Phosphorus treatment in onsite septic systems

Why would we do it and what is the present state of the art?

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Massachusetts Alternative Septic System Test Center
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Phosphorus

- A key “limiting nutrient” in freshwater systems
- When phosphorus enters freshwater ecosystems and nitrogen becomes limiting then harmful algae blooms (HAB) form and present a public health hazard.
- Once phosphorus enters a freshwater ecosystem, it becomes the “gift that keeps on giving” (there is no gaseous phase for removal.

What's the big deal about a little algae?

Health Impacts of Cyanotoxins

CLEAN WATER ACTION
CLEAN WATER FUND

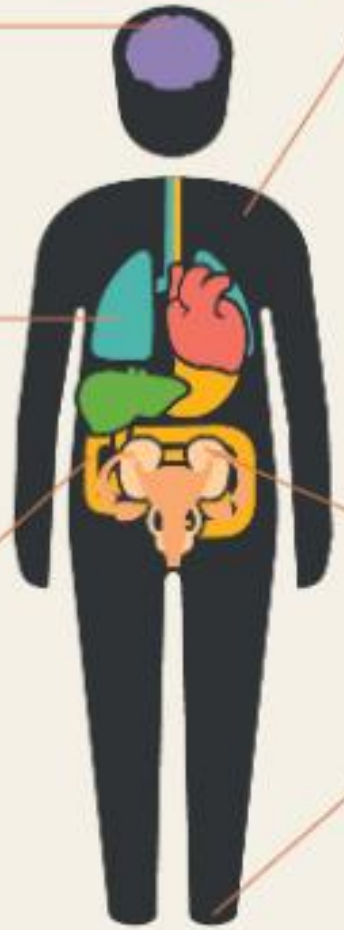
Note: *Not all cyanotoxins lead to all of these health impacts. These listed impacts are caused by microcystins or cylindrospermopsin, the two cyanotoxins that EPA has issued Health Advisories for.*

IN HUMANS

Brain
Source: Ingestion
Symptoms:
- Headache
- Incoherent speech
- Drowsiness
- Loss of coordination

Respiratory System
Source: Inhalation
Symptoms:
- Dry cough
- Pneumonia
- Sore throat
- Shortness of breath
- Loss of coordination

Digestive System
Source: Ingestion, drinking contaminated water, or eating contaminated fish
Symptoms:
- Abdominal pain
- Nausea
- Vomiting
- Diarrhea
- Stomach cramps



Body
Source: Contact, e.g. swimming
Symptoms:
- Irritation in eyes, nose, and throat
- Blistering around the mouth
- Skin rash, including tingling, burning and numbness
- Fever
- Muscle aches (from ingestion)
- Weakness (from ingestion)

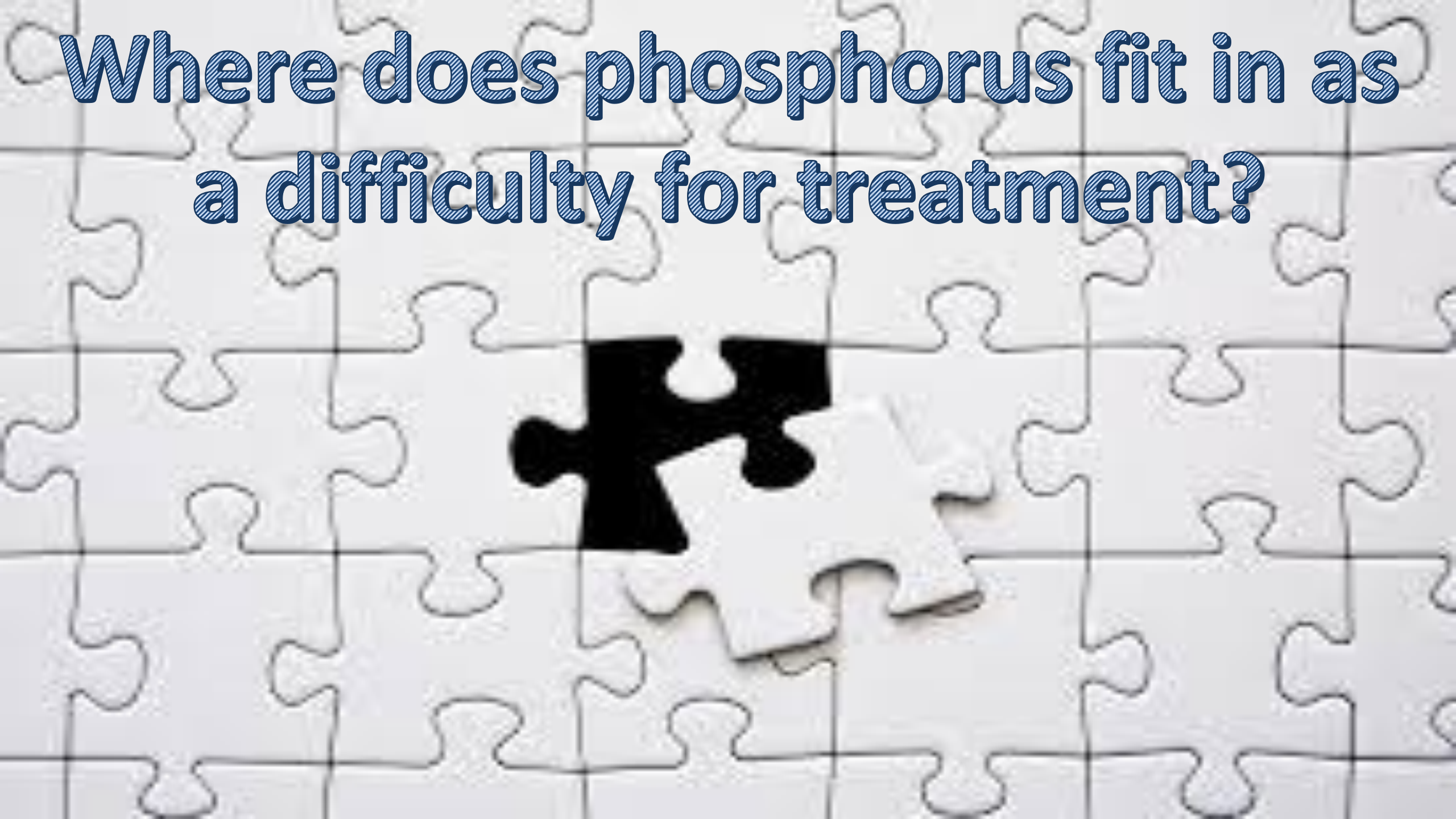
Organs
Source: Ingestion
Symptoms:
- Kidney damage
- Abnormal kidney function
- Liver inflammation

Nervous System
Source: Ingestion
Symptoms:
- Tingling
- Burning
- Numbness

IN PETS

Symptoms:
Vomiting
Fatigue
Shortness of breath
Difficulty breathing
Coughing
Convulsions
Liver failure
Respiratory paralysis leading to death

Where does phosphorus fit in as a difficulty for treatment?



Challenges for onsite septic system treatment

?

Contaminants of emerging concern

Nutrient Phosphorus

Nutrient Nitrogen

Pathogens (bacteria and viruses)

Wastewater “Stabilization” (removal of oxygen demand oxidation of ammonia)

Dispose of volume

Challenges for onsite septic system treatment

?

