Let’s Discuss Phosphorus ontrol Techniques and Technologie

For Design and Installation of Onsite Wastewater Treatment Syst

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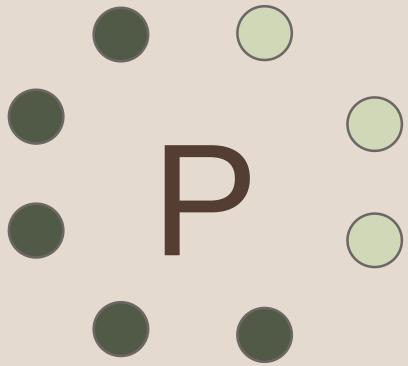
Why is phosphorus important?

- **An essential element in living things**
- **The limiting nutrient in some water bodies**
- **Phosphorus is relatively scarce in the earth’s crust**

The phosphorus atom and its chemistry

- ATOMIC NUMBER (# PROTONS) 15
- ATOMIC WEIGHT (PROTONS + NEUTRONS) 30.9
- TWO ELECTRONS FIT IN THE INNER SHELL (K)
- SECOND SHELL (L) 8 OF POSSIBLE 8 SPOTS FILLED
- THIRD (OUTER) SHELL (M) 5 OF POSSIBLE 8 SPOTS LED

15
P
30.97



Periodic Table of the Elements

Alkali Metals

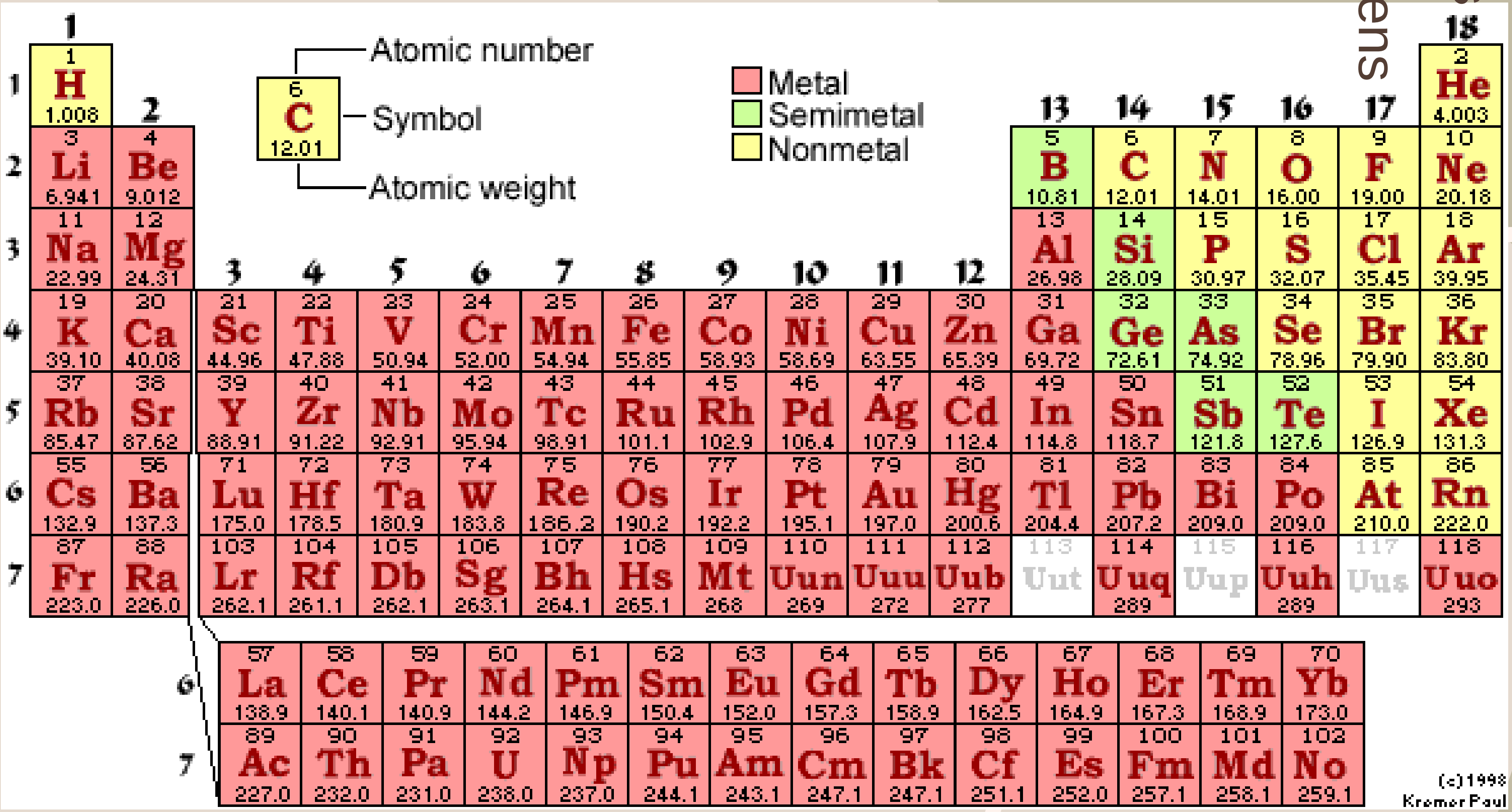
Halogens

Noble Gasses

K

L

M



Atomic number
Symbol
Atomic weight: 6 C 12.01

🟥 Metal
🟩 Semimetal
🟨 Nonmetal

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 H 1.008																	2 He 4.003
2	3 Li 6.941	4 Be 9.012											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
3	11 Na 22.99	12 Mg 24.31											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
4	19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.88	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.39	31 Ga 69.72	32 Ge 72.61	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
