Release of *Cryptosporidium* and *Giardia* (Oo)cysts From Dairy Calf Manure: Impact of Solution Salinity

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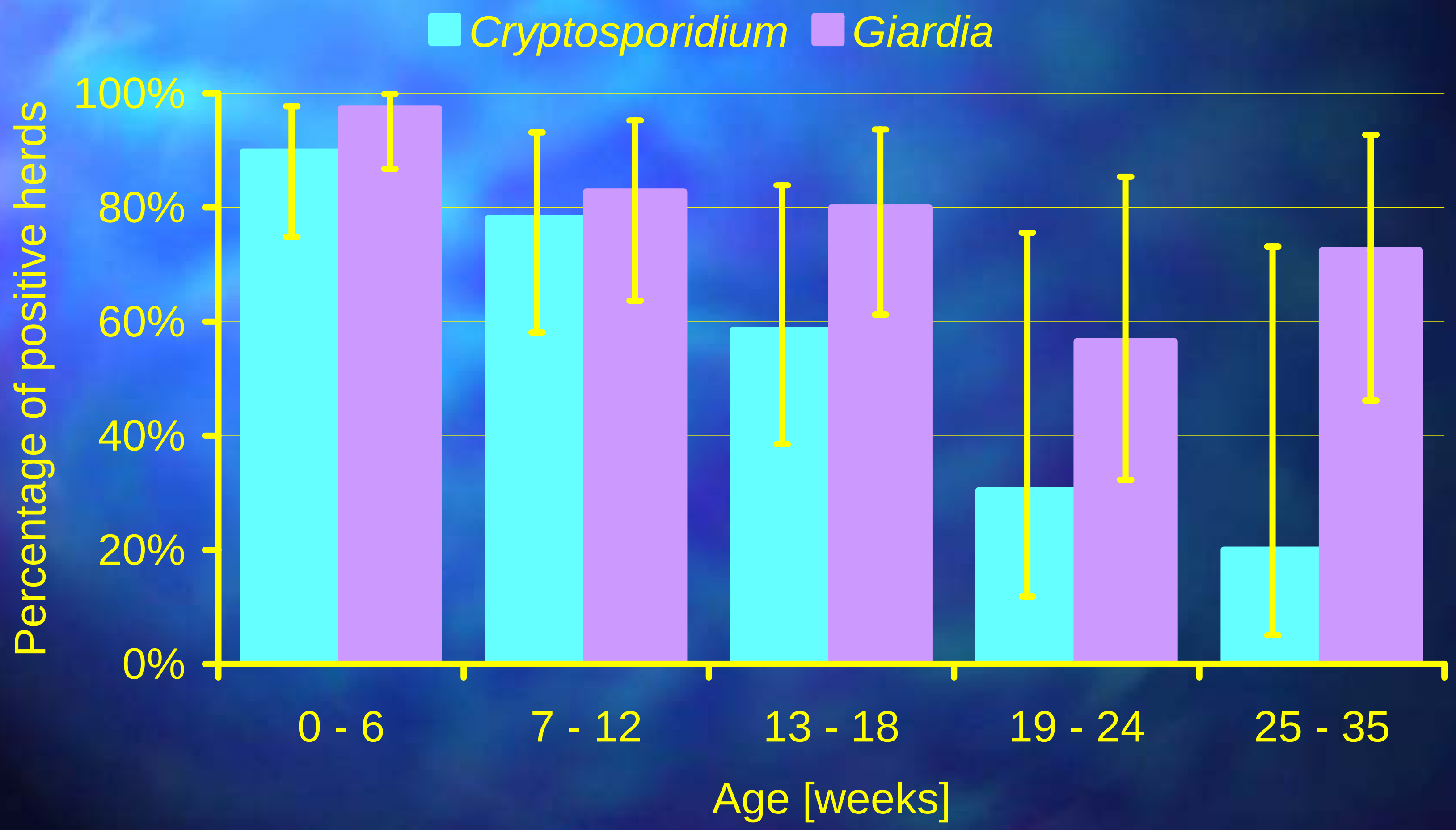
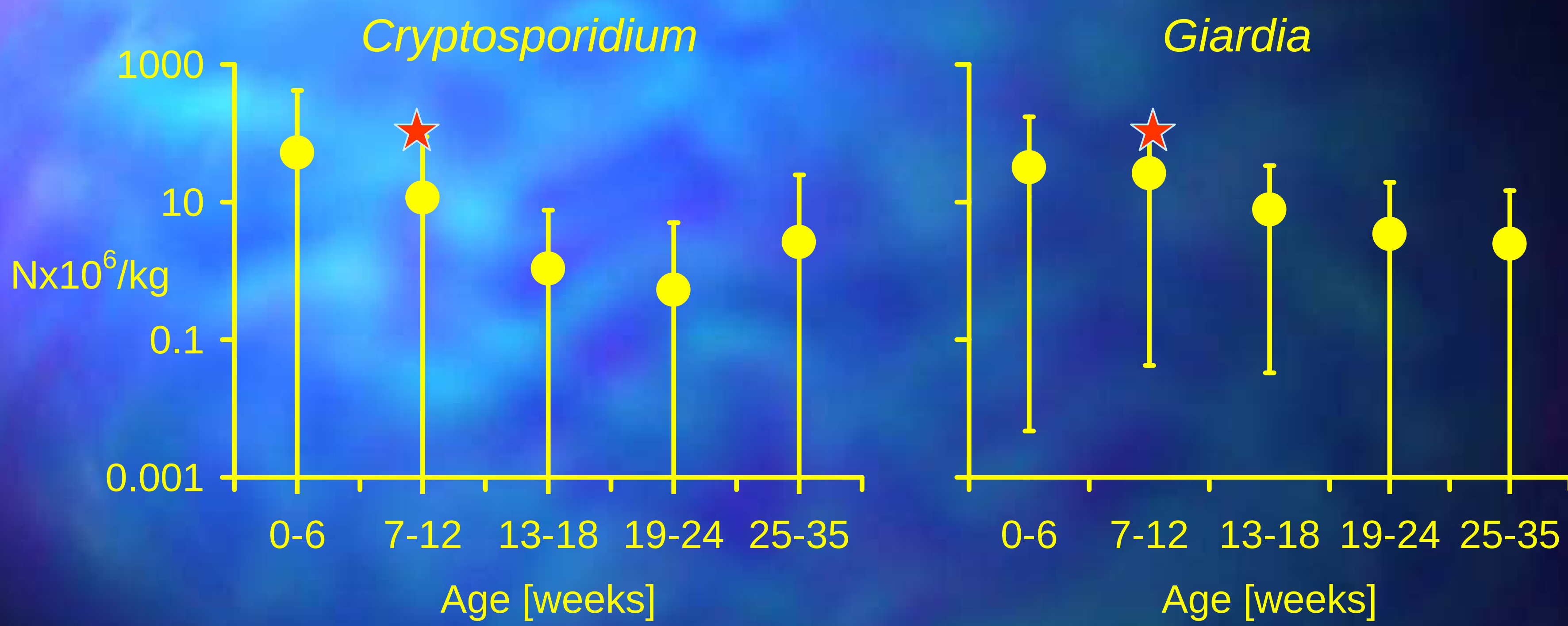
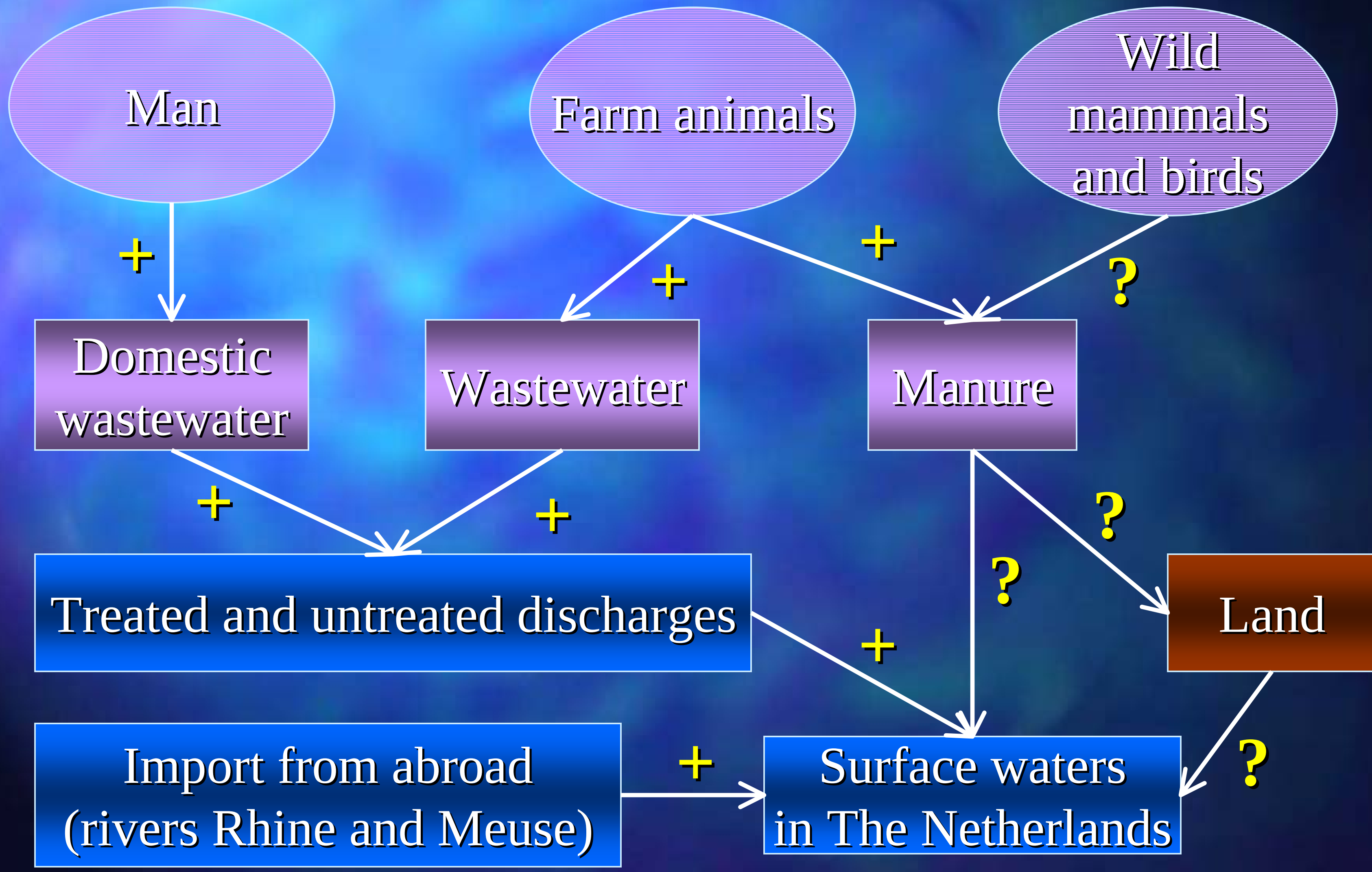
Prevalence in herds of veal calves versus age of veal calves



Average concentrations in positive samples of fresh manure from veal calves versus age



Major pathways of *Cryptosporidum* and *Giardia* to surface waters in The Netherlands



Introduction

- Cattle manure, especially from calves, form an enormous source of *Cryptosporidium* and *Giardia*.

- Due to animal waste application to agricultural land, large numbers of (oo)cysts may reach groundwater and surface water.

- Release rates of (oo)cysts from manure are important boundary conditions for loading rates into the environment.

