LAKE MEAD WATER QUALITY FORUM

ECOSYSTEM MONITORING WORKGROUP

FATHEAD MINNOW STUDY AT CLARK COUNTY WATER RECLAMATION DISTRICT:

December 2008 – March 2011

Basic Research Questions

- Can wastewater effluent over a long period of time have a negative impact on Fathead Minnow growth?
- Will wastewater purified with UF/O_3 treatment reduce adverse impacts, if any?

- EIS for the SCOP project and the endangered species act requires a biological opinion by USF&WS
  - USF&WS and USGS postulated that wastewater effluent could have an adverse impact on the Razorback Sucker
  - Fathead Minnow to serve as a surrogate for the Razorback Sucker

- Conduct research to improve knowledge on long term exposure of the Razorback Sucker to wastewater effluent
- Research would serve to offset any possible negative impacts to the Razorback
- SCOP project not to be built at this time
- Fathead Minnow project would still be completed

- USF&WS and USGS wanted to investigate long term impacts on Fathead Minnows grown in 3 waters:
  - Present BNR with sand filtration and UV disinfection
  - Present BNR with membrane filtration and ozone disinfection
  - Control water (softened potable water)

PARTICIPANTS

- USF&WS
  - Required the study under Section 7 consultation biological opinion for the SCOP EIS
- USGS proposed using existing effluent and control water
  - Ongoing fish studies on carp and bass in Lake Mead
- SNWA
  - Provided research capabilities on EDCs and enteric viruses in drinking water

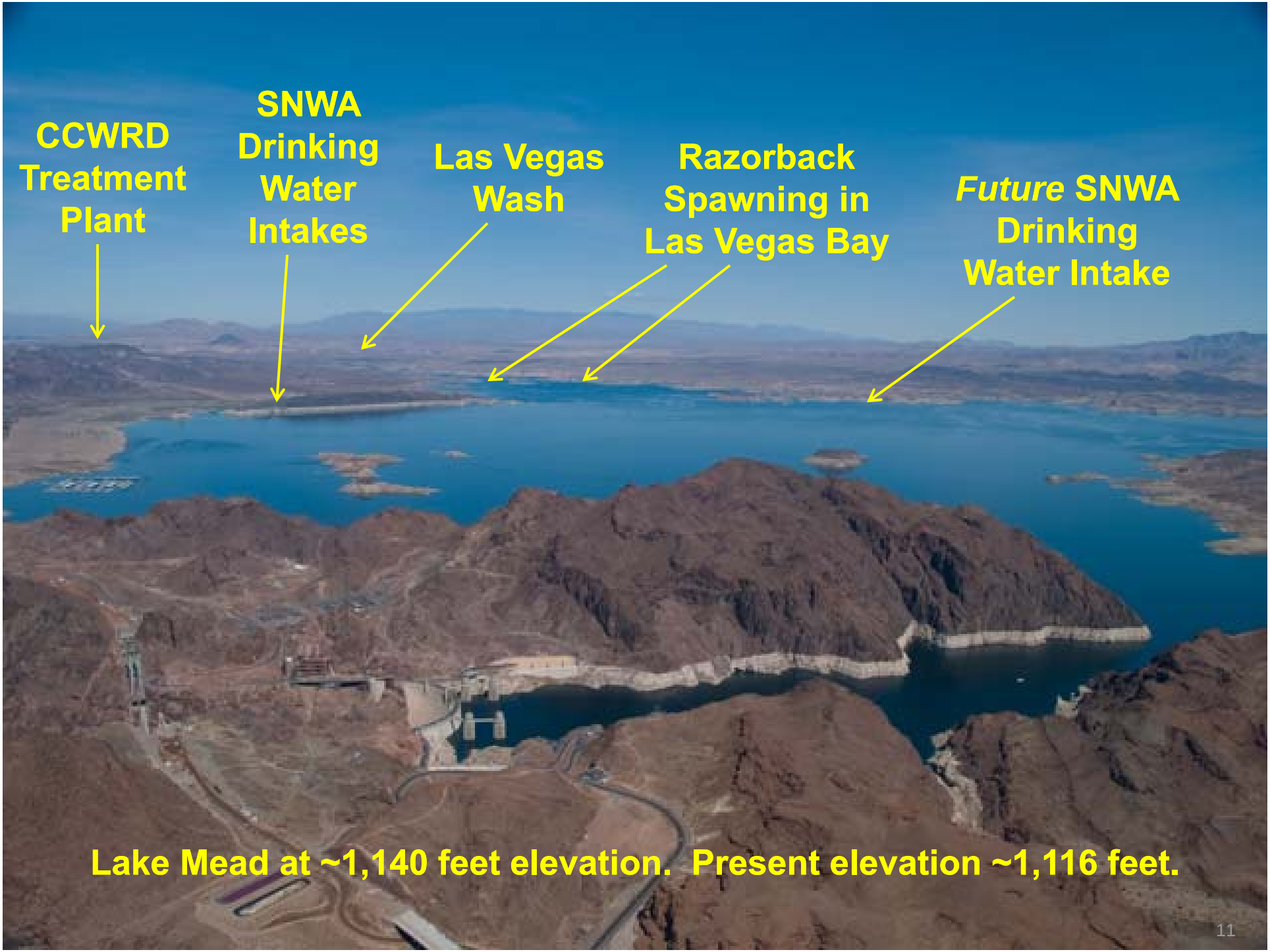
- CCWRD
  - Proposed adding membrane/ozone treatment as best treatment alternative for CCWRD. Built pilot UF/O_3 facility
  - Characterization of improved disinfection of membranes and ozonation
  - Ongoing research on contaminants of concern (EDC, Selenium)
- COH, CLV, CNLV
  - Funding and research for planning and operations

CCWRD's Priorities For Trace Organic Removal

- Continue to protect spawning area of Razorback Sucker in Las Vegas Bay
- Protection of drinking water resource
  - Intakes ≈ 15 miles downstream of wastewater discharges
- Gather background information for development of a consensus on future NPDES permit requirements

Southern Nevada Water Authority (SNWA)

- Treats all drinking water for the Las Vegas Valley
- Conducted virtually all of the trace organic analyses (1999-2011) for CCWRD
- Remaining analyses performed by MWH laboratories
- Conducted all of the enteric virus analyses


CCWRD Treatment Plant
SNWA Drinking Water Intakes
Las Vegas Wash
Razorback Spawning in Las Vegas Bay
Future SNWA Drinking Water Intake
Lake Mead at ~1,140 feet elevation. Present elevation ~1,116 feet.

Trace Organics 1999 - 2011

380…..Total number of samples
48…..Diurnal samples
64…..QA/QC
215…..Different chemical parameters
33…..Different chemical analyses used today as surrogate
18…..Bioassays (Estrogenicity)
>6,000…..Different chemical analyses

Most samples were grab, but with constant flow

Surrogate Trace Organic Parameters

<u>Steroid Hormones</u>

- Female:
  - Estradiol (E2)
  - Estriol (E3)
  - Estrone (E1)
  - Ethynylestradiol (EE)
- Male:
  - Androstenedione
  - Progesterone
  - Testosterone

<u>Other EDCs</u>

- Bisphenol A (plasticizer)
- Octylphenol (detergent degradant)

Pharmaceuticals

- Atenolol – (*blood pressure medication)*
- Atorvastatin – (*cholesterol medication – Lipitor)*
- Carbamazepine – (*anti-convulsant medication)*
- Diazepam – (*anti-depressant – Valium)*
- Diclofenac – (*arthritis medication)*
- Fluoxetine – (*anti-depressant – Prozac)*
- Gemfibrozil – (*heart medication)*
- Ibuprofen – (*pain medication)*
- Iopromide – (*x-ray contrast media)*
- Meprobamate – (*anti-depressant)*
- Naproxen – (*pain medication)*
- Phenytoin – (*anti-convulsant medication – Dilantin)*
- Primidone – (*anti-convulsant medication)*

Pharmaceuticals (cont.)

- Sulfamethoxazole – (*antibiotic)*
- Trimethoprim – (*antibiotic)*

Personal Care Products

- Caffeine (*natural product – stimulant*)
- Benzophenone (*sunscreen ingredient*)
- BHA (*anti-oxidant food preservative*)
- DEET (*insect repellant*)
- Musk Ketone (*synthetic fragrance*)
- Triclosan (*anti-microbial*)

Flame Retardants

- TCEP
- TCPP

Pesticides / Herbicides

- Atrazine

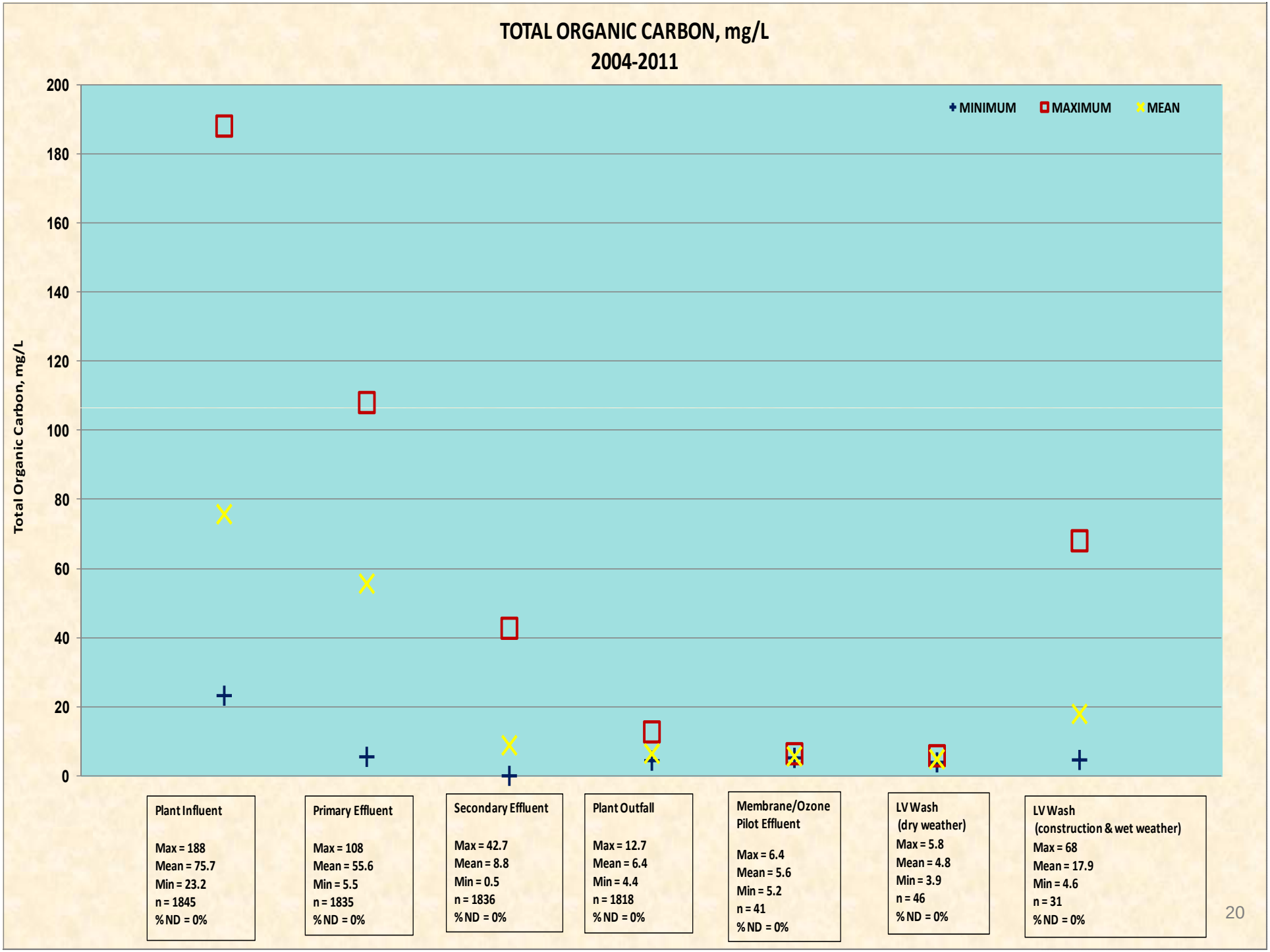
Non-detects (ND) for Trace Organics?

