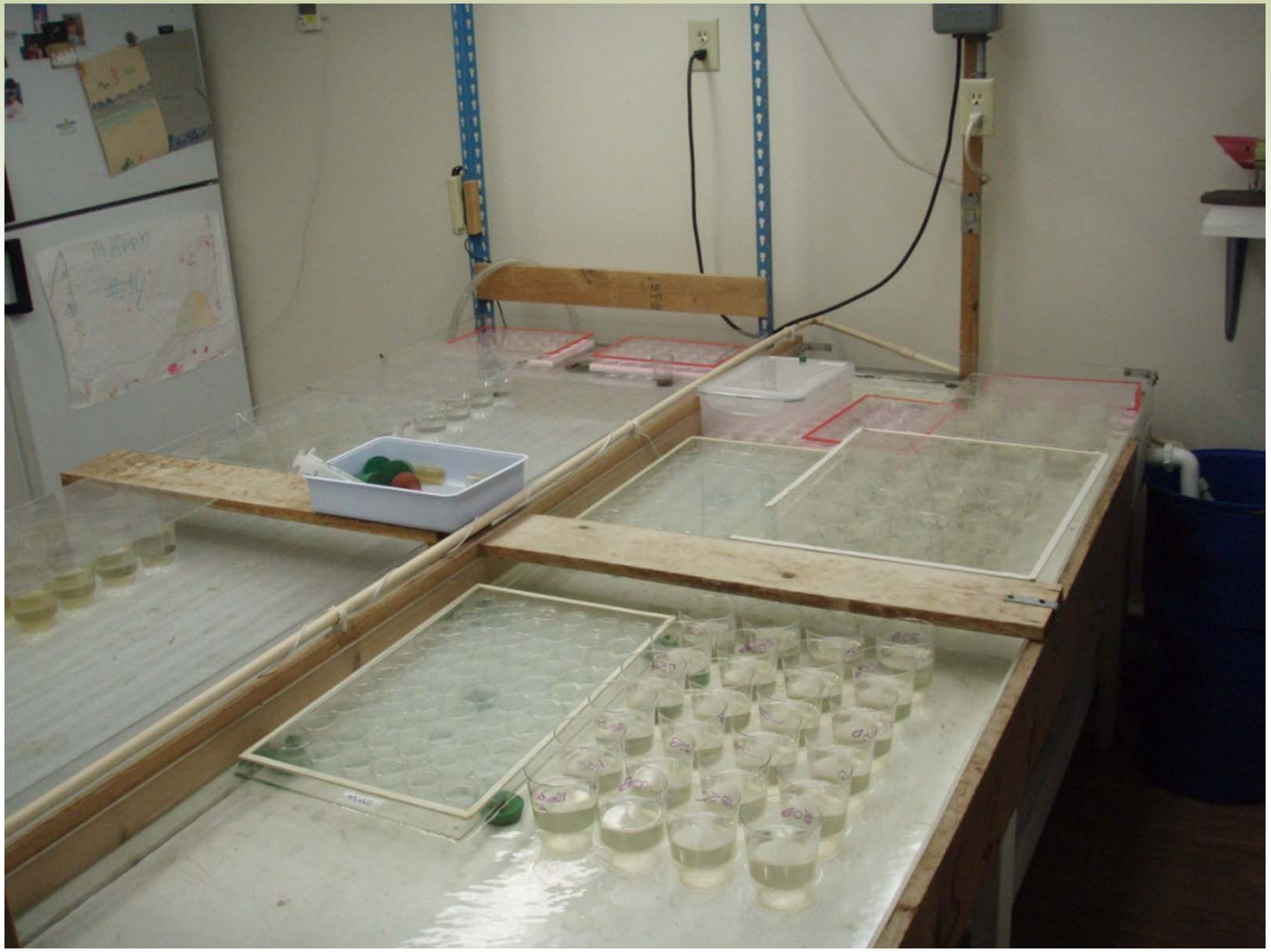
Determining the Aquatic Toxicity of Deicing Materials

- Laboratory-based study to evaluate the aquatic toxicity of liquid deicing chemicals
- Acute and "chronic" tests
- Test species
  - *Ceriodaphnia dubia*
    - Water flea, zooplankton
  - *Pimephales promelas*
    - Fish, fathead minnow
  - *Selenastrum capricornutum*
    - Algae

The Laboratory



Study Design

- Acute and chronic toxic effects
- Acute
  - 48 to 96 hour test
  - Measure survival
- Chronic
  - 7 day test (C. dubia, fathead)
  - 4 day test (algae)
  - Measure growth, reproduction, and survival
- Measureable outcome-endpoints

Study Design
endpoints

- LC50
  - Concentration at which there is a 50% reduction in survival...
- IC25
  - Concentration at which there is a 25% reduction in young production, growth...
- IC50
  - Concentration at which there is a 50% reduction in young production, growth...
- NOEC
  - Highest concentration at which there is no toxicity...

