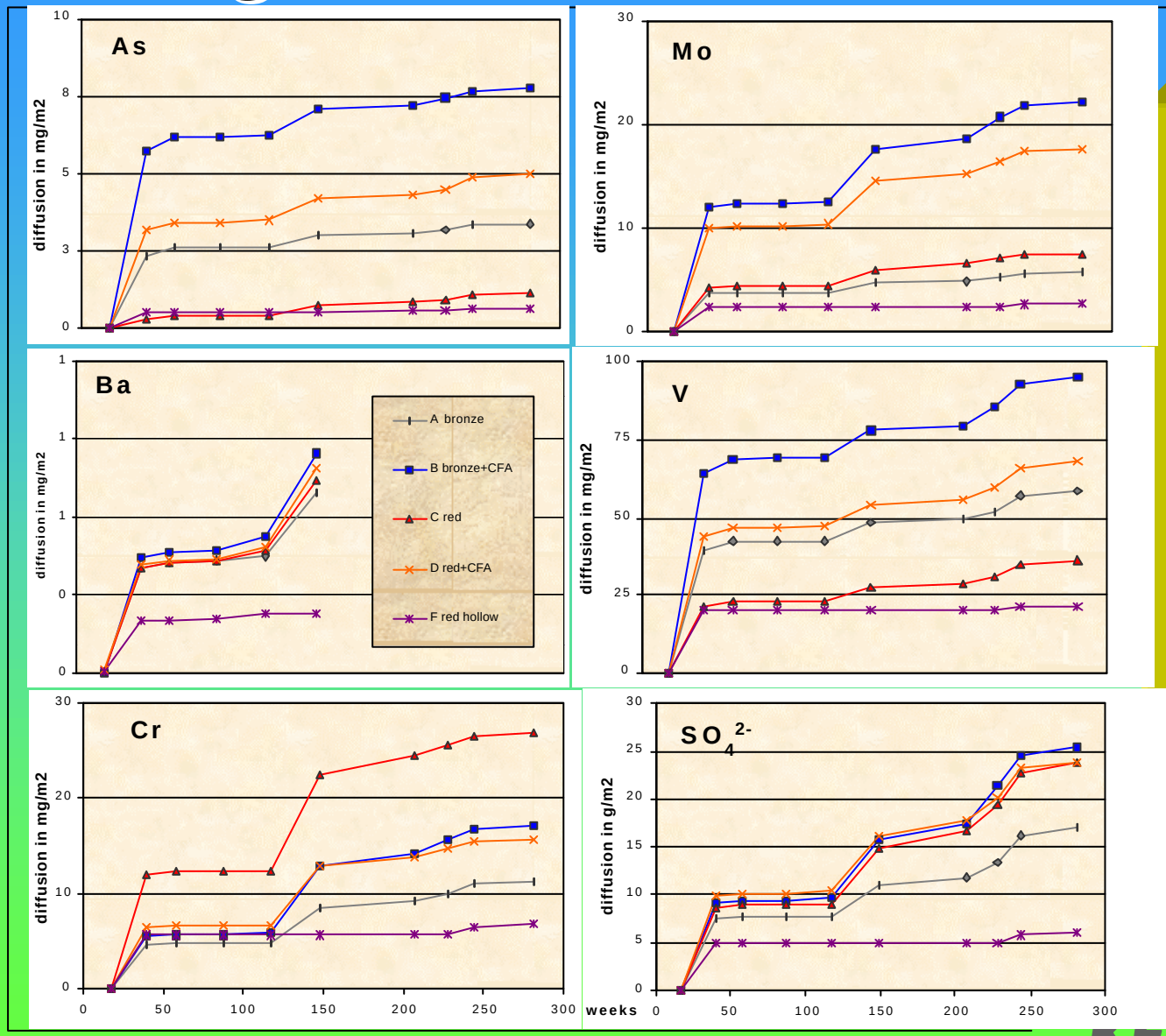
$mg.m^{-2}$



Cumulative Field leaching of bricks in 5½ years under field conditions