- Detection limits varied with parameter
- 38% of analyses ND
- At low concentrations, ND are effectively zero!
- As such, non-detects were plotted as zero
- Because of large percentage of non-detects, median used over mean
- Median used to compensate for both extreme maximums and minimums

Gross Parameters

Total Organic Carbon

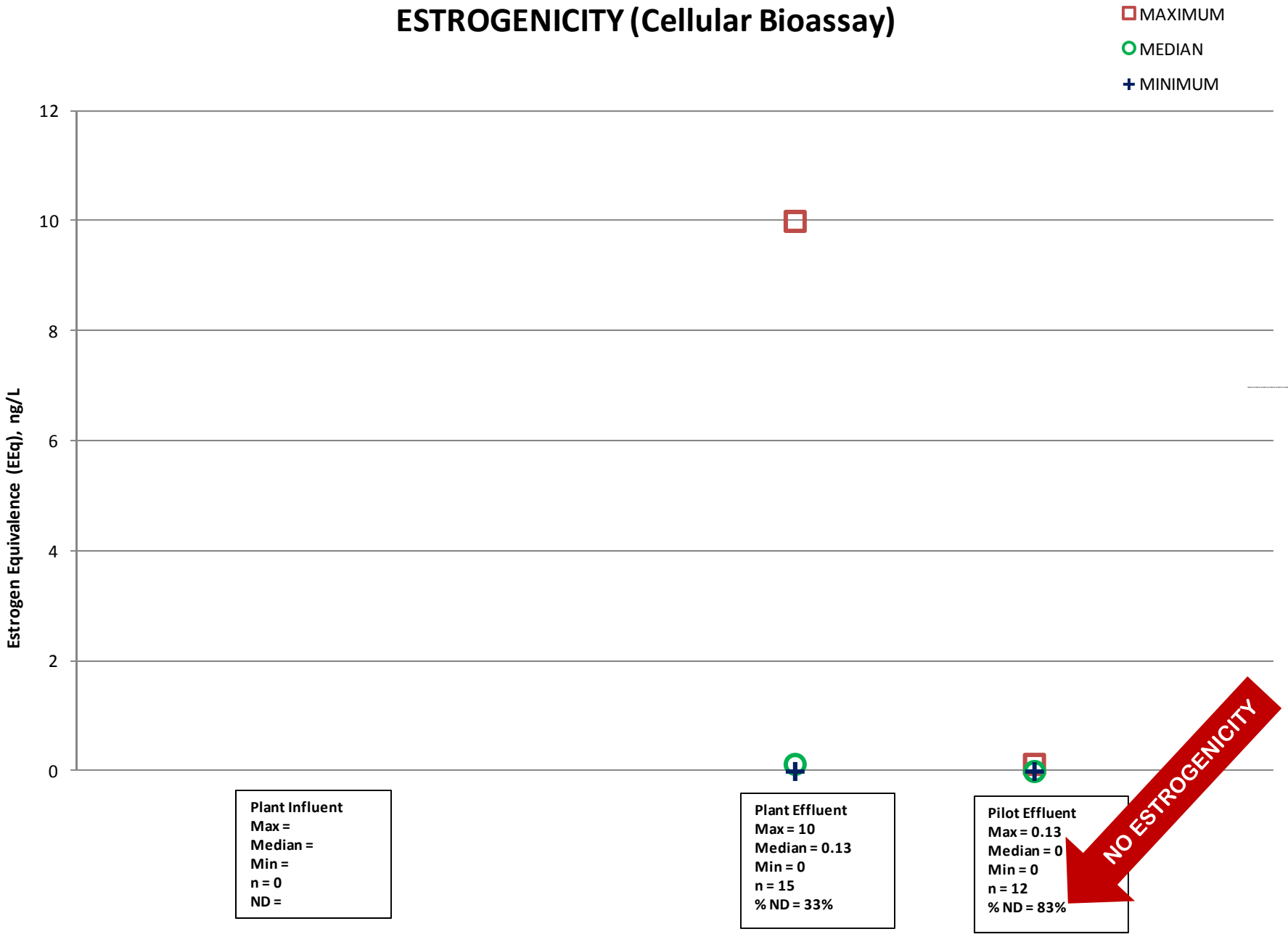
- Gives big picture perspective (mg/L) of what is happening to trace organics
- Individual trace organic compound concentrations (ng/L) are less than a hundredth of a percentage of total organic carbon


TOTAL ORGANIC CARBON, mg/L
2004-2011
Total Organic Carbon, mg/L
200
180
160
140
120
100
80
60
40
20
0
MINIMUM
MAXIMUM
MEAN
Plant Influent
Max = 188
Mean = 75.7
Min = 23.2
n = 1845
% ND = 0%
Primary Effluent
Max = 108
Mean = 55.6
Min = 5.5
n = 1835
% ND = 0%
Secondary Effluent
Max = 42.7
Mean = 8.8
Min = 0.5
n = 1836
% ND = 0%
Plant Outfall
Max = 12.7
Mean = 6.4
Min = 4.4
n = 1818
% ND = 0%
Membrane/Ozone Pilot Effluent
Max = 6.4
Mean = 5.6
Min = 5.2
n = 41
% ND = 0%
LV Wash (dry weather)
Max = 5.8
Mean = 4.8
Min = 3.9
n = 46
% ND = 0%
LV Wash (construction & wet weather)
Max = 68
Mean = 17.9
Min = 4.6
n = 31
% ND = 0%

Estrogenicity

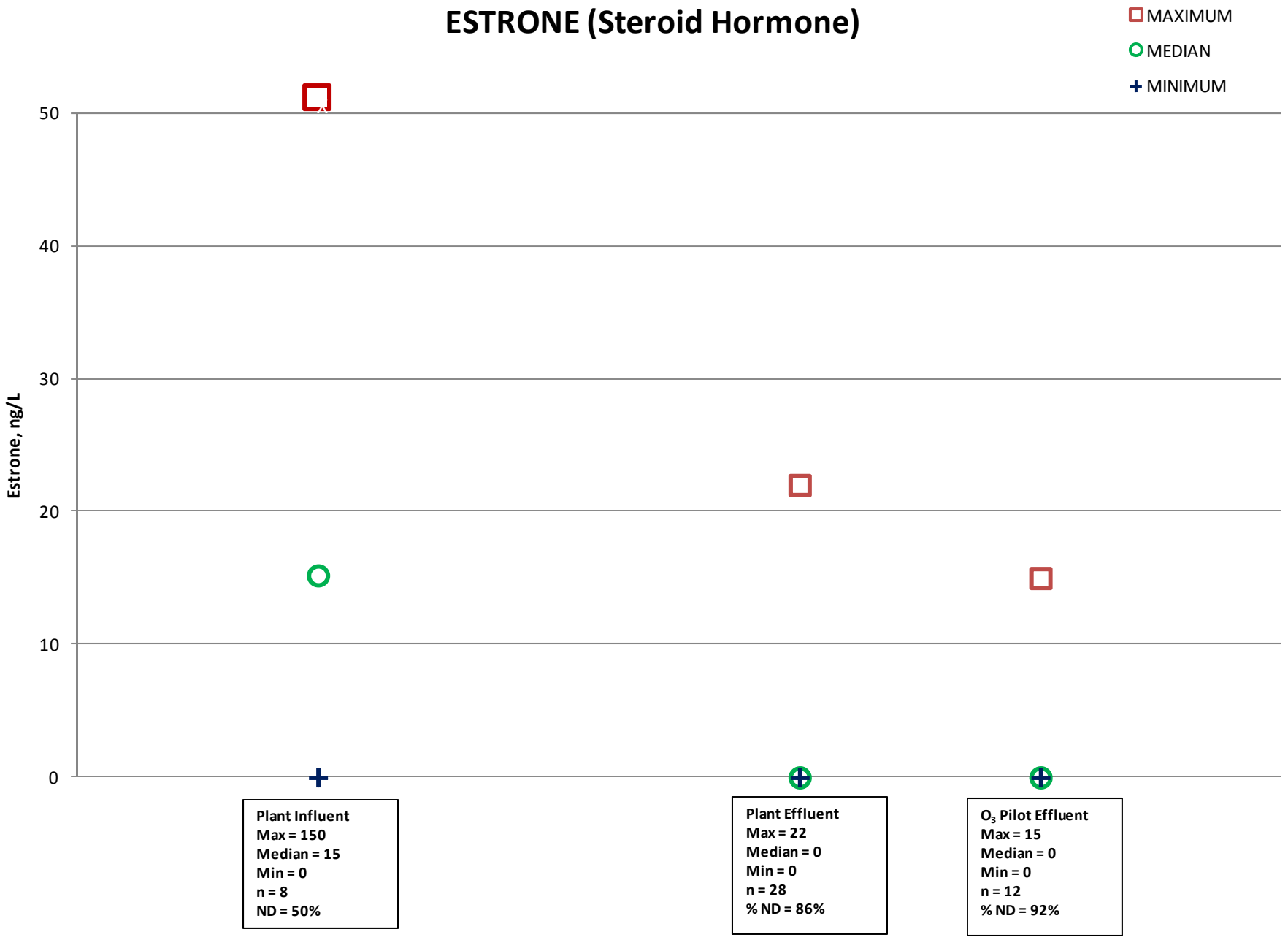
- Is a cellular bioassay
- Represents the sum of all chemicals having hormonal impact

ESTROGENICITY (Cellular Bioassay)