Contaminants of emerging concern

Nutrient
Phosphorus

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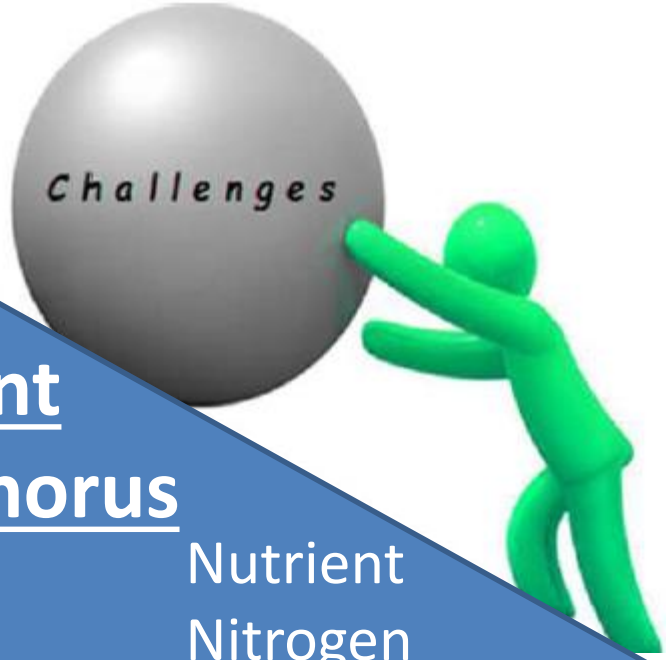


Nutrient Phosphorus

Nutrient Nitrogen

Pathogens (bacteria and viruses)

Wastewater "Stabilization" (removal of oxygen demand oxidation of ammonia)

Dispose of volume

Increasing difficulty

What is the state of the art ?

- Two technologies with Pilot Approval in the Commonwealth of Massachusetts
- At least two additional technologies available but that have not sought approval
- Two soil absorption system techniques that can attenuate phosphorus are available
- One diversion technique is approved but not generally accepted

Systems with Pilot Approval

PhosRID™

“RID” stands for Reactive Iron Dissolution – Iron is combined with phosphorus to make insoluble compounds to immobilize the phosphorus. “Sacrificial” media needs to be replaced at some point

The PhosRID ™ unit

- concrete tank filled with iron-rich porous media
- iron solids in the media are designed to react with the carbon and phosphate to form solids such as vivianite and strengite
- $CH_2O + 4Fe(OH)_3 + 7H^+ \rightarrow 4Fe^{2+} + HCO_3^- + 10H_2O$
- $3Fe^{2+} + 2PO_4^{3-} + 8H_2O \rightarrow Fe3(PO_4)_2 \cdot 8H_2O$ (vivianite)
- $Fe^{3+} + PO_4^{3-} + 2H_2O \rightarrow Fe_3(PO_4) \cdot 2H_2O$ (strengite)

The PhosRID ™ unit

Total Phosphorus. Mean 5.2 mg/l Median 5.2 mg/l

Total Phosphorus Mean 3.9 mg/l Median 4.1 mg/l

Iron Dissolution (solubilized iron combines with phosphate)

Total Phosphorus. Mean 0.2 mg/l Median 0.3 mg/l

Septic Tank

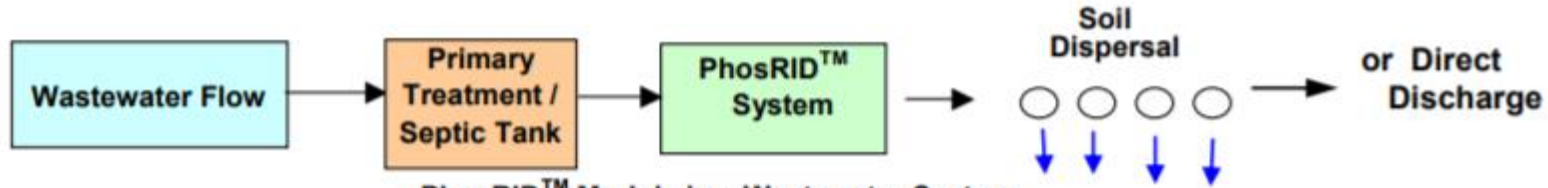
Influent

Mean 5.7 mg/l
Median 5.7 mg/l

Soluble iron compounds containing phosphorus precipitate on sand filter

Remaining iron-phosphorus compounds precipitate on sand as strengite

Source: http://www.lombardoassociates.com/pdfs/phos-rid.pdf



PhosRID™ Module in a Wastewater System

Environmental Engineers/ Consultants

LOMBARDO ASSOCIATES, INC.

188 Church Street
Newton, Massachusetts 02458
www.LombardoAssociates.com
Tel: 617-964-2924
Fax: 617-332-5477
Pio@LombardoAssociates. com

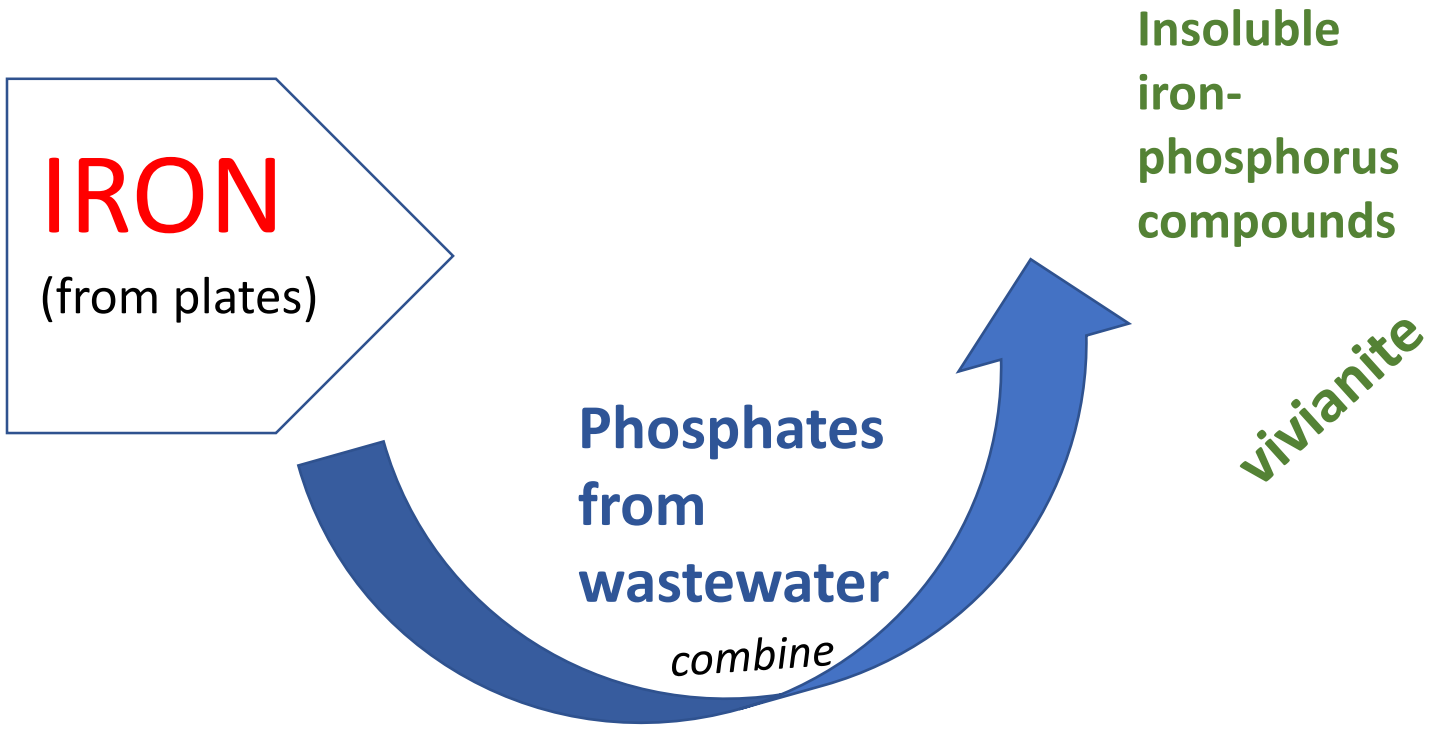
	Site #1 56 Meadow View Drive					Site #2 11 Columbus Ave					Site #3 76 Millbrook				
Date	Average Monthly Flow (gpd)	Septic Tank Effluent TP (mg/l)	PhosRID™ System Effluent (mg/l) TP	BOD	TSS	Average Monthly Flow (gpd)	Septic Tank Effluent TP (mg/l)	PhosRID™ System Effluent (mg/l) TP	BOD	TSS	Average Monthly Flow[1] (gpd)	Septic Tank Effluent TP (mg/l)	PhosRID™ System Effluent (mg/l) TP	BOD	TSS
07/05/07		1.83	0.12			130.9	1.30	<0.02							
08/09/07		9.5	0.1			144.9	4.10	0.08							
09/11/07		9.5	0.11	<4		35.2	5.00	0.04	<4						
12/17/07		8	0.07	<4	<2	17.7	6.30	<0.02	<4	<2					
03/26/08						1.6	9.50	0.03	<4	<2	180.6				
05/14/08						57.9						2.4	0.11	<4	6.0
06/25/08						96.6	4.10	<0.02	12.0	5.0	129.2	2.8	<0.02	<4	<4
07/31/08						307.1					131.2	2.7	<0.02	<4	<2
09/30/08						50.3	8.00	0.03	44.0	17.0					
10/30/08						5.1					85.2	4.2	<0.02	<4	<2
01/28/09						0.7	8.70	<0.02	<12	4.0	123.7	5.3	<0.02	<4	<2
04/30/09											62.8	6.5	0.07		
07/22/09						11.2	4.95	0.03	16.0	<2					
09/10/09							5.70	0.18	<4	10.0					
09/24/09											111.7	3.9	0.01	<4	14
12/23/09												4.2	<0.01	<4	17
05/20/10												4	<0.02	<4	2
07/02/10						29.2	4.50	<.0.02	<4	5.0					
09/30/10												4.8	<0.02	<4	3
11/30/10						90.4	4.5	<0.02	<4	2		3	<0.02	<4	<2
06/23/11												4.8	<0.02		
Average		*7.21*	*0.10*	*<4*	*<2*	*81.1*	*5.77*	*0.05*	*10.8*	*5.6*	*130.0*	*3.98*	*0.03*	*<4*	*<3*
Percent P Removal			98.6%					99.1%					99.3%		