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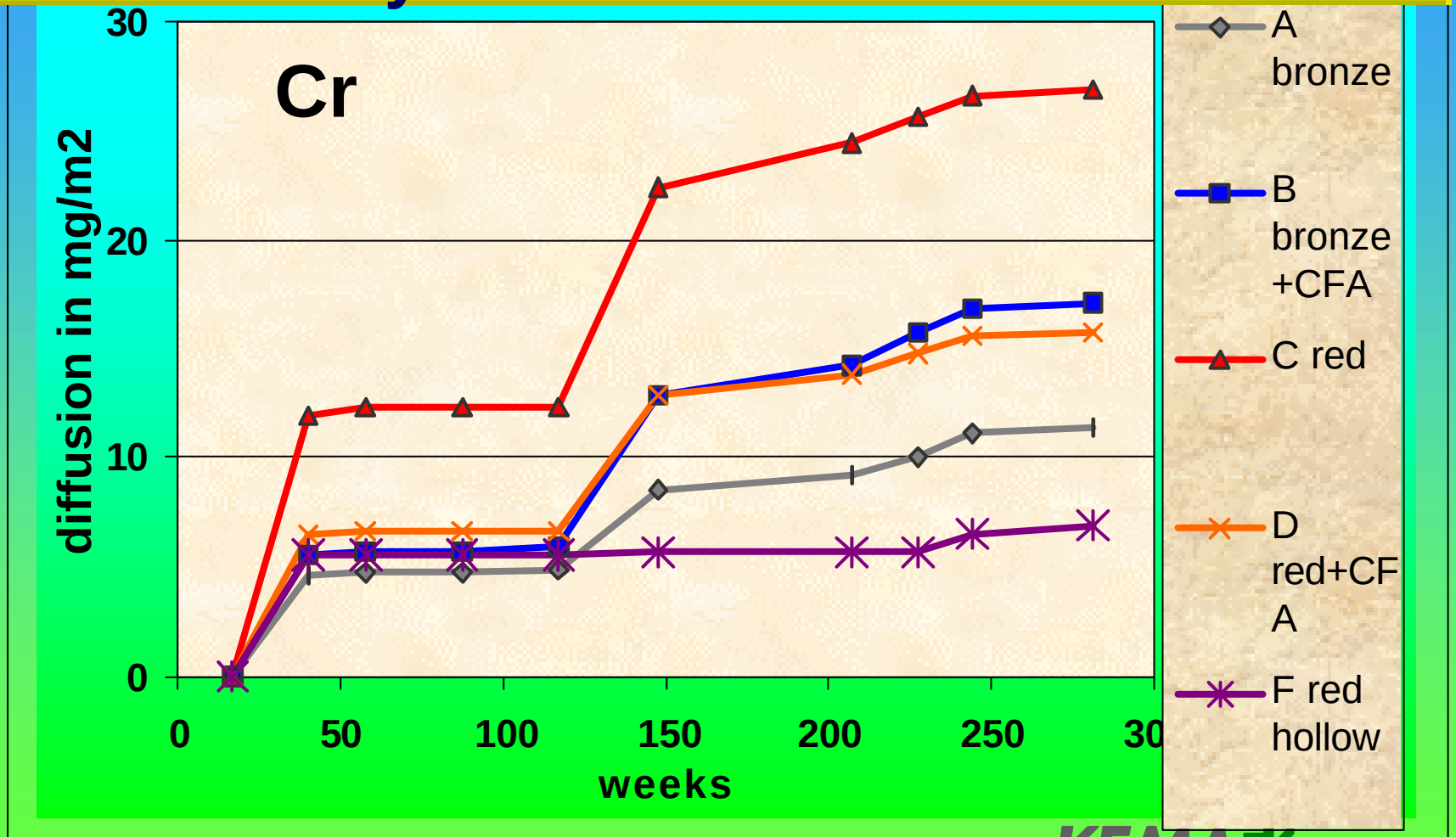