5	37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc 98.91	44 Ru 101.1	45 Rh 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3
6	55 Cs 132.9	56 Ba 137.3	71 Lu 175.0	72 Hf 178.5	73 Ta 180.9	74 W 183.8	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 197.0	80 Hg 200.6	81 Tl 204.4	82 Pb 207.2	83 Bi 209.0	84 Po 209.0	85 At 210.0	86 Rn 222.0
7	87 Fr 223.0	88 Ra 226.0	103 Lr 262.1	104 Rf 261.1	105 Db 262.1	106 Sg 263.1	107 Bh 264.1	108 Hs 265.1	109 Mt 268	110 Uun 269	111 Uuu 272	112 Uub 277	113 Uut	114 Uuq 289	115 Uup	116 Uuh 289	117 Uus	118 Uuo 293

6	57 La 138.9	58 Ce 140.1	59 Pr 140.9	60 Nd 144.2	61 Pm 146.9	62 Sm 150.4	63 Eu 152.0	64 Gd 157.3	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173.0
7	89 Ac 227.0	90 Th 232.0	91 Pa 231.0	92 U 238.0	93 Np 237.0	94 Pu 244.1	95 Am 243.1	96 Cm 247.1	97 Bk 247.1	98 Cf 251.1	99 Es 252.0	100 Fm 257.1	101 Md 258.1	102 No 259.1

(c)1998 Kremer Paul

Goal: Outermost shell electron pattern identical to a Noble Gas

- ADD THREE ELECTRONS - ARGON (ATOMIC NUMBER 18)
- LOSE 5 ELECTRONS - NEON (ATOMIC NUMBER 10)

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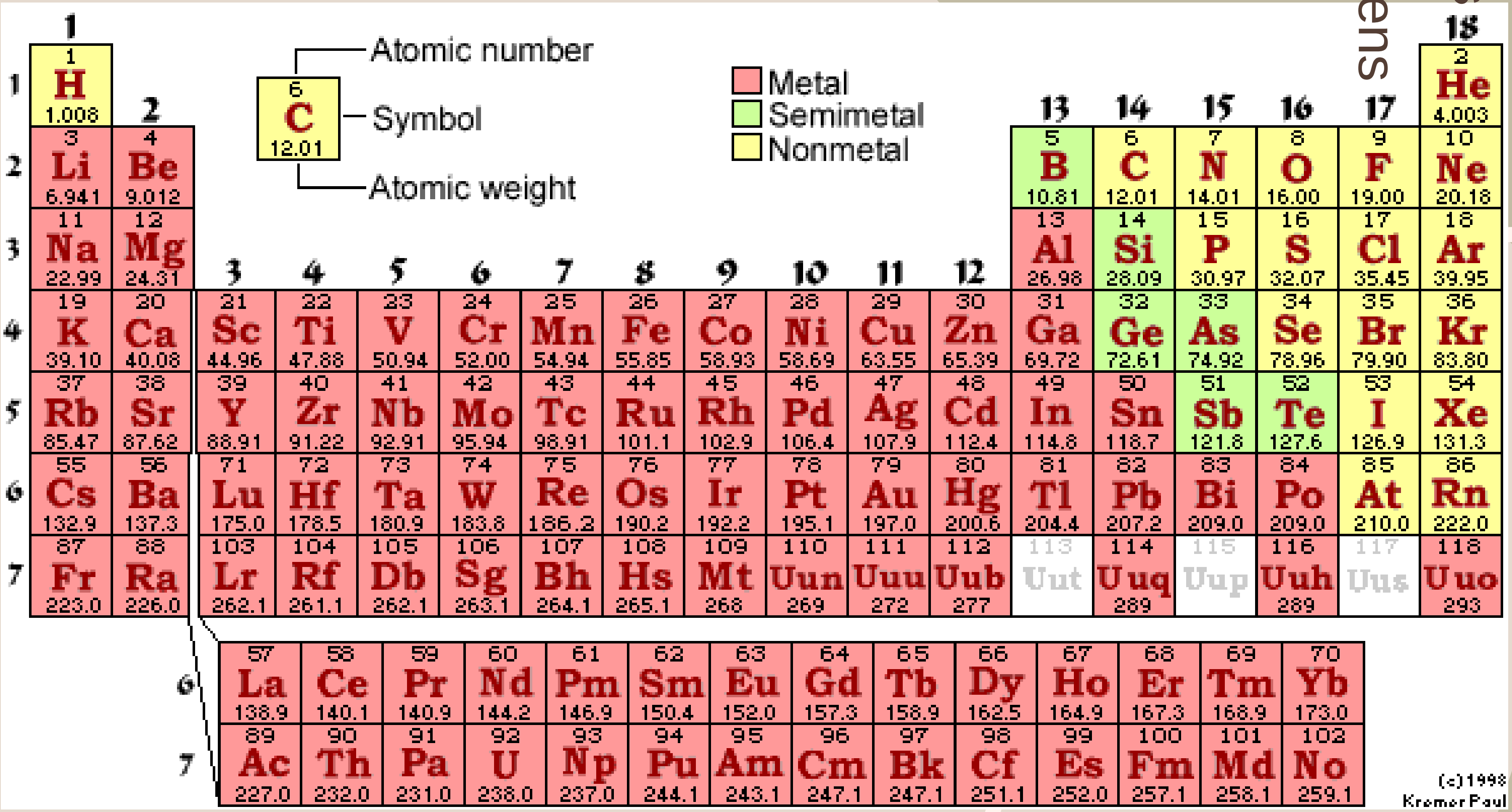
K