PhosRID™

Waterloo
BIOFILTER

Natural iron electrodes are dissolved into the sewage stream as ferrous ions, where they react with phosphorus to form insoluble P-based minerals downstream of the electrodes.

Waterloo BIOFILTER

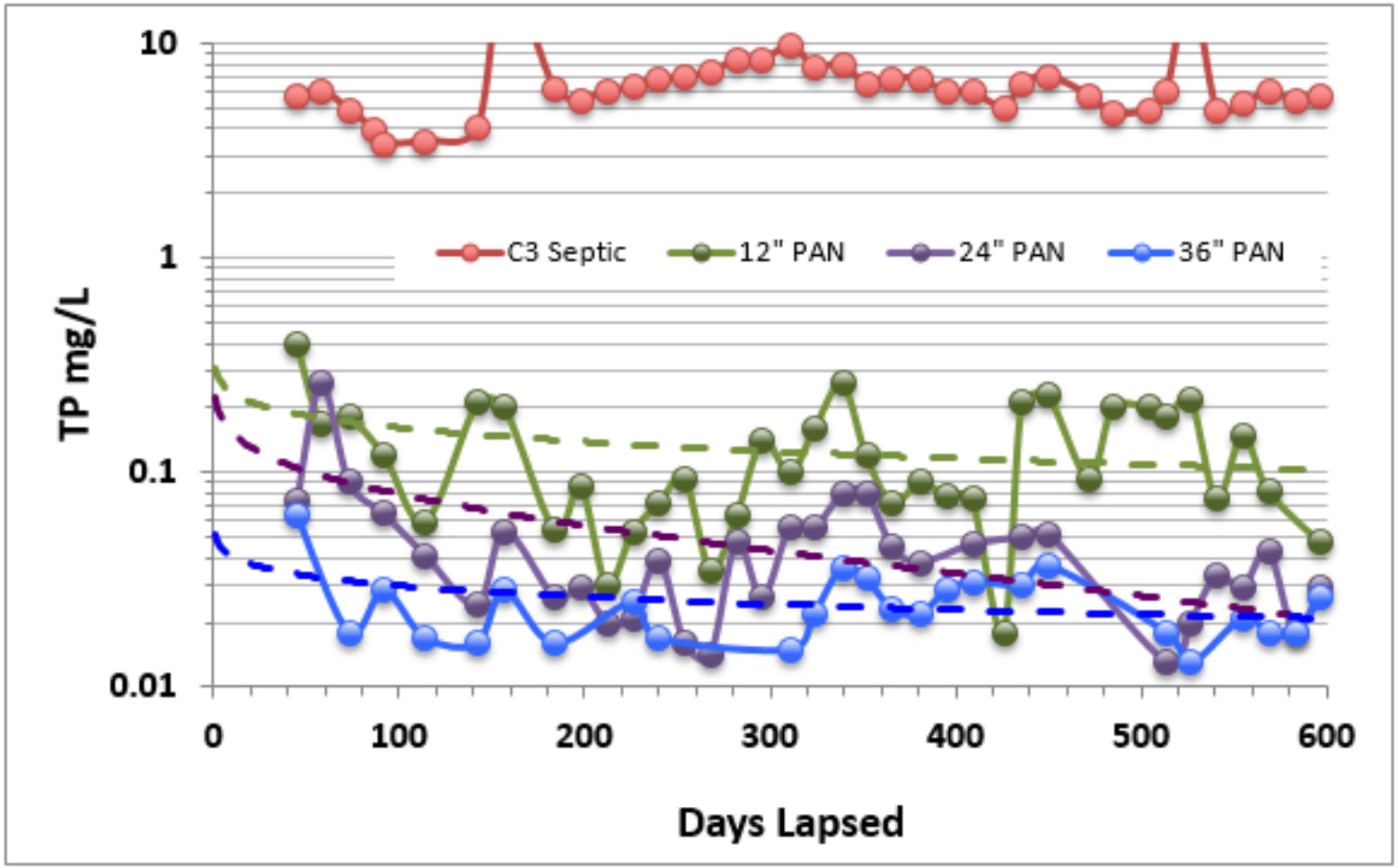


The technology is abiotic, thus temperature independent, consumes ~0.5 kW-hr per day per residence, is largely independent of water characteristics, has no sludge or reactive medium issues, and has no adverse effect on pH

Waterloo EC-P™ (Residential)

Waterloo BIOFILTER

ADVANCES IN PHOSPHORUS REMOVAL IN SEPTIC SYSTEMS
Craig Jowett, Lingling Wu, Jianhui Sun, Christopher James
PAPER PRESENTED AT NOWRA CONFERENCE 2014