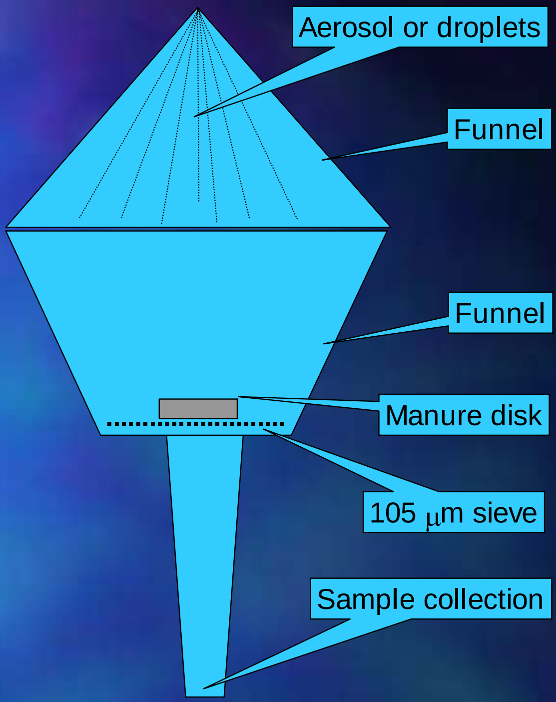
- Manure is exposed to a wide range of solution salinities (rain or urine).

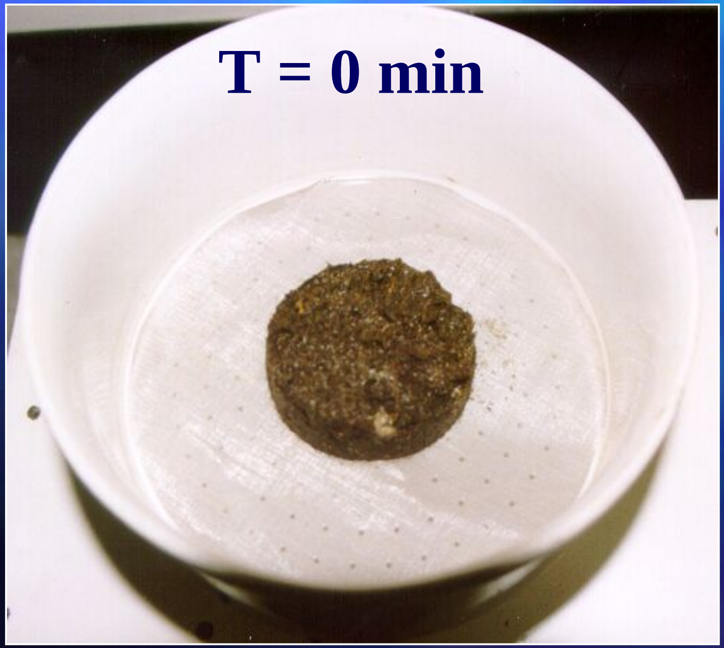
Holstein dairy cattle (Chino, CA)

Manure phase concentrations of (oo)cysts, m_{ip}, N g^{-1}.

	Cryptosporidium	*Giardia*
Average	7.1×10^4	9.5×10^4
S.D.	1.7×10^4	3.0×10^4
N	6	12

Manure Drip Experiments





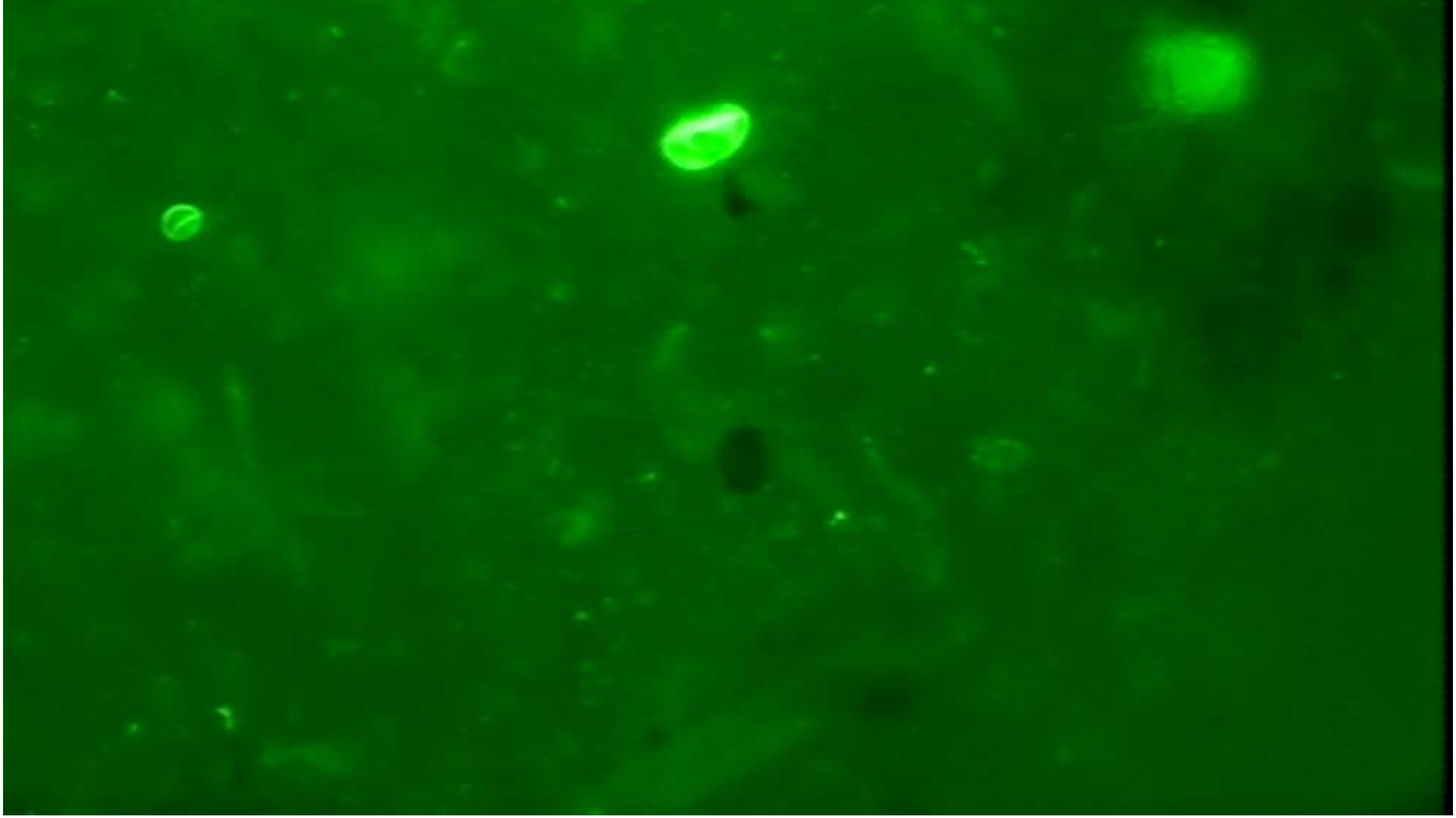
Experimental conditions

Manure	Water application	Q [ml min^{-1}]	EC [dS m^{-1}]	Temp. [°C]
Calf	**Mist**	**10**	**0.3**	**5**
Calf	**Mist**	**2.9**	**0.3**	**5**
Calf	**Drip**	**2.4**	**0.3**	**5**
Calf + Cow 1:10	**Drip**	**2.7**	**0.3**	**5**
Calf + Cow 1:1	**Drip**	**3.0**	**0.3**	**5**
Calf	**Drip**	**2.6**	**0.3**	**23**
Calf	**Drip**	**2.0**	**0.3**	**23**
Calf	**Drip**	**2.5**	**5.0**	**23**
Calf	**Drip**	**2.0**	**9.5**	**23**
Calf	**Drip**	**2.1**	**15**	**23**

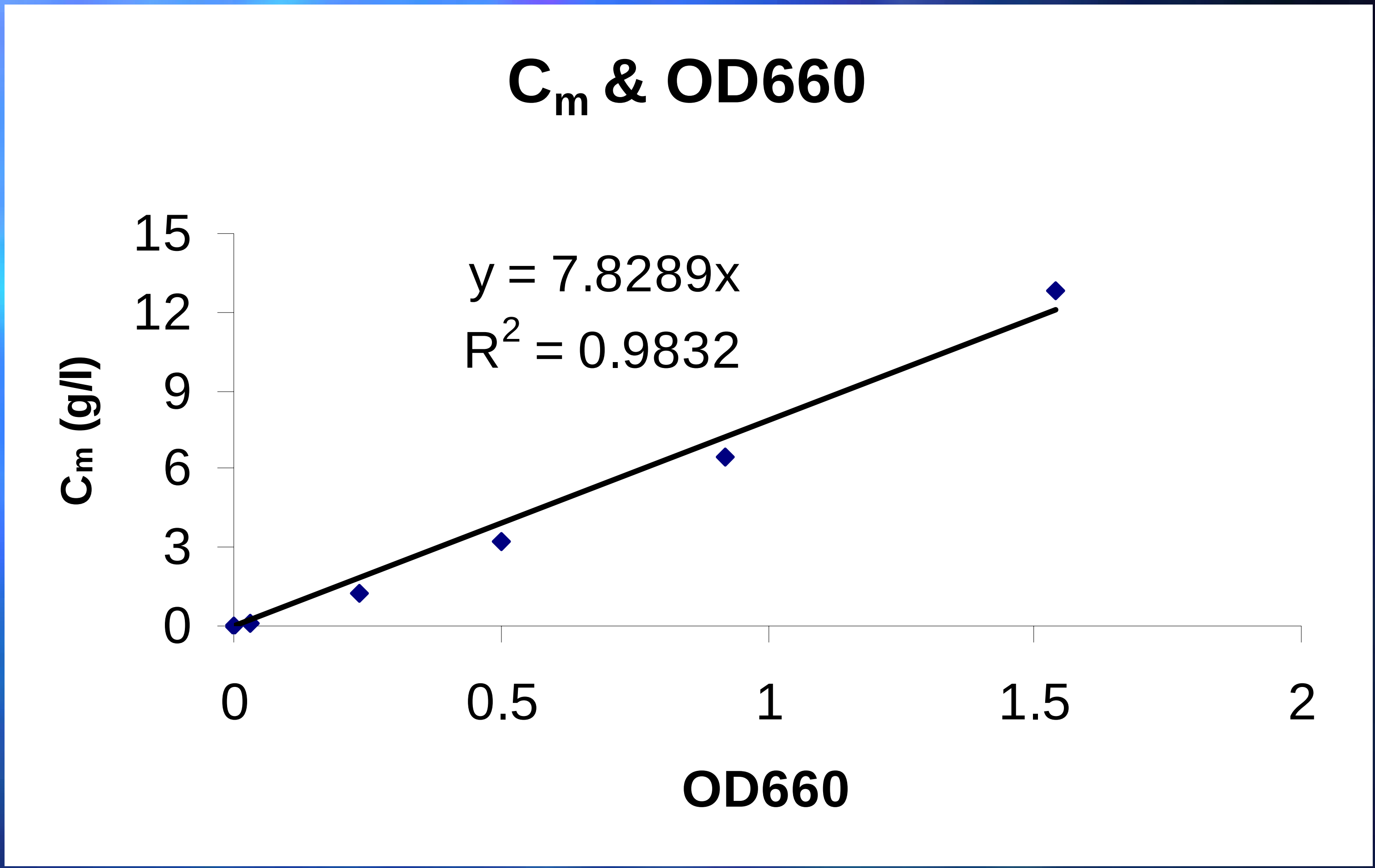
ρ_i =1.1 g cm^{-3} from *Vm* (34.4 ml) and initial weight of manure disk (g).

