“The Reduction of certain Contaminants of Emerging Concern by the GPC Process in the Final Effluent at a Wastewater Treatment System”.

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Who Am I

- MICHAEL B. McGRATH, P.E., P.L.S is the managing principal partner at Holmes and McGrath, Inc., a land surveying and civil engineering firm in Falmouth, MA. He graduated from Northeastern University in Boston, Massachusetts with a Bachelor of Science in Civil Engineering.
- In 1984, Mr. McGrath and his partners designed, permitted, built and operated the **first innovative alternative denitrifying** residential septic system in Massachusetts.
- From 2002 to 2004, Mr. McGrath was a co-founder and part-time employee of Environmental Operating Solutions, Inc., ("EOSi"). EOSi is the manufacturer of the MicroC™ family of carbon products designed for denitrification. Mr. McGrath no longer has any involvement with EOSi.

Our focus is on smaller wastewater treatment systems (largest is 60,000 gpd.)

- Small scale wastewater treatment systems have an advantage in that we can design and use greater retention time than available in municipal wastewater treatment plants.
- Our focus has been on developing a biological method to reduce dissolved nitrogen in final effluent.
- After denitrification, the effluent has low concentrations of 5 Day Biochemical Oxygen Demand and low concentrations of Total Nitrogen.
- As is common in Massachusetts, these systems discharge to the ground.

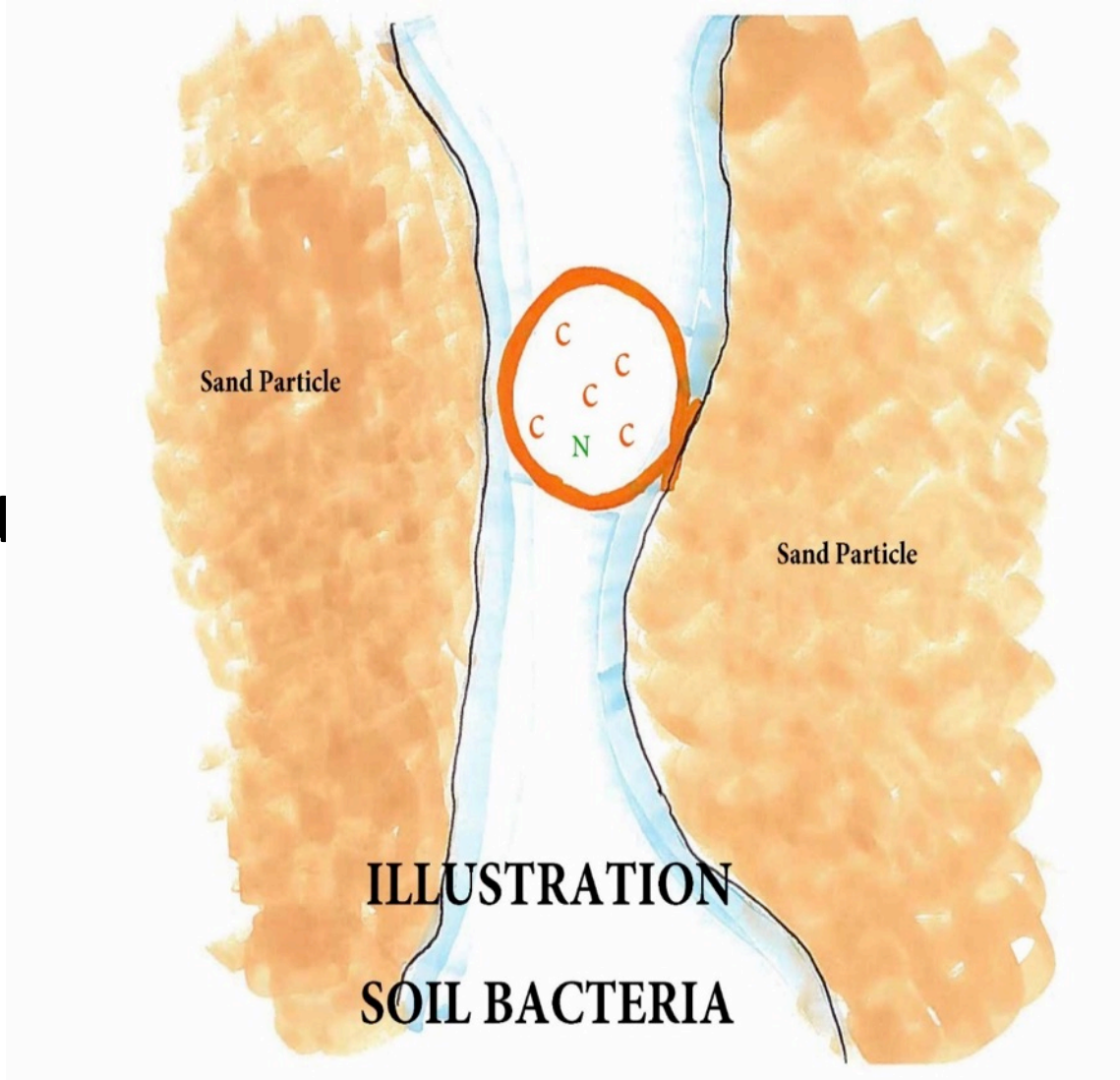
What is the most important factor in discharging treated water to the ground

- We do not use or encourage the soil bacteria to further treat the discharged effluent.
- Soil Bacteria were identified in 2000 by Francis H. Chapelle as the biggest change-makers in ground water.
- We should use the soil bacteria to further treat the water discharged to the natural soils. To do that, we should know how to get the soil bacteria involved.
- There are about 10,000,000 soil bacteria per cubic centimeter in the natural soils in the vadose zone
- So to enlist and enroll the soil bacteria to further treat the effluent, we should understand, in a general way, what the soil bacteria are made of.
- So what do the soil bacteria need to further treat water?

What are the soil bacteria made of?

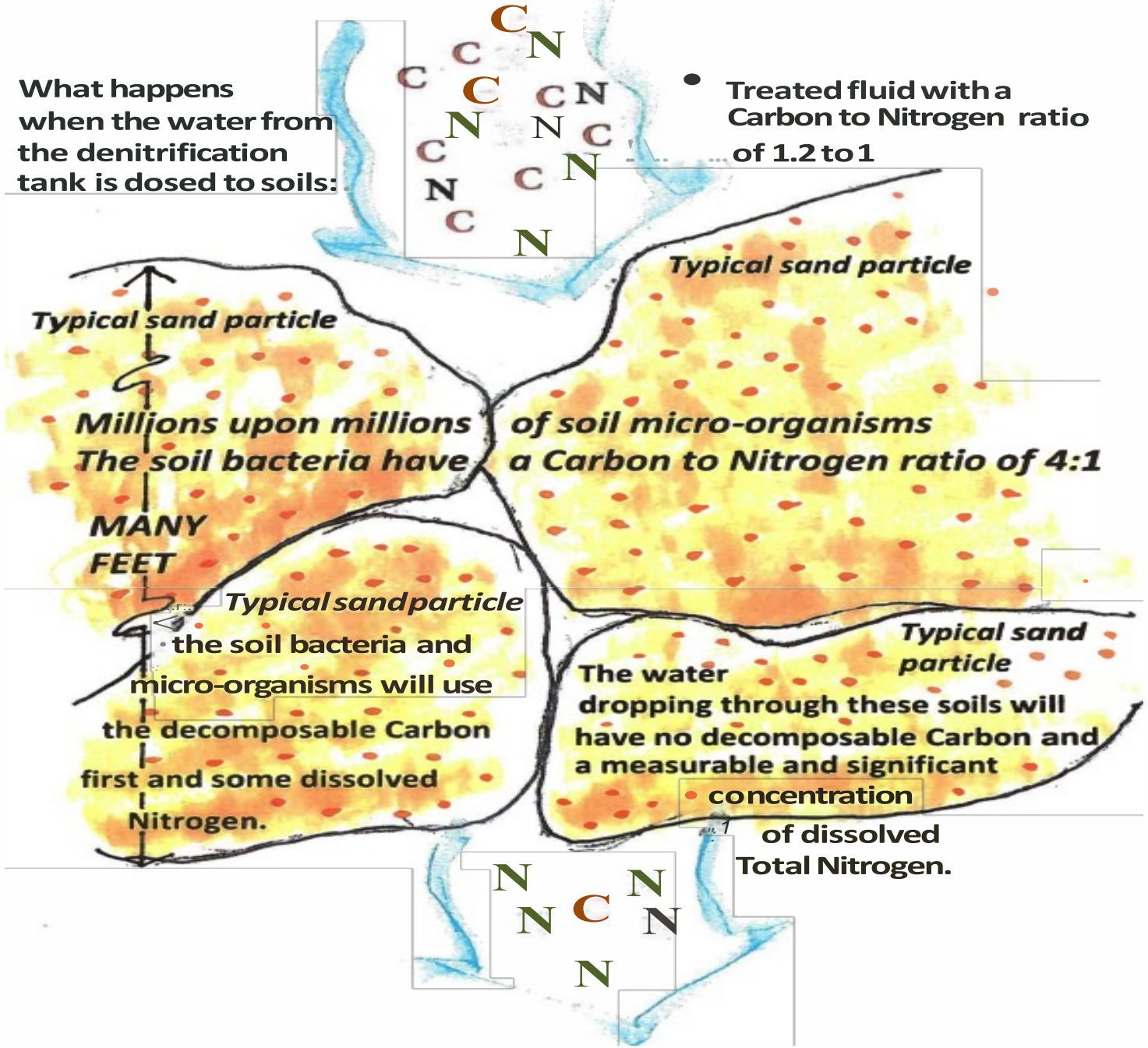
- **What are the general overall makeup of soil bacteria expressed in Carbon and Nitrogen**?

  The soil micro-organisms in the soils have carbon to nitrogen ratios in the range of 3:1 to 5:1 according to Paul and Clark (1996).
- **So to use the Soil Bacteria, we need to feed them.**
- **We do not provide the correct carbon in the water to feed them**



What are the Characteristics of typical Denitrified Fluid at a typical wwtp?