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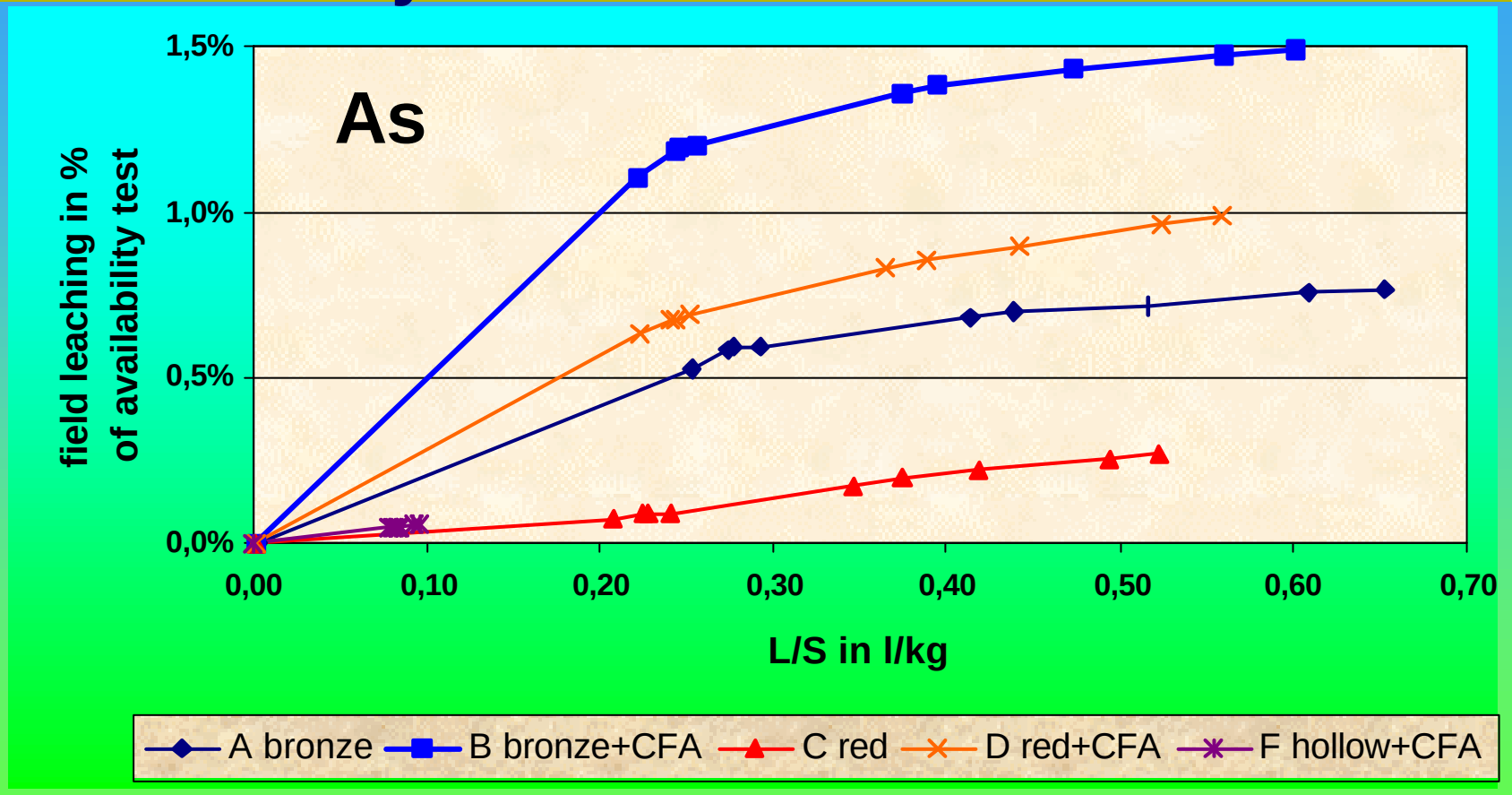