L

M



Atomic number

6
C
12.01

Symbol

Atomic weight

🟥 Metal
🟩 Semimetal
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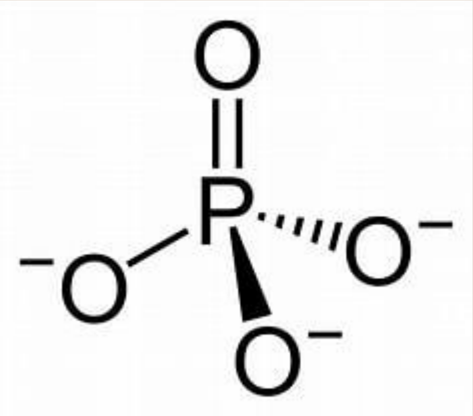
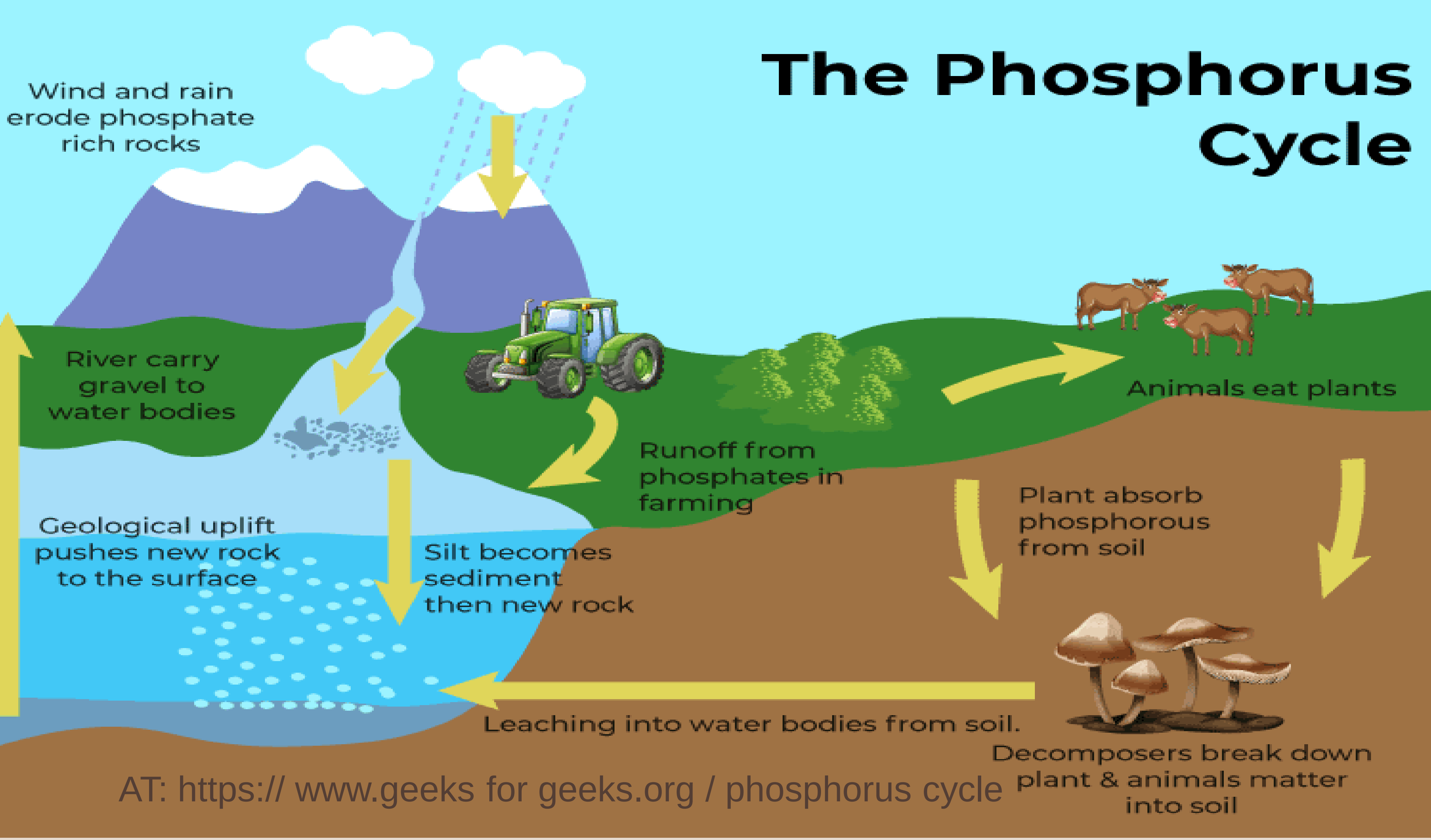
Phosphorus is highly reactive