...compared to the controls

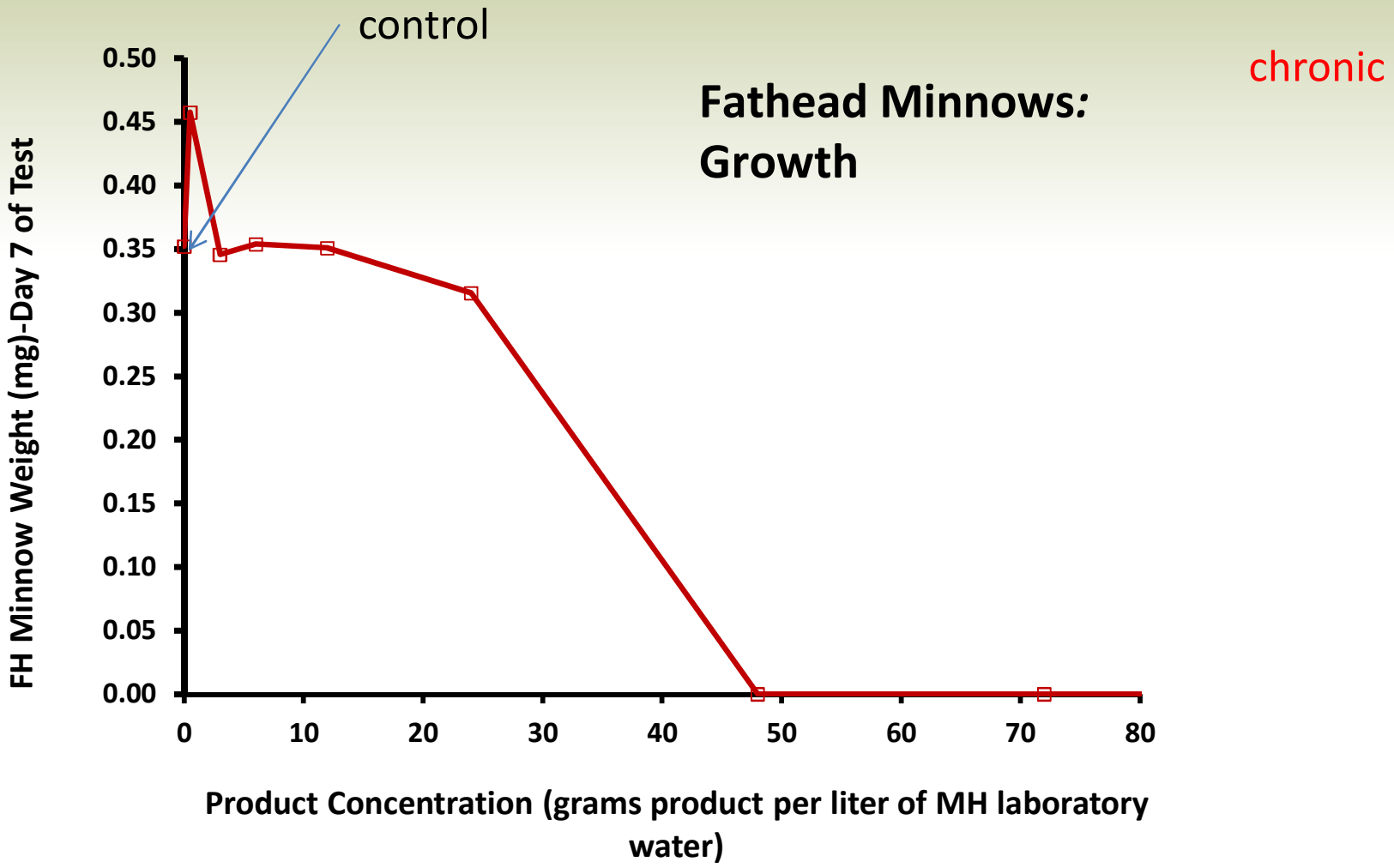
Study Design

- Dose-response
  - Add a range of volumes of deicing chemical to water
  - Get a range of responses from the test organisms
  - Result is a curve showing how the organism responds

