Potable Water Reuse:
Trends in Treatment, Monitoring, and Health

azengineering

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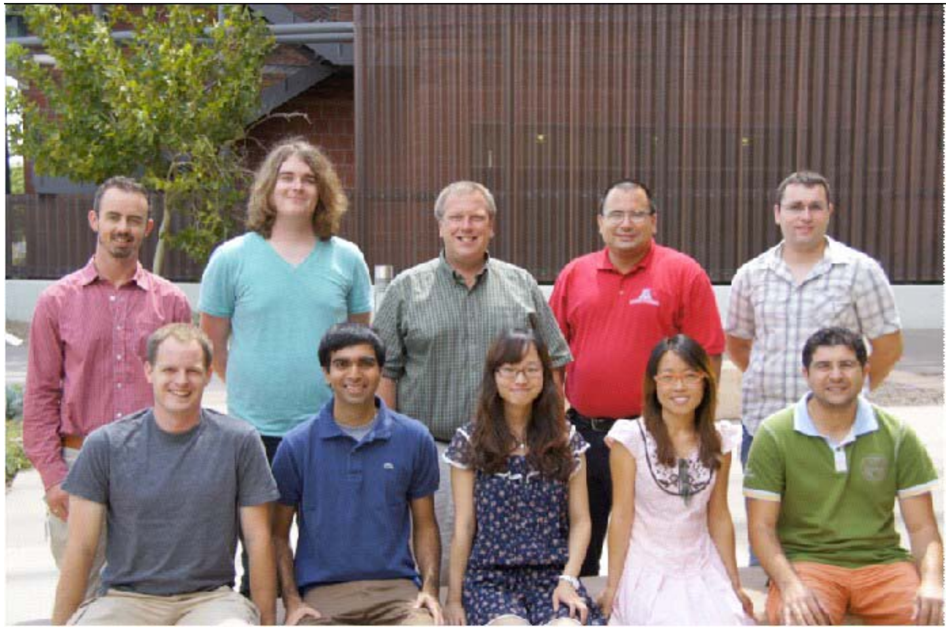


Three Key Topics

I. Water reuse – sustainability through necessity

II. Advances in treatment and detection technologies

III. Exploring chemical mixtures

Top 10 Cities Running Out of Water

10. Orlando
9. Atlanta
8. Tucson
7. Las Vegas
6. Fort Worth
5. San Francisco
4. San Antonio
3. Phoenix
2. Houston
1. Los Angeles






Source: http://247wallst.com/2010/10/29/the-ten-great-american-cities-that-are-dying-of-thirst/3/

Drought in Texas

N

Water in Texas

Th

The thirsty road ahead

Aug

Drought may force the state to take tougher measures

Nov 12th 2011 | AUSTIN | *The Economist*

http://www.economist.com/node/14222305

http://www.economist.com/node/21538196

Aug. 7, 2011. Lake E.V. Spence in Robert Lee, Texas. After years of diminishing water supplies made even worse by the second most severe drought in state history, some communities are resorting to a plan that might have seemed absurd a generation ago: turning sewage into drinking water.

Desperate to drink, West Texas turns to wastewater - CNN.com

By Ed Lavandera , CNN Correspondent CNN.com

Big Spring, Texas (CNN) -- Desperate times call for a tall, cool glass of creativity in this patch of West Texas where water is scarce and quickly disappearing.

But a plan to pump millions of new gallons of drinking water into the system has many people across West Texas holding their noses.

This week construction started on a $13 million water-reclamation facility. That's a fancy way of describing a treatment plant that will turn sewage wastewater into drinking water.

"That's not something I even want to think about," said Eunice Thixton, a Big Spring resident. "It really doesn't sound too good."

Trinity River, Texas

NO WINDING RIVER

Houston considers using its own toilet water as drinking water rather than relying on Dallas flushes

BY TYLER RUDICK

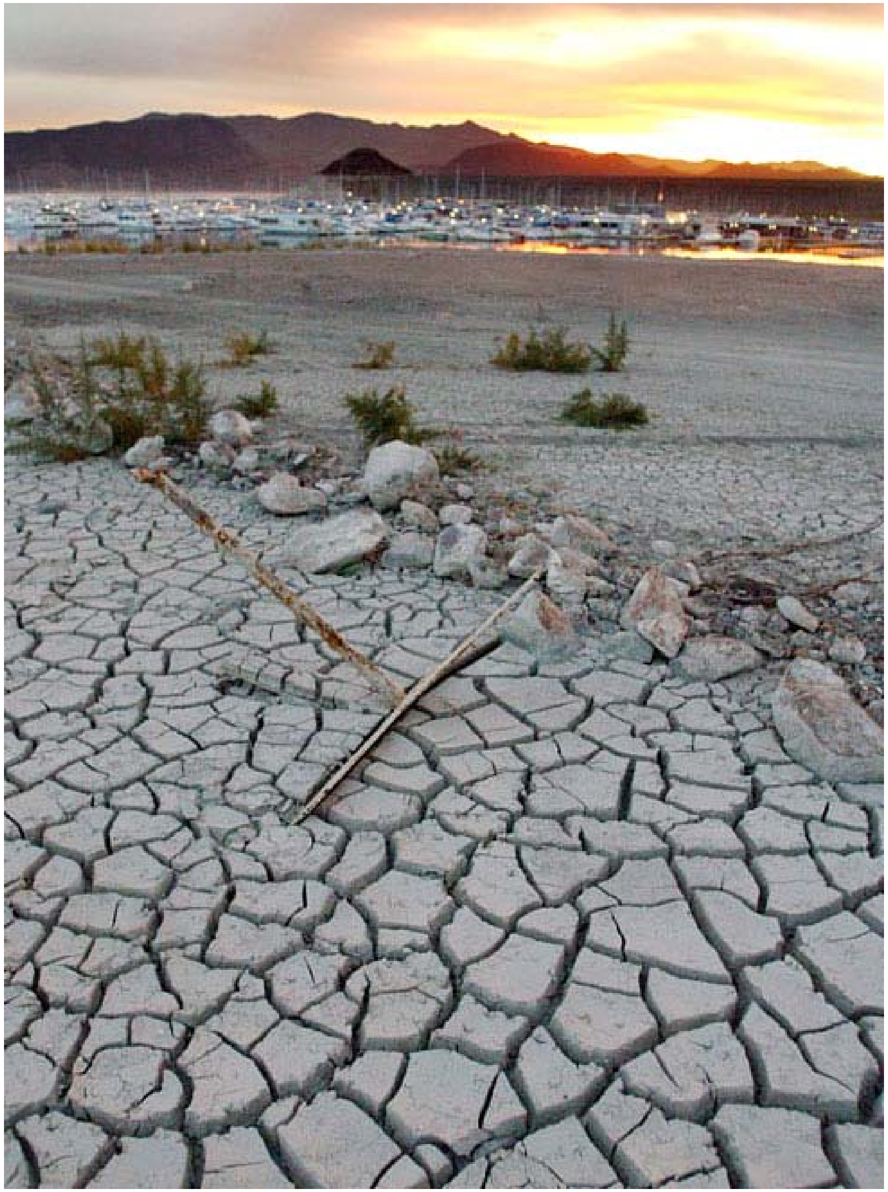
02.23.12 | 11:44 am

When it comes to water, the City of Houston has a not-so-secret weapon in its municipal arsenal — the toilets and sinks of Dallas.

It's not as wretched as it sounds, actually. The water is treated in Dallas before it enters the Trinity River and flows to Lake Livingston, mixing with rain and groundwater before getting tested and pumped across the greater Houston area.

"The water is incredibly clean and nutrient-rich when it leaves the filtration plant," Alvin Wright, spokesperson for Houston's Public Works and Engineering Department says. "Naturally-occurring bacteria and minerals break down any other pollutants in the water as it flows from north Texas."

Report warns water crisis looming in arid Southwest



By Patrick O'Driscoll, USA TODAY

DENVER — The fast-growing states of the arid Southwest must plan for more severe droughts because of a regional warming trend that shows no signs of dissipating, says a new assessment of the Colorado River's water supply.

The report released Wednesday by the National Research Council says agriculture, which uses 80% of the West's water, is the likeliest target for shifting water supplies to growing urban areas. But the council, an agency of the National Academy of Sciences, cautions that "the availability of agricultural water is finite."

Water Use in Southwest Heads for a Day of Reckoning

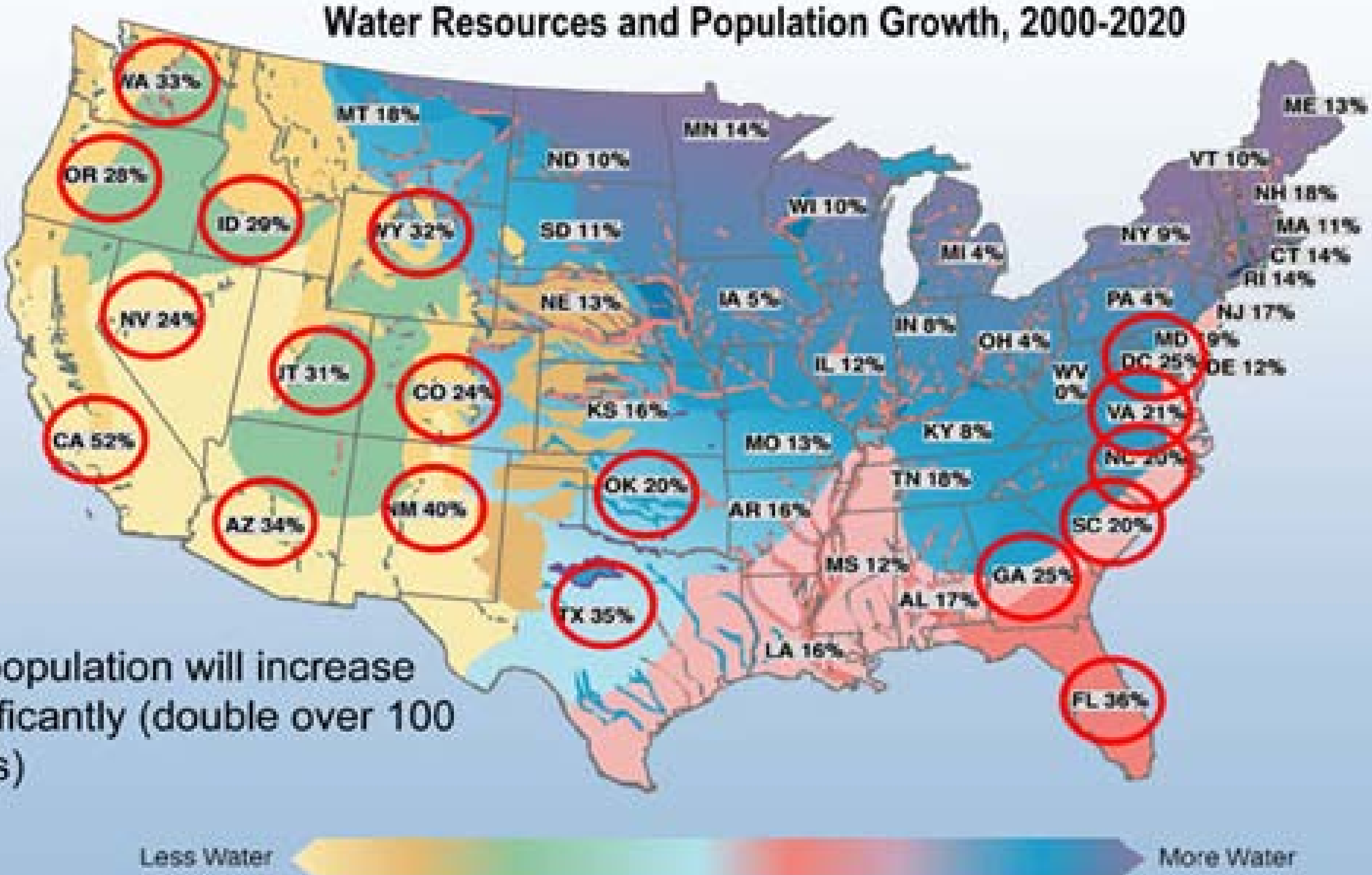
The New York Times

By FELICITY BARRINGER
Published: September 27, 2010

LAKE MEAD NATIONAL RECREATION AREA, Nev. — A once-unthinkable day is looming on the Colorado River.


Water Supplies Are Vulnerable

Population Growth is 20% to 50% in Most Water-Stressed Areas



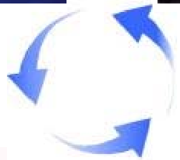
US population will increase significantly (double over 100 years)

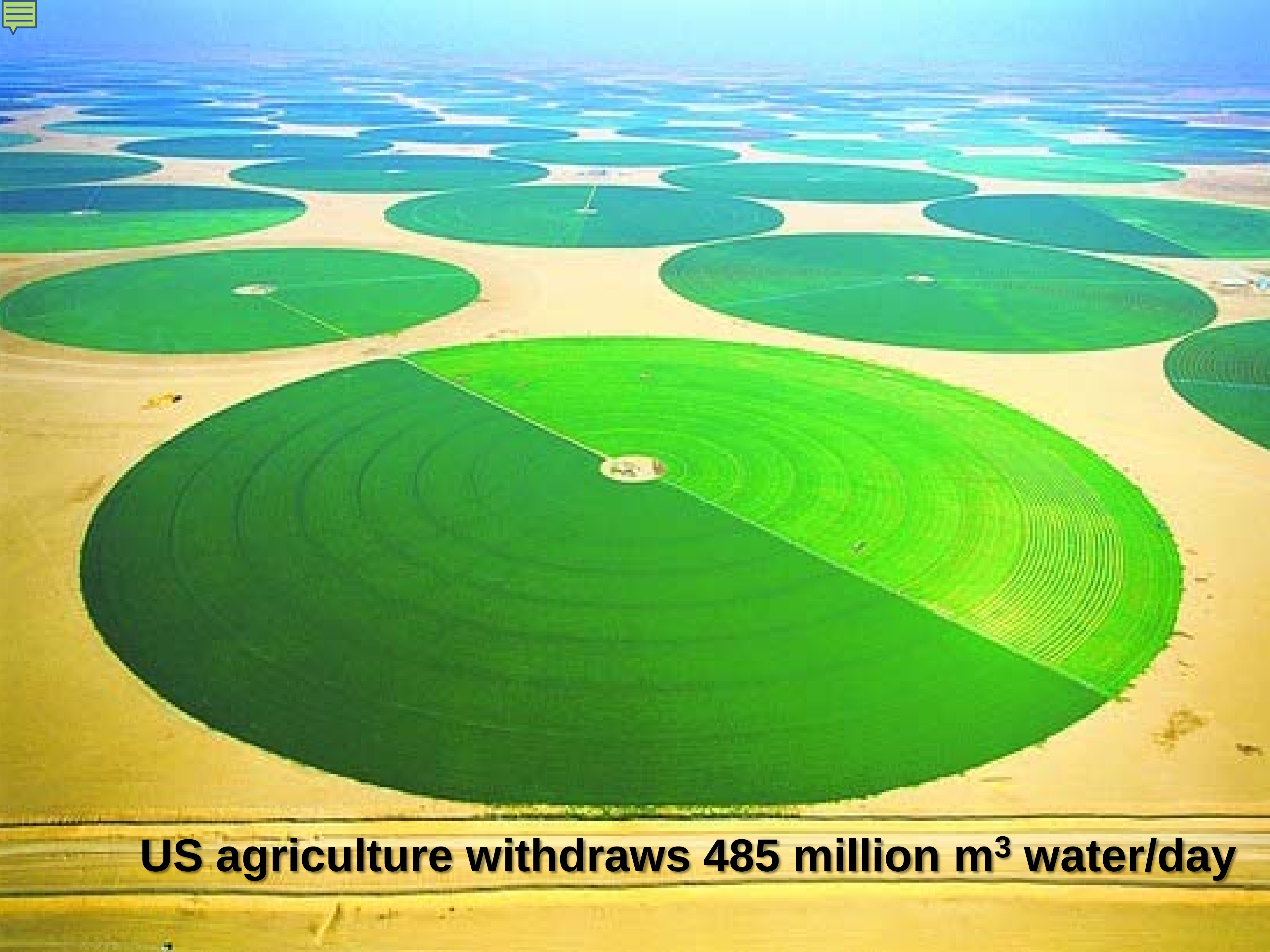
EAO Energy Analysis Office
Understanding Energy Issues

Source: DOE/NETL (M. Chan, July 2002)