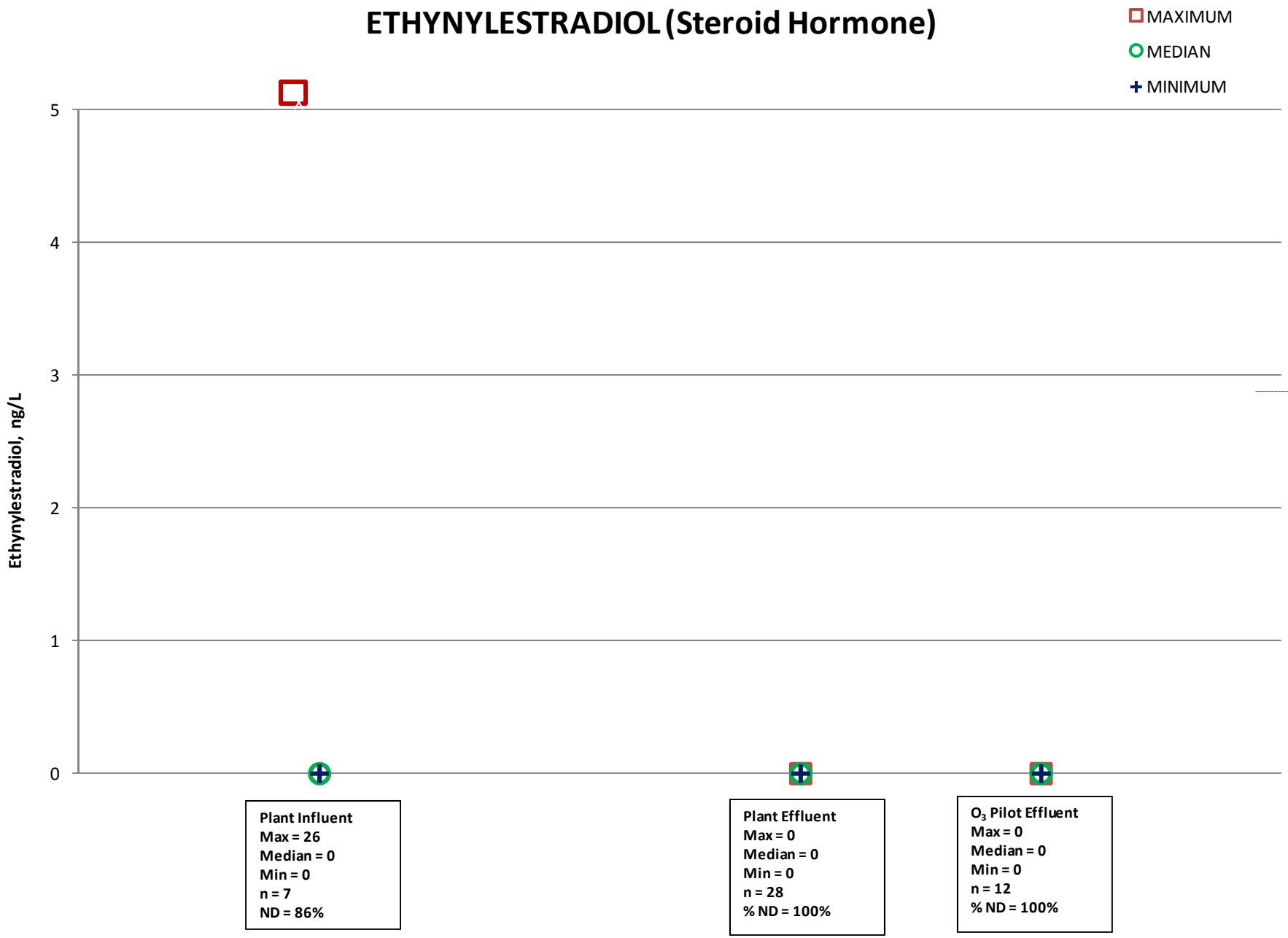


Trace Organic Compounds

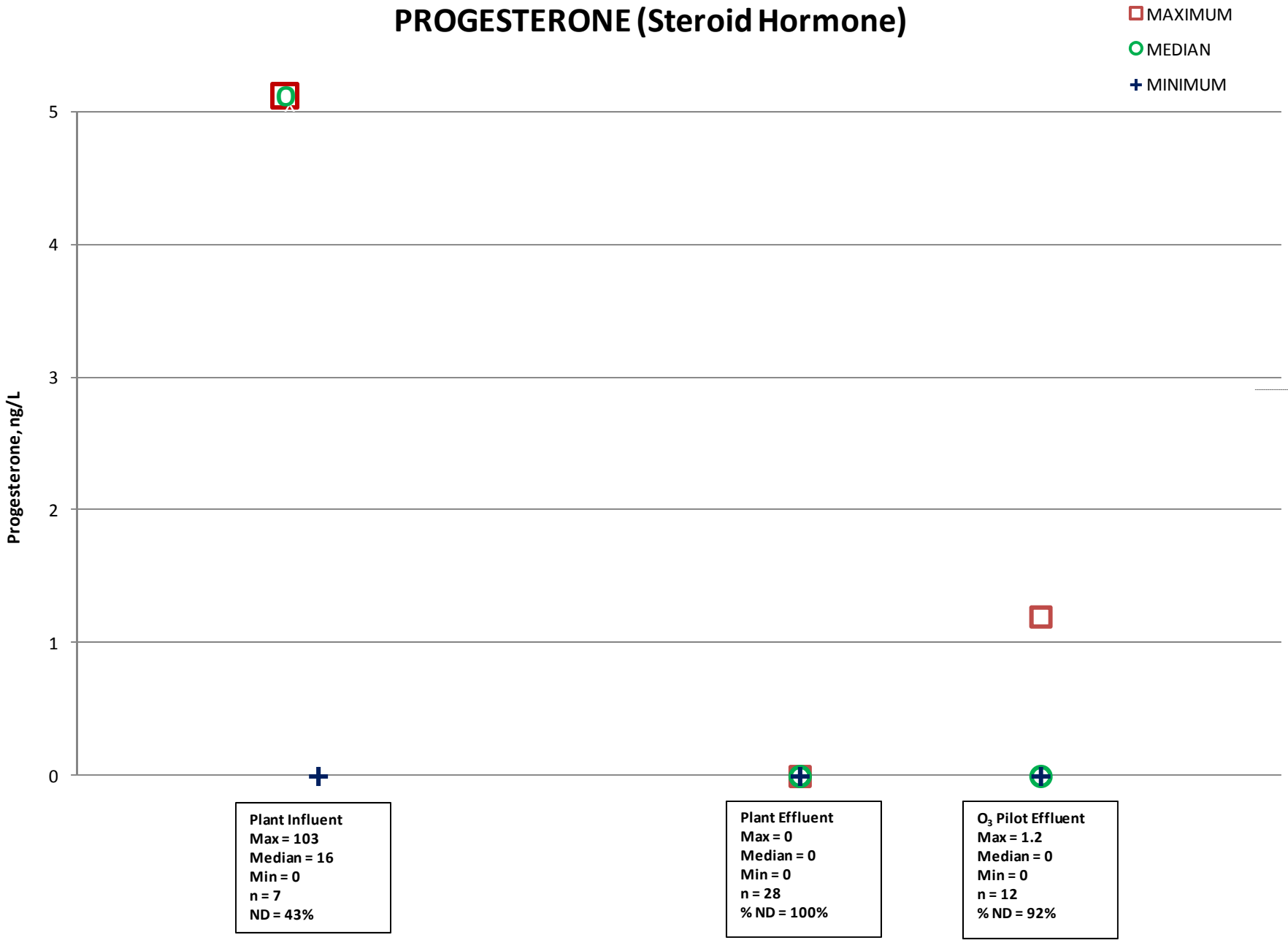
ESTRONE (Steroid Hormone)



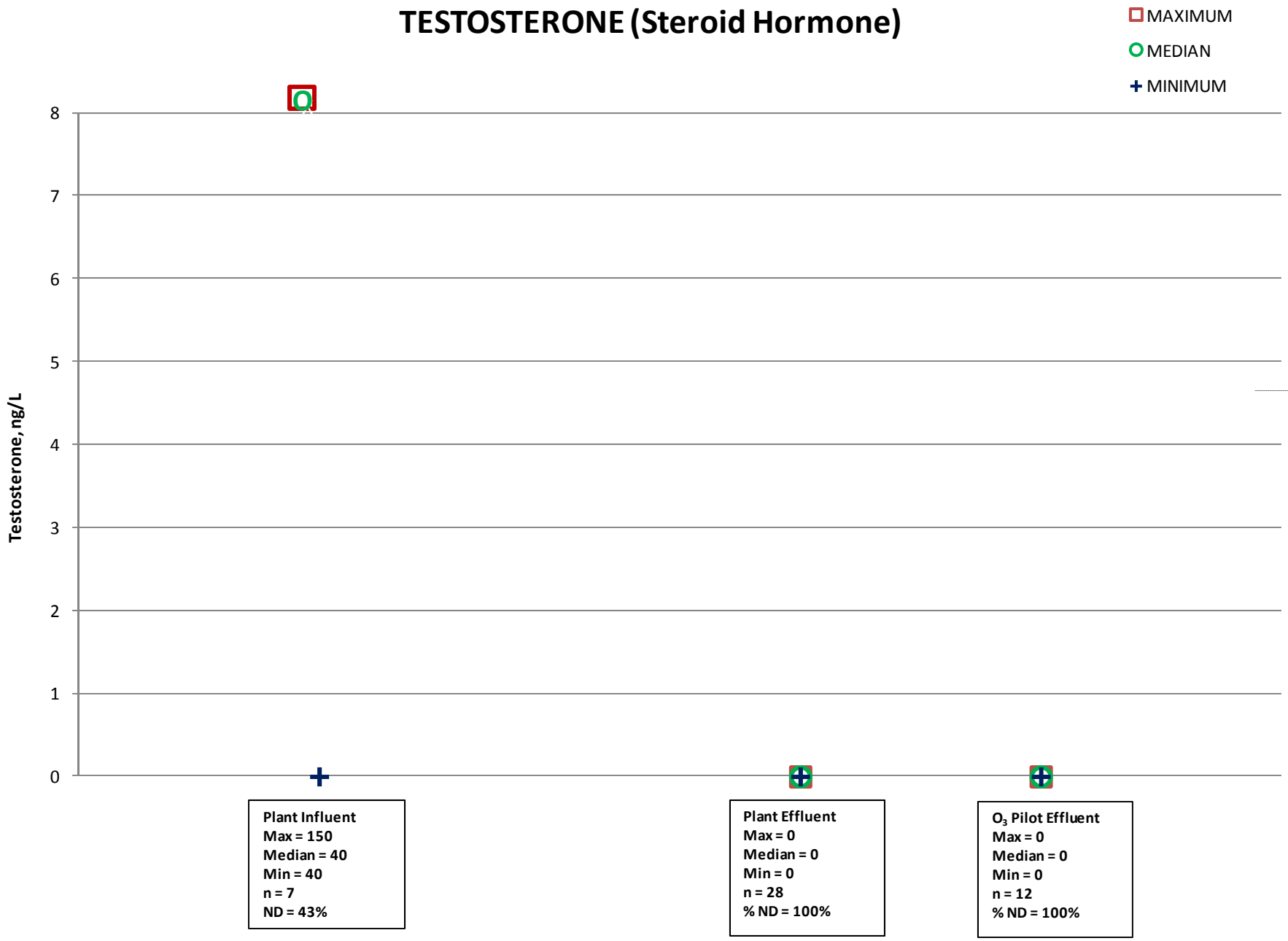
ETHYNYLESTRADIOL (Steroid Hormone)