Products Evaluated

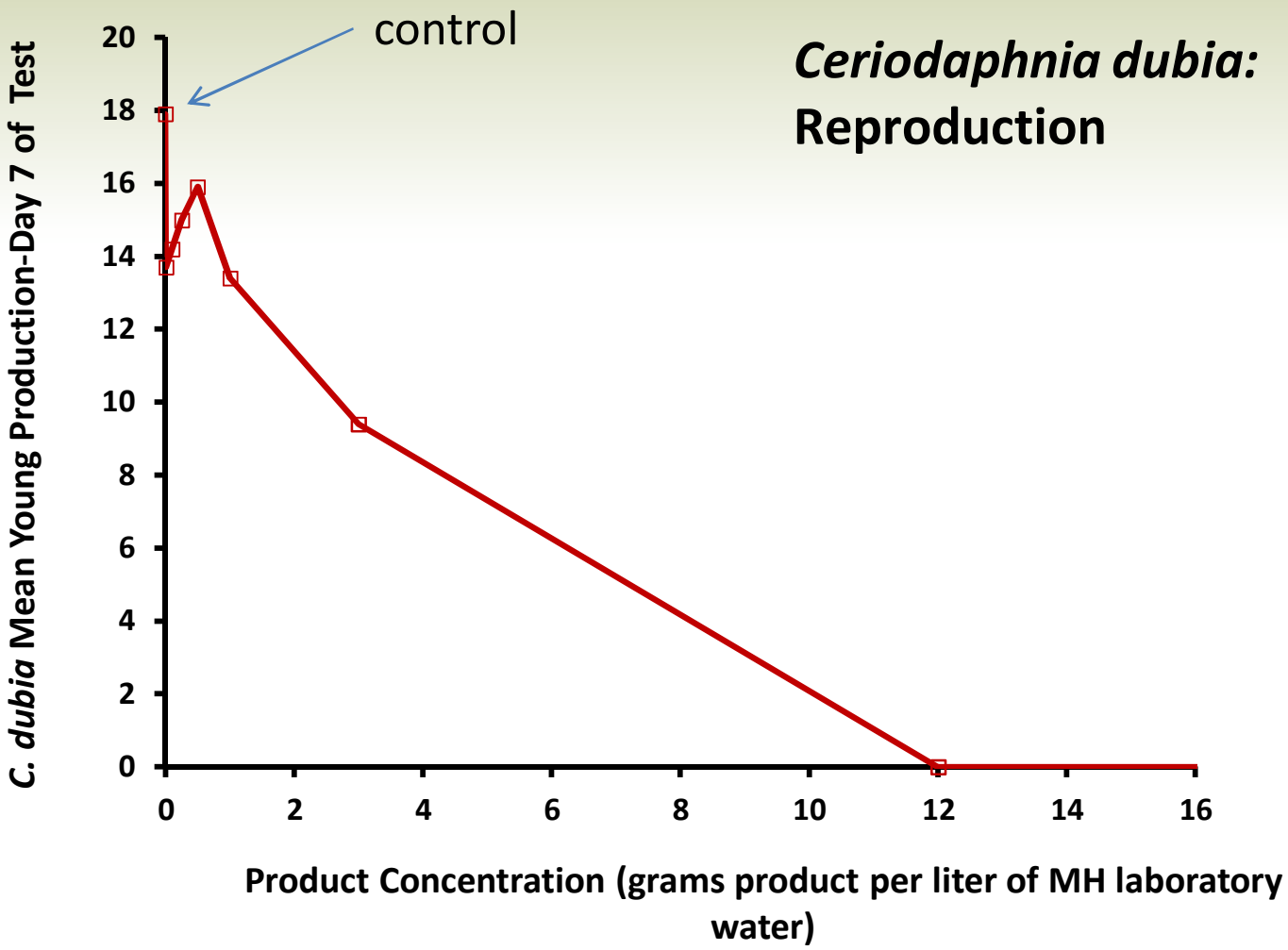
1. Watershed Cl inhibitor with sodium chloride salt brine
2. Beet 55 inhibitor with sodium chloride salt brine
3. FreezGard Cl Plus inhibitor-magnesium chloride
4. Meltdown Apex inhibitor-magnesium chloride
5. Road Guard Plus inhibitor-calcium chloride
6. Boost inhibitor-calcium chloride
7. CF-7 inhibitor-potassium acetate
8. Apogee-glycerol