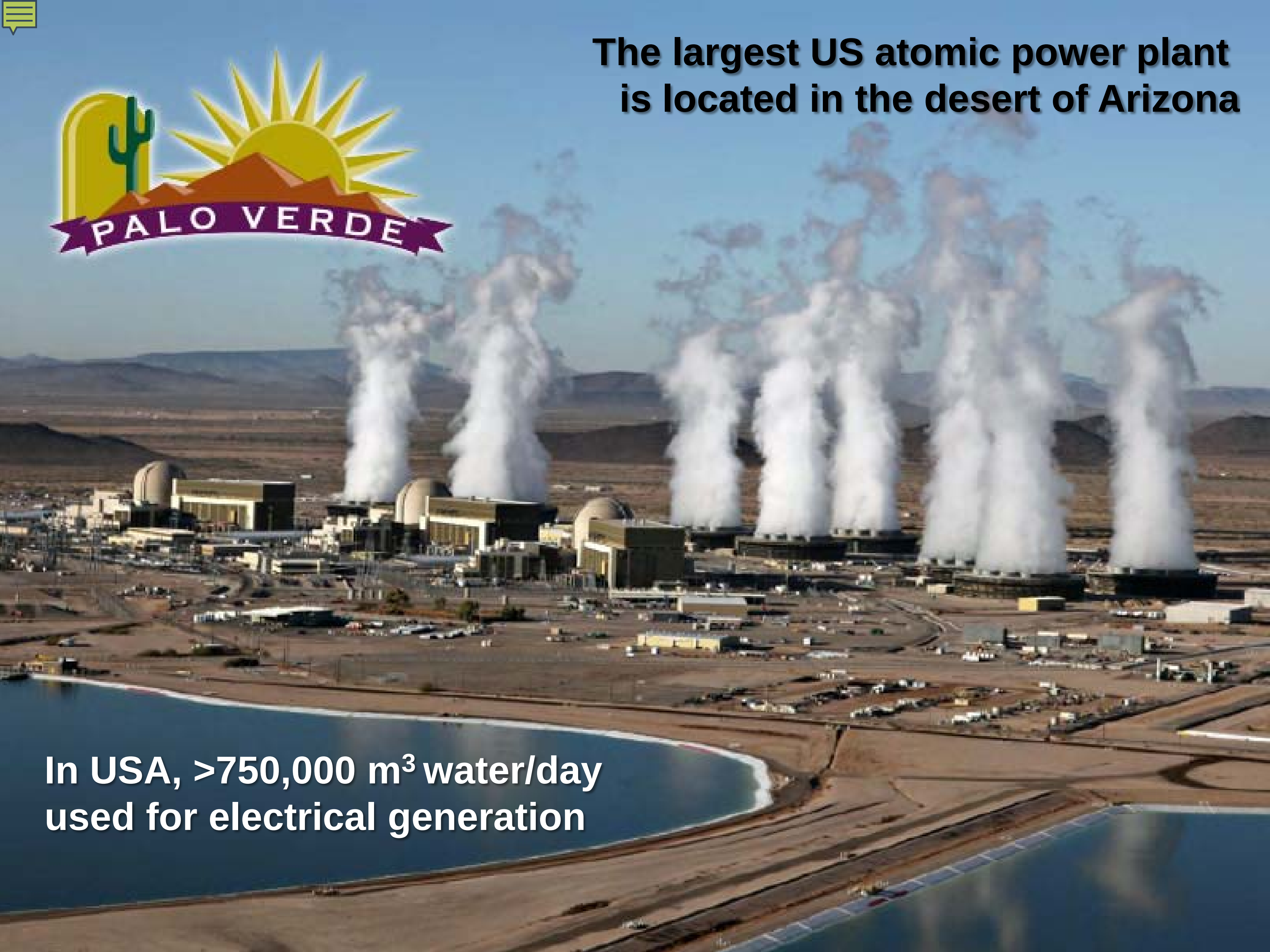
NREL National Renewable Energy Laboratory

Water, Power, and Food: Intimately Related




US agriculture withdraws 485 million m^3 water/day

The largest US atomic power plant is located in the desert of Arizona



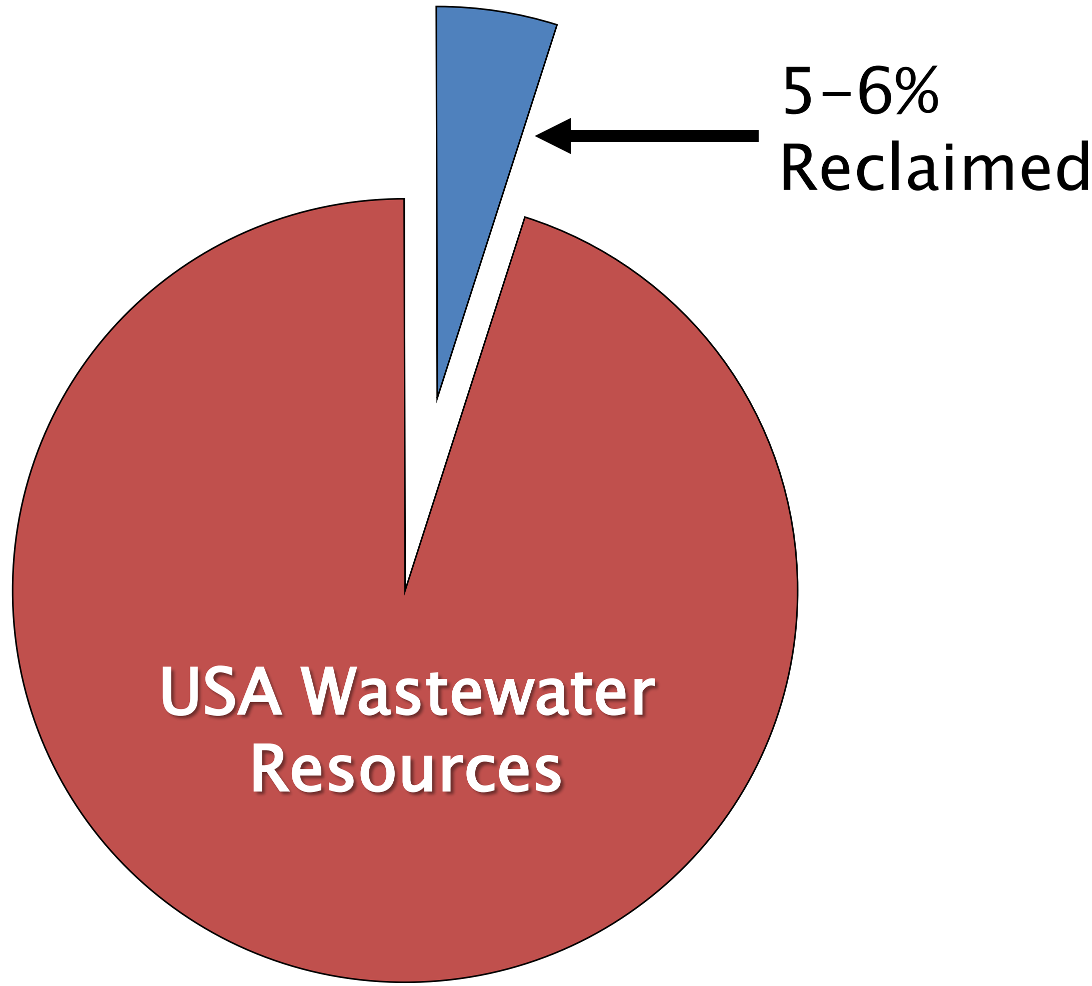
In USA, >750,000 m^3 water/day used for electrical generation

Florida – Ocean Outfall Act

- Prohibits construction or expansion of ocean outfalls
- By 2018 – Existing outfalls reach advanced treatment
- By 2025 – Outfalls only for wet weather events

Potential for Water Reuse

- About 5-6% of municipal wastewater effluent in the U.S. is reclaimed and beneficially reused
- Israel reuses more than 70%
- Singapore reuses 30%, up from 15% in recent years
- Australia, now at 8%, has a national goal of 30% by 2015



Source: Wade Miller – WateReuse Association

NRC Report on Reuse (2012)

USA TODAY

THE NATIONAL ACADEMIES

Advisers to the Nation on Science, Engineering, and Medicine

Report: Drinking wastewater preferable to wasting it

Council touts it as potable after treatment

By Wendy Koch
USA TODAY

Drinking wastewater? The idea may sound distasteful, but new federally funded research says more Americans are doing so – whether they know it or not – and this reuse will be increasingly necessary as the U.S. population expands.

Treated wastewater poses no greater health risks than existing water supplies and, in some cases, may be even safer to drink, according to a report released Tuesday by the National Research Council, a science advisory group chartered by Congress. "We believe water reuse is a viable option" to deal with growing water scarcity, especially in coastal areas, says Jörg Drewes, an engineering professor at the Colorado School of Mines who contributed to the report.

"This can be done reliably without putting the public at risk," he says, citing technological advances. He says it's a waste not to reuse the nation's wastewater, because almost all of it is treated before discharge. This water includes storm runoff as well as used water from homes, businesses and factories.

Of the 32 billion gallons of wastewater discharged every day in the USA, the report says 12 billion – equal to 6% of total U.S. water use – is sent to an ocean or estuary and is thus a lost resource.

Many communities reuse wastewater for irrigation and industrial purposes. Some – notably Cloudcroft, N.M., and California's Orange County – have treatment facilities to reuse it as drinking water.

By Mark Greenberg for USA TODAY

Wastewater treatment: Mechanic Phillip Castro does a routine inspection of the systems at a plant in San Antonio.

In many places, the report says, the public does not realize it is drinking water that was treated after being discharged as wastewater somewhere upstream. For example, wastewater discharged into the Trinity River from Dallas/Fort Worth flows south into Lake Livingston, the source for Houston's drinking water.

Despite the growing importance of this "de facto reuse," the report says there has been no systemic analysis of its extent nationwide since a 1980 study by the Environmental Protection Agency.

"There's always someone downstream," says Alan Roberson of the American Water Works Association, a non-profit group dedicated to clean water. He says wastewater reuse is common, so the council's report is important but not surprising.

Roberson says he expects this recycling will continue to increase, especially for irrigation and industrial needs.

He says it will take longer to establish potable uses because of public skittishness about drinking wastewater, however treated.

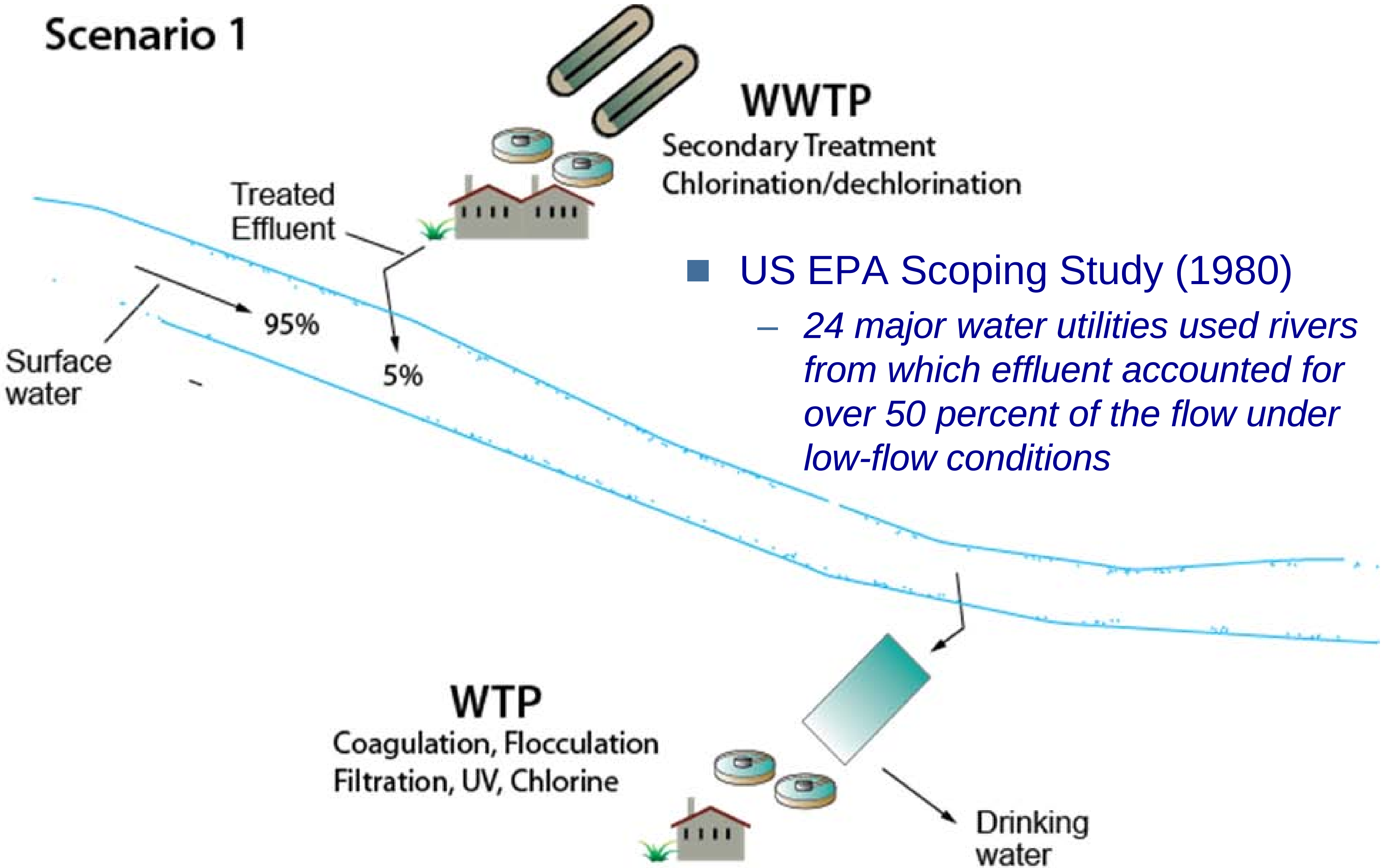
"We have to do something" to address water scarcity, says Olga Naidenko, a senior scientist at the non-profit Environmental Working Group. She says less than 10% of potable water is used for drinking, cooking, showering or dishwashing.

"We flush it down the toilet, literally," she says. Technologies exist to safely treat the water, she says, although some are expensive.

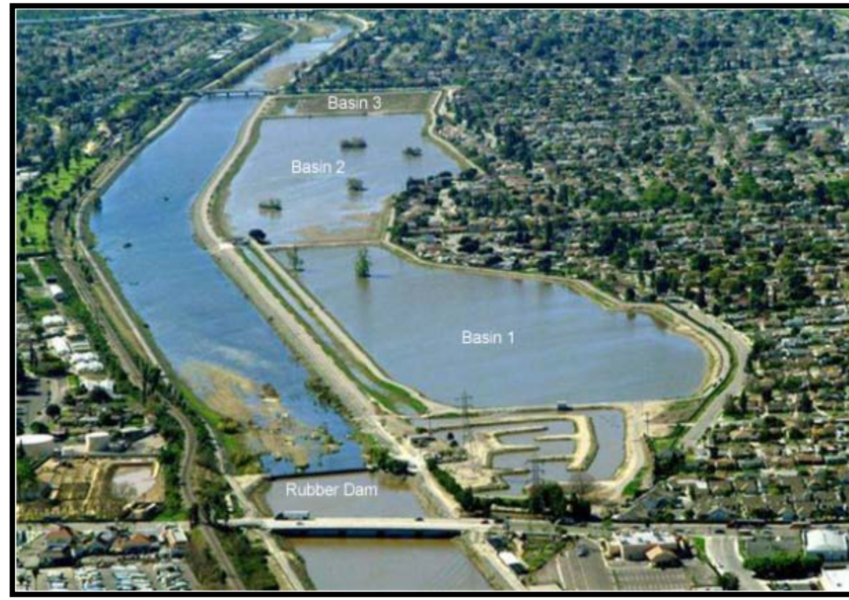
The report says water reuse projects tend to cost more than most water conservation options but less than seawater desalination and other supply alternatives. It calls on the EPA, a co-sponsor of the report, to develop rules that set safe national standards.

