EMERGING CONTAMINANTS IN ARIZONA WATER

A Status Report
September 2016

CONTAMINANT ASSESSMENT • MONITORING • RESEARCH OPPORTUNITIES • IMPACTS • RESOURCES • COMMUNICATION & OUTREACH

ADEQ
Arizona Department of Environmental Quality

Acknowledgements

Misael Cabrera	APEC Sponsor, ADEQ Director
Henry Darwin	APEC Sponsor, ADEQ Director (former)
Trevor Baggiore	APEC Chair, ADEQ Water Quality Division Director
Mike Fulton	APEC Chair, ADEQ Water Quality Division Director (former)
Randy Gottler	APEC Co-Chair, City of Phoenix

Committee Chairs/Co-chairs*

Dan Quintanar	Chair, Outreach and Education Committee Tucson Water
John Kmiec	Chair, Chemical EC Committee Town of Marana
Dr. Jeff Prevatt	Chair, Microbial EC Committee Pima County Regional Wastewater Reclamation Dept.
Cindy Garcia (M)	Co-chair, Outreach and Education Committee City of Peoria
Jamie McCullough	Co-chair, Outreach and Education Committee City of El Mirage
Dr. Channah Rock	Co-chair, Outreach and Education Committee University of Arizona, Maricopa Agricultural Center
Laura McCasland (O)	Co-chair, Chemical EC Committee City of Scottsdale
Steve Baker	Co-chair, Microbial EC Committee Arizona Dept. of Health Services, Division of Public Health Services

Additional APEC Members*

Dr. Morteza Abbaszadegan (M)	Arizona State University, Dept. of Civil and Environmental Engineering
Dr. Leif Abrell (C,M)	University of Arizona, Arizona Laboratory for Emerging Contaminants
Jennifer Botsford (C,O)	Arizona Dept. of Health Services, Office of Environmental Health
Dr. Kelly Bright (M)	University of Arizona, Soil, Water & Environmental Science
Al Brown (O)	Arizona State University, The Polytechnic School
Dr. Mark Brusseau (C,O)	University of Arizona, School of Earth & Environmental Sciences
Alissa Coes (C)	U.S. Geological Survey, Arizona Water Science Center
Nick Paretti	U.S. Geological Survey, Arizona Water Science Center
Patrick Cunningham (O)	The Law Office of Patrick J. Cunningham, LLC
Ron Eisele II	City of Holbrook
Pejman Eshraghi (C)	Haley & Aldrich, Inc.

*Letters after names indicate APEC committee participation:
O = Outreach and Education Committee
C = Chemical EC Committee
M = Microbial EC Committee

Steve Figgins (C)	Farallon Consulting, L.L.C.
Michael Fink	U.S. Army Corps of Engineers, AZ/NV Area Office
Robert Fromm, Jr., MD	Maricopa Integrated Health System
Dr. Chuck Gerba (M)	University of Arizona, Soil, Water & Environmental Science
Brad Hill	City of Flagstaff
Chris Hill (M)	Metro Water District
Dr. Kiril Hristovski (C,O)	Arizona State University, The Polytechnic School
Dr. Anupa Jain (C,O)	City of Chandler
Myra Jefferson	Lion-S Financial Group, LLC
Christopher Jensen	Verde National Resource Conservation District
Sara Presler	Attorney
Dennis Price	Ehrenberg Improvement Association Water Dept.
Dr. Cathy Propper (C)	Northern Arizona University, Dept. of Biological Sciences
Dr. Shane Snyder (C)	University of Arizona, Dept. of Chemical and Environmental Engineering
Dr. Joli Weiss (M,O)	Arizona Dept. of Health Services, Division of Public Health Services
Dr. Doyle Wilson (C,O)	City of Lake Havasu City

APEC Participants*

Molly Collins (O)	Tucson Water
Dr. Kelly Reynolds (O)	University of Arizona, College of Public Health

Support

Chuck Graf	ADEQ
John Calkins	ADEQ
Mason Bolitho	Haley & Aldrich, Inc.
Julie Hoskin	ADEQ
Molly Mullins	ADEQ
Deborah Huie	CH2M Hill, Tucson
Linda Dombrowski	Haley & Aldrich, Inc.

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EXECUTIVE SUMMARY

Emerging Contaminants in Arizona's Water

Arizona Department of Environmental Quality

Prepared by the Advisory Panel on Emerging Contaminants

August 2016

Introduction

This report was compiled by the Advisory Panel on Emerging Contaminants (APEC) to document the most recent available information on emerging contaminants in Arizona's water supplies. Emerging Contaminants (ECs) are found in pharmaceuticals, personal care products, food additives, and industrial chemicals. ECs also include metals, natural and synthetic hormones, and pathogenic bacteria, protozoa, and viruses. The universe of ECs is extensive and continuously changing as new contaminants are identified and new information is gathered on existing contaminants. ECs have the potential to threaten the safety of water supplies in Arizona. The panel provides a forum for open discussion, prioritization and planning related to EC issues of critical interest in the safe use of groundwater, surface water, wastewater, reclaimed water, recycled water and drinking water in Arizona.

Background

In 2010, Governor Janice Brewer convened a Blue Ribbon Panel on Water Sustainability that made recommendations for improving statewide water sustainability through recycling and conservation practices. Two recommendations made by this Panel were to 1) continue an assessment of man-made compounds that are released to the environment that may cause water quality, health, and safety concerns, and 2) increase public awareness and confidence in the use of groundwater, surface water, wastewater, reclaimed water, recycled water, and drinking water. In response to the recommendations, the Arizona Department of Environmental Quality (ADEQ) convened the 35-member APEC in 2012. The panel members include researchers from Arizona's major universities and subject matter experts from water utilities, state regulatory agencies, public health agencies, water quality laboratories, environmental consultants, legal experts, and the public. APEC formed three subcommittees to investigate and document the presence of ECs in Arizona waters and management strategies conducted at both the local and regional level.

APEC tracked the efforts of Arizona's water utilities and researchers in identifying which ECs are present in source waters used for drinking water and treated wastewater. APEC compiled statewide research efforts on occurrence, fate and transport, and applicability of conventional and advanced treatment methods and technologies used to remove ECs from treated wastewater and drinking water in Arizona. This report provides the current federal and state regulatory guidelines, and useful information and resources to water utilities and the public to enhance understanding of this issue and inform educational and outreach efforts.

Research into treatment and removal of ECs has become of elevated importance in Arizona. Although all of Arizona's reclaimed wastewater reuse is currently for non-potable uses, it is likely that reclaimed and recycled wastewater will be used as a source to create drinking water for some municipalities in the not-so-distant future.

The issue of ECs in Arizona's waters is actively being investigated by many entities within the state. These include the drinking water and wastewater utilities of most cities and towns, the three public universities, community colleges, ADEQ, consulting firms, non-governmental organizations, and others. APEC documented 109 ECs that have been measured above detection levels in various Arizona waters. The concentrations at which they have been observed are very low, typically in the parts per trillion range. These concentrations are far below the concentrations determined to cause acute or carcinogenic toxicity impacts to human health. ADEQ's stringent treatment requirements for new and expanding wastewater treatment plants have provided a corollary benefit in aiding EC removal. However, there are indications that low levels of some ECs can impact aquatic organisms and potentially affect some human health functions, such as the endocrine system. Industry and academia continue to pursue research and develop technology to improve the detection, monitoring, and treatment of ECs and communicate those results, and ultimately ensure that Arizona's water supply is safe.

Recommendations

APEC has developed the following recommendations for ADEQ:

- Establish a permanent APEC committee to identify timely research topics and funding opportunities.
- Facilitate the creation of APEC teams/working groups within discrete regions of Arizona.
- Develop collaborative partnerships to enhance proper disposal of medications.
- Sponsor a collaborative program wherein water utilities create a statewide laboratory consortium that would pool resources to develop monitoring programs and determine appropriate analyses.

- Collaborate with research entities such as the University of Arizona Water Resources Research Center, National Science Foundation, the Water and Environmental Technology Centers at the University of Arizona and Arizona State University, and the Water and Energy Sustainable Technology Center at the University of Arizona to create and maintain an electronic central repository of all the research being conducted in Arizona.
- Conduct workshops, training, and seminars for water utilities and the general public in Arizona.
- Advise all Arizona's water utilities when the EPA acts, or proposes to act, on any EC and convene the APEC group to review the proposed action. Examples of EPA actions include listing or de-listing of a constituent as a tracked EC; proposals to regulate an EC as a priority pollutant; and releases of toxicity or occurrence reports.
- Sponsor communication training on risk messaging, in collaboration with APEC and water utilities, for utility managers, public information officers, and public outreach staff.

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1.0 Introduction

The purpose of this report is to inform utilities and the public about the current state of Emerging Contaminants (ECs) in Arizona waters and provide the Arizona Department of Environmental Quality (ADEQ) with recommendations to improve the identification, management, and communication of the occurrence of chemical and microbial ECs in Arizona waters to minimize risk to human health and the environment.

In 2010, Governor Janice Brewer convened the Blue Ribbon Panel on Water Sustainability to make recommendations for improving statewide water sustainability through recycling and conservation practices. One of the recommendations of the panel was for ADEQ to convene a group of stakeholders to address the broad spectrum of ECs that have been detected in Arizona waters (ADEQ, et al., 2010). To that end, ADEQ appointed 35 people to form The Advisory Panel on Emerging Contaminants (APEC) committee, convening it in 2012. APEC includes members of the general public, subject matter experts from the University of Arizona (U of A), Arizona State University (ASU), and Northern Arizona University (NAU), representatives from drinking and wastewater utilities of large and small municipalities, representatives of the public health and legal professions, and environmental professionals.

ADEQ communicated to panel members that the panel's purpose is to provide a forum for discussing, prioritizing, and developing recommendations regarding EC issues with respect to safely using drinking water, treated wastewater, reclaimed water, and recycled water in Arizona. Panel members formed three committees: the Chemical EC Committee, the Microbial EC Committee, and the Outreach and Education Committee. The Chemical and Microbial committees each prepared draft reports addressing those respective ECs in Arizona's waters (ADEQ 1). The Outreach and Education Committee used these reports as the basis for preparing this final report.

1.1 REGULATORY BACKGROUND

1.1.1 Clean Water Act

In 1972, Congress passed the Clean Water Act (CWA), which is administered by the U.S. Environmental Protection Agency (EPA). Under the CWA, wastewater treatment standards for the industry have been set, as well as water quality standards for contaminants in surface water. The CWA prohibits the discharge of pollutants into waters of the U.S.—"zero discharge"—unless authorized by a permit obtained under the National Pollutant Discharge Elimination System (NPDES) permit program. In Arizona, ADEQ has been granted primacy by EPA to administer the NPDES program, calling the permit an Arizona Discharge Elimination System (AZPDES) permit. Nationally, the program reduces the amount of pollutants discharged into the nation's surface waters to keep the waters clean for drinking water supply and other purposes. ADEQ has established surface water quality standards for more than 150 organic and inorganic pollutants as part of achieving this objective.

1.1.2 Safe Drinking Water Act

The Safe Drinking Water Act (SDWA) was passed in 1974 and included about 20 regulated contaminants. Over the years, it has been amended and expanded several times as new compounds have been detected and their toxicity better understood. The EPA currently has National Primary Drinking Water Regulations (NPDWRs) including Maximum Contaminant Levels (MCLs) for 88 chemical and microbial contaminants. The contaminants include 7 microorganisms, 4 indicators of microorganism contamination, 3 disinfectants, 4 disinfection byproducts, 16 inorganic chemicals, 53 organic chemicals, and 4 radionuclides (EPA 1).

The EPA may choose to establish a NPDWR as an MCL or as a Treatment Technique (TT). For example, the inorganic contaminant arsenic has a numerical MCL of 10 parts per billion (ppb), while the microorganism *Cryptosporidium parvum* is regulated via a TT that specifies a Best Available Technology (BAT) to reduce the likelihood of the occurrence of the organism in drinking water systems. The TT represents an alternative approach to an MCL. This TT is used when it is not economically or technologically feasible to ascertain the level of the contaminant.

If the EPA decides to establish an MCL, the SDWA requires that it must be as close as feasible to the Maximum Contaminant Level Goal (MCLG) for the contaminant. The MCLG is the maximum level of a contaminant in drinking water at which no known or anticipated adverse health effect would occur, and which allows an adequate margin of safety. The MCLG does not consider cost or available technologies, and is not an enforceable standard. To set an MCLG, the EPA uses epidemiological and toxicological studies to assess and characterize the risks presented by the contaminant, including both acute and chronic disease outcomes and cancer. Sensitive populations are also identified and factored into the calculation of a protective MCLG. For many carcinogens and microbiological contaminants, MCLGs are set at zero because a safe level often cannot be determined, based on sources of information such as the National Institutes of Health's National Toxicology Program. Toxicologists seek to calculate a dose that is expected to protect people from a 70-year lifetime of exposure and to limit the cancer risk to one case in every million people.

All regulated contaminants fall into one of two categories according to the health effects that they cause: <u>acute</u> effects and <u>chronic</u> effects. Acute effects occur within hours or days of the time that the person consumes the contaminant. A person can experience acute health effects from almost any contaminant if they are exposed to extraordinarily high levels (as in the case of a spill). In drinking water, microbes such as bacteria and viruses are the contaminants with the greatest chance of reaching levels high enough to cause acute health effects. Most people's bodies can fight off microbial contaminants, with no permanent effects. However, when high enough levels occur, they can be dangerous or deadly, especially for a person whose immune system is already weak.

Chronic effects occur after people consume a contaminant at levels over the EPA's safety standards for many years. The drinking water contaminants that can have chronic effects are chemicals (such as disinfection by-products, and pesticides), radionuclides, and naturally occurring elements such as arsenic. Examples of the chronic effects of drinking water contaminants are cancer, liver or kidney problems, or reproductive difficulties.

Because the body of science and research on the topic of drinking water contaminants is constantly evolving, the SDWA requires the EPA to conduct a review of each NPDWR every six years to decide whether or not to revise the regulatory standards.

Due to the SDWA criteria for establishing a NPDWR, the MCL is often less protective than the MCLG. However, MCLs are enforceable. The EPA determines the occurrence of the contaminant, number of Public Water Systems (PWS) affected, the degree to which the PWSs are affected, the number of people affected, the degree of health effects, and the available technologies for achieving the proposed MCL. The EPA must also conduct an economic analysis comparing the costs and benefits. The final MCL is based on a determination that the benefits justify the costs (EPA 2). Public comment is allowed at several stages during the process.

1.2 REFERENCES

ADEQ 1. Chemical and Microbial Committee's Draft Reports *http://static.azdeq.gov/wqd/emerging_chem_contaminants.pdf*.

Chemical Committee, additional resources appended to draft report:

a. Potable Reuse for Inland Locations: Pilot Testing Results from Tucson for a New Potable Reuse Treatment Scheme: *https://www.watereuse.org/wp-content/uploads/2015/10/S2B1_Schimmoller_AZWateReuse_2015.pdf*
b. Analysis of Microplastic Beads and their Removal at a Municipal Wastewater Treatment Plant: *http://static.azdeq.gov/wqd/microplastic_beads.pdf*.
c. Prioritizing Compounds of Potential Concern at the Scottsdale (AZ) Water Campus: *http://static.azdeq.gov/wqd/prioritizing_compounds.pdf*.
d. Microbial Committee draft report: *http://static.azdeq.gov/wqd/emerging_waterborne_path.pdf*.

ADEQ, 2010. Arizona Department of Water Resources; and Arizona Corporation Commission, 2010, Blue Ribbon Panel on Water Sustainability; Final Report; November 3, 139 p.

EPA 1. *http://water.epa.gov/drink/contaminants/index.cfm#Primary*

EPA 2. *https://www.epa.gov/your-drinking-water/table-regulated-drinking-water-contaminants#Microorganisms*

Safe Drinking Water Act: *http://www.fas.org/sgp/crs/misc/rl31243.pdf*

2.0 Glossary of Terms

Absorption - The process by which one substance, such as a solid or liquid, takes up another substance, such as a liquid or gas, through minute pores or spaces between its molecules.

Acre Foot (AF) - The amount of water needed to cover 1 acre to a depth of 1 foot. Equivalent to 325,851 gallons of water. The unit is commonly used by water professionals in Arizona.

Adsorption - The binding of molecules or particles to the surface of a substance.

Advanced Oxidation Process (AOP) - A set of chemical treatment procedures designed to remove organic and some inorganic materials in water and wastewater by oxidation through reactions with ozone (O_3), hydrogen peroxide (H_2O_2) and/or ultraviolet (UV) light.

The Advisory Panel on Emerging Contaminants (APEC) - Formed by the ADEQ to advise ADEQ and water utilities on matters concerning unregulated chemicals and pathogens in water.

Active Management Area (AMA) - Areas in Arizona with heavy reliance on mined groundwater were designated in 1980 as Active Management Areas. The five AMAs (Prescott, Phoenix, Pinal, Tucson, and Santa Cruz) are subject to regulation pursuant to the state Groundwater Code.

Analyte - A substance whose chemical constituents are being identified and measured.

Aquifer - A unit of rock or sediment deposit is called an aquifer when it can yield a usable quantity of water.

Aqua Biota - Plants and animals that are living and growing in water.

Arizona Department of Environmental Quality (ADEQ) - Arizona's environmental regulatory agency charged with the protection and enhancement of public health and the environment.

Arizona Laboratory for Emerging Contaminants (ALEC) - ALEC is located at the U of A to assist faculty, student and staff researchers working in the field of water sustainability to detect, quantify, and speciate organic and inorganic micro-pollutants – including dissolved and nano-particulate components - in complex environmental matrices.

Arizona Pollutant Discharge Elimination System (AZPDES) - Program managed by ADEQ to control pollutants discharged to Arizona's surface waters as mandated by the EPA under the Clean Water Act.

Aquifer Protection Permit (APP) - A permit required by ADEQ for owners or operators of facilities that discharge a pollutant either directly to an aquifer, to the land surface, or the vadose zone in such a manner that there is a reasonable probability that the pollutant will reach an aquifer.

Attenuation - Declining concentrations of ECs from source due to processes such as dispersion, dilution, adsorption, and degradation (such as photolysis and bacterial decomposition).

Best Available Technology (BAT) - Available technology that will meet water treatment goals and is economically achievable.

Best Available Demonstrated Control Technology (BADCT) - Proven treatment techniques that are used to control pollutants in facilities with APPs from ADEQ.

Biofilm - Any group of microorganisms in which cells stick to each other on a surface.

Biosolids - The nutrient-rich organic materials resulting from the treatment of sewage sludge (the name for the solid, semisolid, or liquid untreated residue generated during the treatment of domestic sewage in a treatment facility).

Biologically Activated Carbon (BAC) - A biofilm growth on the surfaces of granular activated carbon which may aid in removal of certain organic microcontaminants.

Carcinogens - Chemicals that cause cancer.

Candidate Contaminant List (CCL) - A list of compounds developed by the EPA that are currently not subject to any proposed or promulgated national primary drinking water regulations, are known or anticipated to occur in public water systems, and which may require regulation under the SDWA.

Central Arizona Project (CAP) - A 336-mile diversion canal in Arizona. The aqueduct diverts water from the Colorado River from Lake Havasu City near Parker into central and southern Arizona.

Clean Water Act (CWA) - Also known as the "Federal Water Pollution Control Act (FWPCA), its goal is to restore and maintain the chemical, physical, and biological integrity of the nation's waters by preventing point and nonpoint pollution sources, providing assistance to publicly owned treatment works for the improvement of wastewater treatment, and maintaining the integrity of wetlands.

Consumer Confidence Report (CCR) - A water quality annual report required from all public water systems which provides information regarding the drinking water source(s), any detected contaminants, and other public educational information.

Drug Enforcement Administration (DEA) - The United States federal law enforcement agency under the U.S. Department of Justice tasked with combating drug smuggling and use within the United States.

Dose - A measure of intake of a substance, usually expressed in units of mg/kg-day (milligrams of drug per kilogram body weight per day).

Drinking Water - Water considered safe enough to be consumed by humans with low risk of immediate or long-term harm.

Drinking Water Treatment Plant (DWTP) - A public or private facility that treats water to ensure it meets drinking water quality standards.

Effluent - Water discharged after treatment by a wastewater treatment plant. See also definitions for *treated wastewater* and *reclaimed water*.

Effluent Dependent Waters (EDWs) - Waters that flow in response to discharge of effluent.

Ephemeral - A wetland, spring, stream, river, pond, or lake that only exists for a short period following precipitation or snowmelt.

Emerging Contaminants (ECs) - Chemical and microbial contaminants that are not regulated under the Safe Drinking Water Act (SDWA) through established drinking water Maximum Contaminant Levels (MCLs).

Endocrine Disrupting Compounds - Chemicals that, at certain doses, can interfere with the endocrine (or hormone) system in mammals.

Fullerene - A molecule of carbon in the form of a hollow sphere, ellipsoid, tube, and many other shapes.

Granulated Active Carbon (GAC) - A form of carbon processed to have small, low-volume pores that increase the surface area available for adsorption or chemical reactions. It is commonly used to adsorb natural and synthetic organic compounds, and compounds that contribute unwanted taste and odor in drinking water treatment.

Gram (g) - A unit of mass equal to a cubic centimeter (10^{-6} m^3) of water. A regular sized paperclip's mass is approximately 1 gram.

Groundwater - Water located beneath the earth's surface in soil pore spaces and in the fractures of rock formations.

Hydrology - The scientific study of the movement, distribution, and quality of water on earth and other planets, including the hydrological cycle, water resources, and environmental watershed sustainability.

Hydrologist - A scientist who researches the distribution, circulation, and physical properties of underground and surface waters.

Integrated Risk Information System (IRIS) - EPA's human health assessment program that evaluates information on health effects that may result from exposure to environmental contaminants.

Maximum Contaminant Level (MCL) - SDWA § 1412(b)(4)(B): An enforceable standard which is set at a "…level… which is as close to the maximum contaminant level goal as is feasible". SDWA defines "feasible" as the level that may be achieved with the use of field proven, cost effective, BAT treatment techniques or other means specified by EPA.

Maximum Contaminant Level Goal (MCLG) - SDWA § 1412(b)(4)(A): A non-enforceable "…level at which no known or anticipated adverse effects… occur and which allows for an adequate margin of safety". MCLGs do not take cost and BAT technologies into consideration. They are sometimes set at a level that water systems cannot meet. For most *carcinogens* (contaminants that cause cancer) and microbiological contaminants, MCLGs are set at zero because a safe level cannot be determined.

Maximum Residual Disinfectant Level (MRDL) - Analogous to an MCL; sets enforceable limits on residual disinfectants in the distribution system.

Microgram (µg) - A unit of mass equal to one millionth (1×10^{-6}) of a gram.

Microgram per liter - A unit of concentration equal to one microgram of a substance present in one liter of water. See also the definition for *parts per billion (ppb).*

Micron (µm) - A unit of length also called a micrometer. One micron is equal to one millionth (1×10^{-6}) of a meter or 0.000039 inches.

Milligram (mg) - A unit of mass equal to one thousandth (1×10^{-3}) of a gram.

Milligram per liter (mg/L) - A unit of concentration equal to one milligram of a substance present in one liter of water. Also known as parts per million (ppm).

Million Gallons per Day (MGD) - A flow rate commonly used by water providers. 1 MGD is approximately equivalent to a flow rate of 695 gallons per minute (gpm).

Minimum Reporting Level (MRL) - The lowest accurately reportable level of a compound based on the analytical method used by the laboratory to measure it.

Nanogram (ng) - A unit of mass equal to one billionth (1×10^{-9}) of a gram. See also the definition for *parts per trillion (ppt)*.

National Institute of Environmental Health Sciences (US NIEHS) – A federal agency that conducts basic research on environmental health and environment related diseases and provides research grant funding for similar research projects.

National Pollutant Discharge Elimination System (NPDES) - As authorized by the CWA, the NPDES permit program controls water pollution by regulating point sources that discharge pollutants into waters of the United States.

National Primary Drinking Water Regulation (NPDWR) - A legally enforceable standard that covers specific contaminants that can adversely affect public health; an NPDWR may be expressed as an MCL or TTs.

Overdraft - A condition where more water is removed from the aquifer than is recharged, resulting in depletion of the aquifer.

Pathogen - A biological agent that causes disease or illness to its host.

Part Per Billion (ppb) - One ppb is equivalent to 1 microgram of something per liter of water (μg/L). A better way to think of a ppb is visualize a drop of something in 13 gallons of water which is equivalent to the fuel tank of a compact car.

Part Per Trillion (ppt) - One ppt is equivalent to 1 nanogram of something per liter of water (ng/L). A better way to think of a ppt is to visualize a drop of something diluted into 10,000,000 gallons of water which is equivalent to 20 Olympic-size swimming pools.

Perennial Stream - A waterway that exists year around.

Personal Care Products (PCP) - Products or toiletries used for personal hygiene and beautification. Also refers, in general, to any product used by individuals for personal health or cosmetic reasons or used by agribusiness to enhance growth or health of livestock. PCPs comprise a diverse collection of thousands of chemical substances, including prescription and over-the-counter therapeutic drugs, veterinary drugs, fragrances, and cosmetics.

Pharmaceutical Drug - A drug used to diagnose, cure, treat, or prevent disease. Drug therapy (pharmacotherapy) is an important part of the medical field and relies on the science of pharmacology for continual advancement and on pharmacy for appropriate management.

Pharmaceutical and Personal Care Products (PPCP) – A general term for a diverse group of chemicals including, but not limited to, prescription and over-the-counter drugs, veterinary drugs, nutritional supplements, fragrances, cosmetics, and sun-screen agents.

Potable reuse - A term used to describe the use of reclaimed wastewater or recycled wastewater as a source of drinking water.

Public Water System (PWS) - A system to provide water to the public for human consumption through pipes or other constructed conveyances, if such system has at least 15 service connections or regularly serves at least 25 individuals.

Recharged water - Water that moved downward from the land surface to groundwater.

Reclaimed water - Used in this report to describe wastewater that has been treated to meet standards for beneficial reuse as defined by the State of Arizona. See also the definitions for *effluent* and *treated wastewater.*

Recycled Water - Treated wastewater (see below).

Regulated Contaminant (RC) - A contaminant that is regulated under the SDWA.

Resource Conservation and Recovery Act (RCRA) - The principal federal law in the United States governing the disposal of solid and hazardous waste.

Riparian - Natural area adjacent to flowing or non-flowing waterways

Safe Drinking Water Act (SDWA) - Enacted in 1974, the SDWA is the main federal law that ensures the quality of Americans' drinking water by establishing standards for drinking water quality and federal oversight for the states, localities, and water suppliers who implement those standards.

Salt River Project (SRP) - The umbrella name for two separate entities: the Salt River Project Agricultural Improvement and Power District, an agency of the State of *Arizona* that serves as an electrical utility for the Phoenix metropolitan area, and the Salt River Valley Water Users' Association, a utility cooperative that serves as the primary water provider for much of central Arizona. It is one of the primary public utility companies in Arizona.

Surface Water - Waters from all sources flowing in streams, canyons, ravines, or other natural channels, or in definite underground channels, whether perennial or intermittent, floodwater, wastewater, or surplus water, and of lakes, ponds, and rivers on the surface.

Treated Wastewater - Water released by a wastewater treatment facility after sewage flows are processed and treated to remove solids and pollutants. See also *effluent* and *reclaimed water*.

Treatment Technique (TT) - SDWA § 1412(b)(7): An enforceable level established "… in lieu of establishing a maximum contaminant level, if…it is not economically or technologically feasible to ascertain the level of the contaminant.". A TT is an enforceable procedure or level of technological performance that public water systems must follow to ensure control of a contaminant. Examples of rules with TTs are the surface water treatment rule and the lead and copper rule.

Unregulated Contaminant (UC) - A contaminant that has no standard set under the SDWA.

Unregulated Contaminant Monitoring Program (UCM) - A program managed by the EPA to collect data for contaminants suspected to be present in drinking water, but that do not have health-based standards set under the SDWA.

Unregulated Contaminant Monitoring Rule (UCMR) - A mandate for public water utilities to monitor for 30 unregulated contaminants for a year to help the EPA determine the occurrence of these contaminants in drinking water and whether or not they need to be regulated for protection of public health. The list of contaminants is updated every five years.

The United States Environmental Protection Agency (EPA) - The EPA was created to ensure that Americans are protected from significant risks to human health and the environment. The EPA directs national policies to balance environmental concerns with those of industry, private sector and public. The EPA also compiles and disseminates scientific information to insure all stakeholders have access to accurate information sufficient to effectively participate in managing human health and environmental risks.

U.S. Geological Survey (USGS) - The USGS serves the nation by providing reliable scientific information to describe and understand the Earth; minimize loss of life and property from natural disasters; manage water, biological, energy, and mineral resources; and enhance and protect our quality of life.

Vadose Zone - The soil area located above the water table.

Water Budget - The sum of all water inputs into a system (precipitation, stream flow, groundwater flow, etc.) minus the outputs of the system (evaporation, transpiration, pumpage, and outflow).

Water Environment and Reuse Foundation (WE&RF) - The WE&RF is a 501c3 charitable corporation seeking to identify, support, and disseminate research that enhances the quality and reliability of water for natural systems and communities with an integrated approach to resource recovery and reuse; while facilitating interaction among practitioners, educators, researchers, decision makers, and the public.

Water Research Foundation (WRF) - the WRF is an internationally recognized leader in water research that is dedicated to advancing the science of water by sponsoring cutting-edge research and promoting collaboration.

Water Resource Research Center (WRRC) - The U of A Water Resources Research Center promotes understanding of critical state and regional water management and policy issues through research, community outreach and engagement, and public education.

WateReuse Research Foundation (WRRF) - The WRRF conducts and promotes applied research on the reuse, reclamation, recycling, and desalination of water.

Water Table - The upper surface of an aquifer.

Watershed - The area of land where all of the water that is under it or drains off of it goes into the same place.

Wastewater - Any water that has been adversely degraded by municipal, agricultural, or industrial use.

Wastewater Treatment Plant (WWTP) - A public or private facility, which treats water that has been degraded through human use. WWTPs may be distinguished by the type of wastewater to be treated, i.e., whether it is sewage, industrial wastewater, agricultural wastewater, or leachate.

World Health Organization (WHO) - A branch of the United Nations which directs and coordinates international health issues, including research and policy making.

3.0 Arizona Water Sources

This section summarizes the sources and characteristics of Arizona waters. Significant water quality differences exist among these sources and they are susceptible to differing contamination threats. Therefore, it is no surprise that the number, type, and concentrations of ECs detected or potentially occurring in the different water sources may vary substantially. To understand these differences, it is helpful to know more about the water sources and the water cycles that link them, as well as the drinking water and wastewater infrastructure that allows these sources to be safely treated, used, and reused.

