FLY ASH USES IN INFRASTRUCTURE AND AGRICULTURE: SCIENTIFIC BACKGROUND FOR PROPOSED REGULATORY PROTOCOLS

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December 2008, a containment failure in Kingston, Tenn. Released approximately 1 billion gallons of coal ash sludge into the adjoining rivers and neighborhood,

Resulting in more than $1 billion in clean up costs.

The European directive sets conditions for landfill disposal assuming the landfill is exposed to rain water for the cases:

- **Runoff over its surface**
- **Percolation through it**
- **Capillary rise from its base**

Dynamics in FA changes (pH, HC, Dissolution rate, $CaCO_3$ precipitation) and soil properties were not considered

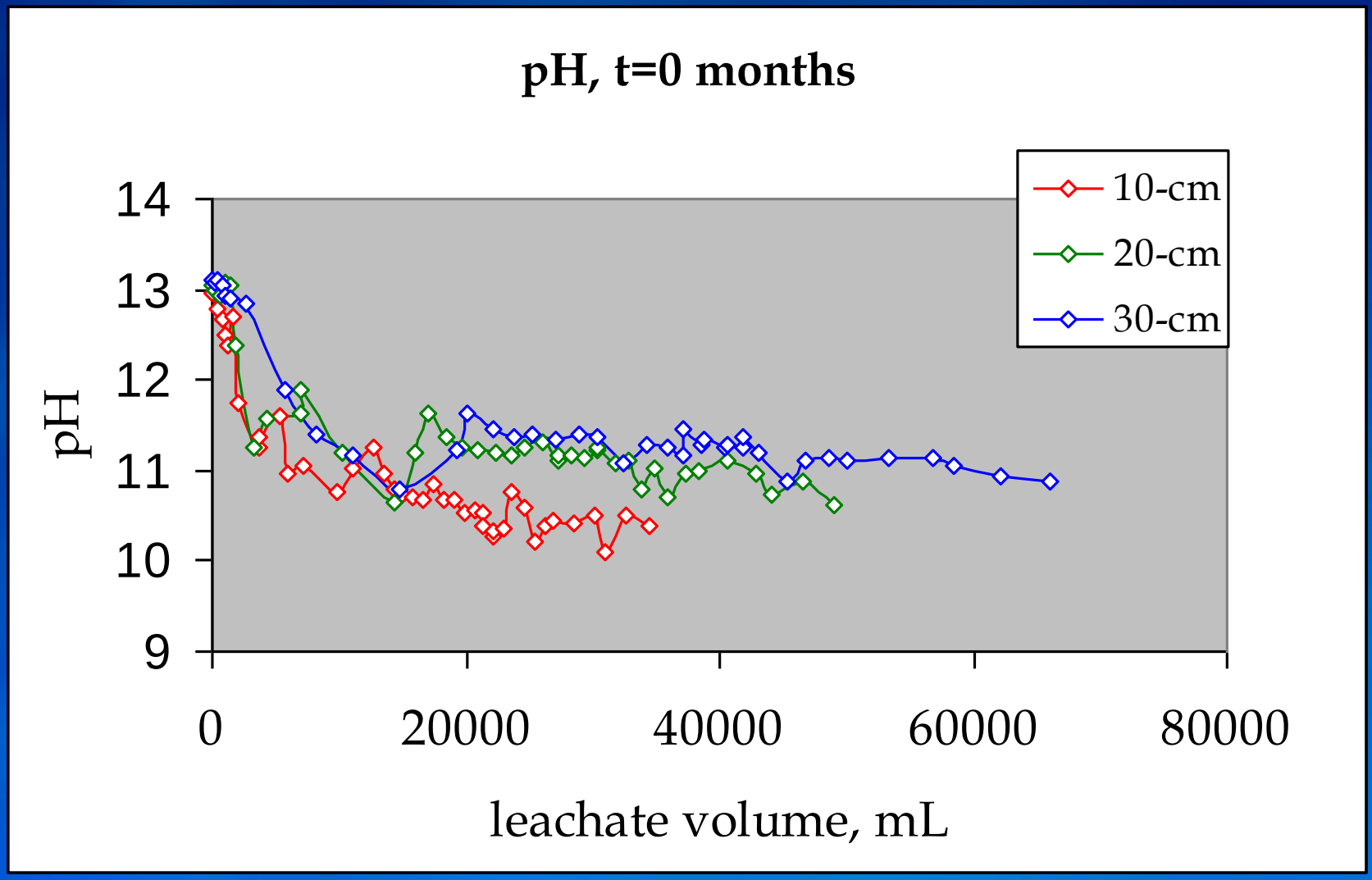
Aging

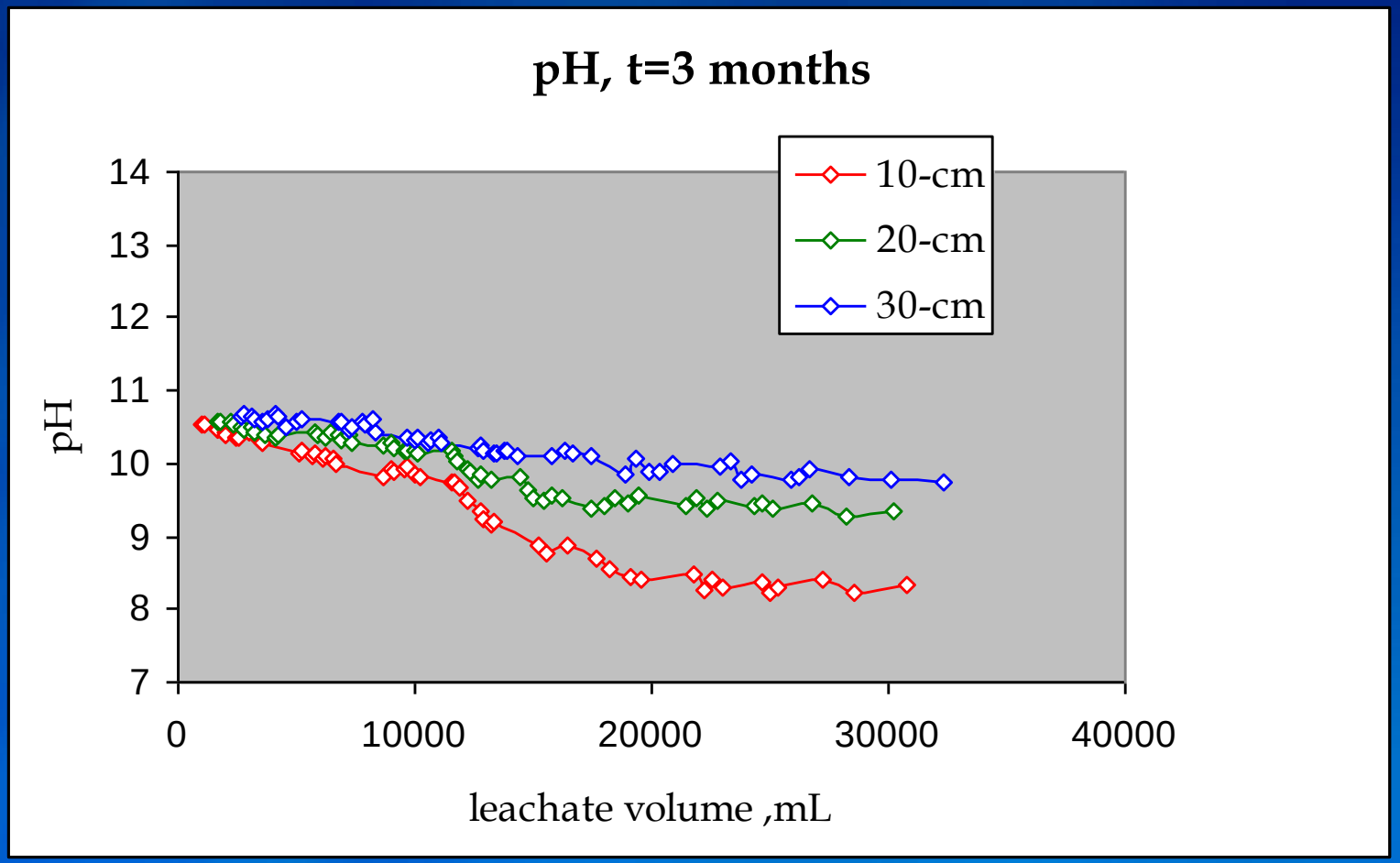
- pH dependent dissolution
- Diffusion rate
- Hydraulic Conductivity