- From seven grab samples of water leaving a denitrification tank at a small wwtp:
- Average BOD_5= 26.2 mg/l
- Average TKN = 6.2 mg/l
- Average NO_3 = 0.8 mg/l
- Average TN = 7.1 mg/l
- Average TSS = 6.1 mg/l
- How much carbon is in this fluid?
- According to Crites and Tchobanoglous, TOC is 0.2 to 0.5 $BOD_{5.}$
- Average TOC would be about 9.2 mg/l
- C:N ratio is 1.3
- What happens when this fluid is discharged into the soil below the soil absorption system?

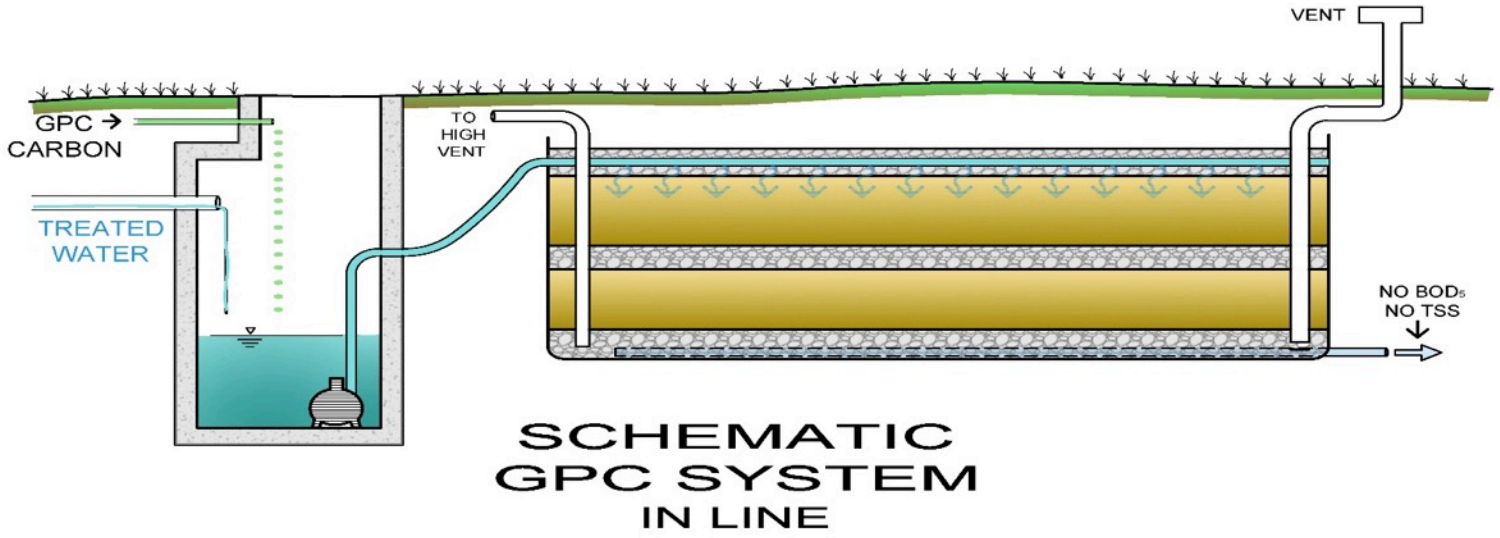

What happens when the water from the denitrification tank is dosed to soils:
Treated fluid with a Carbon to Nitrogen ratio of 1.2 to 1
Typical sand particle
Millions upon millions of soil micro-organisms
The soil bacteria have a Carbon to Nitrogen ratio of 4:1
MANY FEET
Typical sand particle
the soil bacteria and micro-organisms will use the decomposable Carbon first and some dissolved Nitrogen.
Typical sand particle
The water dropping through these soils will have no decomposable Carbon and a measurable and significant concentration of dissolved Total Nitrogen.

Limitations of the discharge of typical treated effluent into the soils

- When highly treated final effluent is discharged into the ground, the discharged water usually has more dissolved nitrogen than dissolved readily decomposable organic carbon on a mass basis.
- The dissolved carbon is usually used by soil micro-organisms before the dissolved nitrogen.
- The dissolved nitrogen will drain and move down through the vadose zone and travel for long distances in the groundwater with limited or minimal microbial attenuation.
- How do we improve on that?
- Simply, we propose to add carbon to the final treated effluent before dosing onto soils.
- How do we prove that? We will test this hypothesis by adding a highly available carbon to treated effluent and applying the mixture to a stratified sand filter, that mimics, in a general way, stratified natural soils.

The GPC Filter Process

This is how we proved my hypothesis. Simply we mix a liquid carbon called GPC carbon into the already treated water and dose the mixture onto a stratified sand filter. This is called the GPC Filter Process



So what happened when we did that?
Final Effluent Testing Results

	BOD_5		TSS		TN		NO_3
	mg/l		mg/l		mg/l		mg/l
Average	**3.1**		**2.3**		**5.1**		**4.5**
TESTS	181		181		181		181
Detected	6		23		n/a		n/a
MRL	3		3				
Total BDL	175		158				
Percent Compliant	100%		98%		92%		96%
Median	**3.0**		**1.5**		**4.2**		**3.5**
High	13.7		14.0		23.1		22.2
Low	3.0		1.5		0.8		0.4

Composite samples taken at Mill Pond Village, West Yarmouth, MA.
May 13, 2011 to October 31, 2014 (3 years, 5 months)
The denitrified fluid has passed through the GPC process. The final GPC effluent passed through ultraviolet light

Analysis of GPC Filter Process performance during the time period of May 13, 2011 to October 31, 2014

- This full size GPC Filter Process removed virtually all detectable BOD_5 concentrations
- This full size GPC Filter Process removed virtually almost all detectable TSS concentrations.
- The dissolved TN concentrations were reduced by an average of 53%.
- The final effluent TN concentration varied from 3 mg/l to 3.6 mg/l.

REDUCTION OF PHARMACEUTICALS AND PERSONAL CARE PRODUCTS (PPCP's)

- Based on advice of a scientist, we decided in the fall of 2014 to test the capability of the GPC Filter Process to reduce PPCP's.
- PPCP's are also described as Contaminants of Emerging Concern (CEC's).
- Grab samples of the influent and effluent of the GPC Filter were taken by an operator in accordance with the protocol issued by Eurofins Eaton Analytical Laboratory for a Broad Spectrum assessment of PPCP's.
- The GPC Filter influent was collected from the GPC Filter pump station.
- The effluent was collected from the ultraviolet light (UV) trough located after the GPC Filter, but the UV lights were turned off before sampling so the UV did not provide any removal factor for the sampled compounds.

Testing Of Contaminants of Emerging Concern

- PPCP's are also described as Contaminants of Emerging Concern (CEC's).
- Eaton Eurofins Analytical Laboratory performs a Broad Spectrum Sweep analysis for 95 chemicals described as PPCP's (Pharmaceuticals and Personal Care Products).
- The Eaton Eurofins test results are reported in concentrations values of 1 in a trillion or in a ng/l concentration in water.
- Reduction rates can only be estimated using multiple tests.
- There is strong evidence that fish can be adversely affected by some organic pharmaceuticals at a concentration of 1 ng/l.
- There is very little known risk to human health at these concentrations.

Limitation on the Presence of Contaminants of Emerging Concern at the test site

- At this location, the upstream wastewater system serves 60 houses.
- There will be detectable presence of CEC's but the dosing is episodic and the presence will be based on the medicine taken and excreted by the people served. The medicine may only be present in certain portions of the flow.
- At a wastewater treatment system with larger flows, there will be most likely a higher mass loading and more varied Contaminants.

Discussion of the Reductions Described

- In an attempt to simplify the discussion of test results, we discuss the reductions observed if the chemical always showed up in the influent in four or five test events. We now have five rounds of tests.
- The GPC Filter Process was started in 2010. The first round of tests were sampled in October 2014.
- Since there is a reduction in the concentrations in 112 of 122 tests, we assert that the reduction in the CEC's passing through the GPC Filter Process is by the soil micro-organisms using the CEC's for metabolism or co-metabolism.
- We assert that any physical removal process would have been exhausted in the four years of operation before we started testing for these Contaminants.
- From a precise point of view, since the concentrations are so low and since the Minimum Reporting Level (MRL) may be a significant portion of a reported concentration value, the reduction rate should be reported as a range. However, for brevity, we will report an average reduction rate for all five rounds.
- The MRL sometime varies with the tested chemical. MRL may even be different between the influent and effluent tests.

Overview of five test events

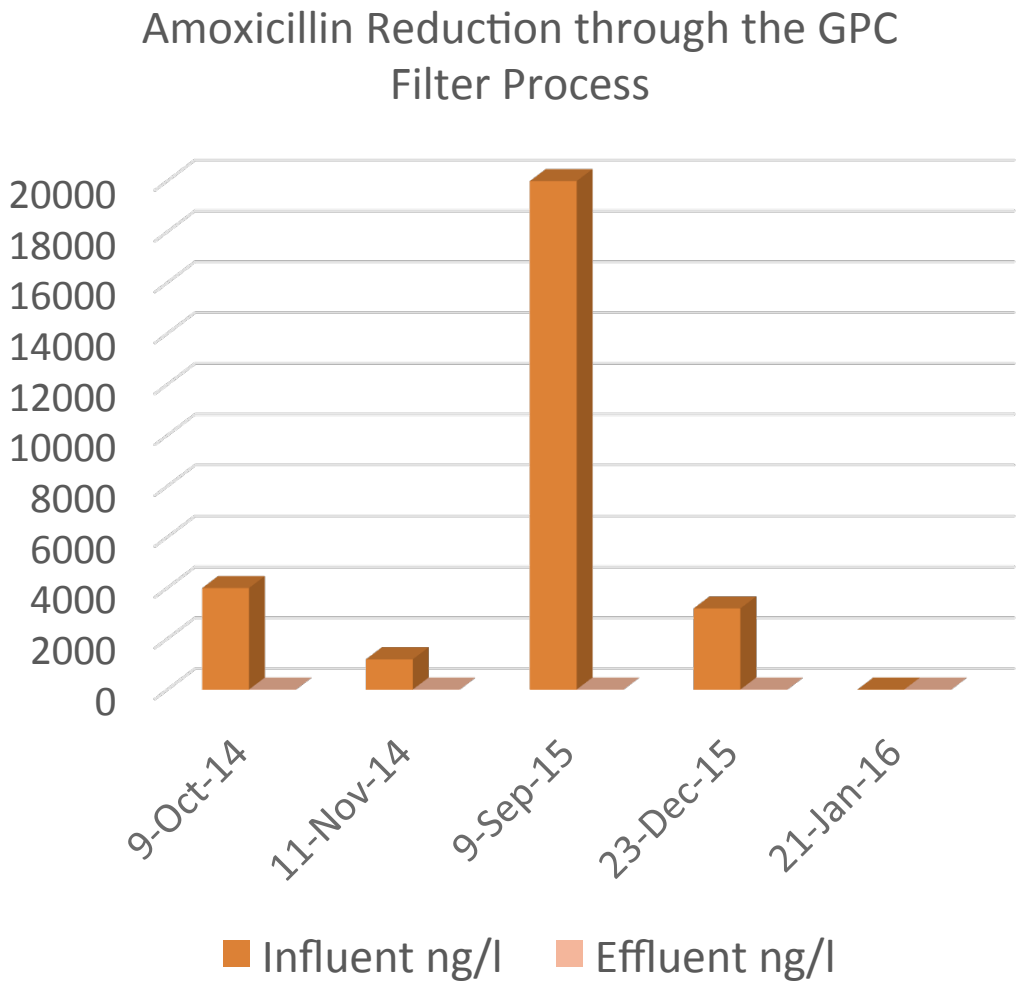
- In each of the test events, Eaton Analyticals reported on the existence of 95 different chemicals.
- In the five test events, there was a sample taken of the influent test of the water dosing the GPC Filter Process and a separate sample of the effluent with the UV light turned off.
- There were 48 total chemicals reported in all five tests.
- There were 122 reported positive concentrations in the influent. There were 112 tests with a reduced concentration in the effluent.
- There were 51 reported reductions between the influent concentrations and measurable effluent concentrations.
- There were 61 reported No Detect in the effluent when there was a positive concentration of the same chemical in the influent.
- There were 10 tests where the effluent concentration is higher than the influent.