This short introduction to Arizona waters is intended to provide a useful framework for information presented on emerging contaminants in the remainder of this report. For the reader desiring more information on Arizona waters, an excellent first stop is the *Arizona Water Atlas*, an eight-part compendium prepared by the Arizona Department of Water Resources (ADWR), which is available online (ADWR, 2010).

3.1 WATER SOURCES

Figure 3.1: Colorado River Watershed
(from: www.usbr.gov)

Arizona's water supply comes from four sources: 1) the Colorado River; 2) other surface waters (the Salt, Verde, and Agua Fria Rivers, with watersheds located entirely within Arizona, and the Gila River, with separate headwater areas originating in New Mexico and Mexico); 3) groundwater; and 4) treated wastewater (also referred to as reclaimed water or effluent). Colorado River water is brought into the state in two ways: diversions out of the main stem of the river below Lake Mead that supply neighboring municipalities and agricultural concerns, and water pumped from Lake Havasu into the Central Arizona Project (CAP) Canal, which is conveyed across the state for many uses in central and southern Arizona, including the Phoenix and Tucson urban areas. Gray water is also mentioned as a possible supply but usage is currently negligible and is not discussed in this report.

On a statewide basis, 53% of Arizona's water supply is surface water comprised of 25% Colorado River water diverted for uses near the river, 16% Colorado River water pumped into the CAP canal, and 12% from in-state rivers. Arizona's other main water source is groundwater, which accounts for 44% of Arizona's total supply. Although comprising only 3% of the total supply, reclaimed water (treated wastewater) is an important resource in many urban areas.

Overall, Arizona's annual total water supply need is 7,838,000 acre-feet (2,554,023,533,900 gallons) according 2006 ADWR data (Figure 3.2).

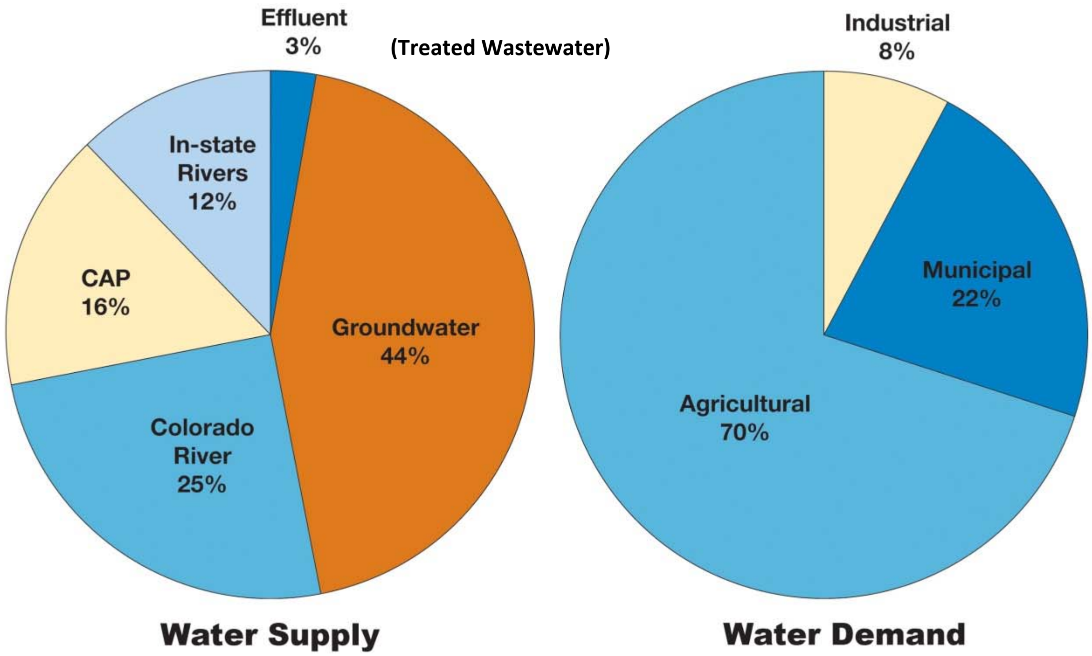


Figure 3.2: Water Supply and Water Demand. Poster by the University of Arizona Water Resources Research Center, based on 2006 ADWR data (from: *Arizona Water*).

By far, the largest proportion of Arizona's water supply goes for agriculture, which accounts for 70% of the total demand. Municipal use, which includes all drinking water, accounts for 22% of the total, and industrial uses take up 8%.

3.1.1 Groundwater

As Figure 3.2 shows, nearly one-half of all water consumed in Arizona comes from groundwater sources. Groundwater is water that occurs beneath the earth's surface and fills the pore spaces of the alluvium, soil, or rock formation in which it is situated. Aquifer is the term used to denote a subsurface formation that stores and can yield a usable quantity of water. An aquifer gains water from recharge, which is the downward percolation of water from the surface, through the vadose zone and into the groundwater table. Much of the recharge in Arizona occurs along mountain fronts where surface waters flowing over relatively impermeable rocks discharge onto more permeable materials such as sands and gravels. Other important sources of recharge include infiltration below the beds of rivers and streams, beneath channels carrying stormwater flows, and below lakes and reservoirs. Less significant is recharge of precipitation that directly infiltrates into Arizona's broad, flat-lying desert surfaces. The amount of water recharged in this way is relatively small, perhaps only a percent or two of annual rainfall, due to high evapotranspiration rates. In contrast, engineered recharge projects using infiltration basins or injection wells are becoming increasingly important as a means of replenishing aquifers in Arizona. The recharge process can occur over days or years depending on factors such as the depth to the aquifer and whether recharged water is traveling through consolidated rock formations or relatively permeable sediments.

An aquifer loses water by pumpage from wells, discharge to springs, streams and rivers, and uptake by riparian plants. Under natural conditions, where wells do not extract water from the aquifer, recharge is balanced by discharge to springs, streams, and rivers and losses to riparian vegetation. Adding well pumpage to this dynamic system has created a condition of overdraft in many aquifers—more water is removed than is recharged—resulting in depletion of the aquifer. Hydrologists speak of the water budget of the aquifer to describe the balance (or imbalance) between recharge and discharge. In Arizona, the primary reason for passage of the Groundwater Management Act of 1980 was to address depletion of aquifers throughout the state. Numerous engineered recharge projects, relying on surface or reclaimed water as a source of supply, have been constructed to augment aquifers that are out of balance. These facilities are located and designed for rapid recharge, which bears on the fate and transport of any ECs that may be present in the source waters.

Arizona is divided into three physiographic provinces based on characteristics of similar landscape, climate, geology, and hydrology. The locations of the three provinces (the Plateau Uplands [the Colorado Plateau], the Central Highlands [also called Transition Zone], and the Basin and Range) are shown in Figure 3.3. The nature of the aquifers and the flow, availability, and use of groundwater within them are distinctly different across the provinces.

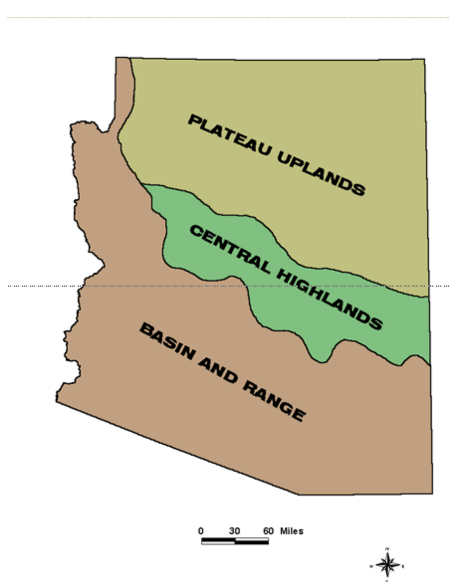


Figure 3.3: Arizona Physiographic Provinces. Modified from The ABC's of Water in Arizona, ADWR May 17, 2000 (*http://www.azwater.gov/AzDWR/PublicInformationOfficer/ABCofWater.htm*)

The Plateau Uplands Province is typified by layers of consolidated sedimentary rocks that form broad plateaus and mesas which are cut by deep canyons (Artiola and Uhlman, 2009). Important aquifers occur in sedimentary sandstones that exhibit sufficient porosity and permeability to store and transmit usable quantities of groundwater (the Dakota, Navajo, and Coconino Sandstones, or D-, N-, and C-Aquifers, Figure 3.4). Limestone aquifers, such as the Redwall (or R-Aquifer), are also important. In these aquifers, groundwater is transmitted through enlarged fractures, conduits, and passages dissolved in the limestone beds. Many of the aquifers in the Plateau Uplands Province are located deep within the sedimentary rock column, requiring drilling of deep wells to tap the groundwater occurring within them. Recharge areas are commonly located at high elevations far from the springs fed by the aquifers (Figure 3.5). Thus, the susceptibility of these aquifers to pollution by ECs and the associated characteristics of occurrence, fate, transport, and potential exposure are very different from elsewhere in the state.

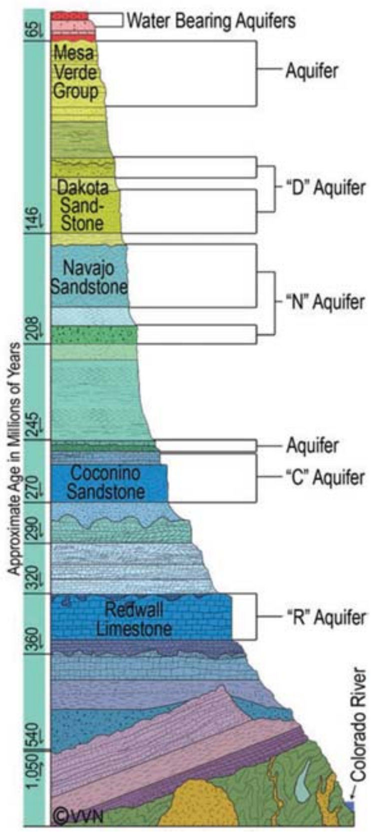


Figure 3.4. Geological Section and Aquifers of the Plateau Uplands Province, (Artiola and Uhlman, 2009)

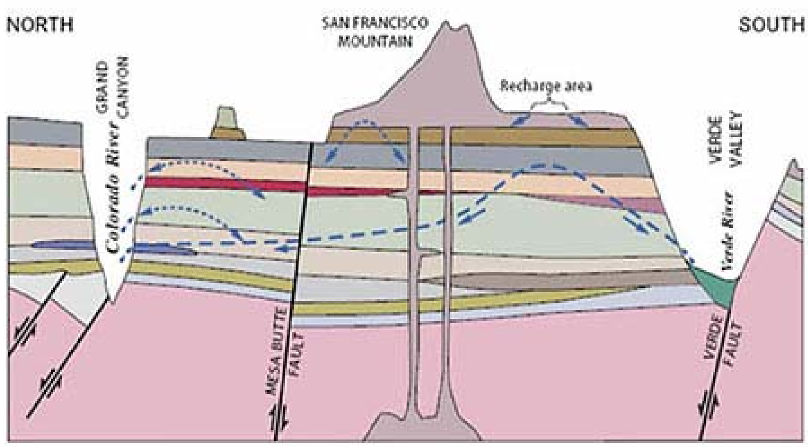


Figure 3.5. Hydrological Cross-section in the Plateau Uplands Province. Modified from Bills and Flynn. 2002.

The Central Highlands Province is a zone of transition that exhibits characteristics of both the Plateau Uplands and Basin and Range Provinces. The northern boundary of the province is the escarpment of the Mogollon Rim where many springs discharge along its base. Aquifers occur in unconsolidated and semi-consolidated sediments deposited in generally smaller, shallower basins than found within the Basin and Range Province. Aquifers also occur within consolidated sedimentary rocks in blocks that have been detached by faulting from the Plateau Uplands Province (see Figure 3.6).

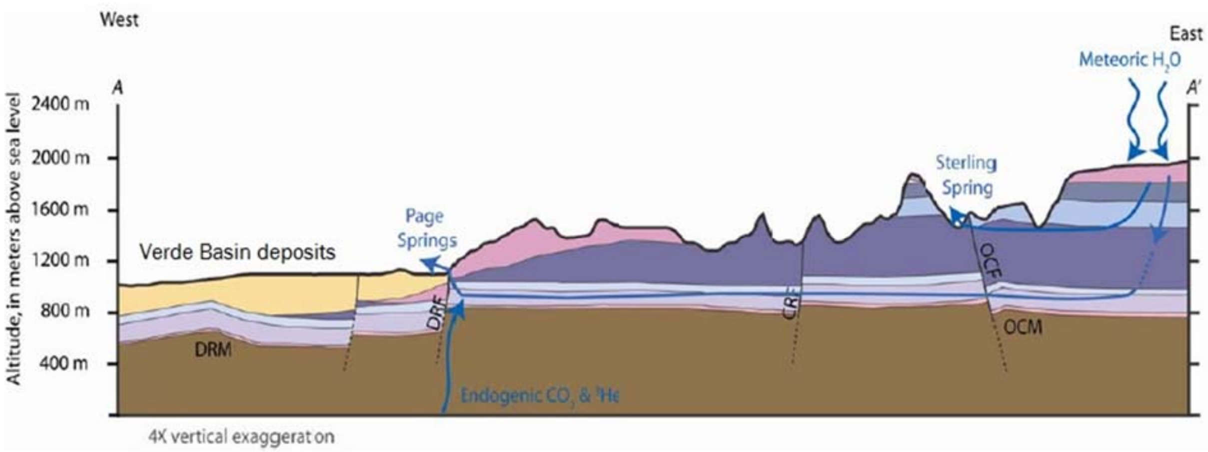


Figure 3.6. Representative Central Highlands Hydrological Profile
(modified from Green, 2008)

This province contains most of the permanent streams in the state, but the aquifers tend to be less productive and drought sensitive. Natural recharge to these aquifers can be limited due to steep topography and rapid runoff of stormwater (ADWR, 2010). Along much of its distance, the Mogollon Rim approximates both the groundwater divide and surface-water drainage between the Little Colorado River and Salt River systems (Arizona Bureau of Mines, 1969).

The Basin and Range Province occupies the western and southern part of the state. Uplifted ranges generally trending north and northwest are separated by down-dropped basins filled with hundreds to thousands of feet of alluvial deposits (Figure 3.7). The deposits consist of unconsolidated and semi-consolidated gravels, sands, silts, clays, and evaporites. Vast amounts of groundwater have accumulated within the deposits in these basins over thousands of years. Over the last one hundred years, great quantities of water have been pumped from these aquifers, fueling the expansion of agriculture and economy in Arizona. However, because wells have withdrawn so much groundwater, aquifer overdraft in many basins has resulted in water table declines of as much as 300 feet or more in some severely affected locations. The alluvial nature of the basins also can facilitate rapid recharge. This has implications for ECs that may occur in treated wastewater and stormwater discharged to natural channels, and in surface water or reclaimed wastewater conveyed to constructed recharge projects.

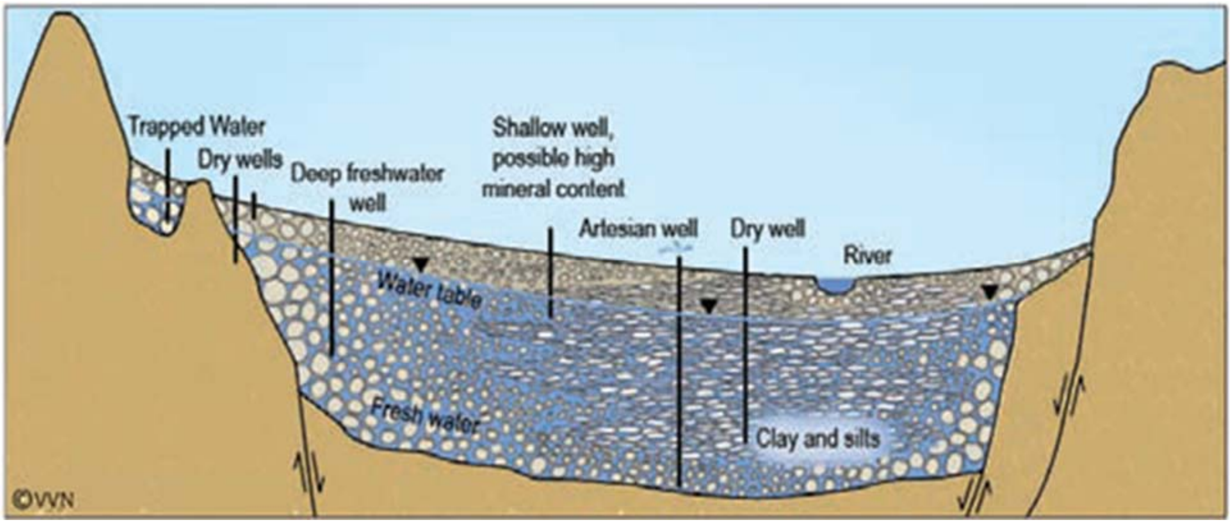


Figure 3.7. Profile of an Alluvial Aquifer in the Basin and Range Province (Artiola and Uhlman, 2009)

3.1.2 Surface Water

The water quality signatures of Arizona's surface water supplies—the Colorado River, which supplies water for uses near the river and in interior Arizona via the CAP canal, and other in-state rivers—reflect the varying water sources and anthropogenic influences within each river's watershed. A simple measure like salinity clearly illustrates that water quality varies significantly among these river systems (Figure 3.8).

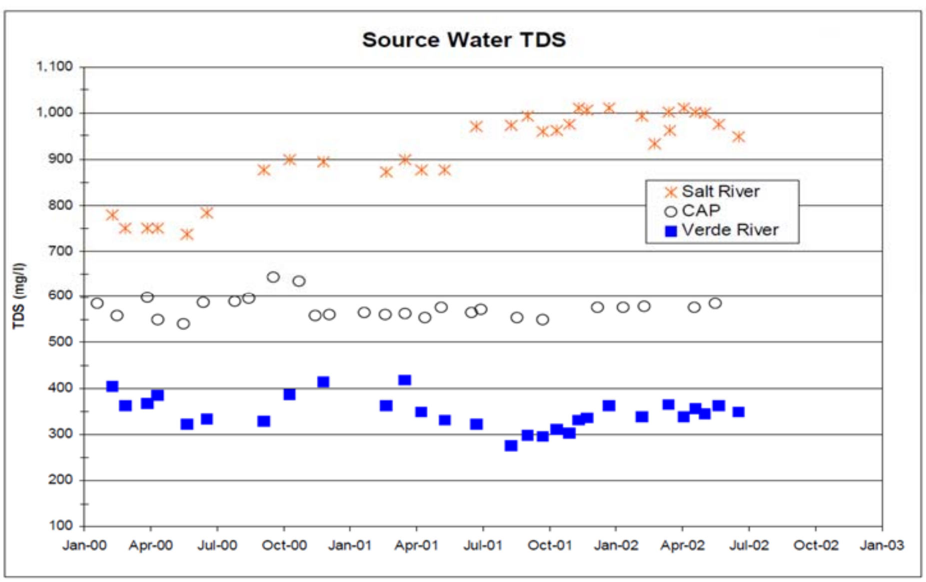


Figure 3.8. Salinity of Arizona Surface Water Supplies as Indicated by Total Dissolved Solids Content (U.S. Bureau of Reclamation, 2003).

The waters in these river systems are susceptible to a host of sources of ECs. These sources include wastewater treatment plant (WWTP) discharges, urban stormwater runoff, contaminants introduced by recreational uses of these waters or rivers, septic tank effluent seepage, irrigation return flows, and other point and nonpoint sources.

The importance of surface water is evident in the fact that the city of Phoenix currently gets about 97% of its drinking water supply from surface sources. Only 3% is pumped from groundwater wells. The five drinking water treatment plants (DWTPs) in Phoenix receive Colorado River water from the CAP Canal and Salt and Verde River water delivered by the Salt River Project (SRP) canal network (City of Phoenix, 2013). Overall, according to ADEQ data, the CAP canal supplies 20 DWTPs in central and southern Arizona (Figure 3.9). Diversions from the Colorado River supply another 14 DWTPs in western Arizona. Altogether, drinking water treatment plants dependent on Colorado River water serve 3,420,000 people in Arizona according to ADEQ.

As a potential source of ECs, the Colorado River, like many rivers throughout the country, contains an appreciable percentage of flow that derives from WWTP treated discharges. Researchers from ASU estimate that Colorado River water released from Lake Mead contains 1 to 2% treated wastewater due to Las Vegas WWTP discharges into the lake (Rice and Westerhoff, 2013). Lake Havasu, which is downstream from Lake Mead (and the source of water pumped into the CAP Canal), may contain as much as 14% treated wastewater during low-flow drought conditions based on modeling and tracer testing. Modeling and tracer testing indicate that treated wastewater discharges also affects the Salt and Verde Rivers (Rice and Westerhoff, 2013).

Figure 3.9. The CAP Canal at the intake to the Mesa Water Treatment Plant
(University of Arizona photo (1996): *http://ag.arizona.edu/azaqua/cyan/photos/mesa.jpg*)

In addition to supplying water for urban and agricultural uses, the CAP Canal supplies water to 22 constructed recharge facilities along its length. The recharge facilities are used to augment groundwater supplies (Figure 3.10). Four of these facilities are authorized to supplement CAP water with Salt and Verde River water when it is available, and six of the facilities recharge CAP water in combination with treated wastewater (ADWR, 2014). In Tucson, at the terminus of the CAP Canal, all of the Colorado River water delivered by the canal is conveyed into constructed recharge basins. Over time, the recharged water has mounded to a level above the original water table of the native groundwater, allowing Tucson to store and bank a much larger volume of water underground than in above-ground reservoirs. At the Central Avra Valley Storage and Recovery Project (CAVSARP), specially-designed wells recover blended native groundwater and recharged Colorado River water for delivery to Tucson Water customers (Figure 3.11). In all cases, recharge at these facilities may transport ECs contained in the surface supplies to groundwater.

Figure 3.10. Spreading basins recharge CAP water at Agua Fria Recharge Project (CAP photo: *http://www.cap-az.com/departments/recharge-program/agua-fria*).

Figure 3.11. Recharge basins at the CAVSARP (Tucson Water photo: *https://www.tucsonaz.gov/water/cavsarp*)

Ephemeral (temporary) water courses generally only flow in direct response to precipitation events. Flow is usually of short duration and absent during the dry season. Ephemeral stream systems are more common in the basin and range areas of the state, as well as in canyons and washes with steep surface topography. Historically in Arizona, many perennial (permanent) and intermittent water courses, fed by high groundwater levels, became ephemeral due to over-pumping of groundwater and consequent lowering of the water table. The Santa Cruz River outside of Tucson is an excellent example of this perennial to ephemeral transition. Figures 3.12 and 3.13 show the before and after condition of the Santa Cruz River near the Congress Street Bridge in Tucson. Due to overdrafting of groundwater, flow in the Santa Cruz ceased by the late 1960s. Ephemeral flows, due to their flashy nature and overland flow paths, should be expected to have distinctly different characteristics with respect to content of ECs.

Figure 3.12: Flow in the Santa Cruz River at Tucson (09482500), November 22, 1930. (Source: USGS: *http://wwwpaztcn.wr.usgs.gov/repeat-photography/santacruz-tucson-1930.html*)

Figure 3.13: Santa Cruz River at Tucson (09482500), February 3, 1964 (Source: USGS, *http://wwwpaztcn.wr.usgs.gov/repeat-photography/santacruz-tucson-1964.html*)

3.1.3 Wastewater

Three percent of all water used in Arizona originates from wastewater sources. These sources can contain significant quantities of ECs depending on the level of treatment (see Section 6.2). Wastewater is water that has been previously used by a municipality, industry, or agriculture and has suffered a loss of quality as a result. For example, agricultural wastewater is runoff from irrigation of crops that may be degraded by sediment, minerals, fertilizer, herbicides, or pesticides. This water may reach a water course or may be captured in tailwater ponds and returned to fields for irrigation. However, when most people think of wastewater, they visualize water flushed down a toilet or sink and into either a sewer system or septic tank. Treated wastewater (also called effluent), is generated by community WWTPs. Treated wastewater that is released for reuse is known as reclaimed water and is the most common type of water recycled in Arizona. Though septic tanks also treat wastewater, its effluent is rarely reused. Effluent and reclaimed water have specific legal definitions in Arizona set by the ADWR and the ADEQ, respectively. Treated wastewater is a general term that covers both and is the term used in this report.

Viable options are few for discharging treated wastewater from a sewage treatment plant. The wastewater may be released to a watercourse, dispensed to infiltration basins for disposal or managed recharge, or conveyed for reuse. In the past, most wastewater in Arizona was discharged to a watercourse. Disposal was usually to a "water of the United States" pursuant to a NPDES permit issued by the EPA under the CWA. In Arizona, EPA authorizes ADEQ to issue the permits, which calls them Arizona Pollutant Discharge Elimination System (AZPDES) permits. Discharge of treated wastewater to normally dry watercourses under an AZPDES permit is becoming increasingly less common in Arizona as the practice of managed recharge in basins has become more established. The U of A mapped 91 miles of such effluent dependent waters (EDWs) in 2009, compared to 351 miles reported in 1987 (Uhlman, et al., 2012). These treated wastewater discharges often support riparian communities where otherwise none would exist. Reaches of the Santa Cruz River downstream of Nogales (Figure 3.14), and further downstream in Tucson and Marana, are excellent examples of EDWs.

Figure 3.14. Santa Cruz River near Nogales: an EDW created by the discharge of the Nogales International WWTP (photo by Channing Turner, Cronkite News. *http://www.tucsonsentinel.com/local/report/040111_nogales_water/mexican-wastewater-plant-threatens-tumacacori-oasis/*)

Treated wastewater may be disposed of by allowing it to infiltrate downward in basins (often called rapid infiltration basins [RIBs]) constructed for this purpose. Disposal by this method is usually limited to small treatment plants where available land area and suitable surface and subsurface soils exist for rapid downward percolation of the treated wastewater. At the smaller residential level, septic tanks discharge to infiltration trenches or subsurface beds, where near surface evapotranspiration often reduces the volume of wastewater that percolates downward.

Treated wastewater also may be conveyed to large impoundments or spreading basins designed explicitly for groundwater recharge. These are highly managed facilities operated to maximize rates and volumes of water stored underground for eventual withdrawal and use. Recharge facilities have become an increasingly important means of wastewater disposition in Arizona. Within ADWR-designated Active Management Areas (AMAs), ADWR allows operators of recharge facilities to accumulate recharge credits which can be used to offset restrictions on groundwater pumpage. ADWR has issued permits for 49 constructed facilities (Underground Storage Facilities [USFs] in the terminology of ADWR) for recharging treated wastewater (Figure 3.15). Six other USFs are permitted to recharge treated wastewater in combination with CAP or surface water. The combined flow permitted by ADWR to the 49 facilities that recharge only treated wastewater is 160,000 acre-feet per year (143 million gallons per day [MGD]). This volume, equivalent to 16 percent of the total sewage treatment plant capacity in Arizona, represents an impressive commitment to water conservation and recycling. Even outside of the AMAs, where ADWR does not offer the recharge credit incentive, interest in recharge is sufficiently high that facilities have been constructed for that purpose.

Figure 3.15. The Sweetwater Wetlands use natural processes to filter treated wastewater before it is delivered to the recharge basins at Tucson Water's Sweetwater Recharge Facility. (Tucson Water photo).

Treated wastewater conveyed for reuse is a highly prized and exploited resource in Arizona. Under Arizona's comprehensive regulatory program for reclaimed water, wastewater reuse has become almost ubiquitous. Of the 300 sewage treatment facilities permitted in Arizona under an Aquifer Protection Permit (APP) by ADEQ, about 180 treatment facilities distribute at least some treated wastewater for reuse. Even more telling is that of the 98 large capacity facilities (greater than 1 MGD), 91 of them distribute treated wastewater for reuse at some time during the year.

The above numbers are highly helpful in understanding the extent of reuse in Arizona, but do not reveal how much treated wastewater is actually reused and for what purposes. An ASU report helps fill that gap (Middel, et al., 2013). The report presents treated wastewater utilization data from 2010 within the Phoenix AMA, which contains 60% of the state's population and thus provides a representative illustration of treated wastewater reuse in Arizona. Five major categories of reuse were identified and quantified within the Phoenix AMA, as follows:

Power	22%
Agriculture	22%
Recharge	21%
Environmental (e.g., Tres Rios)	11%
Landscape, turf irrigation	6%
Subtotal Reused/Recharged	***82%***
Uncommitted (discharged)	18%
TOTAL	**100%**

The ASU study confirmed that 82% of the total volume of treated wastewater produced within the Phoenix AMA is conveyed for reuse or recharge. That percentage actually underestimates total beneficial utilization because some of the water characterized as uncommitted is diverted from the Gila River further downstream for agricultural use (Ray Quay, ASU, personal communication).

To effectively utilize this treated wastewater, extensive distribution systems have been constructed in Arizona (Figure 3.16). The largest system, operated by the City of Tucson, consists of 160 miles of "purple pipe" that distributes treated wastewater to 18 golf courses, 50 parks, 65 schools (including the U of A), and more than 700 single-family homes. During the summer, Tucson may deliver more than 30 MGD of treated wastewater (Tucson Water, 2015).

Figure 3.16. Treated wastewater is aerated before delivery to recharge basins or directly to reclaimed water users by Tucson Water. (Tucson Water photo).

In northern Arizona, the City of Flagstaff operates another large reclaimed water distribution system. Flagstaff's system serves 13 schools and NAU, 18 parks and other landscaped sites, 4 golf courses, 2 cemeteries, the Arizona Snowbowl ski area, and one large manufacturing facility.

The point of the above discussion, in the context of potential occurrence of pharmaceuticals, personal care products (PCPs), and other ECs in treated wastewater water, is that treated wastewater is already almost fully reused in Arizona, therefore the occurrence of ECs is not a hypothetical issue for the future, but one that is already with us.

3.2 WATER CYCLES

A good working definition of the water cycle is the process by which water circulates between the earth's oceans, atmosphere, and land, including precipitation as rain and snow, drainage in streams and rivers, and return to the atmosphere by evaporation and transpiration. Elements and compounds that make up planet Earth are generally mobile and interact with each other, under the right circumstances, and on time scales from seconds to billions of years. This is certainly true for water, both due to its physical and chemical properties and to the planet's position relative to the sun, which allows water to move easily between its solid, liquid, and gaseous states. In the following section, we focus on the water cycle in different ways, briefly discussing the natural hydrological cycle and how this cycle is artificially modified by human activities in urban and rural settings.

3.2.1 The Hydrologic Cycle

The hydrologic cycle is a representation of how water naturally cycles in the environment in its three physical forms, solid (ice and snow), liquid, and gas (water vapor). There is a continuous exchange among these states in the atmosphere, oceans and rivers, organisms (plants and animals), and underground, including aquifers (Figure 3.17).