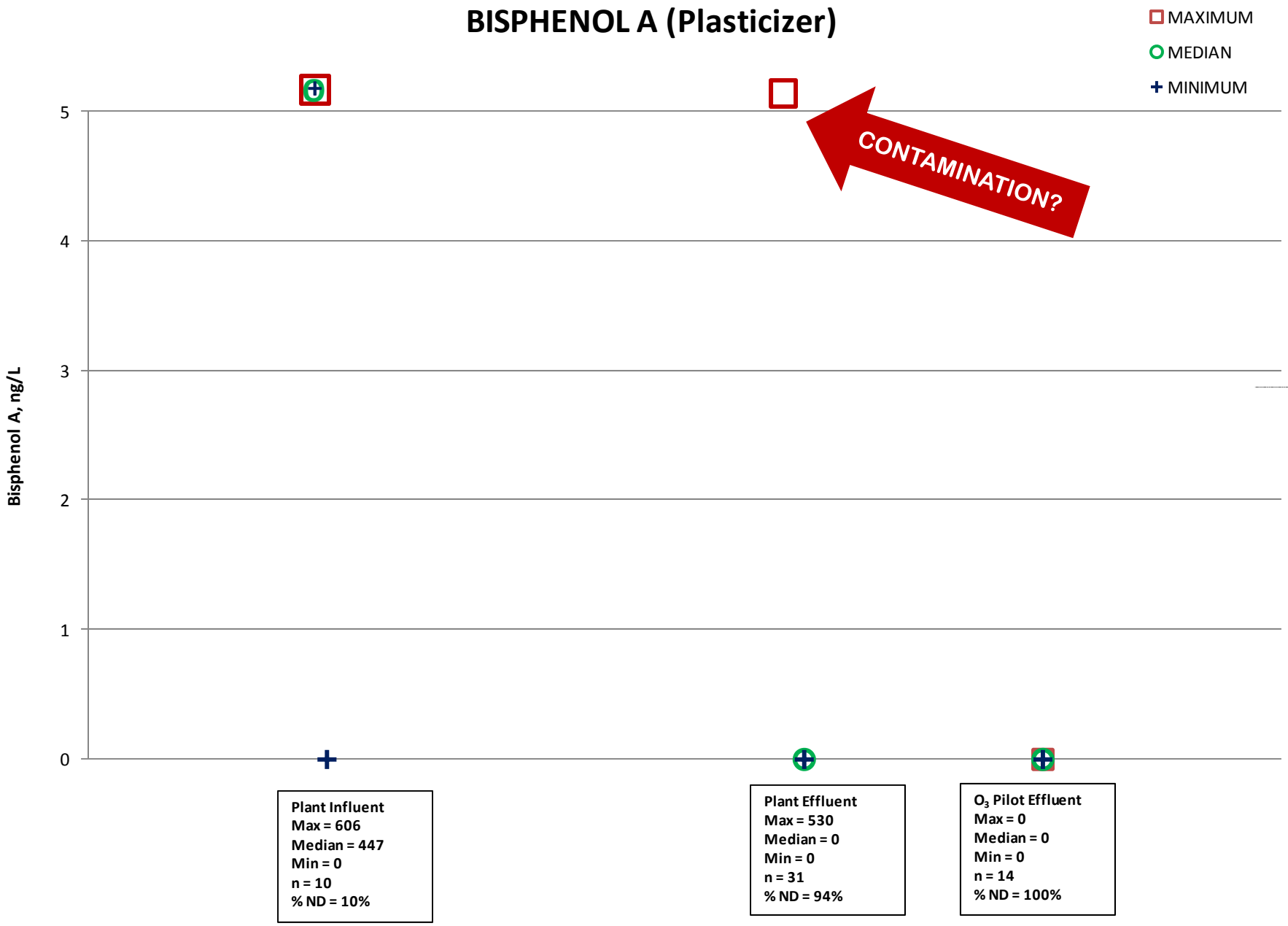
PROGESTERONE (Steroid Hormone)

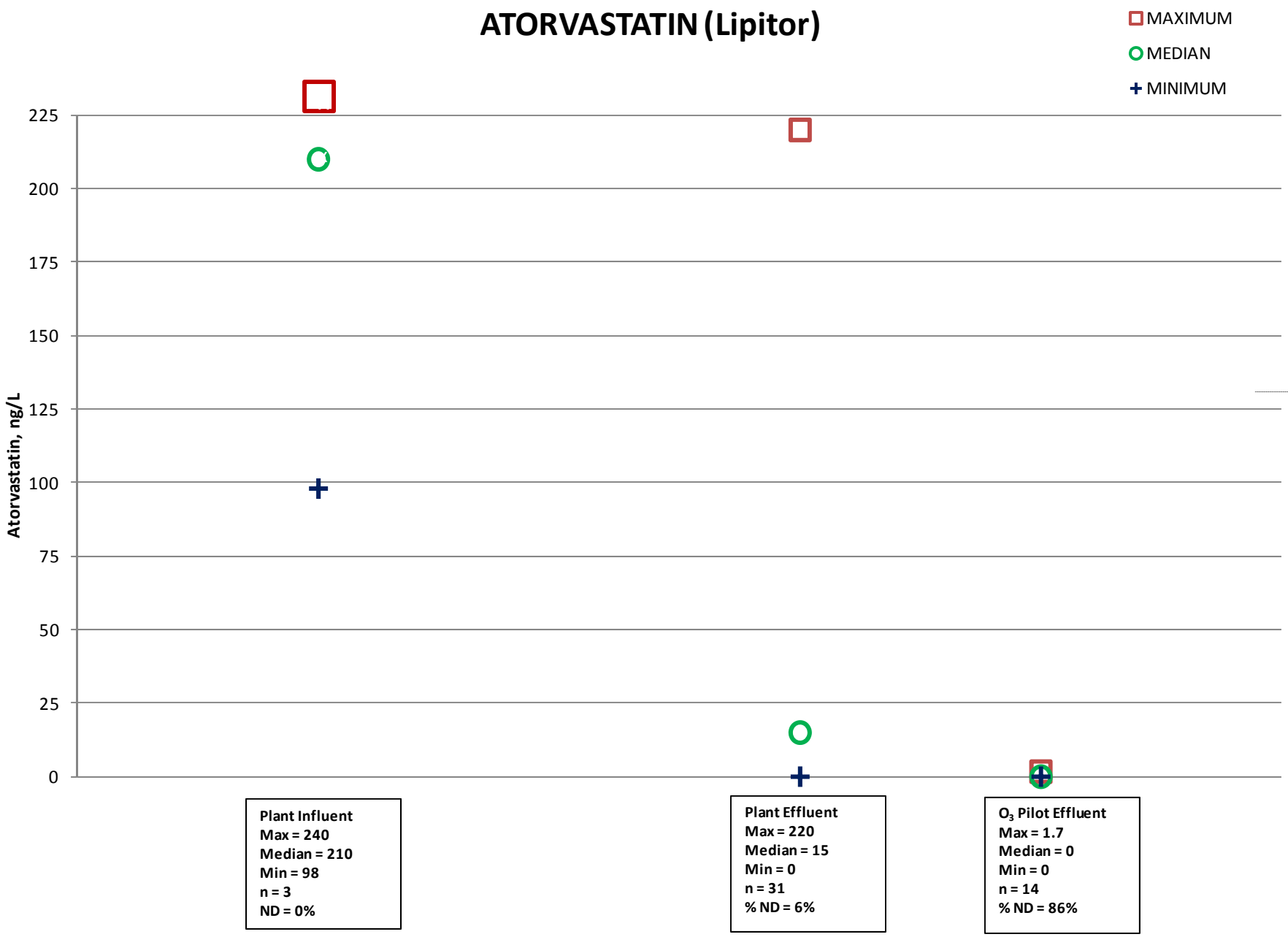


TESTOSTERONE (Steroid Hormone)

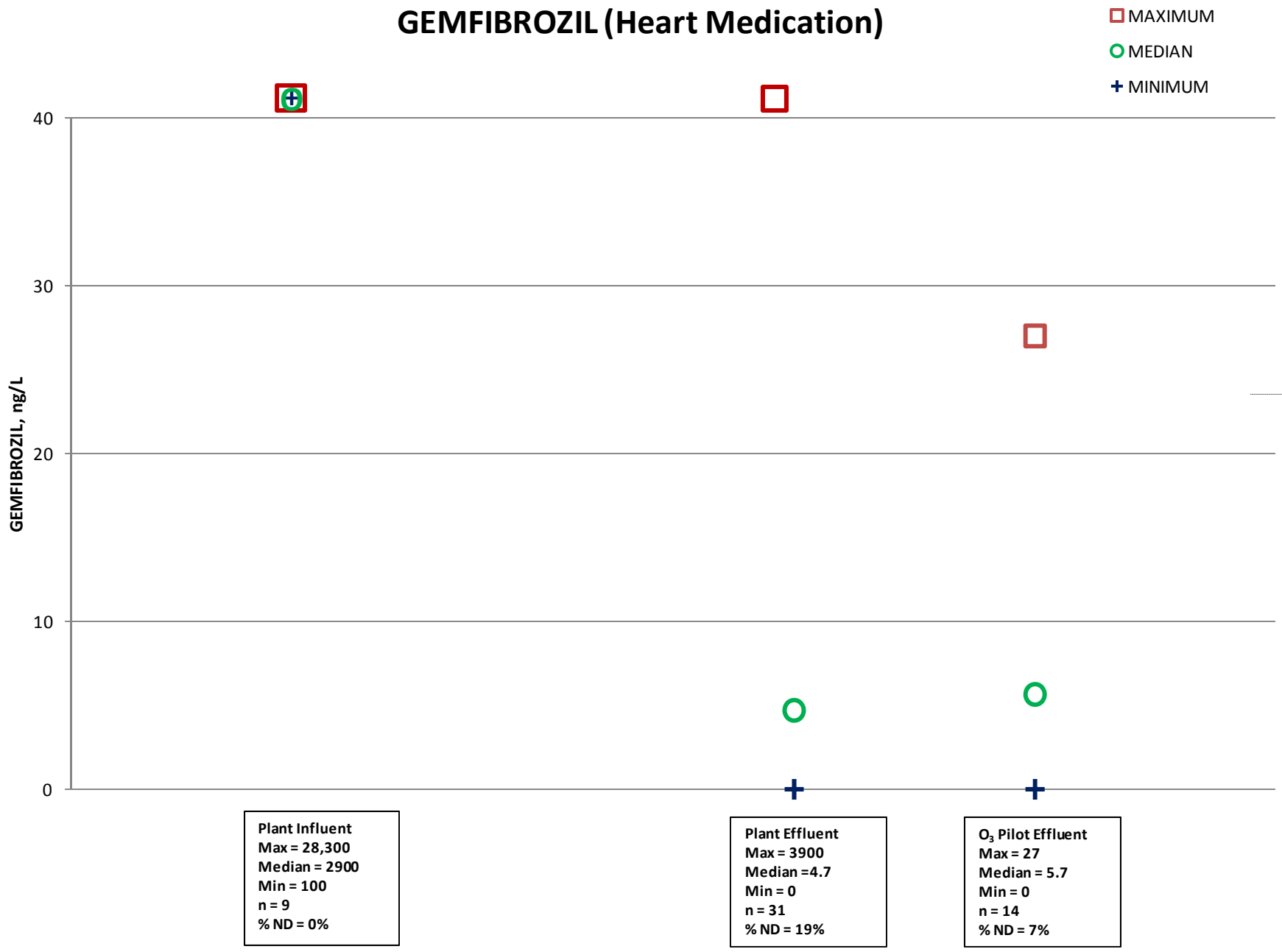


BISPHENOL A (Plasticizer)