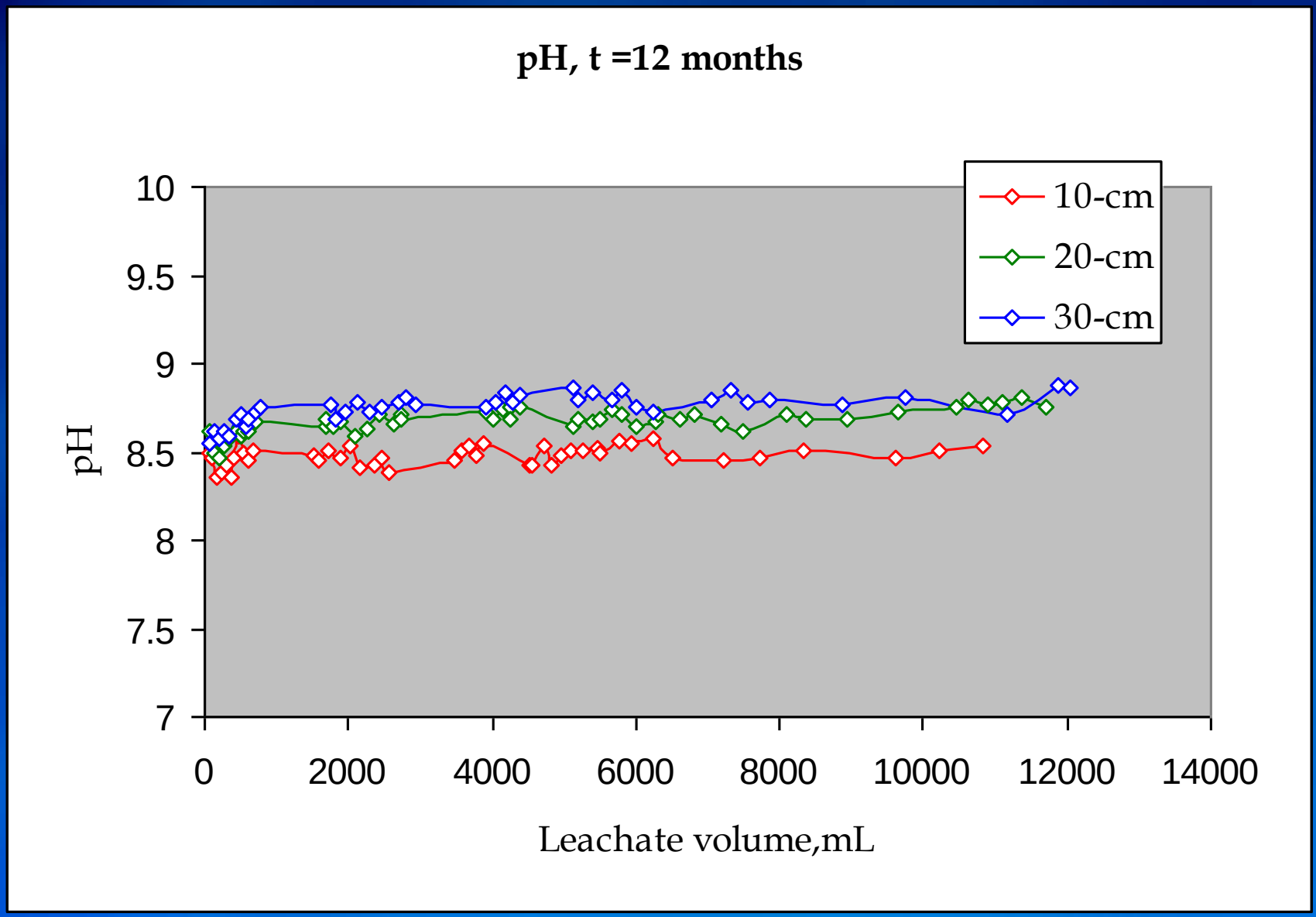
- **pH dependent dissolution**

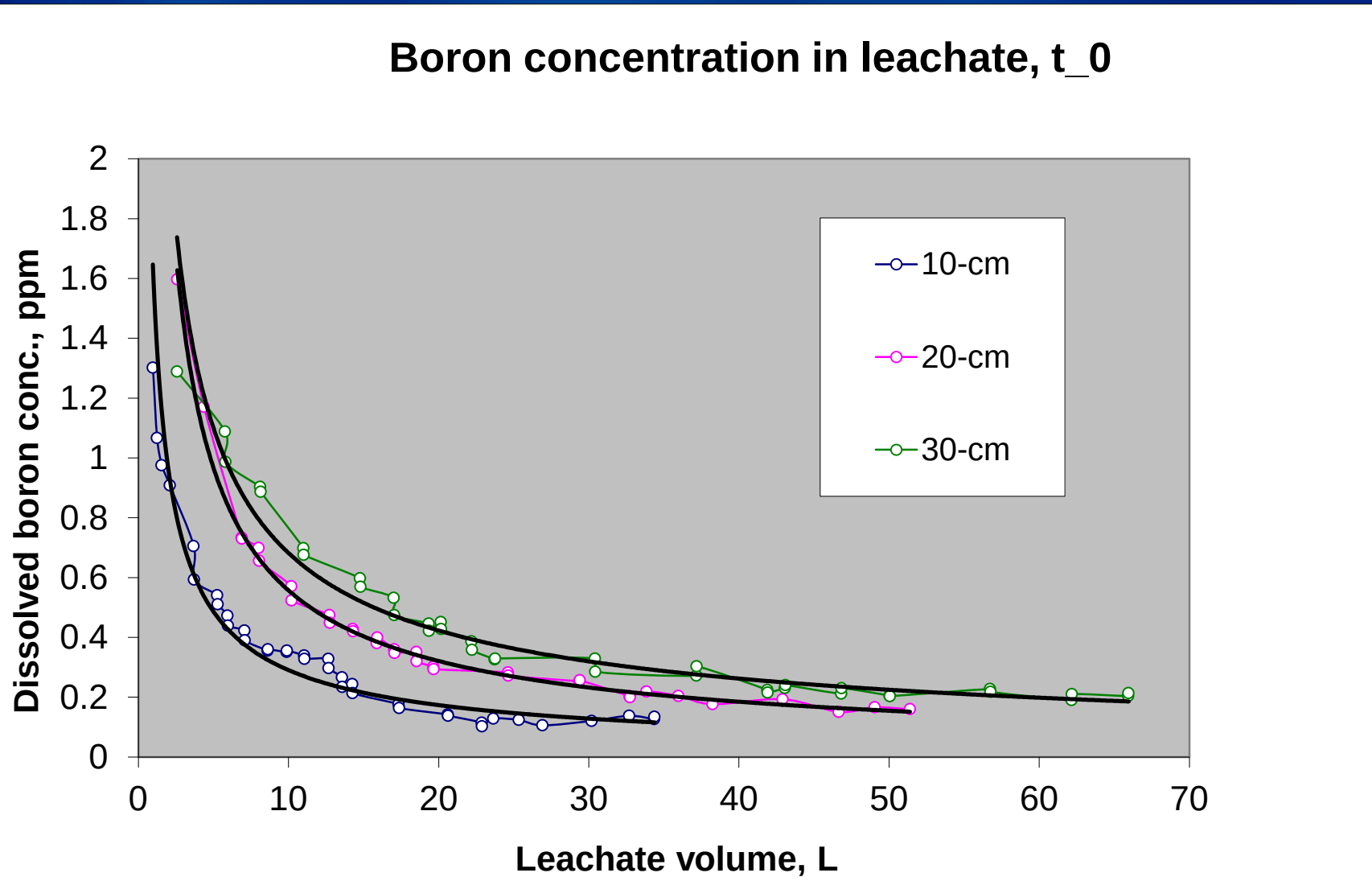
Fly ash from South Africa

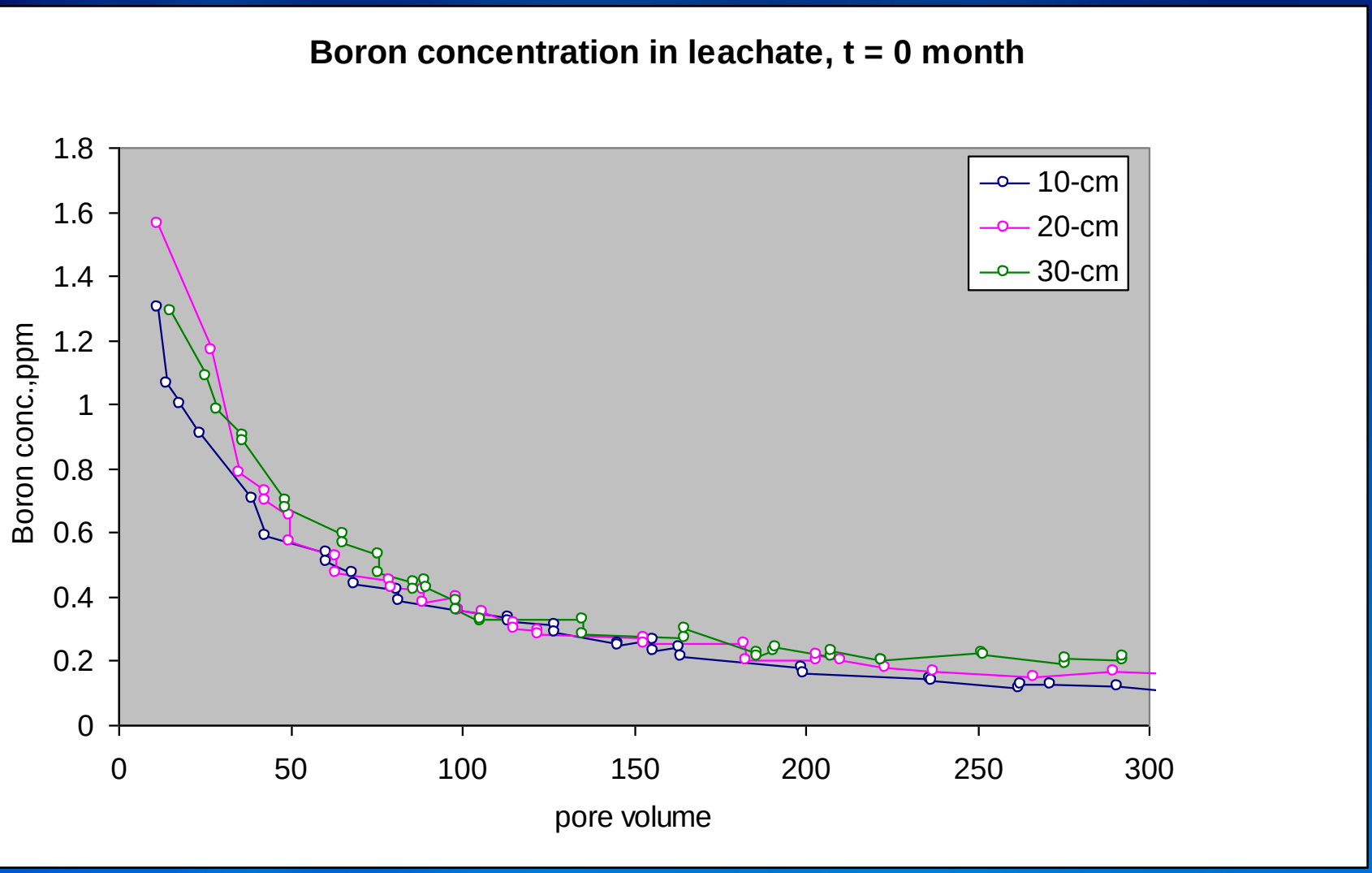
- Fresh and dry fly ash was kept isolated from atmosphere
- Aging time of wet fly ash (water content of 30-40%) exposed to atmosphere for 0,3,6,12 months


pH, t=0 months