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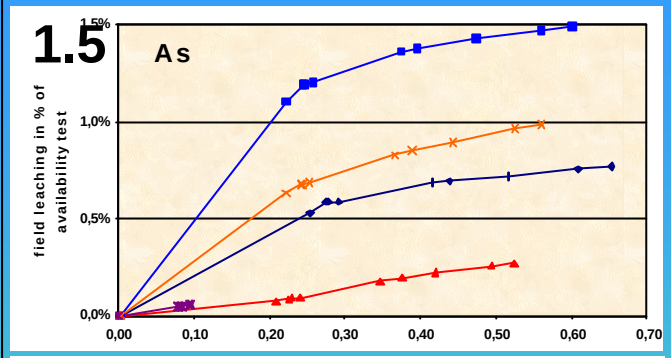
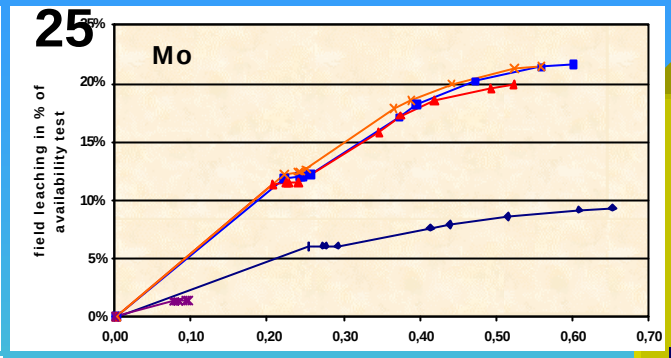
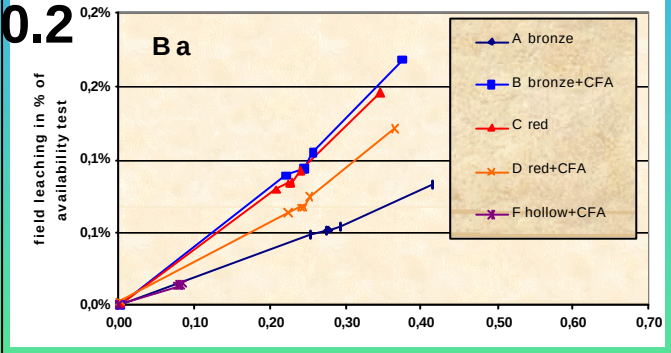
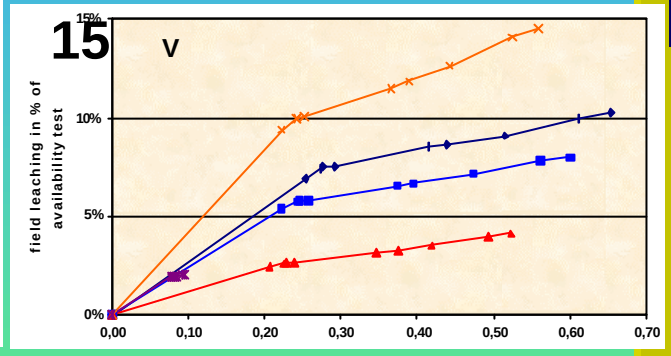
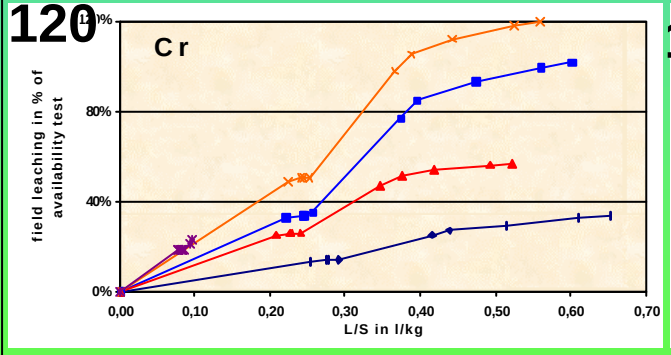
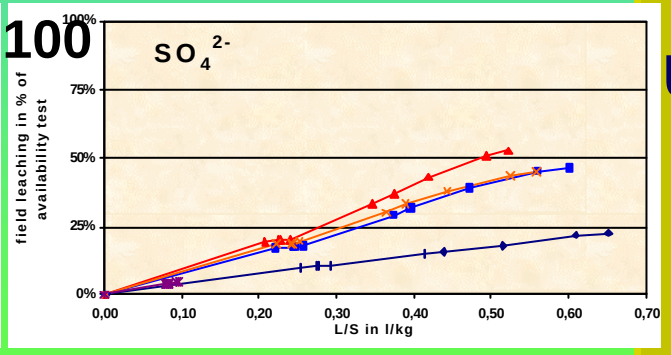