Discussion of overall test results

- Nine chemicals were always found in the influent in all five test events
- Six chemicals were always found in four of the five test events.
- The reduction of these fifteen chemicals dissolved in the water passing through the GPC Filter Process varied.
- Most reductions were very good. The removal of Lidocaine was good (average removal of 57%).
- The reduction of Butalbital (average reduction of 22%), and TCEP (average removal of 30%) were limited.
- The average removal of Sucralose (average removal 12%) was very limited.
- There were 112 tests that had positive reductions out of 122 total tests that showed positive influent concentrations.
- On the following charts we show graphically the reductions for the fifteen chemicals found at least four times out of five events.

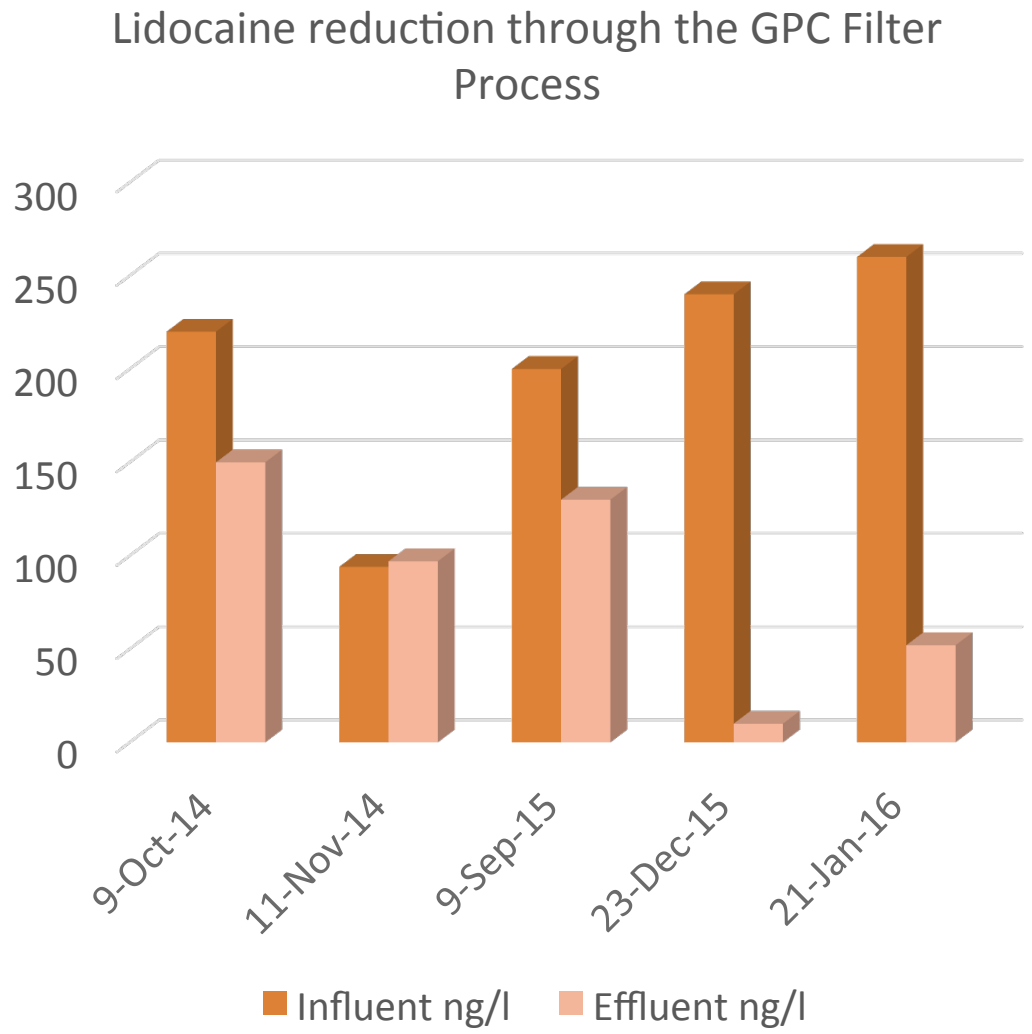
Amoxicillin (semi quantitative)

- Amoxicillin is an antibiotic.
- Highest Influent Concentration reported was 20,000 ng/l.
- Lowest Influent Concentration reported was No Detect.
- The MRL is 20 ng/l.
- Average reduction for five tests was over 99%



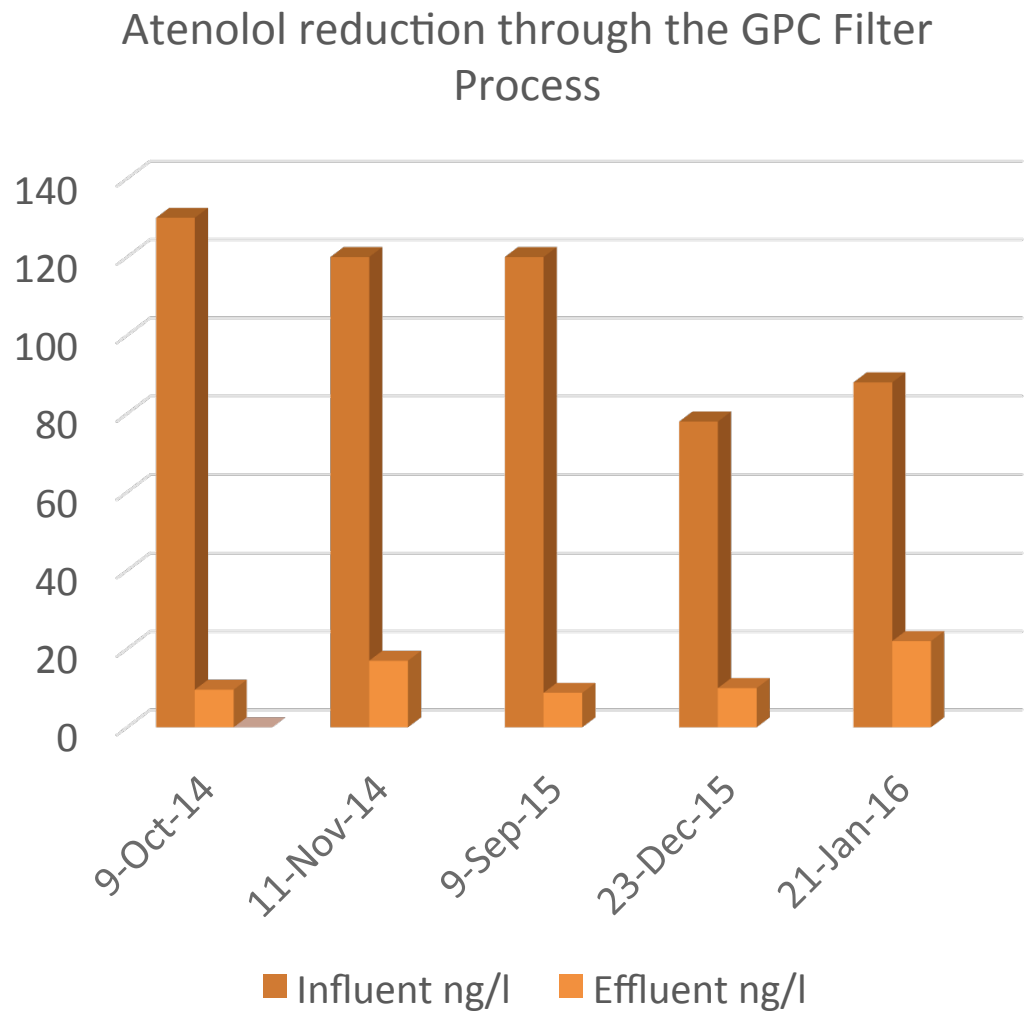
Lidocaine

- Lidocaine is used topically to relieve itching, burning, and pain from skin inflammation.
- Highest Influent Concentration reported was 260 ng/l.
- Lowest Influent Concentration reported was No Detect.
- In the November 2014 test, the effluent concentration value was higher than the influent concentration value
- The MRL is 5 ng/l.
- Average reduction for five tests was about 57%