10-cm
20-cm
30-cm
14
13
12
11
10
9
pH
0
20000
40000
60000
80000
leachate volume, mL

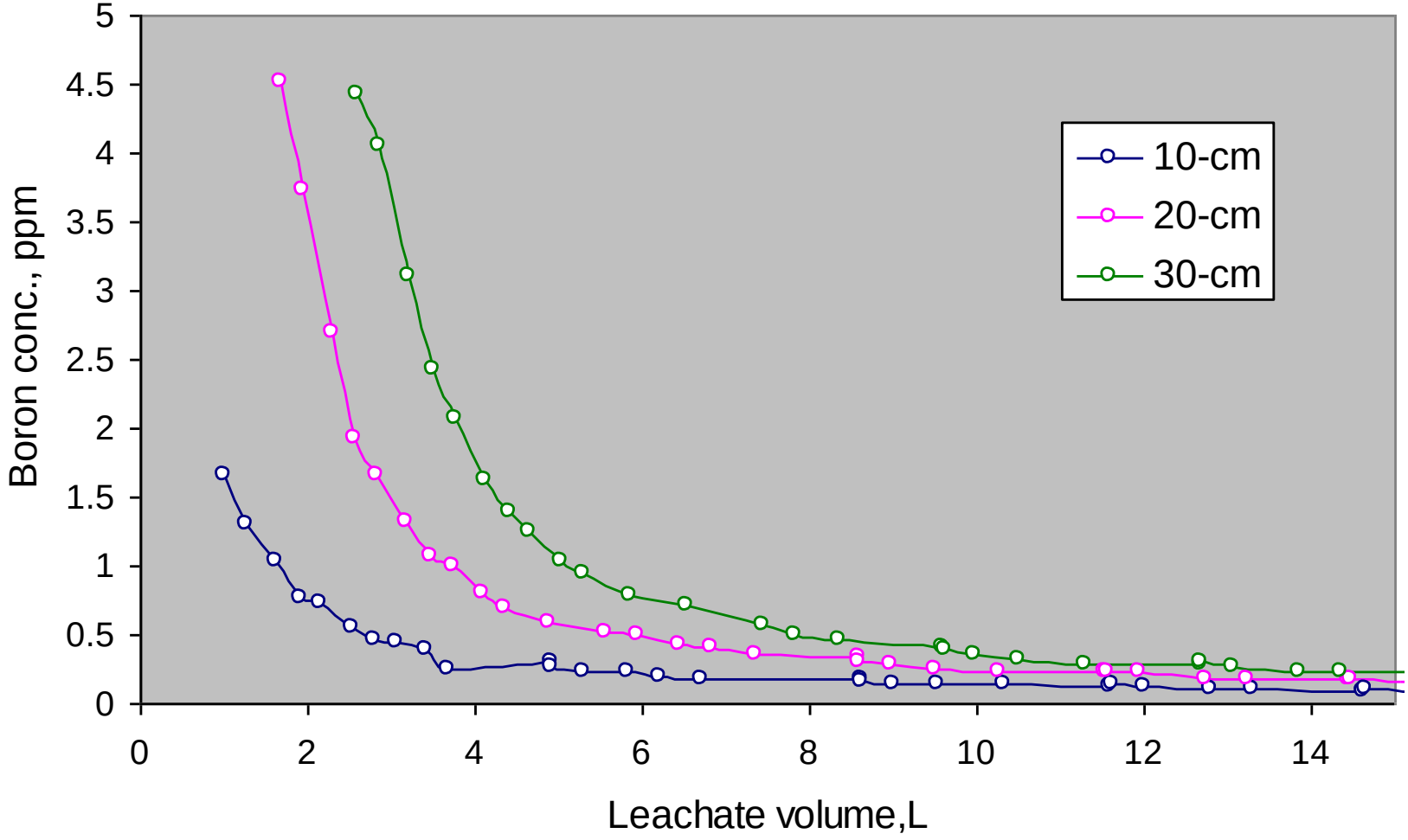

pH, t=3 months
10-cm
20-cm
30-cm
14
13
12
11
10
9
8
7
pH
0
10000
20000
30000
40000
leachate volume ,mL


pH, t =12 months
10
9.5
9
8.5
8
7.5
7
pH
0
2000
4000
6000
8000
10000
12000
14000
Leachate volume,mL
10-cm
20-cm
30-cm