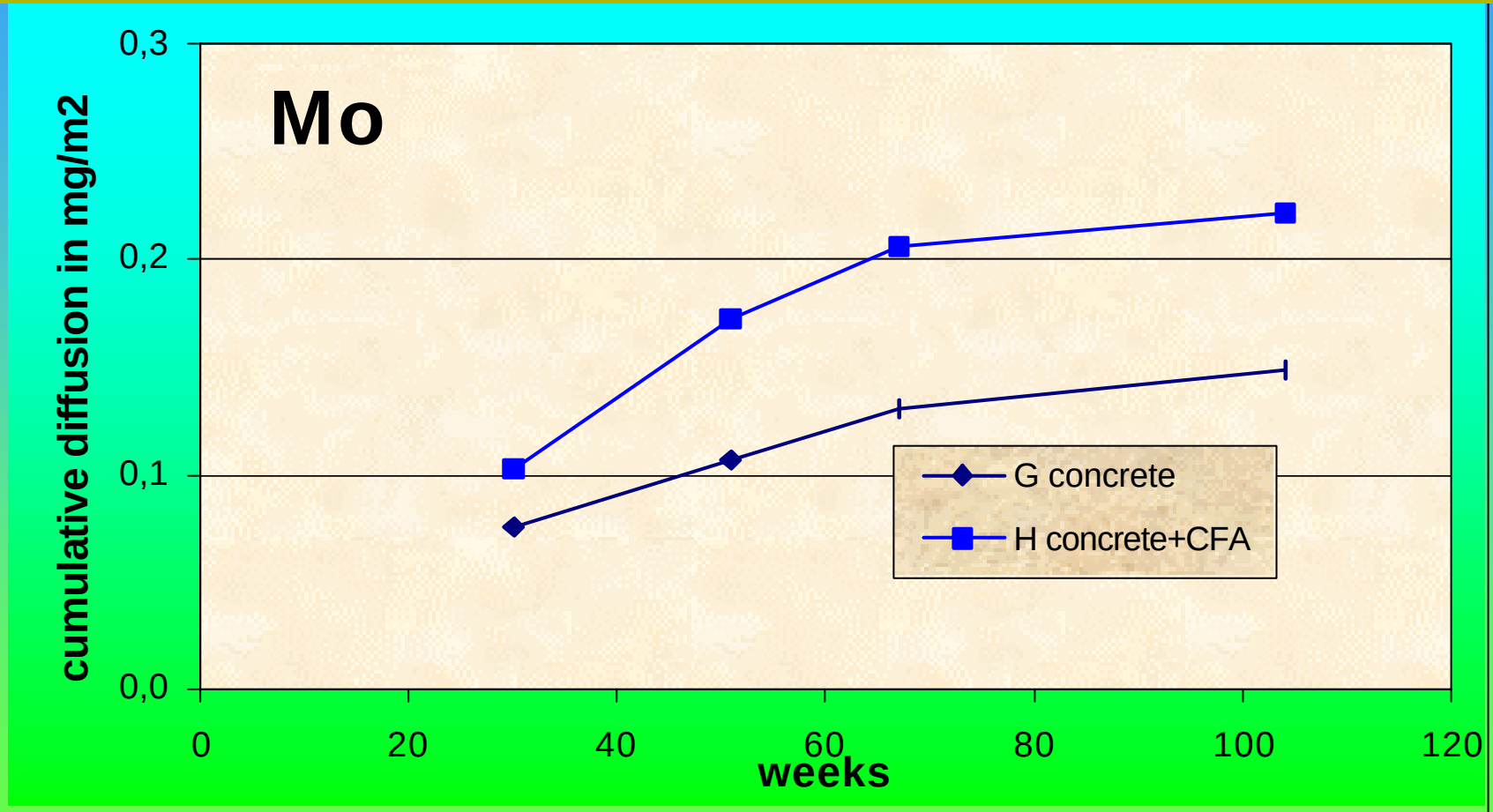




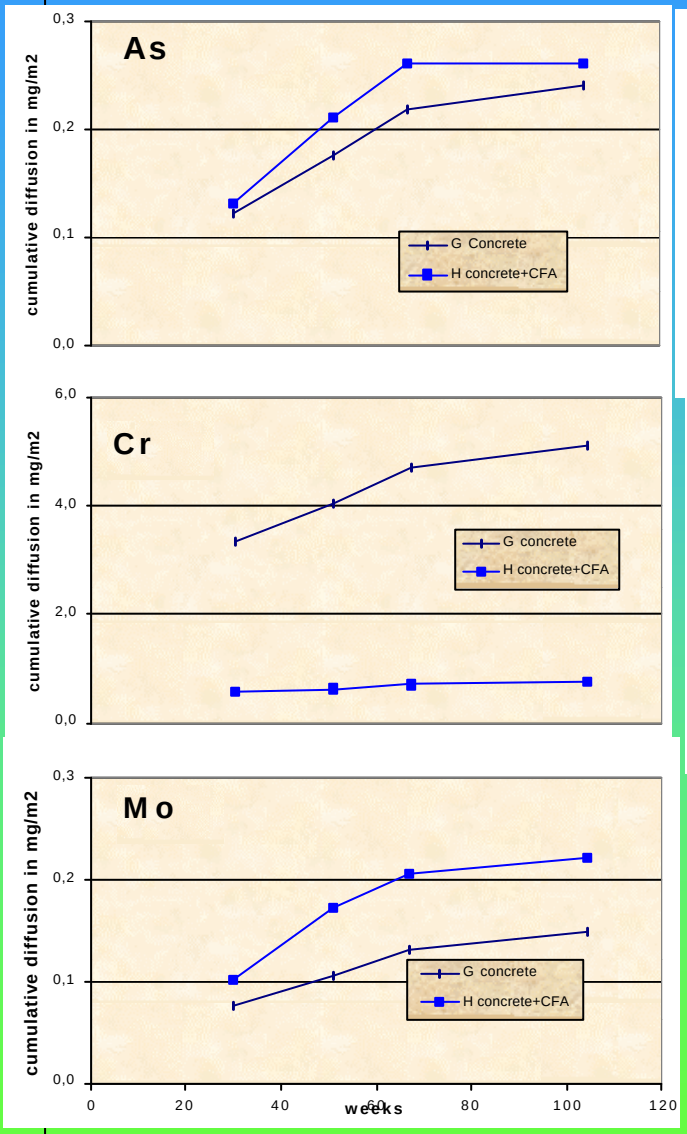