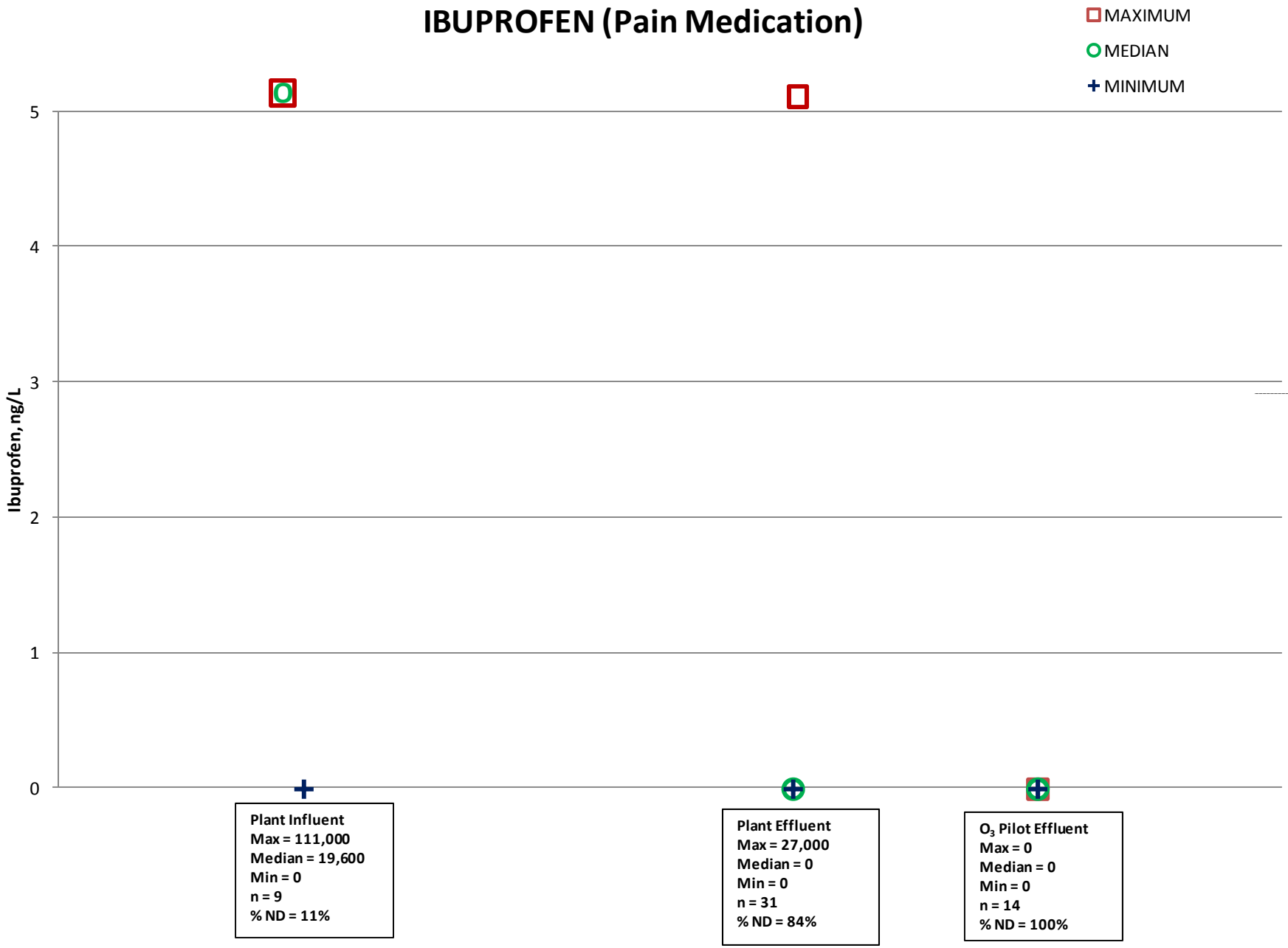


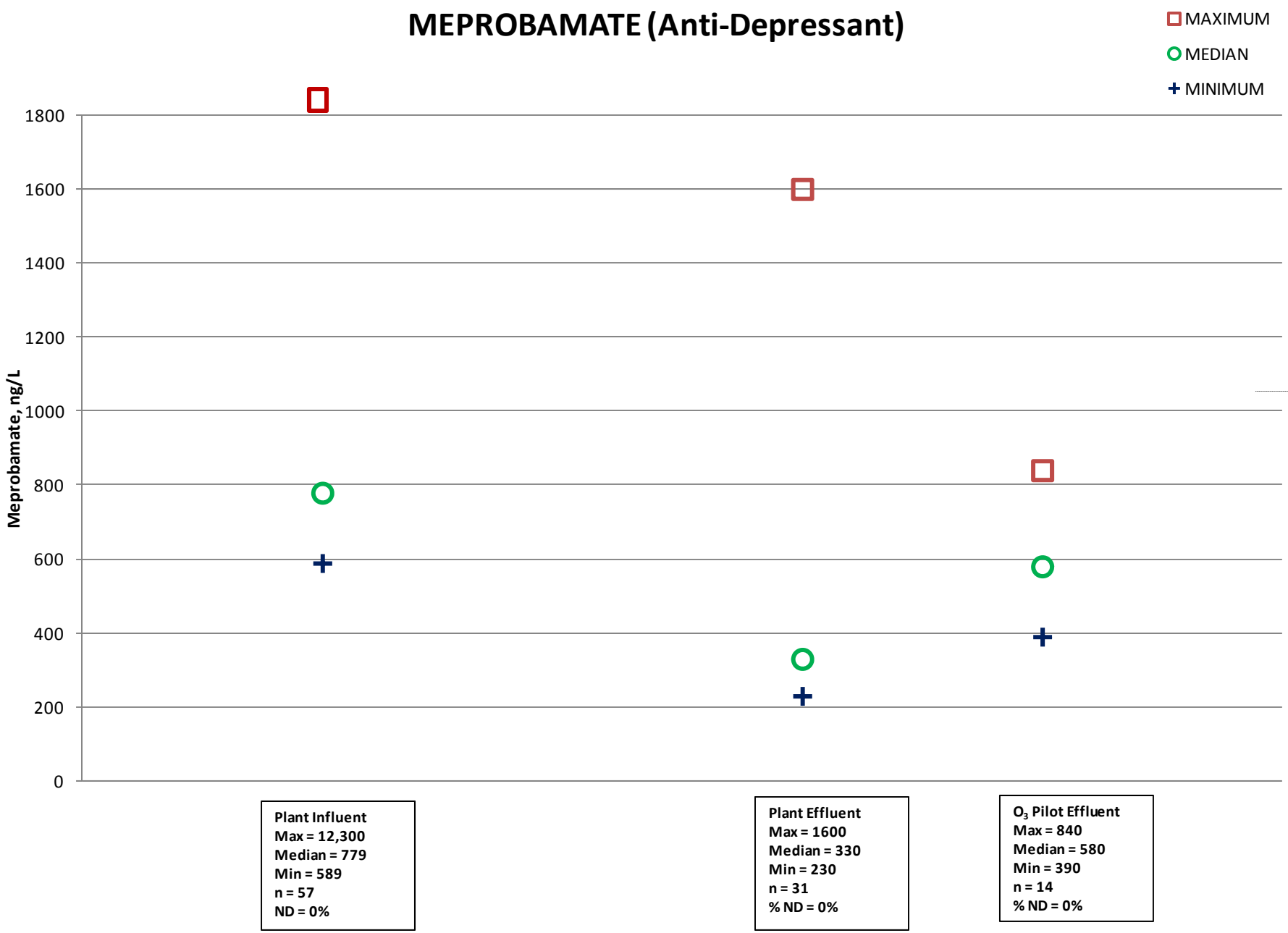

ATORVASTATIN (Lipitor)
MAXIMUM
MEDIAN
MINIMUM
Atorvastatin, ng/L
225
200
175
150
125
100
75
50
25
0
Plant Influent
Max = 240
Median = 210
Min = 98
n = 3
ND = 0%
Plant Effluent
Max = 220
Median = 15
Min = 0
n = 31
% ND = 6%
O3 Pilot Effluent
Max = 1.7
Median = 0
Min = 0
n = 14
% ND = 86%

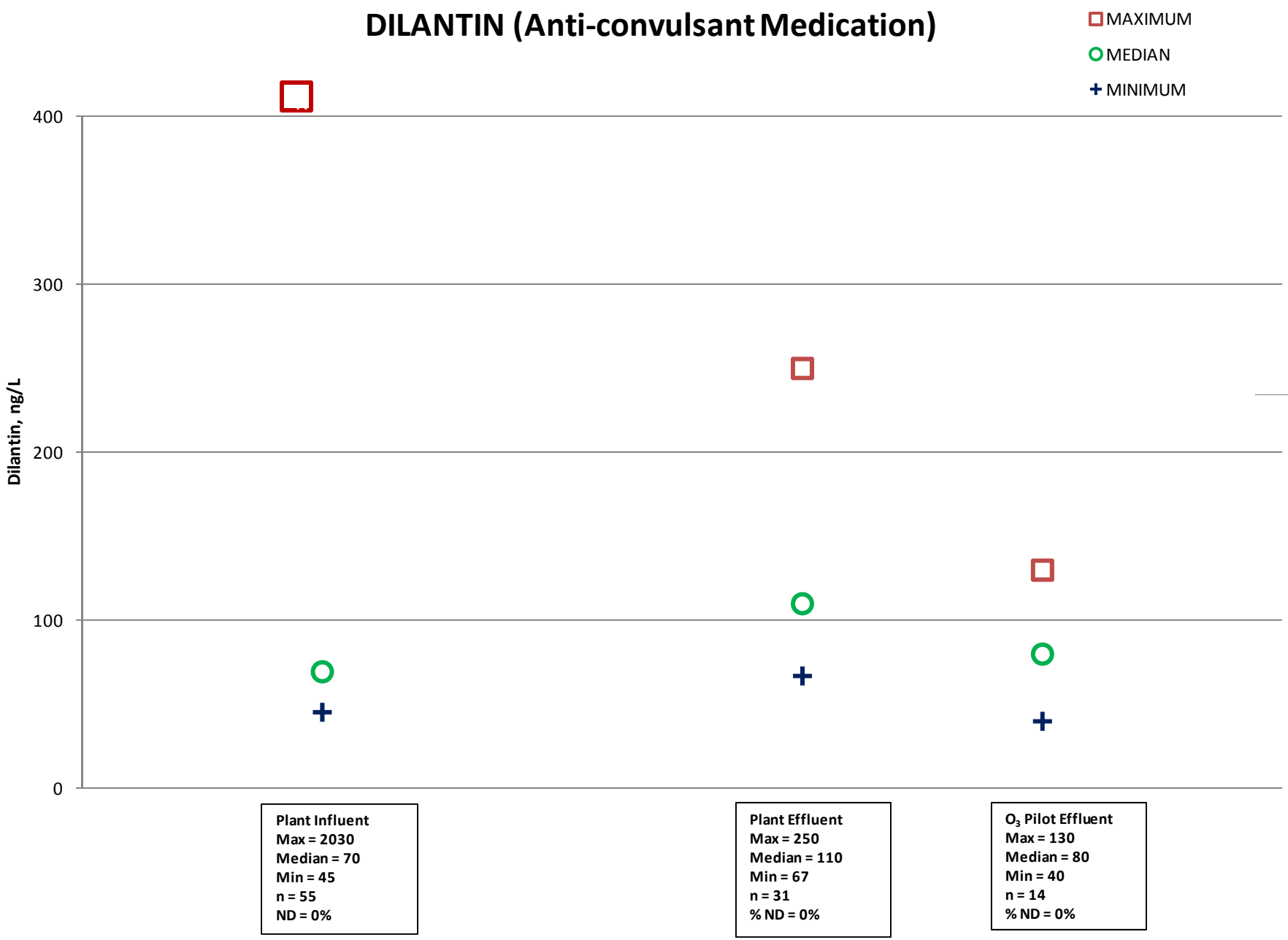
GEMFIBROZIL (Heart Medication)