Detection of *Cryptosporidium* and *Giardia*

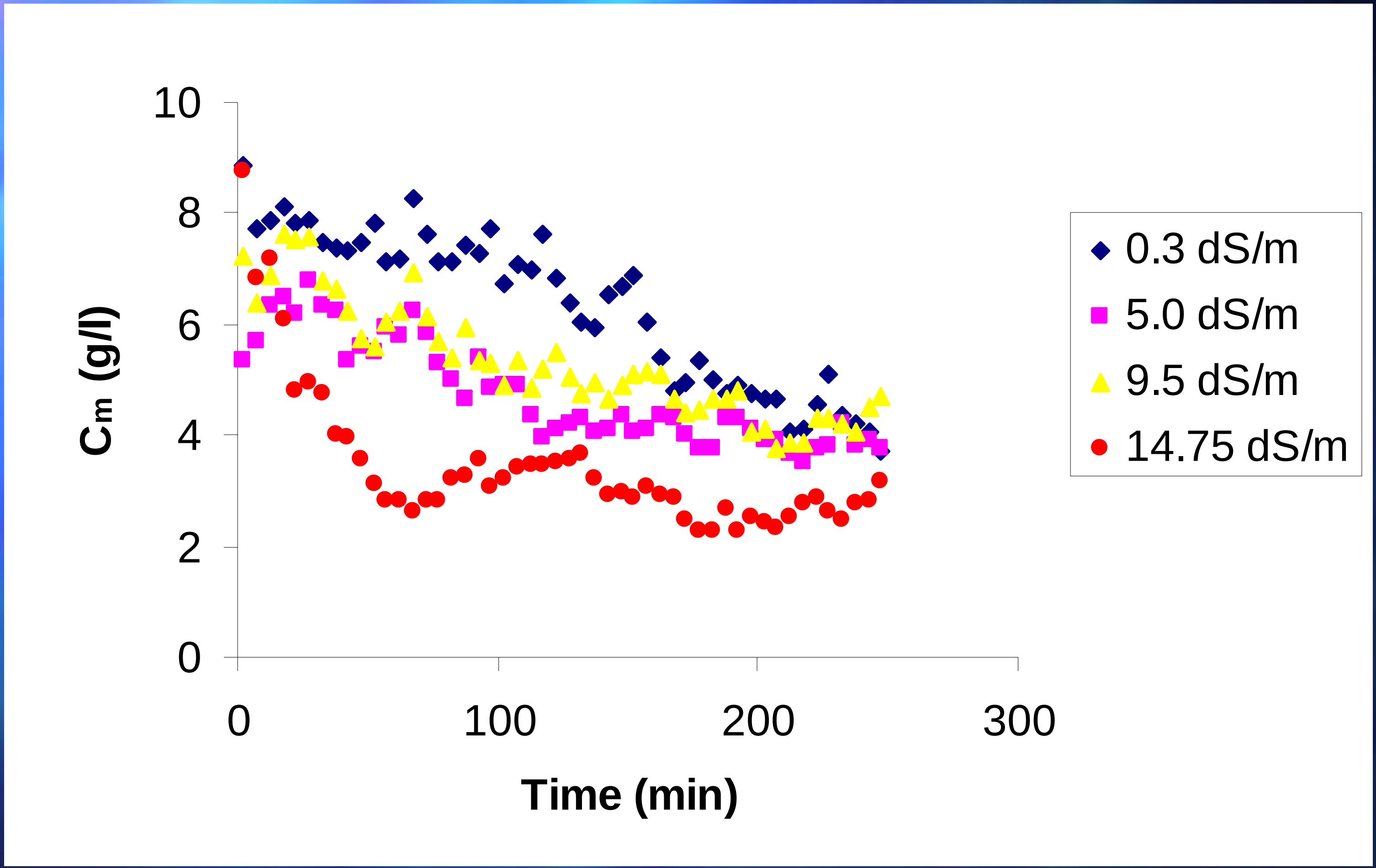
- FITC - Monoclonal Antibody
- Direct Enumeration via Microscopy