- It is never found as a free element on earth
- Predominantly found as phosphate in minerals
- Chemical formula of orthophosphate is PO_4^{3-}



Phosphate found in biological compounds

- **DNA**
- **RNA**
- **ATP/AD**
- **Phospholipids**



AT: https:// www.geeks for geeks.org / phosphorus cycle

Limiting nutrient concept

- Nutrients are substances that provide nourishment essential for growth and maintenance of life
- 25 of the known elements are bio-essential. Just 4 of these: carbon (C), oxygen (O), hydrogen (H) and nitrogen (N) make up 96% of the human body
- All organisms are built from the same six bio-essential elements: carbon, hydrogen, nitrogen, oxygen, phosphorus and sulfur
- Depending upon the circumstances, either carbon, nitrogen, or phosphorus can be the limiting nutrient in an aqueous (watery) environment

Redfield Ratios

- Living things construct certain essential biomolecules using the nutrients C, N, and P
- Alfred Redfield (1934) discovered that marine phytoplankton extracted 1 atom of P for every 16 atoms of N for every 106 atoms of C (1:16:106)
- Whichever nutrient is in the shortest supply in water will limit the size of base of the ocean food chain

The Using Redfield ratios to determine which nutrient is limiting plant growth

- A WATER SAMPLE CONTAINS 500 MOLES CARBON, 74 MOLES N AND 4 MOLES P – WHICH ONE IS THE LIMITING NUTRIENT?
- 500/106 = 4.72 •74/16 = 4.63 •4/1 = 4.0
- PHOSPHORUS IS THE LIMITING NUTRIENT IN THIS WATER BODY

Limiting nutrient for eutrophication by water type

Water type	**Location description**	**Eutrophication by**	**Eutrophication effects**
Fresh water	Temperate streams, lakes, rivers reservoirs	Phosphorous almost exclusively	Uncontrolled algal blooms Reduced H_2O clarity, fish kills
Brackish (mixed) water	Estuaries	Both nitrogen & phosphorus (location specific)	Harmful Algal blooms Habitat degradation
Salt Water	Oceans and Seas	Nitrogen typically	Uncontrolled blue-green algal growth hypoxic zones

Commercial uses of phosphate

- Baking Powder
- Plant Fertilizers
- Fireworks, safety matches
- other uses

Note the following

- Detergents/dishwashing products were not listed as phosphorus containing
- This is a successful case of pollution prevention
- Soap and detergent manufacturers created phosphorus-free alternatives
- Halved the phosphorus load in household wastewater effluent