In urban areas, the natural hydrologic cycle is modified by a diversity of water uses and pathways that typically include components of sophisticated water and wastewater treatment (Figure 3.18). In more rural areas, large scale agricultural practices may be important, and water and wastewater treatment may be smaller in scale and simpler (Figure 3.19). In either case, though, these urban and rural modifications ride on the natural pathways of the hydrologic cycle, such as runoff and percolation into the ground. Thus, with respect to ECs, different sources, histories, modes of occurrence and transport, and impacts are expected.

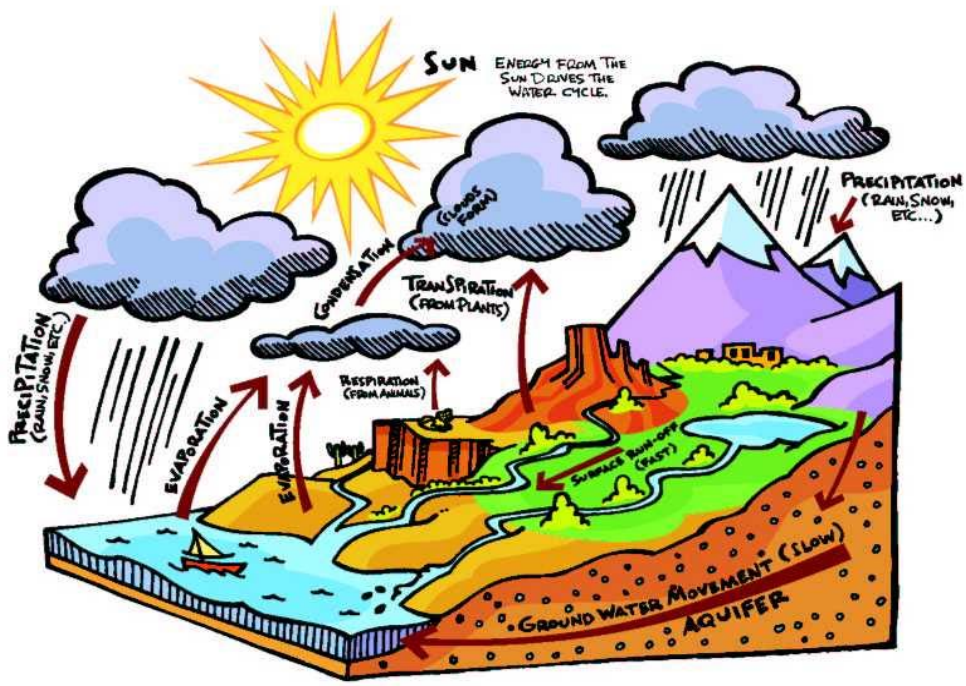


Figure 3.17. Hydrologic Cycle. The ABC's of Water in Arizona (*http://www.azwater.gov/AzDWR/PublicInformationOfficer/ABCofWater.htm*)

3.2.2 The Urban and Rural Water Cycles

Water use in urban areas can be engineered to be very diverse and can involve sophisticated water and wastewater treatment (Figure 3.18). The details of the cycle for any given community may be different depending on the community's size, environmental awareness, and financial capability.

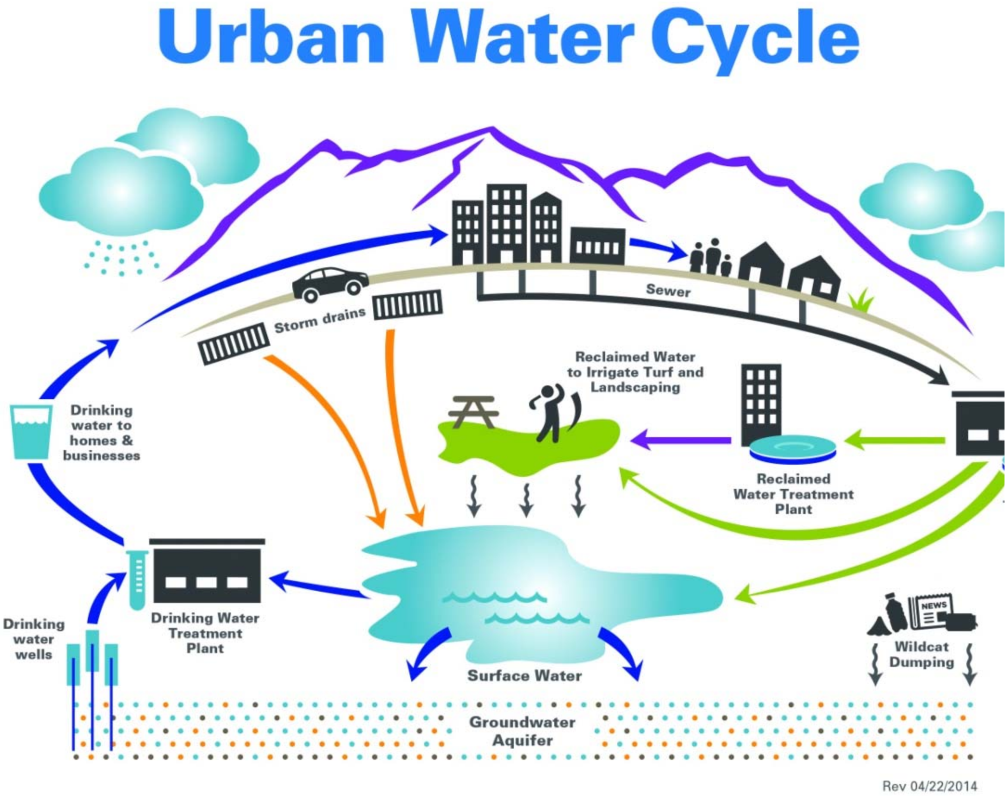


Figure 3.18. Typical urban water cycle illustrating different paths that water can take within a community. (Source: *http://tapintoquality.com/your-water*)

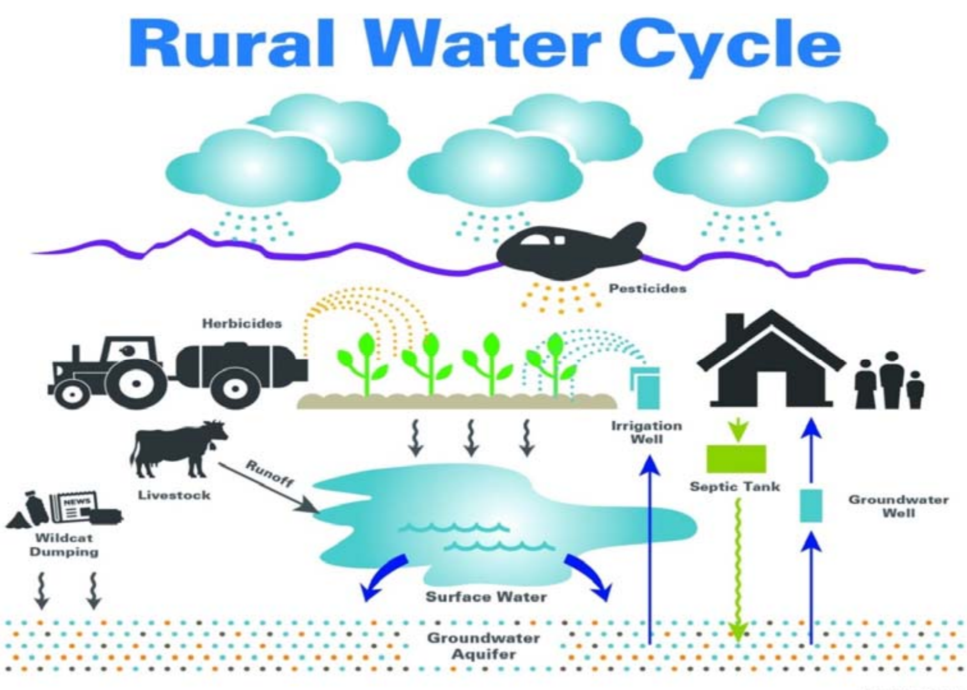


Figure 3.19. Representative rural water cycle indicating agricultural and private water and wastewater components. (Source: *http://tapintoquality.com/your-water*)

The rural water cycle, in contrast, may involve agricultural water pathways, use of private water wells and septic tanks, and possibly a higher risk of drinking water degradation since simpler water and wastewater treatment technologies may be applied before consumption (Figure 3.19). Both urban and rural water cycles though involve some of the same environmental paths, such as percolation into the ground and evapotranspiration, as found in nature.

3.2.3 Drugs in the Water Cycle

ECs may be present in both the urban and rural water cycles, but may have different histories once in the environment and may present different issues in each area. ECs such as prescription, over-the-counter and illicit drugs can enter either the urban or rural water cycles, at many points and may be removed in different ways such as through formal treatment facilities or by eventual degradation in the environment (Figure 3.20).

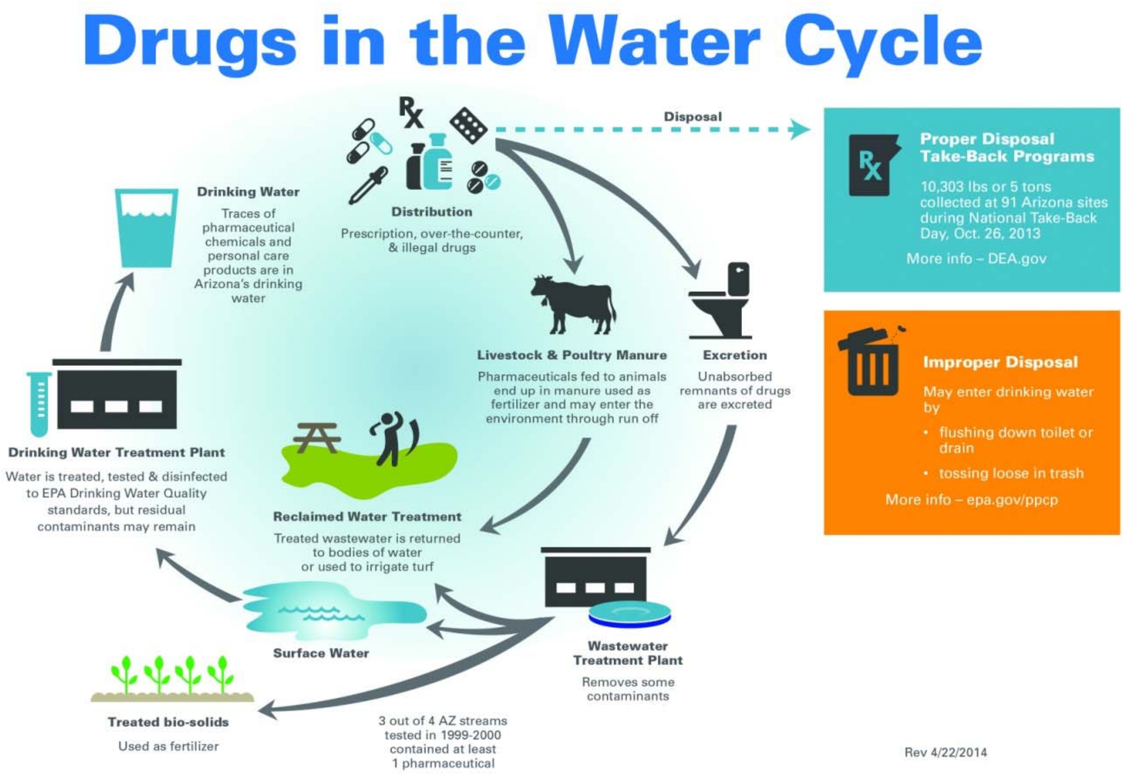


Figure 3.20. Developed by Tucson Water 3/22/2014, based on Circle of Blue *www.circleofblue.org* graphic "Unprescribed: Drugs in the Water Cycle".

3.3 WATER TREATMENT

Water treatment systems are an amalgam of equipment, techniques, and processes for removing physical, chemical, and microbial contaminants that may be present in source water. Contaminants can be naturally occurring and man-made. Treatment systems are designed for different sources and different uses of the treated water. The brief descriptions below highlight the conventional treatment of surface water and groundwater for drinking and the treatment of sewage flows to produce wastewater meeting standards for discharge or reuse.

3.3.1 Surface Water Treatment

Surface water treatment is complex, requiring multiple steps to clean water that comes from rivers, lakes, and streams (see schematic, Figure 3.21). Comprehensive water sample analysis is required throughout the treatment process to verify that treatment is removing contaminants. For example, the City of Phoenix performs multitudes of tests per year on more than 100 substances to monitor the performance of their surface water treatment plants.

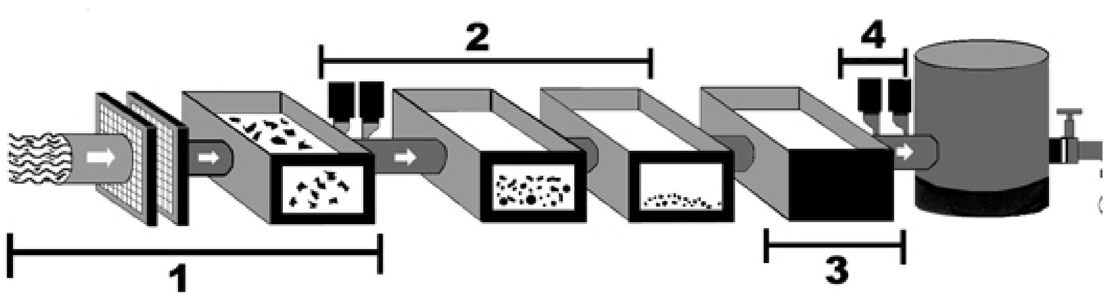


Figure 3.21. Typical community surface water treatment process to produce potable water. (Source: *https://www.phoenix.gov/waterservices/waterquality*)

- **Step 1, Screening and Pre-sedimentation**: Large particles such as plant matter debris and other materials commonly found in river water are removed by screens or settle to the bottom of the pre-sedimentation tank.
- **Step 2, Coagulation, Flocculation and Sedimentation**: A chemical coagulant, such as alum or ferric chloride, is added to the water. This causes the tiny particles to cling together and become heavy enough to settle to the bottom of the basin.
- **Step 3, Filtration**: The cleaner water on the top then passes through filters to remove remaining particulate matter.
- **Step 4, Disinfection**: A small quantity of chlorine, a disinfectant, is added to prevent microbial growth. A small quantity of fluoride may also be added to prevent tooth decay.

Monitoring of water quality continues in the distribution system after the water leaves the treatment plant. Water quality inspectors take samples at numerous points throughout it to confirm that drinking water standards are met as the water travels miles from treatment plant to end user. This is a mammoth task, as the Phoenix drinking water distribution system is enormous, consisting of 7,000 miles of water mains, 110 booster pump stations, 50,000 fire hydrants, and 119,000 valves.

3.3.2 Groundwater Treatment

Water systems supplied by groundwater pumped from wells may employ relatively simple treatment involving chlorination disinfection at the well site (Figure 3.22), to much more complex water treatment incorporating steps similar to surface water treatment.

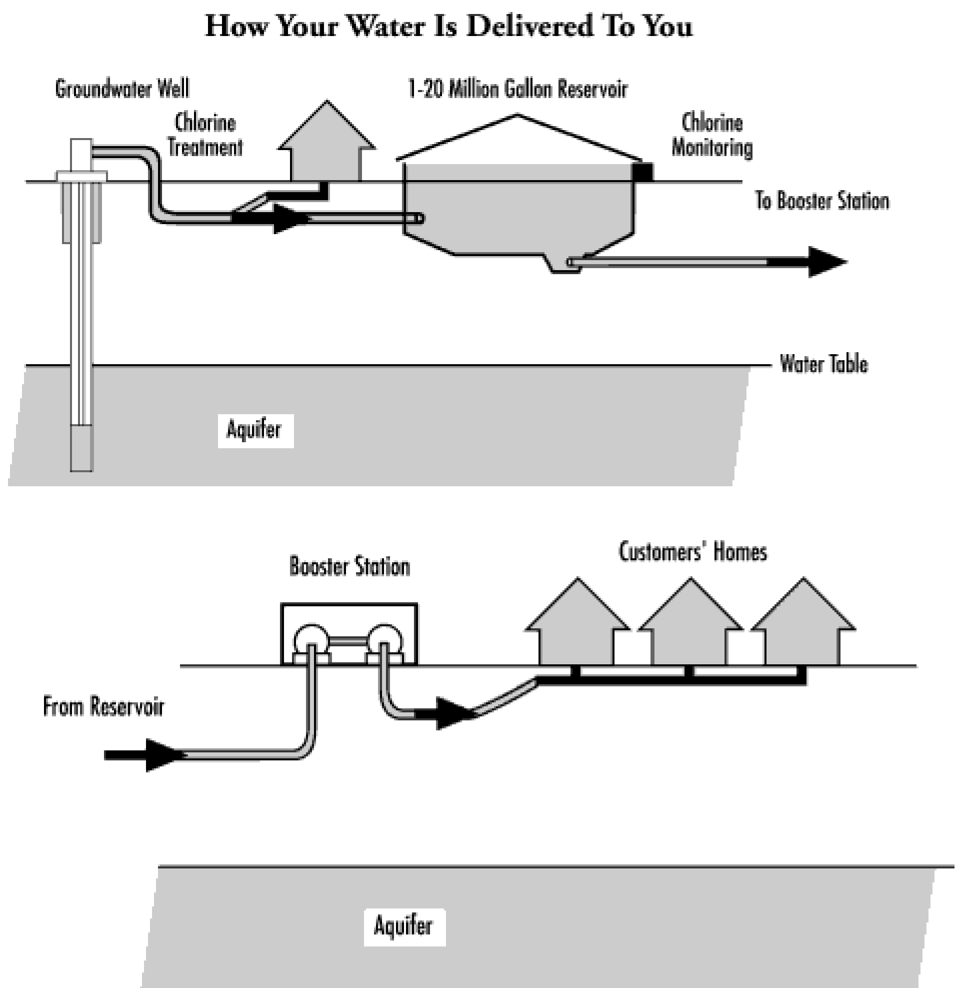


Figure 3.22. Schematic of water delivery from groundwater wells to customers that includes chlorination at the well site, temporary water tank storage and pumping to the customer. (From: *http://www.tucsonaz.gov/water/distribution-system*)

Two examples of cities with advanced groundwater treatment systems are the City of Tucson and Lake Havasu City. The City of Tucson's new Advanced Oxidation Process (AOP) Water Treatment Facility utilizes hydrogen peroxide, UV reactors, and granulated activated charcoal (GAC) to remove 1,4-dioxane and other contaminants. Air blowers then strip out the main contaminant, trichloroethene (TCE), before the chlorinated drinking water goes to customers. Lake Havasu City treats groundwater by first chemically removing arsenic and then using a unique biological sand filter basin technology to extract manganese and iron from the water. Final disinfection is by both UV radiation and chlorine.

3.3.3 Wastewater Treatment

In most cases, water distributed by municipalities for domestic, commercial, and industrial uses goes into a sanitary sewer collection system and flows to a wastewater treatment facility for treatment (Figure 3.23). Traditional sewage treatment consists of primary and secondary steps. Primary treatment involves physical processes such as screening and settling to separate solids from liquid. Secondary treatment relies on biological processes that break down organic wastewater constituents by microbial degradation. Secondary treatment usually incorporates settling, gravity filtration, and disinfection to further improve wastewater quality. The solids that settle out of the wastewater stream (sludge) are typically treated by aerobic or anaerobic digestion and hauled to a landfill for disposal or applied as biosolids to amend agricultural soils.

In Arizona, the Best Available Demonstrated Control Technology (BADCT) provisions of ADEQ's APP program require that all new or expanding sewage treatment facilities incorporate additional treatment steps beyond traditional secondary treatment. These steps produce high quality treated wastewater suitable for a multitude of reclaimed water end uses. An important corollary benefit of these additional steps is that the added treatment provides better EC removal, reducing levels of many contaminants in the treated wastewater.

Specifically, sufficient total nitrogen must be removed from the treated wastewater to meet a standard of less than 10 milligrams per liter (mg/L) (i.e., equivalent to the drinking water MCL for this contaminant). This denitrification step also reduces the levels of many chemical ECs in the treated wastewater.

Likewise, the discharged treated wastewater must meet stringent disinfection standards. For a typical community WWTP, the treated wastewater must be routinely free of fecal coliform and E. coli organisms (no organisms present in 4 of 7 daily samples per week). Disinfection to meet this standard is generally accomplished in conjunction with filtration. If the water is to be reused where access to the public is open, it must be further treated to meet a turbidity standard of 2 Nephelometric Turbidity Units (NTU). Together, these treatment processes greatly reduce or eliminate microbial ECs that might be present.

Because of Arizona's climate and rapid population growth, many communities have had to expand WWTPs or build new ones, thus requiring that the advanced treatment requirements under BADCT be met. For this reason, Arizona is ahead of other parts of the country in the number of high performance treatment plants in operation and the overall high quality of its treated wastewater. Lower levels of chemical and microbial ECs in Arizona's treated wastewater are a significant side benefit of the BADCT regulatory requirements.

If desired, even more advanced technologies such as ozonation, UV light, nanofiltration, microfiltration, ultrafiltration, activated carbon filtration, and reverse osmosis membrane filtration may be incorporated into the treatment train to further reduce or eliminate pollutants before reuse. These technologies are discussed in more detail in Section 5.

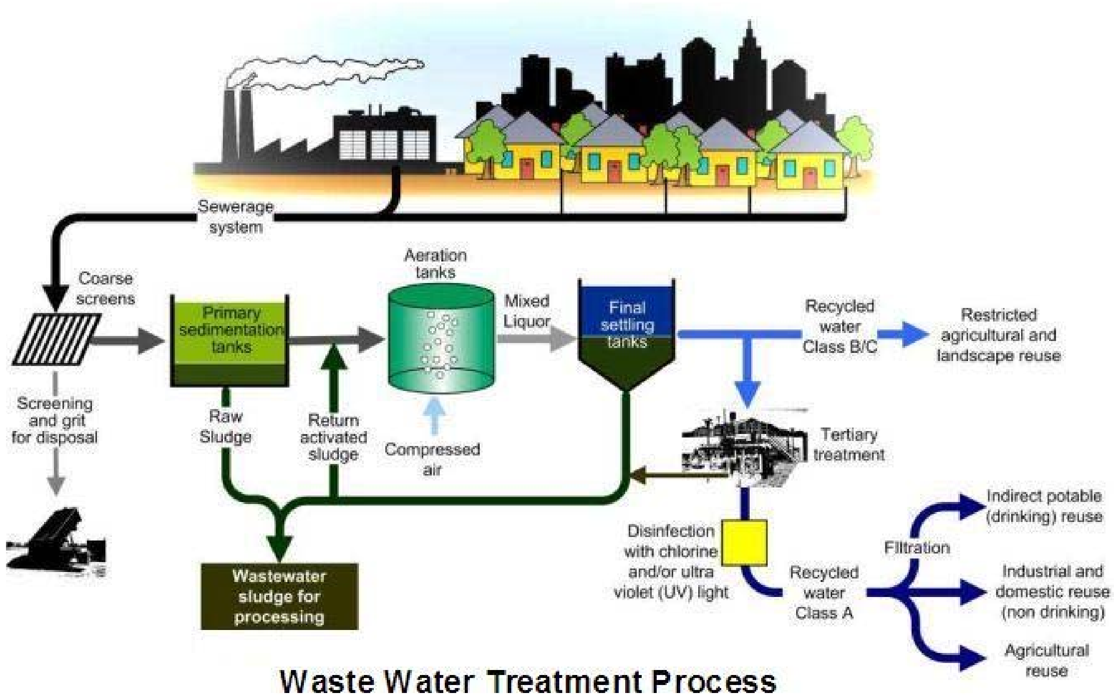
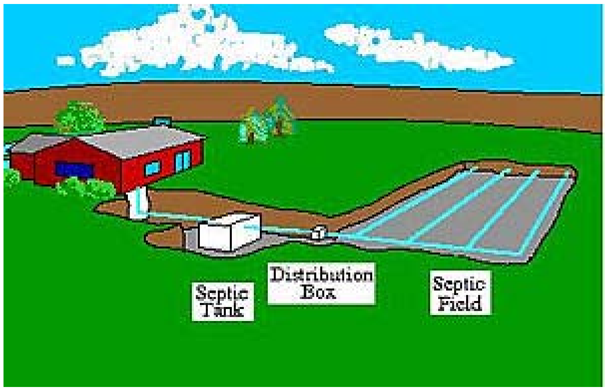


Figure 3.23. Typical activated sludge wastewater treatment train. Biological activity breaks down solids and treats wastewater for discharge or reuse. (Modified from *http://butane.chem.uiuc.edu/pshapley/Environmental/L35/1.html*)

Where centralized sewage collection and treatment systems are not present, on-site wastewater treatment is necessary. Underground septic tanks are the most common form of on-site wastewater treatment in the United States. In Arizona, ADEQ estimates that 20 percent of the population depends on septic tanks for wastewater treatment and disposal. A typical septic system consists of a septic tank and a leach field. Household wastewater is conveyed into the septic tank—a buried, water-tight container usually made of concrete, fiberglass, or polyethylene. The septic tank holds the wastewater long enough to allow solids to settle to the bottom (forming sludge) and oil and grease to float to the top (as scum). Most modern septic tanks are designed with two compartments and baffled outlets to prevent the sludge and scum from leaving the tank. Sludge and scum are removed when the tank is pumped. The tank contents undergo anaerobic bacterial decomposition, producing a wastewater stream that exits the tank into the leach field (Figure 3.24). Within the leach field (also known as the drain field or soil absorption field), the wastewater is further acted on by microbial and natural attenuation processes which reduces levels of bacteria, viruses, nutrients, and other pollutants. However, concentrations of ECs are typically much greater than found in wastewater treated in sewage treatment plants. Very little nitrogen is removed by the septic tank and leach field, and the wastewater can contain a variety of ECs that can percolate with the water into an underlying aquifer.



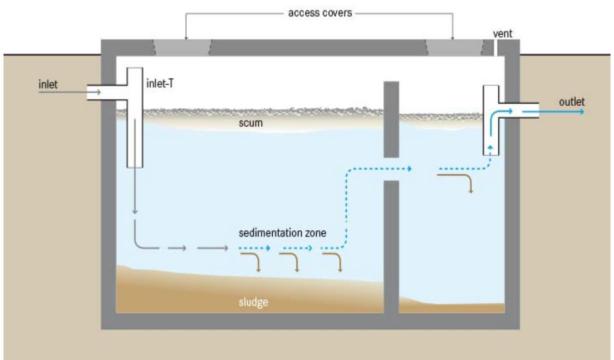


Figure 3.24. Typical septic tank and leach field configuration, with septic tank detail showing sludge and scum accumulation. (From: *http://water.me.vccs.edu/concepts/septictank.html*)

3.4 REFERENCES AND ADDITIONAL RESOURCES FOR SECTION 3

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3.4.2 Arizona's Water Resources

Arizona Water Atlas Volume 8: Active Management Areas Water Atlas: *http://www.azwater.gov/AzDWR/StatewidePlanning/WaterAtlas/ActiveManagementAreas/default.htm*

U of A Water Resources Research Center: *https://wrrc.arizona.edu/*

U.S. Bureau of Reclamation, Lower Colorado Region: *http://www.usbr.gov/lc/phoenix/*

USGS Water Data for Arizona: *http://waterdata.usgs.gov/az/nwis/nwis*

3.4.3 Arizona Geology

The Arizona Geological Survey: *http://www.azgs.az.gov/*

3.4.4 The Hydrologic Cycle

Science Clarified, Hydrologic Cycle: *http://www.scienceclarified.com/He-In/Hydrologic-Cycle.html*

Tucson Water, Our Water Cycle: *https://www.tucsonaz.gov/files/water/docs/swabfg02.pdf*

3.4.5 Drinking Water Treatment

Water Purification: *https://en.wikipedia.org/wiki/Water_purification*

City of Phoenix, Understanding Phoenix's Water Quality: *http://phoenix.gov/waterservices/quality/index.html*

EPA Drinking Water Contaminants – Standards and Regulations: *http://water.epa.gov/lawsregs/guidance/sdwa/upload/2009_08_28_sdwa_fs_30ann_treatment_web.pdf*

3.4.6 Wastewater Treatment

Wastewater Treatment: *https://en.wikipedia.org/wiki/Wastewater_treatment*

How a Septic System Works: *http://www.gbra.org/septic.swf*

EPA Septic Systems (Onsite/Decentralized Systems): *http://water.epa.gov/infrastructure/septic/the-basics.cfm*

4.0 Emerging Contaminants Found in Arizona Waters

There are a vast number of ECs, and they can enter Arizona's source waters in a multitude of ways. This section provides a working definition of ECs for the purpose of this report and describes their general characteristics. APEC researched available studies and reports through 2015 to prepare a table of ECs found in Arizona waters. We have summarized the regulatory programs whereby ECs are detected, monitored, and studied before the EPA issues formal regulations, standards, or guidelines. The information in this section is intended to provide water utility managers with a working knowledge of the different types of ECs and the pertinent regulatory programs to assist in developing monitoring and contingency plans for their utilities.

4.1 DEFINING EMERGING CONTAMINANTS

Any chemical or biological contaminant introduced into water can degrade water quality and may adversely affect human health and/or the environment. The term "emerging contaminants" generally refers to chemicals, biological agents, and naturally occurring elements detected in the environment that may pose a potential or real threat to human health or the environment, but which may not be presently regulated by EPA or ADEQ.

The number of emerging chemicals and microorganisms defined as ECs is vast. APEC has compiled a list of 109 emerging chemicals and microorganisms that have been found in one or more of Arizona waters to date (Appendix A). This list should be useful to Arizona water utilities to make informed water quality management decisions and for conveying EC awareness to the public.

The occurrence and concentration of ECs in each water source described in Section 3.0 varies depending on factors such as climate, geology, watershed characteristics, location, and most importantly, human impacts. In turn, each of these waters poses a different exposure risk to humans depending on the eventual use of the water and the potential for ingestion or other modes of contact.

The majority of the chemical ECs noted in this report are derived from commercial and industrial products, and their occurrence in source waters is due to human activities. For example, human contact with surface water during recreational activities such as tubing (Figure 4.1), allows introduction of ECs through the use of PCPs like sunscreen and insect repellent, consumption of beverages that may contain caffeine and artificial sweeteners, and the use of legal and illicit drugs. Arizona water utilities and agricultural interests located on the main stem of the Colorado River or supplied by the CAP Canal use water impacted by upstream activities of this nature.

The quality of other perennial waterways in Arizona, such as the Verde, Salt and Gila Rivers, is also influenced by recreational activities. Other activities introducing ECs into Arizona waters include agricultural production (pesticide and herbicide runoff from agricultural fields; and pharmaceutical runoff from feedlots), land application of biosolids, urban stormwater runoff (Figure 4.2), and municipal and industrial wastewater discharges. The water cycle figures from Section 3.0 illustrate some of these pathways.