Toxicity Test Dose-Response Example: Watershed CI



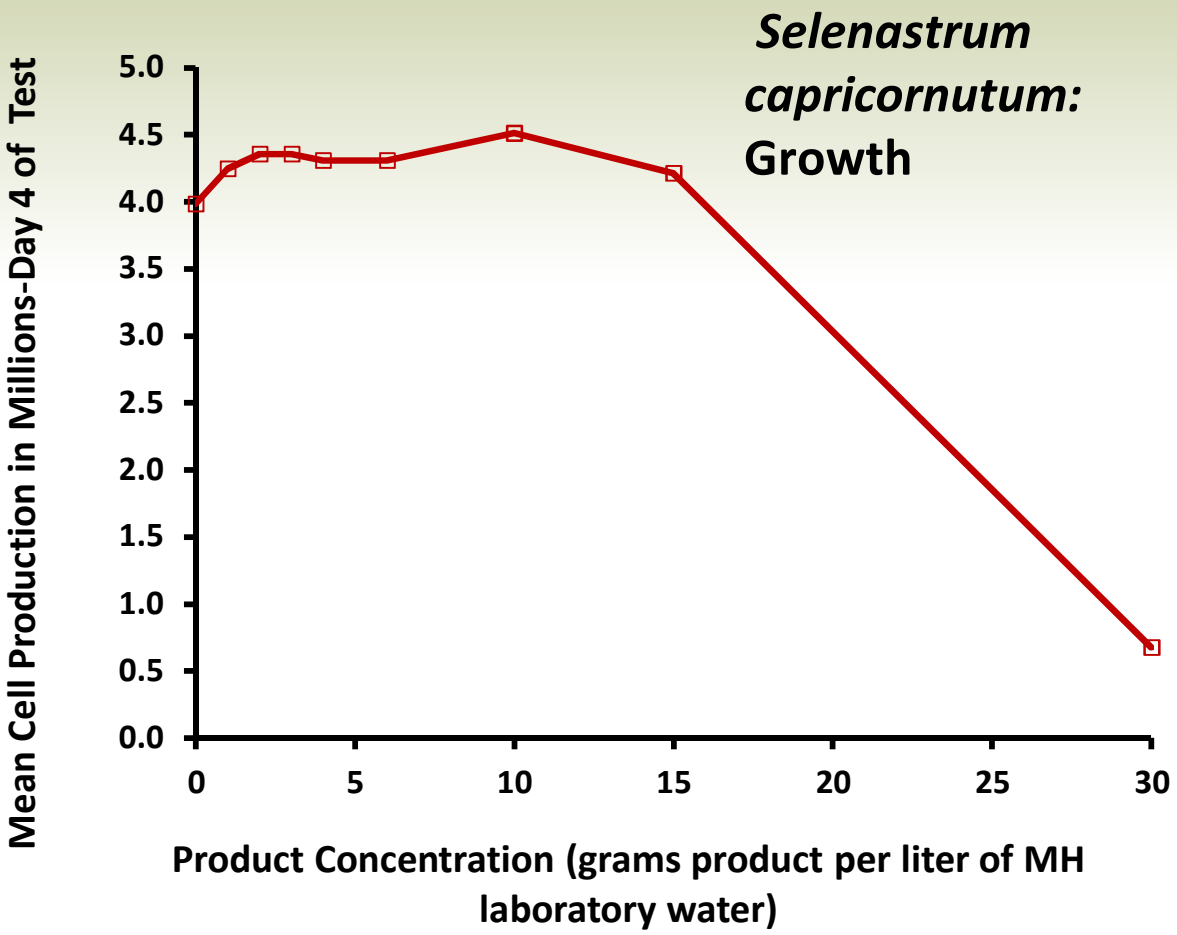
Toxicity Test Dose-Response Example: Watershed CI

chronic



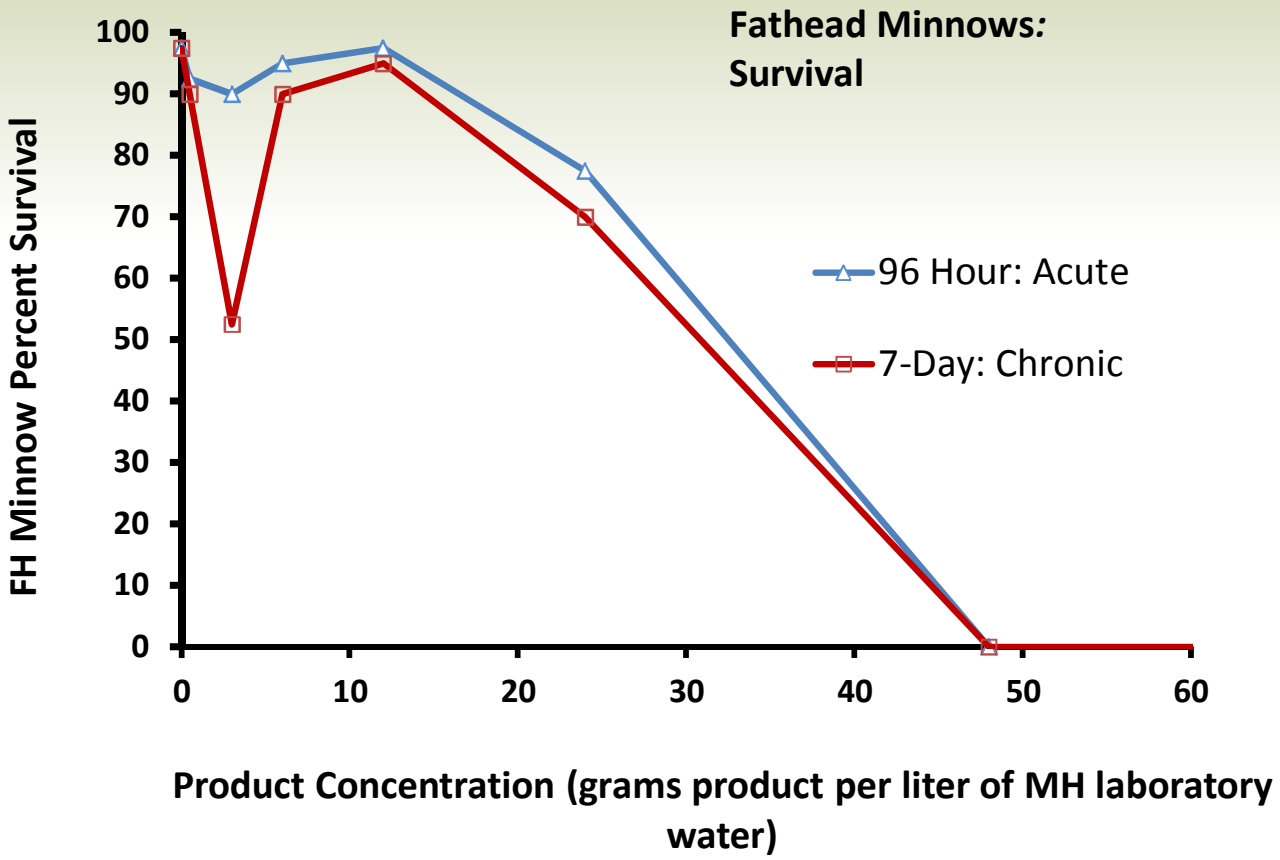
Toxicity Test Dose-Response Example: Watershed CI