"…distinction between *indirect* and *direct* potable reuse is not scientifically meaningful…"

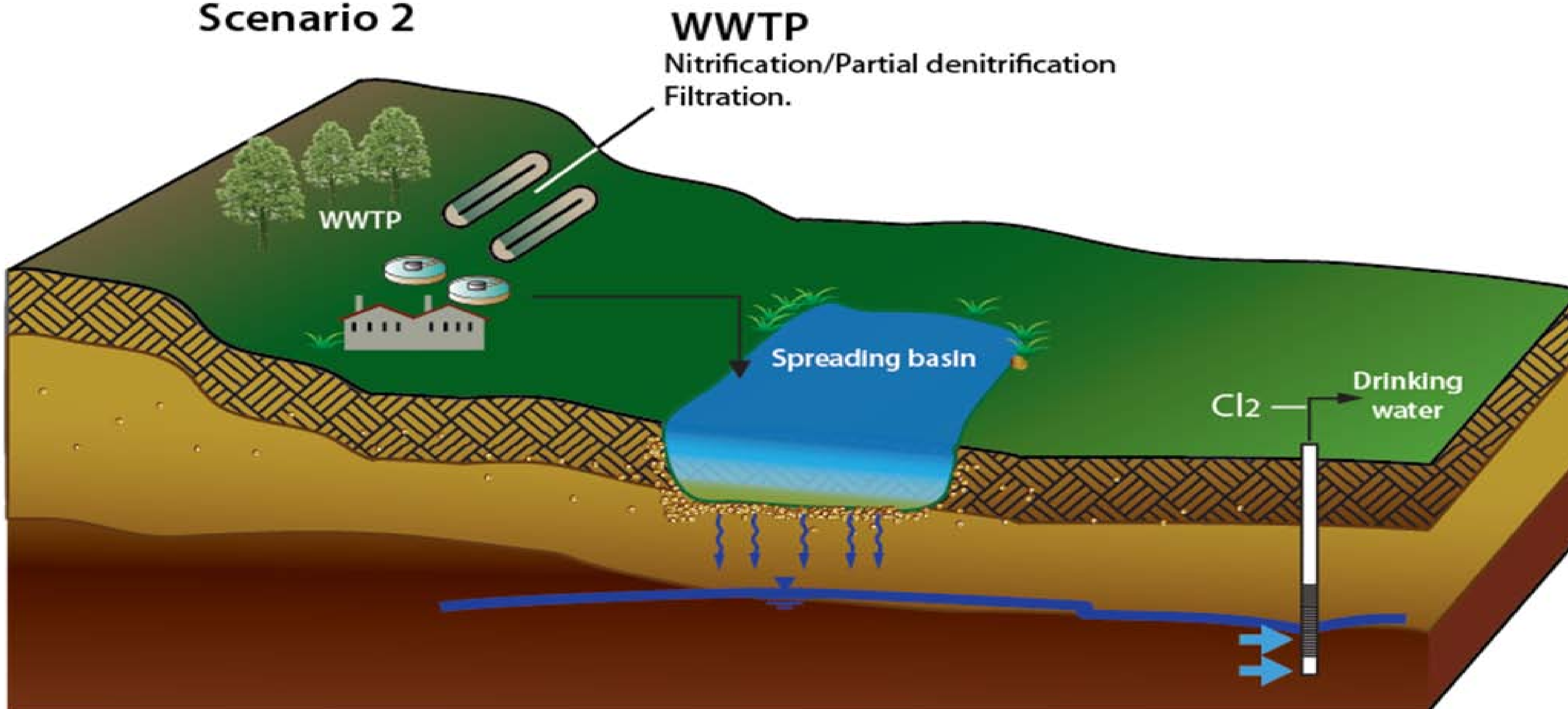
De Facto Reuse



- US EPA Scoping Study (1980)
  - *24 major water utilities used rivers from which effluent accounted for over 50 percent of the flow under low-flow conditions*


Basin 3
Basin 2
Basin 1
Rubber Dam

Scenario 2

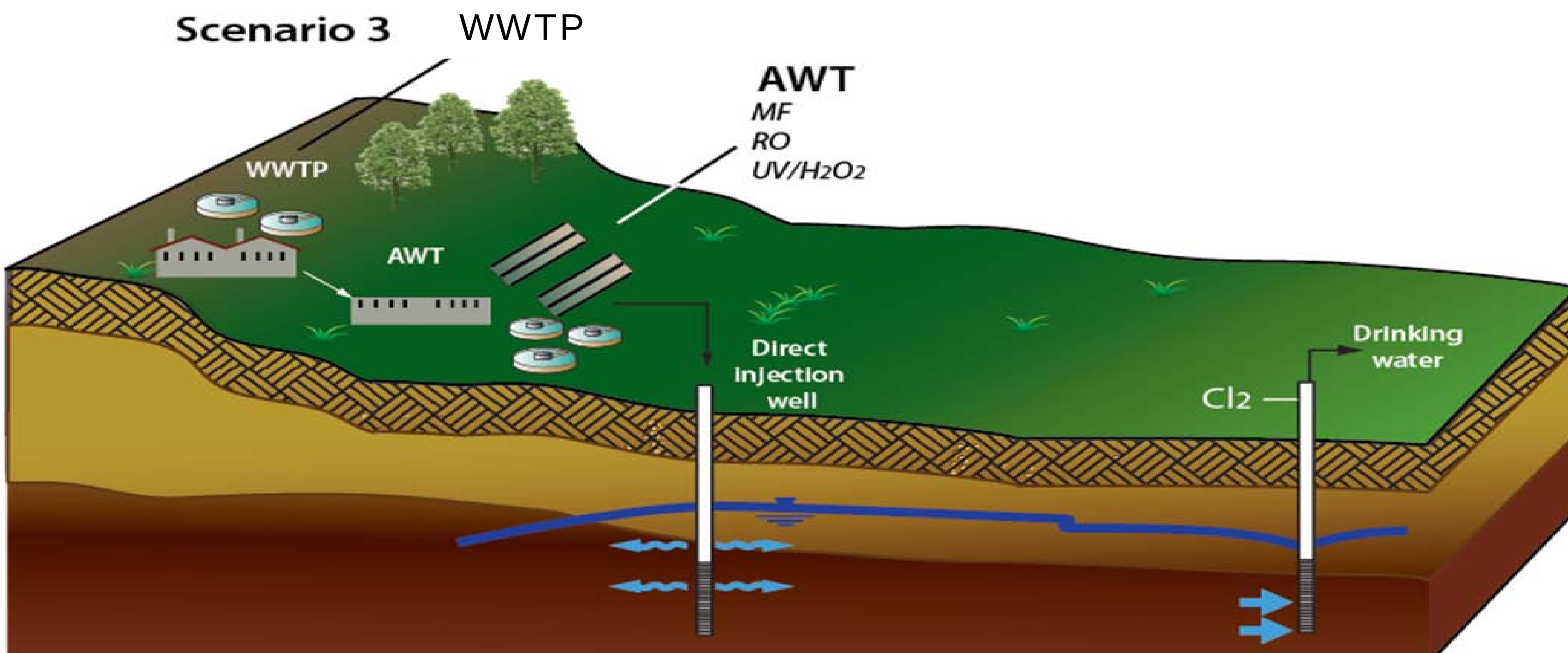

WWTP
Nitrification/Partial denitrification
Filtration.
WWTP
Spreading basin
Cl_2
Drinking
water

Microfiltration (MF)

Reverse Osmosis (RO)

UV-AOP

SAT



Risk Exemplar Contaminants

Pathogens:
- Adenovirus
- Norovirus
- *Salmonella*
- *Cryptosporidium*

Disinfection Byproducts
- Bromate
- Bromoform
- Chloroform
- Dibromoacetic acid (DBCA)
- Dibromoacetonitrile (DBAN)
- Dibromochloromethane (DBCM)
- Dichloroacetic acid (DCAA)
- Dichloroacetonitrile (DCAN)
- Haloacetic acid (HAA5)
- Trihalomethanes (THMs)
- *N*-Nitrosodimethylamine (NDMA)

Hormones and Pharmaceuticals
- 17β-Estradiol (endogenous estrogen)
- Acetaminophen (paracetamol)
- Ibuprofen (pain/inflammation)
- Caffeine (stimulant)
- Carbamazepine (anticonvulsant)
- Gemfibrozil (lipid lowering fibrate)
- Sulfamethoxazole (antibiotic)
- Meprobamate (antianxiety & degradant)
- Primidone (anticonvulsant)

Others
- Triclosan
- Tris(2-chloroethyl)phosphate (TCEP)
- Perfluorooctanesulfonic acid (PFOS)
- Perfluorooctanoic acid (PFOA)

Risk Exemplar Methods

Contaminant concentrations:

- Estimated initial concentration of contaminants in source waters based on literature review
- Estimated removal efficiencies and fate assumptions for steps in 3 scenarios (based on literature review)

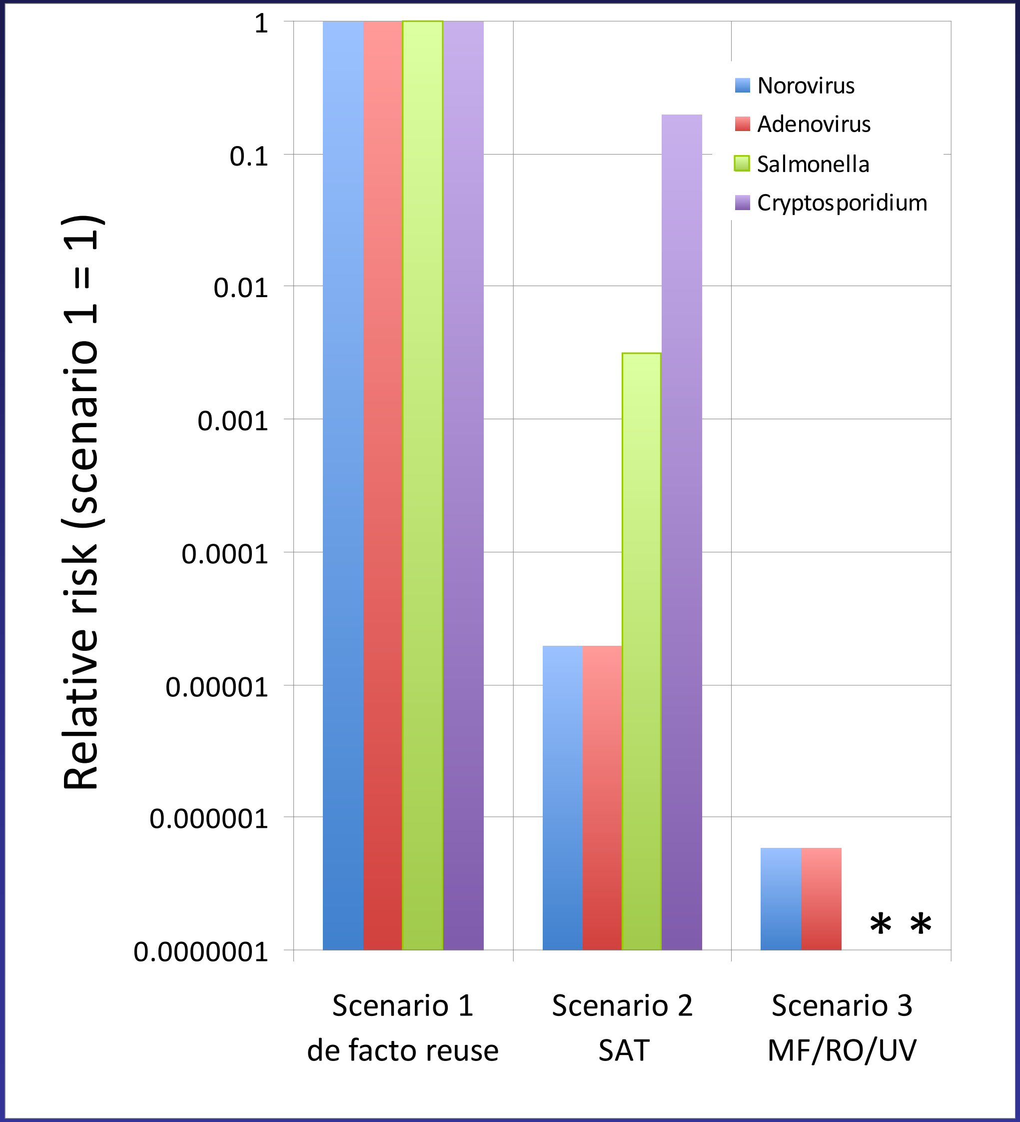
Microbial Risk Assessment:

- Used dose response equations shown in report. Assumed 1 L/d water consumption (unboiled).

Chemical risk assessment:

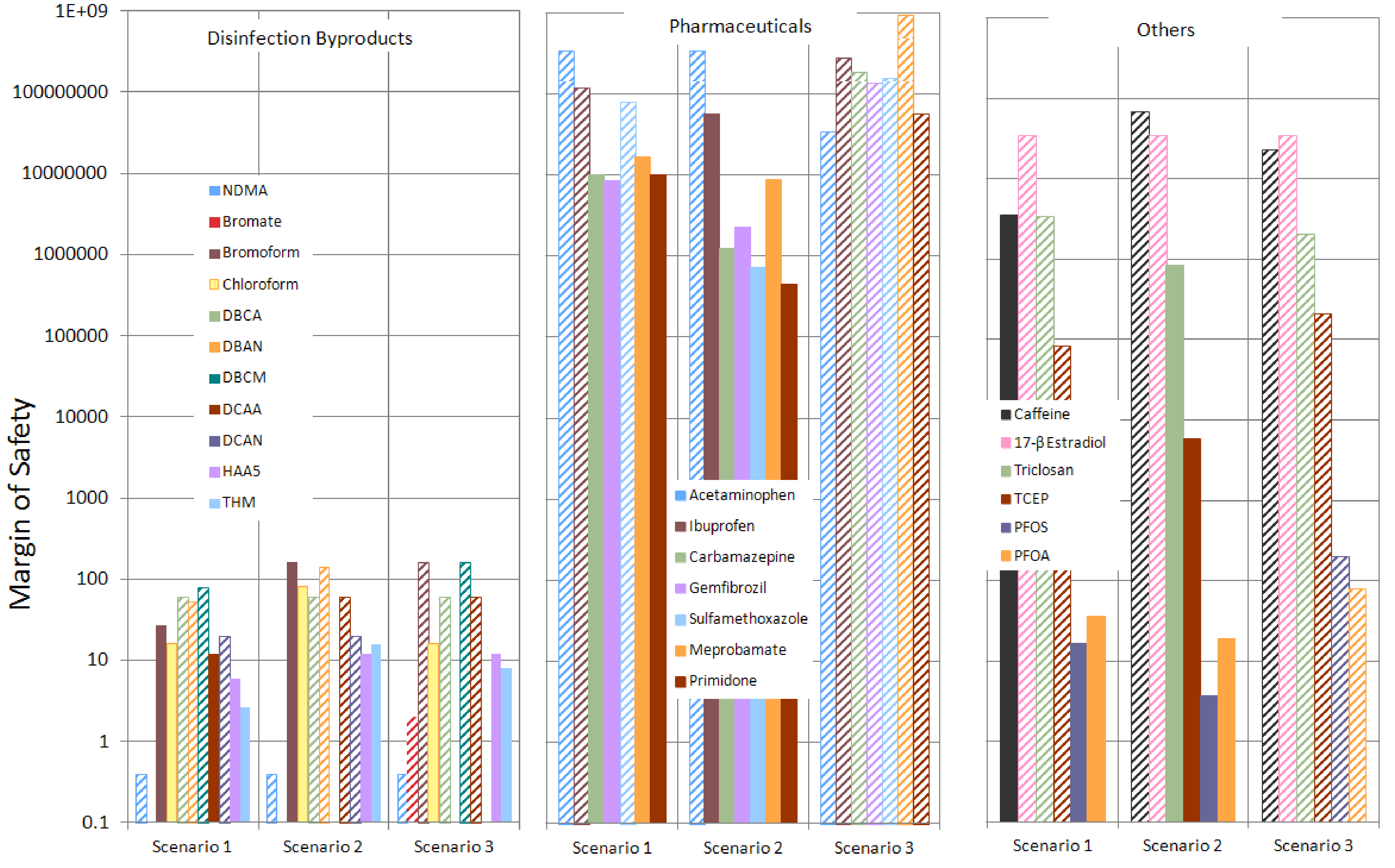
- Risk based action levels (RBALs) determined for chemicals based on 2 L/d consumption (Table A-12)
- Margin of Safety = RBAL / drinking water conc.
- MOS > 1 not considered to be a significant health risk

Risk Exemplar Results: Pathogens



* The risks for *Salmonella* and *Cryptosporidium* in Scenario 3 were below the limits that could be assessed by the model.