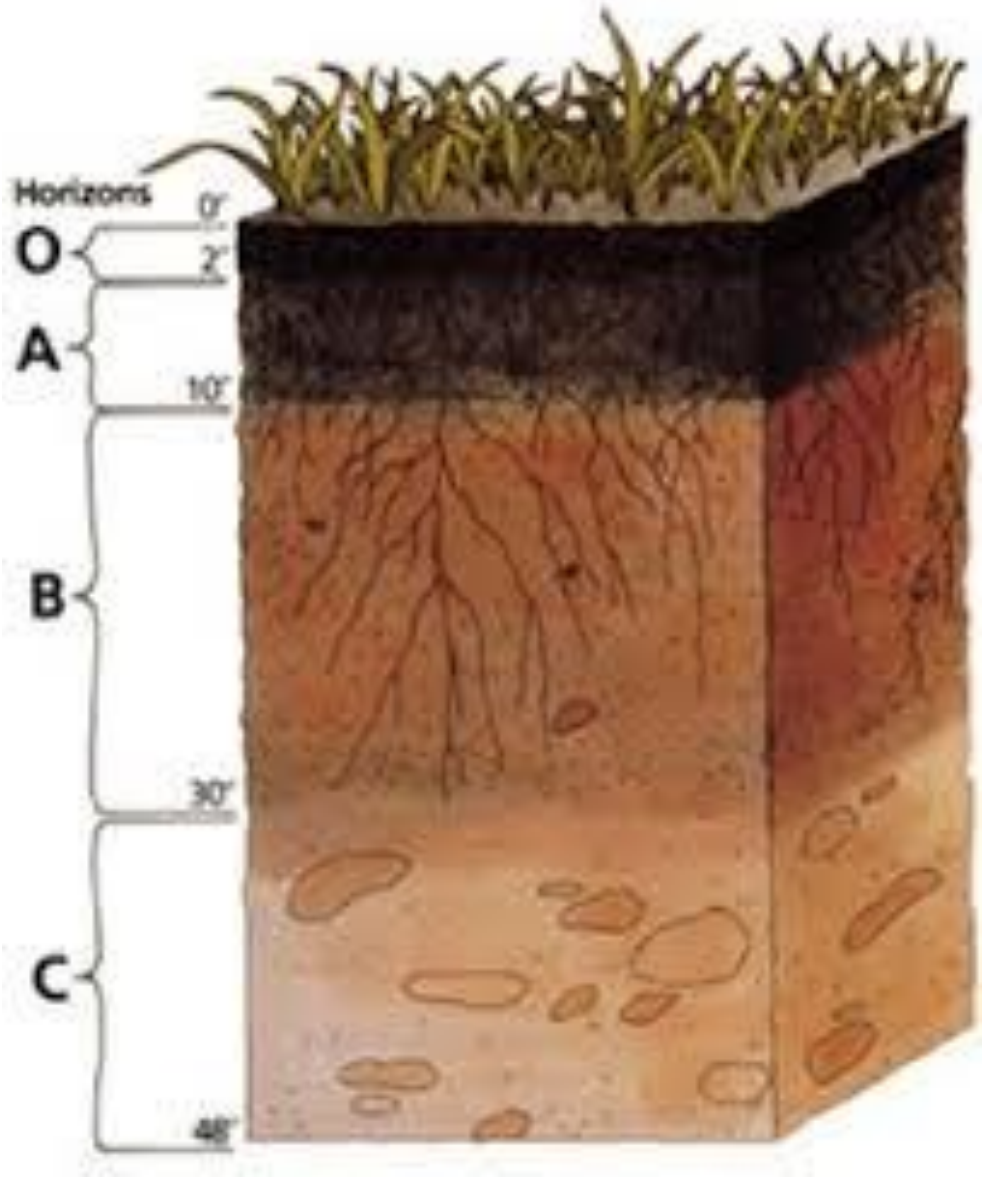
Waterloo BIOFILTER

One Installation in Brewster to begin testing Spring 2019


APPROVED

Ways to encourage the natural processes?

Use the B soil horizon to situate disposal means



Source: https://iwaponline.com/wst/article/77/8/1967/38609/Removal-of-sewage-phosphorus-by-adsorption-and

Soil – Doing what comes naturally

A Horizon

- Soil organic matter degrades to form CO2 and carbonic acid ($H_2CO_3 = H^+ + HCO_3^-$)
- Protons (H^+) help break down Fe-rich silicate minerals, releasing ferrous ions (Fe^{2+}) into solution.
- Organic matter also fosters microorganisms that reduce Fe^{3+} to Fe^{2+}, mobilizing Fe until it encounters an area suitable for precipitation.
- In the oxidizing B-horizon soil, ferrous iron converts to ferric iron (Fe^{3+}), which readily precipitates as the characteristically colored yellow, red, and brown hydroxides.

Source: https://iwaponline.com/wst/article/77/8/1967/38609/Removal-of-sewage-phosphorus-by-adsorption-and

Soil – Doing what comes naturally

B Horizon

- The dissolved iron percolates downwards and precipitates, primarily as oxidized ferric iron oxides and hydroxides, where it becomes part of the underlying B-horizon mineral matrix
- Reactive phosphorus dissolved in water passing through the B-horizon soil binds chemically to iron oxides to ultimately form iron-phosphate minerals
- Stable, insoluble Fe-P minerals form in both oxic and anoxic conditions, e.g., as strengite [$FePO4 \cdot 2H2O$] in oxidizing, ferric ($Fe3+$) conditions, and as vivianite in reducing, ferrous ($Fe2+$) conditions. Strengite has a solubility product constant Ksp = 10^{-22} and vivianite has a Ksp = 10^{-36}.

Advantages to soil-based phosphorus removal

- It’s passive
- Maintains phosphorus in an area where it can be recycled into the soil biomass

Disadvantages to soil-based phosphorus removal

- It is finite in its capacity
- At some point the exhausted soil only passes the phosphorus downstream.

Perc-Rite™ Drip Dispersal

GeoMat™

Shallow soils-based systems that integrate wastewater disposal and treatment by optimizing natural processes are also effective at attenuating phosphorus.

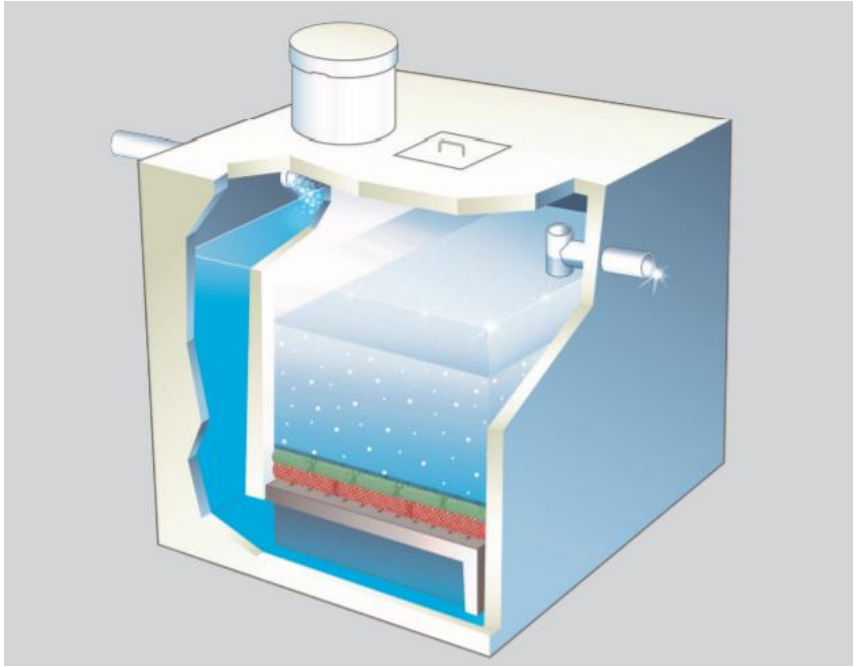
Technologies not yet approved In the Commonwealth of Massachusetts