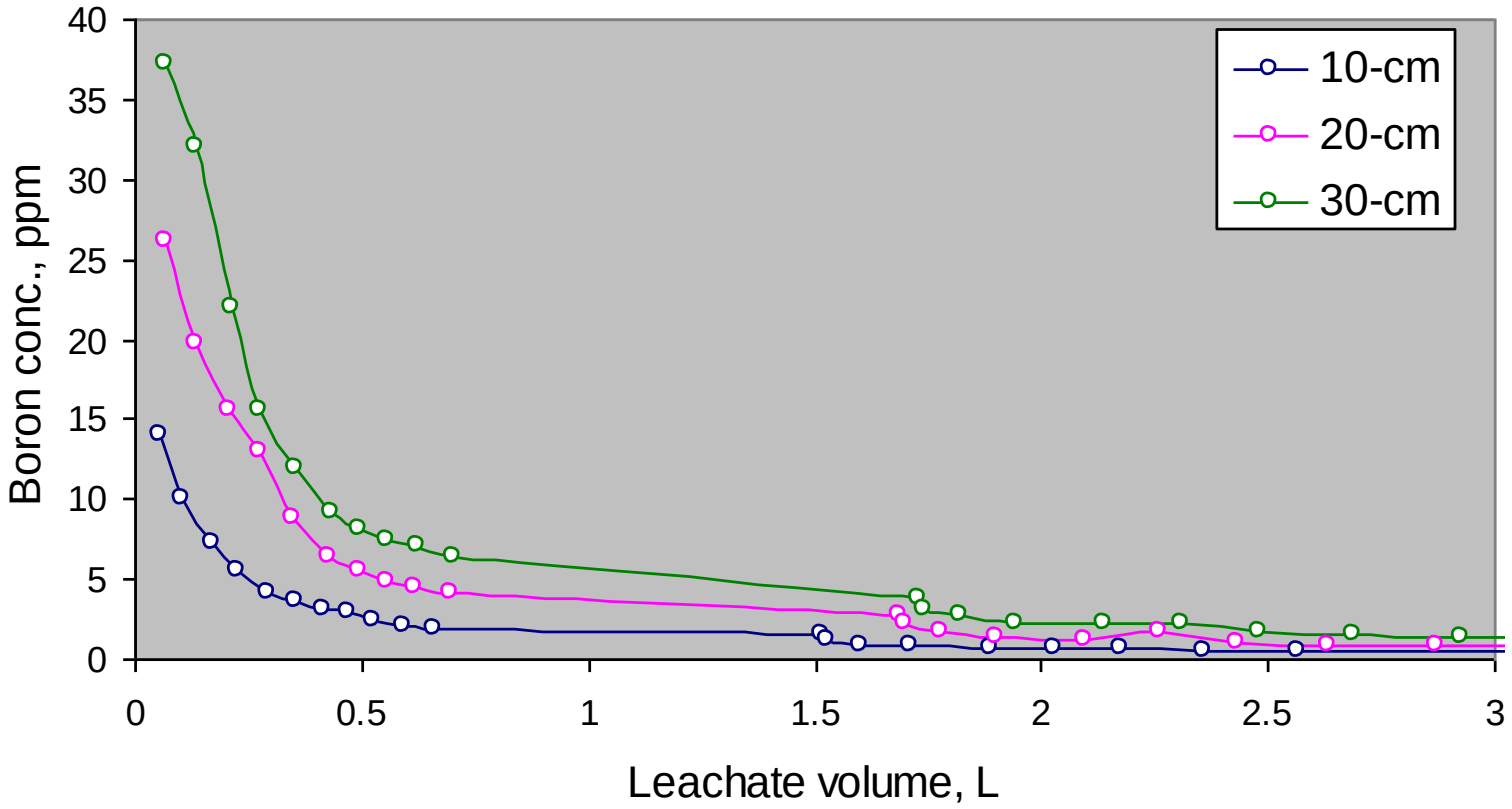

Boron concentration in leachate, t_0
Dissolved boron conc., ppm
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
10
20
30
40
50
60
70
Leachate volume, L
10-cm
20-cm
30-cm


Boron concentration in leachate, t = 0 month
Boron conc.,ppm
pore volume
10-cm
20-cm
30-cm
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
0
50
100
150
200
250
300

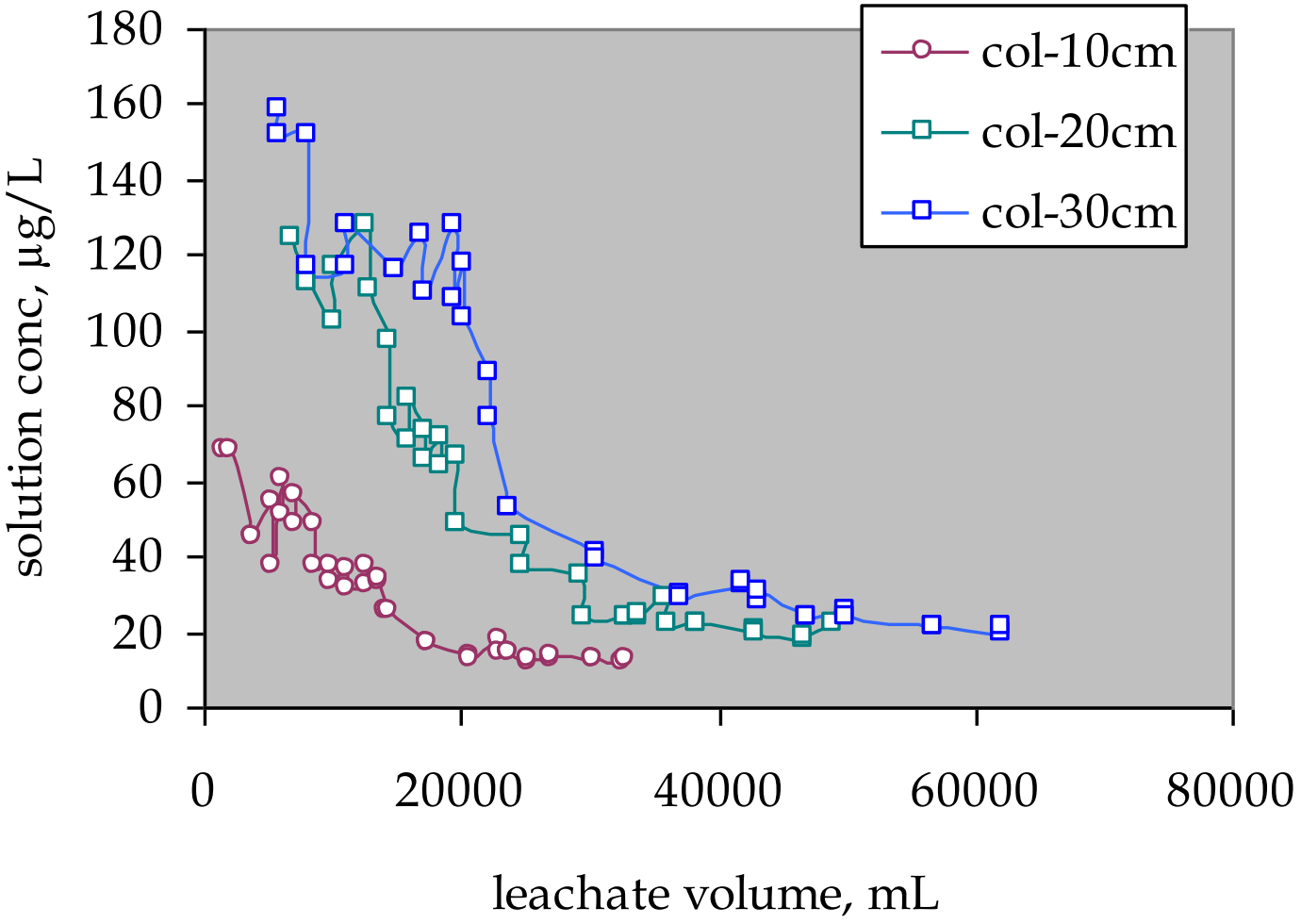
Boron concentration in leachate, t = 3 months