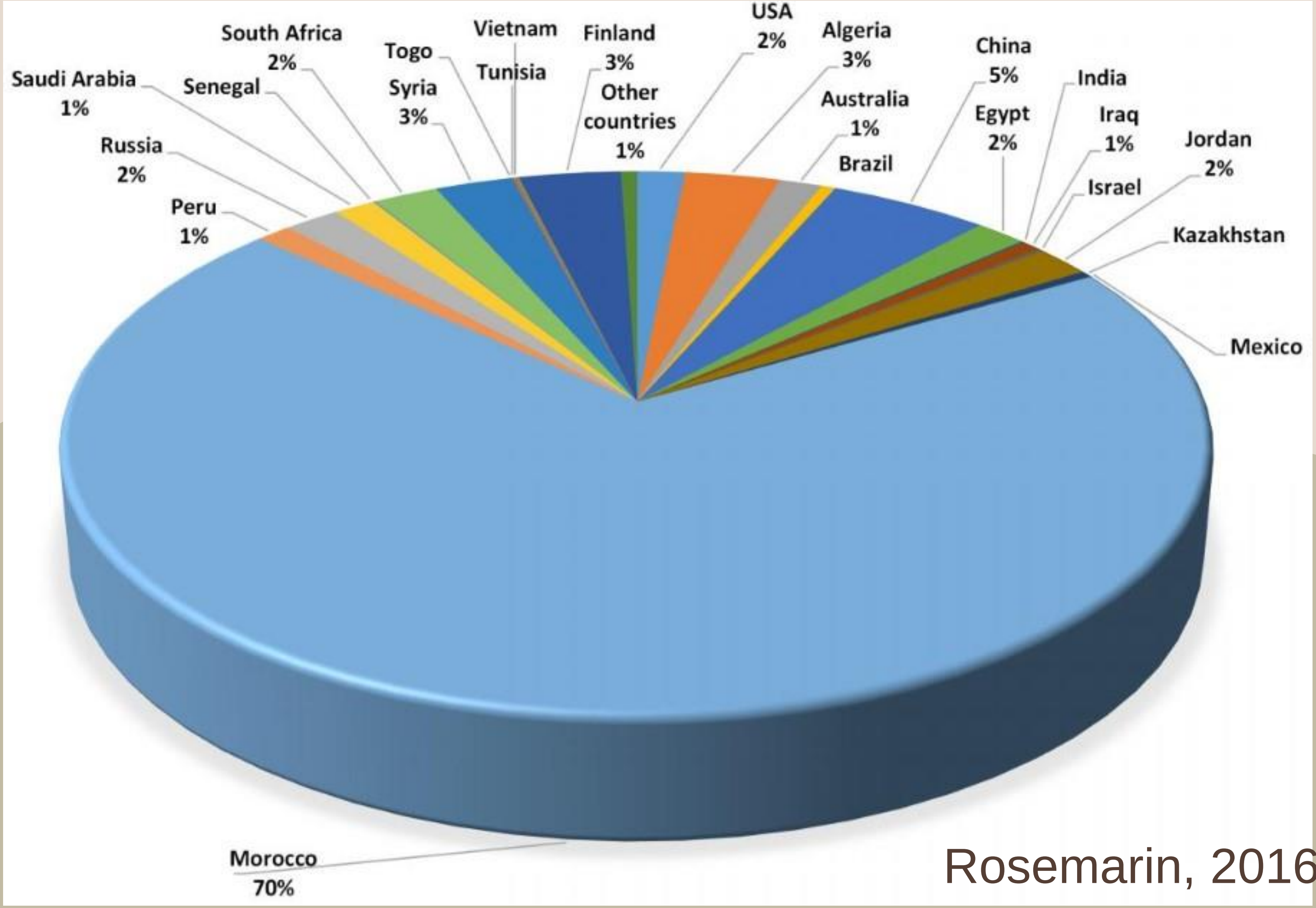
Phosphorite Rock

- Sedimentary rock
- Contains 4% to 20% phosphorite pentoxide (P_2O_5)
- Marketed phosphorite rock is enriched (“beneficiated”) to at least 28%

Other phosphorus minerals and their sources

Mineral name and chemical formula	Where mineral is found
Apatite	Caves, sea islands
Fluorapatite - $Ca_5(PO_4)_3F$	Deep sea hydrothermal vents
Hydroxyapatite $Ca_5(PO_4)_3OH$	Dissolved vertebrate bones
Phosphophyllite	Mines
Turquoise $CuAl_6(PO_4)_4(OH)_84H_2O$	Widespread deposits in arid areas
Vivianite - $Fe_3^{2+}(PO_4)_28H_2O$	Many geologic environments
Struvite – $MgNH_4PO_46H_2O$	Guano deposits, marshes, kidney stones

Distribution of global phosphate rock reserves



Rosemarin, 2016

Phosphorus recycling approaches

- Urine diverting toilets
- Waterless urinals
- Phosphorus removal/reclamation technologies

Phosphorus capturing systems

- Most P-removal technologies have been deve for use at larger wastewater treatment plants that have economies-of-scale, rigorous monitoring, and in-house operating expertise
- Decentralized systems must be reliable with minimal O&M expertise

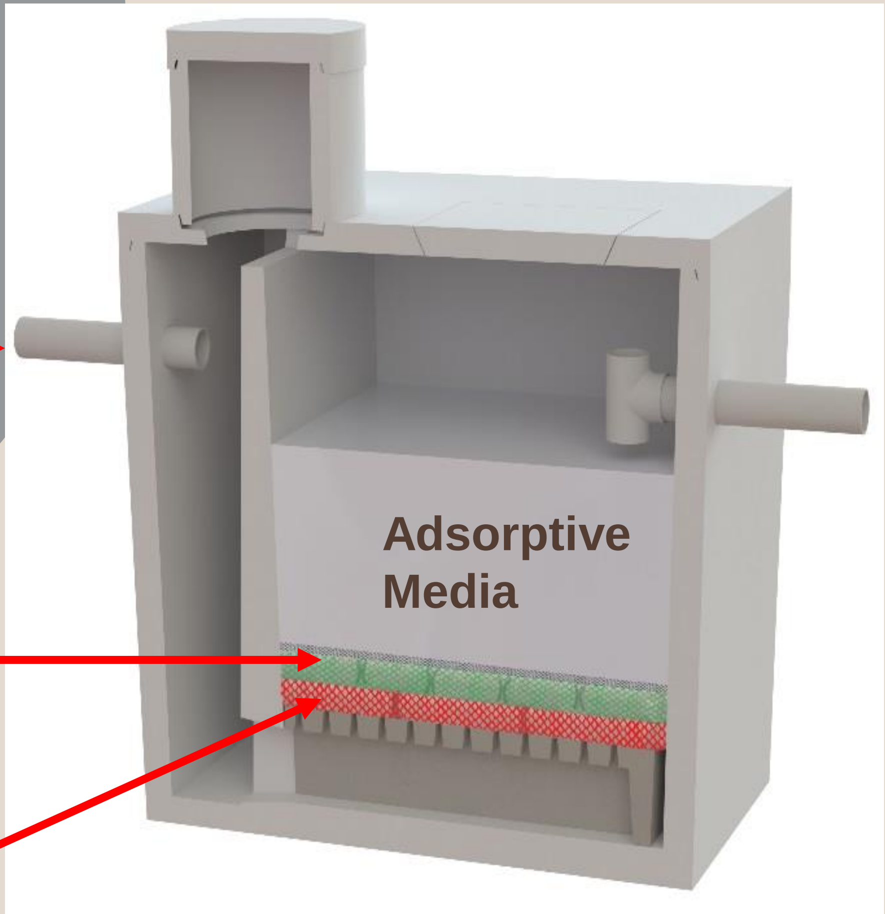
Phosphorus and onsite/decentralized systems