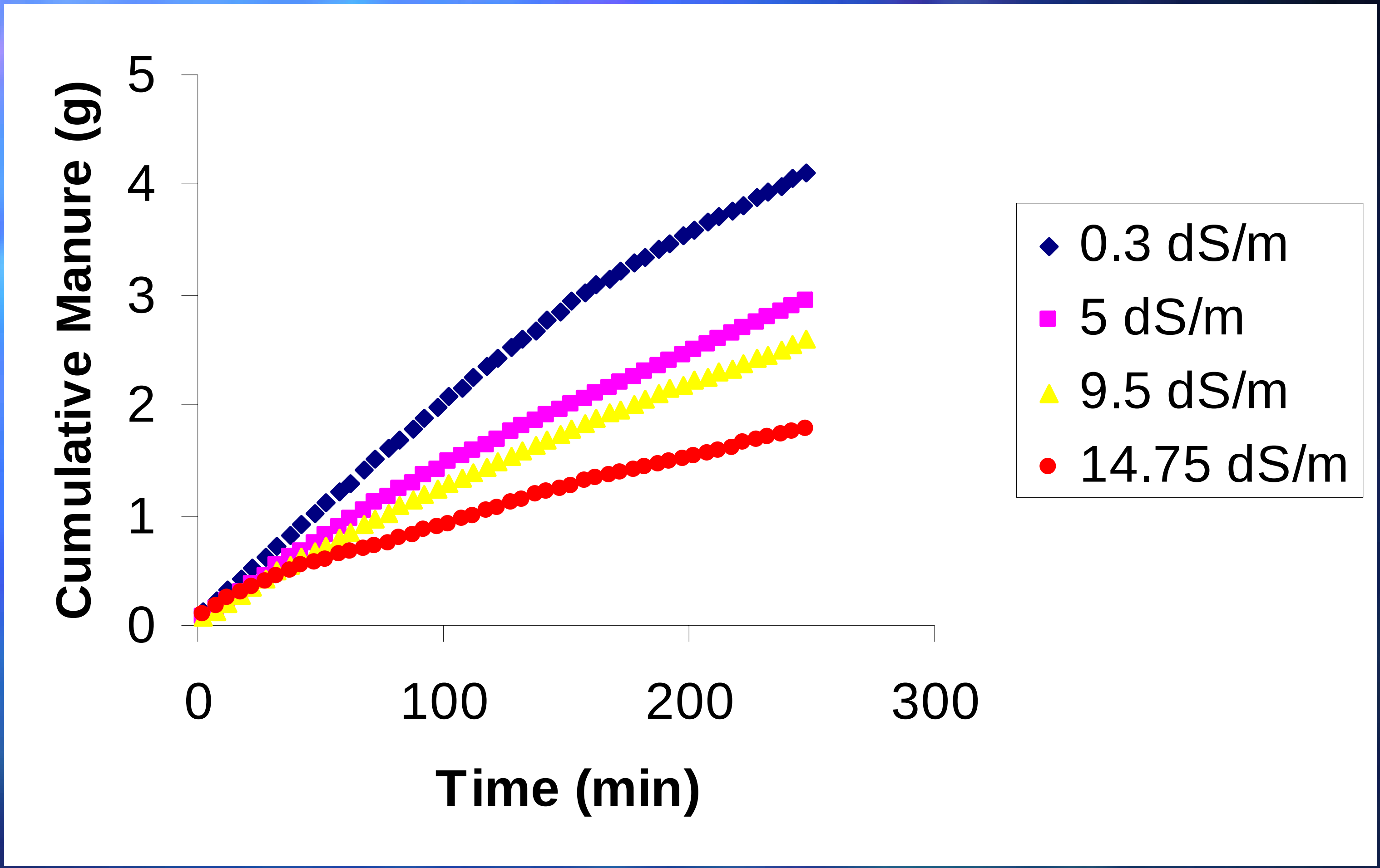
Manure Release

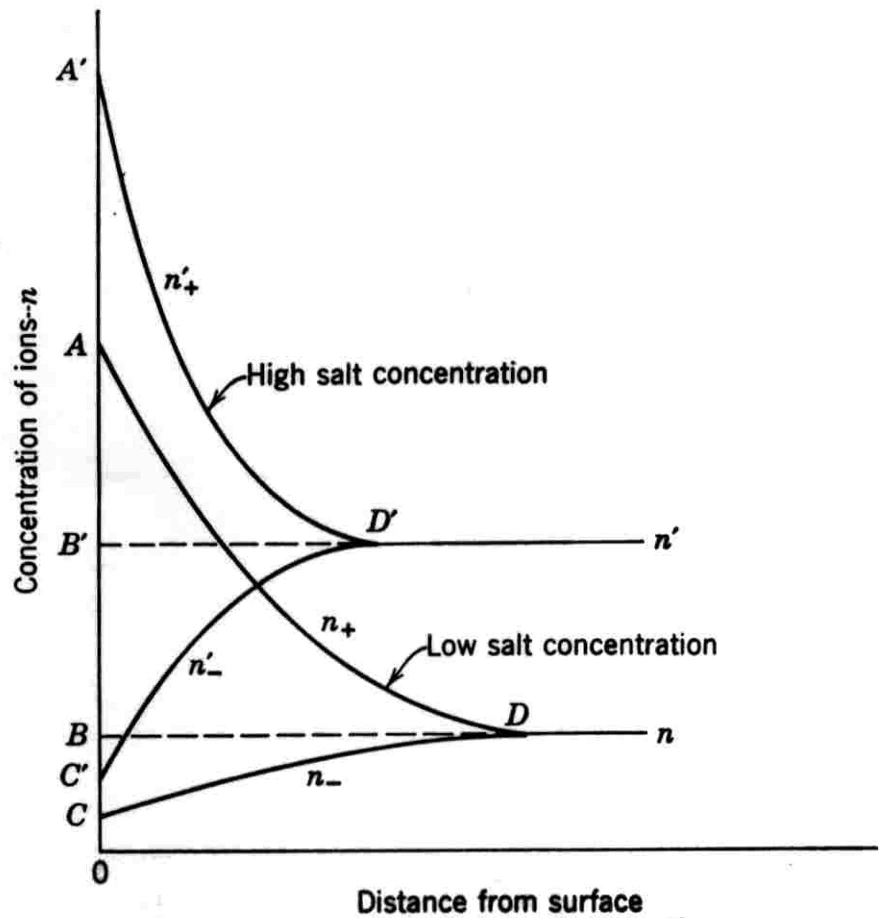


C_m & OD660
y = 7.8289x
R^2 = 0.9832
C_m (g/l)
15
12
9
6
3
0
0
0.5
1
1.5
2
OD660



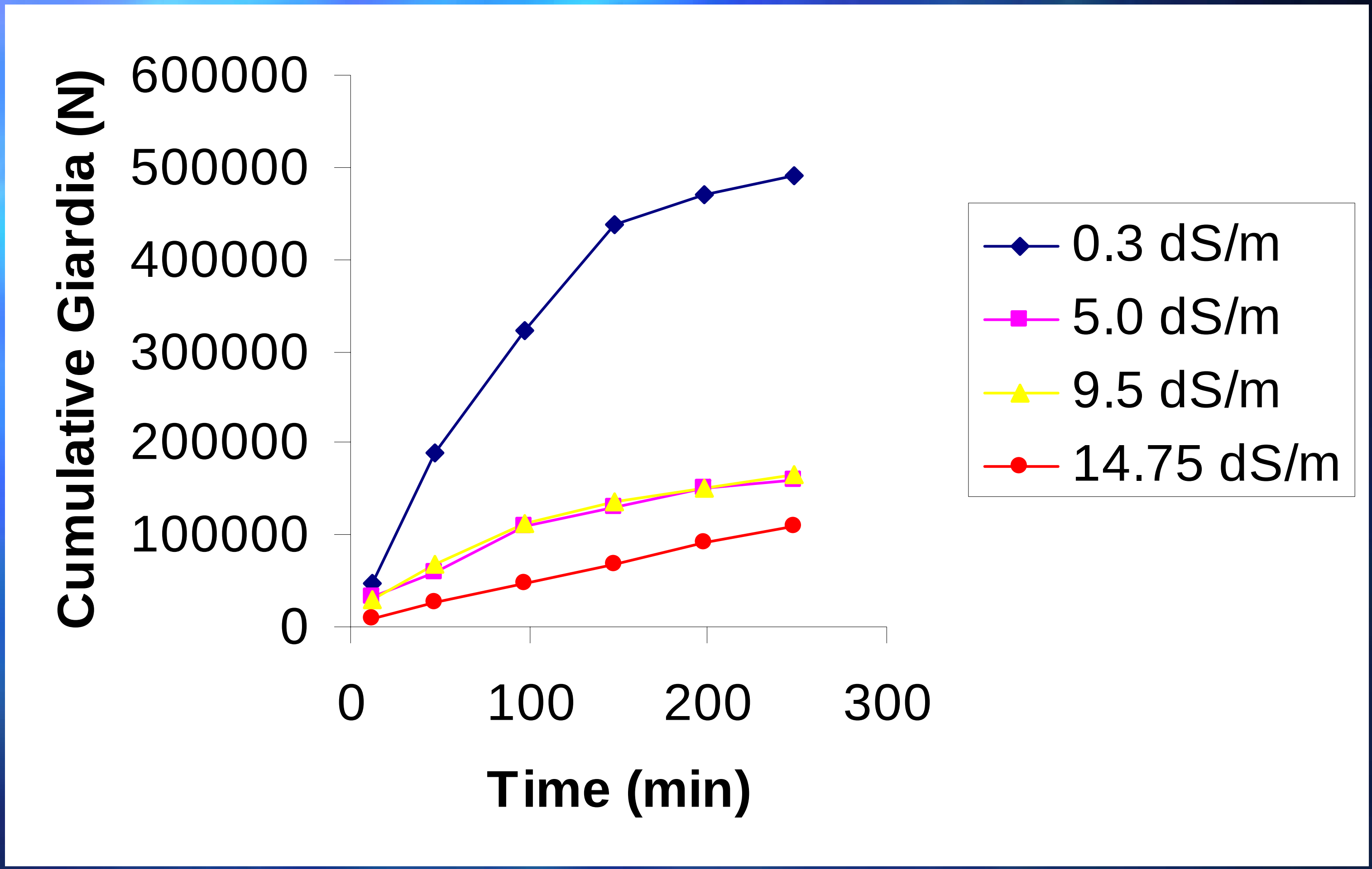
10
8
6
4
2
0
Cm (g/l)
0
100
200
300
Time (min)
0.3 dS/m
5.0 dS/m
9.5 dS/m
14.75 dS/m


Cumulative Manure (g)
0
1
2
3
4
5
0
100
200
300
Time (min)
0.3 dS/m
5 dS/m
9.5 dS/m
14.75 dS/m

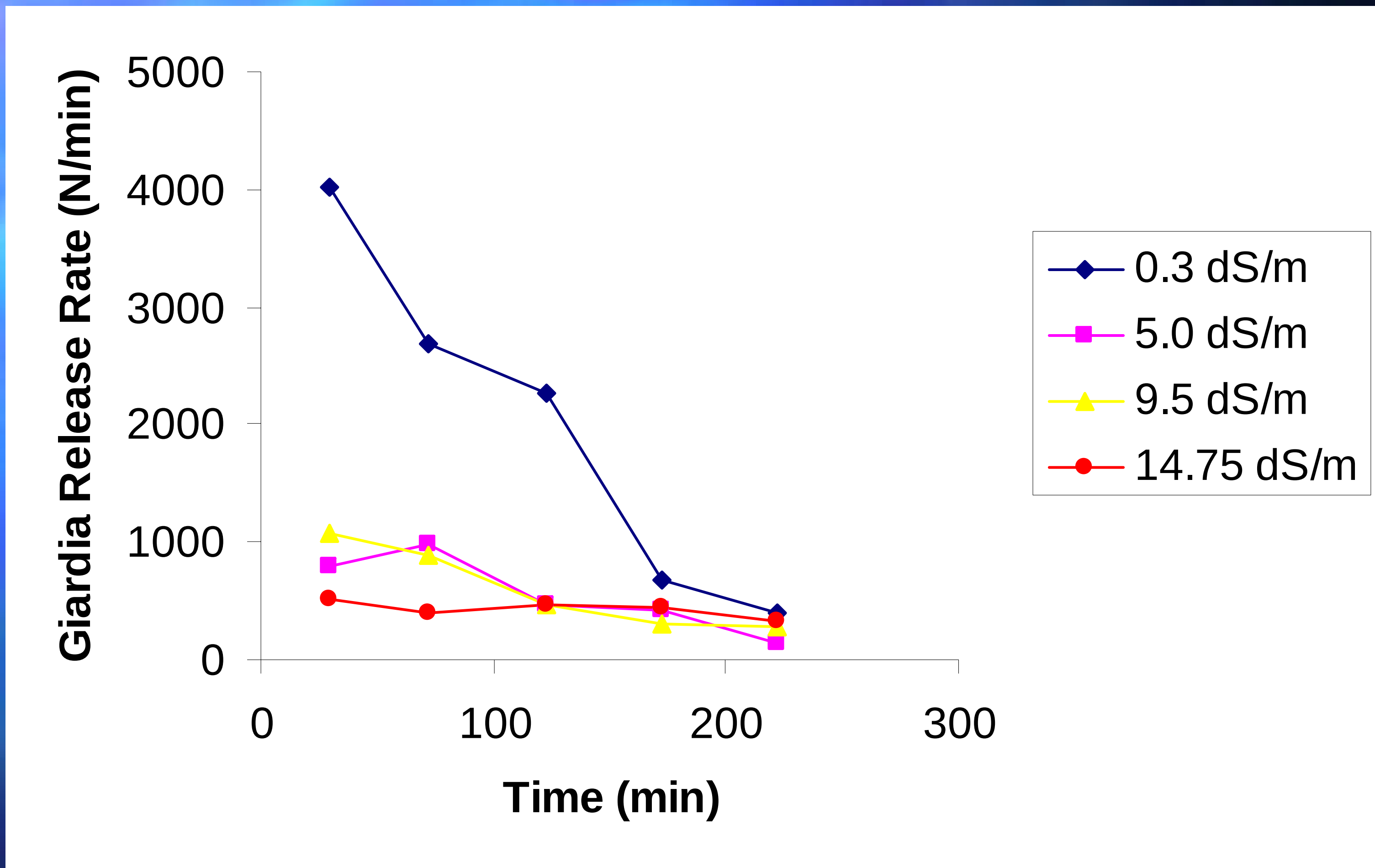


A′
A
B′
B
C′
C
0
n'_+
n_+
n'_-
n_-
D′
D
n′
n
High salt concentration
Low salt concentration
Concentration of ions–n
Distance from surface

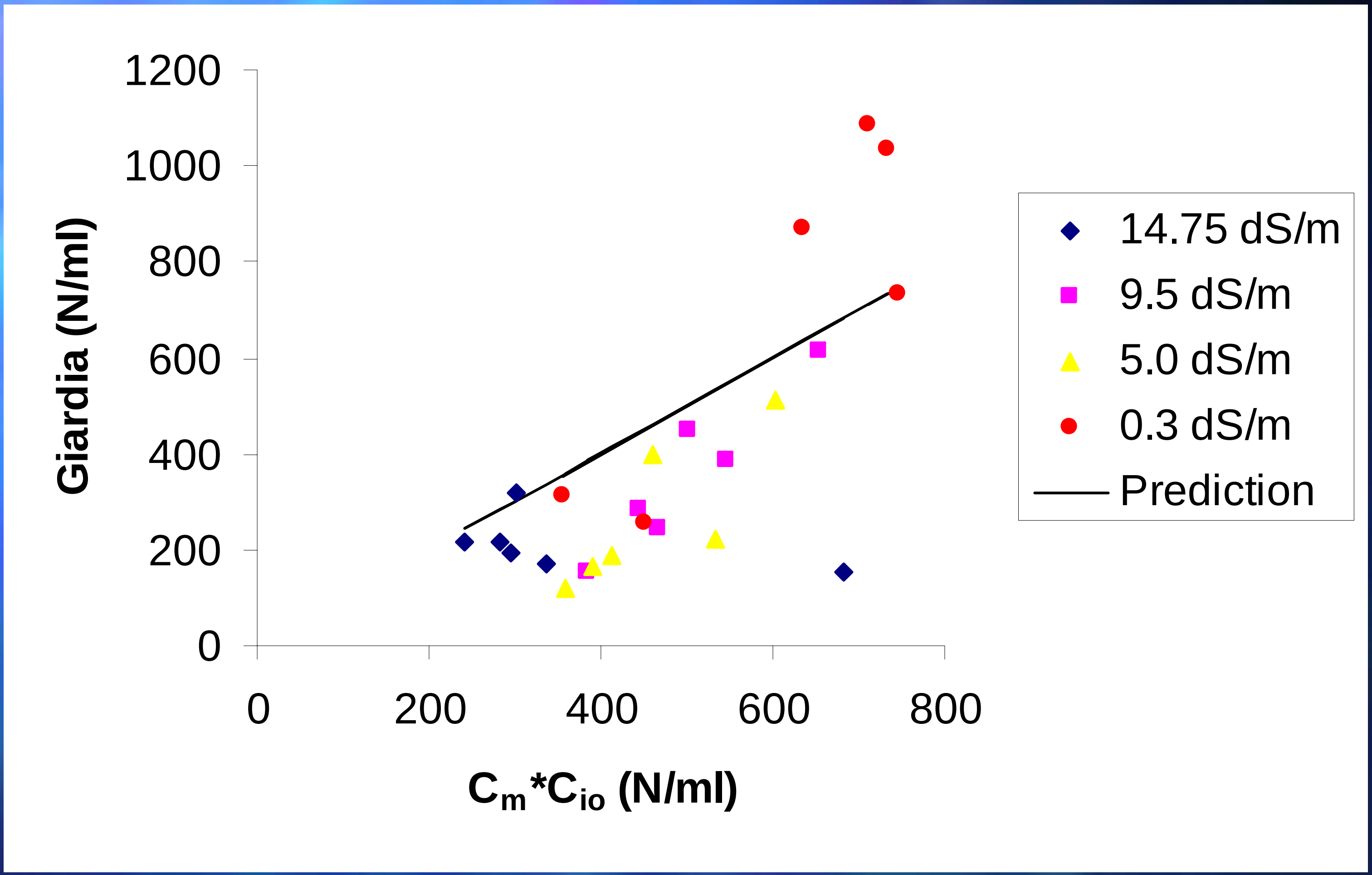
Giardia Release



Cumulative Giardia (N)
600000
500000
400000
300000
200000
100000
0
0
100
200
300
Time (min)
0.3 dS/m
5.0 dS/m
9.5 dS/m
14.75 dS/m