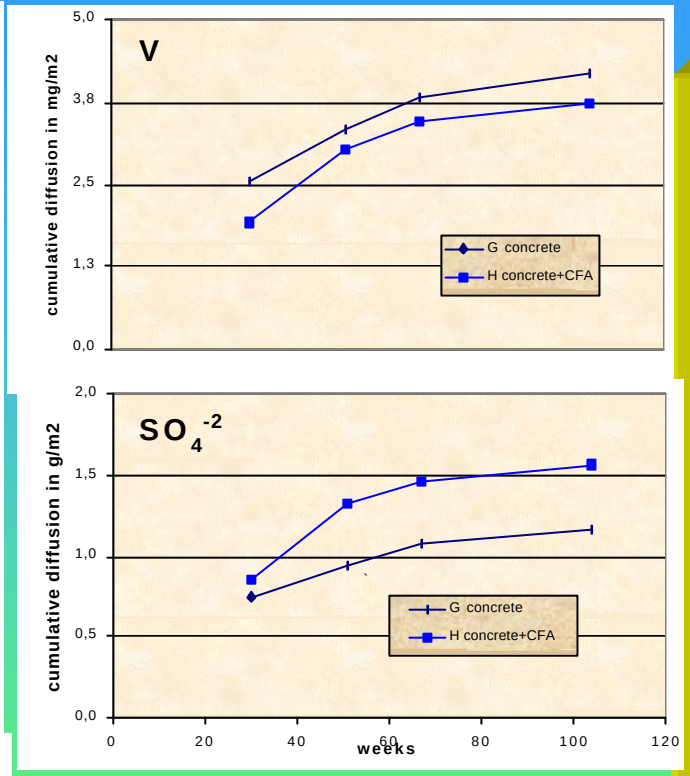
Cumulative Field leaching of bricks in 5½ years under field conditions