Risk Exemplar Results: Chemicals



Planned vs. Unplanned Reuse

Compound	Max Ave. (ng/L)	Site	Health (ng/L)	Ref	Safety Factor
Atenolol	7.4	DW3	70000	AwwaRF 3085	1.1E-04
Atrazine	300	DW3	3000	EPA SDWA	1.0E-01
Caffeine	22	DW4	350	AUS Guideline	6.3E-02
Carbamazepine	110	IPR1	1000	Schriks 2009	1.1E-01
DEET	53	DW3	2500	AUS Guideline	2.1E-02
Diazepam	0.63	DW3	1400	EPA CCL3	4.5E-04
Dilantin	59	DW3	6800	AwwaRF 3085	8.7E-03
Fluoxetine	1.3	IPR1	42000	Schwab 2005	3.1E-05
Gemfibrozil	10	DW4	45000	AwwaRF 3085	2.2E-04
Ibuprofen	10	DW4	400000	AUS Guideline	2.5E-05
Meprobamate	120	DW3	260000	AwwaRF 3085	4.6E-04
Naproxen	4.1	DW4	220000	AUS Guideline	1.9E-05
PFOA	31	DW3	1100	EPA CCL3	2.8E-02
PFOS	59	IPR1	200	EPA CCL3	3.0E-01
Sulfamethoxazole	98	IPR1	35000	AUS Guideline	2.8E-03
TCEP	510	DW3	2500	EPA CCL3	2.0E-01
Trimethoprim	0.73	DW4	61000	EPA CCL3	1.2E-05

Snyder et al., 2011 – WRF 06-006

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Is Flag's drinking water at risk?

CYNDY COLE Sun Staff Reporter | Posted: Tuesday, October 18, 2011 5:30 am

“About two years ago, very small traces of an antibiotic, an anti-seizure medication and a possible cancer-causing agent appeared in four groundwater wells in northwest Tucson.

All of the wells are located downstream of the local sewage treatment plant, which releases its treated sewage water into a riverbed.

When tested, some of Flagstaff's drinking water wells downstream of the Rio de Flag wastewater treatment plant have also shown tiny traces of other pharmaceuticals and hormones, which have an ability to influence growth in amphibians.”

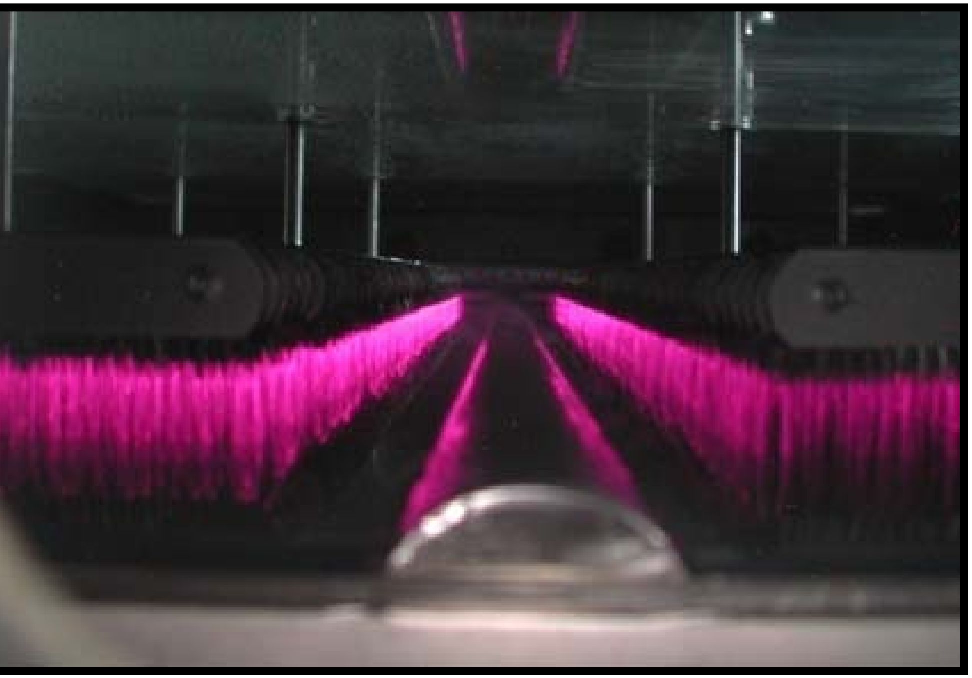
IS IT SAFE?

Three Key Points

I. Water reuse – sustainability through necessity

II. Advances in treatment and detection technologies

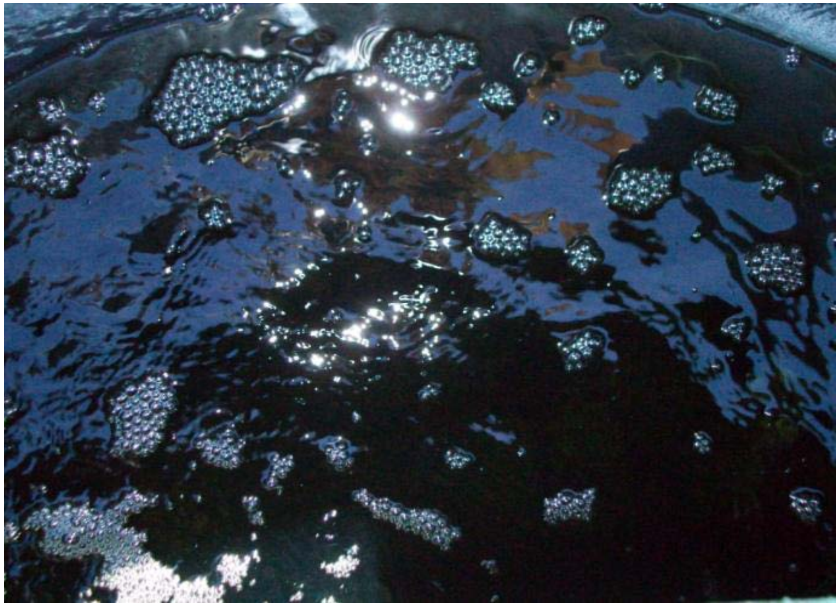
III. Exploring chemical mixtures



Can treatment make this drinkable???

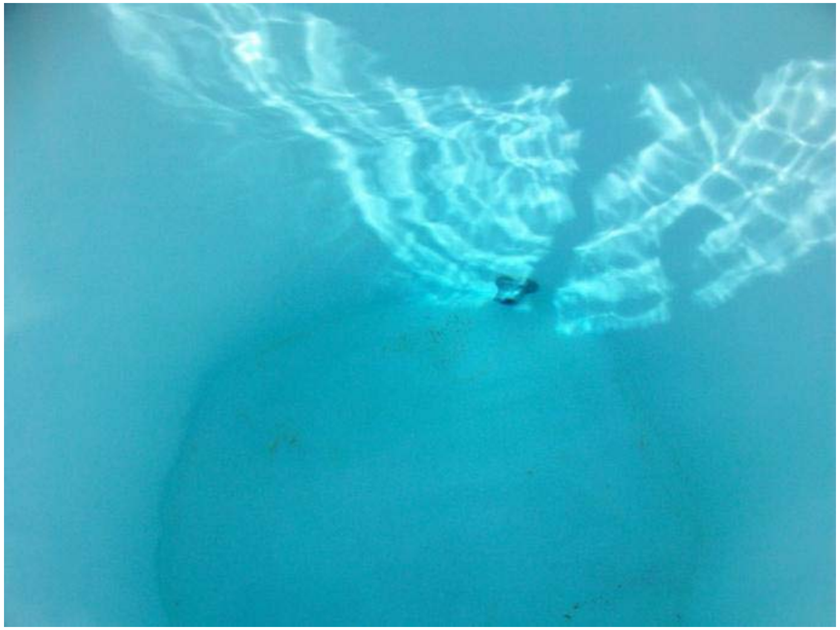
MBR Aeration Basin

MBR Filtrate

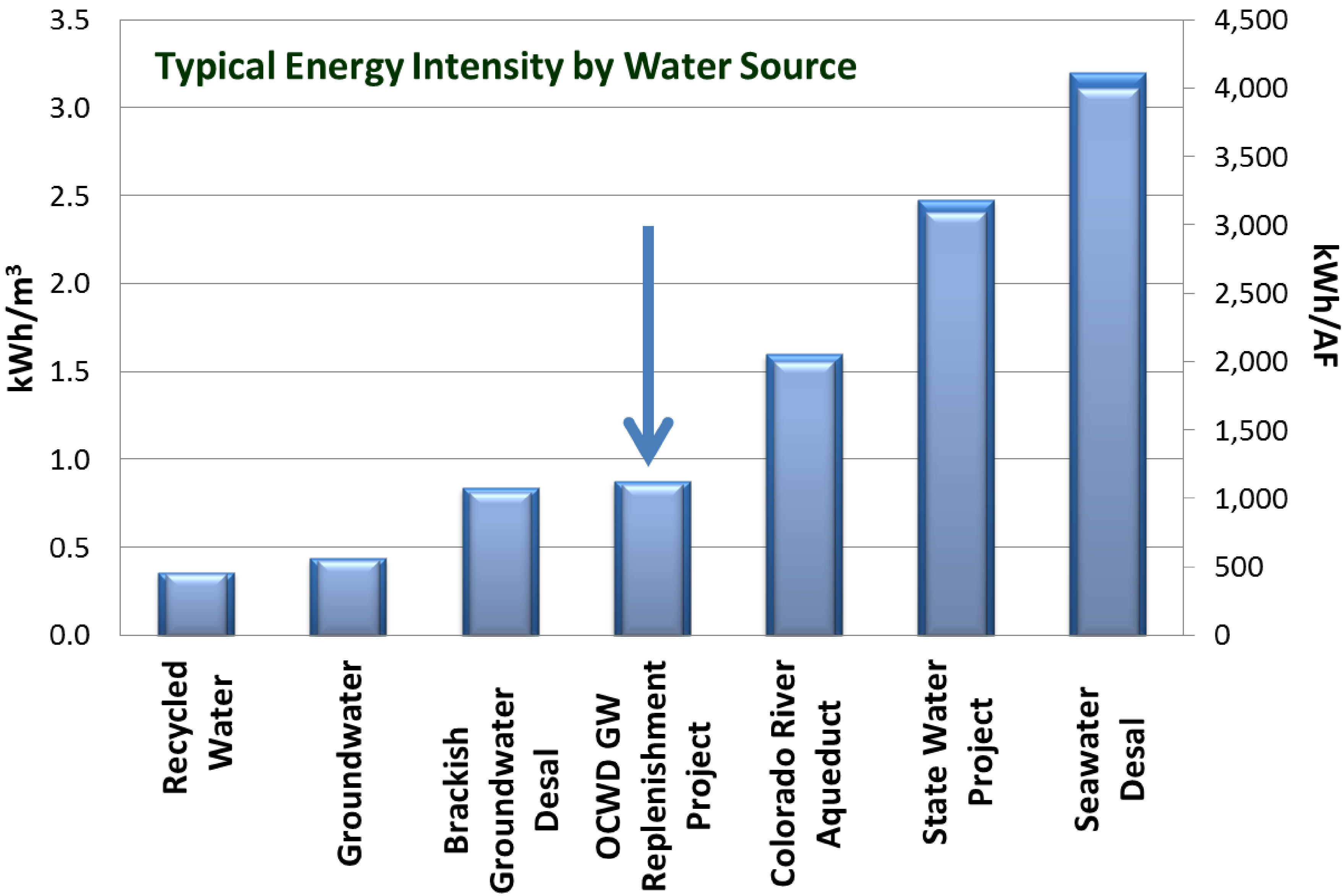


Ozone Effluent

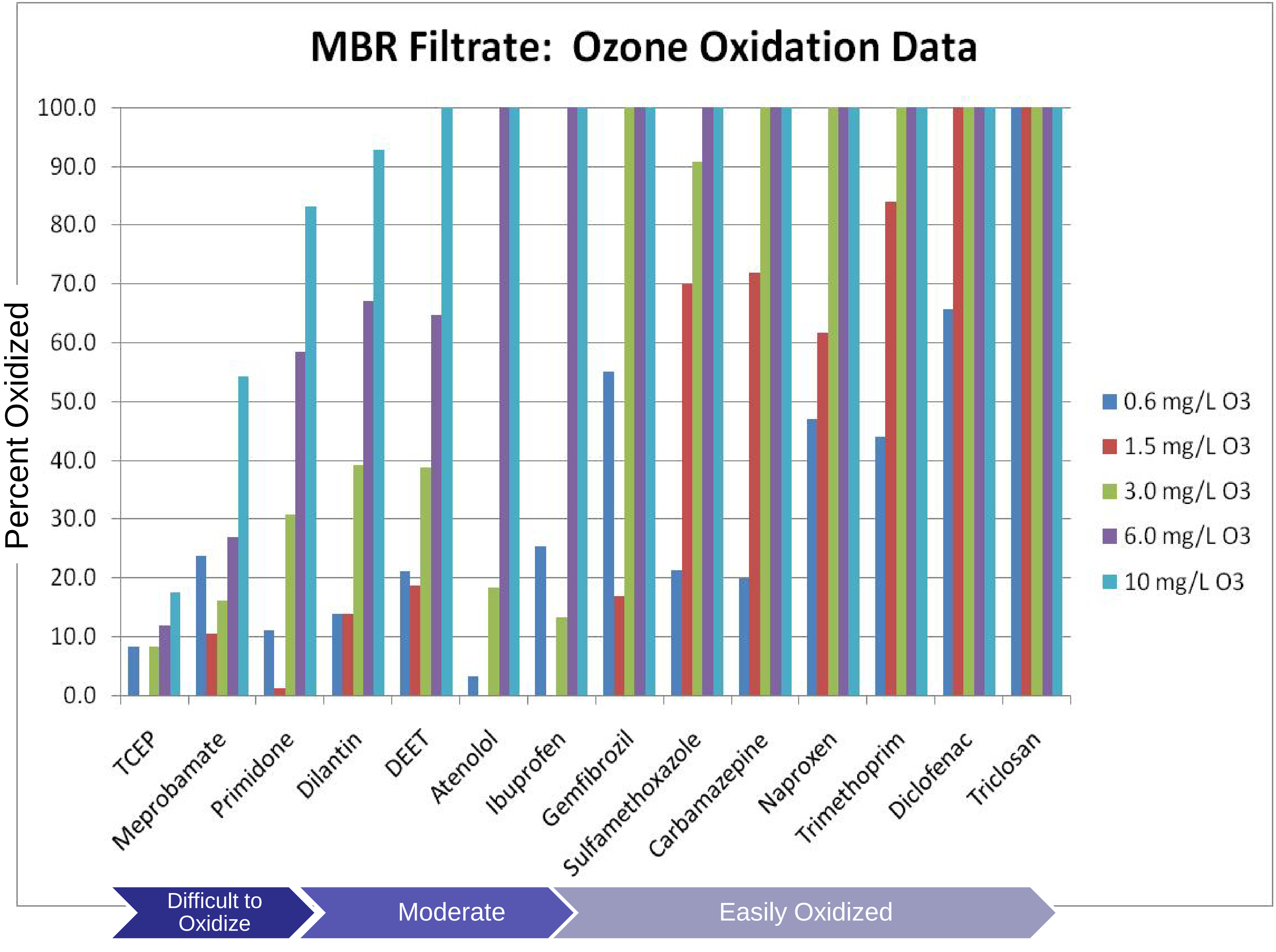
Reverse Osmosis Permeate



Reuse can SAVE energy (despite RO:UV-AOP)