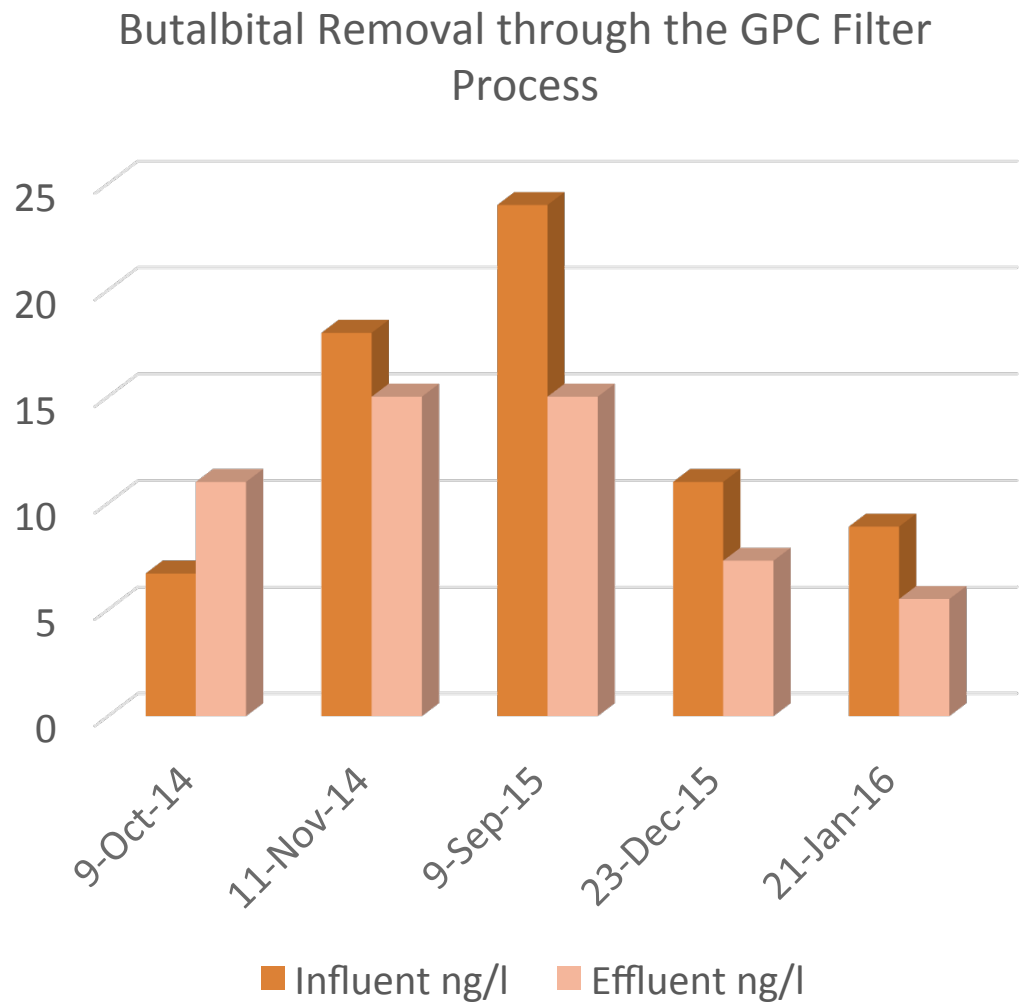
Atenolol

- Atenolol is a beta blocker used to reduce hypertension an sometimes used for cardiovascular disease.
- The highest reported Influent concentration is 130 ng/l.
- The lowest reported concentration was ND.
- The MRL is 5 mg/l.
- The average reduction for five tests was 88%



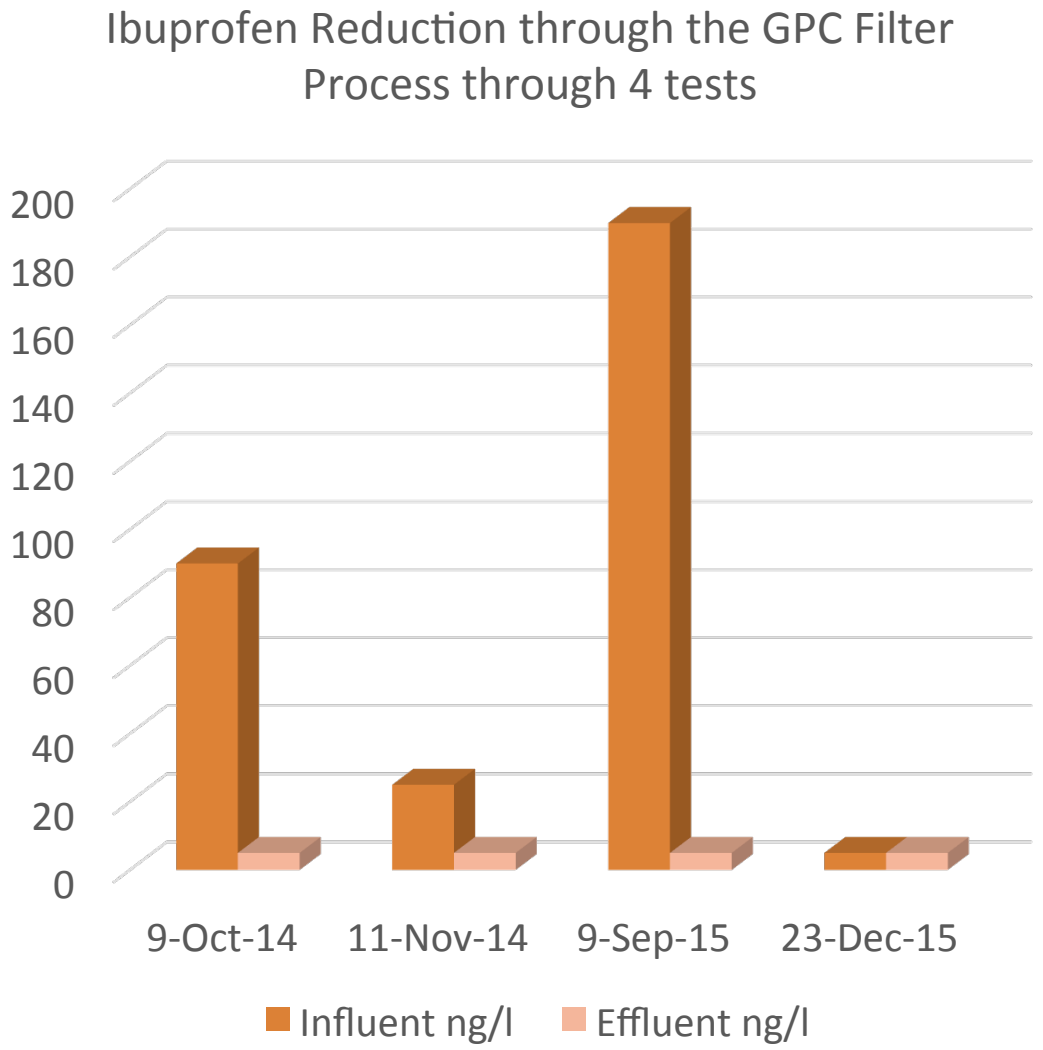
Butalbital

- Butalbital is a barbiturate commonly mixed with other medicines.
- Highest Influent Concentration reported was 24 ng/l. Lowest Influent Concentration reported was 6.7 ng/l.
- There was always a measured concentration value in the effluent.
- In the October 2014 test, the effluent concentration value of 11 ng/l was higher than the influent concentration value of 6.7 ng/l.
- The MRL is 5 ng/l. The reported values are very close to the MRL.
- There is a range of removals but average removal was about 22%



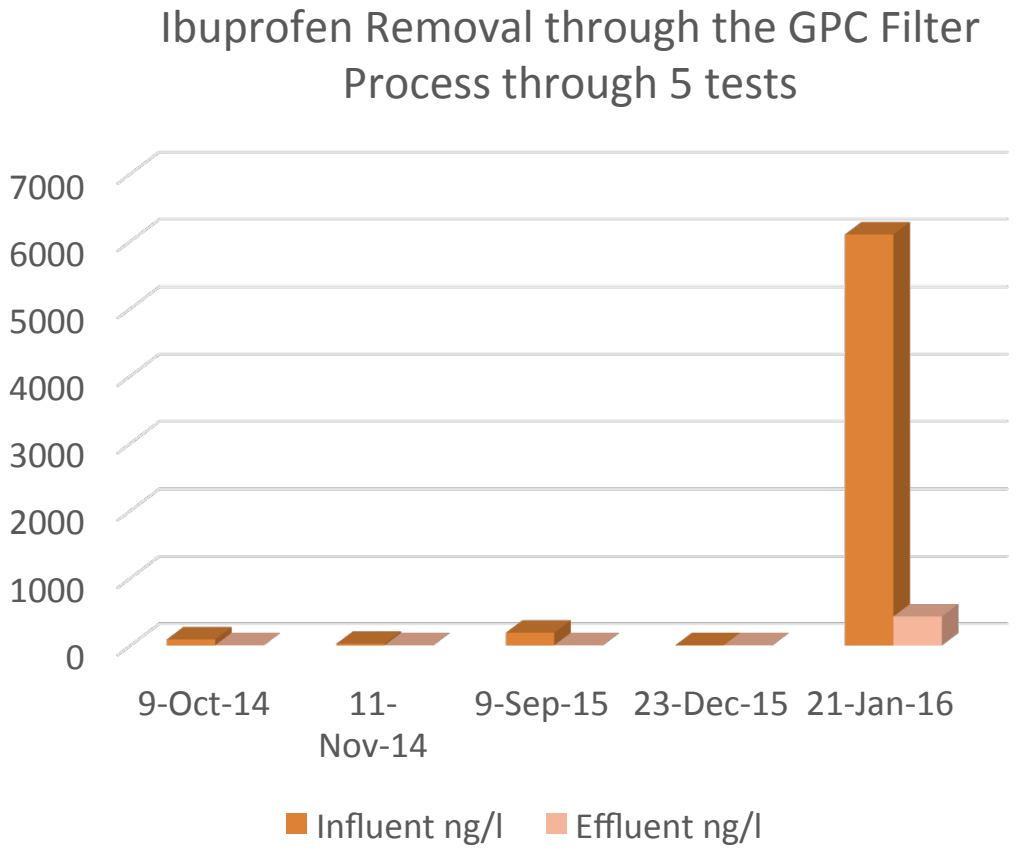
Ibuprofen

- Ibuprofen is a nonsteroidal anti-inflammatory drug used to reduce fever and inflammation. Ibuprofen is available under a variety of trade names including Advil, Motrin and Nurofen.
- Highest Influent Concentration reported was 6100 ng/l on the fifth test. Of the other four tests, the highest influent concentration was 190 ng/l Lowest Influent Concentration reported was No Detect.
- Four of Five effluent tests had No Detect as the measured concentration value in the effluent.
- In the January 2016 test, the influent concentration was 6100 ng/l. The effluent concentration value was 430 ng/l. The MRL was 100 ng/l for the influent test and 10 ng/l for the effluent test.
- The MRL is 10 ng/l for the first four tests.
- There is a range of removals but average removal for the first four tests was over 99%.
- We include an extra graph including the fifth test.