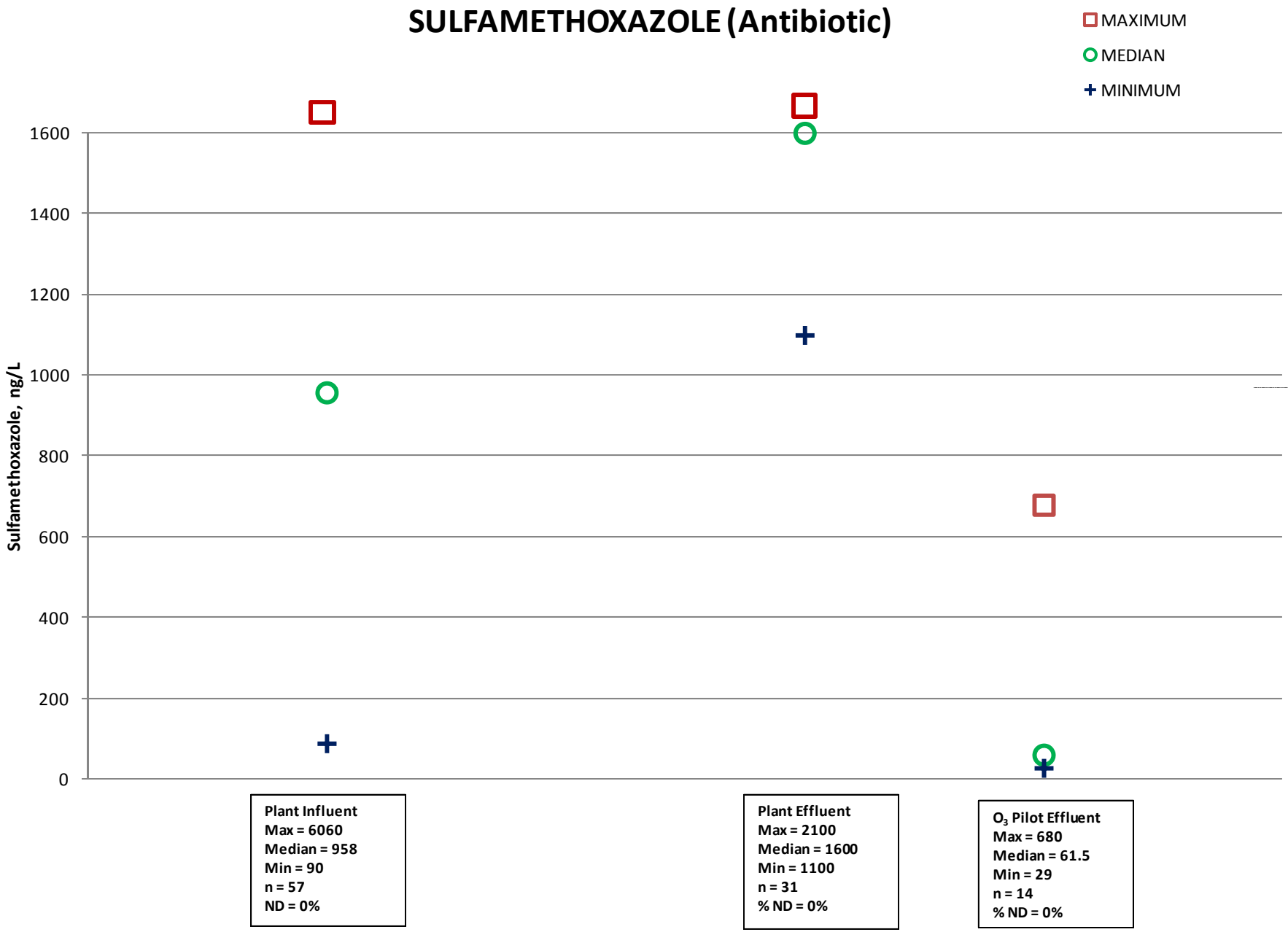


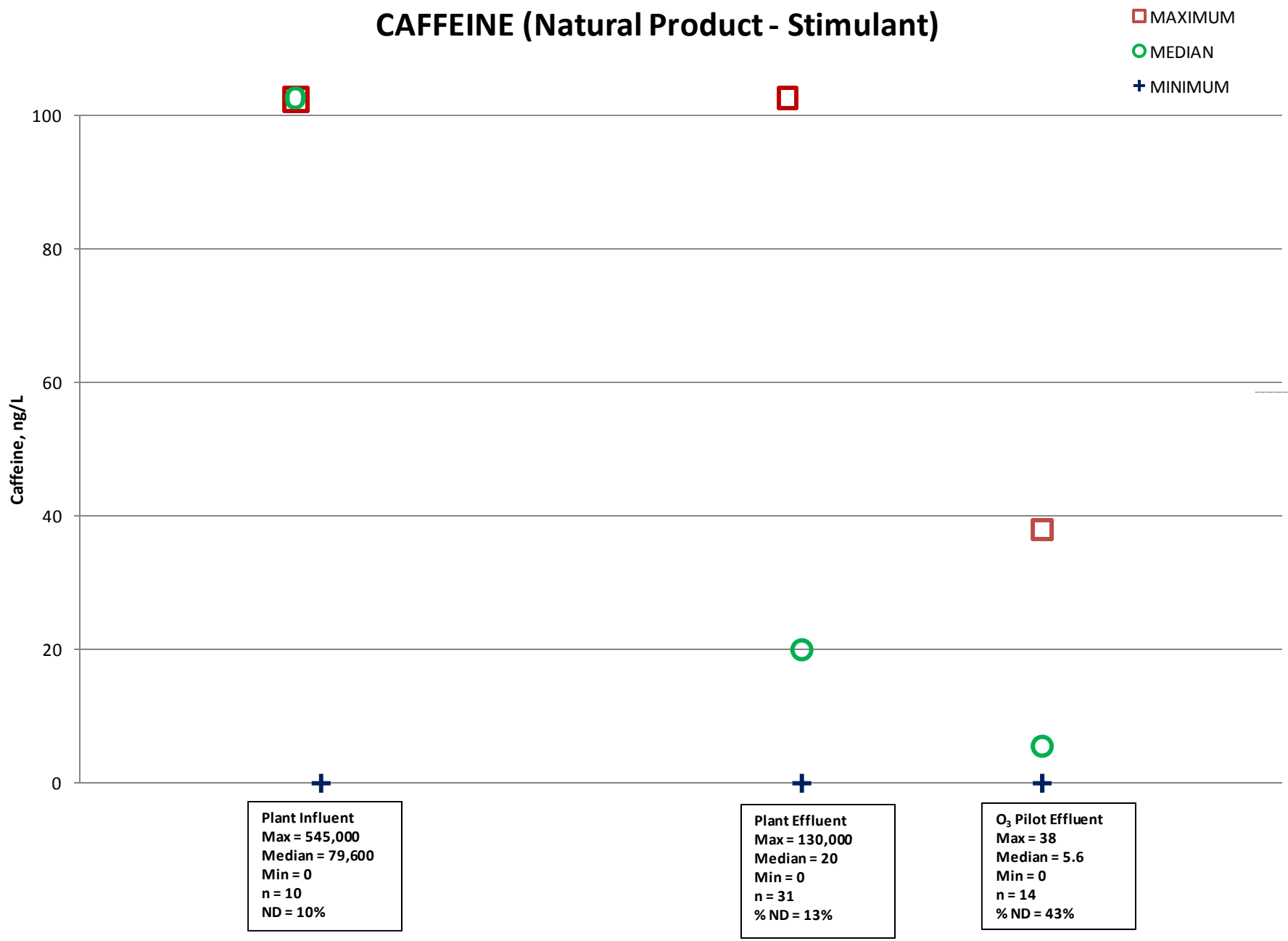
IBUPROFEN (Pain Medication)