- The contribution of phosphorus loadings from individual conventional onsite systems (watertight tank with effluent gravity fed to soil treatment area) is highly variable
- Nutrient removal is not designed into conventional onsite systems
- Depending on the type of soil in the treatment area, irreversible phosphorus precipitation does occur in some soils
- The number of phosphorus precipitation sites in a soil is finite
- Phosphorus will eventually break through to ground water once all the sites in the soil are saturated

Enhanced phosphorus capture options

- Norweco Phos-4-Fade filter and tablets
- Electro chemical / Electro coagulation processes:
  - Premier Tech Water and Environment DpEC: electrochemically dissolves aluminum electrode into wastewater
  - Waterloo Biofilter EC – electrochemically dissolves iron electrode into wastewater

NORWECO PHOS-4-FADE® PHOSPHORUS REMOVAL FILTER

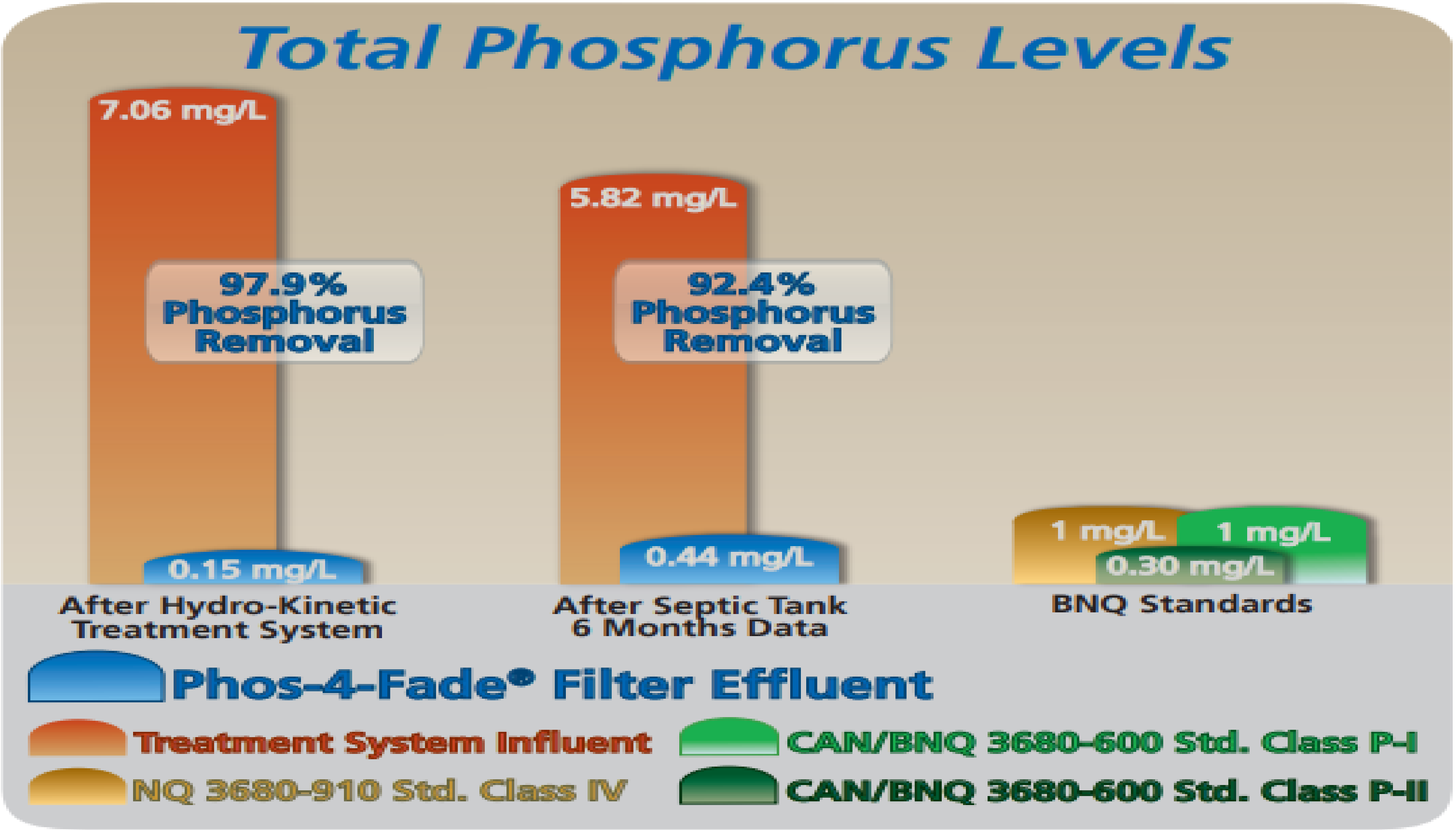