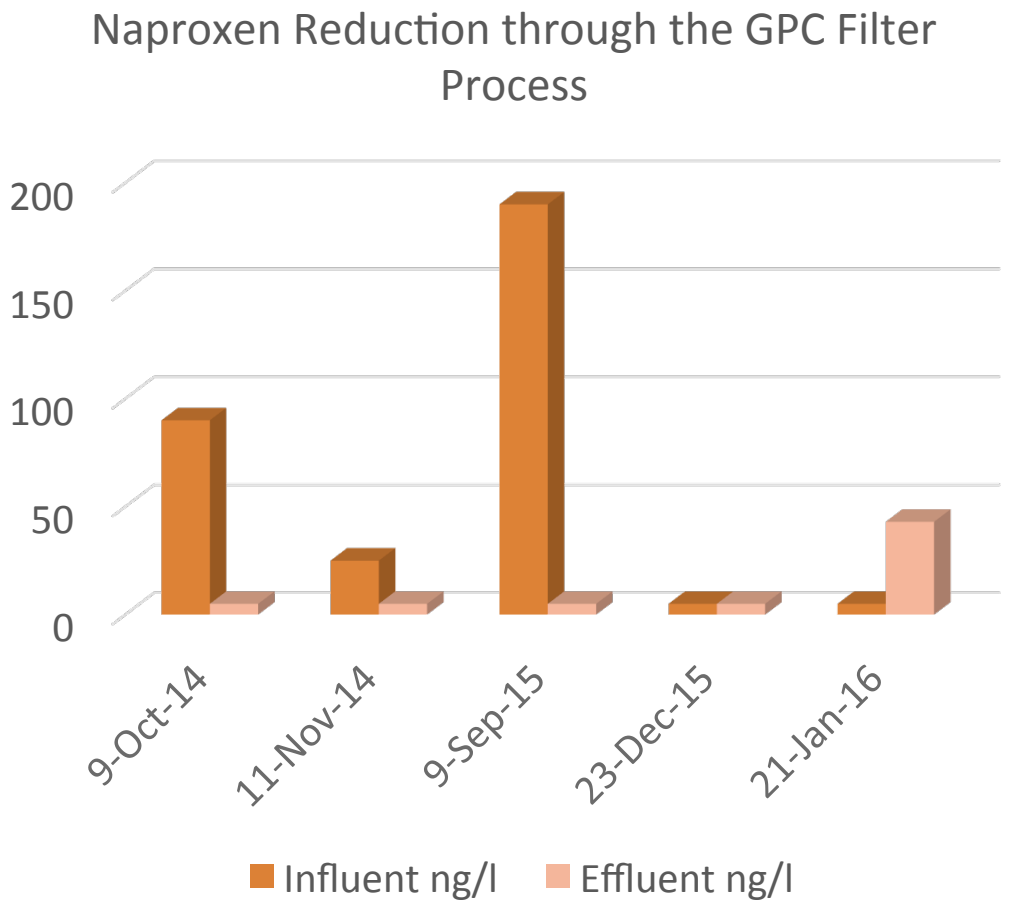
Ibuprofen continued

- Highest Influent Concentration reported was 6100 ng/l on the fifth test. Of the other four tests, the highest influent concentration was 190 ng/l. Lowest Influent Concentration reported was No Detect.
- Four of Five effluent tests had No Detect as the measured concentration value in the effluent.
- In the January 2016 test, the influent concentration was 6100 ng/l. The effluent concentration value was 430 ng/l. The MRL was 100 ng/l for the influent test and 10 ng/l for the effluent test.
- The reduction rate is then variable.
- Since the wastewater system only serves 60 houses, Ibuprofen may not be present all the time in the wastewater.



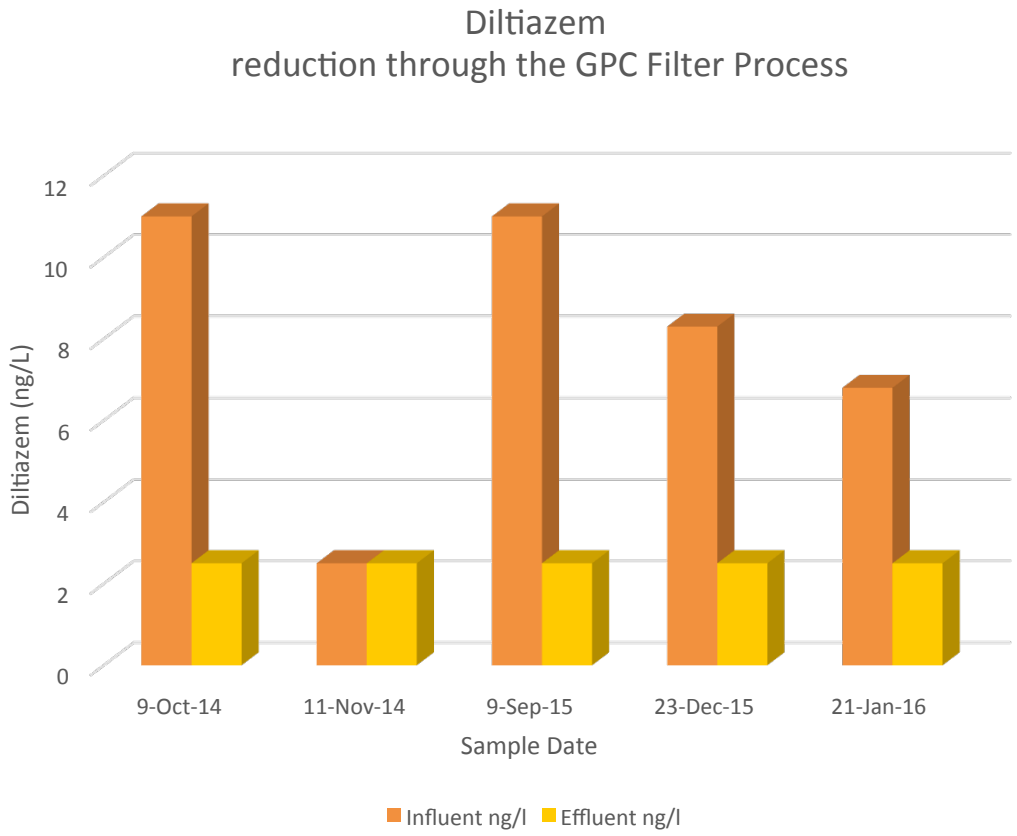
Naproxen

- Naproxen is a nonsteroidal anti-inflammatory drug commonly used for relief from pain, fever, swelling and stiffness. A common trade name is Aleve.
- Highest Influent Concentration reported was 120 ng/l. There were two Influent Concentrations reported as No Detect.
- Four of Five effluent tests had No Detect as the measured concentration value in the effluent.
- In the January 2016 test, the influent concentration was No Detect. The effluent concentration value was 43 ng/l. The MRL was 10 ng/l.
- For the first four tests, the average reduction was over 99%. However, based on the fifth test, the reduction rate is variable.



Diltiazem

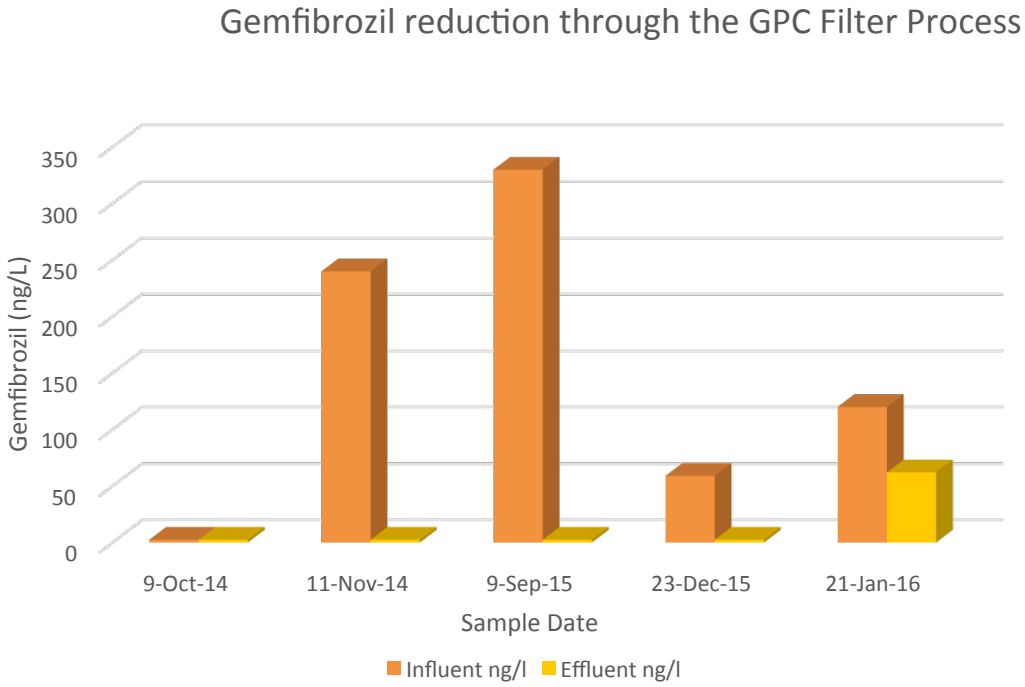
- Diltiazem is a pharmaceutical
- Dilitiazem was detected in four out of five test events.
- The concentration value in the influent ranged from No Detect to 11 ng/l. The effluent concentration was always No Detect.
- The MRL was 5 ng/l. However, the MRL is a significant portion of the reported concentrations.
- The chart is prepared with every ND plotted as half th MRL.
- The average reduction rate is about 68% even though the effluent was always ND.



In this chart, the effluent was always No Detect. The MRL is 5 ng/l. Half the MRL value is plotted to illustrate the significance of the MRL values in some tests.