Cumulative Field leaching of concrete in 2 years under field conditions



$mg.m^{-2}$





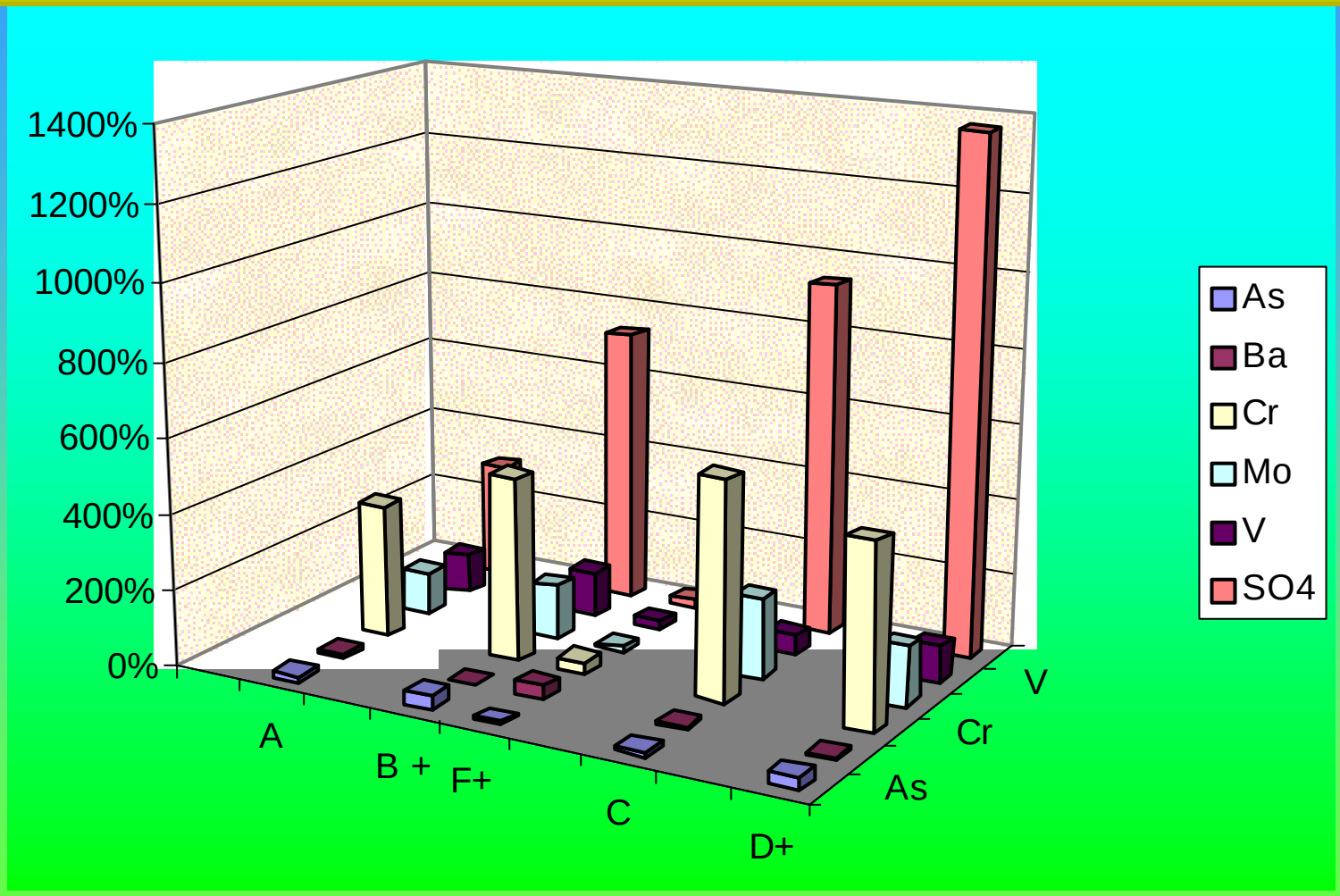
Cumulative Field leaching of concrete in 2 years under field conditions

Limits according to the Buildings Materials Decree and field test results in $mg.m^{-2}$