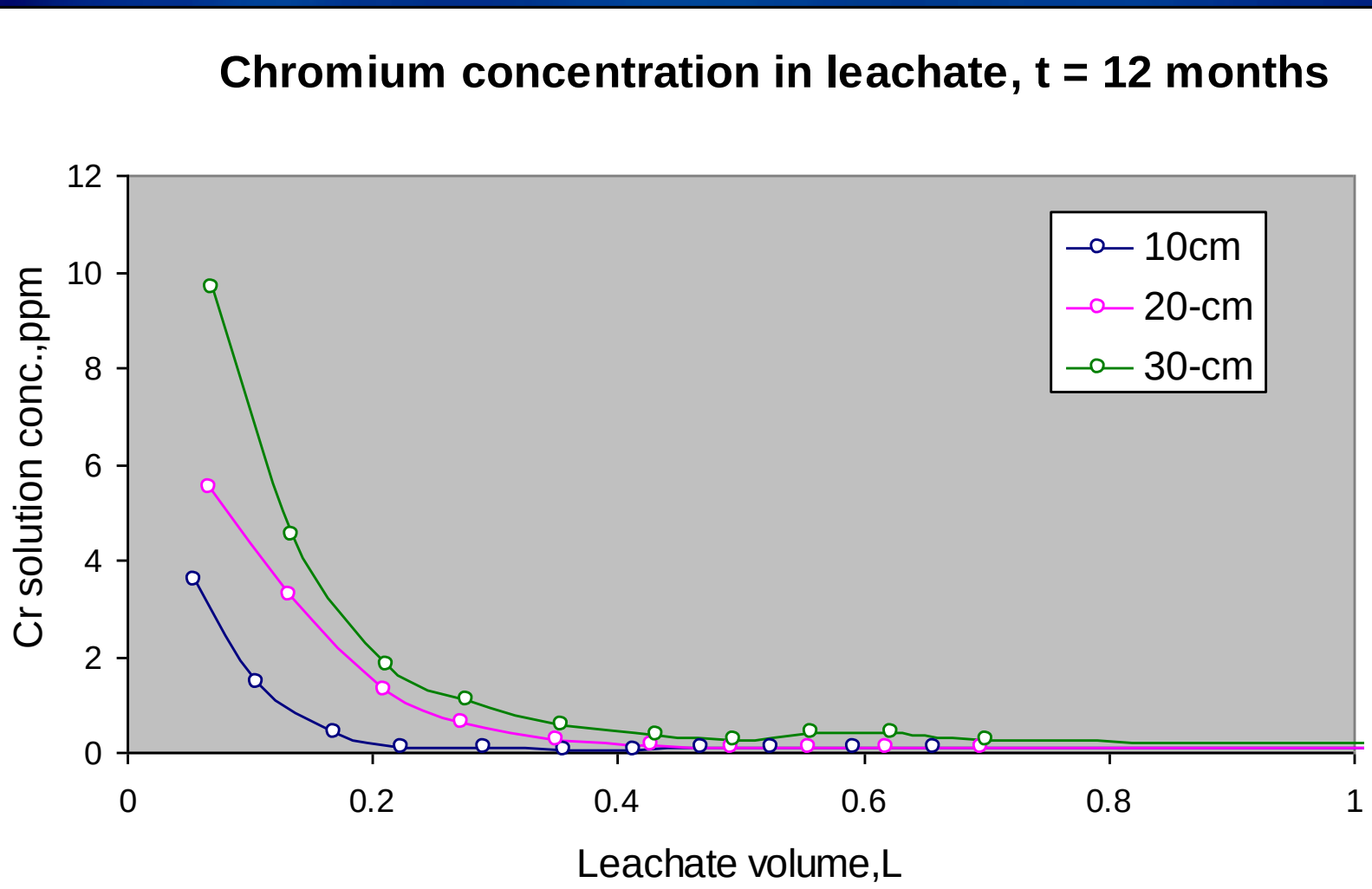


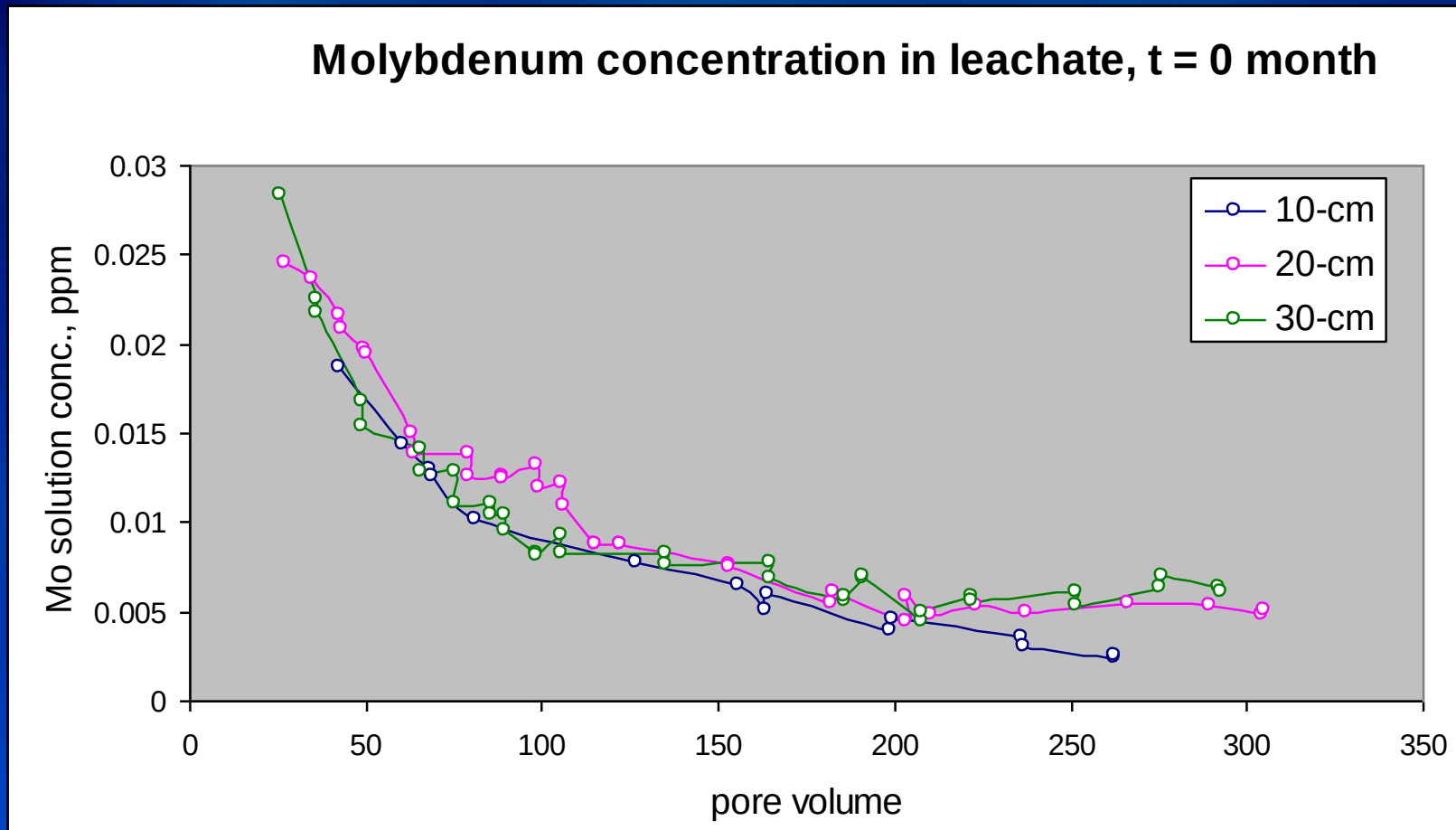
Boron concentration in leachate, t = 12 months