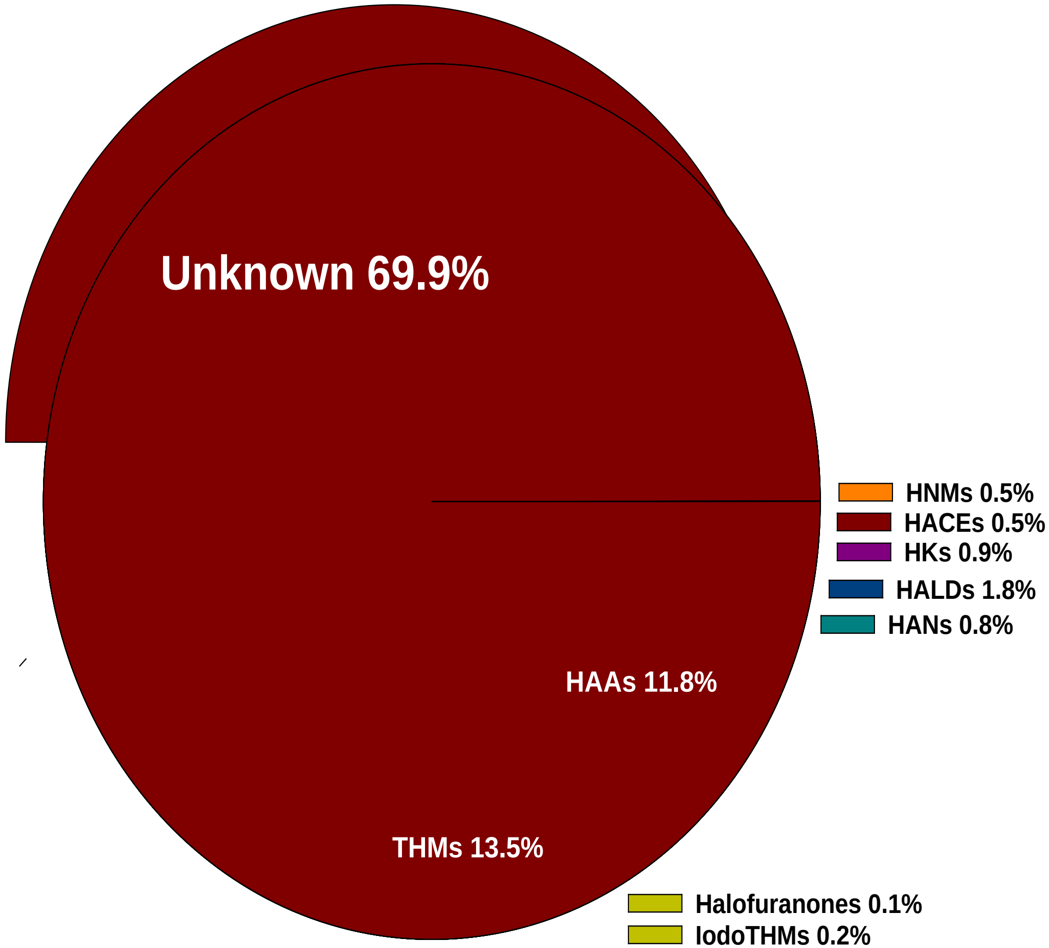


Source: Pacific Institute analysis regarding SDCWA data



MBR Filtrate: Ozone Oxidation Data
Percent Oxidized
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
TCEP
Meprobamate
Primidone
Dilantin
DEET
Atenolol
Ibuprofen
Gemfibrozil
Sulfamethoxazole
Carbamazepine
Naproxen
Trimethoprim
Diclofenac
Triclosan
0.6 mg/L O3
1.5 mg/L O3
3.0 mg/L O3
6.0 mg/L O3
10 mg/L O3
Difficult to Oxidize
Moderate
Easily Oxidized

More than 60% of DBPs are still not known….



Nationwide Occurrence Study, Krasner et al., *Environ. Sci. Technol*. 2006, *40*, 7175-7185.

~50% of TOX >1000 Da: Khiari, et al., Proc. 1996 AWWA Water Quality Technology Conference

Environ. Sci. Technol. 2006, *40*, 7175–7185

Occurrence of a New Generation of Disinfection Byproducts†

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A survey of disinfection byproduct (DBP) occu
the United States was conducted at 12 drinkin
treatment plants. In addition to currently regula
more than 50 DBPs that rated a high priority for
toxicity were studied. These priority DBPs includ
trihalomethanes (THMs), other halomethanes, a no
haloacid, haloacetonitriles, haloketones, halonitromethanes, haloaldehydes, halogenated furanones, haloamides, and nonhalogenated carbonyls. The purpose of this study was to obtain quantitative occurrence information for new DBPs (beyond those currently regulated and/or studied) for prioritizing future health effects studies. An effort was made to select plants treating water that was high in total organic carbon and/or bromide to enable the detection of priority DBPs that contained bromine and/or iodine. THMs and haloacetic acids (HAAs) represented the two major classes of halogenated DBPs formed on a weight basis. Haloacetaldehydes represented the third major class formed in many of the waters. In addition to obtaining quantitative occurrence data, important new information was discovered or confirmed at full-scale plants on the formation and control of DBPs with alternative disinfectants to chlorine. Although the use of alternative disinfectants (ozone, chlorine dioxide, and chloramines) minimized the formation of the four regulated THMs, trihalogenated HAAs, and total organic halogen (TOX), several priority DBPs were formed at higher levels with the alternative disinfectants as compared with chlorine. For example, the highest levels of iodinated THMs—which are not part of the four regulated THMs—were found at a plant that used chloramination with no prechlorination. The highest concentration of dichloroacetaldehyde was at a plant that used chloramines and ozone; however, this disinfection scheme reduced the formation of trichloroacetaldehyde. Preozonation was found to increase the formation of trihalonitromethanes. In addition to the chlorinated furanones that have been measured previously, brominated furanones—which have seldom been analyzed—were detected, especially in high-bromide waters. The presence of bromide resulted in a shift to the formation of other bromine-containing DBPs not normally measured (e.g., brominated ketones, acetaldehydes, nitromethanes, acetamides). Collectively, ~30 and 39% of the TOX and total organic bromine, respectively, were accounted for (on a median basis) by the sum of the measured halogenated DBPs. In addition, 28 new, previously unidentified DBPs were detected. These included brominated and iodinated haloacids, a brominated ketone, and chlorinated and iodinated aldehydes.

Introduction

Moreover, only a limited number of DBPs have been studied for adverse health effects because such studies are extremely expensive.

utilities, utilizing both target compound and broad-screen analyses (*2*). The halogenated compounds, cumulatively, accounted for between 30 and 60% of the total organic halogen (TOX) found in these samples. In 1988–1989, a study of 35 U.S. utilities was conducted, which analyzed for 19 halogenated DBPs and two aldehydes (*3*). On a weight basis, THMs were the largest class of DBPs detected; the second largest fraction was haloacetic acids (HAAs). In addition, Glaze and Weinberg studied the formation of ozonation DBPs at 10 North American utilities in 1990–1991 (*4*). This study demonstrated that aldehydes could be removed with biofiltration (*5*), and bromate formation could be minimized at a lower ozonation pH (*6*).

In 1997–1998, 296 U.S. utilities operating a total of 500 plants conducted a DBP survey under the Information Collection Rule (ICR) (*7*). This survey included measurements for the 4 regulated THMs, 6–9 HAAs (5 are regulated), 4 haloacetonitriles, 2 haloketones, trichloronitromethane (chloropicrin), trichloroacetaldehyde (chloral hydrate), cyanogen chloride, chlorite, chlorate, bromate, glyoxal, methyl glyoxal, and 11 other aldehydes. The ICR, which included the same DBPs from the earlier studies (*3*, *4*), greatly expanded our knowledge on the occurrence of these DBPs.

Other DBPs of health concern have had less extensive monitoring. The chlorinated furanone 3-chloro-4-(dichloromethyl)-5-hydroxy-2-(5*H*)-furanone (MX) has been measured in a limited number of studies in the United States (*8*, *9*) and elsewhere (*10*). For example, Kronberg and colleagues found from 15 to 67 ng/L of MX in chlorinated drinking water from three towns in Finland (*10*). MX, its geometric isomer (*E*)-2-chloro-3-(dichloromethyl)-4-oxobutenoic acid (EMX), and their oxidized and reduced forms were found in U.S. waters (*11*), while MX and brominated analogues of MX (BMXs) have been identified in Japanese drinking waters (*12*).

Trihalonitromethanes with bromine have been identified in bench-scale chlorination studies (*13*), and bromopicrin

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Occurrence and Mammalian Cell Toxicity of Iodinated Disinfection Byproducts in Drinking Water

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An occurrence study was conducted to measure five iodo-acids (iodoacetic acid, bromoiodoacetic acid, (*Z*)-3-bromo-3-iodo-propenoic acid, (*E*)-3-bromo-3-iodo-propenoic acid, and (*E*)-2-iodo-3-methylbutenedioic acid) and two iodo-trihalomethanes (iodo-THMs), (dichloroiodomethane and bromochloro-iodomethane) in chloraminated and chlorinated drinking waters from 23 cities in the United States and Canada. Since iodoacetic acid was previously found to be genotoxic in mammalian cells, the iodo-acids and iodo-THMs were analyzed for toxicity. A gas chromatography (GC)/negative chemical ionization-mass spectrometry (MS) method was developed to measure the iodo-acids; iodo-THMs were measured using GC/high resolution electron ionization-MS with isotope dilution. The iodo-acids and iodo-THMs were found in waters from most plants, at maximum levels of 1.7 μg/L (iodoacetic acid), 1.4 μg/L (bromoiodoacetic acid), 0.50 μg/L ((*Z*)-3-bromo-3-iodopropenoic acid), 0.28 μg/L ((*E*)-3-bromo-3-iodopropenoic acid), 0.58 μg/L ((*E*)-2-iodo-3-methylbutenedioic acid), 10.2 μg/L (bromochloroiodomethane), and 7.9 μg/L (dichloroiodomethane). Iodo-acids and iodo-THMs were highest at plants with short free chlorine contact times (< 1 min), and were lowest at a chlorine-only plant or at plants with long free chlorine contact times (> 45 min). Iodide levels in source waters ranged from 0.4 to 104.2 μg/L (when detected), but there was not a consistent correlation between bromide and iodide. The rank order for mammalian cell chronic cytotoxicity of the compounds measured in this study, plus other iodinated compounds, was iodoacetic acid > (*E*)-3-bromo-2-iodopropenoic acid > iodoform > (*E*)-3-bromo-3-iodo-propenoic acid > (*Z*)-3-bromo-3-iodo-propenoic acid > diiodoacetic acid > bromoiodoacetic acid > (*E*)-2-iodo-

chlorodiiodomethane > bromoiodoacetic acid > *E*-2-iodo-3-methylbutenedioic acid > (*E*)-3-bromo-3-iodo-propenoic acid > (*E*)-3-bromo-2-iodopropenoic acid. In general, compounds that contain an iodo-group have enhanced mammalian cell cytotoxicity and genotoxicity as compared to their brominated and chlorinated analogues.

This order of toxicity correlates with the leaving tendency of the halogens in SN2 reactions: I > Br ≫ Cl.

Introduction

In a recent Nationwide Disinfection Byproduct (DBP) Occurrence Study (*1*), iodo-acids were identified for the first time as DBPs in drinking water disinfected with chloramines (*1, 2*). The iodo-acids included iodoacetic acid, bromoiodoacetic acid, (*Z*)-3-bromo-3-iodo-propenoic acid, (*E*)-3-bromo-3-iodo-propenoic acid, and (*E*)-2-iodo-3-methylbutenedioic acid (Figure 1). Gas chromatography (GC) with low- and high-resolution electron ionization (EI)-mass spectrometry (MS) was used to identify them, and they were confirmed through a match of mass spectra and GC retention times using authentic chemical standards (*2*). There is concern about these new iodo-acid DBPs because iodoacetic acid is highly cytotoxic and more genotoxic in mammalian cells than bromoacetic acid, the most genotoxic of the regulated haloacetic acids (HAAs) (*2*). Additionally, iodoacetic acid causes developmental abnormalities in mouse embryos (*3, 4*).

Iodo-trihalomethanes (iodo-THMs) have been predicted to be more toxic than chlorinated and brominated THMs (*5*), which are currently regulated in the United States (*6*). Iodo-THMs were included in the Nationwide DBP Occurrence Study and were highest in drinking waters treated with chloramines (*1*). In one plant, the summed concentrations of the six iodo-THMs was 81% of the sum of the four regulated THMs (*1*). Even though iodo-THMs have been known as DBPs since the mid-1970s (*7, 8*), there have been very few measurements in drinking water (*1, 9, 10*), and virtually no toxicity data.

Because chloramines produce significantly lower levels of the regulated THMs and HAAs (*11, 12*), many drinking water treatment plants in the United States have switched from chlorine to chloramines. However, evidence indicates that the formation of iodinated DBPs may be higher with chloramination than with chlorination (*1, 10, 13*). Our goals were to develop an analytical method to quantify five iodo-acids in drinking water, measure their occurrence in several waters treated with chloramination, and investigate the effect

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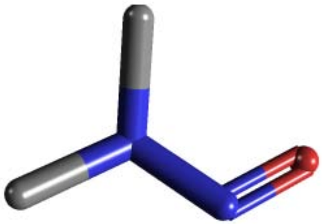
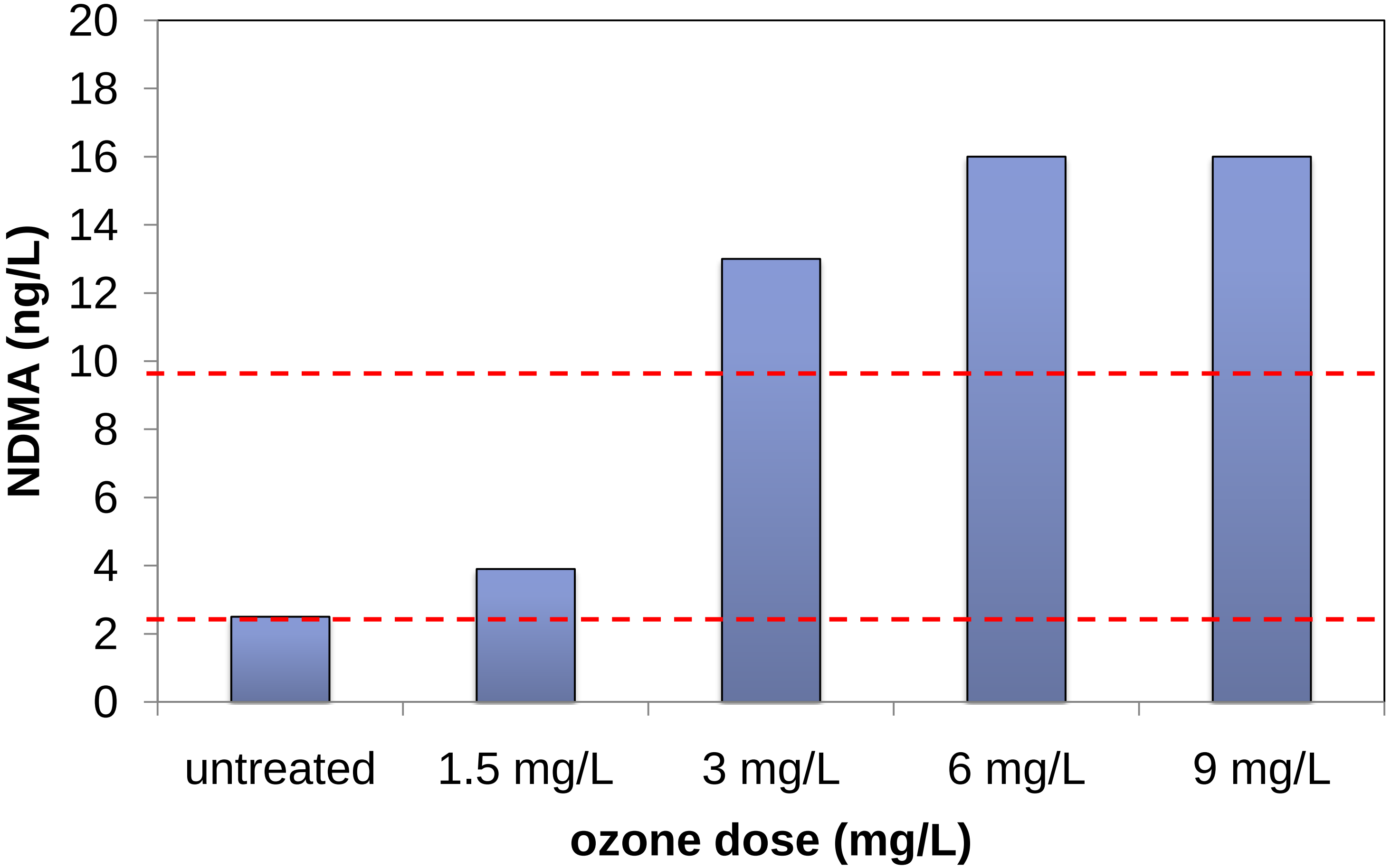
§ University of Delaware.
‖ CanSyn Chem. Corp.
⊥ U.S. Environmental Protection Agency, National Risk Management Research Laboratory.
University of Illinois—at Urbana–Champaign.
∇ Currently at the University of Torino, Torino, Italy 10125.