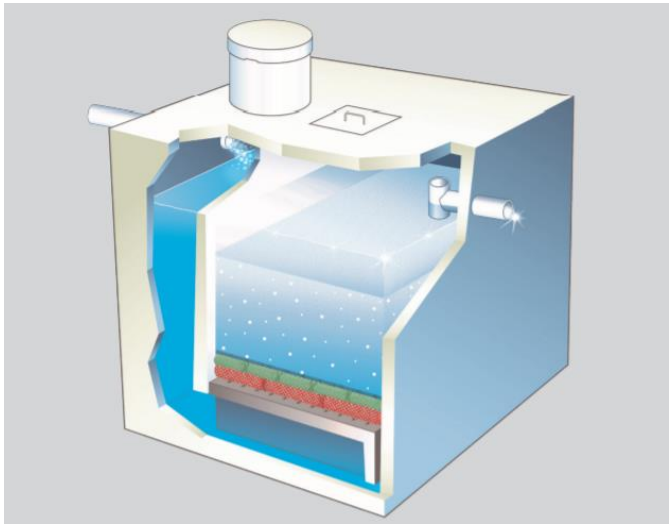
- Passive unit following septic tank or treatment unit
- Uses gravity dispersal over an adsorptive media layer

norweco®

PHOS-4-FADE®

PHOSPHORUS REMOVAL FILTER





norweco®

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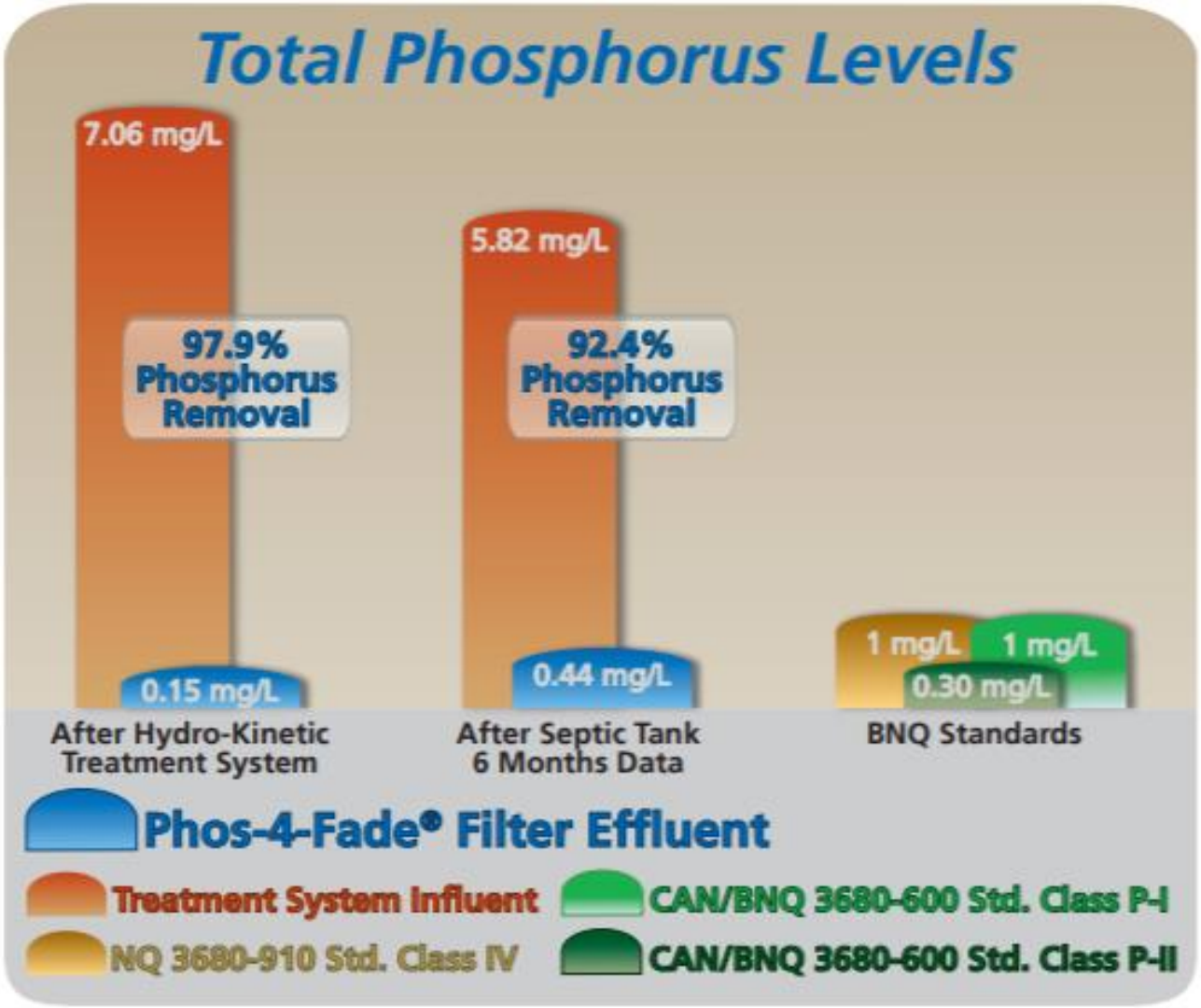


PREMIER TECH AQUA

BNQ Certified NQ 3680-510

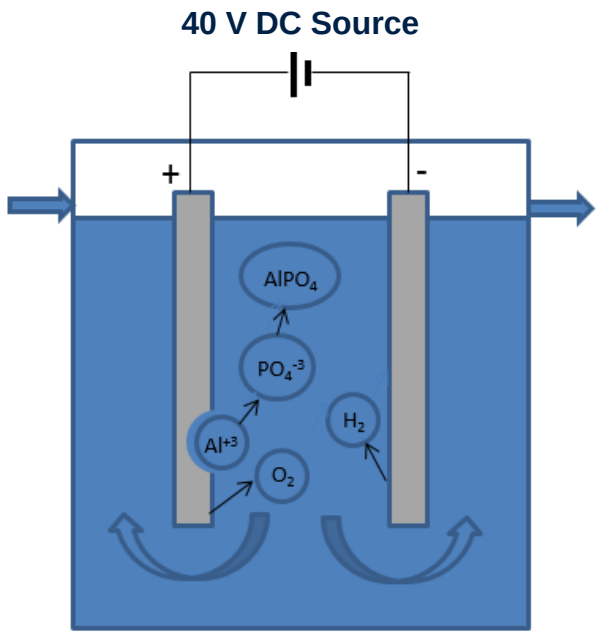
CAN/BNQ Certified NQ 3680-600

DpEC

Self-Cleaning Phosphorus Removal Unit

The Electro-Coagulation (EC) Principle

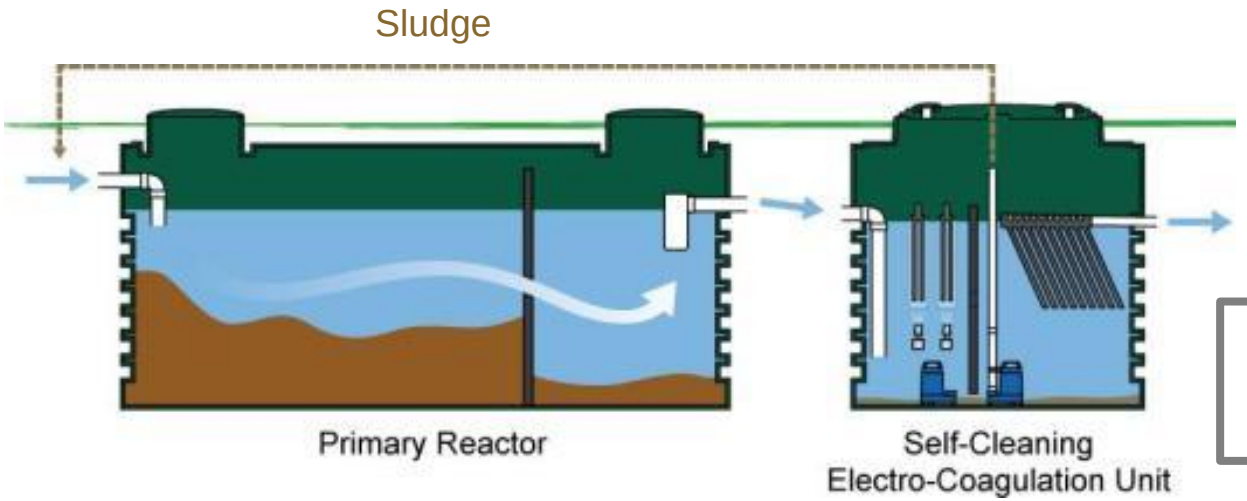
- Principle of EC: low intensity electric current (DC) applied between 2 submerged electrodes.
- PO_4^{-3} is removed from wastewater by allowing it to react with Al^{+3} cation, which will precipitate under the form of $AlPO_4$.