Figure 4.1. Tubers on the Salt River.
(From: www.saltrivertubing.com)

Figure 4.2. Urban Runoff in the Santa Cruz River. Photo by Tucson Water Media

The degree to which drinking water is impacted by the presence of ECs depends on both the ability of ECs to enter a source water supply and the capability of the treatment processes used to remove chemical and microbial contaminants before release into the PWS. Both untreated wastewater and treated wastewater typically contain higher concentrations of ECs than other types of water. Current conventional treatment processes and disinfection practices remove many, but not all, ECs. Advanced treatment methods, discussed in more detail in Section 6.4, are required. These advanced treatment processes have been shown to greatly decrease concentrations of many ECs to below current detection limits; however, they cannot remove all ECs.

ECs are largely unregulated by the EPA as their occurrence and effects have not been well documented and the agency is constrained by federal law on setting the policy for monitoring ECs. The process in the SDWA for ECs involves three steps to evaluate whether a contaminant should be regulated. These criteria provide helpful guidance to determine the relative importance of individual ECs for Arizonans and are sound criteria for Arizona policy makers to consider:

1. Will the contaminant have an adverse effect on human health?

2. Is the contaminant known to occur, or is there a substantial likelihood that the contaminant will occur in PWS at a frequency and level to pose a public health concern?

3. Would best management practices for the contaminant provide a meaningful opportunity to reduce the risk to humans?

The United States Congress and the President of the United States, in the SDWA Amendments in 1996, set these three criteria as the public policy for this country to guide selection of ECs for the regulation by EPA. Section 1412(b)(1), SDWA, 42 U.S. CODE 300G-1 (b)(1) (A): Congressional Research Service, Safe Drinking Water Act (SDWA): A Summary of the Act and its Major Requirements (2010), p.4 to 7. See: *http://www.fas.org/sgp/crs/misc/RL31243.pdf*

In this report, there are a small number of chemicals and microbial contaminants that the EPA currently regulates under the SDWA, yet still appear on the unregulated contaminant (UC) list. This is because sufficient new information regarding toxicity or occurrence has come to light to merit a reexamination of the original basis for regulatory standard setting. In any case, the UCs and a few regulated contaminants (RCs) have been recognized by EPA, academia, industry, water purveyors, and public health officials as persistent in the environment or have the potential to negatively impact human health, wildlife, and aquatic ecological systems.

4.2 LIST OF EMERGING CHEMICAL AND MICROBIAL CONTAMINANTS

The list of 109 ECs that APEC compiled (Appendix A) includes both synthetic and naturally occurring chemicals and microorganisms that have been detected in Arizona waters. APEC developed this list based on whether the compound has been detected in one or more of Arizona source water and/or drinking water. The listed ECs represent a wide variety of use categories, including industrial chemicals, PCPs, pharmaceuticals, flame retardants, pesticides, herbicides, surfactants, corrosion inhibitors, steroids, illicit drugs, and microorganisms and their toxins. Table 4.1 summarizes the broad categories of ECs and the type of water tested. Those ECs that have not been detected or have not been tested for in Arizona are not listed. Thus, the list in Appendix A is a work in progress and should be updated as new ECs are detected.

Table 4.1: EC Groups Detected in Arizona Waters

Constituent Categories	Colorado River	Other Rivers Streams Lakes	Groundwater	Wastewater Reclaimed Water	Drinking Water
Pharmaceuticals	Yes	Yes	Yes	Yes	Yes
Personal Care Products	Yes	Yes	Yes	Yes	Yes
Industrial Chemicals	Yes	Yes	Yes	Yes	Yes
Flame Retardants	Yes	Yes	Yes	Yes	Yes

Table 4.1: EC Groups Detected in Arizona Waters

Constituent Categories	Colorado River	Other Rivers Streams Lakes	Groundwater	Wastewater Reclaimed Water	Drinking Water
Pesticides/Herbicides	Yes	Yes	Yes	Yes	Yes
Surfactants	Yes	Yes	Yes	Yes	Yes
Steroids	Yes	No	No	Yes	No
Illicit Drugs	Yes	Yes	No	Yes	No
Naturally Occurring Compounds	Yes	Yes	Yes	Yes	Yes
Microorganisms	Yes	Yes	Yes	Yes	Yes
Cyanotoxins	Yes	Yes	No	No	No

Yes = Records indicate that one or more ECs in the group have been detected in source water samples.

No = A records review indicates that ECs associated with this group have not been detected or not tested for in waters sampled from these sources.

The list of ECs provided in Appendix A should prove useful to aid public water purveyors, regulators, academia, and consultants in the development of guidance and monitoring plans and best management practices. The list can be used to help focus research needs and funding in Arizona and may also be used to increase public awareness of the types of ECs in Arizona waters.

4.3 DESCRIPTIONS OF EMERGING CONTAMINANT GROUPS

The following is a brief description of common uses of the constituent categories for chemical and microbial ECs. Appendix A contains the list of ECs detected in Arizona waters and their common uses.

4.3.1 Pharmaceuticals

A pharmaceutical is a drug sold by prescription or over the counter to treat illnesses. Examples of pharmaceuticals are antibiotics, anticonvulsants, anti-inflammatories, anti-depressants, and tranquilizers (Figure 4.3). Other examples are medications used for heart regulation, decongestants for clearing sinus cavities, and medications used in skin disinfection. Many are found in treated wastewater unless they are removed by advanced treatment processes.

Figure 4.3. Over-the-counter drugs. (*http://www.sleepapneadisorder.info*)

All pharmaceuticals are used at concentrations or doses that are many times higher than concentrations found in treated drinking water and treated wastewater. Many of them have no known deleterious effect on humans at the ultra-low doses present in water supplies and drinking water, although not all have been tested adequately at these levels.

4.3.2 Personal Care Products

PCPs consist of those chemical compounds used daily for personal hygiene, protection, or beautification (Figure 4.4). They include chemicals found in fragrances, lotions, shampoos and sunscreens; antibacterial agents and antifungal agents found in soaps; and insecticides found in insect repellent. They are commonly detected in treated wastewater supplies unless advanced treatment methods are used to remove them.

Figure 4.4. Types of Personal Care Products: (*http://www.womensvoices.org*)

4.3.3 Industrial and Commercial Products

Industrial and commercial products consist of chemical compounds used in manufacturing chemicals and final products with commercial and residential applications. One example is benzotriazole, which has a variety of applications ranging from direct use as a restrainer in photographic emulsions to indirect uses in the pharmaceutical industry. Other manufactured chemicals include explosives, flame retardants, pesticides, herbicides, corrosion inhibitors, artificial sweeteners, solvents, and surfactants. These ECs are most commonly found in surface water and treated wastewater supplies due to improper disposal practices or stormwater runoff from parking lots, yards, and farms.

Another industrial and commercial product group that is receiving increased attention are the perfluorinated organic compounds such as PFOS and PFOA (perfluorooctane sulfonate and perfluorooctanoic acid, respectively). These compounds are fluorinated organics, and were extensively used in the United States for many years before ultimately becoming phased out of production by 2002. These compounds were commonly used as protectants for surfaces in industrial and commercial products due to their water-repelling properties. Another common use of perfluorinated compounds was in the manufacture of firefighting foams. Because of their strong molecular structure, perfluorinated compounds can reside in the environment indefinitely.

4.3.4 Steroids and Hormones

Steroids consist of naturally-occurring hormones and manufactured or synthetic steroid hormones. Hundreds of distinct steroids are found in animals, fungi, plants, and elsewhere and many steroids are necessary to life at all levels. Cholesterol, estradiol, estrone, progesterone, 17β-estradiol, and testosterone (Figure 4.5) are naturally occurring hormones that are excreted regularly by the human body. Hormones and steroids are sometimes prescribed to treat cancer, menopause, and osteoporosis. Ethinyl estradiol is a synthetic hormone used in the formulation of oral contraceptive pills. Many of these compounds are found in treated wastewater streams and in surface waters used for recreation. The effects of low doses of these hormones on humans are not known, but studies indicate that they may have a negative impact on fertilization of fish eggs (Bhandari, et al., 2015) and other aquatic organisms.

Figure 4.5. Birth control pills can contribute to the presence of hormones in source water. (From: *http://www.brown.edu*)

4.3.5 Illicit Drugs

Two illicit drugs have been detected in treated urban wastewater and the Colorado River, and are included in the list as they are widely used. Methamphetamine is a neurotoxin and psychostimulant derived from ephedrine or pseudoephedrine (Figure 4.6). MDMA (ecstasy) is a psychoactive drug manufactured from safrole, an oily liquid present in the sassafras tree. The presence of these drugs illustrate that as new illicit drugs gain widespread use, they can become ECs in source water used to create drinking water, through recycling of wastewater and from surface water recreational uses.

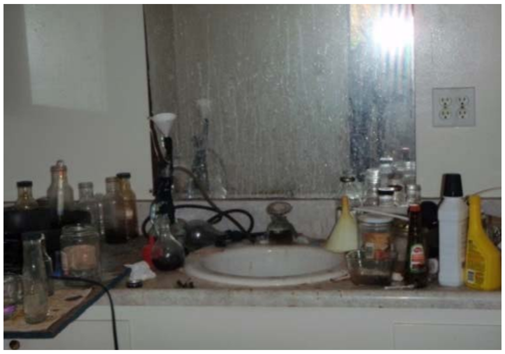

Figure 4.6. Methamphetamine lab. (From: *http://www.biomaxenvironmental.com*)

4.3.6 Naturally Occurring Elements

There are several naturally occurring elements listed in Appendix A that may be introduced into source waters either naturally by leaching from geological sources, or artificially from mining or degradation of manufactured products. Though cobalt, chromium, molybdenum, strontium, and vanadium (Figure 4.7) have been known for centuries, they have only been suspected to cause human health issues within the past few decades. Health-related studies have

Figure 4.7. Vanadinite ore can leach vanadium into groundwater. (From: *http://www.commons.wikimedia.org*)

intensified on these elements and though they have not yet been regulated by the EPA, they are listed on the Unregulated Contaminant Monitoring Rule 3 (UCMR3), which required PWS that serve more than 10,000 customers to test for these metals until December 2015.

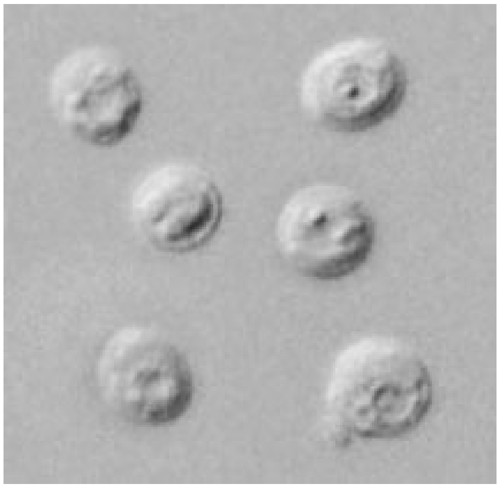

Figure 4.8. *Cryptosporidium* oocysts.
(From: *http://www.cdc.gov/dpdx/cryptosporidiosis/gallery.html#oocystswetmount*)

4.3.7 Microorganisms

Many microorganisms are either beneficial or benign to humans, but there is a growing number of recognized pathogens that have been shown to have a negative impact on human health.

Pathogens should not be present in treated drinking water or treated wastewater. Conventional treatment and disinfection with chlorine or chlorine based disinfectants remove the pathogens from the treated drinking water and treated wastewater before delivery to customers or discharge into the environment. However, as the treated drinking water is delivered through a distribution system, water-borne pathogens such a *Vibrio cholerea* and *Cryptosporidium* (Figure 4.8) can enter the distribution system through treatment failures, pipe breaks, low pressure events, and backflow events. Other pathogens such as *Naegleria fowleri, Legionella pneumophila, and Mycobacterium avium* are water-based pathogens which can enter the drinking water distribution system as listed, but are microorganisms that can continue to live in a water environment within the pipes of a drinking water distribution system in the presence of chlorine based disinfectants. Water-based pathogens require specific environmental conditions to exist to be able to cause illness in human beings. The EPA has specific information on each microorganism on their website listed at the end of this section.

Many of these microorganisms live in biofilms, which can form inside pipes and other infrastructure used to carry drinking water. Some are carried along with suspended particles in the source water. The primary treatments for drinking water created from surface water include coagulation, filtration using a maximum filter size of 0.1 micron to remove bacteria and fine suspended particles, and chlorination or ozonation to remove the remaining bacteria. The primary treatment for drinking water created from groundwater is soil aquifer treatment (recharge through the vadose zone) and chlorination. The primary treatment for removing biofilm from distribution systems includes unidirectional flushing at scouring velocities, flushing with steam, hyperchlorination, and ozonation.

Arizona water providers remain vigilant in the testing and treatment for emerging microorganisms because seven microorganisms have been found in Arizona waters (Appendix A). Treatment regimens are available for each microorganism found in Arizona waters. For example, the *Naegleria* Advisory Panel in 2004-2011 investigated the occurrence of the *Naegleria fowleri* organism in Arizona waters, and developed management guidance for drinking water utilities. In addition, APEC formed a subcommittee to investigate the occurrence of five emerging microorganisms in Arizona waters. Their report "*Emerging Waterborne Pathogens of Concern in the State of Arizona*" can be accessed at the following link: *http://static.azdeq.gov/wqd/emerging_waterborne_path.pdf*.

4.4 CONCENTRATIONS OF ECS IN ARIZONA WATERS

Generally, concentrations of ECs in an untreated water supply source and in conventionally treated drinking water are in the range of parts per trillion (nanograms per liter [ng/L]). One part per trillion or 1 ng/L is equivalent to a drop of something diluted into 10,000,000 gallons of water, which is equivalent to 20 Olympic-size swimming pools. Some ECs may also be present below the analytical detection limits in any given situation. Figure 4.9 shows concentrations of some ECs found in the Colorado River from samples collected in 2007, 2008, and 2014 by Lake Havasu City and the Bureau of Reclamation.

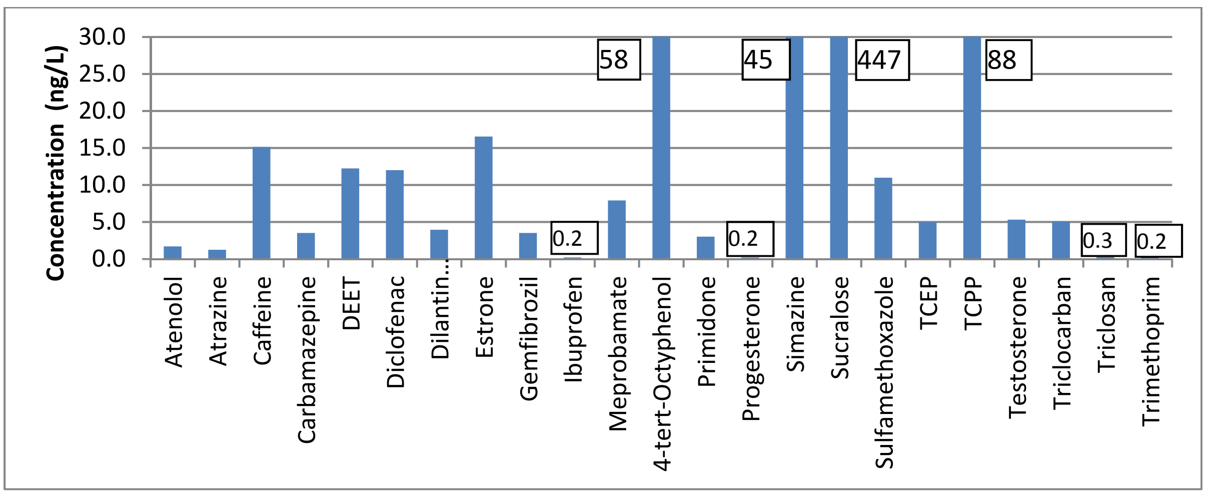

Figure 4.9: Average concentrations of selected ECs analyzed in the Colorado River.
(From: Wilson and Jones-Lepp, 2013)

The concentrations of ECs at a specific water supply point (surface-water intake or groundwater water supply well) will depend on three factors: 1) the distance of the supply point from the discharge point, 2) the concentration of the EC in the discharge, and 3) the magnitude of attenuation (e.g., degradation, dilution) affecting the EC during transport from the discharge point to the supply point.

The concentrations of ECs generally decline with distance from their discharge points in surface or groundwater supply systems, though some, like sucralose (an artificial sweetener), may persist at the same concentration for long distances. Natural dispersion, dilution, adsorption, and a variety of decay processes (e.g., photolysis and bacterial decomposition) all contribute to reduce concentrations away from sources. The molecular structural stability of each compound along with exposure to varying physical, chemical, and biological environmental conditions determines how quickly a compound will degrade or attenuate break down into simpler components.

4.5 POTENTIAL ECOLOGICAL AND HEALTH IMPACTS

According to the World Health Organization (WHO), trace quantities of pharmaceuticals in drinking water are very unlikely to pose risks to human health because of the substantial margin of error or margin of safety between the concentrations detected and the concentrations likely to evoke a pharmacological effect (WHO, 2012). Scientific and medical studies concerning human health and ecological impacts in the laboratory and in the field have been conducted over the last three decades for most of the compounds in Appendix A. The studies are highly varied with respect to diversity of species involved, types of water and the dissolved concentrations of compounds applied or detected in investigations, time length of exposure, and how much the research delved into potential impacts. Chemicals categorized as pharmaceuticals are tested for direct toxicity effects, but typically not for hormonal effects such as endocrine disruption. The National Institute of Environmental Health Sciences (NIEHS) states that the potential for endocrine disruption and similar effects are important to consider even at low concentrations of relevant pharmaceuticals. Some chemicals that are not considered endocrine disruptors have been shown to not be harmful to human health at low concentrations measured in parts per billion (micrograms per liter [µg/L]) or parts per trillion (ng/L), yet some have been linked to biological disruption in amphibians, fish, crustaceans, and various microorganisms at these low levels (NIEHS, 2010). Antibiotics that have been found in our waters are a concern with respect to bacterial ecology where certain species may become more resistant to these antibiotics or transfer resistant genes to other microorganisms.

With the exception of sucralose, research has found that all of the chemical compounds listed in Appendix A have some potential or real negative impact on either human health or on the environment (e.g., aquatic wildlife). Some ECs such as 1,4-dioxane, tris (1-chloro-2-propyl) phosphate (TCPP), hexavalent chromium, and perfluorooctanoic acid (PFOA) are either known or suspected carcinogens (compounds that can cause cancer), while current research indicates that others only affect lower life forms in aquatic environments.

Although some information is known on the ecological or human impacts from exposure to ECs, none have been thoroughly investigated for all potential health impacts at the low concentrations that are being detected in Arizona waters. An additional complicating factor is that the potential impacts of simultaneous exposure to multiple ECs are difficult to investigate.

The effects of “normal” pathogenic bacteria on human health are generally well known; however, the effects of antibiotic resistant bacteria that may be present in treated drinking water and treated wastewater have not been as well studied. According to the WHO, antimicrobial resistance (resistance to antibiotics that historically are used to treat infections) is a serious global problem (WHO, 2014). Antibiotic resistant bacteria could be a potential problem in treating patients effectively against these and non-resistant pathogens that may acquire antibiotic resistance. Research is currently being conducted to determine if antibiotic resistant genes and antibiotic resistant bacteria are present in Arizona waters.

4.6 CURRENT EMERGING CONTAMINANT REGULATORY FRAMEWORK

4.6.1 The Contaminant Candidate List

The SDWA also sets the public policy and a process to determine which ECs may require regulation by the EPA. The EPA must periodically publish this list of ECs on the contaminant candidate list (CCL) and decide whether to regulate at least five or more contaminants on the list (called Regulatory Determinations). The agency prioritizes research and data collection efforts to decide whether to regulate one or more of the five contaminants based on the following three criteria:

1. The contaminant may have an adverse effect on the health of persons;
2. The contaminant is known to occur, or there is substantial likelihood that the contaminant will occur, in PWSs with a frequency and at levels of public health concern; and
3. In the sole judgment of the Administrator, regulation of such contaminant presents a meaningful opportunity to reduce the health risk for persons served by PWSs.

Currently the EPA is evaluating strontium, 1,3-dinitrobenzene, dimethoate, terbufos and terbufor sulfone to determine if these ECs should be regulated.

There have been three CCLs published to date. In developing the CCL 3, the EPA implemented an improved process that builds on evaluations used for CCL1 and CCL2, and on substantial expert input and recommendations from the National Academy of Science's National Research Council (NRC) and the National Drinking Water Advisory Council (NDWAC) to create the CCL3 list (EPA 2).

A combination of the 5-year CCL cycle, 6-year NPDWR cycle, and the public process of rulemaking can result in 8 or more years of time to pass before an EC may become regulated by the establishment of a NPDWR. Establishment of new NPDWRs is infrequent. A total of 227 ECs have been listed on the three different CCLs. Since 1998, only one EC (perchlorate) has been proposed by the EPA to move forward into the NPDWR final rulemaking process. Currently, perchlorate remains unregulated.

4.6.2 The Unregulated Contaminant Monitoring Program

The Unregulated Contaminant Monitoring Program (UCM) is the monitoring program EPA uses to gather occurrence data for ECs selected from the CCL. Drinking water samples are collected by public water utilities and analyzed by state certified and licensed laboratories for the contaminants on the UCMR list (EPA 3). Similar to the CCL3, the UCMR is in its third iteration and is referred to as UCMR3. The EPA selects contaminants from the CCL to place on the UCMR list, and these two programs are used together to identify and determine occurrence levels for UCs in drinking water. Contaminants selected from the CCL3 list are being collected under the current UCMR3 program which began in 2013 and ended December 2015 (EPA 6). In February 2015, the EPA published a draft CCL4 list that is now under review.

Under UCMR3, EPA required PWSs to collect data on 30 unregulated contaminants. Because there are no MCLs, results were reported to the Minimum Reporting Level (MRL) which is the lowest accurately reportable limit based on the analytical method used to measure the concentration of a specific contaminant. The UCMR3 has three lists of target unregulated contaminants. The lists are the Assessment Monitoring (List 1), Screening Survey (List 2), and Pre-Screen Testing (List 3). The lists include the following contaminants shown in Table 4.2.

Table 4.2. UCMR 3 Lists	
List 1: Assessment Monitoring List - Chemicals	
Volatile Organic Compounds: 1,2,3-trichloropropane 1,3-butadiene Chloromethane (methyl chloride) 1,1-dichloroethane Bromomethane (methyl bromide) Chlorodifluoromethane (HCFC-22) Bromochloromethane (halon 1011) **Synthetic Organic Compound** 1,4-dioxane **Oxyhalide Anion** 1,4-dioxane	**Metals** Vanadium Molybdenum Cobalt Strontium Chromium Chromium-6 **Perfluorinated Compounds** Perfluorooctanesulfonic acid (PFOS) Perfluorooctanoic acid (PFOA) Perfluorononanoic acid (PFNA) Perfluorohexanesulfonic acid (PFHxS) Perfluoroheptanoic acid (PFHpA) Perfluorobutanesulfonic acid (PFBS)

Table 4.2. UCMR 3 Lists
List 2: Screening Survey - Hormones
17-β-estradiol
1-α-ethynylestradiol (ethinyl estradiol)
16-α-hydroxyestradiol (estriol)
Equilin
Estrone
Testosterone
4-androstene-3,17-dione
List 3: Pre-Screening Test - Viruses
Enteroviruses
Noroviruses

4.7 REGULATORY OUTLOOK

Although most of the ECs are not regulated by the EPA, a few are regulated and have MCLs established. This reclassification of regulated compounds as ECs has happened due to new information regarding toxicity or occurrence. This subcategory includes both chemicals and microorganisms. For example, atrazine and simazine are chemical herbicides that are considered ECs, but are regulated at an MCL of 0.003 mg/L for atrazine and at 0.004 mg/L for simazine, respectively. Other examples include *Cryptosporidium* species and *Legionella* species which are emerging pathogens considered ECs but are also regulated under a TT approach that is “a required process intended to reduce the level of a contaminant in drinking water (EPA 4).

Certain ECs are also being studied through the EPA’s Integrated Risk Information System (IRIS) for potential future regulatory action. According to the EPA website, “IRIS is a human health assessment program that evaluates information on health effects that may result from exposure to environmental contaminants”. Through the IRIS Program, the EPA provides the highest quality, science-based human health assessments to support the Agency's regulatory activities. The IRIS database is web accessible and contains information on more than 550 chemical substances (EPA 5).

As more research is conducted on the universe of chemical and microbial ECs, more of these contaminants will undoubtedly be listed as candidates for investigation on the CCL and UCM programs that may be legislated for federal regulation.

4.8 MONITORING PROGRAMS

In addition to the UCM program, some drinking water and wastewater utilities in Arizona have implemented their own occurrence monitoring programs focusing on identifying the presence and the concentrations of ECs that may be in their local water sources and drinking water distribution systems. As ECs are identified, utilities can investigate modified or new treatment methods that may be required to remove them. As this body of information grows, it will provide critical data documenting which ECs are present or absent in Arizona waters, inform the public and policymakers regarding the risks of ECs, and form the basis for possibly implementing new innovative advanced treatment methods to remove or reduce the presence of ECs in source water and drinking water.

As new regulations are developed, Arizona public water providers will need to ensure that drinking water continues to be treated and tested to a quality that renders it safe to drink. Arizona public water providers are committed to protecting public health.

4.9 REFERENCES AND ADDITIONAL RESOURCES

4.9.1 References

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EPA 2. *http://water.epa.gov/scitech/drinkingwater/dws/ccl/ccl3.cfm*

EPA 3. *http://water.epa.gov/lawsregs/rulesregs/sdwa/ucmr/ucmr3/laboratories.cfm*

EPA 4. *https://www.epa.gov/your-drinking-water/table-regulated-drinking-water-contaminants#Microorganisms*

EPA 5. *http://www.epa.gov/iris/*

EPA 6. https://www.epa.gov/dwucmr/third-unregulated-contaminant-monitoring-rule

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Wilson, D. C. and Jones-Lepp, T. L., 2013. Emerging Contaminant Sources and Fate in Recharged Treated Wastewater, Lake Havasu City, Arizona, *Environmental and Engineering Geoscience*, Vol.XIX, No. 3, p. 231-251.

4.9.2 Additional Resources

Clean Water Rule: *http://www2.epa.gov/cleanwaterrule*

Safe Drinking Water Act: *http://www.fas.org/sgp/crs/misc/RL31243.pdf*

Arizona's Safe Drinking Water Information System: *https://www.azdeq.gov/environ/water/dw/*

EPA Table of Regulated Drinking Water Contaminants: *https://www.epa.gov/your-drinking-water/table-regulated-drinking-water-contaminants*

Integrated Risk Information System (IRIS): *http://www.epa.gov/iris/*

Contaminant Candidate List: *http://water.epa.gov/scitech/drinkingwater/dws/ccl/ccl3.cfm*

Unregulated Contaminant Monitoring Rule (UCMR): *http://water.epa.gov/lawsregs/rulesregs/sdwa/ucmr/ucmr3/laboratories.cfm*

5.0 Emerging Contaminant Research In Arizona

Research studies on ECs began in the 1970s by the U.S. Geological Survey (USGS). These studies focused on detecting, identifying, and monitoring ECs in groundwater and surface water across Arizona. Many organizations, including public water utilities and research institutions, have participated in occurrence studies in recent years because they provide a water quality signature of which ECs have been present over time. More recent studies have focused on mitigating known ECs by evaluating the effectiveness of conventional and advanced treatment methods to reduce or eliminate those that have been identified in drinking water sources. Research into treatment and removal of ECs has become of paramount importance in Arizona. Although all of Arizona's reclaimed treated wastewater is currently recycled for non-potable uses, it is being seriously discussed as a source of drinking water for many municipalities in the future.

5.1 OCCURRENCE STUDIES

5.1.1 U.S. Geological Survey

The USGS has been sampling for ECs in groundwater, surface water, and aquatic biota across Arizona since the early 1970s. The earliest detections were for Diazinon, a general purpose insecticide which was found in 1972 in samples collected from the Gila River at Gillespie Dam (USGS 1).

Figure 5.1. The Lower Salt River Valley near Phoenix. (From: *https://en.wikipedia.org/wiki/Salt_River*)

Since 1986, ECs have been detected in water and aquatic biota samples in the Colorado River and its tributaries, including the lower Colorado, near Lee's Ferry, and at the northern International boundary with Mexico (USGS 2; Radtke et al., 1988; Tadayon et al., 1997; Gebler, 2000; Hinck et al., 2006; and Walker et al., 2009).

From 1996 to 2010, ECs were detected in aquatic biota and groundwater samples collected in northern Arizona in the Verde River, Granite Creek, and in Prescott. Surface water samples collected at Rio de Flag and Lake Powell were also found to have ECs (Gebler, 2000).

In central Arizona, the USGS first detected ECs in streams, aqua biota, and groundwater in 1996 throughout the West Salt River Valley and has consistently detected them since then in surface water, groundwater, urban runoff, constructed wetlands, and wastewater effluent samples (Gebler, 2000; Gellenbeck and Anning, 2002, Edmonds and Gellenbeck, 2002, Barber et al., 2003; Barnes et al., 2002; and Kolpin et al., 2002).

In southern Arizona, the USGS first detected ECs in 1998 in samples collected from streams, aqua biota, and groundwater throughout the Upper Santa Cruz Basin, ranging from Oro Valley to Nogales. From the late 1990s to 2010, ECs have been detected in treated wastewater in the Santa Cruz River downstream of treatment facilities. The Santa Cruz River receives treated wastewater as its primary water source during the winter months. Samples collected as far downstream as 10.5 miles from the treated wastewater outflow contained EC concentrations at levels near those detected in samples collected from the outflow structure. The USGS has been monitoring ECs in southeastern Arizona since the 1980s and detected ECs in groundwater samples collected in 1996 and 2008 throughout the San Pedro Basin, (Leake and Hanson, 1987; Graham and Monical, 1997; Petty et al., 2000; Gebler, 2000; Gellenbeck and Anning, 2002; Barnes et al., 2002; Kolpin et al., 2002; Cordy et al., 2004; Walker et al., 2009; Tillman, 2009; and Tillman, 2010).

5.1.2 Tucson Area

Tucson Water has been investigating and evaluating the presence of ECs in its source water, drinking water, and reclaimed water for over a decade. In 2000, the utility developed a three phase surveillance program consisting of:

1. Literature search on ECs related to occurrence, monitoring, analyses, regulations, and treatment.

2. Participation in local, regional, and national research studies.

3. Developing and implementing a monitoring program for groundwater, surface water, recharged surface water, recharged wastewater, and reclaimed water.