INLET CHAMBER

SECONDARY FILTRATION MEDIA

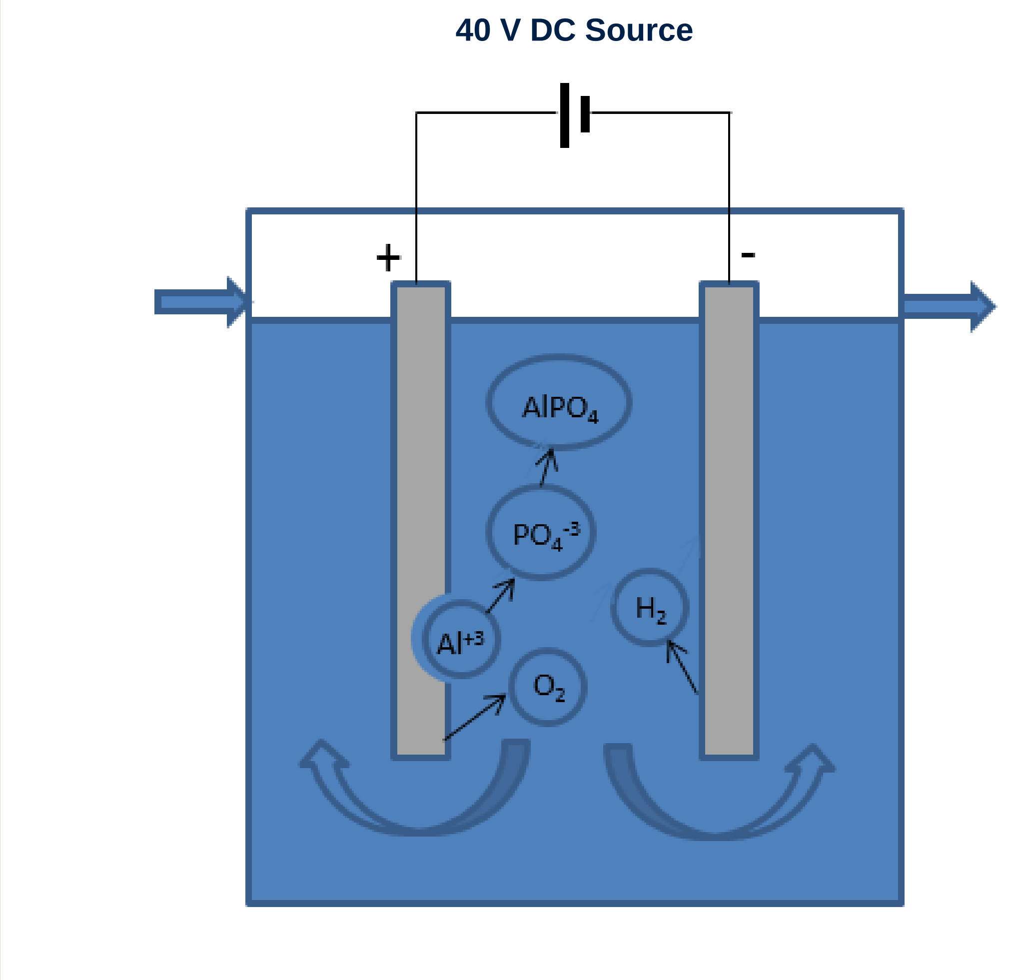
PRIMARY FILTRATION MEDIA

Results of BNQ testing



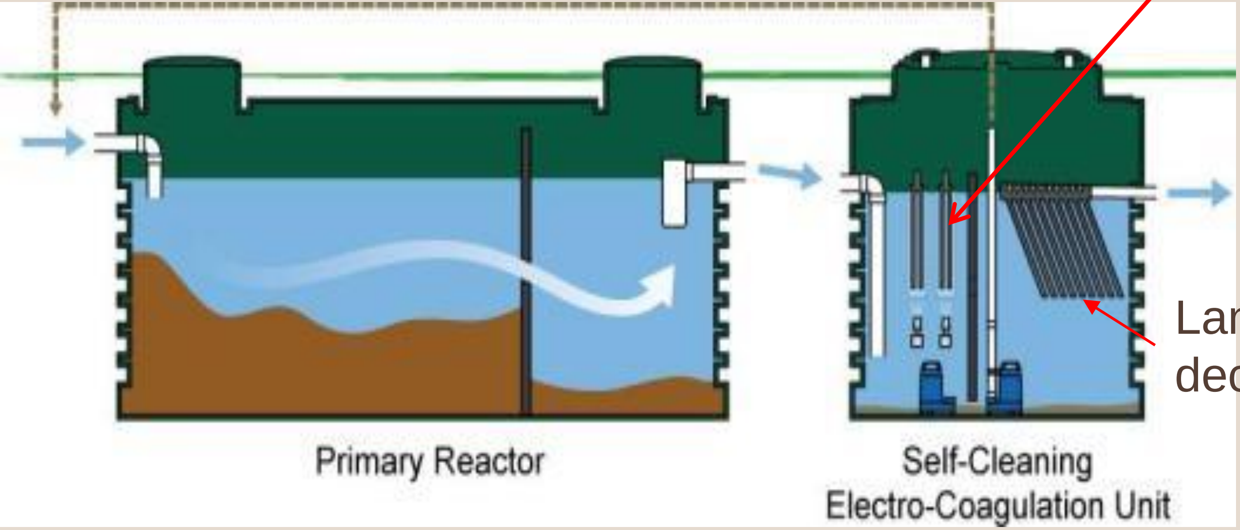
Premier Tech Water and Environment DpEC electro-coagulation (EC) principle

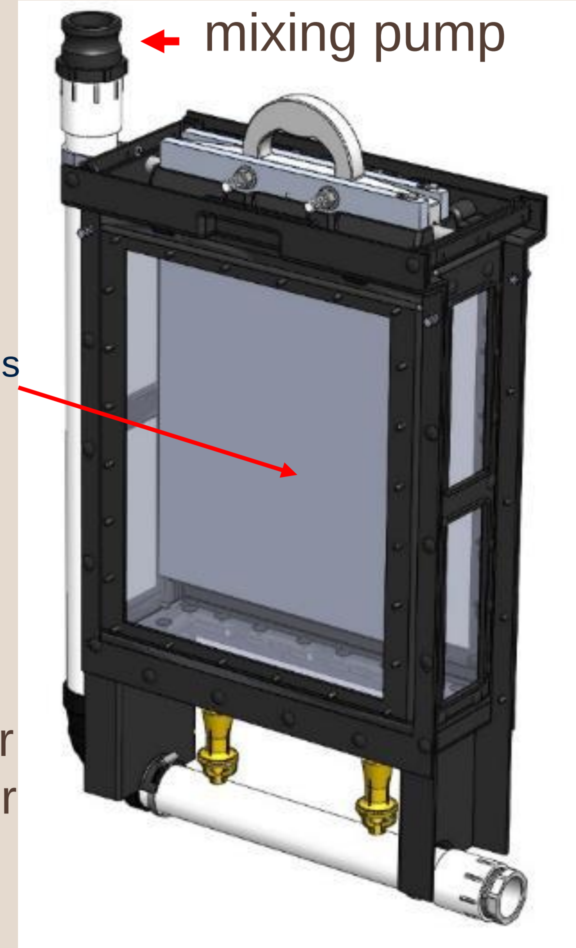
- Principle of EC: low intensity electric current (DC) applied between 2 submerged aluminium electrodes
- PO_4^{3-} is removed from wastewater by allowing it to combine with Al^{3+} cation, which will



Electro-coagulation (EC) unit

- **Uses aluminum electrodes**
- **Operates on command**





Connection to the mixing pump

Electrodes

Lamellar decanter

PTWE DpEC BNQ Certification results

	Parameters	**Influent primary reactor**	**Effluent EC**	**Effluent Ecoflo Biofilter**	**% Removal**	**Classification**
DpEC w/ Ecoflo Biofilter	TSS (mg/L)	231 ± 65	**33 ± 23**	**2 ± 2**	99.5%	BIV