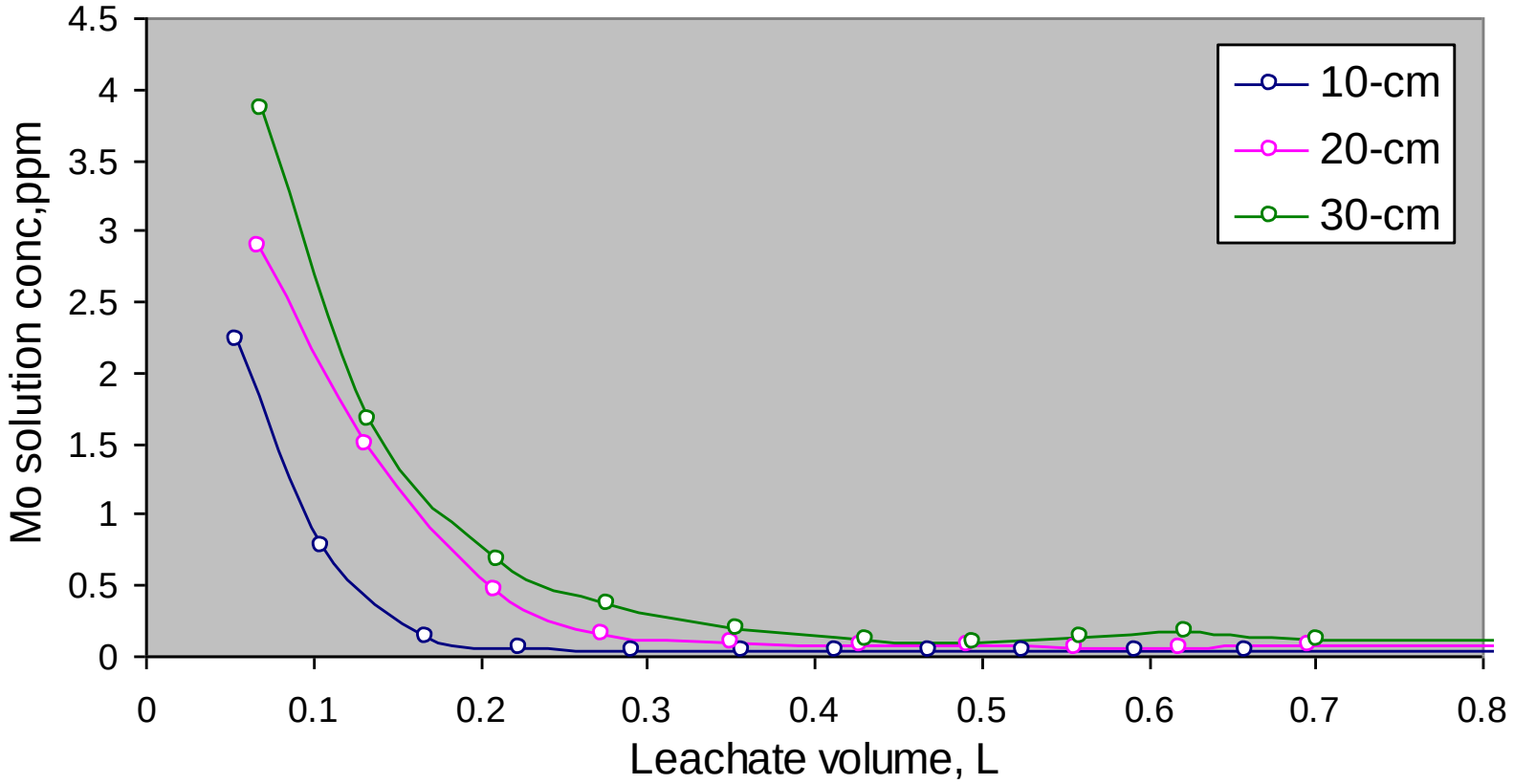
Chromium concentration in leachate, t=0month




Chromium concentration in leachate, t = 12 months
Cr solution conc.,ppm
12
10
8
6
4
2
0
0
0.2
0.4
0.6
0.8
1
Leachate volume,L
10cm
20-cm
30-cm


Molybdenum concentration in leachate, t = 0 month
Mo solution conc., ppm
0.03
0.025
0.02
0.015
0.01
0.005
0
0
50
100
150
200
250
300
350
pore volume
10-cm
20-cm
30-cm

Molybdenium concentration in leachate, t = 12 months



HYDRAULIC CONDUCTIVITY


91 806 56
TOYOTA

Fly ash in roadbed
Infiltration rate as a function of time

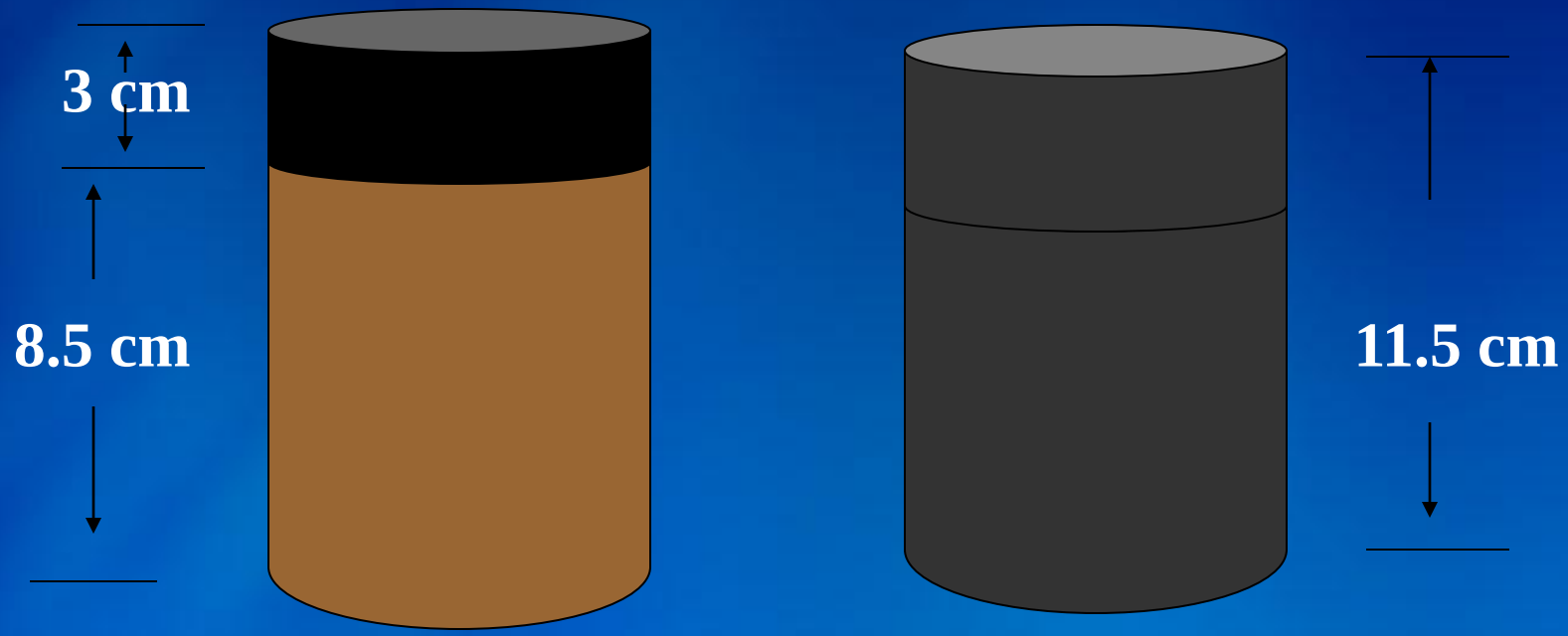
Year	Infiltration rate mm/h	STDEV
2005	21.6	5.2
2006	11.8	3.6
2007	7.0	2.4

Hence, compacted coal ash layer behaves as an inert monolith when used in road infrastructure.