Gemfibrozil

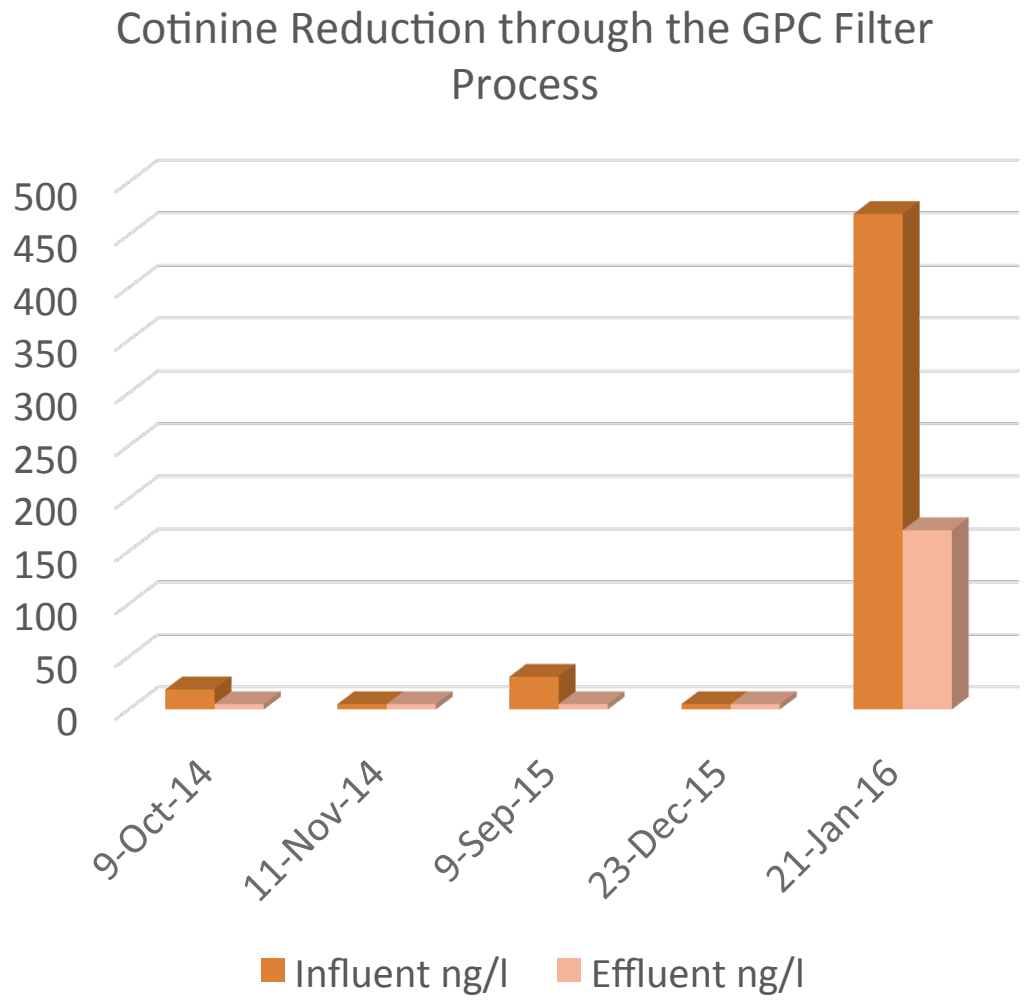
- Gemfibrozil is a pharmaceutical
- Gemfibrozil was detected in four out of five test events.
- The concentration value in the influent ranged from No Detect to 330 ng/l. The effluent concentration was No Detect in four tests. The fifth test effluent concentration was 62 ng/l.
- The MRL was 5 ng/l. The chart is prepared with every ND plotted as half the MRL.
- The average reduction rate is about 90%.



The MRL is 5 ng/l.

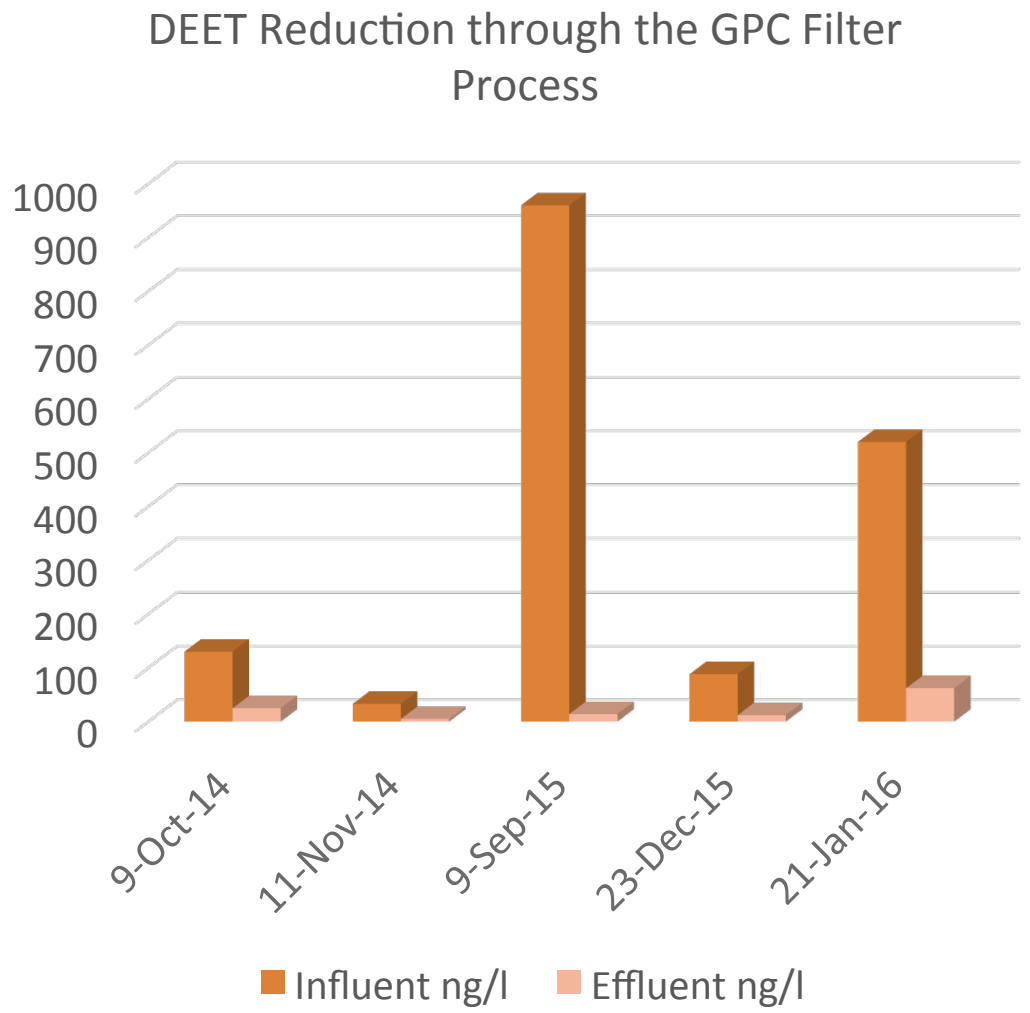
Cotinine, a household chemical

- Cotinine is a metabolite of tobacco.
- Highest Influent Concentration reported was 470 ng/l in the January 2016 test. There were two Influent Concentration values reported as No Detect. The other two influent concentration were 19 ng/l in Oct. 2014 and 31 ng/l in Sept 2015
- Four of Five effluent tests had No Detect as the measured concentration value in the effluent.
- In the January 2016 test, the effluent concentration value was 170 ng/l. The MRL was 10 ng/l.
- For the first four tests, the average reduction was over 99%. However, based on the fifth test, the reduction rate is variable.



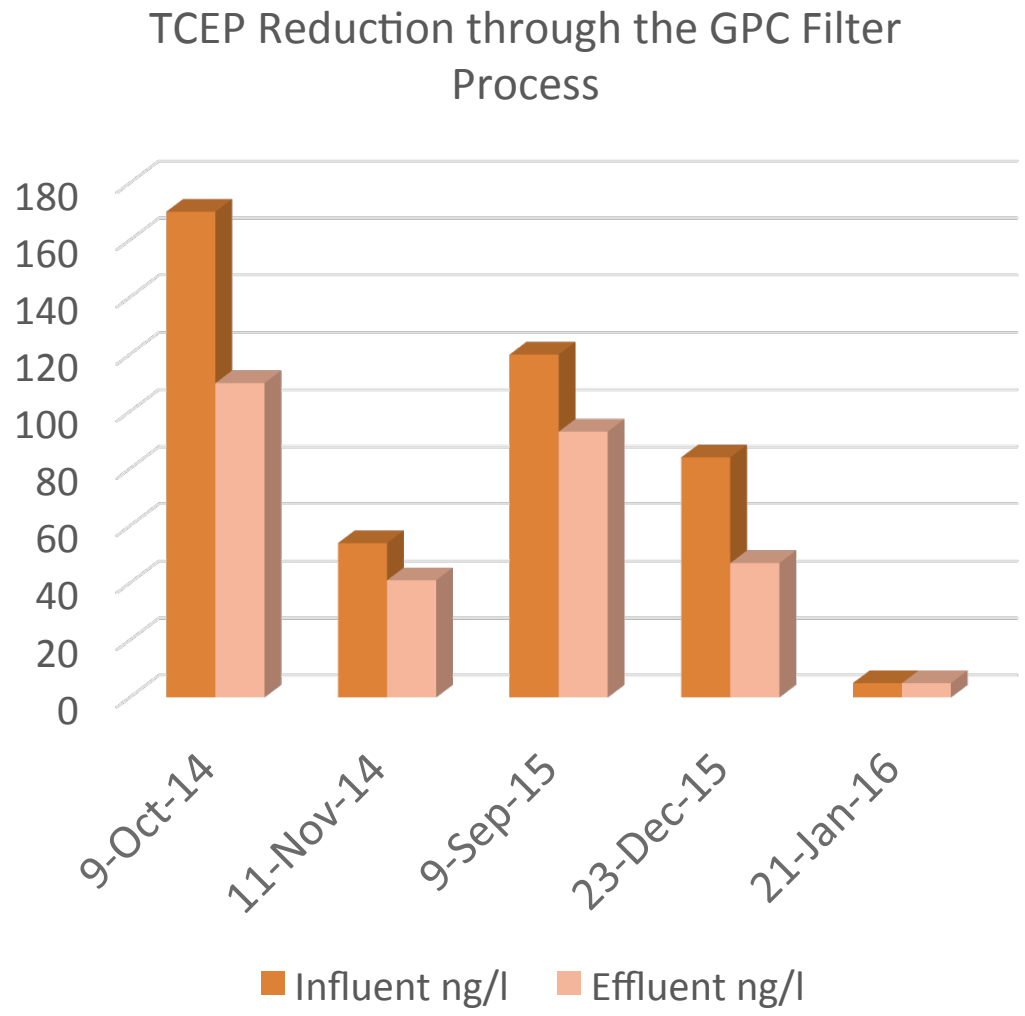
DEET

- DEET is the most common active ingredient in insect repellants. DEET is applied to skin and clothing.
- Highest Influent Concentration reported was 960 ng/l in the Sept 2015 test. The lowest influent concentration was 33 ng/l
- There were always reductions in that the concentration values of the effluent were always lower than the influent.
- The average reduction for all five tests were about 93%.