PREMIER TECH AQUA

System Description

- Phosphorus removal unit using electro-coagulation (EC)
  (Patent pending in Canada, United States and Europe)



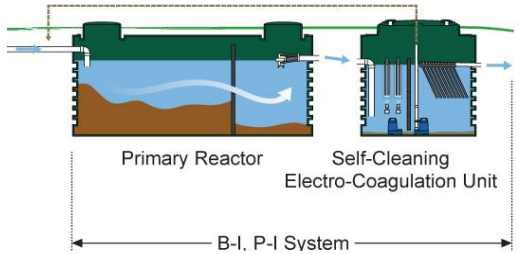
TSS: 30-40 mg/L
BOD_5: 50-60 mg/L
Ptot: < 0.8 mg/L

To final dispersal or further treatment

- Unit treating up to 2,200 L/d (580 gallons)
- Unit volume of 2,000 liters (528 gallons)

PREMIER TECH AQUA

Certification Results



- CAN/BNQ results: Primary Reactor + EC Unit

Parameters	IPR	ECE[1]	Removal	Classification
TSS (mg/L)	231 ± 65	**33 ± 23**	86%	BI
$CBOD_5$ (mg/L)	188 ± 63	**53 ± 23**	72%	BI
P total (mg/L)	5.1 ± 1.7	**0.4 ± 0.4**	92%	PI
FC (log)	6.4 (2,272,815)	**4.8 (62,773)**	1.6	na
pH	8.0	**8.2**	na	
n	159	**159**	na	

[1] ECE: Electro-coagulation Unit Effluent

PREMIER TECH AQUA

Life Span

- Electrodes lifespan: 3,930 h

PREMIER TECH AQUA

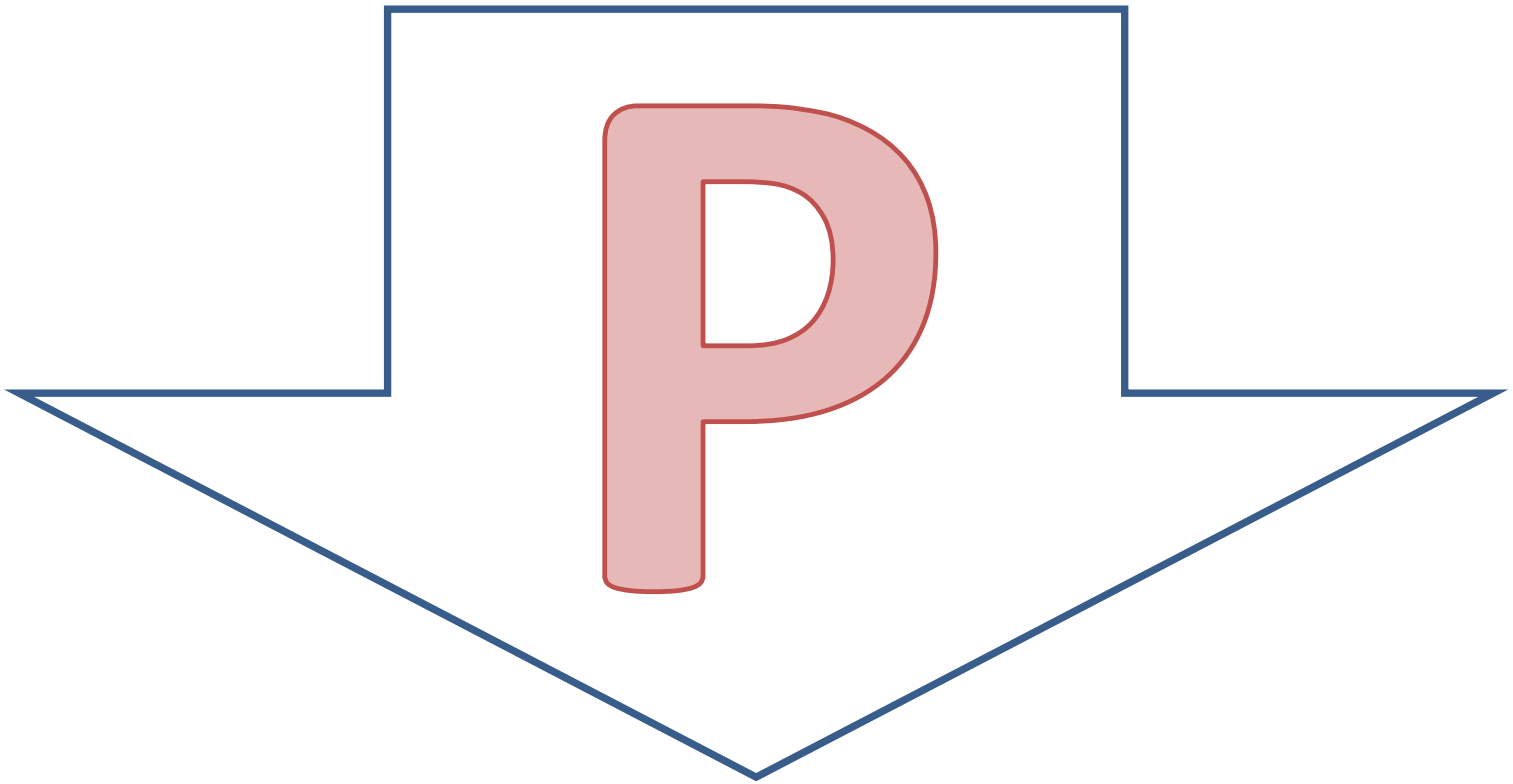
Finally

Lest we forget....

Phoenix R-200

Know your sources

Septic Systems

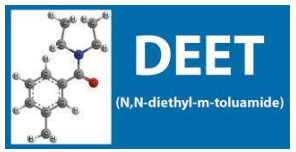


OR

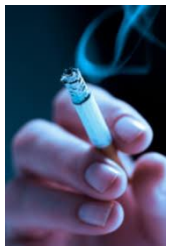
Septic Systems

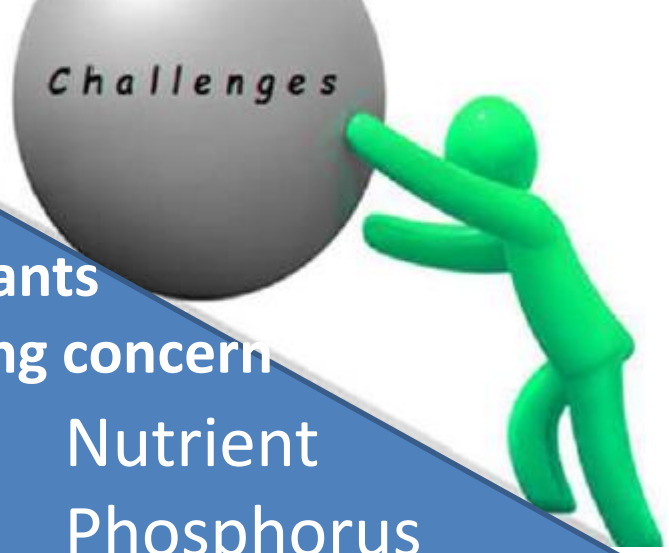
Contaminants of Emerging Concern: Challenges going forward – What we know and what we still don't know

What are Contaminants of Emerging Concern?