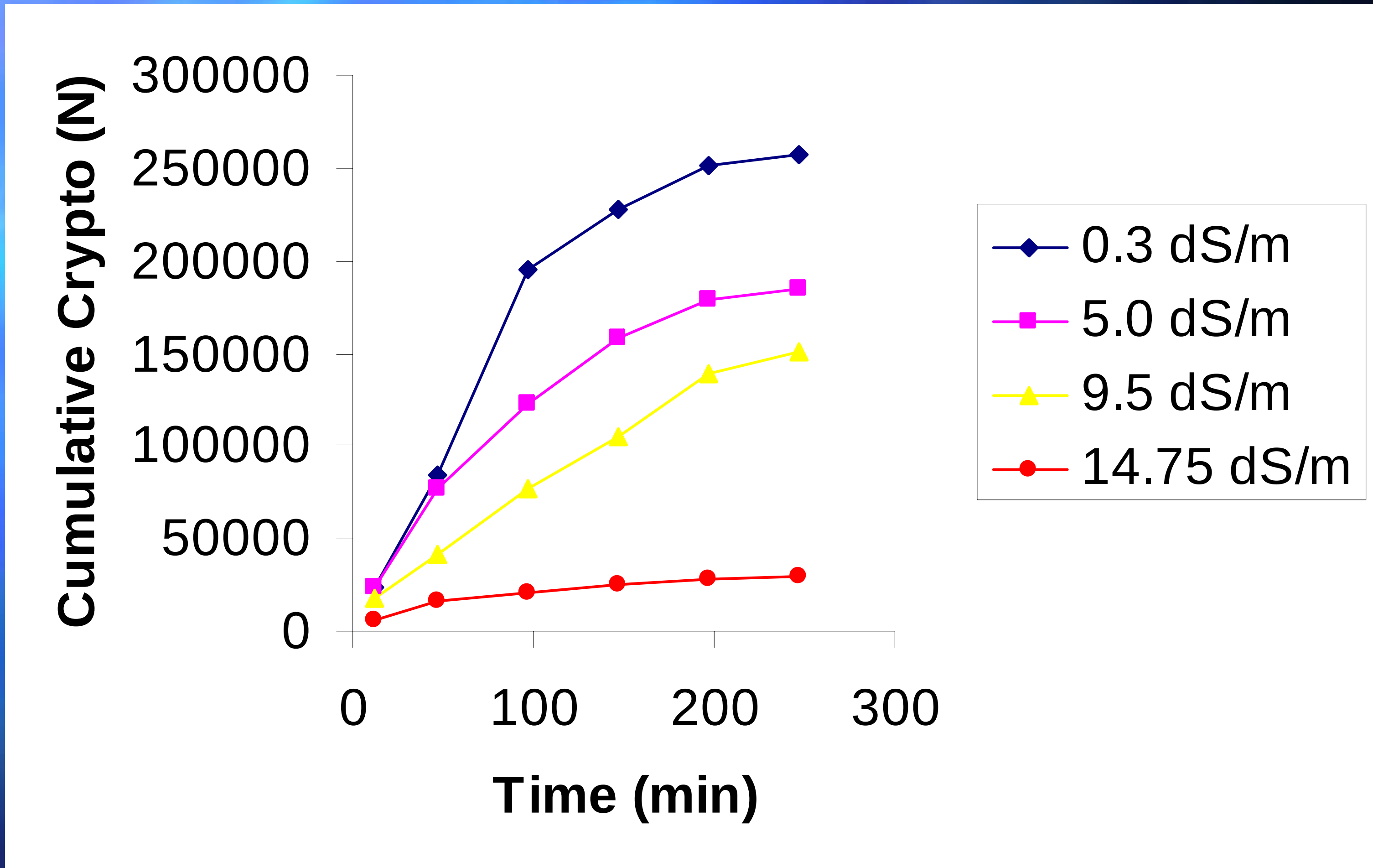


Giardia Release Rate (N/min)
5000
4000
3000
2000
1000
0
0
100
200
300
Time (min)
0.3 dS/m
5.0 dS/m
9.5 dS/m
14.75 dS/m

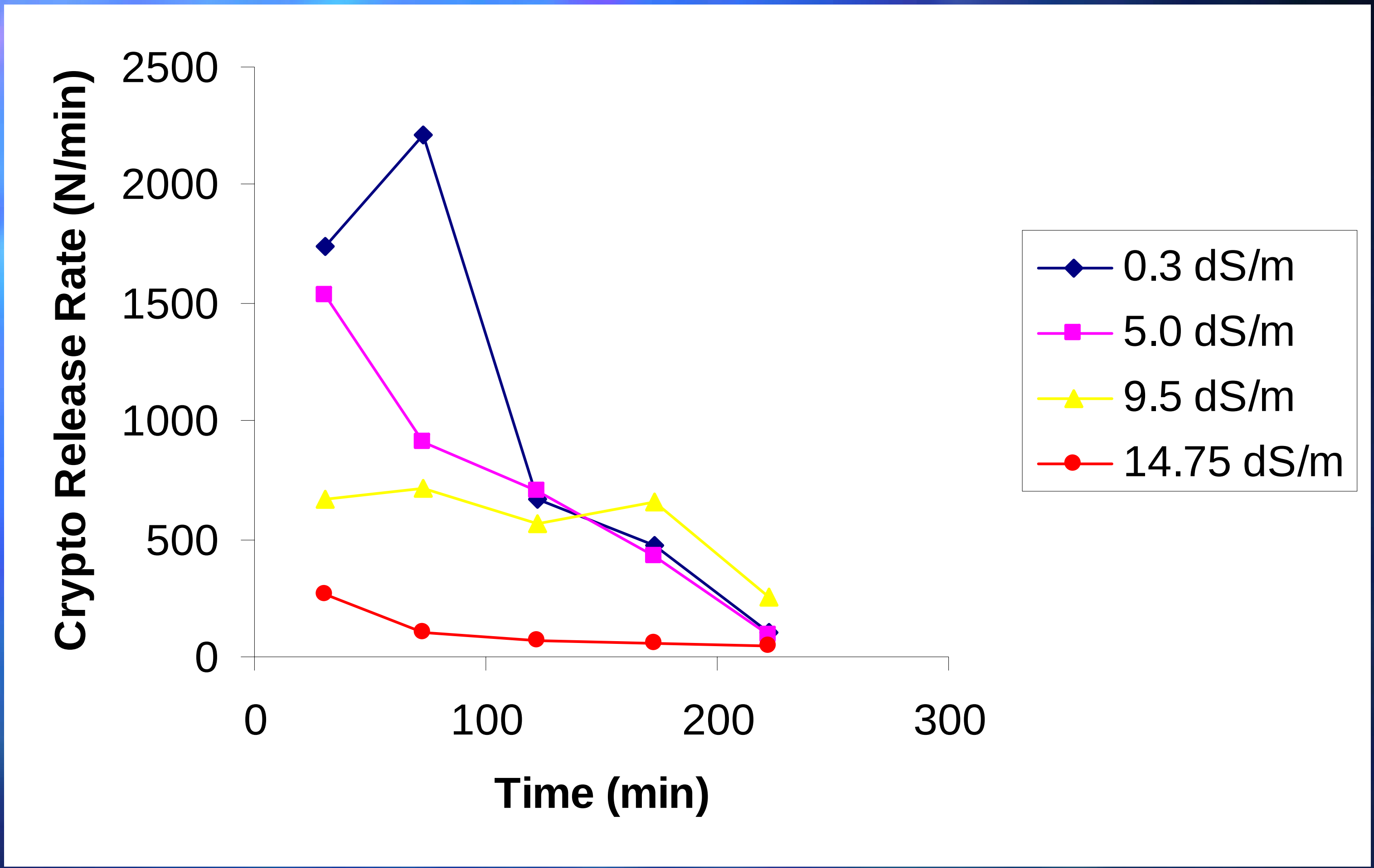


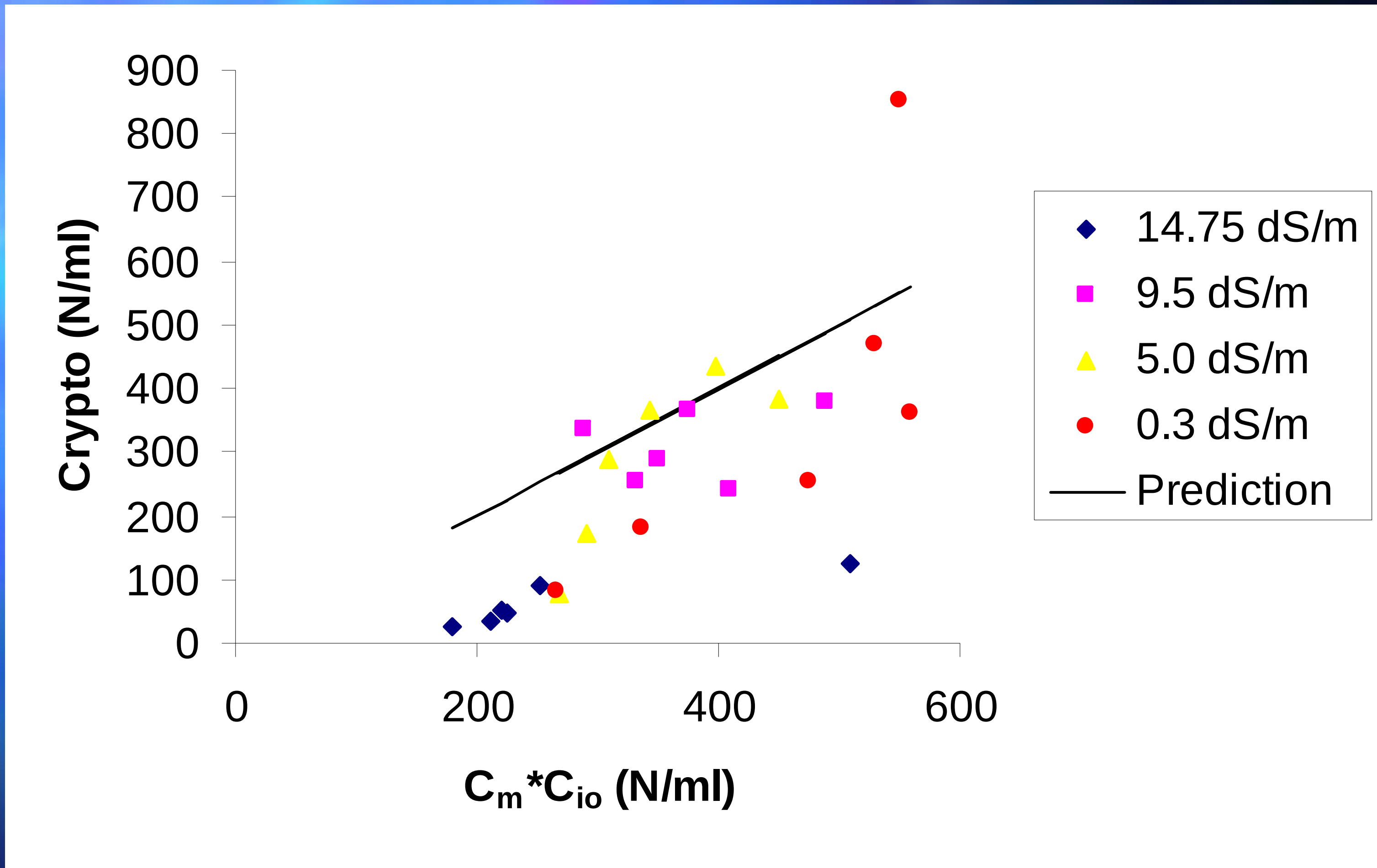
1200
1000
800
600
400
200
0
Giardia (N/ml)
0
200
400
600
800
C_m*C_{io} (N/ml)
14.75 dS/m
9.5 dS/m
5.0 dS/m
0.3 dS/m
Prediction