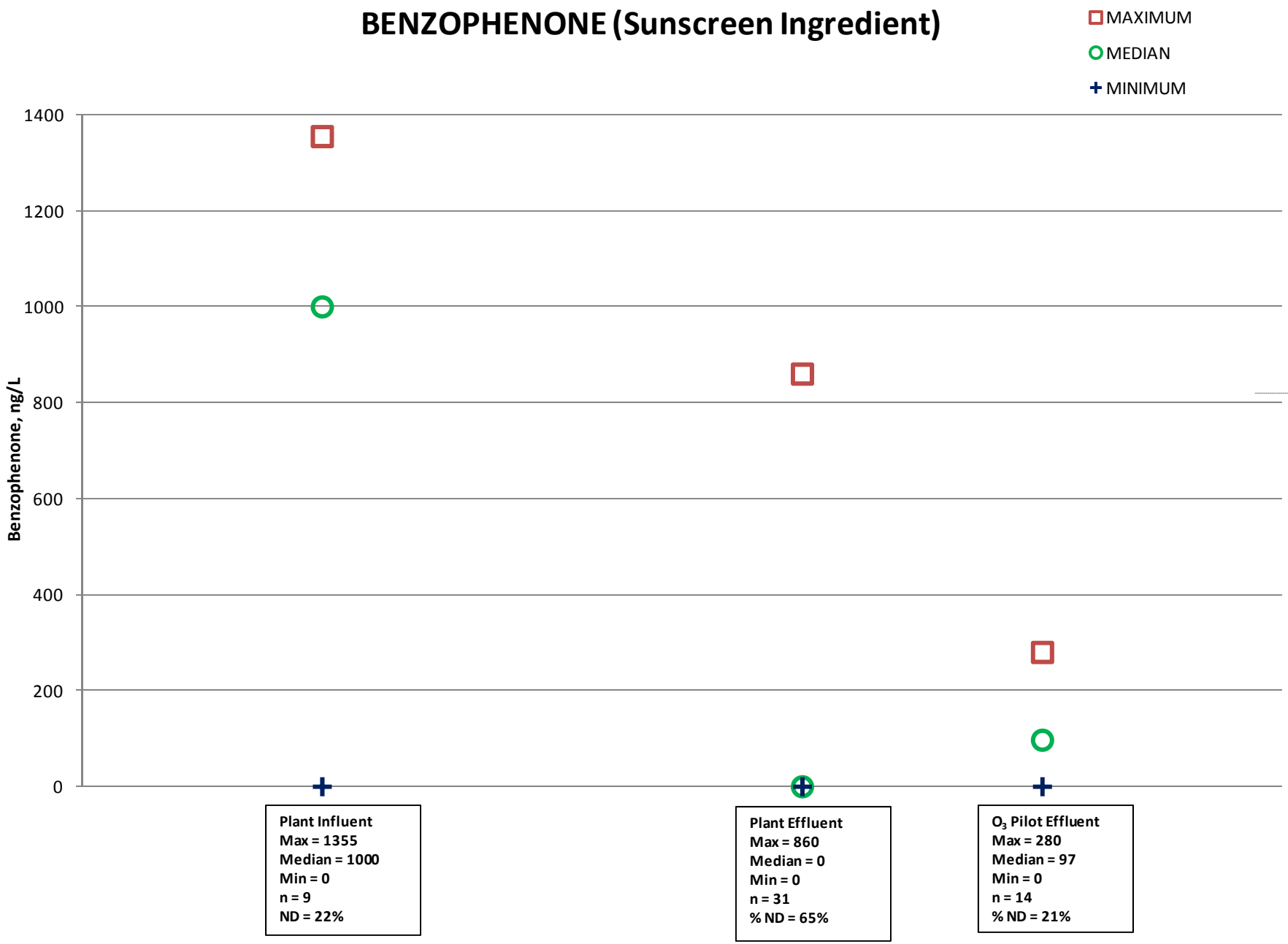


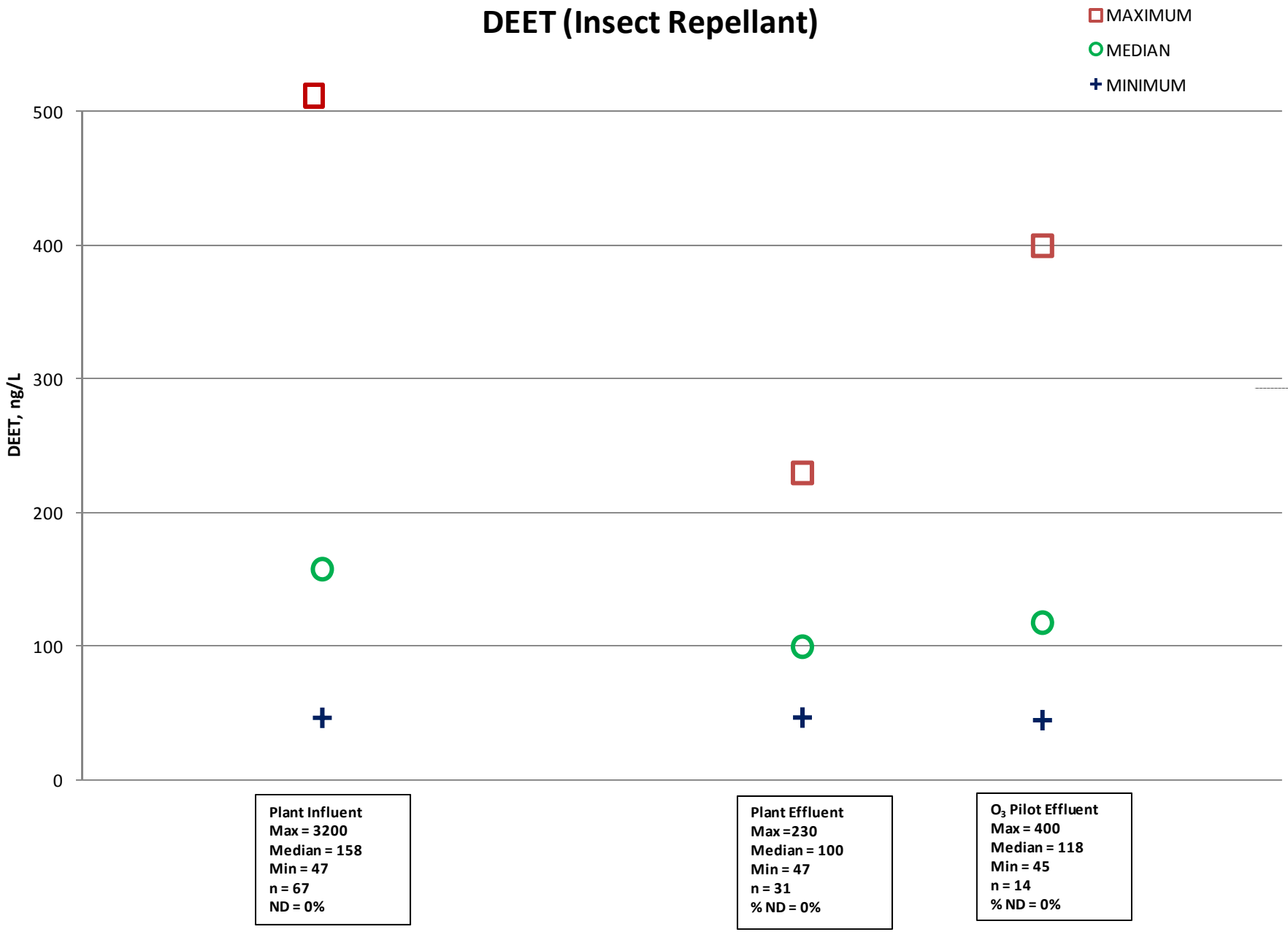

MEPROBAMATE (Anti-Depressant)
MAXIMUM
MEDIAN
MINIMUM
Meprobamate, ng/L
1800
1600
1400
1200
1000
800
600
400
200
0
Plant Influent
Max = 12,300
Median = 779
Min = 589
n = 57
ND = 0%
Plant Effluent
Max = 1600
Median = 330
Min = 230
n = 31
% ND = 0%
O3 Pilot Effluent
Max = 840
Median = 580
Min = 390
n = 14
% ND = 0%

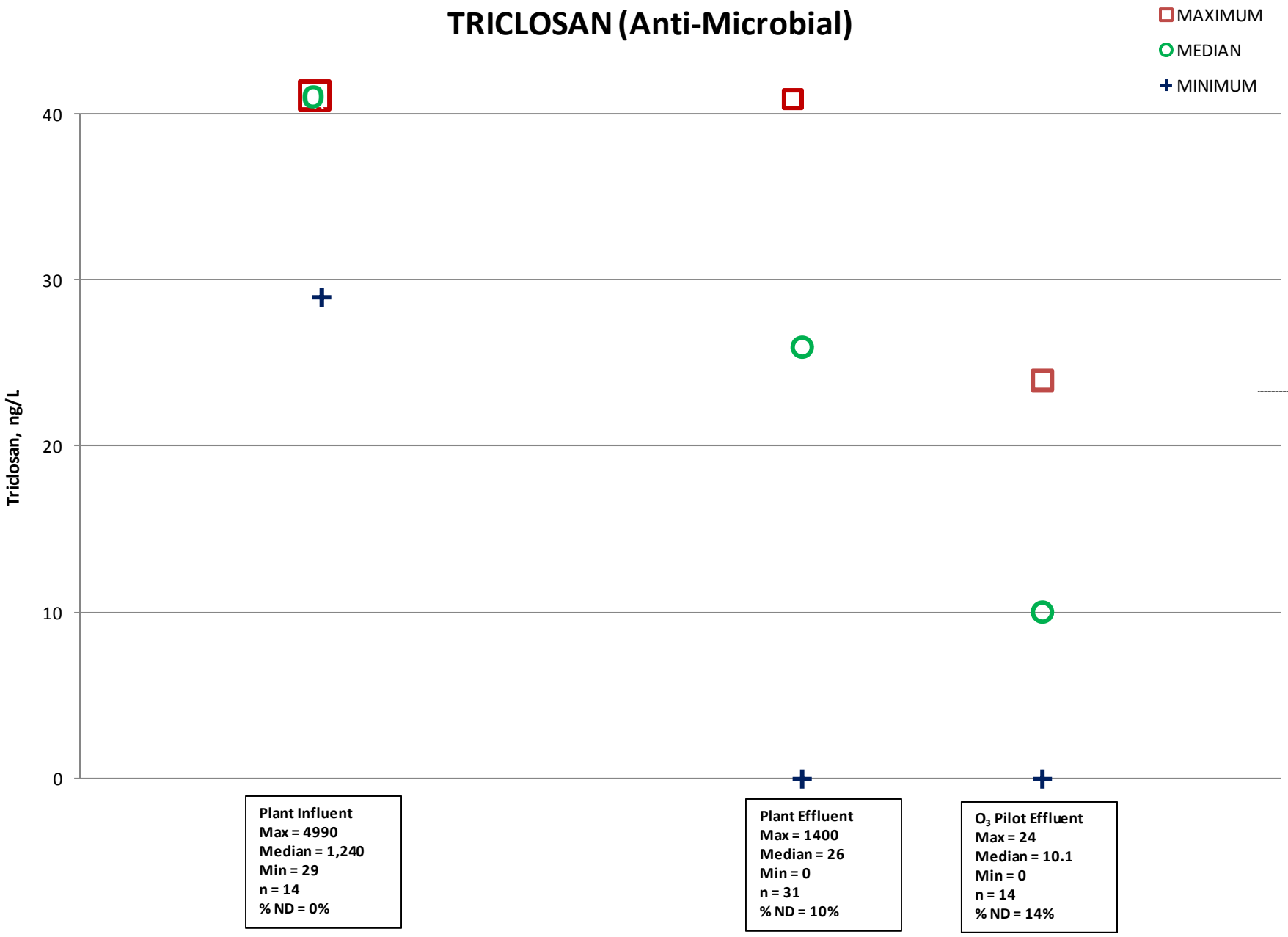

DILANTIN (Anti-convulsant Medication)
MAXIMUM
MEDIAN
MINIMUM
Dilantin, ng/L
400
300
200
100
0
Plant Influent
Max = 2030
Median = 70
Min = 45
n = 55
ND = 0%
Plant Effluent
Max = 250
Median = 110
Min = 67
n = 31
% ND = 0%
O_3 Pilot Effluent
Max = 130
Median = 80
Min = 40
n = 14
% ND = 0%

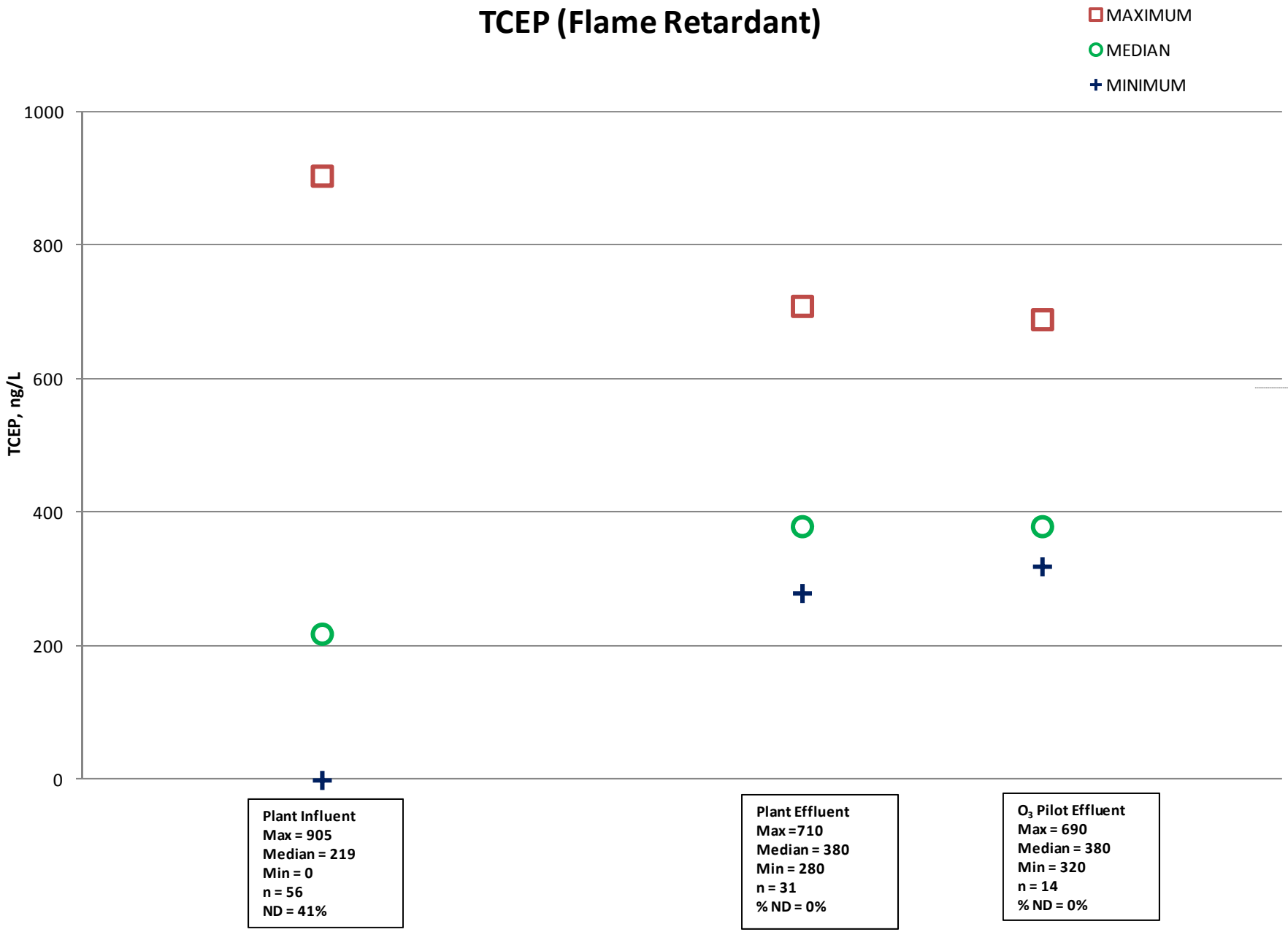

SULFAMETHOXAZOLE (Antibiotic)
MAXIMUM
MEDIAN
MINIMUM
Sulfamethoxazole, ng/L
1600
1400
1200
1000
800
600
400
200
0
Plant Influent
Max = 6060
Median = 958
Min = 90
n = 57
ND = 0%
Plant Effluent
Max = 2100
Median = 1600
Min = 1100
n = 31
% ND = 0%
O3 Pilot Effluent
Max = 680
Median = 61.5
Min = 29
n = 14
% ND = 0%