10.1021/es801169k CCC: $40.75
Published on Web 09/24/2008

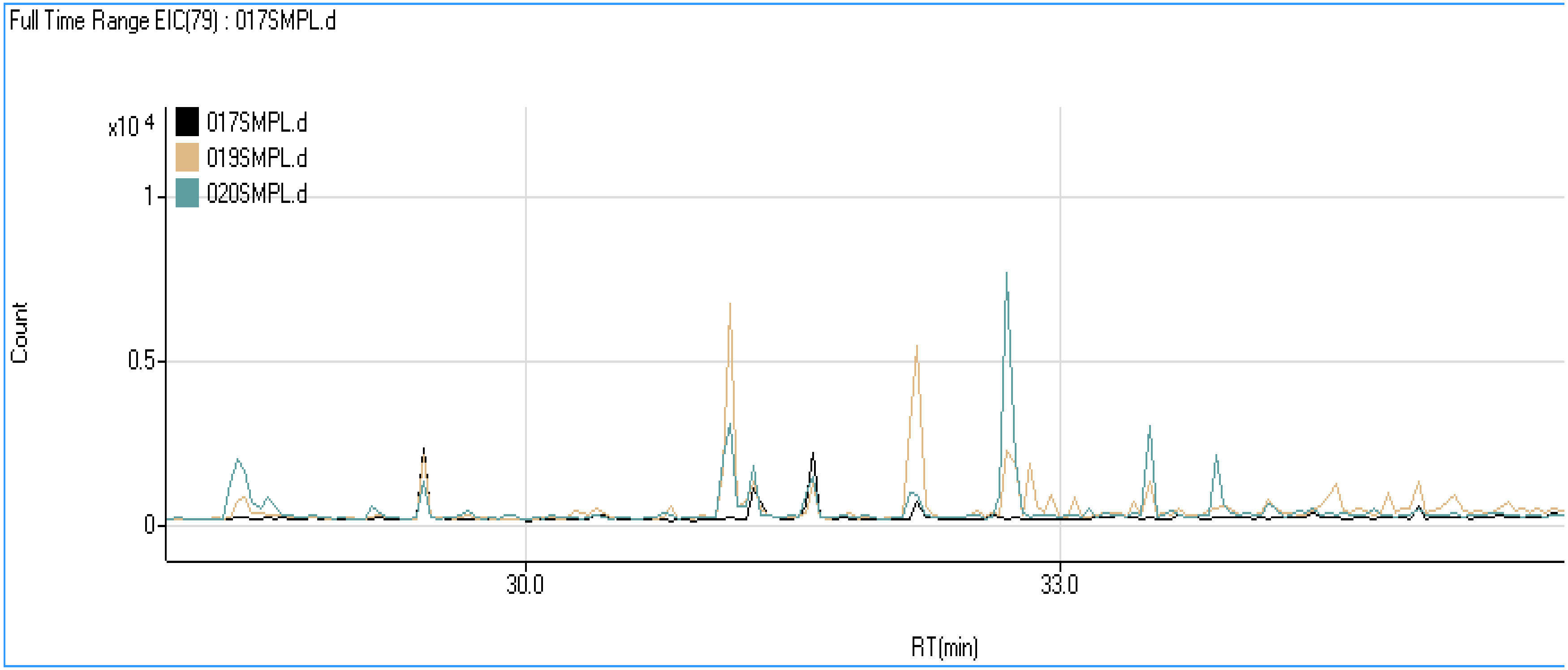
Ozonation and Formation of Nitrosamines
N-Nitrosodimethylamine (NDMA)





GC-ICPMS

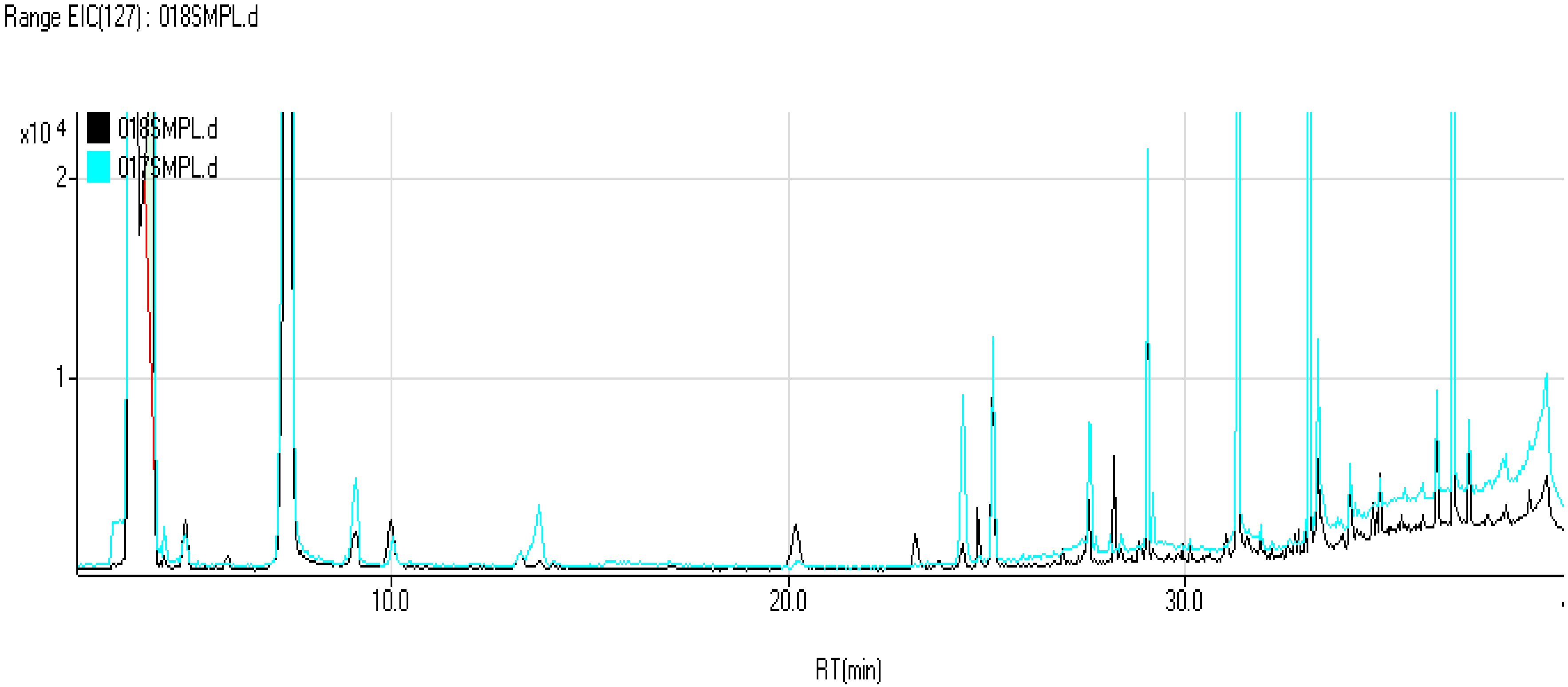
- Brominated DBPs in effluent



^{79}Br GC-ICPMS chromatograms for extracts of wastewater effluent: Non-treated Ozonated Chlorinated & Ozonated

GC-ICPMS

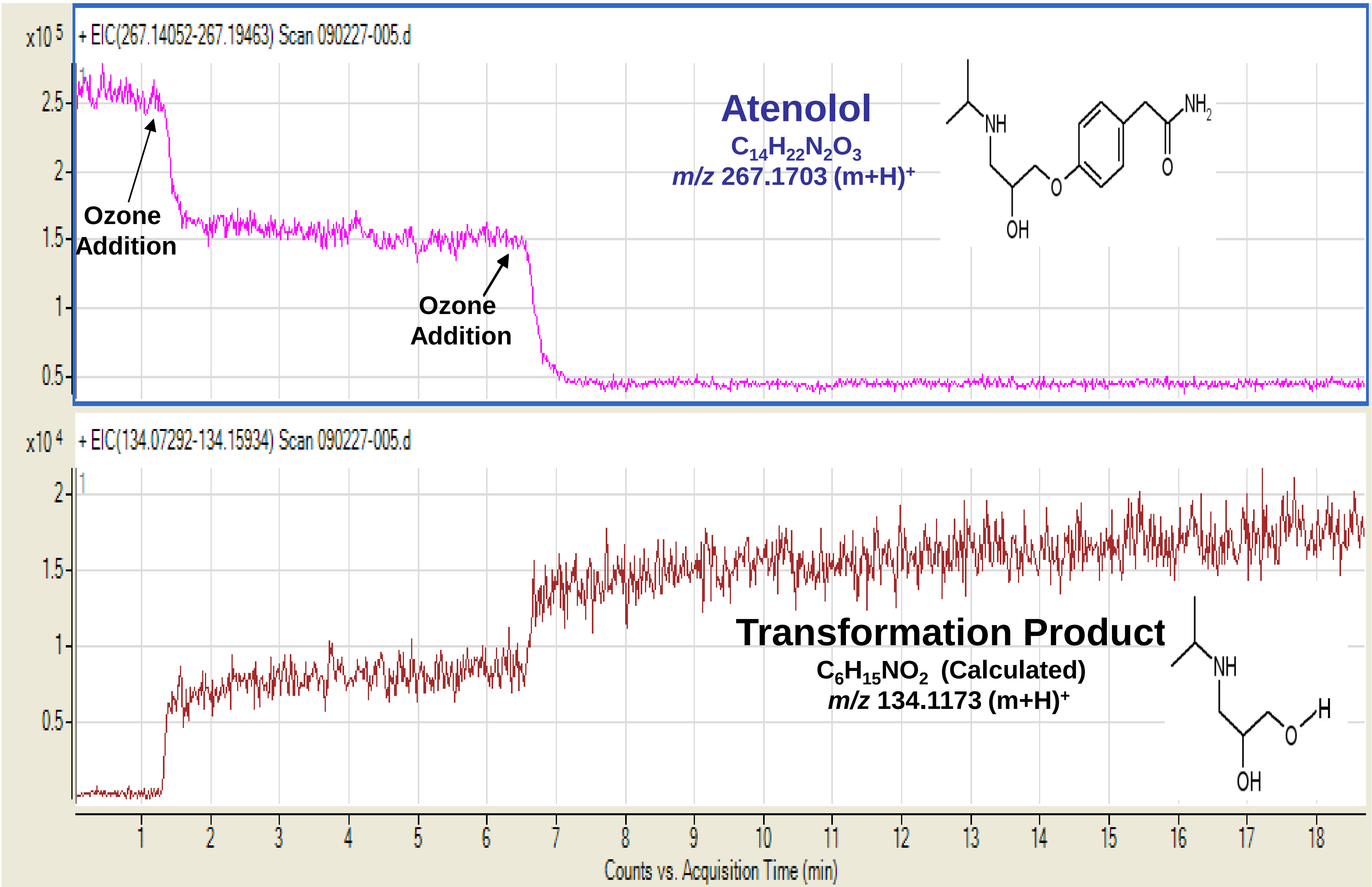
- Iodinated DBPs in effluent



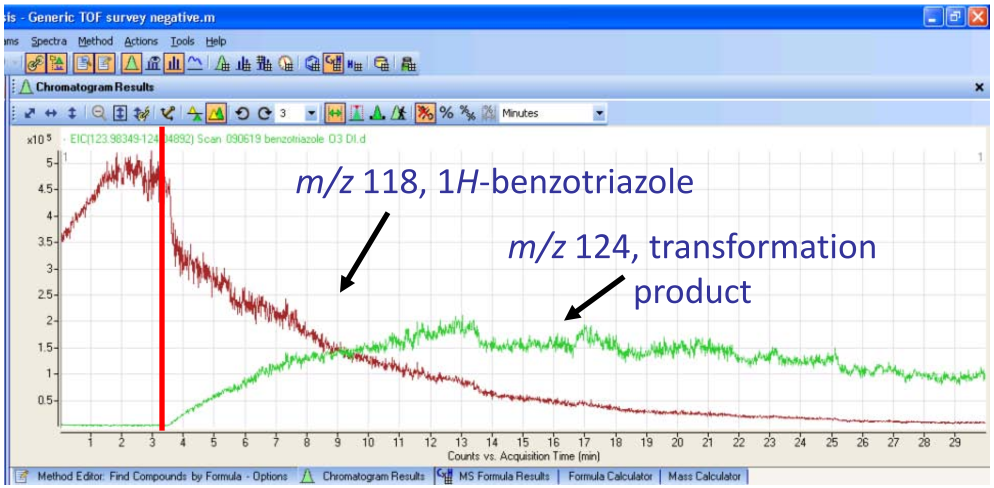
^{127}I GC-ICPMS chromatograms for extracts of wastewater effluent: Non-Ozonated and Ozonated

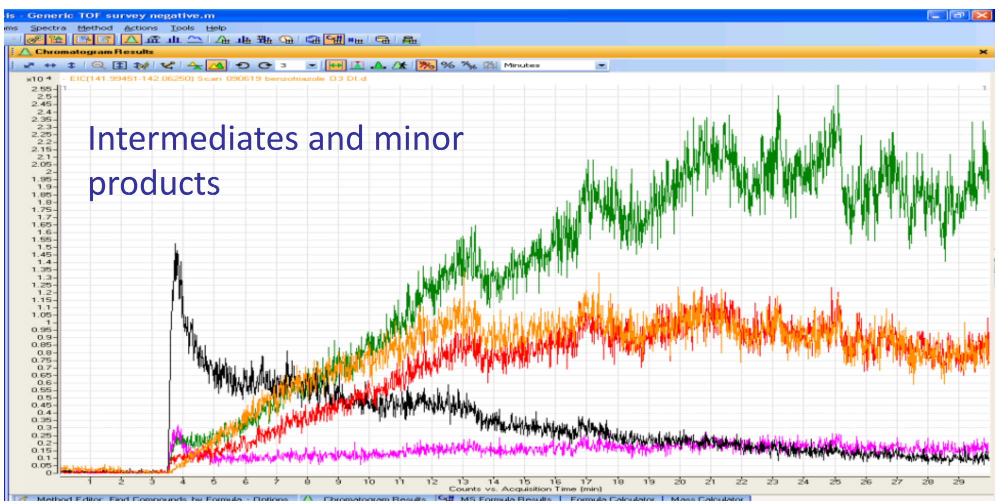

HTC

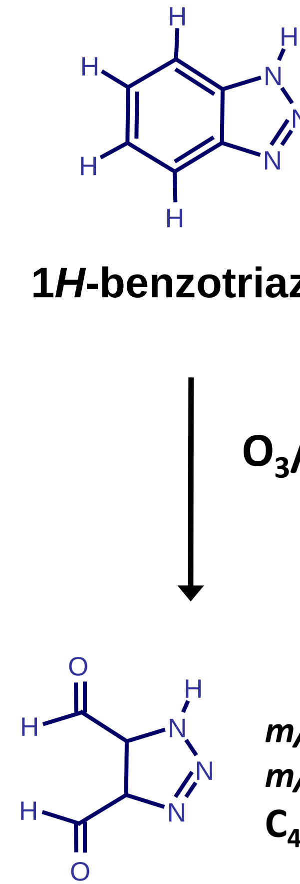
Ozone Reaction Products



Benzotriazole + Ozone







1*H*-benzotriazole

O_3/ $^{\bullet}OH$

***m/z* 124.01522 (meas.)**
***m/z* 124.01525 (calc.)**
$C_4H_3N_3O_2$

1*H*-1,2,3-triazole-4,5-dicarbaldehyde

Mawhinney, DB, BJ Vanderford, and SA Snyder. (2012) *Environmental Science & Technology* 46 (13):7102-7111.