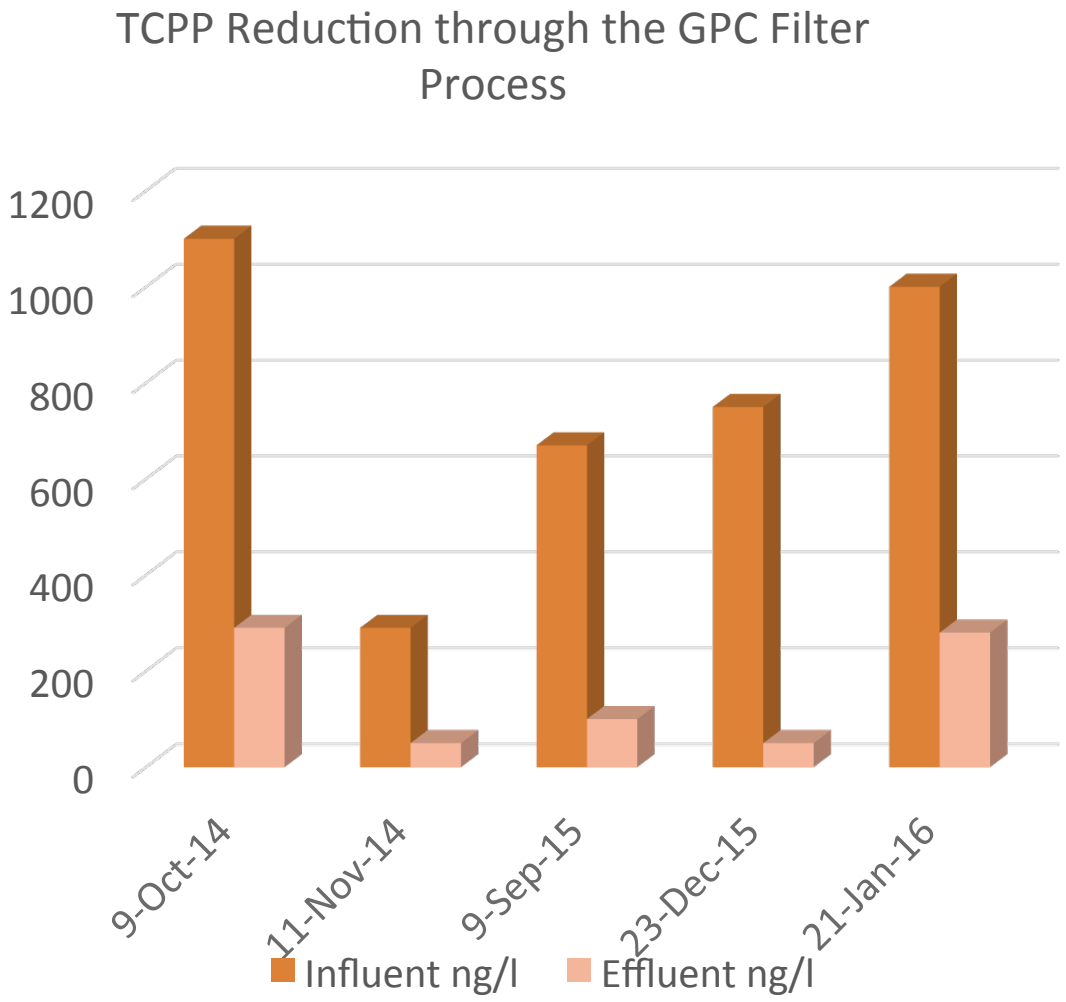
TCEP

- TCEP is also called TCEP(Tris(2-chloroethyl) phosphate). There is another TCEP but the tested TCEP is a flame retardant.
- Because of its suspected reproductive toxicity, it is listed as a substance of very high concern under the European Union's Reach regulations.
- TCEP is considered difficult to treat.
- TCEP was detected in the first four rounds.
- The reduction rate is about 30%.



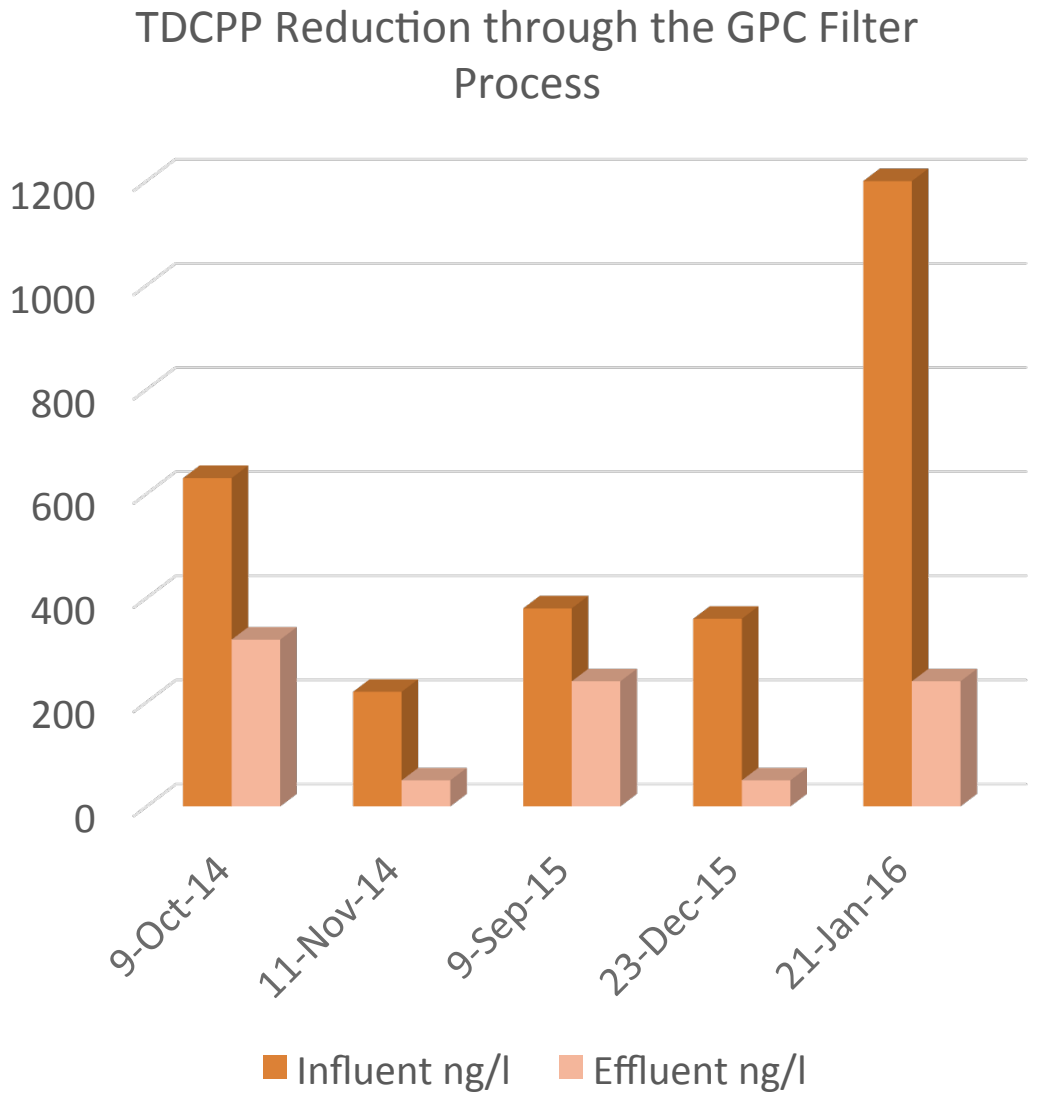
TCPP

- TCPP is also called Tris (chloroisopropyl) phosphate (TCPP). TCPP is a flame retardant.
- TCPP is considered difficult to treat in wastewater treatment.
- TCPP was always detected in the influent water. TCPP was detected in three of the effluent tests.
- Two effluent tests were No Detect.
- The MRL was 100 ng/l.
- The reduction rate is about 80%.