Cryptosporidium Release

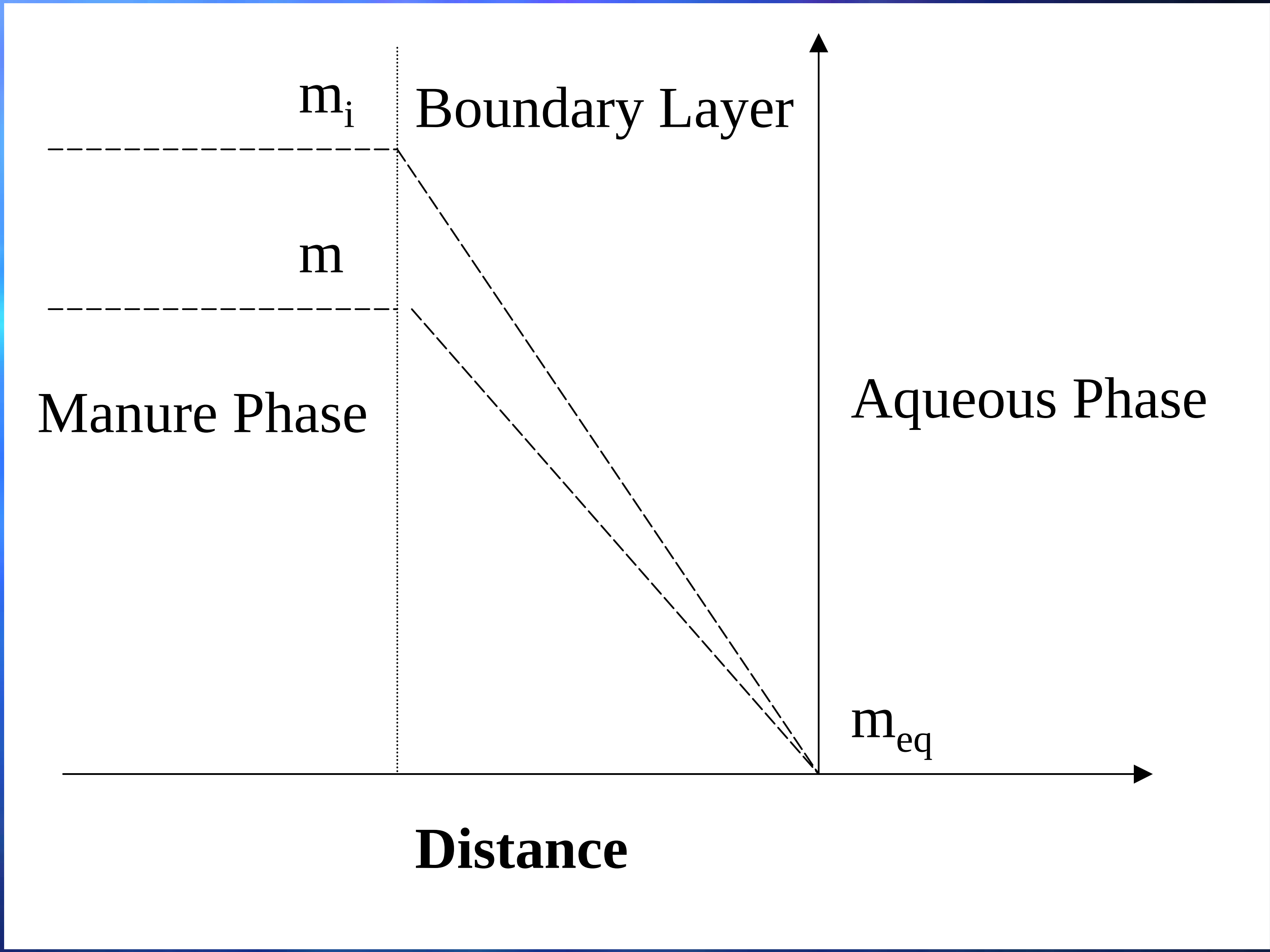


Cumulative Crypto (N)
300000
250000
200000
150000
100000
50000
0
0
100
200
300
Time (min)
0.3 dS/m
5.0 dS/m
9.5 dS/m
14.75 dS/m


Crypto Release Rate (N/min)
2500
2000
1500
1000
500
0
0
100
200
300
Time (min)
0.3 dS/m
5.0 dS/m
9.5 dS/m
14.75 dS/m



Crypto (N/ml)
900
800
700
600
500
400
300
200
100
0
0
200
400
600
C_m*C_{io} (N/ml)
14.75 dS/m
9.5 dS/m
5.0 dS/m
0.3 dS/m
Prediction



m_i
Boundary Layer
m
Manure Phase
Aqueous Phase
m_eq
Distance

Theory

$$\frac{dm}{dt} = k_{wm}\left[m_{eq} - m\right] \Rightarrow -k_{wm} m \Rightarrow -\alpha\left(\frac{m}{m_i}\right)^{\beta} m$$

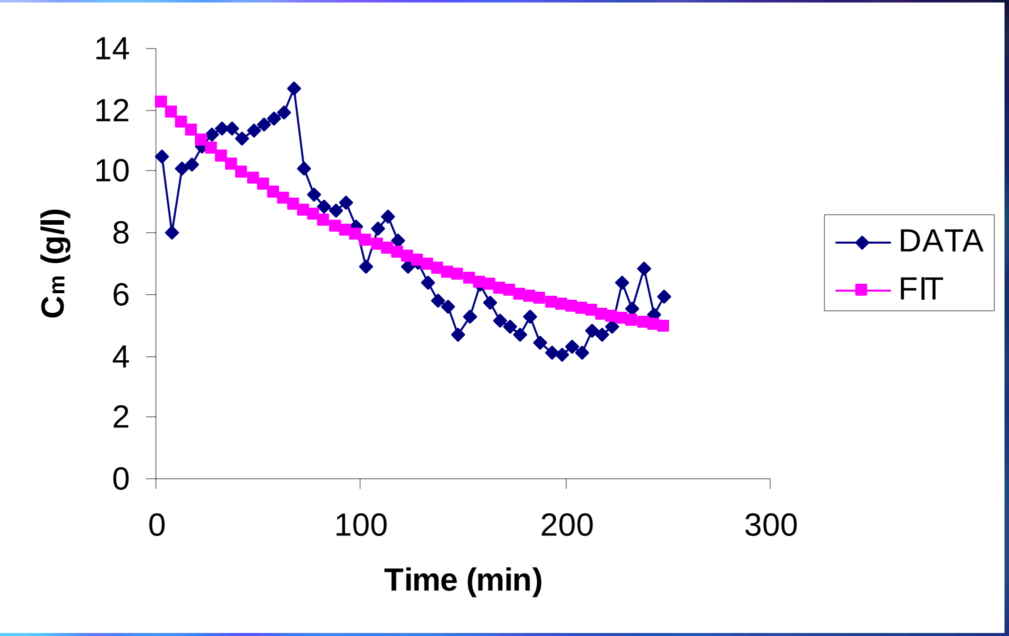
$$m(t) = m_i \cdot (1 + \alpha\beta t)^{\left(-\frac{1}{\beta}\right)}$$

$$M_w(t) = V_m \cdot \left(m_i - m(t)\right)$$

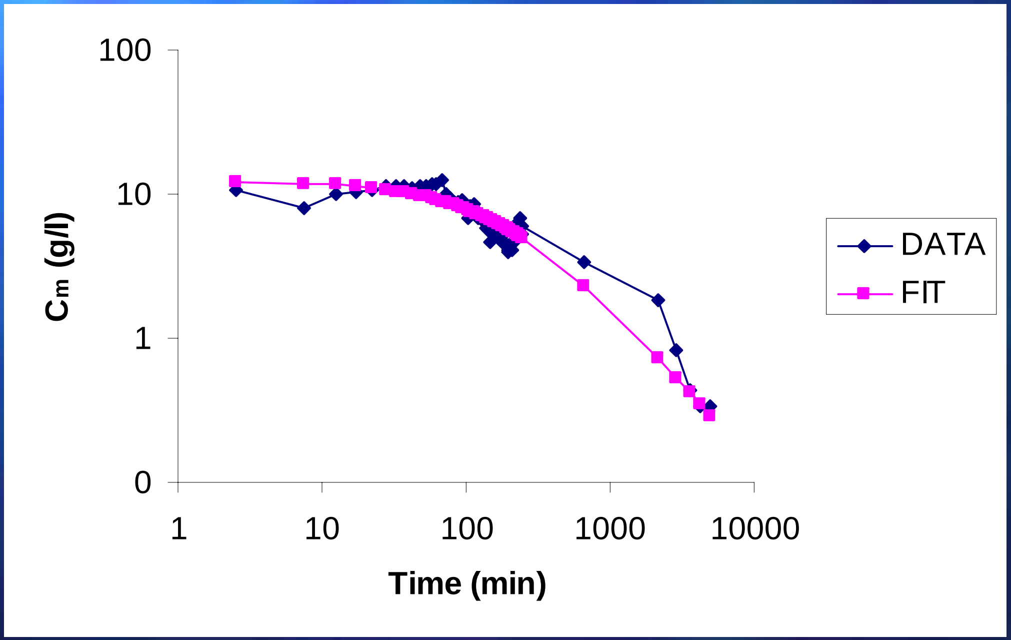
$$C_m(t) = \frac{dM_w}{Q\,dt} = \frac{m_i \alpha V_m}{Q}(1 + \alpha\beta t)^{-\left(\frac{\beta+1}{\beta}\right)}$$

$$C_o = C_{io} \cdot C_m \cdot E_{ro}$$

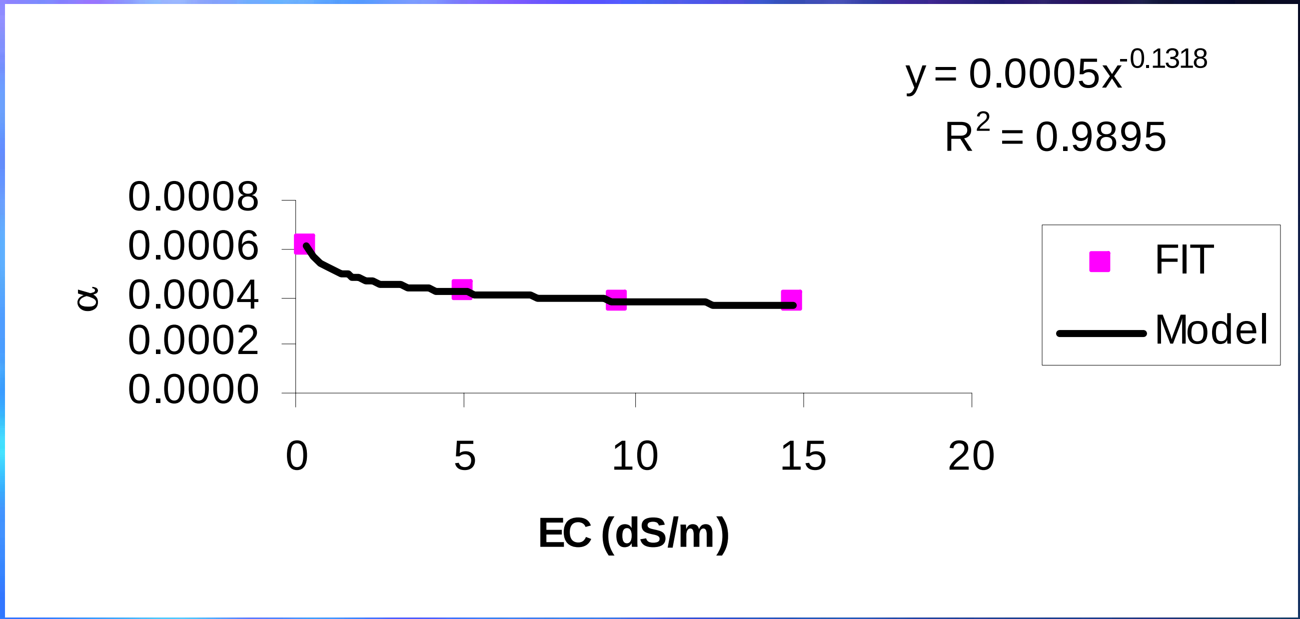
α - fitting parameter (T^{-1})
β - fitting parameter (-)
C_m - aqueous phase manure concentration ($M\ L^{-3}$)
C_{io} - initial manure phase (oo)cyst concentration ($N\ M^{-1}$)
C_o - aqueous phase (oo)cyst concentration ($N\ L^{-3}$)
E_{ro} - (oo)cyst release efficiency (-)
k_{wm} - lumped manure mass transfer coefficient (T^{-1})
m - bulk manure phase concentration ($M\ L^{-3}$)
m_{eq} - manure phase concentration in equilibrium with the aqueous phase ($M\ L^{-3}$)
m_i - initial bulk manure concentration ($M\ L^{-3}$)
M_w - cumulative manure mass in the aqueous phase (M)
Q - aqueous phase flow rate ($L^3\ T^{-1}$)
t - time (T)
V_m - volume of manure (L^3)