The expanding suite of ECs monitored annually from drinking water, recharged surface water, and groundwater sources include pharmaceuticals, pesticides, industrial chemicals and fire retardants, synthetic and naturally occurring hormones, and ingredients found in PCPs. The data are compiled and evaluated for trending compounds that are found at each location and used as baseline data in research efforts. A copy of the current Tucson Water EC analyte list is included as Appendix B of this report.

Tucson Water has collaborated with the USGS, the U of A, the Water Research Foundation (WRF), the WateReuse Research Foundation (WRRF), and numerous other entities to determine the presence and influence of ECs. References to studies that Tucson Water has been involved in are listed in the 2013 draft report generated by the APEC Chemical Subcommittee entitled "*Emerging Chemical Contaminants of Concern in the State of Arizona's Water*" (APEC 1).

5.1.3 University of Arizona

The U of A Contaminant Transport Laboratory (CTL) has been investigating the transport and fate of numerous contaminants in subsurface environments for 25 years. These contaminants include several listed ECs such as 1,4-dioxane, atrazine, perfluorinated compounds (PFCs), hexavalent chromium, nanoparticles, and several pathogens (including *Cryptosporidium* and *Giardia*). This research has contributed to improved understanding of the persistence of these constituents in the environment, and potential means by which to treat groundwater contaminated by these constituents. A web site address for the CTL is provided at the end of this section.

Figure 5.2. Giardia Lamblia cell. (*https://en.wikipedia.org/wiki/Giardia_lamblia*)

In addition to the CTL, the U of A established the Arizona Laboratory for Emerging Contaminants (ALEC) in 2009. Since its inception, ALEC has been in a collaborative and leadership role investigating the occurrence of ECs in different types of water. With support from the WRF, ALEC provided a preliminary assessment of the presence and persistence of endocrine disrupting compounds, pharmaceuticals, and PCP levels in source waters and treated wastewaters to Pima County Wastewater Reclamation Department, Tucson Water, the City of Phoenix Water Services Department, and other United States municipalities (Chorover et al., 2014). ALEC has used these analyses to investigate the influence of dissolved organic matter (DOM) and colloidal organic matter (COM) on standard laboratory practices of extraction and analysis (detection and quantification), and to determine the effects of various watershed DOM and COM sources (Wickramasekara et al., 2012; Hernandez-Ruiz et al., 2012; Hernandez-Ruiz et al., 2013).

In coordination with a National Science Foundation (NSF), ALEC supported the Critical Zone Observatory project on Mount Lemmon (Maxwell, 2013), ALEC investigated the effect of soil biogeochemical processes on fate and transport of ECs from wastewater effluent into surface waters in 2012-2013. ALEC has worked in environmentally burdened communities along the U.S.-Mexico border on several projects including: investigating measurements of TCE found in nursing mothers' breast milk to provide correlation with particular water use behaviors (Beamer et. al., 2012); an EPA supported investigation with Friends of the Santa Cruz River to measure perfluorinated chemicals and sucralose in private wells near the Upper Santa Cruz River that may indicate treated wastewater intrusion downstream of the Nogales International WWTP; and an ongoing survey of pharmaceutical contaminants in different water types from the Mexicali Valley, MEX., in collaboration with scientists from the Universidad Autónoma de Baja California.

ALEC investigated antibiotic resistance by measuring the impact of solids retention time on antibiotic resistance at several Arizona WWTPs, specifically the degradation of antibiotic compounds, the proliferation of antibiotic resistant bacteria, and the persistence of antibiotic resistance genes during the wastewater treatment process. Different antibiotic classes were shown to have different removal efficiencies during the biological treatment processes; as a function of solids retention time therefore, operating conditions at each WWTP could be optimized for highest efficiency removal (Walston, 2013).

In 2006, a graduate student with the U of A collected water samples to investigate rainwater chemistry associated with water harvesting systems in central Tucson. The samples were collected from a cistern, from the first flush piping designed to divert the initial rooftop runoff away from the cistern, and from a nearby roadway stormwater runoff point. The samples were analyzed for six metals (aluminum, arsenic, copper, lead, iron and zinc), total and suspended solids (TDS/TSS), volatile and semi-volatile organics, bacteria, oil and grease, and major ion chemistry. ECs were not specifically analyzed. Lead, iron, and aluminum were detected in over half of the samples collected, and lead exceeded the EPA's primary standards in samples collected from the first flush system and the stormwater runoff at the beginning of the study. The author interpreted the lead, iron, and aluminum concentrations to air deposition and buildup of pollutants on the rooftop and ground during the preceding dry period. TDS exceeded the EPA secondary standard in over half of the samples collected from the first flush piping. Elevated levels of TDS are of concern because the particles can serve as a means of transport for bacteria, viruses, and other compounds, including ECs. Total coliforms and E. coli were detected in nearly all samples collected, most likely due to contact with animal waste (Brosnihan, 2006).

Another U of A researcher collected water samples in 2013 from an urban (Central Tucson) and a rural Arizona rainwater harvesting system and had them analyzed for microbial contaminants (total coliforms, E. coli, and Enterococcus), heavy metals (including eight Resource Conservation and Recovery Act [RCRA] regulated metals), and perfluorinated chemicals in order to address the concern that no water quality standards exist for harvested rainwater, despite the fact that this non-traditional water source can be utilized for irrigation of food crops, residential landscapes, and other sites with high probability of human contact. This study also tested low-cost filters for their efficacy in removal of microbial and chemical contaminants in the water leaving the tanks. Study results indicated that water samples collected before the monsoon season did not contain indicator bacteria such as total coliforms or E. coli. The highest levels of indicator organisms were recorded after the first substantial amount of rainfall, indicating that rooftop buildup of fallen leaves and bird droppings may have caused some degradation in rainwater quality. The concentrations of the RCRA-regulated metals were below regulatory limits. The filters appeared to be ineffective at the removal of indicator bacteria and metals (McLain, 2013). Further studies are needed to continue to investigate the quality of harvested rainwater during different wet periods over the course of a year.

5.1.4 Lake Havasu City

Figure 5.3. Lake Havasu City. From: *http://news.algaeworld.org/?s=lake+havasu+city*)

A town of 53,000, Lake Havasu City sits on the shores of Lake Havasu. In this area, surface and subsurface water flow towards the lake. In late 2008, the city initiated a treated wastewater (effluent) recharge program via vadose injection wells for potential banking and recovery. As there are no known hydrologic barriers to the lake from the recharge site, the city attempted to identify all possible sources of a selected group of 40 ECs in order to monitor their fate as the recharged effluent migrated away from the recharge site. Most of the ECs are well known for their persistence in the environment and many are included on the list given in Appendix A of this report.

Beginning in 2007, the city collected water samples from the Colorado River, Lake Havasu, untreated and treated source water, treated wastewater, recharged treated wastewater, groundwater down gradient from a recharge site, and locations down gradient from more than 25,000 septic tanks. Chemical ECs were detected in all of the water types in low ppt concentrations. The treated wastewater had the highest number of ECs detected (33 out of 40) of all the water types tested, with 18 ECs detected in surface water samples and 6 ECs detected in the city's untreated source water. All six ECs detected in the untreated source water remained unchanged during short, high-intensity UV radiation prior to chlorination, and five of the six ECs were detected in finished water after chlorination at the same concentrations as in the source water. Expectedly, the structure of the antibiotic sulfamethoxazole was altered during chlorination as the concentration of this compound decreased to below detection limits (Dodd and Huang, 2004).

Recharged treated wastewater can migrate away from the recharge site and eventually end up as return flow into the lake two miles away. Water samples from monitoring wells up to 2,000 feet down gradient of the recharge site revealed that eight ECs were detected in a higher concentration in the ppb range (Wilson and Jones-Lepp, 2013). The results complement earlier studies.

5.1.5 Phoenix Metro Area

Drewes et al. (2003) made an early attempt to delineate the fate of ECs in recharged groundwater in the Phoenix area and found that caffeine, diclofenac, ibuprofen, naproxen, and gemfibrozil decreased to below detection levels within six months of recharge, while carbamazepine and primidone persisted for more than eight years.

The ASU School of Sustainability conducted several studies in the mid- to late-2000s on a variety of focus topics concerning ECs in the environment. Surface water tested included the Verde River, Salt River, and the CAP canal system (Chiu and Westerhoff, 2010). Modeling efforts have been made to better understand wastewater treatment techniques for the removal of individual ECs (Weir et al., 2010).

5.1.6 Flagstaff Area

Figure 5.4. City of Flagstaff Wildcat Hill WWTP. (*http://www.flagstaff.az.gov/index.aspx?NID=120*)

The City of Flagstaff has used reclaimed water for more than 30 years, and today recycles more than 700 million gallons of water each year for non-potable use. The city has voluntarily conducted five sampling events from 2002 to 2014 that tested for a variety of ECs in Lake Mary and its drinking water and reclaimed water. Reclaimed water samples detected 33 ECs out of 87 that were analyzed. The first study was conducted with the USGS and NAU on treated wastewater and reclaimed water and found similar types of ECs and their concentrations as those found around the U.S. The study also evaluated the potential for treated wastewater to affect thyroid hormone activity in a model amphibian system. Most studies have evaluated the effects of exposure to aquatic vertebrates such as fish and frogs, and the findings vary, but the most consistent effects suggest that mixes of ECs in treated wastewater may act as estrogens and ultimately affect sexual development. However, there is evidence that thyroid hormone signaling and the stress hormone axis may also be disrupted. The long-term health effects on these organisms at either the individual or population level has not been investigated. (Propper, 2006; Wolff et al., 2015; Searcy et. al., 2012; Pottinger and Matthiessen, 2016).

In January 2013, the Flagstaff City Manager convened an Advisory Panel of local, state, and national experts, including researchers, health officials, and water professionals, to discuss what ECs mean to Flagstaff. The initial focus of the panel discussions was "human health impacts". The panel recommended that the city focus on four ECs detected in its reclaimed water; and form a subgroup of the Panel to outline a study of the health impacts of antibiotic resistant genes and antibiotic resistant bacteria.

The City is participating in two research efforts on ECs and microbial antibiotic resistance. The first is a Water Environment and Reuse Foundation (WE&RF) effort led by the U of A and the University of Nevada – Las Vegas, investigating the occurrence, proliferation, and persistence of antibiotic resistant genes and bacteria during the wastewater treatment process. The second study is a NSF effort led by Virginia Tech University, the U of A, and the Translational Genomics Research Institute, investigating the relative abundance and diversity of antibiotic resistance genes and pathogens in reclaimed versus potable water distribution systems. Both of these projects began in 2014.

Investigators at NAU are continuing research efforts towards understanding the biological effects of exposure to ECs. Specific projects include 1) understanding the interaction between ECs and other environmental influences on development of aquatic vertebrates, 2) the effects of exposure to treated wastewater on reproductive development, and 3) outcomes of adult and developmental exposure to arsenic concentrations similar to those found in surface and/or groundwater. The research results have not yet been finalized.

5.2 TREATMENT TECHNIQUES

Research has shown that using conventional water and wastewater treatment methods, such as sand filtration, settling tanks, and aerators alone have limited capability to fully remove many ECs and additional steps are necessary to greatly reduce concentrations of these compounds. Those treatment processes examined, but found of limited value, include coagulation, lime softening, biofiltration, and UV photolysis. However, other processes such as chlorination, powder activated carbon (PAC), GAC, ozonation with hydrogen peroxide, and UV light with hydrogen peroxide, as well as membrane filtration (microfiltration, ultrafiltration, and nanofiltration, including reverse osmosis [RO]), have been shown to essentially remove more than 99% of many unregulated and regulated ECs.

Figure 5.5. Typical WWTP Aeration Basins. (From David Ragsdale, Engineer EPA Region 10. Office of Water & Watersheds. April 2007.)

Chlorination and ozonation oxidize compounds by breaking down ECs to smaller molecules that are easier to remove. An effective removal technique of ECs is using an AOP. The AOP has three combinations of treatment steps:

- Ozone combined with hydrogen peroxide;
- UV light combined with hydrogen peroxide; and
- Ozone combined with UV light.

Membrane filtration such as nanofiltration (which removes particles between <0.001 and 0.01 μm) and RO filtration techniques in wastewater treatment have shown success in removing substantial percentages of ECs (up to 95%) (Kim et al., 2007).

Tucson Water began a pilot project in 2014 in collaboration with CH2M Hill as Principal Investigator, WRRF, the U of A, and an engineering firm to explore an alternative treatment configuration using a treatment scheme of soil aquifer treatment, nanofiltration, ozone, and biologically activated carbon (BAC)/GAC adsorption (Figure 5.6).

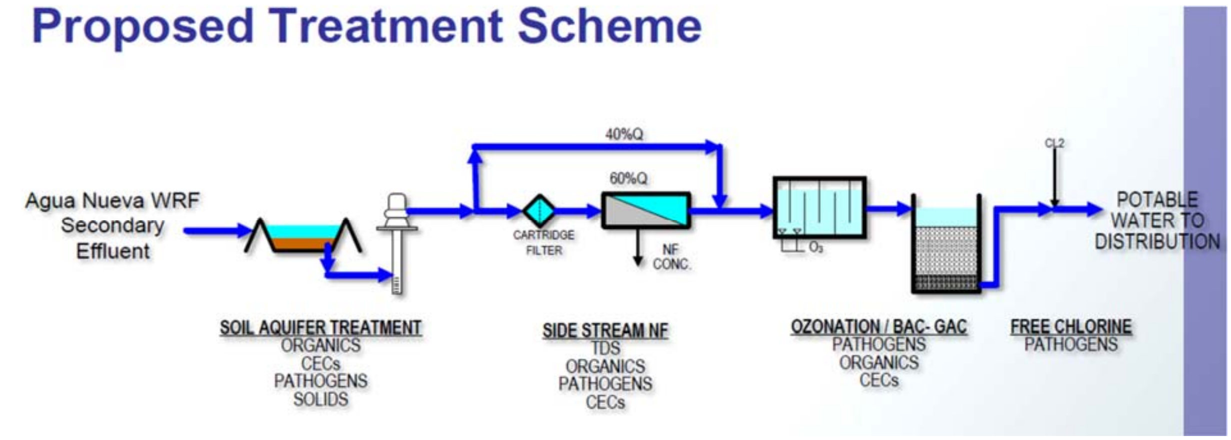

Figure 5.6. Conceptual Design for the Agua Nueva WRF Secondary Treatment Process.
(From: Schimmoller, et al., 2015)

The goal of this research was to test multiple treatment barriers and determine how effective they are in removing organic chemicals and pathogens from treated wastewater. Tucson Water also evaluated how effective this multi-barrier approach was in reducing energy consumption throughout the process and how efficient the treatment was in removing salts that impact the treatment process. Preliminary results indicate using a multi-barrier treatment was effective in removing total organic carbon and 44 ECs from the treated wastewater. The combination of multiple treatment barriers in this sequence reduced the salt concentrate below EPA's secondary standard of 500 mg/L, reduced disinfection by-products to below regulated levels, demonstrated removal of viruses and protozoa, and reduced energy costs (Schimmoller et al., 2015). Final results are pending. A copy of the project presentation can be accessed at *https://www.watereuse.org/wp-content/uploads/2015/10/S2B1_Schimmoller_AZWateReuse_2015.pdf*.

There are drawbacks to some of the processes. For example, membrane filtration such as RO is expensive to install and operate. It creates brine that must be carefully disposed of, and only 80% of treated water is recovered. Chlorination generates chlorinated by-products such as trihalomethanes and haloacetic acids, that are regulated by a maximum residual disinfectant level (MRDL) and their generation must be minimized.

PAC and GAC can be used either in drinking water or wastewater treatment processes to improve odor and taste, and remove many ECs through adsorption of compounds to the carbon particle surfaces.

5.2.1 Advanced Treatment Facilities in Arizona

The following are examples of advanced water treatment methods being used in Arizona to remove ECs from wastewater and drinking water. Before implementing any advanced treatment methods, the City of Scottsdale and Tucson Water performed research studies and pilot testing that determined which advanced treatment method was the most cost effective and proven method in removing the EC of concern at each utility.

5.2.1.1 Scottsdale Water Campus – Wastewater

Scottsdale's primary Water Reclamation Plant located at the Water Campus provides state-of-the-art technology to treat wastewater generated in north and central Scottsdale for irrigation of turf (primarily golf courses). The treatment process includes nitrification and denitrification, followed by tertiary treatment and disinfection, that provides class A+ reclaimed water, as defined by ADEQ. As part of the assured water supply program, the city also conducts groundwater recharge at the Water Campus using reclaimed water. Before recharge, the Class A+ reclaimed water is treated through the Advanced Water Treatment (AWT) Plant. The AWT consists of microfiltration, RO, UV, post-treatment stabilization, and vadose zone recharge wells.

5.2.1.2 Tucson Water – Groundwater

Tucson Water's Tucson Airport Remediation Project (TARP) and AOP treatment plants (Figure 5.7) provide a two-step treatment process using conventional and state-of-the-art technologies to remove TCE and 1,4 dioxane from groundwater used to produce drinking water. From the 1940s to the 1970s, industries near the Tucson International Airport (TIA) released TCE and 1,4-dioxane as by-products of aircraft manufacturing. These hazardous wastes went into pits, seeped into the ground, and contaminated an area of the aquifer.

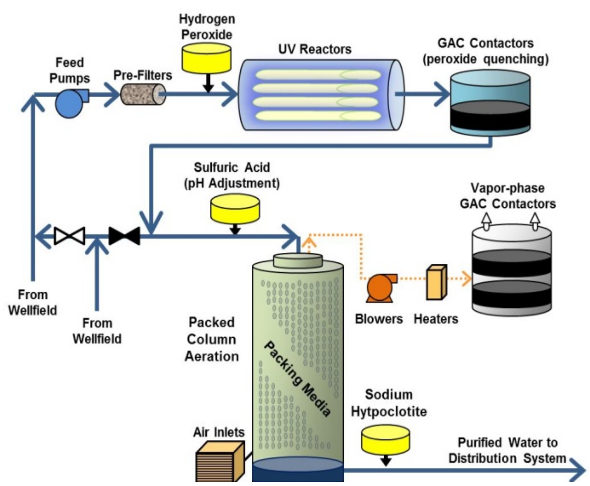

Figure 5.7. Schematic of the AOP Plant. (*https://www.tucsonaz.gov/files/water/docs/how_aop_works_2012.pdf*)

AOP uses hydrogen peroxide and UV light to form a powerful photochemical reaction by creating hydroxyl radicals that destroy and remove the 1,4-dioxane, viruses, bacteria, and other contaminants in the groundwater. Any remaining hydrogen peroxide is removed using GAC. Once the 1,4-dioxane is removed to a non-detectable level, this water is further treated to remove TCE using an air stripping treatment process. This highly treated groundwater water is chlorinated and introduced into Tucson Water's drinking water distribution system.

5.2.1.3 Raytheon and U.S. Air Force - Groundwater

A different AOP treatment method, using hydrogen peroxide and ozone, was started in 2008 at Raytheon's Plant 44 facility to remove 1,4-dioxane and TCE in groundwater extracted with a pump-and-treat system. The treated water is reinjected into the aquifer onsite as part of the pump-and-treat design. The Plant 44 site is part of the same TIA Area National Priority List Superfund site as Tucson Water's TARP and AOP treatment facilities.

5.3 NEW RESEARCH AREAS

New ECs are being identified every day as laboratory testing becomes more robust and reliable and new health information is made available as a result of ongoing research efforts. Public utilities, research foundations, state and local regulatory agencies, and academia are all actively identifying research topics. EPA has developed two programs that directly address the issue of physiological outcomes from exposure to ECs. The Endocrine Disruption Screening Program was built to create assays that allow for understanding whether individual compounds affect reproduction and thyroid hormone function that induce adverse outcomes. The Toxicity Forecaster program is a suite of high throughput and computational tools used to rapidly evaluate compounds for potential toxicological and endocrine disrupting outcomes. Scientists at EPA are using data derived from both programs to determine which compounds may be of greatest human and wildlife health concerns.

5.3.1 Chemical Contaminants

The list of ECs is ever expanding as new compounds are detected by improved analytical methods, which can detect these chemicals at ultra-low levels, and from newly published research data and information on the effects of these compounds. As a result, health guidelines can be issued ahead of a regulation to provide guidance to drinking water utilities and the consumer on what concentration is considered harmful when drinking tap water. This area of research is advancing as new chemical groups are added to the list. For example, PFCs and hexavalent chromium are currently being researched and studied by EPA, academia, and other research groups to determine their occurrence and prevalence in water sources and drinking water, and the toxic effects of consuming low concentrations that may be found in drinking water.

5.3.2 Microbial Contaminants

Unregulated emerging pathogens and other biological entities such as enterovirus, norovirus, prions, thermophilic amoebas, and endotoxins are also causing concern. There is limited research into this area, although emerging water-based pathogens such as the amoeba *Naegleria fowleri* have been detected in chlorinated municipal drinking water systems (APEC, 2014).

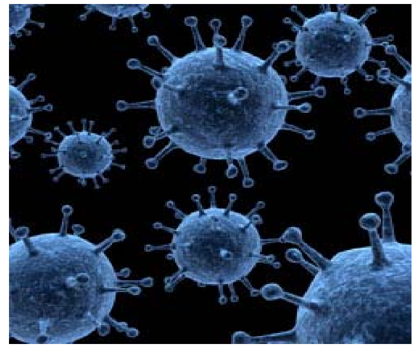

Figure 5.8. Enterovirus. (*http://www.epa.gov/microbes/rese*

Currently there are no rapid methods that can reliably identify these types of water-based pathogens and more research is needed to develop rapid and reliable methods of detection.

In most cases the emerging pathogens can be removed by chlorination although enterovirus and noroviruses are more resistant to low level disinfection and may require advanced treatment methods to remove them from water sources and drinking water.

5.3.3 Nanoparticles

Nanoparticles represent a newly-recognized EC in the form of colloidal-sized material that has at least two dimensions between approximately 1 and 100 nanometers (~one billionth of a meter). More than 1,000 consumer products contain nanoparticles including plastic beads for abrasive cleaning in toothpaste, titanium oxides in UV radiation blockers, carbon fullerenes in medical and conduction applications, polymers that are used in drug delivery, and nanosilver which has high antimicrobial properties when used in water purification. Research efforts are ongoing concerning toxicity, fate and transport, and removal. Research is also being conducted on how nanoparticles can be used to clean water.

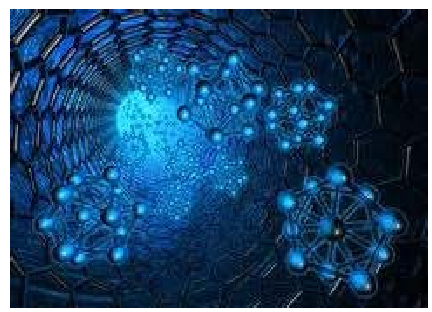

Figure 5.9. Nanoparticles. (*dreamstime.com*)

5.3.4 Microplastic Beads and Fibers

Microplastic beads are found in PCPs such as exfoliating scrubs, toothpastes, shower gels, and soaps. They range from 50 to 500 microns in size and are flushed down the drain as part of their intended use. The category also includes plastic-based clothing, including polyester and many synthetic fabrics that break down in the washing machine and release tiny fibers into the water (Gettler, 2015). Microplastic beads and fibers

Figure 5.10. Microplastic beads. (*http://www.npr.org/2014/05/21/313157701/why-those-tiny-*

may not be completely recoverable through conventional wastewater treatment and so may be released into the environment where they may persist and attract chemicals such as dichlorodiphenyl-trichloroethane (DDT), polychlorinated biphenyls (PCBs), and flame retardants. They have been detected in lakes, oceans, fish, lobsters, mussels, oysters, and higher in the food chain. A recent study has developed an analytical method for detection and quantification for microplastic beads in treated wastewater, determined the fate of microplastics in a municipal wastewater treatment system, and determined a significant removal rate was possible using conventional wastewater treatment (Suri et al., 2015). A copy of Suri's presentation on microplastic beads can be accessed at *http://static.azdeq.gov/wqd/ microplastic_beads.pdf*. Research efforts are ongoing concerning toxicity, fate and transport, and treatment for removal of microplastic beads and fibers from treated wastewater.

5.4 POTABLE REUSE

All of Arizona's reclaimed wastewater reuse is currently for non-potable irrigation, industrial activities, or augmentation of local groundwater supplies. In the near future, reclaimed wastewater and recycled wastewater will be used as a water source to create drinking water for many municipalities. *Potable reuse* is the term used to describe use of reclaimed water or recycled wastewater as a source of drinking water. Potable reuse can occur in two ways: direct and indirect. Direct potable reuse is the intentional advanced treatment of wastewater with the delivery to a water plant for distribution as a potable water supply for end users. This is done without returning the treated wastewater to the environment prior to a recapture of the water at a later time for potable treatment and use. In Arizona, only indirect potable reuse is employed.

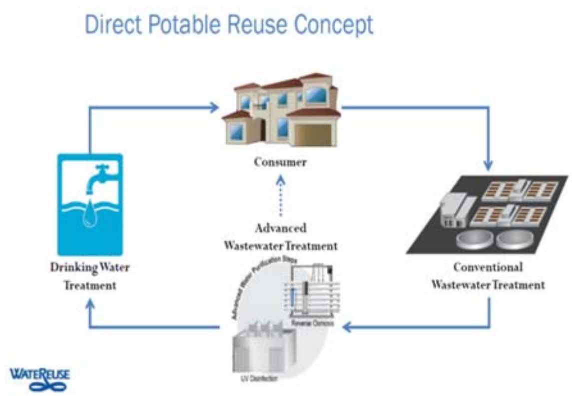

Figure 5.11. Direct potable reuse.
(From: Meeker, M. Southern California Water Conference. November 2014)

Indirect potable reuse is when the treated wastewater is returned to the environment, either a surface water body or recharged into an aquifer, then recovered later by a water treatment facility or groundwater well with the intent to deliver as potable water.

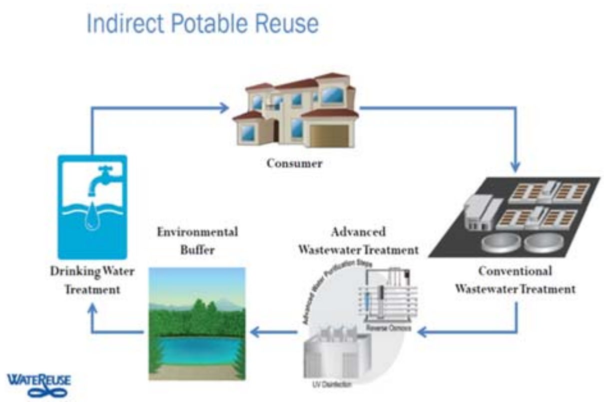

Figure 5.12. Indirect potable reuse.
(From: Meeker, M. Southern California Water Summit, November 2014)

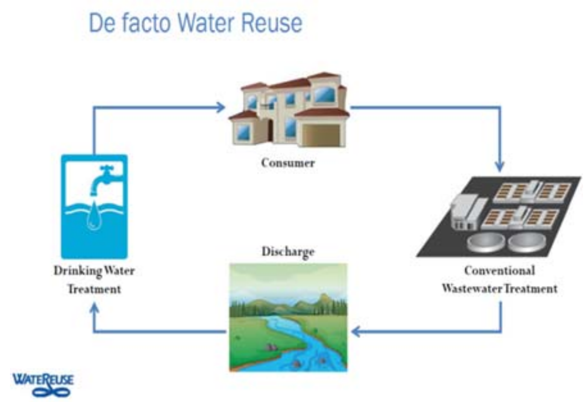

Figure 5.13. De facto water reuse.
(From: Meeker, M. Southern California Water Summit, November 2014)

De facto potable reuse is actually very common for many major surface water potable sources (e.g., Colorado River). For example, City A discharges treated wastewater into a river (which is a common practice). City B, located downstream of City A, uses water from that same river for its potable water supply (also common practice for many cities and towns). Thus, City B is implementing defacto potable reuse. For Arizona, de facto indirect potable reuse is practiced in many locations as treated wastewater recharge occurs in the State's aquifers, all of which are designated for potable supply. This type of de facto potable reuse is very prevalent in the Tucson and Phoenix metropolitan areas.

With the potential for water shortages during drought cycles, direct potable reuse may become an optional water resource strategy for communities with stressed water resource supplies. WateReuse Arizona has taken the lead on organizing a statewide initiative to study the potential for Arizona to develop direct potable reuse standards. Arizona rules currently prohibit direct use of reclaimed water as a potable supply. This initiative was a direct recommendation from the Governor's Blue Ribbon Panel on Water Sustainability in 2010 (ADEQ, 2010). With the creation of the Steering Committee on Arizona Potable Reuse (SCAPR), state agencies and some municipalities are investigating the feasibility, logistics, and legalities of direct potable reuse by observing similar activities initiated in California, Texas, and elsewhere. ECs, many of which survive traditional wastewater treatment processes, are being considered for possible mitigation if direct potable reuse is implemented in Arizona.

Part of the SCAPR research will focus on treatment techniques available to assist in minimizing exposure to ECs. Currently in Tucson, the U of A in collaboration with Tucson Water and the Pima County Regional Wastewater Reclamation Department conducted research on how nanofiltration and ozonation might be used effectively to remove ECs from recycled water that would be used for potable reuse. The study concluded that a multi-barrier treatment approach was effective in removing 44 chemical ECs (WRRF 13-09). In addition, online sensors are being tested to determine if real-time sensors can be used to detect verifiable anomalies within the treatment process and be able to correct them before delivering that water to the customer (WRRF, 14-01). These types of studies are needed to further advance our knowledge about the feasibility of treating recycled water to drinking water standards. This area of research needs to be expanded to be able to use recycled water as a viable source for multiple applications.

SCAPR intends to use the information gathered from APEC to help understand the diversity and complexity of unregulated ECs in the environment in Arizona. A web site for SCAPR is listed as an additional resource in Section 5.6.