- Antibiotics
- Hormones (synthetic and natural)
- Metabolites (cotinine)
- Psychoactive drugs
- Lipid regulators
- Pain relievers
- Fragrances
- Chemotherapy drugs
- Fire retardants
- Cleaning products
- others





Challenges for onsite septic system treatment

Contaminants of emerging concern

Nutrient
Phosphorus

Nutrient
Nitrogen

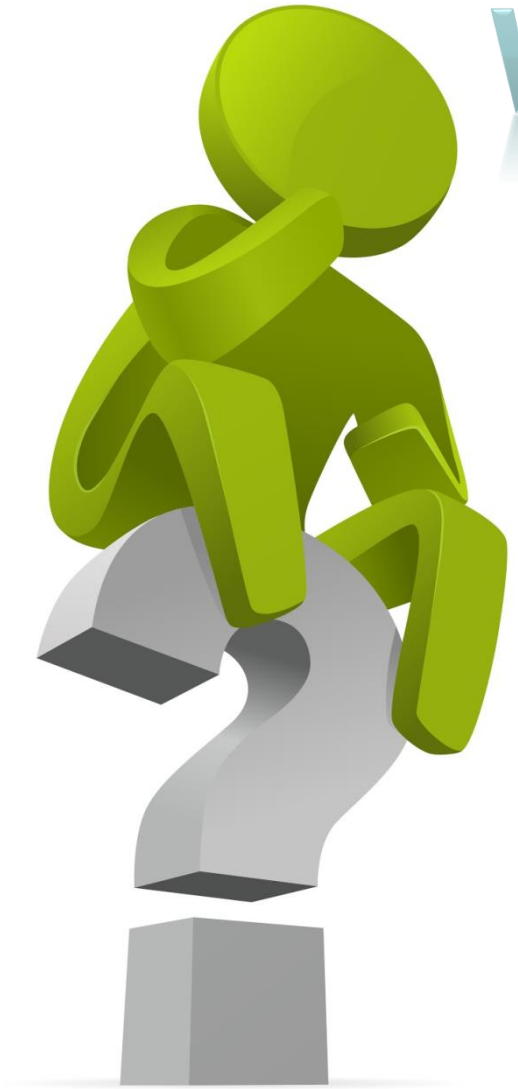
Pathogens
(bacteria and viruses)

Wastewater “Stabilization”
(removal of oxygen demand
oxidation of ammonia)

Dispose of volume

Increasing difficulty

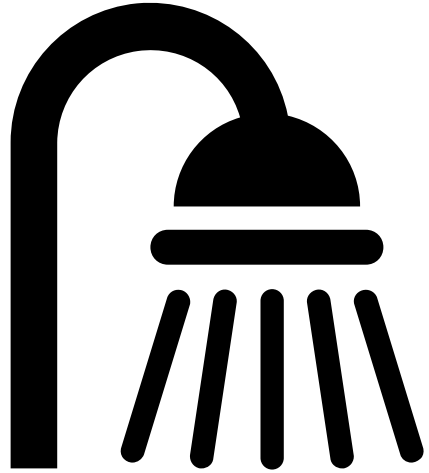
WHY SHOULD WE CARE?



2 GOOD REASONS

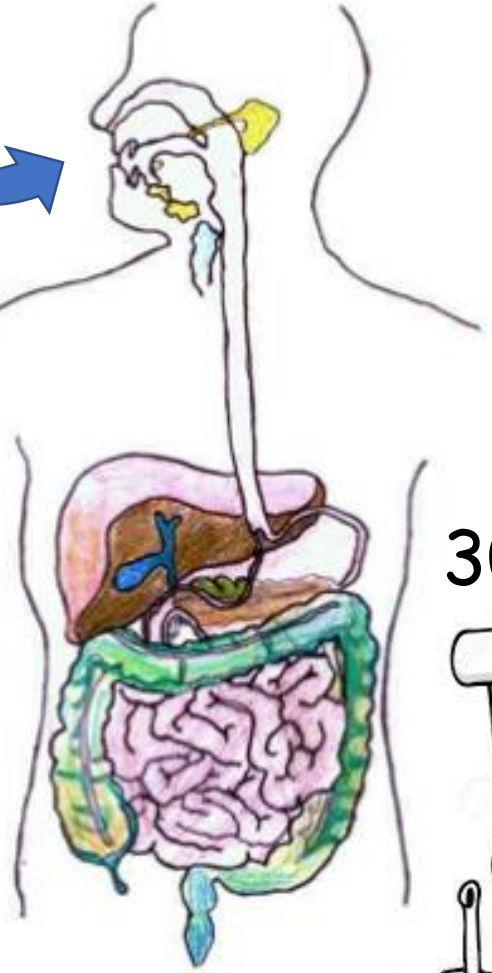
Reason 1

100 % ingested



DEET, MUSK
PCP

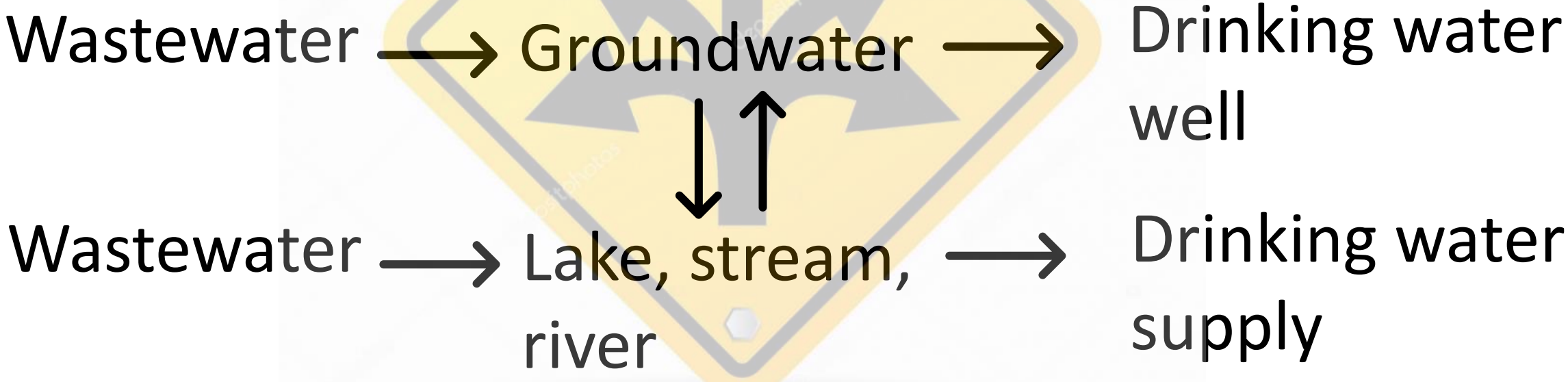
One person's wastewater is another person's medication.



30-90% Excreted

Reason 1

There are numerous pathways from wastewater to drinking water supplies that do not complete the removal of CEC.



Reason 1

Although therapeutic doses are rarely encountered, the effect of long-term exposure to many contaminants of emerging concern on humans is not known

(although some animal studies suggest some negative effects)

exposure

Reason 2

Humans may not get a good dose but they do !

Intersex occurrence in rainbow trout (Oncorhynchus mykiss) male fry chronically exposed to ethynylestradiol.