Three Key Points

I. Water reuse – sustainability through necessity

II. Advances in treatment and detection technologies

III. **Exploring chemical mixtures**

- Announced by Lisa Jackson March 22nd, 2010

1. Address contaminants as groups
2. Development of technologies
3. Multiple statutes for drinking water
4. Partner with states to share monitoring data

http://www.webdialogues.net/cs/epa-dwcontaminantgroups-library/download/dlib/1860/EPA_Discussion_Paper.pdf.pdf?x-r=pcfile_d

Defining Group(s)
Potential Factors to Consider

- Has similar health effect endpoint
- Removed by common treatment or control processes
- Measured by common analytical method(s), directly or indirectly, under full scan
- [Known or likely co-occurrence]

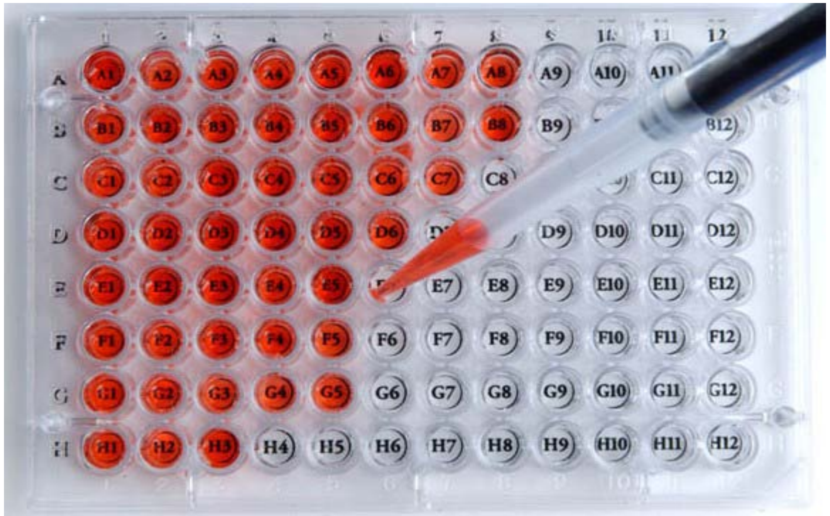
The more "promising" groups are likely to have many of these factors in common.

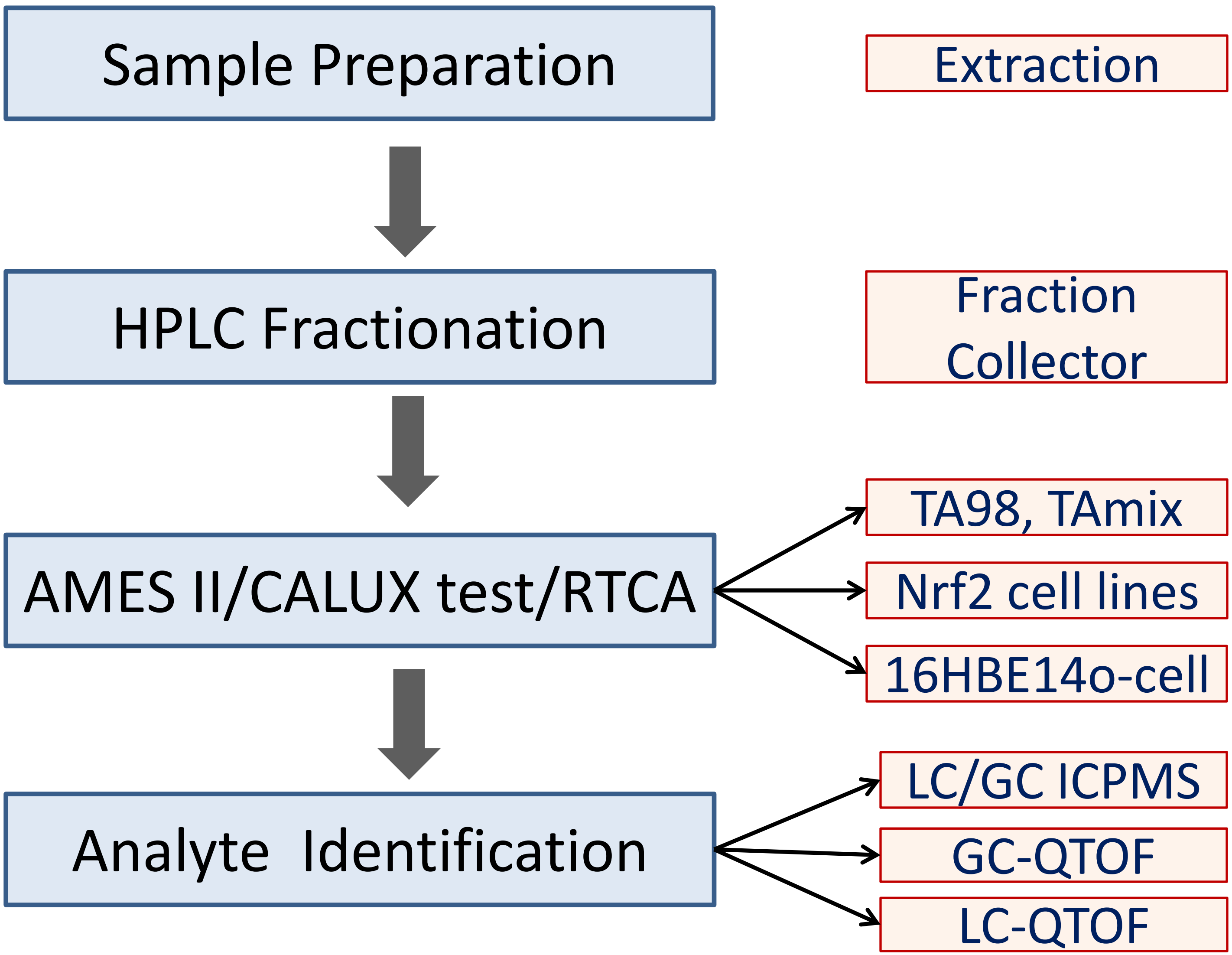
Groups Initially Identified

- Volatile Organic Compounds (VOCs)
- Synthetic Organic Compounds (SOCs)
- Inorganic Compounds (IOCs)
- Carcinogenic VOCs
- Non-carcinogenic VOCs
- Pesticides
- Carbamates
- Organophosphates
- Chloroacetanilides
- Triazines
- Conazoles
- Disinfection Byproducts
- Nitrosamines
- Perfluorinated compounds (PFOS/PFOA/PFCs)
- Estrogenic Compounds
- Androgenic Compounds
- Pharmaceuticals
- Antibiotics
- Cholinesterase Inhibitors
- Thyroid Inhibitors

Analytical Chemistry VS Bioassay

Targeted Analytical	**Mechanistic Bioassay**
Known compounds	Knowns/unknowns
Quantitative	Semi-quantitative
Individual compounds	Synergism/Antagonism




Sample Preparation
Extraction
HPLC Fractionation
Fraction Collector
AMES II/CALUX test/RTCA
TA98, TAmix
Nrf2 cell lines
16HBE14o-cell
Analyte Identification
LC/GC ICPMS
GC-QTOF
LC-QTOF

Green Valley, Arizona
Xylem – UV & Ozone Pilot

H_2O_2 dosing

UV system control

flow meter

Venturi injector

booster pump

O_3 analyzer

O_3 catalyst

UV reactor

Outlet

Inlet

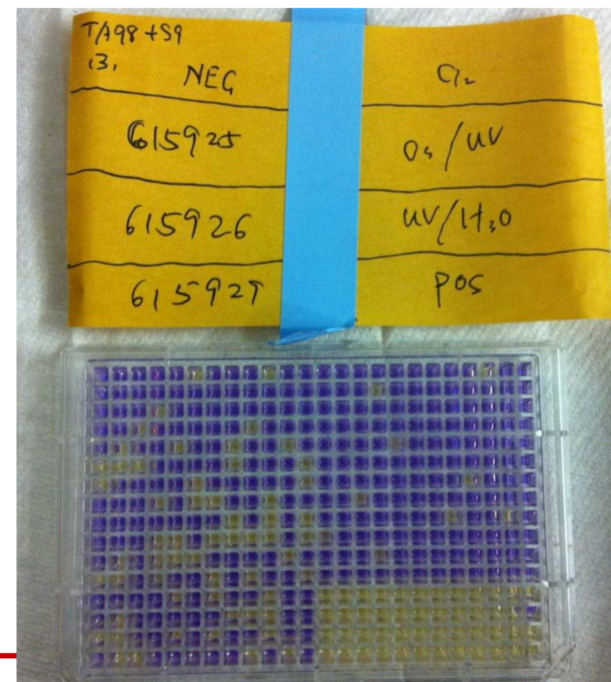
AMESII test

1. Overnight culture

2. Transfer to 24-well plates

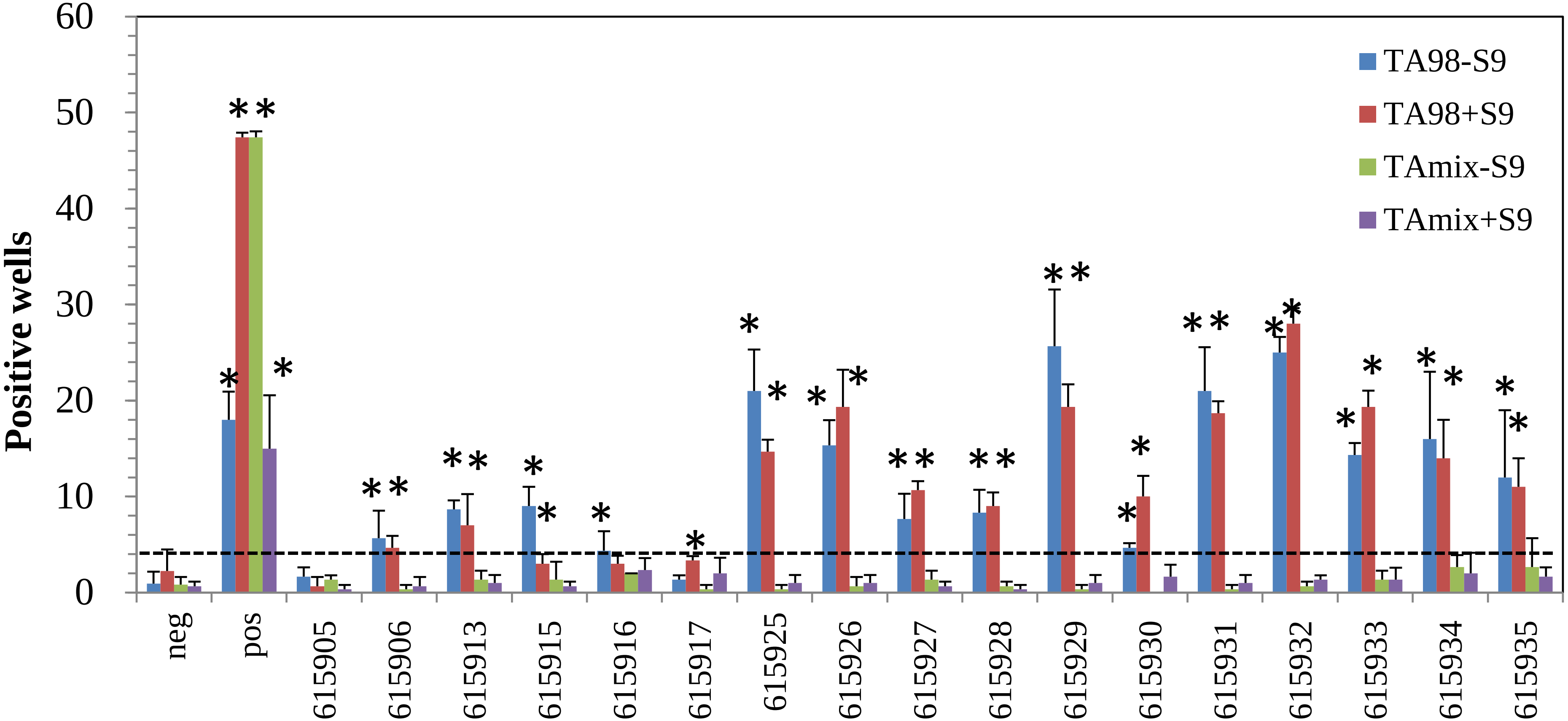
Sample (in DMSO)
S9
Bacteria
Exposure media

3. Add indicator media, transfer to 384-well plates



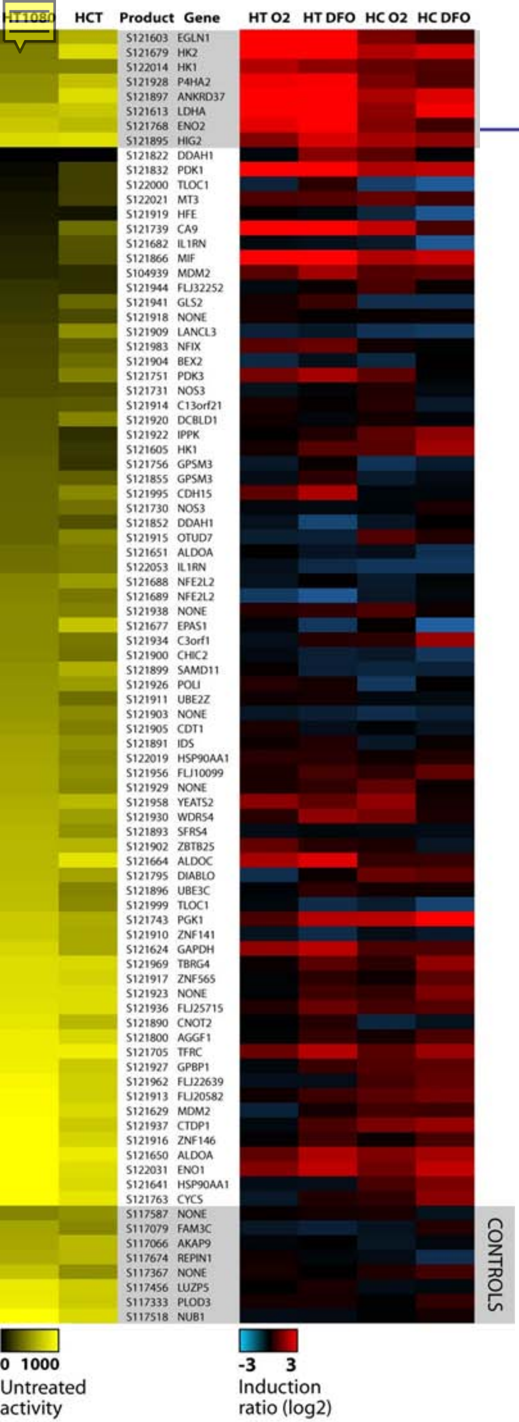
4. After 48h, check the results

AMESII results – UV MP

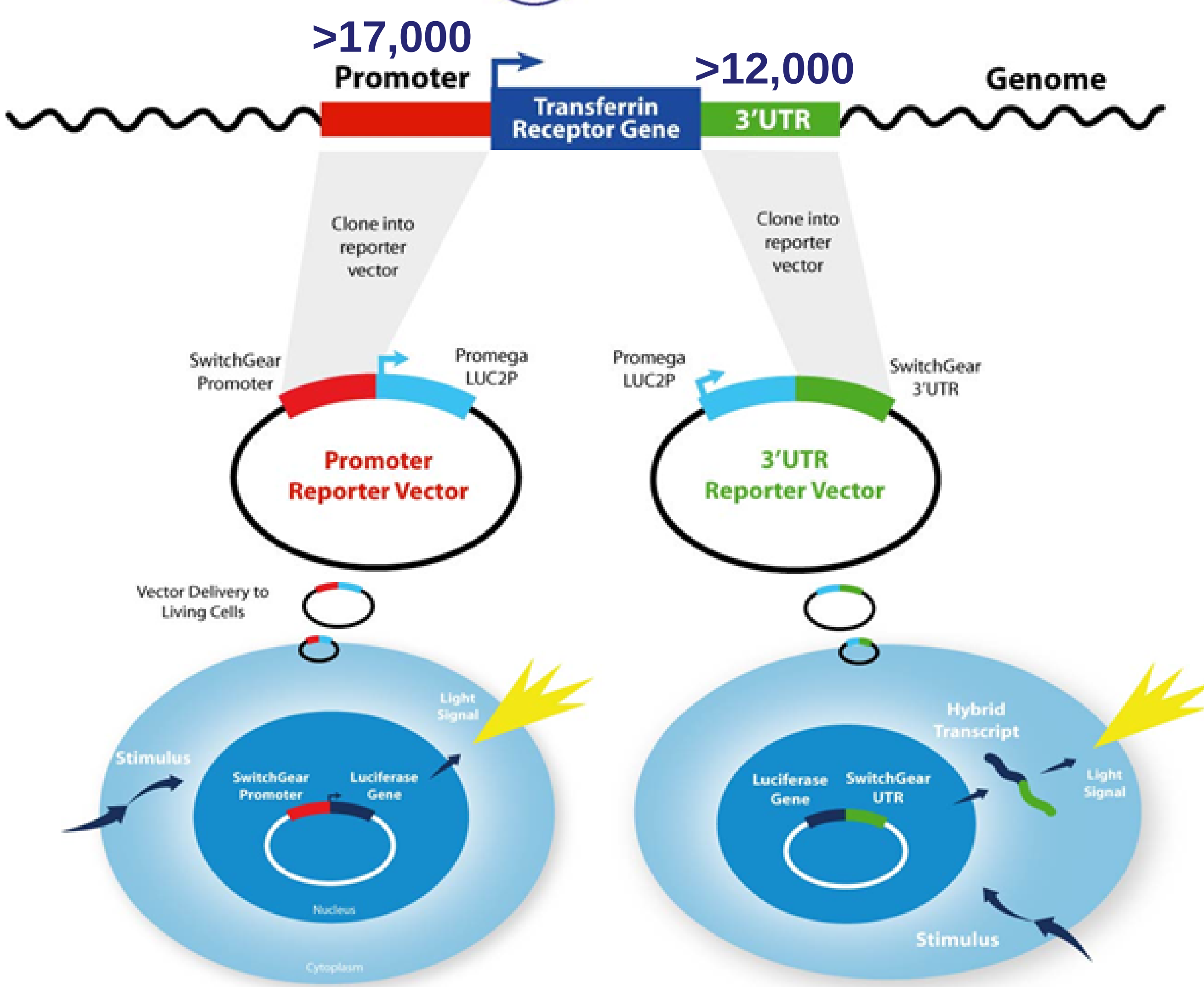


* $P < 0.05$

------ > 2fold baseline (Mean_{neg}+Std)