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5.5.2 Additional Sources of Information

USGS Water Data Center

U.S. Geological Survey Water-Quality Data for the Nation: *http://waterdata.usgs.gov/nwis/qw*

Occurrence Studies

USGS Website for published reports: *http://pubs.er.usgs.gov/*

U of A Contaminant Transport Group: *http://www.u.arizona.edu/~brusseau/home.htm*

Arizona Laboratory for Emerging Contaminants: *http://www.alec.arizona.edu/*

Tucson Water, Water Quality webpage: *http://www.tucsonaz.gov/water/water-quality*

ASU School of Sustainability*: http://schoolofsustainability.asu.edu*

Pima County Wastewater Management Plan, 2013 AZPDES Annual Report: *http://webcms.pima.gov/UserFiles/Servers/Server_6/File/Government/Environmental%20Quality/Water/Stormwater/2013-Annual-MS4-Report.pdf*

Pima County Storm Water Quality and Rainwater Harvesting

Pima County Stormwater webpage: *http://webcms.pima.gov/cms/One.aspx?portalId=169&pageId=62831*

Treatment Techniques

WateReuse.org: *https://www.watereuse.org/foundation*

City of Tucson AOP Water Treatment Facility: *http://www.tucsonaz.gov/water/aop*

NanoParticles

EPA Emerging Contaminants – Nanoparticles (Dec 2010): *https://archive.epa.gov/region9/mediacenter/web/pdf/emerging_contaminant_nanomaterials.pdf*

NOAA, Are Your Clothes Shedding Plastic Into the Ocean? (April 30, 2012): *http://response.restoration.noaa.gov/about/media/are-your-clothes-shedding-plastic-ocean.html*

Potable Reuse

Steering Committee on Arizona Potable Reuse (SCAPR): *http://www.azwater.org/members/group_content_view.asp?group=141433&id=434712*

WateReuse Arizona: *http://www.watereuse.org/sections/arizona*

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Toxicology

EPA The Endocrine Disruption Screening Program: *https://www.epa.gov/endocrine-disruption/endocrine-disruptor-screening-program-edsp-overview*

The Toxicity Forecaster Program: *https://www.epa.gov/chemical-research/toxicity-forecasting*

6.0 Guidance for Utilities

This section will provide utilities with information to determine the best approach to collect and interpret occurrence data and information that provides the EC signatures for their source water and distribution system. Each utility is unique in their individual watershed and distribution system configuration, and each has the ability to implement a watershed and land use approach to investigate sources of water pollution.

In 2013, APEC's Outreach and Education Subcommittee sent a 26-question online survey to water utilities to determine their concerns with ECs. Using the survey results and information gathered on the occurrence of ECs in water, APEC categorized, reviewed, and interpreted the types and sources of ECs, potential and known public health effects, diverse treatment techniques, and pollution prevention strategies.

To effectively address and manage ECs, utilities need to develop a decision framework to make sound decisions on monitoring programs, data collection and interpretation strategies, use of treatment technologies, response protocols, and corrective actions. In addition, it is critical that utilities create partnerships and collaborations with multiple groups to understand and advance the scientific knowledge of the different aspects of ECs and how they are interrelated to drinking water and treated wastewater. Collaborative partners include other utilities, research foundations, consultants, university researchers, non-governmental agencies, public health agencies, and government agencies.

This section also provides recommendations for water utilities to use as guidelines in creating a communications and surveillance framework to address the significance of ECs found in their watershed and drinking water distribution systems. Suggestions for collaborative partnerships are provided throughout. Water utilities have an obligation to address the public's questions concerning water quality issues. Two major difficulties that water utilities experience involve a) communicating a satisfactory answer when they do not have all of the information to give a complete response, and b) providing an effective and clear public communication on the information that is available.

6.1 APEC SURVEY

ECs are at the forefront of discussions among various stakeholder groups including water and wastewater utilities and the general public. The APEC survey was designed to gauge the utilities' level of awareness, interest, and preparedness related to ECs. The survey included questions in four areas: 1) which ECs were of concern to them and their customers, 2) what communication tools and resources that utilities use for information, 3) how prepared utilities are to address ECs, and 4) what resources they need to improve their overall knowledge and customer communication.

More than half of the respondents are “somewhat concerned” with ECs in their water systems, and they felt that their customers were also “somewhat concerned” with the issue. Respondents were primarily concerned with the presence of nanomaterials, disinfection byproducts, and fire retardants. However, based on customer interactions, most utilities believe their customers are primarily concerned with pharmaceuticals, PCPs, and microbial contaminants. Most utilities indicated they direct their customers to Federal or State regulatory agency websites for more information on ECs. Notably, most utilities indicated they have not developed a formal plan to monitor for or respond to the occurrence of ECs in their water. However, more than half of the respondents indicated they were prepared to provide information on ECs to their customers.

6.2 CREATING A DECISION FRAMEWORK

Since most ECs are not regulated, water utilities must make decisions about how to address them, whether to monitor for them, how to interpret, and how to respond to occurrence data. As our understanding of the tools to evaluate ECs advance, new or existing contaminants will be detected for the first time and new health effects will emerge for them. Note that concerns by customers and the public may develop before any regulatory decisions are made about the significance of particular ECs in drinking water. Utilities will need to discuss and decide what action, if any, to take in addressing this issue. Creating a decision framework provides the avenue to request guidance from regulatory agencies and the scientific community as a first step, to proactively address emerging water quality issues and set water quality goals that can support utilities as they address these complicated water quality and public health issues.

This decision framework will help to determine the potential actions, if any, which a utility may need to take when an EC is found in their water supplies. Utilities must figure out how to balance the potential risk of exposure to water with ECs against the cost of monitoring and controlling the exposure, which may divert resources away from other priorities within the water system. At a minimum, the framework should include the following components: developing analytical methods and monitoring programs, conducting occurrence, fate and transport studies, and improving treatment efficiency.

The WRF report on project WRF 4169 “Water Utility Framework for Responding to Emerging Contaminant Issues” (Daniel and Bywater, 2012) provides an example of how a utility can create a decision framework using a web-based tool. The framework contains the following areas: Emerging Issue Arises, Investigate Sound Science, Goal Setting, Finalize Plan, Take Action, Continued Reevaluation, Communication, and Continuously Incorporate New Information. This tool is interactive between the framework areas and the linked resources and provides editable worksheets. Utilities can tailor the framework to meet their specific needs.

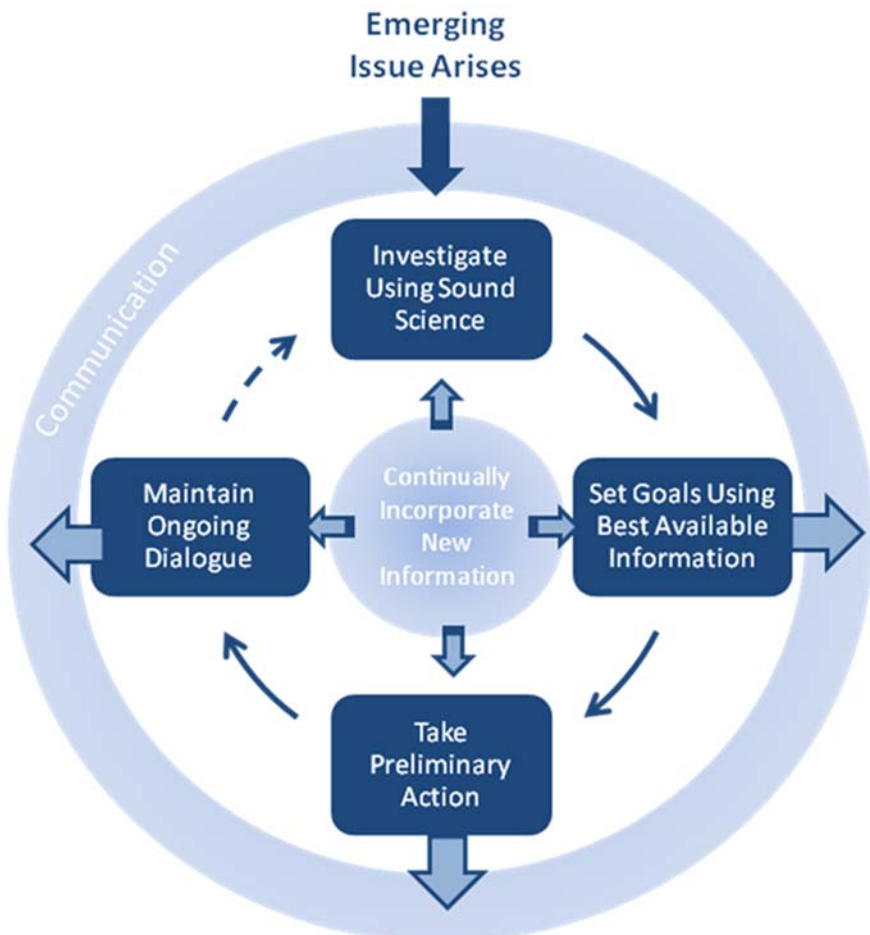

Figure 6.1. Decision Framework for responding to emerging contaminants.
(From: Water Utility Tool for Responding To Emerging Contaminant Issues, [Daniel and Bywater, 2012])

Three utilities that have developed decision frameworks addressing ECs are East Bay Municipal Utilities District (EBMUD) (Huntsinger, 2012), the San Francisco Public Utilities Commission (SFPUC) (Kennedy/Jenks, 2013), and the City of Scottsdale, Arizona.

6.2.1 East Bay Municipal Utilities District

EBMUD developed a Water Quality Construct as the roadmap to address water quality issues and set water quality goals. The first step was to assess drivers such as legislation, regulations, customer expectations, security, cost-benefit, health, and aesthetic information. Once the drivers were identified, research needs and water quality priorities were established and programs were developed to formulate an action plan. The action plan included setting water quality goals, identifying research studies or projects that could lead to operational changes, capital improvement projects, and improved EC monitoring. The Water Quality Construct provides improved communication to reach an understanding of whether to take action and what actions to take as necessary.

6.2.2 San Francisco Public Utilities Commission

SFPUC's Water Quality Division developed an approach that is specific to addressing ECs entitled "Proposed Approach for CECs in SFPUC's Drinking Water System" (Kennedy/Jenks, 2013). This approach provides a method to organize and prioritize activities including development of a sampling program, determining the appropriate sample analysis, data analysis and interpretation methods, literature review, participation in applied research, risk assessments, public outreach development, and stakeholder engagement.

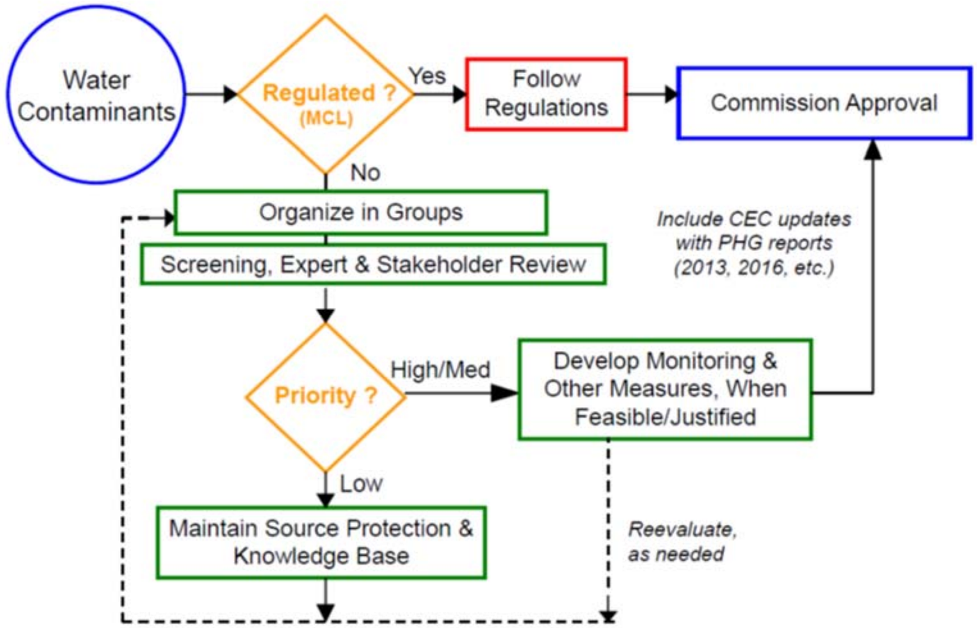

Figure 6.2. SFPCE Flowchart for screening and prioritizing ECs.
From Kennedy/Jenks Consultants, 2013

6.2.3 City of Scottsdale

In 2013, the City of Scottsdale expanded its Water Reclamation Plant and Advanced Water Treatment Facility at its Water Campus by increasing the capacity of the membrane filtration and RO treatment trains. Ozonation and UV photolysis treatment techniques were added for the removal of ECs. The facility treats Class A+ reclaimed water for the purpose of recharging groundwater using vadose zone injection wells. As part of the design and pilot testing of this expansion, the City and its engineers developed a decision framework for prioritizing the ECs to be monitored. Under this framework, an initial broad list of compounds was developed that could be present/found in the water being treated at the Advanced Water Treatment Facility.

The number of targeted chemicals were reduced and prioritized by evaluating the following factors:

- How often a chemical was cited in the current literature.
- Research associated with wastewater and reclaimed water systems.
- Chemicals representing different categories of ECs such as pharmaceuticals, industrial compounds, and steroids.
- Availability of internal laboratory standards.
- Which chemicals could be removed by the Advanced Water Treatment Facility.
- Which chemicals were being monitored by wastewater utilities with similar operations.
- Which chemicals were included on regulatory watch lists.

The review process produced a list of ECs, termed Compounds of Potential Concern (CPC), used to monitor the removal effectiveness of Scottsdale's advanced treatment processes (Cotton, et al., 2009). This list is included in Appendix B.

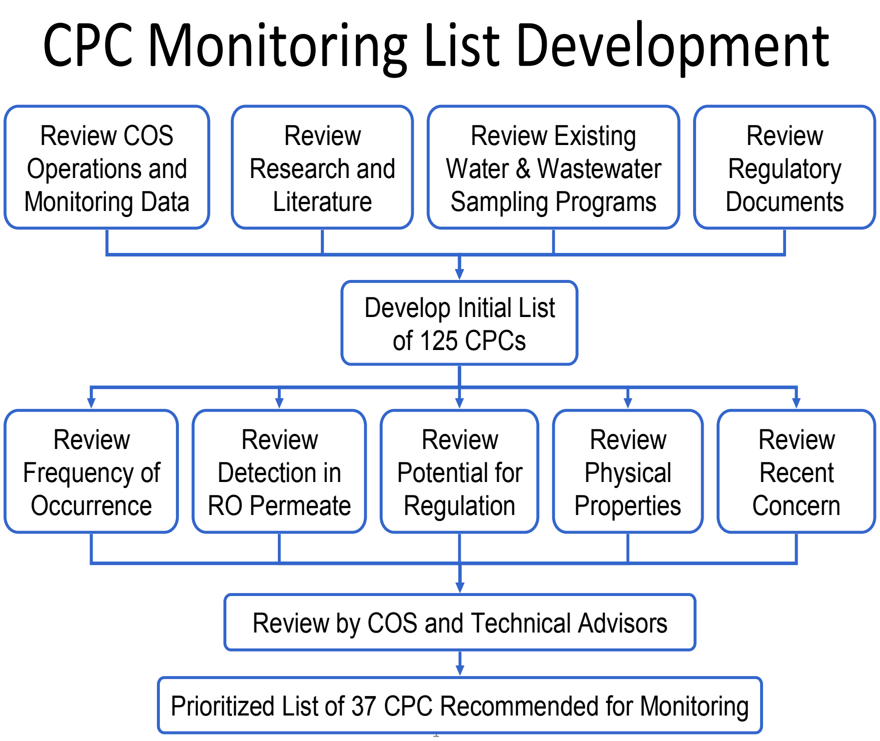

Figure 6.3. From: Prioritizing Compounds of Potential Concern at the Scottsdale (AZ) Water Campus, (Appendix B; Lee and Bryant, July 8, 2014).

6.3 CREATING A MONITORING AND SURVEILLANCE OCCURRENCE PROGRAM

By participating in federal surveillance occurrence programs such as the UCMR, drinking water utilities are already monitoring for ECs in their watersheds and distribution systems. The data and information collected through these programs provide a snapshot of the ECs that may be found in a utility's watershed and distribution system, and contributes to the national knowledge base on the occurrence of ECs. Utilities can use the UCMR sampling plan and results as a basis for creating and tailoring a monitoring and surveillance component of a decision framework.

Beyond EPA's efforts, individual communities and water systems can develop a monitoring and surveillance program to determine the occurrence of a broader list of ECs that is tailored to the utility's unique setting. The program should focus on the intended use of the data. Sampling and analytical protocols should be chosen to achieve the best, most consistent results for each individual community. The information gathered should be of known quality and complete enough to assist water systems in making sound water quality policy decisions. The program should provide information related to reasonable likelihood of occurrence, sampling frequency, sample collection consistency, reasoning for location selection, availability of robust analytical methods, and direction regarding interpretation of the data.

Establishing a monitoring and surveillance program is costly. As an example, the list of ECs monitored by Tucson Water shown in Appendix B costs in excess of $1,075 per sample. Therefore, the community should make every effort to ensure the acquired water quality data is clearly interpreted and applied. To accomplish this, it is necessary to develop a monitoring and surveillance plan that is detailed and specific enough to ensure reliable and consistent measurements.

According to ADEQ, when developing a monitoring and surveillance plan, the following items should be considered (ADEQ, 2008):

- Purpose and Background – What information is already known? What monitoring has been performed previously? Why is there a concern to be investigated? Is it mandated or investigative in nature? What will be accomplished by performing this monitoring?
- Project Description and Objectives – What questions are expected to be answered by the results? Specify the amount and quality of data required of the plan. Are there any standards to compare the results to?
- Site Descriptions – Define sampling site information including background/reference sites, bracketing sites, critical public health sites, and other relevant information. Include information on collection of representative samples and be sure that the sites selected are adequate to represent the location being sampled.

- Analytes and Field Measurements – Ensure that the analytical techniques chosen for the plan are robust and repeatable. They should provide data of a reliable quality and provide values low enough to be pertinent to the investigation. It is impossible to acquire a result for every possible contaminant, so this is a good place to specify a list of analytes that represents a cross section of contaminant types. See Appendix A for a suggested target analyte list.
- Field Documentation – Identify information that will be tracked during the sampling event. This may be critical for the proper interpretation of the results. This documentation should include weather conditions (past and current, as applicable), sampling issues, any deviations from the plan, flow information, sample identification, date & time of sample collection, etc.
- Monitoring Schedule and Target Conditions – When will monitoring be performed? Will it be targeted or at a specified frequency? What conditions existed when background samples were collected?
- Field Methods and Quality Control – Describe field protocols for the collection of samples. Include descriptions of protocols, equipment calibration quality control procedures and any other applicable details. It is important to incorporate proper sampling techniques to avoid introduction of contaminants during sample collection. The latest analytical techniques are so sensitive that they have been known to pick up trace levels of contaminants from the sampler’s breath. Think about how to test and maintain sampling equipment to prevent sample contamination.
- Lab Methods and Quality Control – Include details about laboratory methods and procedures. Determine if duplicate samples, split samples or field blanks are needed, and at what frequency. Determine data quality expected from each analysis. Make sure the laboratory performing the analysis has acceptable quality assurance and quality control procedures in place to ensure reliable data production. Determine the desired detection limit for the chosen ECs and insure the laboratory has the equipment capable of reaching it.
- Data Processing, Validation and Analysis – Describe how data will be compiled and summarized. Specify data quality requirements necessary to consider the values achieved are true and accurate. Determine what information collected should be used to determine what actions may need to be taken. How will it be determined if resampling is necessary or when results when will be invalidated when devising follow-up actions? How often does the data need to be evaluated and summarized? How will standards for action be developed?

- Field Safety – Consider that staff may be sampling some potentially harmful contaminants. Specify personal protective equipment needs during sampling to prevent contact with the sample source. Ensure that staff is aware of the closest emergency services, carry first aid kits, take adequate water, sun protection, etc.
- Staff Expertise and Training Needs – Be sure that all staff are familiar with the protocols specified in the plan from sample collection to data validation, interpretation, and use.

Developing a plan will ensure that the community and the utility will make the most efficient use of time, funding, and resources that will answer the questions at hand.

6.4 TREATMENT METHODS

Treatment methods vary depending on chemistry of the water source, the contaminants that need to be removed, regulatory drivers, customer drivers, type of treatment method, and cost. As described in Section 3, conventional treatment and disinfection practices are used by Arizona utilities to treat surface water and groundwater to produce drinking water, and to treat wastewater to produce reclaimed water. Although conventional treatment and disinfection practices remove regulated chemicals and microorganisms, they are only effective in removing some of the chemical and microbial ECs.

6.4.1 Advanced Treatment Techniques

In addition to conventional treatment (see Section 3.3) utilities can use advanced treatment techniques such as ultrafiltration, microfiltration, nanofiltration, RO, ozonation, and advanced oxidation techniques such as UV disinfection or ozonation combined with hydrogen peroxide oxidation to remove chemical contaminants from water that cannot be removed by conventional treatment methods. These advanced treatment techniques can be used independently or in combination with conventional treatment methods to remove regulated contaminants and ECs from source water and drinking water. Below is a general description of three advanced treatment techniques.

Reverse osmosis filters out viruses, salts, and a variety of chemicals. Water is forced through tubes that contain tightly wound membranes with tiny pores, leaving other dissolved materials behind.

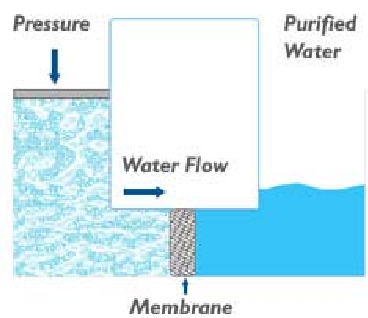

Figure 6.4. Reverse Osmosis. (*http://www.softwaterfiltration.com/reverse-osmosis-functionality/*)

UV light treatment is used to supplement other types of disinfection (Figure 6.5). It cannot be used alone since there is not any residual present to prevent biological growth in the distribution system.

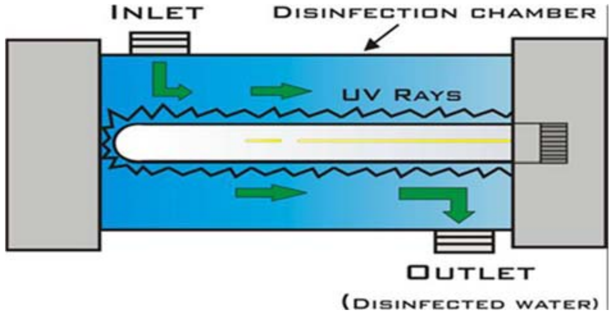

Figure 6.5. Ultra-Violet Light Treatment. (From: *https://www.uswatersystems.com/blog/2013/07/warning-dont-ever-put-a-uv-light-on-an-undersink-reverse-osmosis-undersink-system/*)

AOP treatment techniques are used to destroy any remaining chemicals and microbes present in the water (Figure 6.6). These techniques include using ozone, hydrogen peroxide, and UV light.

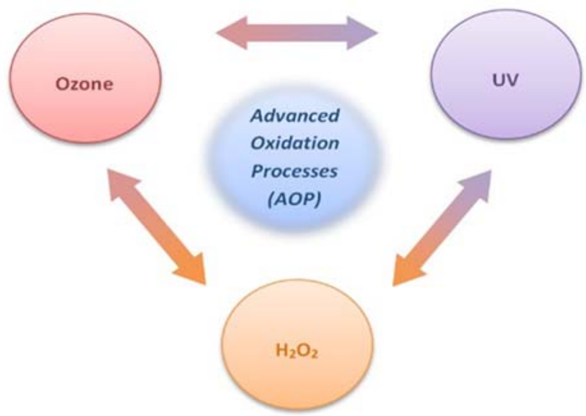

Figure 6.6. AOP Treatment Techniques. From: *http://www.aniwater.com/water-treatment/advanced-oxidation-reactions.html*

6.4.2 Advanced Filtration Treatment Methods

Filtration is another treatment method that can remove ECs from water. The filtration spectrum is comprised of different types of filters with different size pores as shown on Figure 6.6. There are six filter types that make up the filtration treatment spectrum: Coarse screens (0.25 in.) that remove large objects; sand filters (10 microns) that remove things like hairs; microfilters (0.1 micron) that remove bacteria; ultrafilters (0.01 micron) that remove viruses and organic chemicals; nanofilters (0.001 micron) that remove calcium and iron molecules; and RO filters (0.0001 micron) that remove nitrate molecules.

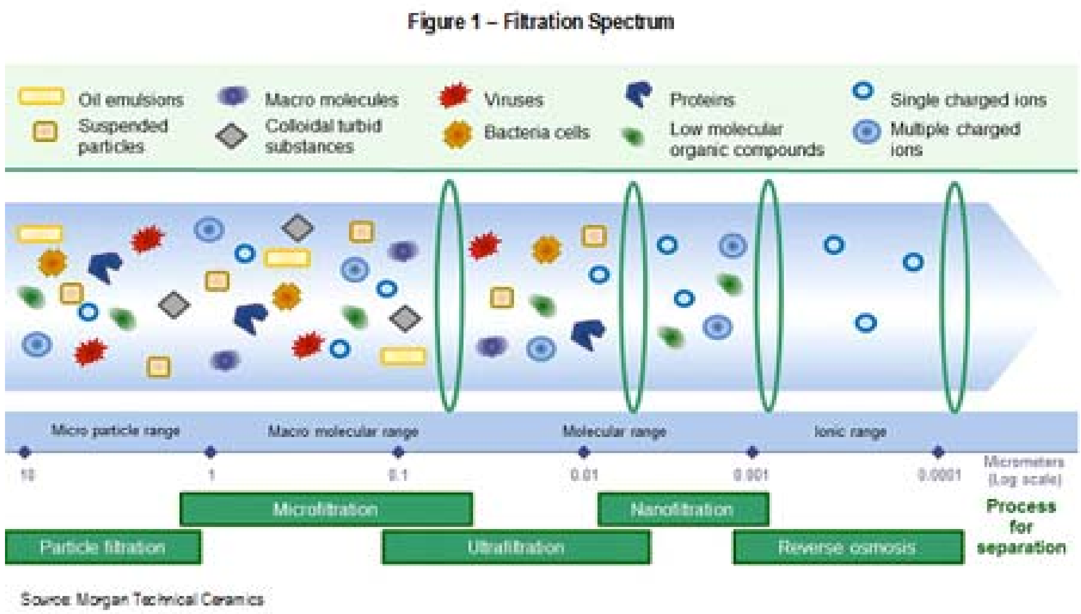

Figure 6.7. Filtration Spectrum. (From: Morgan Technical Ceramics)

6.4.3 Membrane Bioreactor Advanced Treatment

Microfiltration or ultrafiltration can be used as a single treatment process or combined with other treatment methods to improve the removal rates of ECs in wastewater. An example is using a Membrane Bioreactor (MBR) treatment method that combines microfiltration or nanofiltration with a suspended growth of bacteria contained in a bioreactor (Figure 6.8). The bacteria breakdown the solids present in the wastewater and the membrane retains the particles in the reactor for continued degradation releasing only clean water.

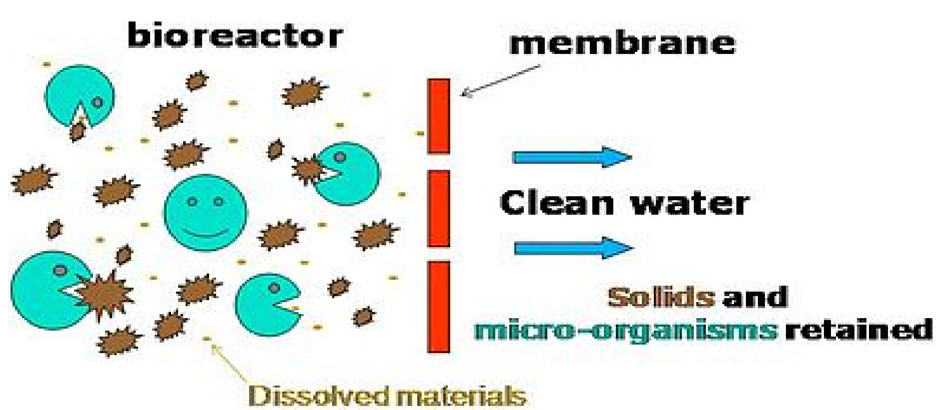

Figure 6.8. Simple Schematic of MBR Process.
(From: *https://en.wikipedia.org/wiki/Membrane_bioreactor)*

Even though using an MBR treatment process improves the reduction and removal of ECs, this treatment method does not remove all ECs as shown in the Figure 6.9.

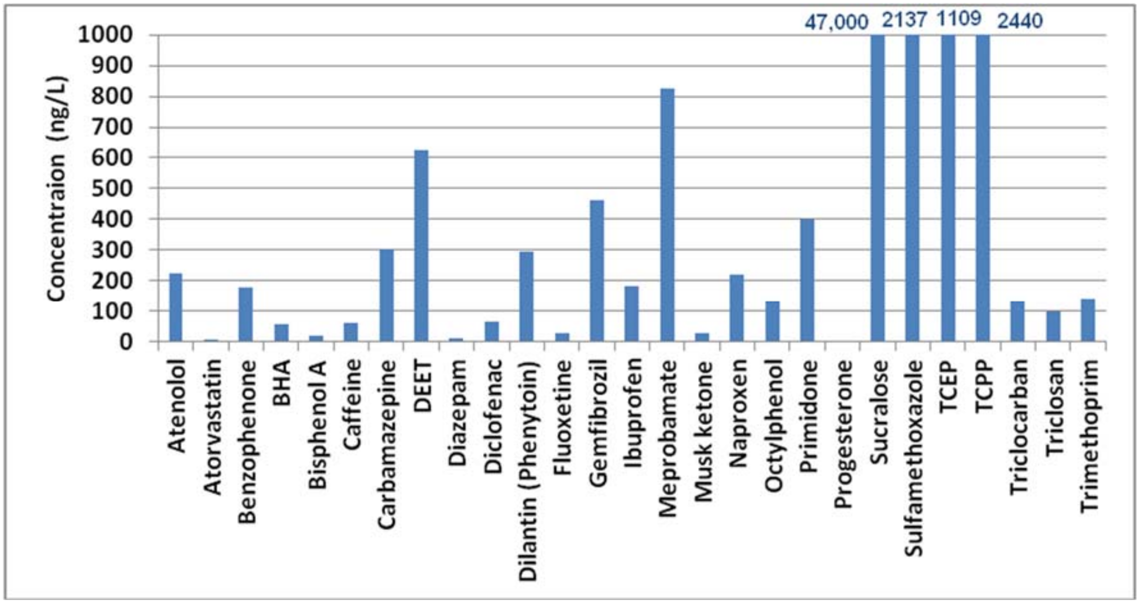

Figure 6.9. Average concentrations of ECs in Lake Havasu City's treated wastewater after treatment using a 0.4 micron MBR process (from Wilson and Lepp, 2013).

The water industry, utilities, and researchers are continuously studying how to best apply conventional and advanced treatment techniques and improve their ability to remove as many ECs as possible using different configurations and combinations of conventional and advanced treatment methods. New and novel treatment techniques are being developed to further enhance removal of chemical and microbial contaminants in drinking water and from treated wastewater used for potable reuse.