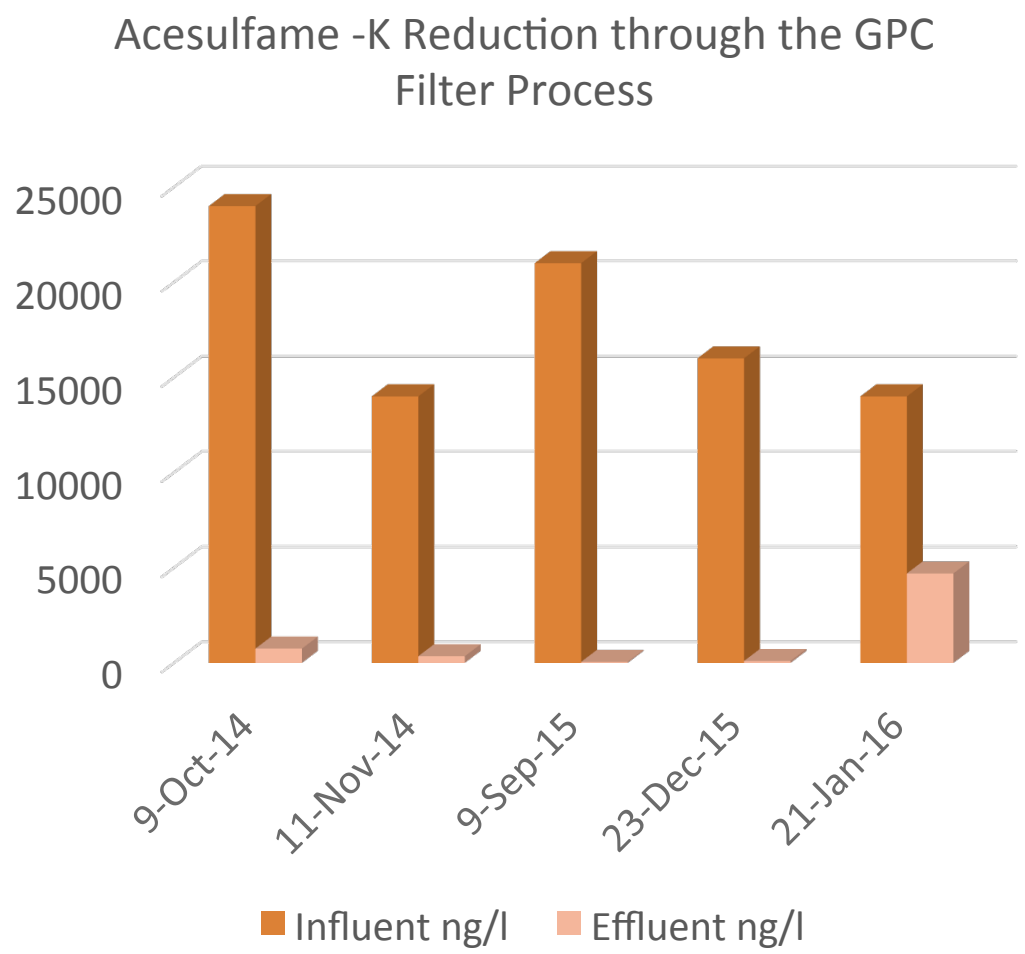
TDCPP

- TDCPP is also called Tris (1,3-dichloroisopropyl) phosphate (TDCPP). TDCCP is a flame retardant.
- TDCPP is considered difficult to treat in wastewater treatment
- TDCPP was always detected in the influent water. TDCPP was detected in three of the effluent tests.
- Two effluent tests were No Detect.
- The MRL was 100 ng/l.
- The reduction rate is about 68%.



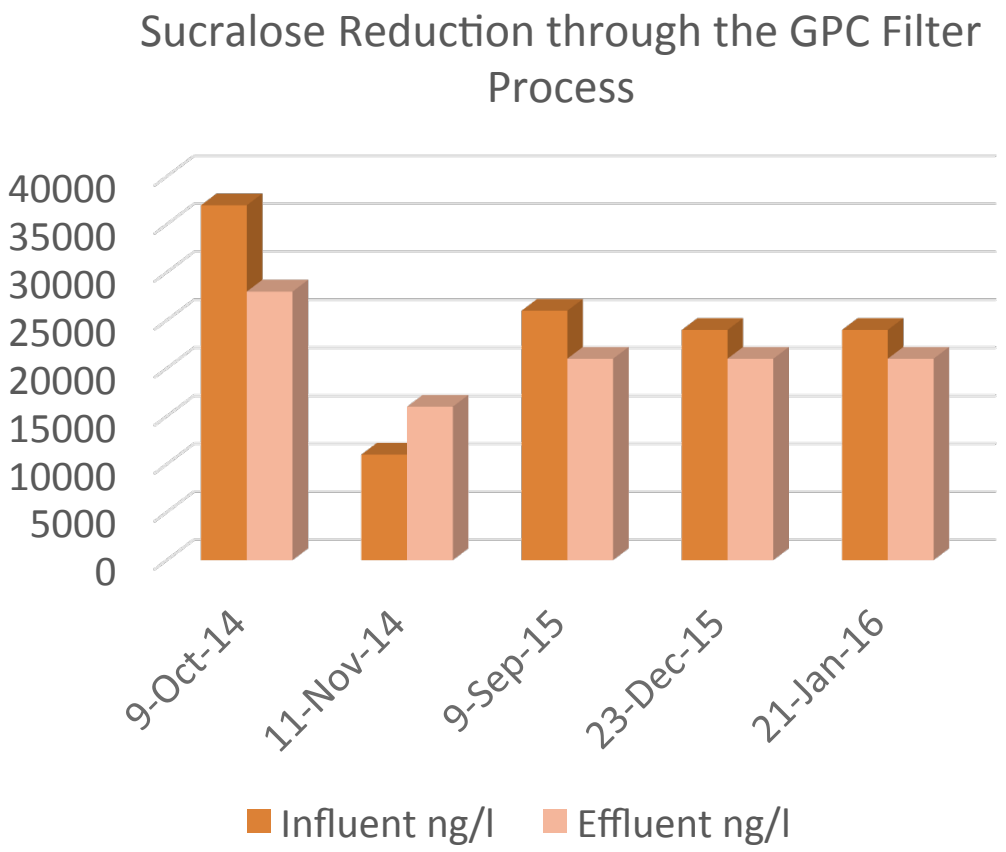
Acesulfame - K

- Acesulfame potassium is a calorie-free artificial sweetener, also known as Acesulfame K or Ace K.
- Acesulfame K was always detected in the influent and effluent waters.
- The MRL was 200 ng/l for the influent and the MRL for the first four effluent tests was 20 ng/l. The MRL was 200 ng/l for the Jan 2016 effluent test.
- The reduction rate is about 93%.



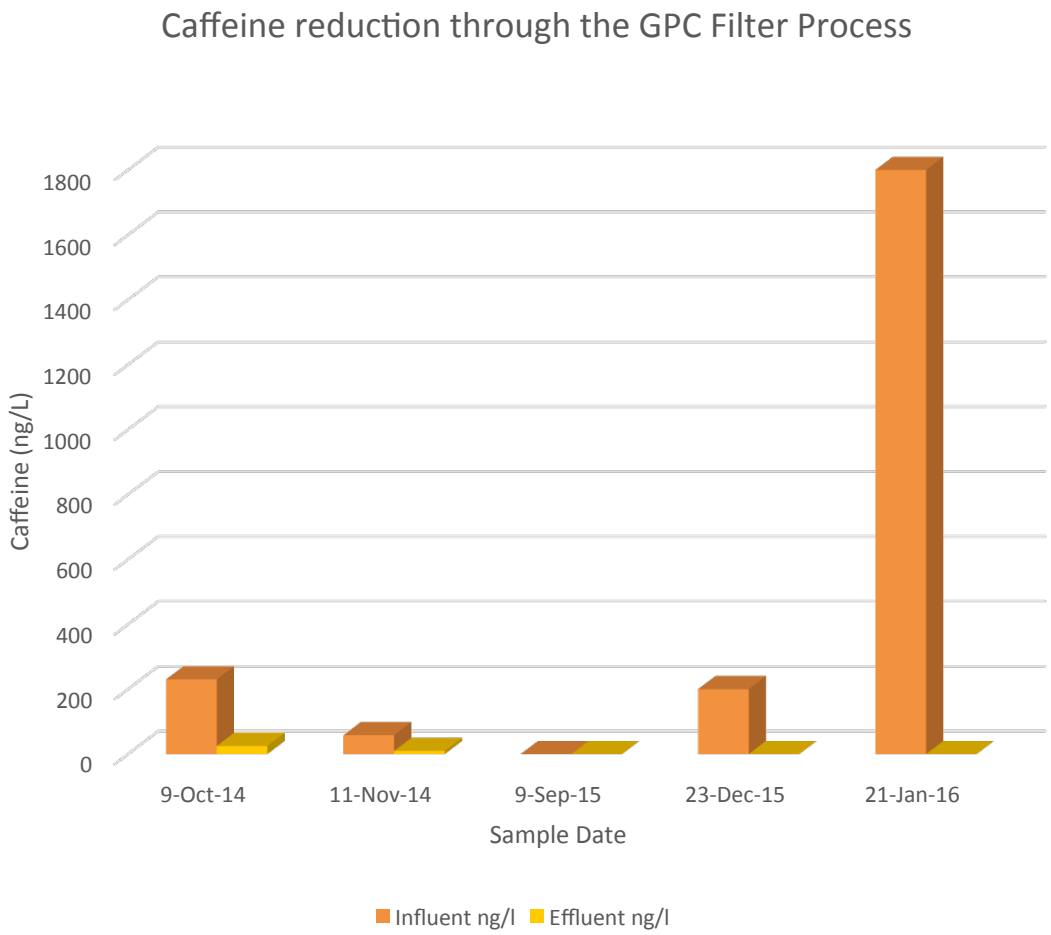
Sucralose

- Sucralose is a calorie-free artificial sweetener also known as Splenda.
- Sucralose was always detected in the influent and effluent waters.
- The MRL was 1000 ng/l.
- Sucralose was considered biologically inert. But more recent studies assert that the long term environmental effects are unknown.
- The average reduction rate is about 12%. But in the November, 2014 test, the effluent concentration was higher than the influent concentration.
- This chemical has the lowest observed reduction through the GPC Filter Process



Caffeine

- Caffeine is a legal central nervous system stimulant. Caffeine is in coffee, tea and cola. 90% of adults consume caffeine.
- Caffeine was detected in four out of five test events.
- The MRL was 5 ng/l.
- The concentration value in the influent ranged from No Detect to 1800 ng/l. However, the Jan. 2016 value was nine times the highest of the other four concentration values. The effluent concentration ranged from No Detect (twice) to 25 ng/l.
- The average reduction rate is about 92% treating the Jan. 2016 concentration as an outlier



Further discussion

- The operation of the GPC Filter Process is intuitively more efficient in the reduction of PPCP's than the operation of membranes or other filtration of treated water.
- Both membranes and filtration technologies trap these chemicals on the upstream side of the filters.
- In contrast, the GPC Filter Process seemingly effectively destroys the removed chemicals. With the GPC Filter Process, there is no upstream material filtered out of the water. With the GPC Filter Process, there is no upstream brine to be treated.

Why should you add a GPC Filter Process to your small scale wastewater treatment facility.

- The GPC Filter Process will reduce non-conformities in the discharge of treated water to the soils.
- The GPC Filter Process will reduce BOD_5 and TSS to low concentrations
- The GPC Filter Process will further reduce dissolved TN concentrations.
- The GPC Filter Process will further reduce most dissolved organic Contaminants of Emerging Concern.
- The GPC Filter Process will allow the owner, the engineer and the operator to discharge the best possible water into the environment.
- Thank You

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