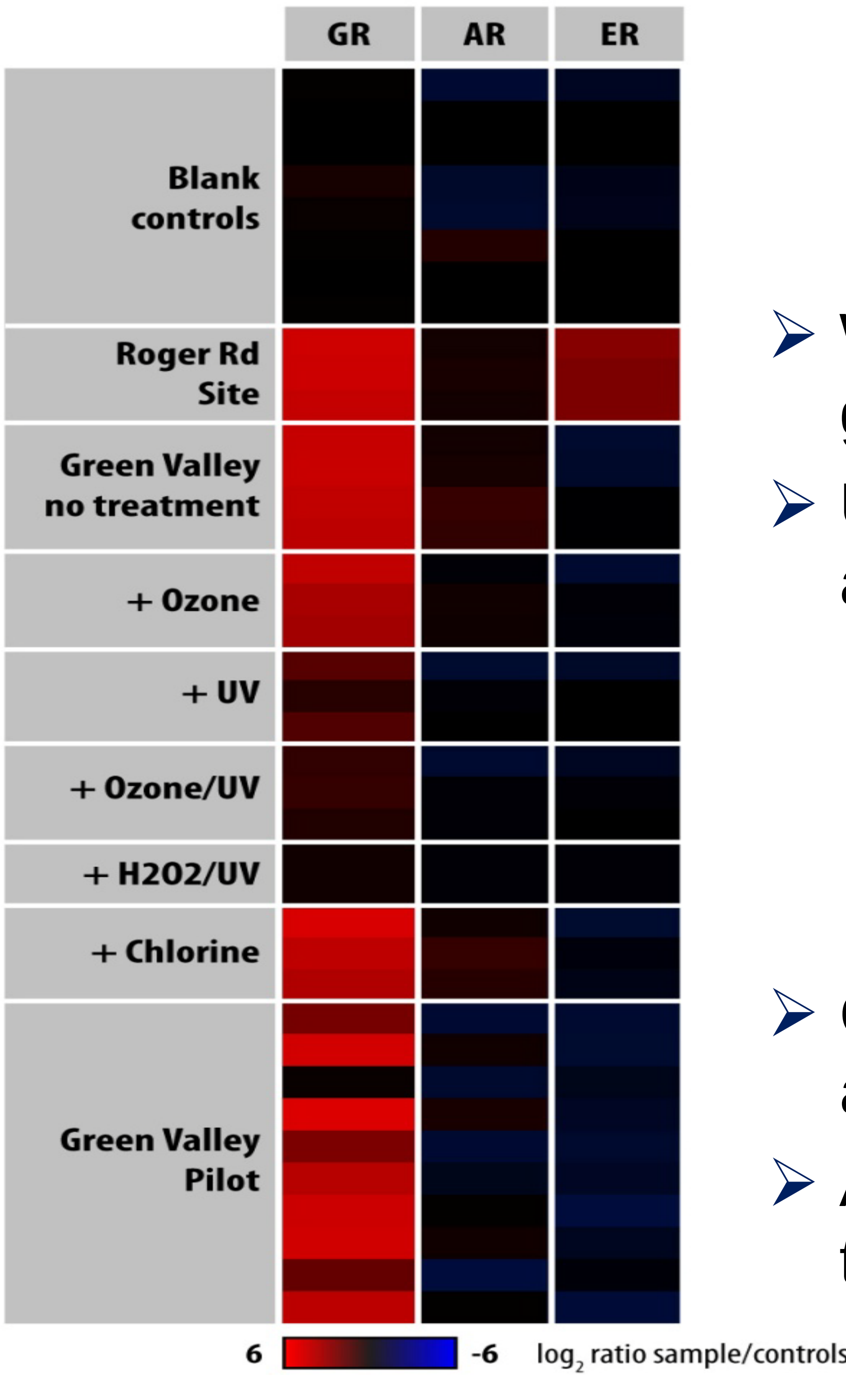


SWITCHGEAR GENOMICS



Light signal= promoter activity

Light signal= UTR activity



Results from Ozone & UV Water Reuse Pilot Testing (n=4 seasons)

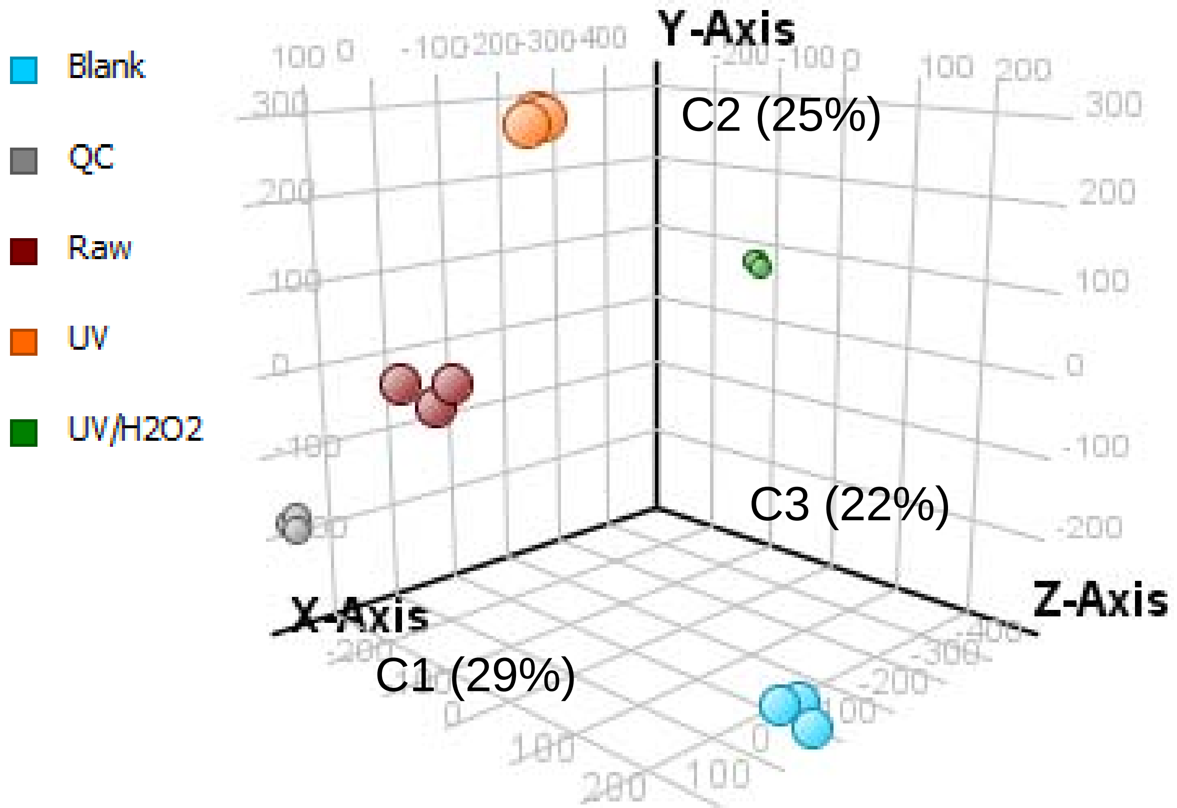
- WWTP effluent had elevated glucocorticoid (GR) activity
- UV processes are most effective at removing GR activity
  - Agonist appears to be UV sensitive (↑ quantum yield)
  - Guides structural elucidation (i.e., NDMA)
- Chlorine and ozone poor for attenuating GR activity
- Antagonistic ER and AR activity to be investigated

Analytical Approach for Unknowns

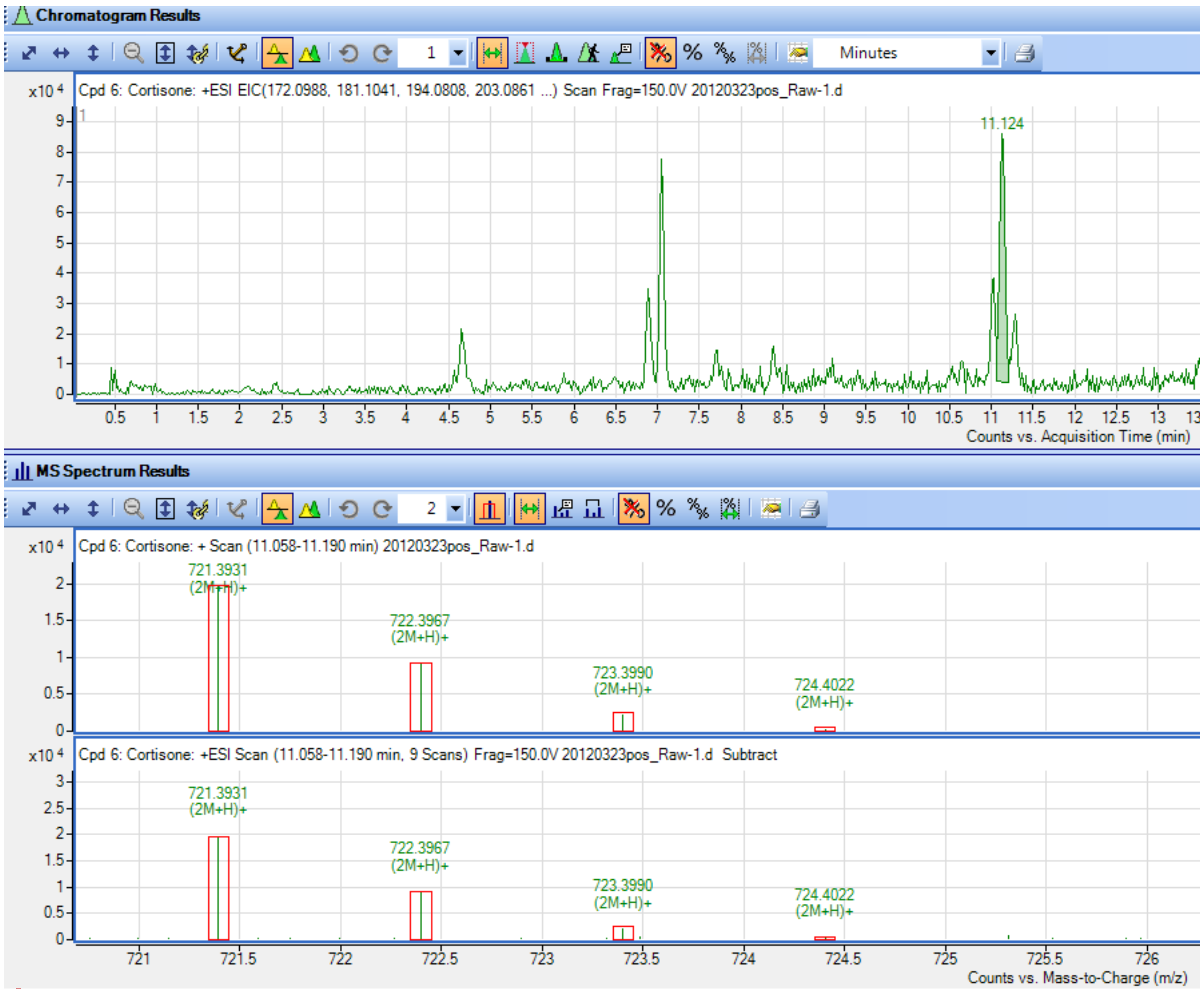
UHPLC(Dionex)-QTOF (AB Sciex)

UHPLC-QTOF (Agilent)

MPP Process



QTOF Discoveries



Possible:
Cortisone/
Prednisolone

($C_{21}H_{28}O_5$)

QTOF Discoveries

Possible: Dexamethasone/ Betamethasone

(Formula:C22H29FO5)


WARNING
CHALLENGES
AHEAD

&


Opportunity
Next Exit

DIRECT POTABLE REUSE

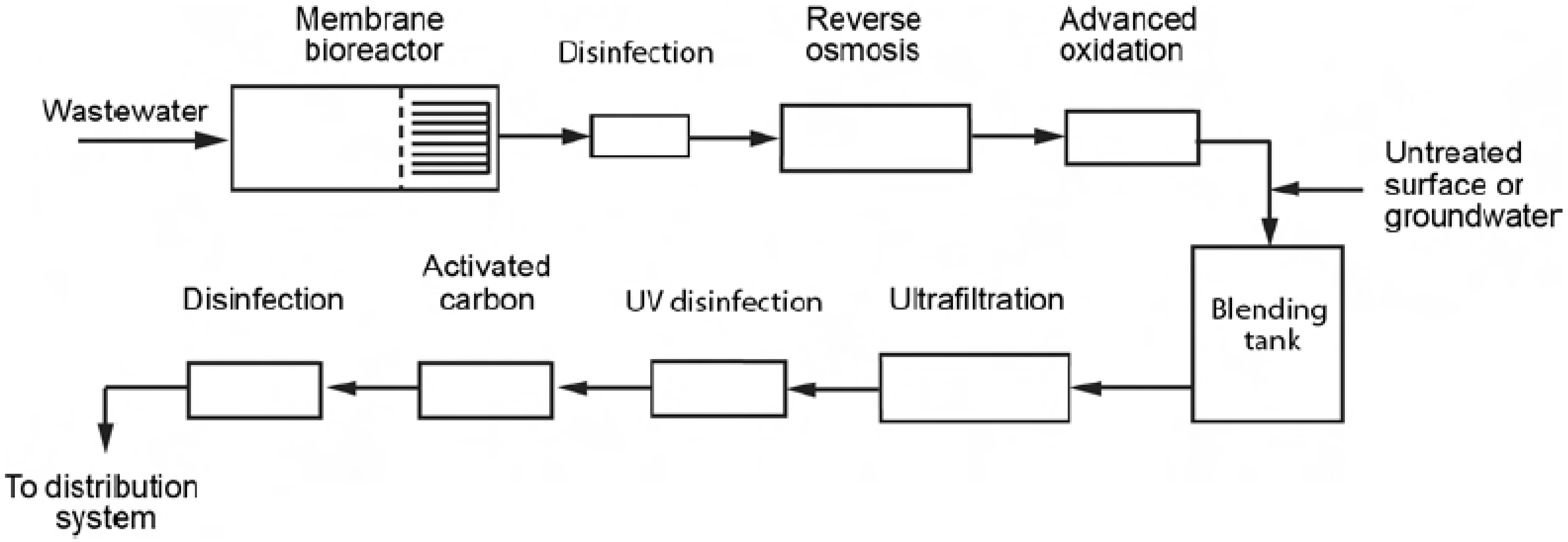


Figure 3-7

Schematic of Cloudcroft, NM DPR treatment process flow diagram (Adapted from Livingston, 2008).


REAL UVT
BioSentry

Three Key Points

- *All water has been, or will be, reused*
  - Global sustainability depends on recycling water
  - This activity will contribute new chemicals to water
- *Treatment and detection technologies are advancing*
  - Membrane and oxidation technologies are reliable
  - Any contaminant can be removed
  - However, detection is a function of the analytical method
- *Water Reuse will Continue to Advance*
  - Potable water reuse is growing, including direct potable reuse
  - Real-time on-line monitoring systems are critical
  - We can produce safe potable water from wastewater!

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JMAR

suez environnement, United Water

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DIONEX

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