chronic



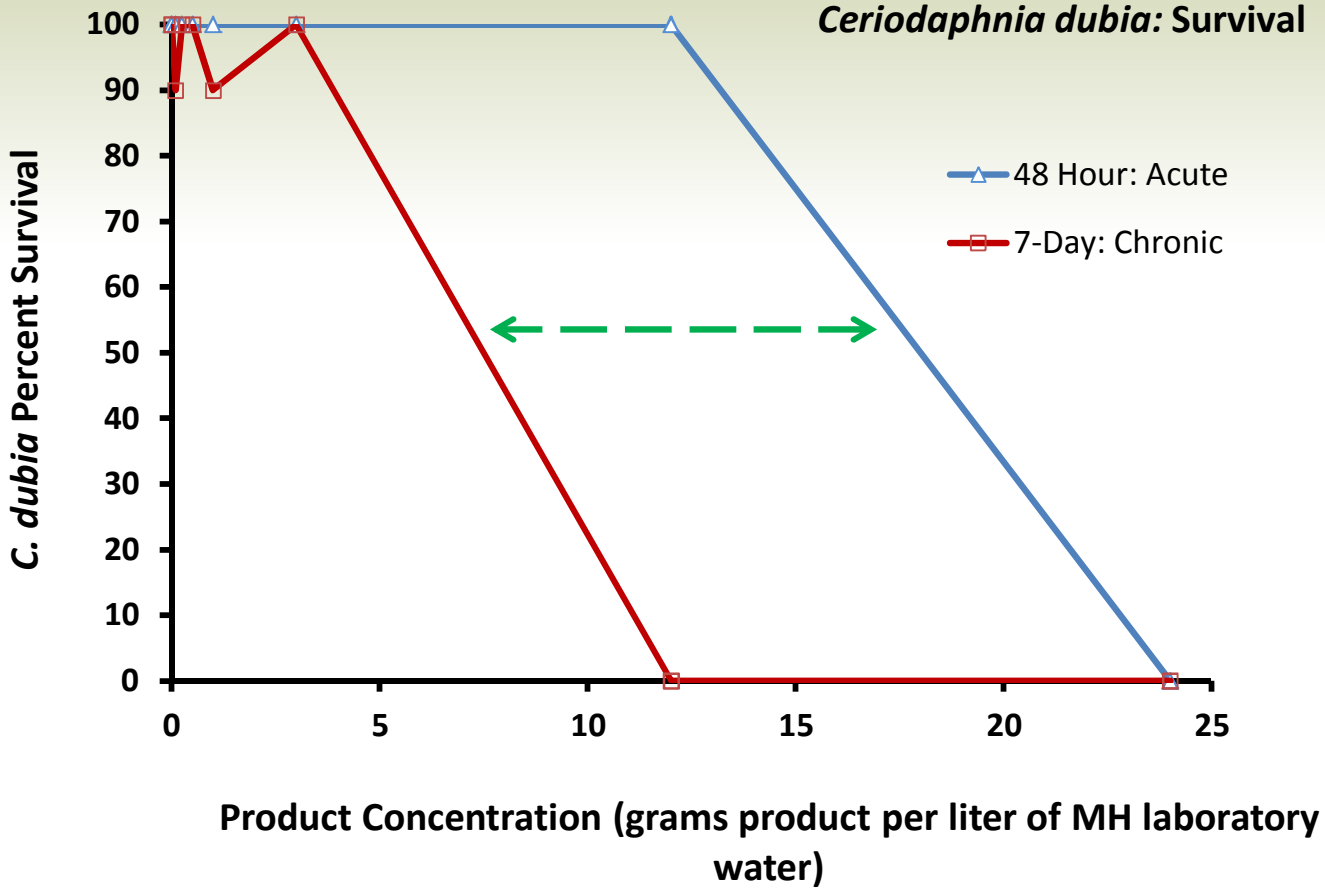
Toxicity Test Dose-Response Example: Watershed CI