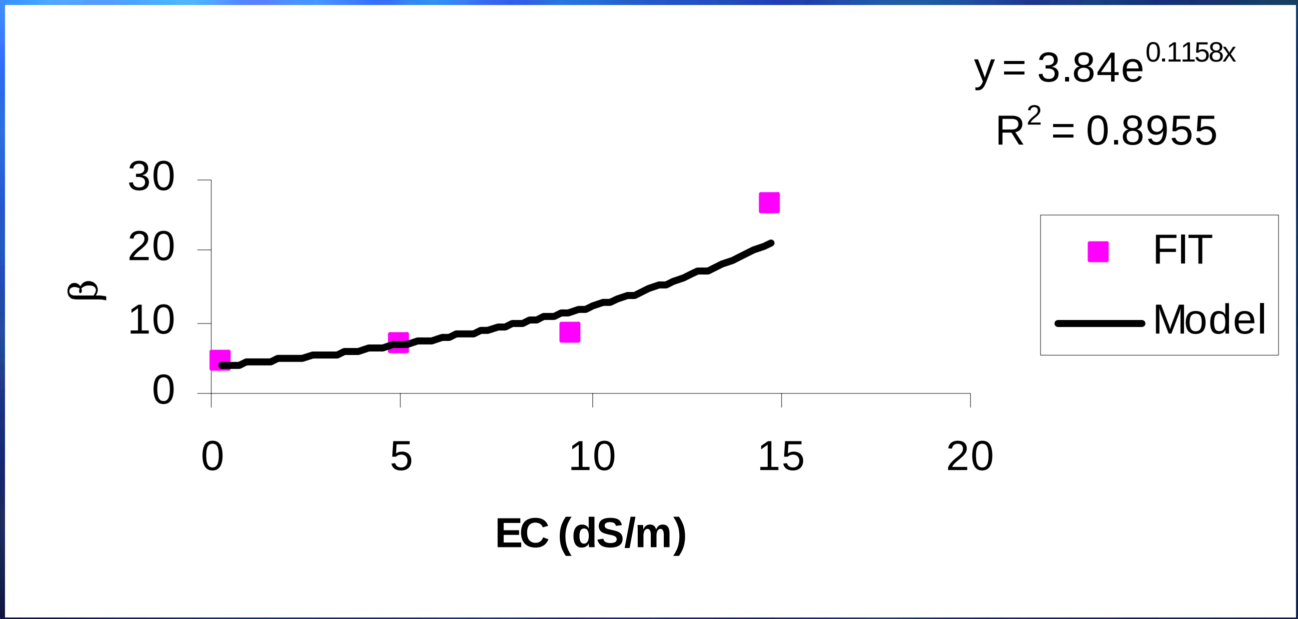
14
12
10
8
6
4
2
0
0
100
200
300
Cm (g/l)
Time (min)
DATA
FIT



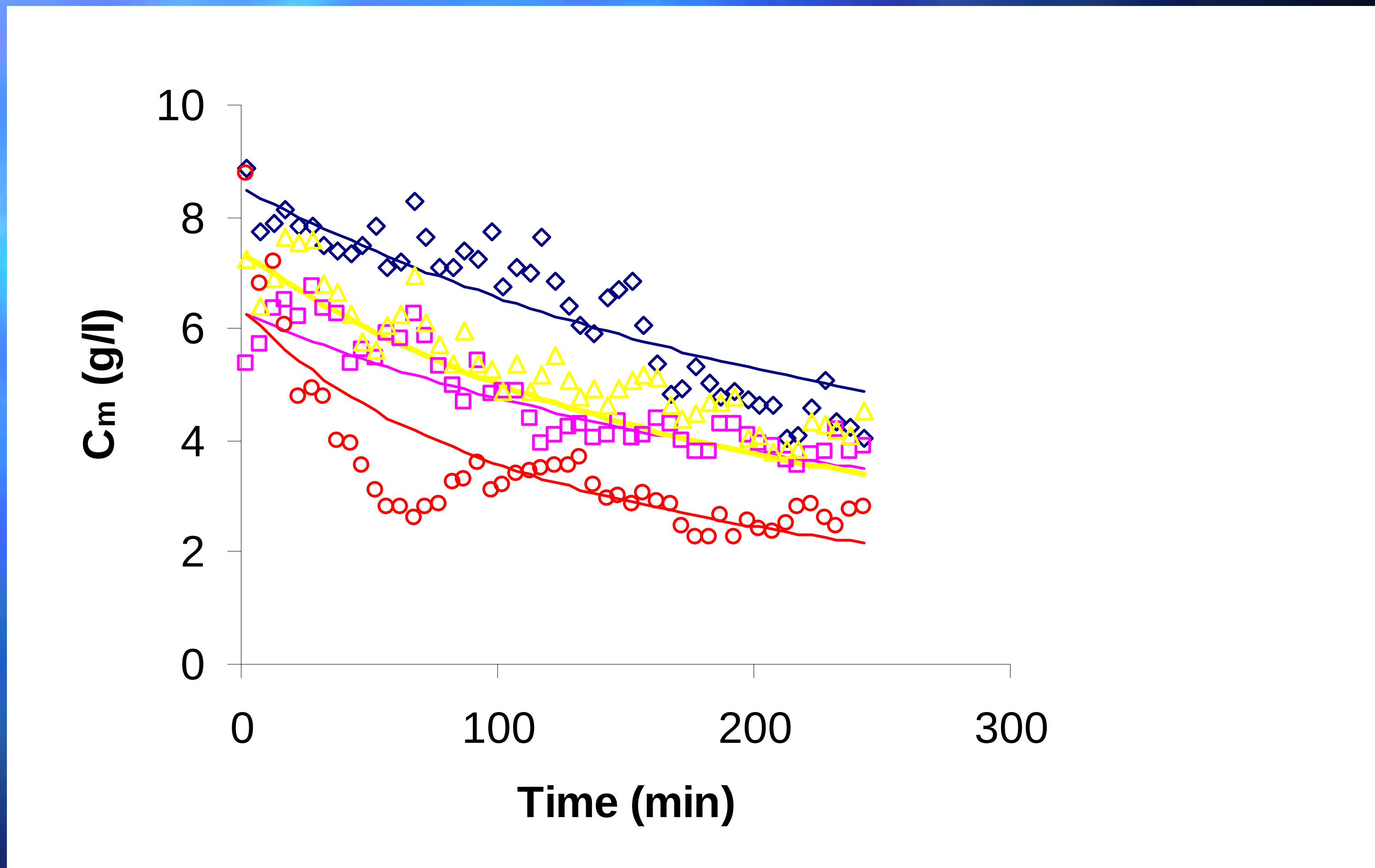
100
10
1
0
1
10
100
1000
10000
Cm (g/l)
Time (min)
DATA
FIT



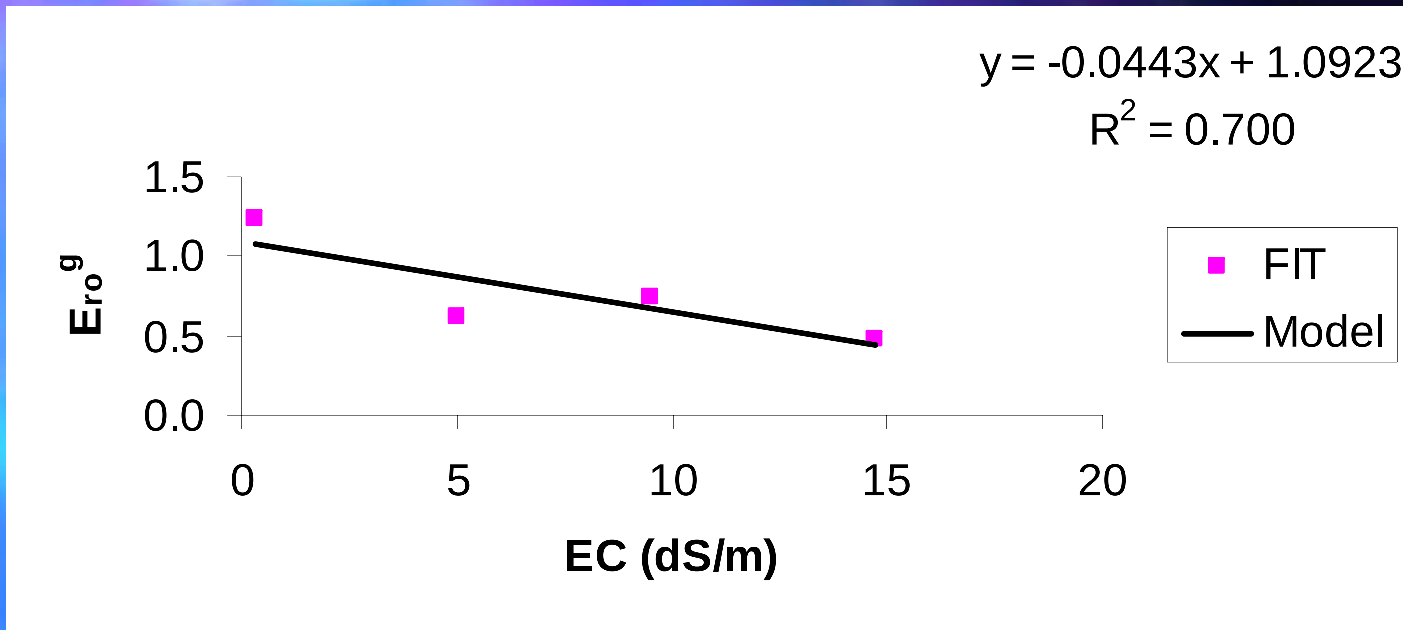
y = 0.0005x-0.1318
R2 = 0.9895
0.0008
0.0006
0.0004
0.0002
0.0000
α
0
5
10
15
20
EC (dS/m)
FIT
Model