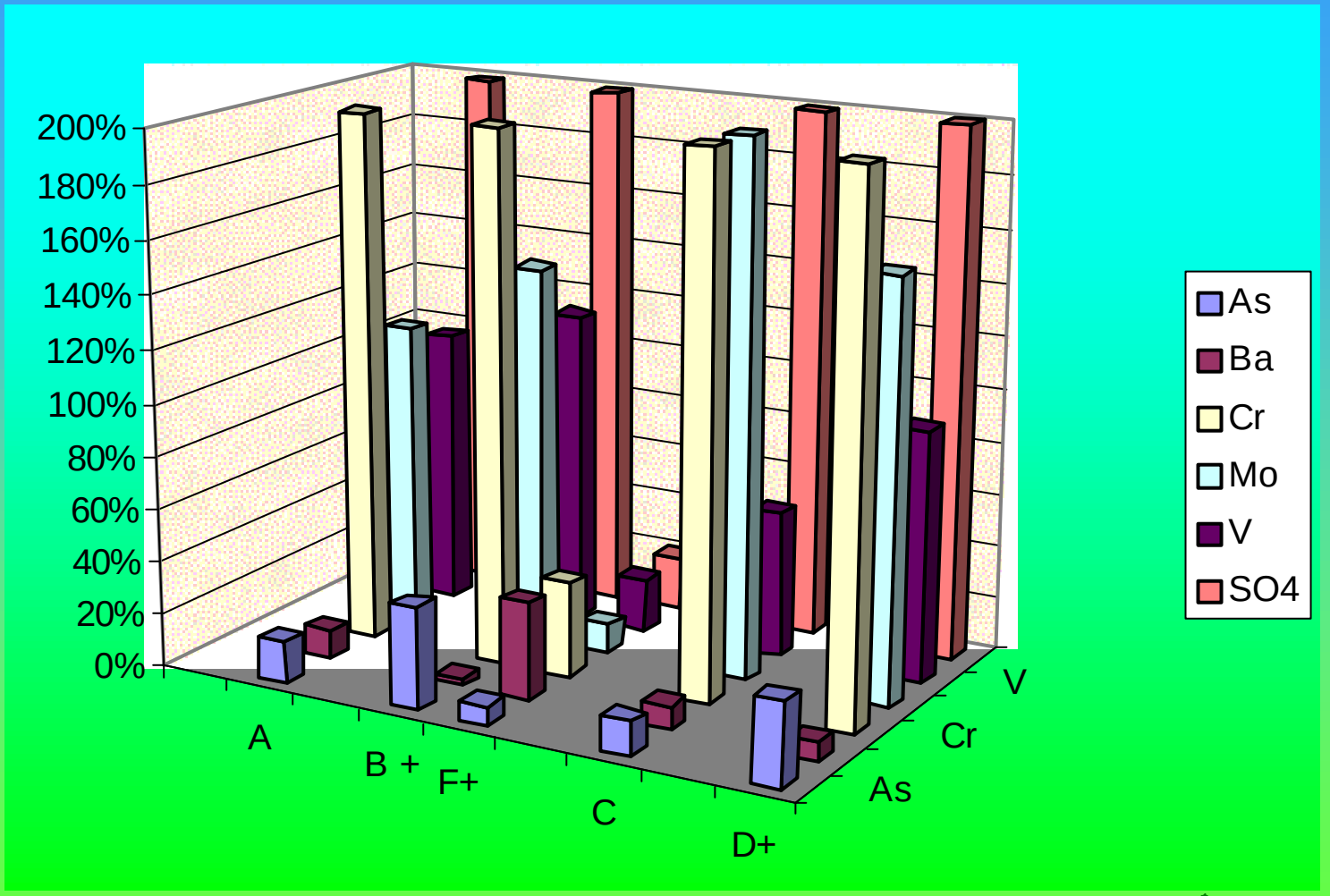
time	100y	5.5 years[3)]									2y	
	BMD	test	field	test	field	field	test	field	test	field	field	field
wall		A	A	B	B	F	C	C	D	D	G	H
As	435	24.9	3.4	23.1	7.8	0.6	10.2	1.2	18.4	5	0.12	
Ba	6300	8.1	0.6	40	0.7	0.2	11.6	0.6	14.8	0.7		
Cd	12											
Co	300											
Cr	1500	3.7	11	4	17.1	6.9	5.3	26.9	3.7	15.7	1.2	0.8
Cu	540											
Hg	4.5											
Mo	150	5.8	5.7	17.7	22.2	2.7	4.1	7.6	12.8	17.6	0.1	0.2
Ni	525											
Pb	1275											
Sb	39											
Se	15											
Sn	300											
V	2400	63.8	58.6	91.3	95.5	21.6	74.3	36.2	82.1	68.2	4.2	3.7
Zn	2100											
SO_4^{2-}	100000	6320	17000	3950	25300	6000	2880	23700	1990	23900	1200	1600

$mg.m^{-2}$

Field leaching in % of diffusion test (5,5 years)



Field leaching in % of diffusion test (5,5 years)



Conclusions

- CFA (20%) in bricks and concrete can meet the strict Dutch leaching limits

- the leaching of As, Mo and sulphate increases. V also shows this increase of leaching in bricks, but not in concrete. The leaching of Cr is however rather complicated; in one clay it shows an increase in leaching after adding CFA and in another clay and in concrete it shows a decrease.

- the results of the diffusion test extrapolated to the observed 5½ years give a reasonable pre-diction of the leaching of Mo and V; however, it overestimates the leaching of As and Ba and it underestimates the leaching of Cr and sulphate, with respect to the half-brick wall.

Thank you for your attention

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