Acute and Chronic



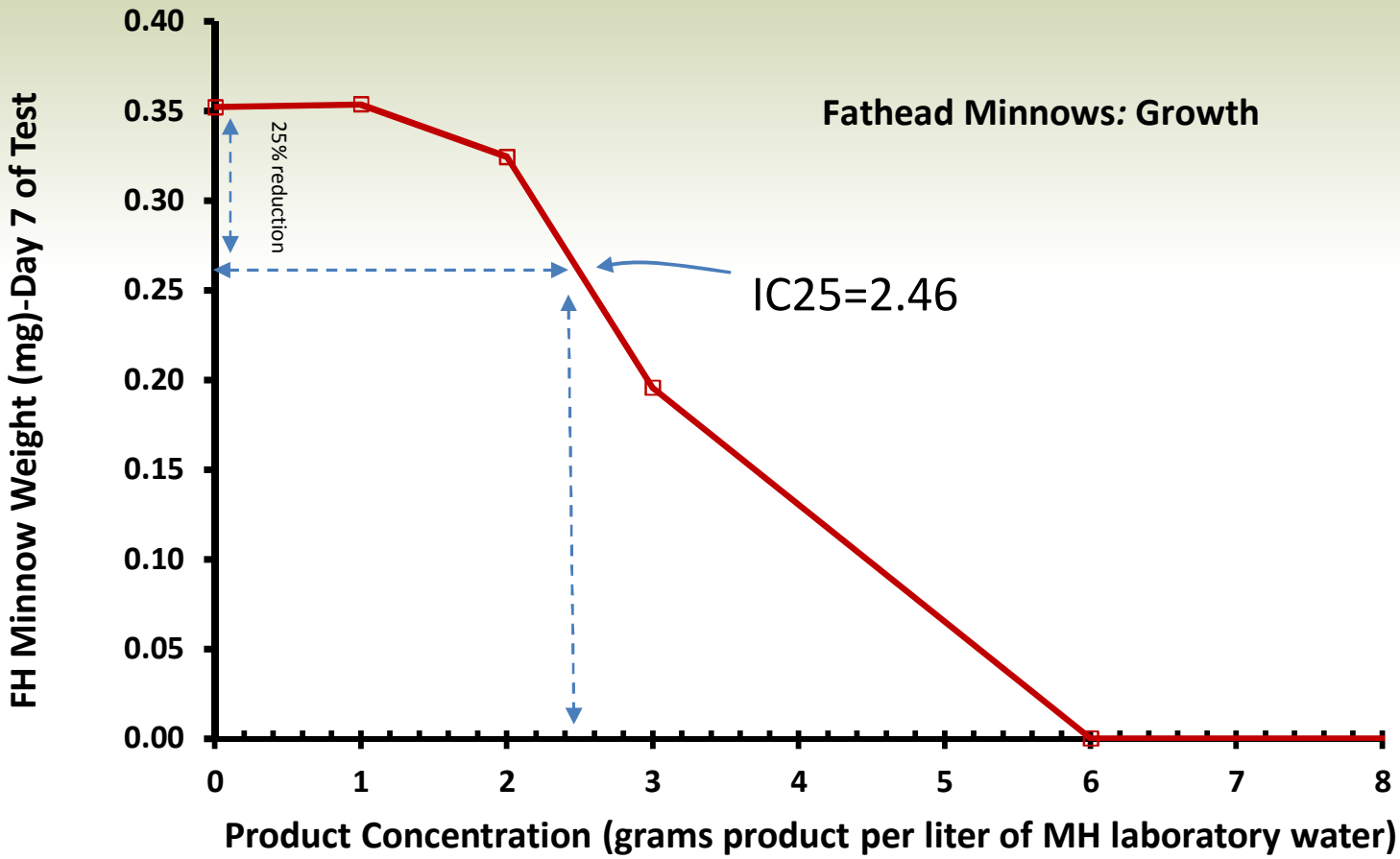
Toxicity Test Dose-Response Example: Watershed CI