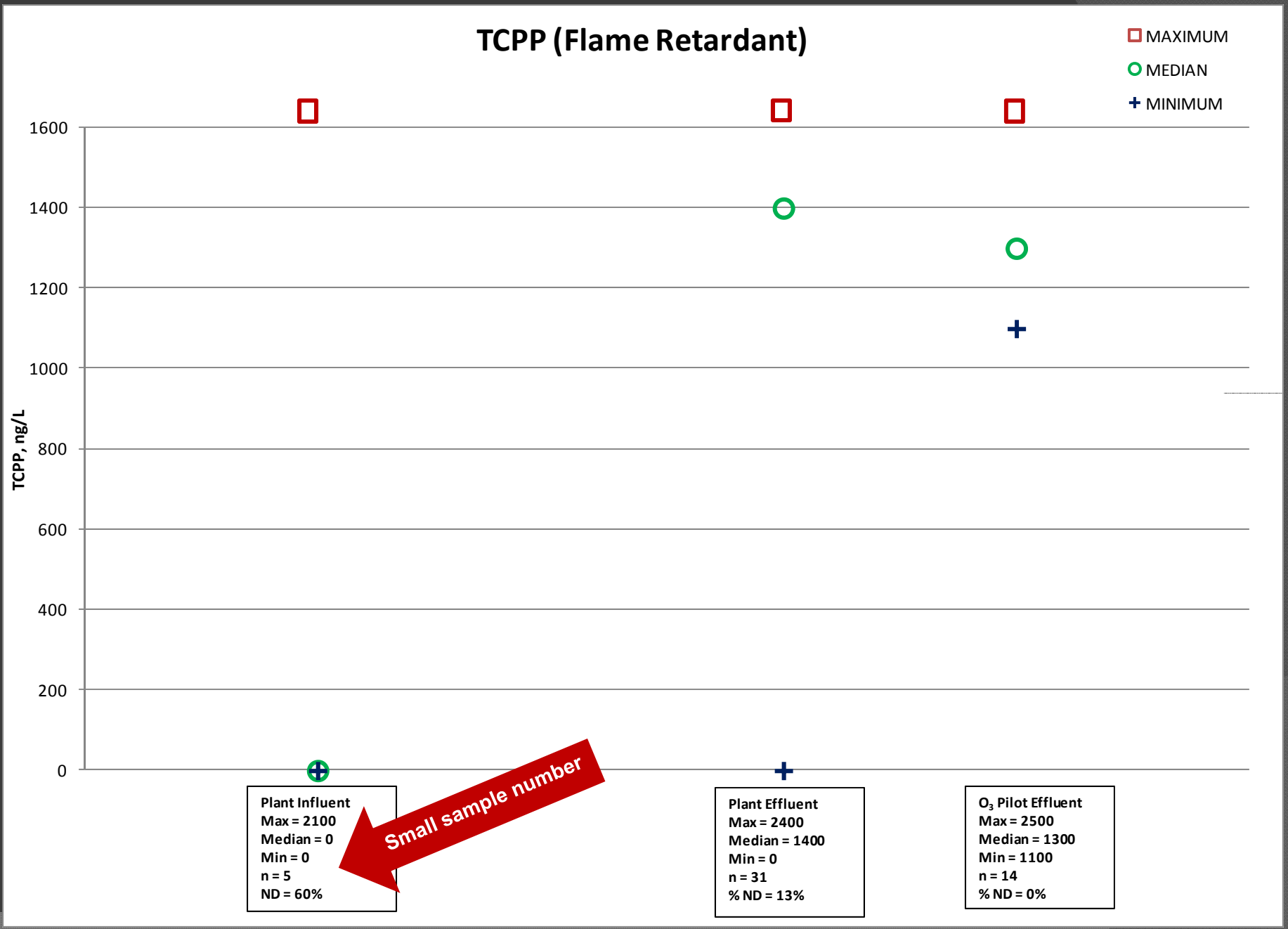

CAFFEINE (Natural Product - Stimulant)
MAXIMUM
MEDIAN
MINIMUM
Caffeine, ng/L
100
80
60
40
20
0
Plant Influent
Max = 545,000
Median = 79,600
Min = 0
n = 10
ND = 10%
Plant Effluent
Max = 130,000
Median = 20
Min = 0
n = 31
% ND = 13%
O3 Pilot Effluent
Max = 38
Median = 5.6
Min = 0
n = 14
% ND = 43%


BENZOPHENONE (Sunscreen Ingredient)
MAXIMUM
MEDIAN
MINIMUM
Benzophenone, ng/L
1400
1200
1000
800
600
400
200
0
Plant Influent
Max = 1355
Median = 1000
Min = 0
n = 9
ND = 22%
Plant Effluent
Max = 860
Median = 0
Min = 0
n = 31
% ND = 65%
O3 Pilot Effluent
Max = 280
Median = 97
Min = 0
n = 14
% ND = 21%


DEET (Insect Repellant)
MAXIMUM
MEDIAN
MINIMUM
DEET, ng/L
500
400
300
200
100
0
Plant Influent
Max = 3200
Median = 158
Min = 47
n = 67
ND = 0%
Plant Effluent
Max =230
Median = 100
Min = 47
n = 31
% ND = 0%
O3 Pilot Effluent
Max = 400
Median = 118
Min = 45
n = 14
% ND = 0%


TRICLOSAN (Anti-Microbial)
MAXIMUM
MEDIAN
MINIMUM
Triclosan, ng/L
40
30
20
10
0
Plant Influent
Max = 4990
Median = 1,240
Min = 29
n = 14
% ND = 0%
Plant Effluent
Max = 1400
Median = 26
Min = 0
n = 31
% ND = 10%
O3 Pilot Effluent
Max = 24
Median = 10.1
Min = 0
n = 14
% ND = 14%


TCEP (Flame Retardant)
MAXIMUM
MEDIAN
MINIMUM
TCEP, ng/L
1000
800
600
400
200
0
Plant Influent
Max = 905
Median = 219
Min = 0
n = 56
ND = 41%
Plant Effluent
Max =710
Median = 380
Min = 280
n = 31
% ND = 0%
O3 Pilot Effluent
Max = 690
Median = 380
Min = 320
n = 14
% ND = 0%


TCPP (Flame Retardant)
MAXIMUM
MEDIAN
MINIMUM
TCPP, ng/L
1600
1400
1200
1000
800
600
400
200
0
Small sample number
Plant Influent
Max = 2100
Median = 0
Min = 0
n = 5
ND = 60%
Plant Effluent
Max = 2400
Median = 1400
Min = 0
n = 31
% ND = 13%
O3 Pilot Effluent
Max = 2500
Median = 1300
Min = 1100
n = 14
% ND = 0%

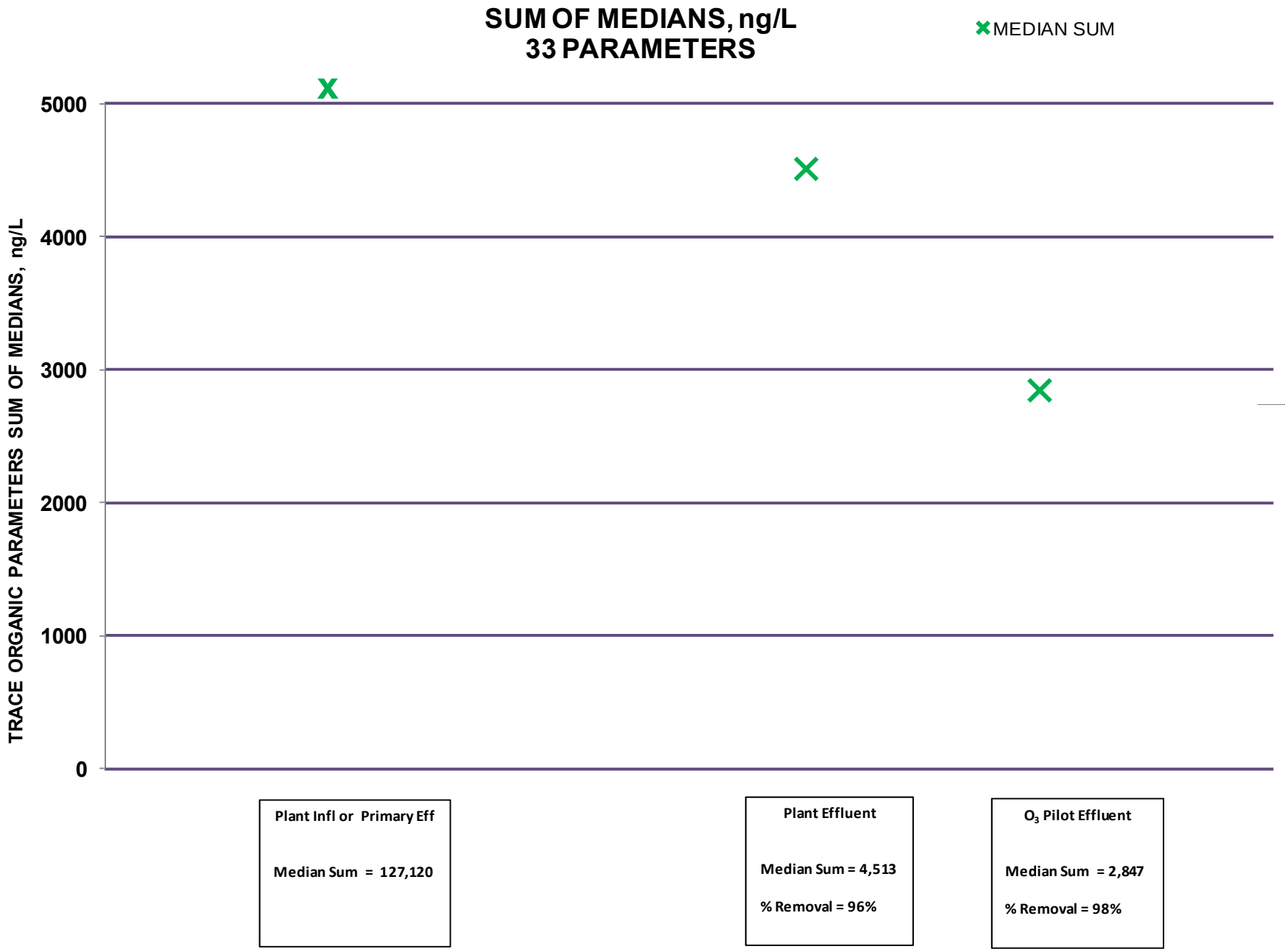
BNR Membrane Filtration/Ozone Disinfection Pilot

- 33 indicator compounds
- 27 were consistently found in the plant influent
- 19 were removed >70%
- 2 were not removed

Indicator Compounds Medians or Maximums Removed >70%

For a BNR Plant With Membrane Filtration/Ozone Disinfection

- Diclofenac
- BHA
- Sulfamethoxazole
- Atenolol
- Fluoxetine?
- Meprobamate?
- Carbamazepine
- DEET
- Gemfibrozil
- Bisphenol A
- Naproxen
- Triclosan
- Trimethoprim
- Caffeine
- Dilantin?
- Atrazine
- Diazepam?
- Atorvastatin
- Benzophenone


SUM OF MEDIANS, ng/L
33 PARAMETERS
MEDIAN SUM
TRACE ORGANIC PARAMETERS SUM OF MEDIANS, ng/L
5000
4000
3000
2000
1000
0
Plant Infl or Primary Eff
Median Sum = 127,120
Plant Effluent
Median Sum = 4,513
% Removal = 96%
O3 Pilot Effluent
Median Sum = 2,847
% Removal = 98%

Conclusions

- BNR with membrane filtration and ozone disinfection:
  - Significantly lowers the concentrations of trace organics
  - Removes virtually all of the estrogenicity

Conclusions (cont.)

- Grab samples for trace organics give highly variable results
- Future designs
  - Consider intermittent nature and peak discharges of trace organics
  - Consider daily composites to find trace organics present

Conclusions (cont.)

- Ozone Treatment
  - Decreases variability
  - Decreases trace organic concentrations
  - Increases % of non-detects

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Clark County Water Reclamation DISTRICT

The "Clean Water Team"