6.5 PARTICIPATING IN RESEARCH

It is essential that utilities participate in research to begin to understand the type of ECs and associated public health risk, if any, which may be found in their source waters, distribution systems, and drinking water. There are several ways utilities can collaborate in research efforts that can be cost effective. One inexpensive way is to provide in-kind services such as water samples for analyses, locations for field testing, current and historical water quality data, and technical expertise. Other areas of research include occurrence, fate and transport studies; development of new analytical methods, and new treatment method efficacy studies.

Interagency partnerships with research foundations, public health, other water and wastewater utilities, and state universities are valuable opportunities for collaboration. Utilities can become members of the NSF Water & Environmental Technology (WET) Center which is an Industry and University Cooperative Research Program (I/UCRC) with a focus on studying water quality issues and new technology for water treatment. There are over 30 industry members involved in research studies with the WET Center. The lead institution is Temple University with two other research site locations at the U of A and ASU. A website address is located under additional resources for this section.

Figure 6.10. The WEST Center at the Agua Nueva Facility in Tucson, AZ. *(http://west.arizona.edu/sites/default/files/u39/newsletter_vol1-issue1_new.pdf)*

The newly created Water and Energy Sustainability (WEST) Center is affiliated with the U of A and aspires to be a world renowned venue for research, education, outreach, and industrial partnerships in water treatment technologies, contaminant monitoring tools, energy minimization and production, and innovative educational and training components. The WEST Center is co-located with Pima County's Agua Nueva Water Reclamation Facility and will host an annual water and energy technology summit to bring in entities from around the world to discuss opportunities in water and energy technologies. The center will supply training and technology transfers to technicians, utility personnel, and U of A students, and provide unique services to the private sector through existing facilities and capabilities. A web address is provided in the Additional Resources section.

Collaborations with national research groups like the WRF, WE&RF, and the WRRF require some monetary commitment to fund the research but allow utilities to guide and evaluate the research projects. Suggestions for leveraging financial resources such as general costs, grants, partnering with local universities and governmental agencies, and determining the need for fee increases or bond levies can be found in Section 6.7.

6.6 COMMUNICATION

With the increase of awareness of ECs, wastewater and water utilities and municipal governments are regularly tasked with public information dissemination. Before utilities and municipal governments can disseminate information on ECs to their water customers, they need substantial data and a clear understanding of the issues. Typically, the water customer will want to know:

- What is the contaminant?
- Has it been discovered in the water sources in my community?
- What are the sources of the contaminant?
- What are the health risks?
- What are the analyses methods to detect and identify the contaminant?

- What are the treatment methods available to remove it?
- What is the cost?
- What are you doing about it?
- Can it harm me and my family?
- What can I do to protect myself and my family?

A clear understandable message is vital for the public. This is an opportunity to educate the public on how they can prevent some of the pollution, for example through proper disposal of:

- prescription drugs (Figure 6.11),

Figure 6.11. www.doctoroz.com

- personal care products (Figure 6.12),

Figure 6.12. Chemicalfreelife.tumblr.com

- and household hazardous waste (Figure 6.13).

Figure 6.13. www.hazwastehelp.org

Education is essential to prevent water pollution and empower the public to be part of the solution, which can reduce skepticism, over reaction and uncertainty. In the event of a water system interruption, contamination incident or other public concern issue, water system managers and regulatory agencies will serve their public best by recognizing and understanding the psychological, social, and cultural factors that influence public perception of risk. This subsection is an overview of an extensive body of research into citizen response that Public Information Officers (PIOs) for water systems and regulatory agencies may be confronted with after disclosing information that has the potential to alarm even one person. A good practice for utility and regulatory agency PIOs is early acknowledgment and disclosure of potentially negative information because trust may be lost if heard first from a reporter, internet source, social media source, or friend. It is human nature to be skeptical of government and the utilities to which they pay their bills. Many also fear exposure to involuntary risks that are beyond their control and may involve highly technical knowledge to fully understand the context of the risks. This combination of human factors has been dubbed “low trust, high concern” by risk communication professionals.

6.6.1 Low Trust, High Concern Model

To help water system managers and regulatory agencies understand the “Low Trust, High Concern” model of human risk perception, Table 6.1 provides a summary of the research. The term “outrage” is used to express the most extreme human emotional response to a fear factor. People are more likely to believe and accept current, factual public information that is associated with the outrage factors listed on the left side of Table 6.1. Several of the outrage factors fall within the scope of public water systems as we have observed in the Flint, Michigan case. For example, many members of the public do not have the financial resources to suddenly be forced to purchase bottled water from a grocery store. If a water contamination incident is due to a chemical or microorganism with insufficient toxicological data or other public health information regarding risk, then the public may become even more enraged over the incident.

Table 6.1. Outrage Factors; Safer vs. Riskier

LESS Outrage	MORE Outrage
Voluntary	Coerced
Natural	Industrial
Familiar	Exotic
Not Dreaded	Dreaded
Chronic	Catastrophic
Knowable	Unknowable
Individually Controlled	Controlled by Others
Fair	Unfair
Morally Irrelevant	Morally Relevant
Trustworthy Source	Untrustworthy Source

Water system managers and regulatory agencies will provide the best public service possible by developing sound risk communication plans that incorporate timely information that educate the consumer as to what it means to have an EC present in the drinking water. This includes providing an understanding of the type of EC found, the risks in consuming that EC and what the consumer can do to protect themselves and their families.

Over the years, agencies have successfully used the Seven Cardinal Rules of Risk Communication that were originally developed by Vincent T. Covello and Frederick W. Allen in 1988. Some examples are listed at the end of this section. One of the most succinct listings of the seven rules is found on the Agency for Toxic Substances and Disease Registry (ATSDR) webpage (*http://www.atsdr.cdc.gov/*):

Seven Cardinal Rules of Risk Communication (Covello and Allen, 1988):

1. **Accept and involve the public as a partner.** Your goal is to produce an informed public, not to defuse public concerns or replace actions.

2. **Plan carefully and evaluate your efforts.** Different goals, audiences, and media require different actions.

3. **Listen to the public's specific concerns.** People often care more about trust, credibility, competence, fairness, and empathy than about statistics and details.

4. **Be honest, frank, and open.** Trust and credibility are difficult to obtain; once lost, they are almost impossible to regain.

5. **Work with other credible sources.** Conflicts and disagreements among organizations make communication with the public much more difficult.

6. **Meet the needs of the media.** The media are usually more interested in politics than risk, simplicity than complexity, danger than safety.

7. **Speak Clearly and with Compassion.** Never let your efforts prevent your acknowledging the tragedy of an illness, injury or death.

People can understand risk information, but they may still not agree with you; some people will not be satisfied.

6.6.2 Public Perception

A subtopic of risk communication is public participation. Public participation is a successful method for reducing public fear and outrage after a negative or potentially negative disclosure. A fact finding and disclosure course of action should help to improve public understanding and reaction to potentially alarming news. The goal of risk communication through public participation is to reduce public misperceptions and misunderstandings, thereby increasing trust and reducing fear.

Research shows that the public wants to know that the responsible organization and spokesperson genuinely cares and empathizes with them. They also need and deserve all available factual information. The PIO must avoid the use of unnecessary, indefensible or unproductive uses of absolutes such as the words no, not, never, nothing, and none. Remember, there is risk in everything people do in their daily lives. So, don't tell people there is "no risk", they won't believe it.

6.6.3 Risk Comparisons

Risk comparisons are a common approach used to convey relative risk. When dealing with the issues of ECs in drinking water, PIOs often lack the answers to questions being asked by the public. Best practices for PIOs include:

- Acknowledge uncertainty;
- Explain that risks are difficult to assess and estimate based on the incomplete information;
- Explain how risk assessments were obtained;
- Announce problems and share risk information promptly;
- Tell people the degree of certainty (highly improbable to certain) that you have in the currently available information;
- Tell people when you expect to have more information; and
- Tell people what is being done to reduce uncertainty.

The goal of risk comparisons is to make a risk number more meaningful by comparing it to other numbers. Some members of the public may disagree with the risk comparison. Some individuals may perceive that the messenger is attempting to trivialize the problem. This is counter to the recommended best practice of remaining neutral. An involuntary, unfair, and dreadful risk is unlikely to be accepted. People have a right to make their own evaluation of risk comparisons. Risk numbers cannot preempt those decisions.

The most effective risk comparisons are:

- Comparisons of the same risk at two different times;
- Comparisons with a regulatory standard;
- Comparisons with different estimates of the same risk;
- Comparisons of the risk of doing something versus not doing it;
- Comparisons of alternative solutions to the same problem; and
- Comparisons with the same risk as experienced in other places.

A typical approach taken by leaders and spokespersons of private and public organizations is to develop an idea (new product or service) or policy (proposed regulation); decide that the public must embrace the concept; announce the product, service, or policy; and then defend the decision to sell or impose the product, service, or policy upon the public. This traditional model of "selling the product, service or policy" has been coined by Larry Susskind as the "decide, announce, defend" (DAD) approach. DAD should be avoided because it does not acknowledge and utilize public ideas that may benefit the outcome. The organization is immediately perceived by the public as not neutral. Some public members may be offended, especially if they perceive an attitude of arrogance.

6.6.4 Public Participation

Dealing with ECs at the state level is not expected to include rulemaking. If an EC-related policy of any kind is contemplated, then a public participation process is necessary. A sustainable decision is one that is publicly acceptable, environmentally compatible, technically feasible, and economically viable. Public involvement is done best when the public is involved in the decision-making process.

Techniques for reducing public fear, anger and outrage include:

- Be neutral. Do not be dragged into polarized debates.
- Acknowledge current problems and empathize.
- Discuss achievements with humility; give credit to critics who often provide innovative ideas on how to craft a proposed policy change.
- Share control and be accountable; do research with stakeholders.
- Understand unvoiced concerns and underlying motives (greed, ego, fear, etc.).
- Do not speak in jargon.
- Be an active listener.
- Conduct meetings in the affected community.
- Use face-to-face communication wherever possible.

Best practices for public participation include:

- Include all stakeholders.
- Scrutinize information to avoid erroneous information dissemination.
- Find the balance between giving too little and too much information.

- Provide feedback to public input.
- Know your audience (personally affected persons, activists, politicians, etc.).
- Identify the best and worst questions you may be asked.
- Incorporate recommendations from the public into the final decision to the maximum extent possible.

The International Association for Public Participation (IAP2) describes public participation as a spectrum of an increasing level of public impact on a proposed public policy decision (Suskind and Field, 1996). Figure 6.14 displays the range of goals of that a decision-maker may choose, depending upon the specific policy type.

IAP2'S PUBLIC PARTICIPATION SPECTRUM

The IAP2 Federation has developed the Spectrum to help groups define the public's role in any public participation process. The IAP2 Spectrum is quickly becoming an international standard.

INCREASING IMPACT ON THE DECISION →

	INFORM	CONSULT	INVOLVE	COLLABORATE	EMPOWER
PUBLIC PARTICIPATION GOAL	To provide the public with balanced and objective information to assist them in understanding the problem, alternatives, opportunities and/or solutions.	To obtain public feedback on analysis, alternatives and/or decisions.	To work directly with the public throughout the process to ensure that public concerns and aspirations are consistently understood and considered.	To partner with the public in each aspect of the decision including the development of alternatives and the identification of the preferred solution.	To place final decision making in the hands of the public.
PROMISE TO THE PUBLIC	We will keep you informed.	We will keep you informed, listen to and acknowledge concerns and aspirations, and provide feedback on how public input influenced the decision. We will seek your feedback on drafts and proposals.	We will work with you to ensure that your concerns and aspirations are directly reflected in the alternatives developed and provide feedback on how public input influenced the decision.	We will work together with you to formulate solutions and incorporate your advice and recommendations into the decisions to the maximum extent possible.	We will implement what you decide.

Figure 6.14. IAPs public participation spectrum to show the varying levels of public impact a developed policy or program. From: *http://c.ymcdn.com/sites/www.iap2.org/resource/resmgr/Foundations_Course/IAP2_P2_Spectrum.pdf?hhSearchTerms=%22spectrum%22*

6.6.5 Water Research Foundation Tools

The WRF published a report in late 2013 discussing consumer perceptions and attitudes towards endocrine disrupting compounds (EDCs) and chemicals from pharmaceuticals and personal care products (PPCPs) in drinking water (WRF 4323, 2013). The report includes a list of recommendations for water utilities. Two key recommendations from this report include: 1) provide transparent communications about contaminants, and 2) provide impartial communication about contaminants in a neutral tone. The WRF has published other relevant publications including a Water Primer on EDCs/PPCPs for Public Outreach (WRF 4387a, 2015); and an on-line network for water utilities to collaborate on EDCs found in their areas (WRF 4261, 2013). Several other WRF reports on the topic of ECs are in progress including a project to develop core messages for the water community to communicate with different audiences about the risks of key or priority ECs. It will also provide guidance to water utilities regarding risk communication for different types of ECs in general (WRF 4457, 2015). WRF has also developed a Knowledge Portal tool to provide information on ECs, including Fact Sheets, links to related research projects, and other web tools and resources. The link to the WRF-Knowledge Portal is provided under Additional Resources for this section. In summary, effective EC Communication Strategies should include:

- Building partnerships with other organizations;
- Adopting best practices to improve risk (safety) communication; and
- Knowing your audience and tailoring messages accordingly.

6.7 FINANCIAL CONSIDERATIONS

Utilities must manage and adapt to the many challenges of aging infrastructures, optimizing treatment technique, growth, and increased maintenance costs that are involved in managing the utility business. How do utility management and operation management teams plan for and execute the priorities involved in running a utility while focusing on customer service, meeting water quality regulatory compliance, engaging in research efforts, and balancing reduced resources and budgets?

Many utilities draw from the same source waters and can reduce the cost of their investigations by partnering with others on projects of mutual benefit and interest. It is advantageous to pool dollars and resources to achieve a multi-utility benefit.

6.7.1 Budgeting

Once a utility has identified one or more ECs which require further investigation, a general cost estimate and schedule should be developed. Identifying the goals, project scope, and available resources will make it easier to develop a rough budget and focus resources. Preliminary questions include:

- How often and at what concentrations are the ECs detected in the source water?
- At what concentrations are the ECs detected in the water served to the customer?
- Are the ECs being studied by other entities? Have guidance levels been issued? Do the studies indicate health risks? How likely are the ECs to come under federal regulations and when?
- Is the public concerned about the ECs?
- If multiple ECs are present, which will require treatment?
- What are the utility's desired maximum levels for the ECs in the water?
- Is the desired level feasible given current technology and budget?
- Can treatment methods already in use by the utility be modified to remove the ECs?
- What kinds of technologies are readily available to remove the EC? Will pilot or bench testing be needed?
- Will the utility's existing treatment and delivery facilities accommodate the treatment method, or will additional facilities be required?

The EPA has developed information resources to assist with cost estimation for selected treatment technologies (EPA, 2007). Information on bench and pilot scale testing needed for utilities is also available from the EPA (EPA, 1996).

6.7.2 Financial Resources

6.7.2.1 Grants

Government agencies and private utilities have the opportunity to partner with universities who are conducting studies of ECs. When partnering with universities, the in-kind portion of a grant may not be required. The partnerships could be used to fund a study in an area of Arizona that has not yet identified any contaminants, discover health risks for newly discovered ECs, or create new materials for information dissemination.

Various agencies within the federal government provide grants for water and wastewater utilities to conduct monitoring programs and upgrade equipment. The U.S. Senate published a summary of federal agencies that issue grants and a guide to navigating the grant process (Gillibrand, 2015).

Technology Research Initiative Fund (TRIF) grants can be used for water infrastructure projects. The grants fund significant research projects in the biosciences; sustainability, and information sciences. The grants are supported at ASU, NAU, and the U of A. Utilities can collaborate with any Arizona state university to obtain TRIF funding.

6.7.2.2 Capital Improvement Programs

Most utility Capital Improvement Programs (CIP) expenditures are projected for 5 to 10 years. Municipal utilities will need to be able to predict a modification in treatment if a particular EC becomes regulated and requires advanced treatment. Cities can receive revenues for CIP through local sales and property taxes, and state sales and income taxes. Other funding options for CIP are municipal bonds, lease-purchase agreements, improvement districts, federal grants, and user fees.

6.8 ADDITIONAL TOOLS

Utilities should collaborate with peers at conferences and through organizations such as the American Water Works Association (AWWA). The AWWA website also has many tools to assist water and wastewater utilities in EC management strategies, source water protection, customer service, risk communication, and more.

The EDC Network for Water Utilities (WRF 4261, 2013) is an online network that is hosted by the WRF to promote collaboration among water utilities and improve a utility's response to challenges posed when PPCPs and EDCs are found in source water and in drinking water. This secure website is an excellent resource for water utilities to share best practices, documents, other tools, and materials related to EDCs and PPCPs. The EDC Network is open to utility professionals, regardless of whether they are a subscriber.

6.9 REFERENCES AND ADDITIONAL RESOURCES

6.9.1 References

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WRF 4261, 2013. The EDC Network for Water Utilities, Project 4261, June. *http://edcnetwork.net*

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WRF 4387a, 2015. Development of a Water Primer on EDCs/PPCPs for Public Outreach. June. *http://www.waterrf.org/Pages/Projects.aspx?PID=4387*

WRF 4457, 2015. Context and Core Messages for Chromium, Medicines and Personal Care Products, NDMA, and VOCs-Report 4457, To be Completed in 2015. *http://www.waterrf.org/Pages/Projects.aspx?PID=4457*

6.9.2 Additional Resources

Collaborative Partnerships

The Western Coalition of Arid States (WESTCAS): *http://www.westcas.org/index.html*

Water Environment and Reuse Foundation (WE&RF): *http://www.werf.org/*

National Science Foundation (NSF): *http://www.nsf.gov/*

WEST Center: *http://west.arizona.edu/*

Arizona Water Association (AWA): *http://www.azwater.org/group/research-committee*

WET Center: *http://wet.asu.edu*

Example EC Lists

City of Scottsdale 2008 CPC List: *https://www.watereuse.org/files/images/Marshall_Brown.pdf*

Example Public Communication

Haley, P., City of Gilbert, Arizona Water Conservation, 2015, *http://gilbertaz.gov/Home/Components/News/News/909/17?backlist=%2f*

Water Treatment Technologies

Edzwald, James, 2011. Water Quality & Treatment: A Handbook on Drinking Water, 6th Edition. Published by: American Water Works Association, ISBN-13: 978-0071630115

Grants and Grant Application Procedures

Gillibrand, US Senator, 2015: A Guide to Water and Wastewater Funding Programs How to Navigate the Funding Process. *http://www.gillibrand.senate.gov/services/grants_central/*

TRIF Grant Funding: *http://azregents.asu.edu/public/specialprogramsandinitiatives/trif/TRIF.htm*

<u>Risk Communication</u>

Agency for Toxic Substances & Disease Registry (ATSDR): Risk Communication: Myths and Actions, (Chess *et al*. 1988): *http://www.atsdr.cdc.gov/risk/riskprimer/vision.html*

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Northern Illinois Health Consortium: *http://www.illinoispandemicflu.org/planning-and-preparing/crisis-communication/7-cardinal-rules-of-risk-communication*

US Air Force: *http://www.au.af.mil/au/awc/awcgate/epa/risk_comm_principles.pdf*

International Association for Public *Participation* (IAP2): *http://www.iap2.org/*

Water Research Foundation Knowledge Portal: *http://www.waterrf.org/knowledge/CECs/Pages/default.aspx*

7.0 Guidance for the Public

One of the stated purposes of APEC is to “Provide guidance on effectively communicating issues of unregulated emerging chemical and microbial contaminants to the citizens of Arizona”. This section contains general guidance to the public regarding drinking water and ECs. It serves as a resource for anyone wishing to learn more about water quality, suggests actions to improve water quality in the home, business and community, and explains the regulatory framework that guides utilities in maintaining safe drinking water. Any member of the public who has additional questions should first call their water provider. Any person seeking additional information can also contact their county health department or the ADEQ.

7.1 HOW SAFE IS MY WATER?

The United States has constructed and maintains one of the safest and healthiest drinking water systems in the world. This system not only includes the best available demonstrated control technology, but encompasses a robust regulatory framework for monitoring, inspection, and enforcement. The purpose of this regulatory framework is to ensure that public water systems (PWS) serve you drinking water that is safe to drink. PWS are defined as water systems that serve 15 or more connections, or 25 or more people, for more than 60 days a year. In Arizona, ADEQ has delegated authority to two Arizona counties, Pima and Maricopa, to oversee PWS within their jurisdictions under the SDWA (except for PWS operated by federal, state, or county governments). For PWS customers outside of Pima and Maricopa counties, ADEQ oversees all aspects of the state's safe drinking water programs, except for PWS on tribal lands, which are regulated by the EPA or, in the case of the Navajo Nation, by the Navajo Nation EPA. SDWA regulations, further supported by health guidelines, research, and water quality monitoring, help ensure that drinking water from PWS systems in Arizona is clean and safe to drink.

The quality of the drinking water served varies over time due to changes in the water sources from which it is drawn, regulatory updates, and the disinfection and treatment methods used. The aging infrastructure of water distribution systems and poorly maintained private plumbing may negatively impact the quality of the water after it has left the treatment plant. In addition, the list of ECs is ever expanding due to the ability to detect more minute quantities of chemicals in the environment, and the introduction of new industrial, commercial, and PCPs. The improper disposal of products containing ECs, and accidental or deliberate contamination, may also affect the number and type of ECs that may be present in source water and drinking water.

7.1.1 Where Can I Get Information?

Information about ECs in your source water and drinking water may be available from your water utility, ADEQ, Arizona Department of Health Services (ADHS), Centers for Disease

Control (CDC), and the EPA if testing of your source water and system for ECs has been conducted. Your water utility will have information that pertains to your local water quality in their Consumer Confidence Report and possibly on their website.

7.1.1.1 Consumer Confidence Report

EPA requires all PWS to provide an annual water quality report (also known as a Consumer Confidence Report or CCR) to their customers. This report is usually made available in July either online or by mail. The CCR provides information on the quality of local drinking water, including the water's source and the regulated contaminants detected in the water in the past year. All CCRs must provide consumers with the following fundamental information about their drinking water:

- The lake, river, aquifer, or other source;
- A brief summary of the susceptibility to contamination of the source, based on the state's source water assessments;
- The level (or range of levels) of any contaminant found in local drinking water, as well as EPA's health-based standard (maximum contaminant level) for comparison;
- The likely source of that contaminant in the local drinking water supply;
- The potential health effects of any contaminant detected in violation of an EPA health standard and an account of actions taken to restore safe drinking water;
- An educational statement for vulnerable populations about avoiding Cryptosporidium;
- Educational information on nitrate, arsenic, or lead in areas where these contaminants may be a concern; and
- Phone numbers and web sites for additional information.

In addition to the required information that must be included in the CCR, water utilities may voluntarily include information and data on ECs and aesthetic contaminants found in their drinking water based on results from any monitoring by the utility. If a utility is participating in the UCMR monitoring program for unregulated contaminants, the utility must report any detected contaminants under that program in the CCR.

The goal of the annual water quality reports is to inform and educate customers and consumers on which contaminants were found in the past year. This helps customers make health-based decisions regarding the use of their drinking water.

7.1.1.2 Public Notification

Another way to receive information on the quality of drinking water is through public notification. PWS must inform you if your drinking water has become contaminated by a regulated chemical or a regulated microorganism that exceeds the EPA regulatory standards in the past year in their distribution systems. However, reporting detections of ECs is not covered under the public notification requirement.

7.1.1.3 State Resources

ADEQ maintains information on all PWS in the state under the Arizona Safe Drinking Water Information System (AZSDWIS). The ADEQ database can be searched by PWS number, system name, location, and type of analysis conducted. The web site is listed under Additional Resources for this section. EC results are not included in AZSDWIS.

The ADHS provides the public with historical information on water-borne diseases detected in Arizona as part of its annual "Infectious Disease Outbreak Summary Report" (ADHS 1). For more current information, contact the county health department directly. Contact information for each local health department is listed on the ADHS web site. The EPA compiles and summarizes all state reports into an annual report on the condition of the nation's drinking water provided at the web site listed at the end of this section.

7.1.1.4 Federal Resources

The CDC provides information on the occurrence of water-borne diseases from drinking water. In September 2013, the CDC published a summary of the reported water-borne diseases from both regulated and unregulated sources of drinking water throughout the United States (CDC, 2013). The report summarizes data from 2009 – 2010. Overall, the incidence of water-borne disease is very low in comparison to the large number of people exposed and the large number of PWS in the United States. There are 155,000 regulated PWS in the U.S. serving 286 million consumers, in addition to 45 million people served by private systems. During the reporting period, there were 1,040 illnesses, 85 hospitalizations, and 9 deaths attributed to drinking water consumption. The proportion of outbreaks associated with PWS appears to have declined nationally. There were no reported outbreaks of water-borne disease in Arizona according to this report.

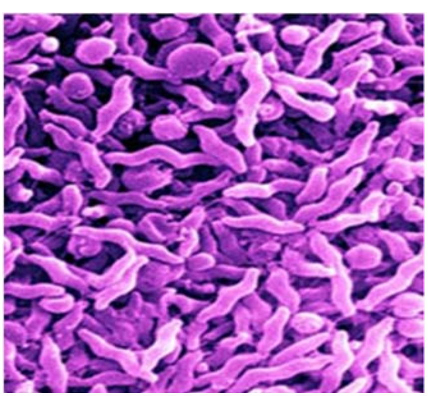

Figure 7.1. *Campylobacter jejuni* bacteria can cause an infection in the small intestine. (From: *https://www.schmidtandclark.com/campylobacte*

On a national level *Legionella* accounted for 58% of outbreaks and 7% of illnesses, and *Campylobacter* (Figure 7.1) accounted for 12% of outbreaks and 78% of illnesses. The most commonly identified deficiencies found at outbreak sites were *Legionella* in plumbing systems, followed by deficiencies in untreated groundwater and distribution systems (CDC, 2013).

Many of the ECs listed in Appendix A are being studied by the EPA, the CDC, and other entities. Some compounds such as dichloroethene have been regulated by the EPA based on toxicology information. Other compounds such as naphthalene have been studied and the EPA has determined that regulatory levels are not necessary. Information is available on both regulated and unregulated compounds through the EPA's IRIS program and through the CDC. Links to organizations with additional information on specific ECs are provided in Section 7.8.

The EPA maintains information on specific chemical ECs in its UCMR program database as discussed in Section 4. In order not to duplicate EPA efforts, the CDC does not track chemical EC data from PWS; however, the CDC does have a database available to locate studies on the toxicology effects of some ECs in drinking water. You can search the CDC website by typing in the contaminant name coupled with the phrase "drinking water".

The United States' drinking water supply is one of the safest in the world, as reflected by the low incidence rate of water-borne diseases and illnesses. However, challenges remain for PWS operators and managers. Accidents, equipment malfunctions, distribution system breakage, and incomplete treatment sometimes happen, potentially presenting a risk from consumption of contaminated tap water. The goal of PWS and regulatory agencies is to continuously improve drinking water systems so that these events are minimized or eliminated, thus ever enhancing the safety of the nation's drinking water.

7.2 WHAT CAN CONSUMERS AND BUSINESSES DO TO HELP?

Consumers and businesses can help by properly disposing of chemicals, petroleum products, and PPCPs, and by purchasing products that are less toxic. Household hazardous wastes are products labeled toxic, danger, poison, flammable, corrosive, ignitable, or reactive. These products are potentially harmful to people, pets, and the environment and should never be poured down the drain.

Figure 7.2. www.epa.gov/dfe

Some of the chemicals listed as ECs are found in common everyday products used in households and workplaces such as paints, cleaners, solvents, oils, pesticides, and PCPs. They should never be poured down the drain. When these products are improperly disposed of in a sanitary sewer system, they can enter drinking water sources. Chemicals can also enter drinking water sources through improper disposal onto the ground or in landfills. Other products which require proper disposal include batteries, fluorescent lamps, lamp ballasts, smoke detectors, medical waste, certain types of cleaning products, and electronics.

7.2.1 Household Hazardous Waste Programs

If your town or city has a household hazardous waste program, you can safely dispose of chemicals and products through these programs.

Many cities conduct occasional household hazardous waste collection events. Households should safely store unwanted chemicals and products until taking them to collection events in your community. Stores that sell automotive products usually accept used motor oil, antifreeze, and other automotive fluids. Persons who service their own vehicles should always find a facility to accept waste oil. Never flush it into a drain, place it in a sewer, spill it onto the ground, or place it into the municipal solid waste collection system. Some hardware and electronics stores will accept used batteries, compact fluorescent light bulbs, and unwanted electronic devices such as old monitors and hard drives. More information on recycling and proper disposal of such waste is listed at the end of this section.

Figure 7.3. Hazwaste collection. (From: *http://twinoakslandfill.com/hhw-4/*www.twinoakslandfill.com)

Because regulatory programs in Arizona do not reach all businesses, Arizona relies on voluntarily recycling, reusing and reducing wastes. Arizona's Pollution Prevention Program provides incentives for reducing and recycling wastes.

Businesses that generate more than 100 kilograms of hazardous waste per month are not permitted to dispose of them in the municipal solid waste stream. However, businesses generating lower amounts of hazardous waste, called "Conditionally Exempt Small Quantity Generators", are allowed to dispose very small quantities into the municipal solid waste stream under certain conditions. Households also may legally dispose of very small quantities of hazardous waste through the municipal solid waste collection process. However, because the environmental controls for municipal solid waste are less protective than the regulatory requirements for non-exempt hazardous wastes, there is a potential for these chemicals to eventually contaminate drinking water sources. Unwanted chemicals should be directed to solid waste handling facilities that specialize in managing hazardous waste or recycling the waste. Businesses may choose to pay a waste management company to safely dispose of their waste. Most oils, solvents, and paints from the exempt sources can be recycled.

7.2.2 Dispose-A-Med Programs

Medicines, pharmaceuticals, and many unwanted or expired PCPs (including items such as lotions, soaps, cosmetics, and insect repellent) harm our source waters in Arizona. These items should never be flushed down a drain or toilet, because they can contaminate water supplies. Disposal of unwanted or expired PCPs in municipal trash collection is far superior to disposal to a sanitary sewer. Some communities accept PCPs at household hazardous waste collection events.

Figure 7.4. From: *http://webcms.pima.gov/UserFiles/Servers/Server_6/Image/Government/Dispose%20A%20Med/dispose-a-med-takeback.jpg*

Proper disposal of medicines and pharmaceuticals is a special case and requires special care by consumers. Return unused, unneeded, or expired prescription drugs to pharmaceutical take-back locations for safe disposal. Ask your local pharmacy about pharmaceutical take-back programs or bring them to your pharmacy for disposal.