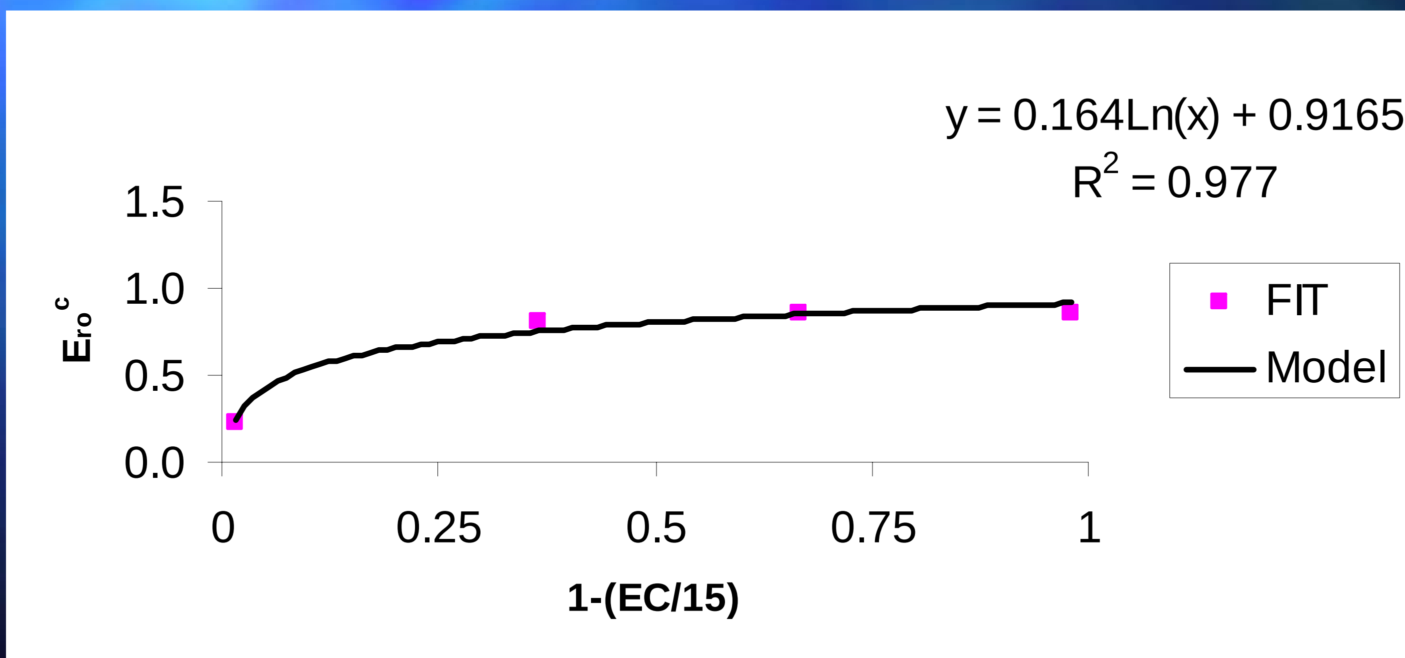


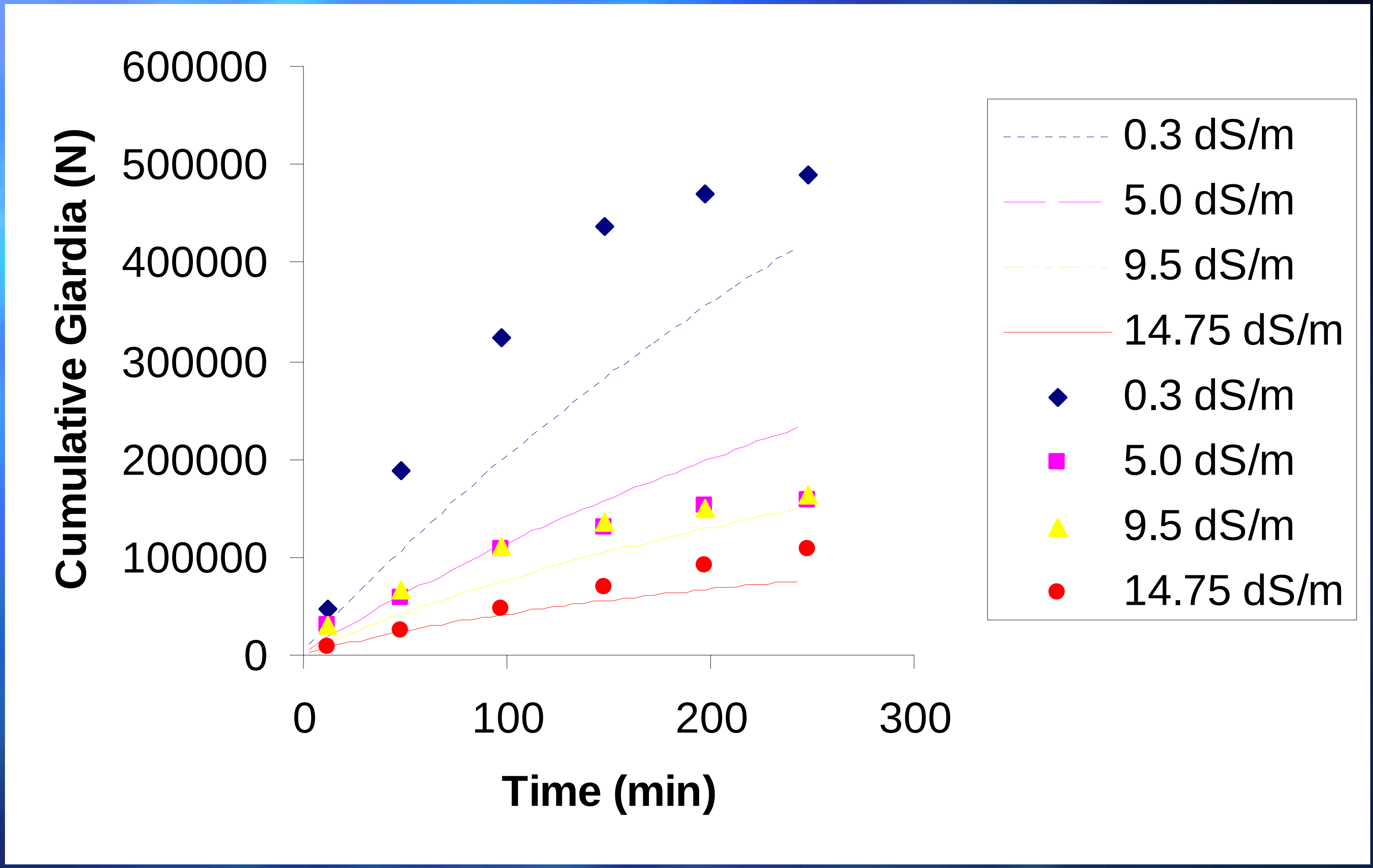
y = 3.84e0.1158x
R2 = 0.8955
30
20
10
0
β
0
5
10
15
20
EC (dS/m)
FIT
Model

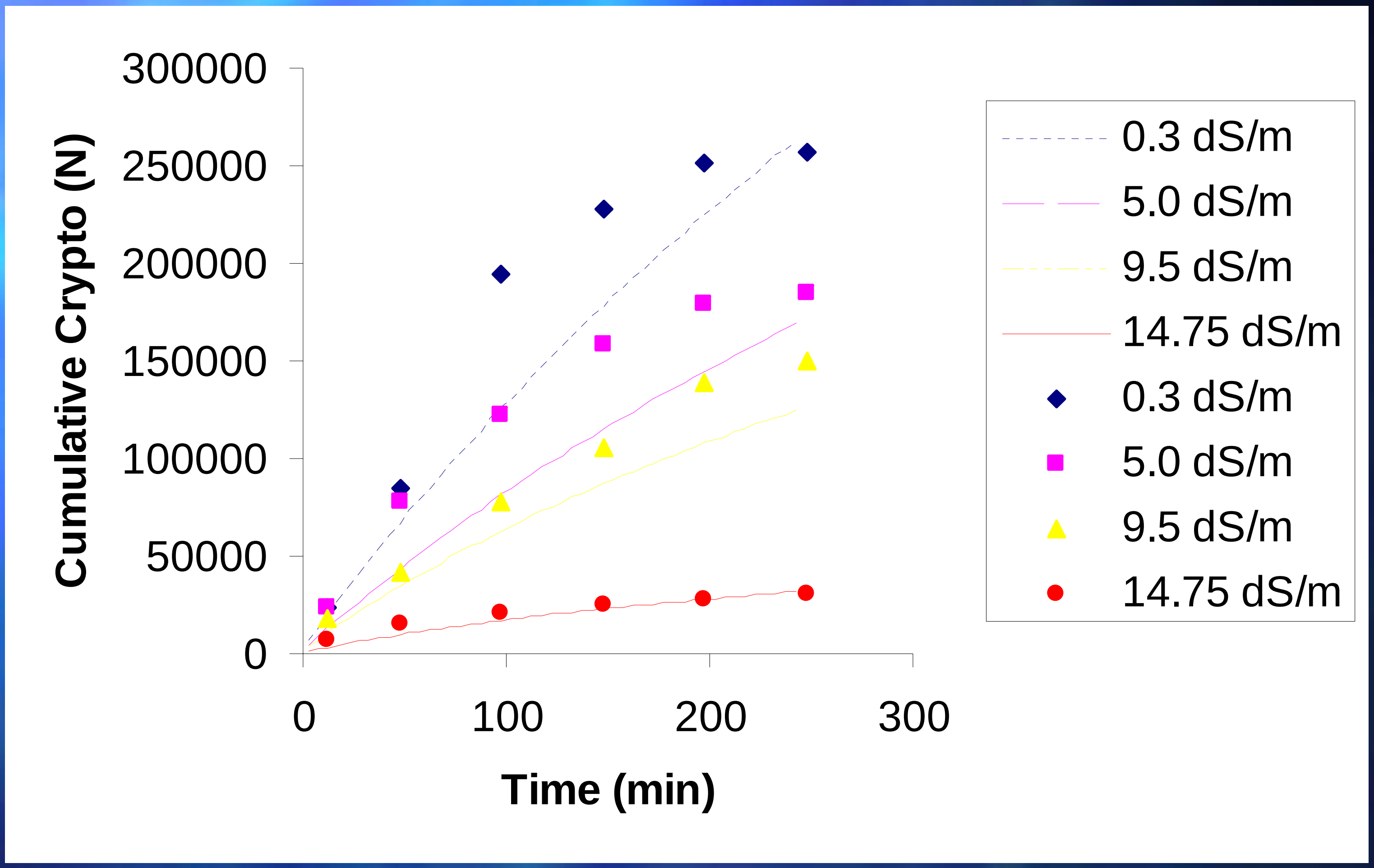


10
8
6
4
2
0
Cm (g/l)
0
100
200
300
Time (min)


y = -0.0443x + 1.0923
R^2 = 0.700
1.5
1.0
0.5
0.0
E_{ro}^{g}
0
5
10
15
20
EC (dS/m)
FIT
Model


y = 0.164Ln(x) + 0.9165
R^2 = 0.977
1.5
1.0
0.5
0.0
E_{ro}^{c}
0
0.25
0.5
0.75
1
1-(EC/15)
FIT
Model


600000
500000
400000
300000
200000
100000
0
Cumulative Giardia (N)
0
100
200
300
Time (min)
0.3 dS/m
5.0 dS/m
9.5 dS/m
14.75 dS/m
0.3 dS/m
5.0 dS/m
9.5 dS/m
14.75 dS/m



300000
250000
200000
150000
100000
50000
0
Cumulative Crypto (N)
0
100
200
300
Time (min)
0.3 dS/m
5.0 dS/m
9.5 dS/m
14.75 dS/m
0.3 dS/m
5.0 dS/m
9.5 dS/m
14.75 dS/m

Conclusions

- Effluent concentrations of manure and (oo)cysts were initially several orders of magnitude below their initial concentration in the manure.
- Increasing the solution salinity tended to decrease the manure and (oo)cyst concentrations and, hence, the cumulative amount released into the aqueous phase.
- Increasing salinity was hypothesized to stabilize the manure by compression of the diffuse double layer thickness between negatively charged colloidal material in the manure.
- (Oo)cyst release efficiencies tend to decrease with increasing salinity.
- A conceptual model was developed to predict manure and (oo)cyst release and loading rates from manure.