Acute and Chronic



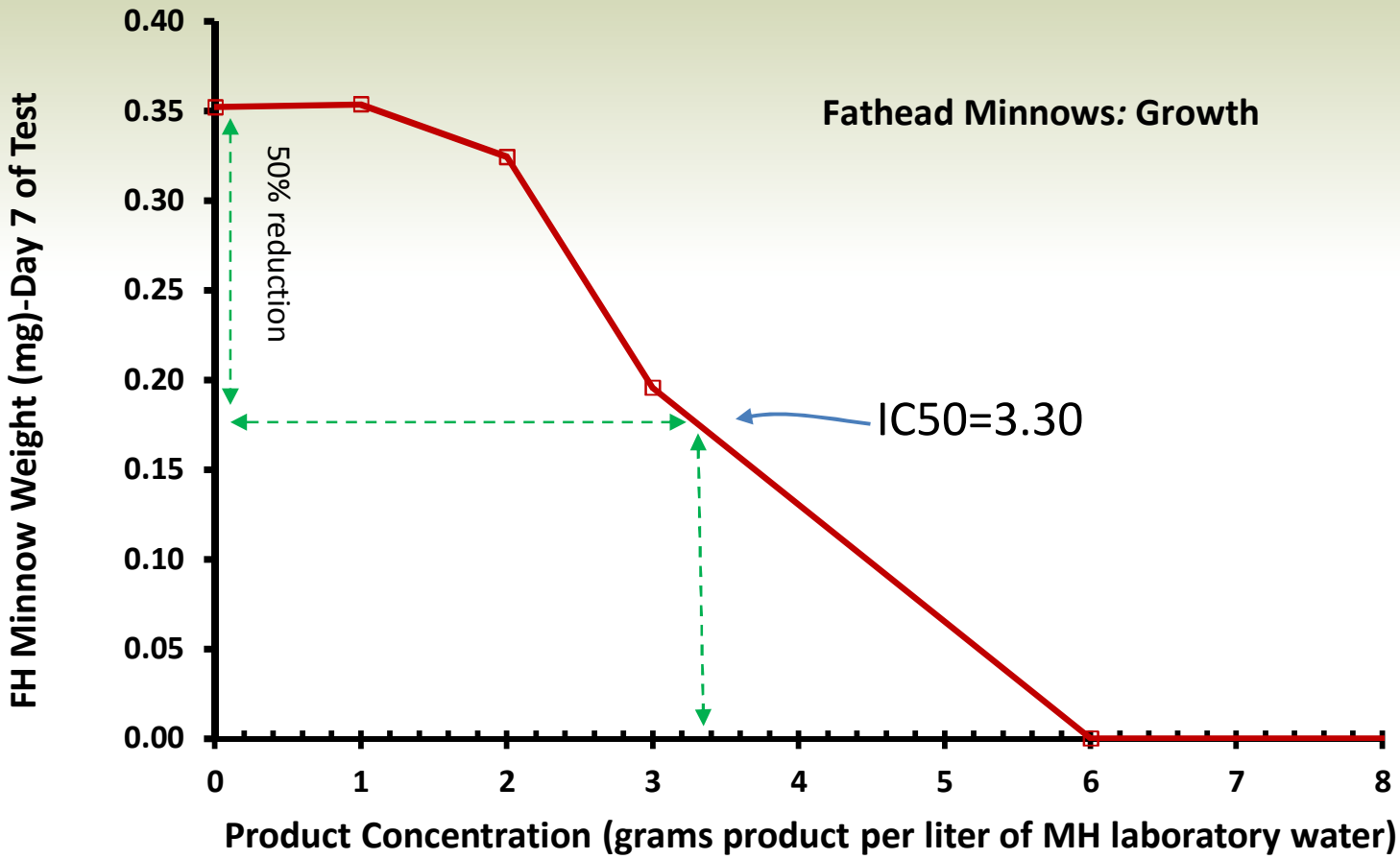
Endpoints example
RoadGard Plus

chronic



Endpoints example
RoadGard Plus

chronic



Endpoint Tables
mass based

Ceriodaphnia dubia

Product	Toxicological Endpoint as Product (grams product/liter of diluent)						
	Acute NOEC (survival)	Acute LC50 (survival)	Chronic NOEC (survival)	Chronic LC50 (survival)	Chronic NOEC (young production)	Chronic IC25 (young production)	Chronic IC50 (young production)
Watershed Cl: Inhibitor + Salt (NaCl)	12.0	17.0	3.00	4.81	1.00	0.990	3.43

Mass of Product/Volume of Diluent = Mass of liquid product diluted in runoff and the receiving water body

Endpoint Tables
volume based

Ceriodaphnia dubia

Product	Toxicological Endpoint as Product (milliliters of product/liter of diluent)(1)						
	Acute NOEC (survival)	Acute LC50 (survival)	Chronic NOEC (survival)	Chronic LC50 (survival)	Chronic NOEC (young production)	Chronic IC25 (young production)	Chronic IC50 (young production)
Watershed Cl : Inhibitor + Salt (NaCl)	9.4	13.3	2.3	3.8	0.8	0.8	2.7

Volume of Product/Volume of Diluent = volume of liquid product diluted in runoff and the receiving water body

For the practitioner!