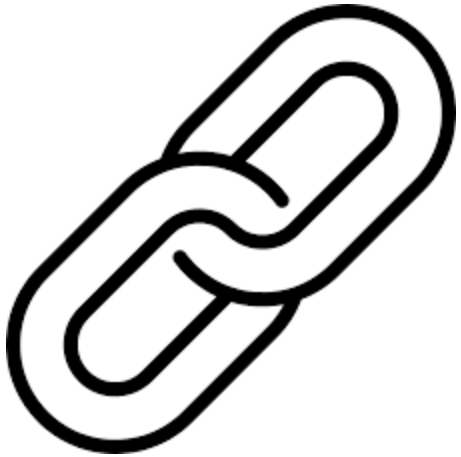
Reproductive effects of endocrine disrupting chemicals, bisphenol-A and 17b-oestradiol, on Cerastoderma edule from south-west England: field study and laboratory exposure

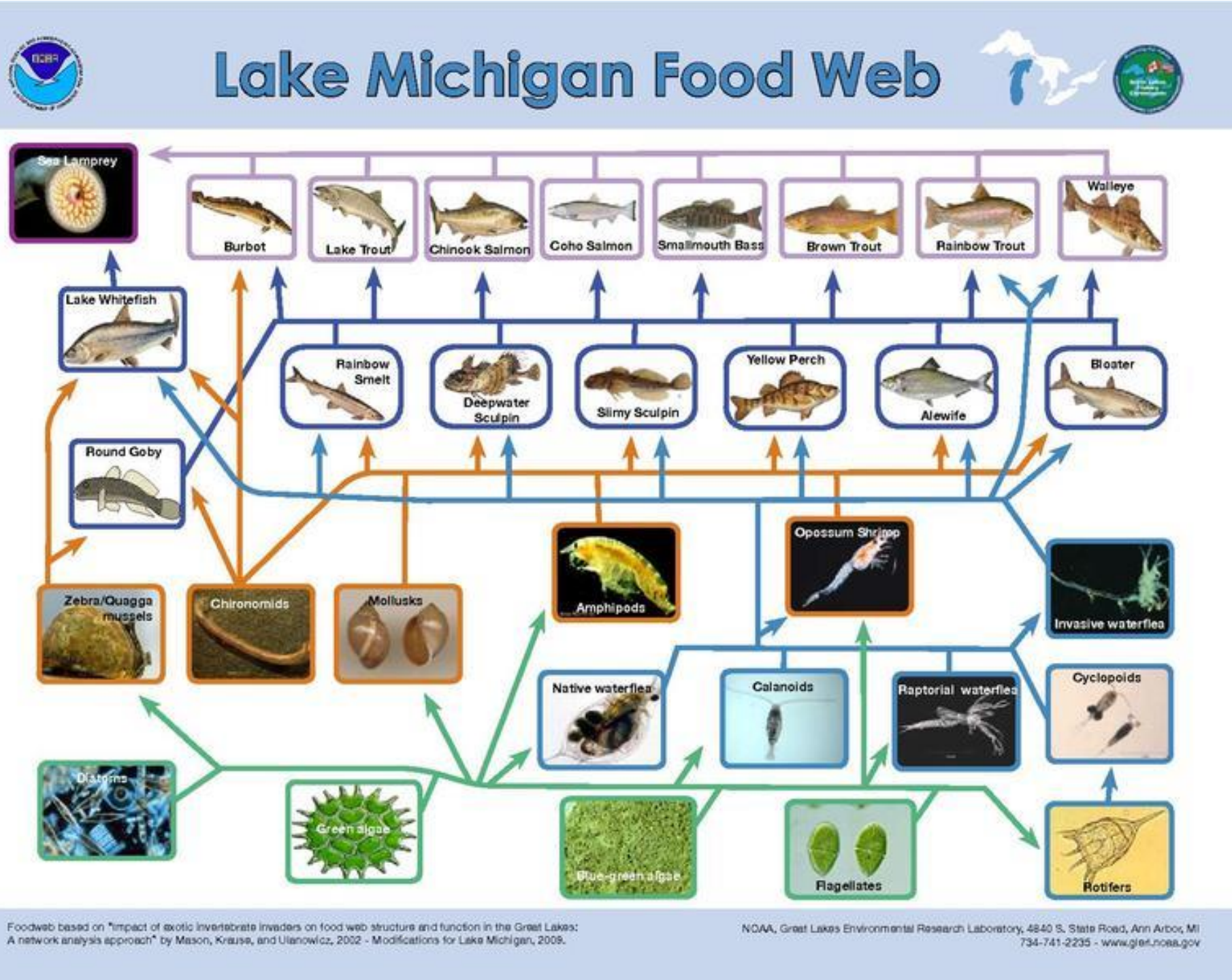
Carbamazepine disrupts molting hormone signaling and inhibits molting and growth of Eriocheir sinensis at environmentally relevant concentrations.

Effect of polycyclic musk compounds on aquatic organisms: A critical literature review supplemented by own data

Reason 2

We are all linked





Concern #1

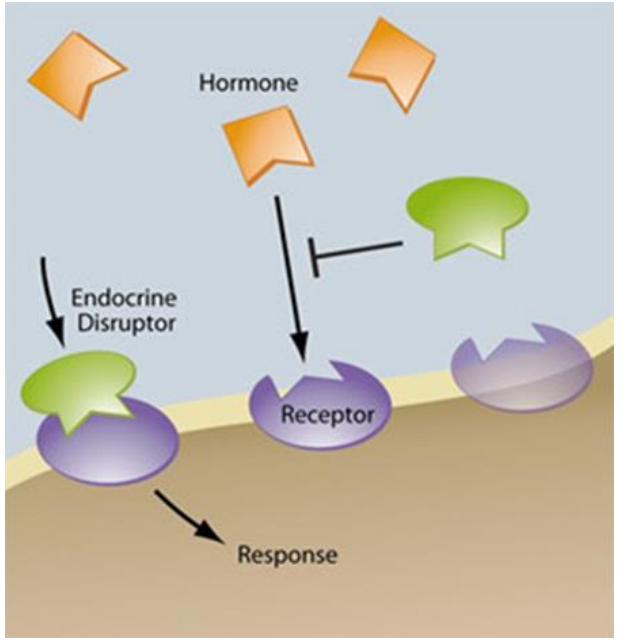
Case in point....

Collapse of a fish population after exposure to a synthetic estrogen

Karen A. Kidd *, †, Paul J. Blanchfield *, Kenneth H. Mills *, Vince P. Palace *, Robert E. Evans *, James M. Lazorchak ‡, and Robert W. Flick ‡

A very little bit goes a long long way.

How does this happen? It turns out that you actually <u>can</u> fool Mother Nature.



Many hormones are regulated by feedback loops where the concentration of the hormone limits its further production.

Some CEC "lock into" receptors and hence may sent the wrong signal to the body, either shutting off or ramping up the production of the hormone.

Top Ten things you can do or advise folks to do to protect freshwater ponds and lakes from the impacts of septic systems

- Design - Shallow systems treat better (although they may require more space);
- Design - Maximize the distance to groundwater when placing soil treatment areas;
- Design - Timed-dosed low-pressure distribution treats better;
- Design – Loading rate is the key (lower HLR usually means better treatment);

Top Ten things you can do or advise folks to do to protect freshwater ponds and lakes from the impacts of septic systems

- Use – Avoid overuse of anti-bacterial products – your septic system is a biological reactor;
- Use – Don’t flush unused medications;
- Use - Don’t excessively use disinfectants;
- Use – Maintain your system regularly;
- Keep traffic off of your soil treatment area, and;
- Practice water conservation and CHECK ALL FIXTURES REGULARLY FOR LEAKS.

Questions?