	CBOD$_5$ (mg/L)	188 ± 63	**53 ± 23**	**2.0 ± 0.1**	98.6%	BIV
	P total (mg/L)	5.1 ± 1.7	**0.4 ± 0.4**	**0.1 ± 0.1**	99%	PII
	FC (log)	6.4 (2,272,815)	**4.8 (62,773)**	**<0.3 (<2)**	> 6	DIII
	pH	8.0	**8.2**	**7.5**	n/a	
	n	159	**159**	**159**	n/a	
DpEC w/ Sand filter	TSS (mg/L)	231 ± 65	**33 ± 23**	**1 ± 1**	99.6%	BIV
	CBOD$_5$ (mg/L)	188 ± 63	**53 ± 23**	**2 ± 1**	99.1%	BIV
	P total (mg/L)	5.1 ± 1.7	**0.4 ± 0.4**	**0.04 ± 0.02**	99.4%	PII
	FC (log)	6.4 (2,272,815)	**4.8 (62,773)**	**1.7 (51)**	4.5	DIII
	pH	8.0	**8.2**	**7.5**	n/a	
	n	159	**159**	**159**	n/a	

Waterloo biofilter EC-P

- Electro-chemical process
- EC-P placed in septic tank or first tank of advanced treatment system
- Low current continuously passes through an iron electrode
- Dissolves iron into water
- Combines with phosphate to make stable, insoluble minerals
- Effluent passed through a filter to capture precipitate

thank you

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