SOIL PROPERTIES

Fly ash above soil

Fly ash-soil mixture



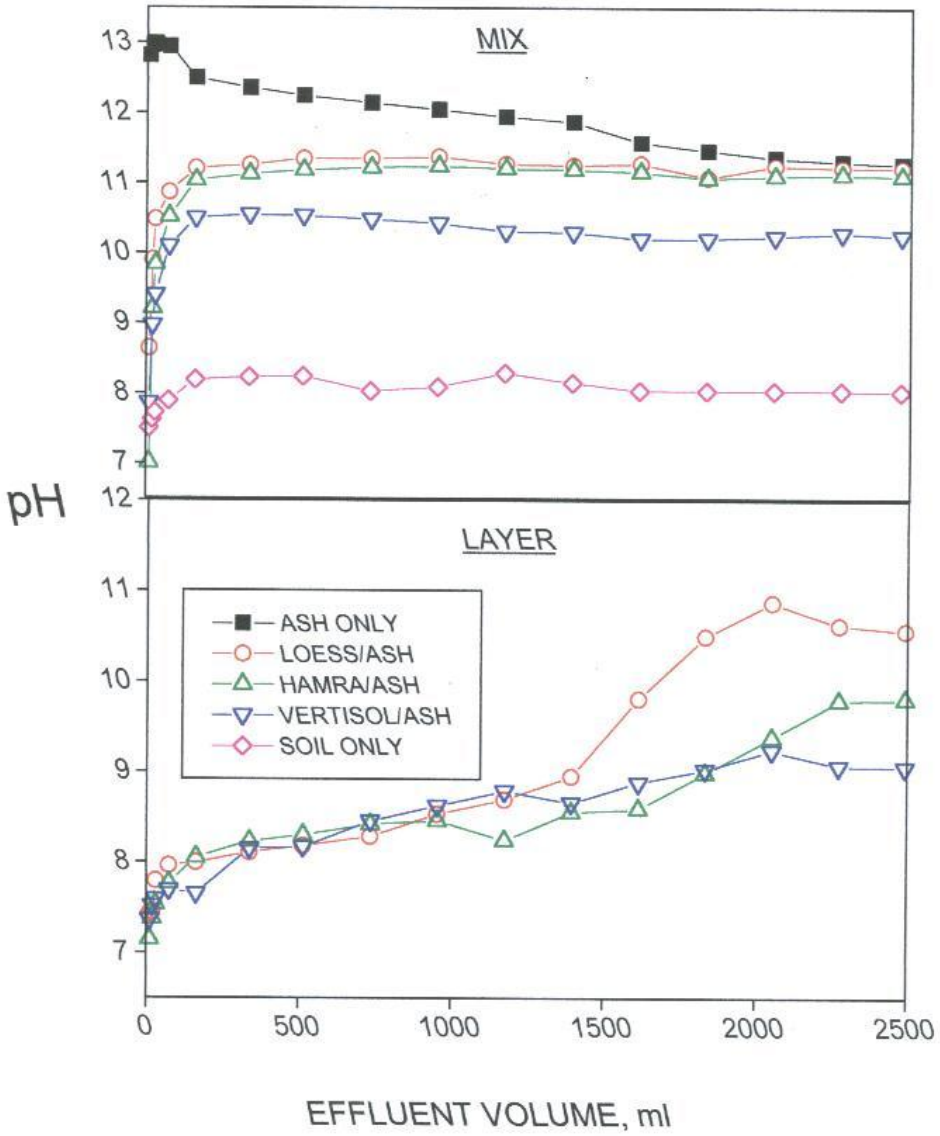
PV 128 mL

PV 120 mL

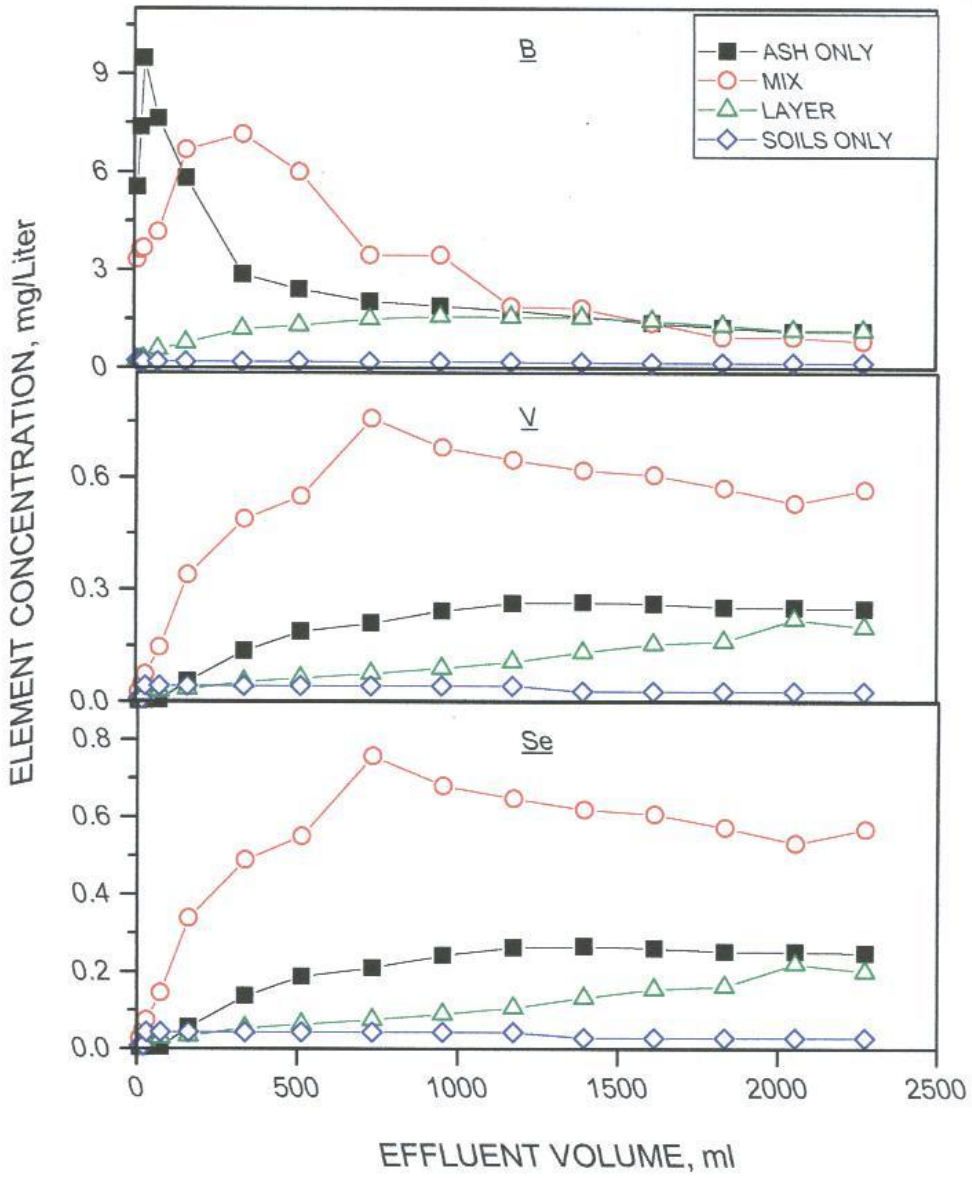
Soil: 250 g

Fly ash: 50 g

Water flux 108 mm/h



איור 16: השתנות ה- pH בתשטיף עמודת אפר, קרקע ואפר עם קרקע בצורת אריזה של תערובת הומוגנית ושיכוב כתלות בנפח הנקבובים שעבר בעמודה.



איור 17: השתנות ריכוז המיקרואלמנטים B, V ו-Se בתשטיף מעמודת אפר, קרקע ורטיסול ואפר עם קרקע ורטיסול בצורת אריזה של תערובת הומוגנית ושיכוב כתלות בנפח התמיסה השוטפת.

$$Q_B = T\{1 + \frac{PR}{F(Q_T - Q_B)}[1 + K_{OH}(OH)]\}^{-1}$$

$$P = 1 + K_h * 10^{14} * (OH)$$

$$F = K_{HB} + K_B(P - 1)$$

BORON

Mixing of fly ash in soil at a rate of 20% on soil weight basis at an area of a quarter of an acre at 30 cm deep.

The amount of fly ash in the soil:

Q_{FA} = 0.3 m X10^3 m^3 * 1.3 ton m^{-3} * 0.2 = 78 ton

The soil amount in the layer:

M_S = 390 ton - 78 ton = 312 ton

The total amount of boron released to solution from fly ash in the tube

QB = 0.665 mg B / 3.5 g FA = 0.19 mg B/g FA

QB = 17X10^{-6} mol / g FA

The total amount of boron released from fly ash in the soil layer

Q_{BT} = 1.37X10^3 mol / 312X10^6 g = 4.39X10^{-6} mol B/g soil

Q_{BT} =

Adsorbed Boron by soil:

$$Q_B = T\{1 + \frac{PR}{F(Q_T - Q_B}[1 + K_{OH}(OH)]\}^{-1}$$

$$P = 1 + K_h * 10^{14} * (OH)$$

$$F = K_{HB} + K_B(P - 1)$$

T = 6.8 X 10^{-6} mol/g ; R = 0.48 X 10^{-3} L/g

Q_{AB} = 2.98X10^{-6} mol/g = 3.22X10^{-5} g boron / g soil

The amount of adsorbed boron by the soil in the FA layer

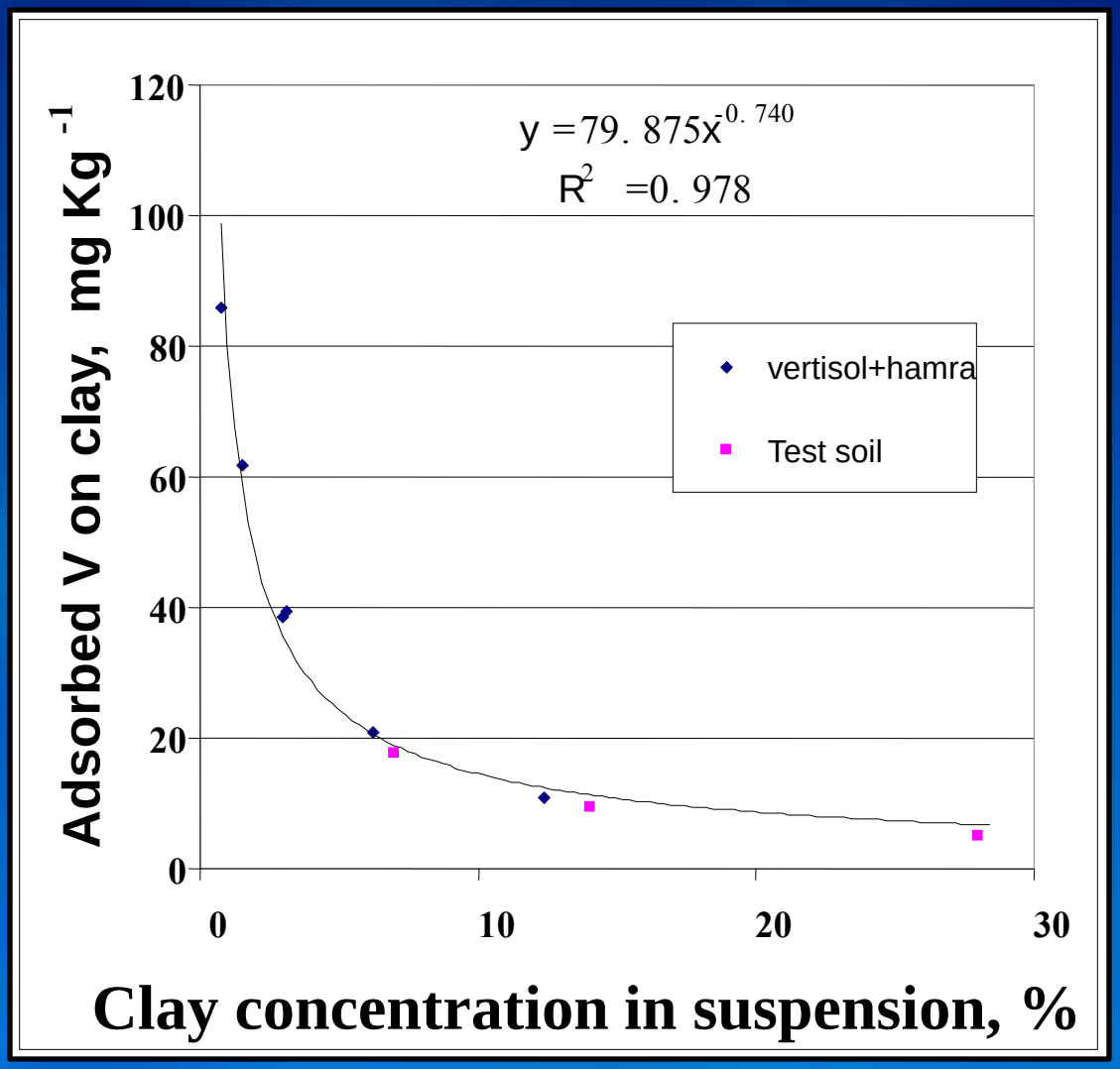
3.22X10^{-5} g B / g soil X 312X10^6 g soil = 10.046X10^3 g B

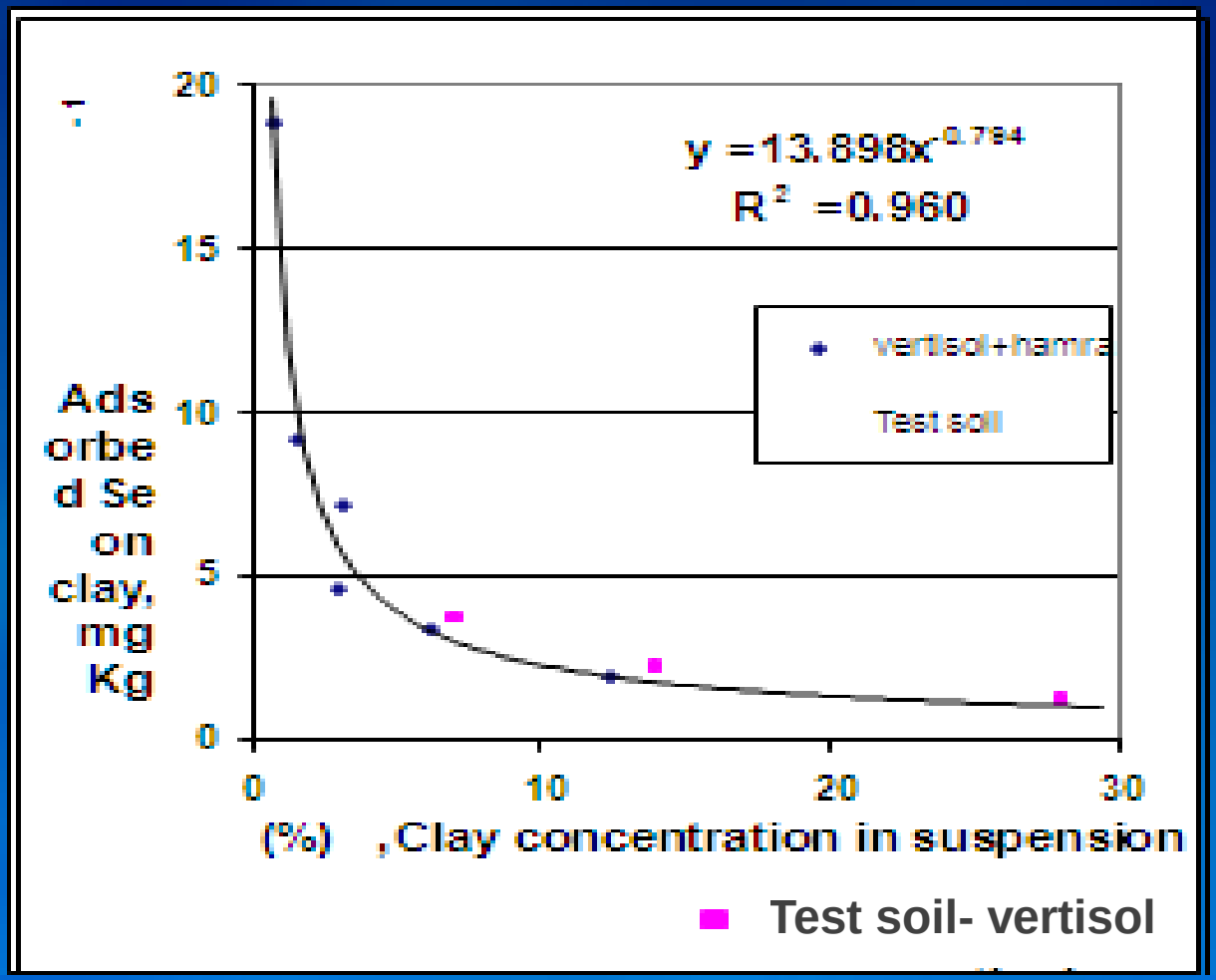
The total amount of leachable boron in the added fly ash

78X10^3 kg FA X 0.665 g B/3.5 kg FA = 14.82X10^3 g B

The leachable boron fraction:

(14.82X10^3 – 10.046X10^3) / 14.82X10^3 = 0.32 (32%)


y = 79.875x^-0.740
R2 = 0.978
vertisol+hamra
Test soil
Adsorbed V on clay, mg Kg -1
120
100
80
60
40
20
0
0
10
20
30
Clay concentration in suspension, %


y =13.898x^-0.784
R² =0.960
vertisol+hamra
Test soil
Adsorbed Se on clay, mg Kg
20
15
10
5
0
0
10
20
30
(%) ,Clay concentration in suspension
Test soil- vertisol

$$Qse = 13.898 * X^{-0.794}$$

$$Q_v = 79.875 * X^{-0.74}$$

$$Qse = 13.898 * X^{-0.794}$$

CONCLUSIONS

- **The regulatory protocol for fly ash uses in road construction, infrastructure and agriculture should take into consideration the following:**

- **Fly Ash Aging and pH dependant dissolution rate of elements**

- **Soil Characterization and depth**

- **Water quality, velocity rate and flow direction in the aquifer related to the application location of FA**

- **The oxyanions concentrations in the leachate are independent of the fly ash column length when the leachate volume is presented**
- **Models to simulate dissolution of some elements from fly ash in soils as a function of pH and soil properties were developed**


THANK YOU