Endpoint Tables
salt content based

Ceriodaphnia dubia

Product	Chemical Used for Endpoint Calculation	Stock Concentration (grams salt / liter of product)[2]	Toxicological Endpoint as Primary Salt (milligrams salt/liter of diluent)[1]						
			Acute NOEC (survival)	Acute LC50 (survival)	Chronic NOEC (survival)	Chronic LC50 (survival)	Chronic NOEC (young production)	Chronic IC25 (young production)	Chronic IC50 (young production)
Watershed Cl : Inhibitor + Salt (NaCl)	Na + Cl	288	2705	3826	676	1084	225	223	773
Beet 55: Inhibitor + Salt (NaCl)	Na + Cl	224	1760	2782	17.6	102	1.76	12.4	64.8

Mass of salt per volume of product/volume of diluent = mass of salt diluted in runoff and the receiving water body

To normalize products based upon salt mass per unit volume and to promote comparison

Which inhibitor is more chronically toxic?

Ranking

Ranking by Total Product Mass

Product	Relative Toxicological Rank
Watershed CI: Inhibitor + Salt (NaCl)	1
Boost (CaCl2)	2
Road Guard Plus (CaCl2)	3
Beet 55: Inhibitor + Salt (NaCl)	4
FreezGard CI Plus (MgCl2)	5
Apogee (Glycerol)	6
Meltdown Apex (MgCl2)	7
CF-7 (K-Acetate)	8

Ranking by Salt Mass

Product	Relative Toxicological Rank
Watershed CI: Inhibitor + Salt (NaCl)	1
Boost (CaCl2)	2
Road Guard Plus (CaCl2)	3
FreezGard CI Plus (MgCl2)	4
Meltdown Apex (MgCl2)	5
Beet 55: Inhibitor + Salt (NaCl)	6
CF-7 (K-Acetate)	7

Ranking by Salt Type

For this current study (from most to least toxic):

K-Acetate > $MgCl_2$ > $CaCl_2$ > NaCl

Salt only toxicity from the literature:

K-Acetate > $MgCl_2$ > $CaCl_2$ = NaCl

Other Observations
dissolved oxygen

Dissolved Oxygen Measured During The Test

Product	*C. dubia*		Fathead Minnow		*Selenastrum Capricornutum*
	Dissolved Oxygen (mg/L)				
	At Acute LC50	At Chronic IC50	At Acute LC50	At Chronic IC50	At IC50
Watershed CI : Inhibitor + Salt (NaCl)	7.91	8.09	5.1	6.54	9.49
Beet 55: Inhibitor + Salt (NaCl)	4.26	7.69	1.70	6.24	9.64
FreezGard CI Plus ($MgCl_2$)	7.96	8.04	4.70	7.09	9.53
Meltdown Apex ($MgCl_2$)	8.07	8.19	7.20	7.38	8.14
Road Guard Plus ($CaCl_2$)	7.24	7.74	4.24	4.60	8.16
Boost ($CaCl_2$)	5.54	7.33	3.28	3.97	9.01
CF-7 (K-Acetate)	7.29	7.98	4.64	6.50	9.05
Apogee (Glycerol)	7.16	7.70	4.54	5.58	9.78

Reminder: Daily Renewals

Dissolved oxygen effects still possible in the receiving water body

Other Observations
species sensitivity to products

Acute Toxicity:

more sensitive.....less sensitive

fathead minnow > *Ceriodaphnia dubia*

(96 hour test) (48 hour test)

Chronic Toxicity:

more sensitive.....less sensitive

Ceriodaphnia dubia >>> Selenastrum > fathead minnow

(7 day test) (4 day test) (7 day test)

Conclusions

- Testing provided high-quality data set for a selected number of liquid deicing products
- Testing results can be used to make estimates of potential toxicological impact on receiving waters, recognizing that:
  - Receiving water may have different chemistry than the laboratory water used in this study
  - Some of the product may be retained in soils and this will need to be considered in any impact assessment.
- Acute or chronic data use
  - Depends upon typical storm length for given region of country
  - Depends upon the receiving water body, e.g.
    - Large river = acute
    - Lake = chronic

Conclusions: potential future work

- Temperature
  - Need to determine if these products are more or less toxic at low temperatures
- Longer term dissolved oxygen loss and effects on toxicity
- Product retention and decay
- Study effects with exposure periods representative of storm events