Some communities and drug stores sponsor “take back” or “Dispose-A-Med” programs to minimize the abuse of prescription medications among teens and to prevent accidental drug poisonings of children and the elderly. An additional benefit to the programs is the reduction of the quantity of unused pharmaceuticals that may contaminate drinking water sources. In 2010, the Drug Enforcement Administration (DEA) began a nationwide program to collect expired, unused and unwanted prescription drugs at more than 5,200 locations nationwide.

The DEA began hosting National Prescription Drug Take-Back events six years ago. At that time the Controlled Substances Act had no legal provision for patients to rid themselves of unwanted prescription drugs except to give them to law enforcement because pharmacies and hospitals were banned from accepting them. Most people flushed their unused prescription drugs down the toilet, threw them in the trash, or kept them in the household medicine cabinet, resulting in contamination of the water supply, theft, and abuse. Since its first National Take-Back Day in September 2010, DEA has collected more than 5.9 million pounds (over 2,400 tons) of prescription drugs throughout all 50 states, the District of Columbia, and several U.S. territories. New disposal regulations were published in 2014 under the Secure and Responsible Drug Disposal Act. Implementing the Act expanded the options available to safely and securely dispose of potentially dangerous prescription medications on a routine basis. Between 2010 and 2015, DEA sponsored 10 National Prescription Take-Back Days. In five years, 5,525,021 pounds of drugs have been collected across the nation. The public may find authorized collectors in their communities by calling the DEA Office of Diversion Control’s Registration Call Center at the number shown at the end of this section.

The Pima County Health Department formed a Dispose-A-Med community coalition in 2009. It provides information on where the community can properly dispose of unused prescription medication such as at permanent drop off locations. A list of all locations in Arizona is provided in Appendix D.

Figure 7.5. The Town of Gilbert's permanent prescription and OTC medication drop box. From: *http://www.gilbertaz.gov/Home/Components/News/News/909/17?backlist=%2F*

The Town of Gilbert, Arizona has established a permanent box in the lobby of the Gilbert Police Department which accepts unwanted prescription and over-the-counter medications 24 hours a day.

Because prescription take back programs are operated by the DEA, they require involvement of local law enforcement. Additional information on proper disposal of unused pharmaceuticals is available from ADEQ, DEA, EPA, FDA, the Pima County Health Department, and your local law enforcement offices.

7.2.3 Purchasing Less Toxic Products

Another beneficial practice recommended for businesses and households to consider is reducing the purchase of products that contain hazardous ingredients. Alternative cleaning methods or products that do not contain hazardous ingredients are available.

The EPA has established a certification program for chemical product manufacturers who wish to develop and market products that are less harmful to the environment. Many cleaning compounds in conventional products biodegrade slowly or break down into more toxic and persistent chemicals. The program is called "Design for the Environment" (DfE). A DfE-labeled product contains the safest possible ingredients. When you see the DfE label on a product, it means that it will not be toxic to humans and it will biodegrade readily to less harmful products. Mild pH, low volatility, and low potential to catch fire enhance the safety profile of these products.

The safer health profile especially benefits children who spend a large part of their day in indoor environments and can be particularly sensitive to the chemicals in some cleaning products. It also helps to ensure a safer workplace for janitors, maintenance staff, housekeepers, and others who must use cleaning chemicals in confined spaces on a daily basis.

In order to be certified as a DfE product, the ingredients must the safest in their class. DfE products cannot contain carcinogens, mutagens, or reproductive or developmental toxicants. The ingredients must not be persistent, bioaccumulative, or toxic chemicals. Packaging material encasing DfE products will not contain toxic elements, including heavy metals, Biphenyl A (BPA), or similar plasticizers. Additional restrictions are evaluated by the EPA-approved certifying organizations. Readers interested in DfE should go to the EPA web pages shown at the end of this section.

7.3 HOME WATER TREATMENT

Most people do not need to treat drinking water in their home to make it safe. However, a home water treatment unit can improve water's taste, and EPA has stated that people with severely weakened immune systems or other specific health conditions, or those concerned about specific contaminants present in local drinking water, may wish to further treat their water at home. EPA does not, however, endorse specific units.

Before purchasing a home treatment device, you should consider the following:

- All water sources contain minerals and some contaminants. If a water source meets the EPA's National Primary (NPDWS) and Secondary (NSDWS) Drinking Water Standards, it is considered safe to drink.
- No water treatment device can completely eliminate all minerals and all contaminants from water all of the time.
- Proven treatments, if properly operated and maintained, can provide backup protection, further reducing contaminants below NPDWS and/or NSDWS levels.
- Before buying a home water treatment device, know the quality of your water source and decide:
    - which contaminants you want reduced,
    - to what level, and
    - how much treated water you need every day?
- Home water treatment devices can break down and, if improperly maintained, can contaminate your drinking water.
- Home treatment devices require regular use and periodic maintenance. They are not "install and forget" devices.

***Source:* **Arizona-Know Your Water**. *Published by the University of Arizona's College of Agriculture and Life Sciences, 2006; page 73.*

7.3.1 Point of Use and Point of Entry Systems

There are different options for home treatment systems. Point-of-use (POU) systems treat water at a single tap. Point-of-entry (POE) systems treat water used throughout the house. POU systems can be installed in various places in the home, including on or below the counter top, on the faucet, or under the sink. POE systems are installed where the water line enters the house. POU and POE devices may use filtration, ion exchange, RO, and distillation to remove contaminants. All types of units are generally available from retailers or by mail order. Prices can reach well into the hundreds and sometimes thousands of dollars depending on the method and location of installation and the need for additional plumbing.

7.3.2 Home Treatment Methods

Activated carbon filters absorb organic contaminants that cause taste and odor problems. Depending on their design, some units can remove chlorination byproducts, certain cleaning solvents, and pesticides. To maintain the effectiveness of these units, the carbon canisters must be replaced periodically. Activated carbon filters are efficient in removing metals such as lead and copper if they are designed to absorb them. Because ion exchange units can be used to remove minerals from your water, particularly calcium and magnesium, they are sold for water softening. Some ion exchange softening units also remove radium and barium. Ion exchange systems that employ activated alumina are used to remove fluoride and arsenate from water. These units must be regenerated periodically with salt or the resin heads replaced by a reputable vendor. Reverse osmosis treatment units generally remove a more diverse list of contaminants. They can remove nitrates, sodium, dissolved inorganics, and organic compounds. Distillation units boil water and condense the resulting steam to create distilled water. Depending on their design, they may allow vaporized organic contaminants to condense back into the product water, thus minimizing the removal of organics. Note that no one unit can remove everything. Table 7.1 shows some of the characteristics of each treatment type.

You may choose to boil your water to remove microbial contaminants. Special care must be taken because boiling reduces the volume of water by about 20% and concentrates those contaminants not affected by the temperature of boiling water, such as nitrates, metals, and pesticides. Prior to purchasing any device, have your water tested by a certified laboratory to determine if contaminants are present and assist you to determine the contaminants you want removed. Tests conducted by salespeople that want you to buy the product should be evaluated with skepticism. Each county in Arizona maintains a list of certified laboratories for drinking water testing, as does the Arizona Department of Health Services (ADHS). The ADHS list can be accessed at:
https://app.azdhs.gov/bfs/labs/elbis/drinkingwatertestinglabs/drinkingwatersearchcontentpage.aspx.

Table 7.1 Common Point of Use Treatment Methods

TREATMENT DEVICE	WHAT IT DOES TO WATER	TREATMENT LIMITATIONS
Activated Carbon Filter (includes mixed media that remove heavy metals)	√ Adsorbs organic contaminants that cause taste and odor problems. √ Somedesigns remove chlorination byproducts; √ Some types remove cleaning solvents and pesticides	Is efficient in removing metals such as lead and copper Does not remove nitrate, bacteria or dissolved minerals
Ion Exchange Unit (with activated alumina)	√ Removes minerals, particularly calcium and magnesium that make water "hard" √ Some designs remove radium and barium √ Removes fluoride	If water has oxidized iron or iron bacteria, the ion-exchange resin will become coated or clogged and lose its softening ability
Reverse Osmosis Unit (with carbon)	√ Removes nitrates, sodium, other dissolved inorganics and organic compounds √ Removes foul tastes, smells or colors √ May also reduce the level of some pesticides, dioxins and chloroform and petrochemicals	Does not remove all inorganic and organic contaminants
Distillation Unit	√ Removes nitrates, bacteria, sodium, hardness, dissolved solids, most organic compounds, heavy metals, and radionucleides √ Kills bacteria	Does not remove some volatile organic contaminants, certain pesti-cides and volatile solvents Bacteria may recolonize on the cool-ing coils during inactive periods

**Source: EPA water on tap (*http://nepis.epa.gov/Exe/ZyPDF.cgi/P1008ZP0.PDF?Dockey=P1008ZP0.PDF*)

All POU and POE treatment units need maintenance to operate effectively. If not maintained properly, contaminants may accumulate in the units and make the water worse. Some vendors may make claims about their product's effectiveness that have no merit. Units are tested for safety and effectiveness by two organizations: The National Sanitation Foundation and the Underwriters Laboratory. The Water Quality Association also represents the household, commercial, industrial, and small community treatment industry and can help locate a professional that meets their code of ethics. EPA and other government agencies do not test or certify treatment units. For a good description of home water treatment options, refer to the U of A publication "*Arizona: Know Your Water*" at the website shown under Additional Resources for this section.

7.3.3 Non Public Water Systems

Systems which serve less than 15 connections or fewer than 25 people are not PWS and are not regulated by ADEQ or local agencies. If you are on such a system and wish to learn about the safety of your water, select a certified laboratory and submit a sample of the water for analysis of major chemistry, volatile organic compounds, metals, and bacteria. ADEQ links to the ADHS list of qualified laboratories referred to in Section 7.3.2. If you live in Maricopa or Pima counties, you can contact the county agency responsible for PWS management for information on local certified laboratories who can test the water supply. Web sites are shown under Additional Resources for this section.

In 2010, the CDC formed a working group of professionals and the public to identify, evaluate, and recommend interventions to protect people from drinking contaminated water from unregulated drinking water sources. The Private Well Initiative group is currently working on ways to promote access to water quality analytical results from unregulated sources (CDC 2).

7.4 PUBLIC WATER SYSTEM COMMUNICATIONS

Water quality and related information gathered by a PWS is classified as public information. Customers and the public have a right to that information. PWS managers and regulatory agencies may proactively communicate that information to utility customers and the general public. Only a few exceptions exist, including information associated with personnel matters and homeland security mandates such as vulnerability assessments.

As part of standard water system operations, a proactive PWS will respond to customer concerns about all aspects of water system management. This is essential in building trust with customers and the public. PWS managers and regulators should work together to establish a mutual proven record of trust, credibility, and customer satisfaction. In doing so, they become reputable sources of information on ECs in water, any associated health effects, and any actions being taken to minimize or eliminate these contaminants in the water supply.

7.5 REGULATORY INFORMATION

Through the UCMR provisions of SDWA, selected utilities provide the EPA with data and information on the occurrence of ECs found in drinking water that are listed in the CCL. SDWA provides a pathway for setting standards for contaminants that are currently unregulated. The process includes investigating the occurrence of the EC, assessing its health effects, identifying viable treatment options, and ultimately establishing regulatory standards. Section 4 provides details on this regulatory process and links to references for further information.

Because of the need for health information before new drinking water regulations are established, the EPA publishes Health Advisories semi-annually. Health advisories contain

MCLGs and present data allowing readers to examine recommended exposures over lifetime, 10-day or 1-day exposure scenarios. The EPA defines the lifetime health advisory level as the concentration of a chemical in drinking water that is not expected to cause any carcinogenic effects after a lifetime of exposure. The health advisories also present concentrations of a chemical in drinking water corresponding to an excess estimated lifetime cancer risk of 1 in 10,000. EPA can also consider more conservative cancer risk levels of 1 in 100,000 and 1 in 1,000,000 respectively found in the IRIS and other source documents. An example of a recent EPA Drinking Water Health Advisory can be found under the Additional Resources for this section.

Individual states, some water utility providers, and water utility non-governmental organizations are conducting research on ECs. Many reports of research findings are available for review. The reports are published in the scientific literature, CCRs, and web pages for government research organizations and privately funded foundations. Please refer to the sources listed at the end of this section.

7.6 FUNDING FOR MONITORING OF ARIZONA'S WATERS

Monitoring for ECs is paid for primarily through water rates. However, utilities can also fund investigations of EC occurrence and treatment methods through different avenues such as foundational, state, and federal research grants. The cost of these investigations can vary depending on the extent of the monitoring programs and the depth of the proposed research.

7.7 REFERENCES AND ADDITIONAL RESOURCES

7.7.1 References

ADHS 1. 2014 Infectious Disease Outbreak Summary Report.
http://www.azdhs.gov/...disease.../disease...reports/2014-infectious-disease-outbreak -summary-report.pdf

Arizona-Know Your Water. The University of Arizona's College of Agriculture and Life Sciences, 2006; page 73.
http://wsp.arizona.edu/sites/wsp.arizona.edu/files/uawater/documents/AZKYW/AZKnowYourWaterII_high.pdf

CDC, 2013. "Surveillance for Waterborne Disease Outbreaks Associated with Drinking Water and Other Nonrecreational Water — United States, 2009–2010". September.

CDC 2. Private Well Initiative. *http://www.cdc.gov/nceh/hsb/cwh/pwi.htm*

EPA 1, Providing Safe Drinking Water in America: National Public Water Systems Report, 2013 *http://www2.epa.gov/compliance/providing-safe-drinking-water-america-national-public-water-systems-report*

7.7.2 Additional Resources

The Safe Drinking Water Act:

http://water.epa.gov/lawsregs/guidance/sdwa/upload/2009_08_28_sdwa_fs_30ann_monitoring_web.pdf

Emerging Contaminant Databases

Agency for Toxic Substances and Disease Registry (ATSDR): *http://www.atsdr.cdc.gov/*

World Health Organization, Chemical Hazards in Drinking Water: *http://www.who.int/water_sanitation_health/dwq/chemicals/*

EPA's Integrated Risk Information System: *http://www.epa.gov/iris/*

Centers for Disease Control: *http://www.cdc.gov/nceh/hsb/cwh/pwi.htm*

Public Water Systems

ADEQ, Arizona's Safe Drinking Water Information System: *https://www.azdeq.gov/environ/water/dw/*

Arizona Safe Drinking Water Information System search page: *http://azsdwis.azdeq.gov/DWW_EXT/*

Consumer Confidence Reports

EPA Safe Drinking Water Act, Consumer Confidence Reports: *http://water.epa.gov/lawsregs/rulesregs/sdwa/ccr/index.cfm*

EPA Water Resources, Drinking Water: *http://water.epa.gov/drink/info/*

ADEQ Water Quality Division, Safe Drinking Water, Compliance Assistance: *https://www.azdeq.gov/environ/water/dw/ssc.html#ccr*

http://www.scottsdaleaz.gov/water/dringing-water

http://www.scottsdaleaz.gov/Assets/ScottsdaleAZ/Water/2014+Water+Quality+Report.pdf

EPA's Safe Drinking Water Hotline at 1-800-426-4791

Public Notification

Arizona Public Water System Providers: *https://azdeq.gov/environ/water/dw/index.html*

EPA Providing Safe Drinking Water in America: National Public Water Systems Report: *http://www2.epa.gov/compliance/providing-safe-drinking-water-america-national-public-water-systems-report*

Center for Disease Control

CDC, Surveillance for Waterborne Disease Outbreaks Associated with Drinking Water and Other Nonrecreational Water — United States, 2009–2010: *http://www.cdc.gov/mmwr/preview/mmwrhtml/mm6235a3.htm*

Microorganisms

EPA Drinking Water Contaminants – Standards and Regulations: *http://water.epa.gov/drink/contaminants/#Microorganisms*

World Health Organization: *http://www.who.int*

Recycling and Proper Disposal of Household and Business Wastes

EPA Reduce, Reuse, Recycle: *http://www.epa.gov/osw/conserve/materials/hhw.htm*

ADEQ Waste Programs Division: Solid Waste Management: Recycling: *https://www.azdeq.gov/environ/waste/solid/recycle.html*

ADEQ Waste Programs Division: About the Pollution Prevention (P2) Planning Program: *https://www.azdeq.gov/environ/waste/p2/programs.html*

Disposal of Pharmaceuticals

ADEQ Waste Programs Division, Prescription Drug Disposal: *https://www.azdeq.gov/environ/waste/solid/ic.html*

ADEQ Prescription Drug Disposal: *https://www.azdeq.gov/environ/waste/solid/download/pharm_drug_disposal_brochure-10-25-11.pdf*

Arizona Prescription Drug Drop Box Locations: *http://www.azcjc.gov/ACJC.Web/Rx/Drop%20Box%20Locations.pdf*

DEA Drug Take-Back Program: *http://www.dea.gov/divisions/hq/2014/hq092314.shtml*

DEA Office of Diversion Control's Registration Call Center at 1-800-882-9539

https://www.epa.gov/hw/household-hazardous-waste-hhw

FDA How to Dispose of Unused Medicines:
http://www.fda.gov/ForConsumers/ConsumerUpdates/ucm101653.htm

http://water.epa.gov/scitech/swguidance/ppcp/index.cfm

Pima Count, Dispose A Med:
http://webcms.pima.gov/cms/One.aspx?portalId=169&pageId=135181

U.S. Dept. of Justice National Take-Back Initiative:
http://www.deadiversion.usdoj.gov/drug_disposal/takeback/

<u>Design for the Environment (DfE)</u>

EPA Green Chemistry: *http://www2.epa.gov/green-chemistry*

EPA Safer Choice: *http://www.epa.gov/dfe*

<u>Home Water Treatment Options/</u>

Arizona Know Your Water:
http://wsp.arizona.edu/sites/wsp.arizona.edu/files/uawater/documents/AZKYW/AZKnowYourWaterII_high.pdf

<u>Testing and Certification for Home Water Treatment Systems</u>

National Sanitation Foundation: *http://www.nsf.org/services/by-industry/water-wastewater/residential-water-treatment/point-of-use-and-point-of-entry-systems*

Water Quality Association Certified Water Treatment Products: *http://www.wqa.org/*

<u>Non PWS Information</u>

Arizona Department of Environmental Quality: *https://www.azdeq.gov/environ/water/index.html/*

Maricopa County Department of Environmental Health:
http://www.maricopa.gov/envsvc/envhealth/

Pima County Department of Environmental Quality: *http://webcms.pima.gov/environment/*

Risk Communication Programs

Covello V., Allen F., 1988. Seven Cardinal Rules of Risk Communication. U.S. Environmental Protection Agency. *http://www.au.af.mil/au/awc/awcgate/epa/risk_comm_principles.pdf*

Northern Illinois Health Consortium, The EPA's 7 Cardinal Rules of Risk Communication: *http://www.illinoispandemicflu.org/planning-and-preparing/crisis-communication/7-cardinal-rules-of-risk-communication*

ATSDR, A Primer on Health Risk Communication: *http://www.atsdr.cdc.gov/risk/riskprimer/vision.html*

Sample EPA Health Advisory

EPA: *http://water.epa.gov/action/advisories/drinking/upload/dwstandards2012.pdf*

County Health Department Contacts

Arizona Department of Health Services: *http://www.azdhs.gov/diro/liaison/county-health-departments.htm*

8.0 Recommendations

APEC has developed recommendations for ADEQ based on the information discussed in this report. APEC recognizes that resources at all levels of government are under duress and that staffing and funding may simply not be available to implement any recommendation – no matter how sound or well meaning. Nevertheless, we believe these recommendations will improve the identification and management of ECs in Arizona's waters so as to minimize risk to human health and the environment.

1. ADEQ should establish a permanent APEC to:
   - Compile a list of treatment strategies and technologies being used by utilities in Arizona.
   - Update this report and the list of ECs as new information and new ECs are found in Arizona waters.
   - Identify and document issues involving ECs affecting Arizona's waters
   - Maintain the current membership structure of the full APEC committee, the Chemical Contaminant Subcommittee, the Microbial Contaminant Subcommittee and the Outreach and Education Committee.
2. ADEQ should consider facilitating the creation and collaboration of APEC teams/working groups within discrete regions of Arizona to collect and disseminate information to utilities and the public regarding the presence of ECs in waters in their region.
3. Create an APEC Research subcommittee to identify research topics, projects, and funding sources annually that are affecting waters in Arizona. The research committee would provide recommendations to facilitate collaboration among major research institutions and water utilities. The research subcommittee would identify topics and align them with requests for proposals that are publicized annually by the WRF, WE&RF, WRRF, and other research entities. The following are APEC's recommended research topics:
   - Further research to determine if antibiotic resistant genes and antibiotic resistant bacteria are present in Arizona waters and their health implications.
   - Continue research on cost-effective water and wastewater treatment technologies for ECs listed on the CCL4 that have been found in Arizona source water and drinking water (see Appendix A).

- Conduct research identifying inexpensive laboratory methods that are available for use by utilities in assessing the presence of ECs in source water, treated wastewater, recycled water, and drinking water.
- Build upon past research to verify the presence of ECs in harvested rainwater.
- Initiate research on the presence of ECs in bottled water sold in Arizona.
- Initiate research on the health effects of consuming low concentrations of ECs in drinking water.
- ADEQ should consider collaborating with the City of Flagstaff on health effects and occurrence monitoring for the four compounds detected in their reclaimed water: 17-beta estradiol, N-nitrosodimethylamine (NDMA), triclosan, and caffeine.

4. ADEQ has conducted a very successful electronics waste recycling program for years. Using its success as a guideline, ADEQ should consider:

- Developing collaborative partnerships with pharmacy companies and law enforcement to conduct drug and medication "take-back" collection events.
- Developing collaborative partnerships with county Dispose-A-Med programs around the state such as the one in Pima County.

5. ADEQ should consider sponsoring or facilitating a collaborative program where utilities in Arizona can participate in creating a statewide laboratory consortium to pool resources to create monitoring programs and determine the appropriate analyses on the occurrence of ECs in recreational waters, source waters, treated wastewater, recycled water, and drinking water.

6. In collaboration with entities such as the WRRC, NSF WET Center, and the WEST Center, ADEQ should create and maintain an electronic central repository of all the research being conducted in Arizona on ECs and make it accessible to utilities, researchers and the public.

7. In collaboration with APEC, ADEQ should conduct workshops and seminars for water utilities and the general public based on this report and its recommendations.

8. Advise all water utilities as soon as EPA acts, or proposes to act, on any EC. The EPA's actions could include listing or de-listing of a constituent as a tracked EC; proposals to regulate an EC as a priority pollutant; and releases of toxicity or occurrence reports.

9. ADEQ, in collaboration with APEC, should sponsor risk communication training to prepare water utility managers, PIOs, and public outreach staff for incidents involving an EC occurrence or treatment failure.

APPENDIX A

LIST OF EMERGING CONTAMINANTS

APPENDIX A
LIST OF EMERGING CONTAMINANTS
Emerging Contaminants in Arizona Water
Prepared by the Advisory Panel on Emerging Contaminants
Sponsored by the Arizona Department of Environmental Quality

Emerging Contaminant	Legal Status*	Common Uses	Presence in the Colorado River and CAP Canal	Presence in Treated Wastewater and Reclaimed Water	Presence in Ground-water	Presence in Other Surface Waters	Presence in Drinking Water
Organic Chemicals			nd = not detected; nt = not tested				
Acesulfame-K		Artificial sweetener	yes	yes	nt	yes	yes
AHTN (Tonalide)		Fragrance	nt	yes	nd	yes	nt
Albuterol		Bronchodilator	yes	yes	nd	nt	nd
Aldicarb sulfone		Insecticide ingredient	nt	nt	nt	yes	nt
Atenolol		Treats angina and high blood pressure	yes	yes	nd	nt	yes
Atorvastatin		Lowers high cholesterol and triglyceride levels	nd	yes	nd	nt	nd
Atrazine	MCL	Triazine class herbicide	yes	yes	yes	yes	yes
Azithromycin		Antibiotic	yes	yes	yes	nt	yes
Benzophenone		Prevents ultraviolet light from damaging scents and colors in products such as perfumes and soaps	nd	yes	yes	yes	nd
Benzopyran		Anti-inflammatory and anti-cancer agent	nd	yes	nd	yes	nd
Benzotriazole		Corrosion inhibitor and drug precursor	nt	yes	nt	nt	nt
Bromochloromethane (Halon 1011)	CCL	Formerly used in fire extinguishers	yes	nt	nt	yes	yes
Bromomethane		Fumigation, soil sterilizer, used to make other products	nt	nt	nt	yes	yes
Butalbital		Used with acetaminophen and aspirin for headaches and pain	yes	nt	nt	nt	nt
Butylated hydroxyanisole (BHA)		Food Preservative	nd	yes	yes	No	nd
n-Butylbenzene		Medical - induce cell death in vitro and for bioconversion	yes	nt	nt	yes	yes
sec-Butylbenzene	CCL	Solvent and polymer linking agent	nt	nt	nt	yes	yes
tert-Butylbenzene		Solvent and polymer linking agent	nt	nt	nt	yes	yes
Caffeine		A psychoactive central nervous system stimulant	yes	yes	nd	nt	yes
Carbamazepine		Treats seizures, nerve pain, or bipolar disorder	yes	yes	yes	yes	yes
Carisoprodol		Muscle relaxant	yes	nt	yes	nt	yes
Chlorodifluoromethane (HCFC-22)	CCL	Former propellant and refrigerant	nt	nt	nt	yes	yes
Chlorpyrifos		Insecticide	yes	nt	nt	yes	nd
Ciprofloxacin		Antibiotic	nt	yes	nt	nt	nt
Cotinine		An alkaloid found in tobacco; a metabolite of nicotine	yes	nt	nt	nt	nd
Cyanotoxins	CCL	Natural group of cyclic heptapeptides produced by aquatic cyanobacteria	yes	nt	nt	yes	nd
DCPA mono/di degradate	CCL-N	Herbicide	nt	nt	nt	yes	yes
DEET		Insect repellent	yes	yes	yes	yes	yes
Desethy-desisopropyl atrazine (DiA)		Herbicide - metabolite of atrazine	yes	nt	yes	nt	yes
Diamino-s-chlorotriazine (DACT)	CCL	Herbicide	yes	yes	nt	nt	nd
Diazepam		Treats anxiety, muscle spasms, seizures	nd	yes	yes	yes	nd
Diazinon	CCL	Insecticide	yes	nt	nt	yes	nd
Dibromochloropropane (DBCP)	MCL	Agricultural pesticide	nt	nt	nt	yes	yes
Dichlorodifluoromethane		Formerly used as an aerosol	yes	nt	nt	yes	yes
Dichloroethene	MCL	A comonomer in polymerization and in semiconductor fabrication	nt	nt	nt	yes	yes
2,4-Dichlorophenoxyacetic acid		Herbicide	yes	nt	nt	nt	nt
cis-1,3-Dichloropropene	CCL-N	Agricultural pesticide	nt	nt	nt	yes	yes
trans-1,3-Dichloropropene	CCL-N	Pesticide	nt	nt	nt	yes	yes
Diclofenac		Nonsteroidal anti-inflammatory drug (NSAID)	yes	yes	yes	yes	nd
Dilantin (Phenytoin)		Anticonvulsant	yes	yes	yes	yes	yes

Emerging Contaminant	Legal Status*	Common Uses	Presence in the Colorado River and CAP Canal	Presence in Treated Wastewater and Reclaimed Water	Presence in Ground-water	Presence in Other Surface Waters	Presence in Drinking Water
1,4-Dioxane	CCL	Stabilizer for the solvent trichloroethane	nt	nt	yes	nt	yes
Diuron	CCL	Herbicide	yes	nt	nt	nt	nt
Erythromycin	CCL	Antibiotic	yes	nd	nd	nt	nd
Estradiol (17β-estradiol, E2)	CCL	Natural human sex hormone and steroid used to treat symptoms of menopause, osteoporosis, cancer	yes	yes	nd	nt	nd
Estrone	CCL	One of several natural estrogens	yes	yes	nd	nt	nd
Ethinylestradiol (EE2)	CCL	A synthetic estrogen used in many formulations of combined oral contraceptive pills	nd	yes	nd	nt	nd
Fipronil		Insecticide	nt	nt	nt	yes	nd
Fluoxetine		SSRI that treats depression and obsessive-compulsive disorder	yes	yes	yes	yes	yes
Gemfibrozil		Lowers high triglyceride and cholesterol levels	yes	yes	yes	nt	nd
Hexachlorobutadiene		Scrubber to help remove chlorine containing compounds	nt	nt	nt	yes	yes
Hydrocodone		Narcotic pain reliever	nt	yes	nt	nt	nd
Ibuprofen		Nonsteroidal anti-inflammatory drug (NSAID)	yes	yes	yes	yes	yes
Iohexal		Medical contrast agent	yes	nt	nt	yes	yes
Iopromide		Medical contrast agent	yes	nd	nd	nd	nd
Isopropylbenzene		Component of crude oil and used to make phenol and acetone	nt	nt	nt	yes	yes
MDMA (Ecstasy)		A phenethylamine and amphetamine classes of drugs widely known as Ecstasy	yes	yes	nd	nt	nd
Meprobamate		Tranquilizer	yes	yes	yes	yes	yes
Methamphetamine		A neurotoxin and potent psychostimulant used to treat attention deficit hyperactivity disorder and helps with weight loss in obese patients	yes	yes	nd	yes	nd
Musk ketone		Fragrance	nd	yes	yes	nt	nd
Naphthalene	CCL-N	Moth balls, used to make dyes, concrete, and plasterboard	yes	nt	nt	yes	yes
Naproxen		Nonsteroidal anti-inflammatory drug (NSAID)	yes	yes	yes	yes	yes
Nifedipine		Calcium channel blocker for chest pain and high blood pressure	yes	nt	nt	nt	nt
N-Nitrosodiethylamine (NDEA)		Cosmetics, pesticides, and rubber products; a disinfection byproduct	nt	nt	nt	yes	yes
N-Nitrosodimethylamine (NDMA)		Produced as by-product of several industrial processes and present at very low levels in certain foodstuffs, especially those cooked, smoked, or cured. A disinfection byproduct in water and wastewater treatment.	nt	yes	yes	nt	yes
4-nonyphenol	CCL	An alkyphenol ingredient of antioxidants, lubricating oil additives, detergents	yes	nt	nt	nt	nt
4-Octylphenol		Manufacture of nonionic surfactants, plasticizers, antioxidants, fuel oil stabilizer, intermediate for resins, fungicides, bactericides, dyestuffs, adhesives, rubber chemicals octyl phenol isomers.	yes	yes	yes	yes	nd
Oxolinic Acid		Quinolone antibiotic	nt	nt	yes	nt	yes
Oxybenzone		Ingredient in sunscreens	yes	yes	yes	yes	nd
Perfluorohexanesulfonic acid		Emulsion polymerization - stain repellants, polishes, paints, coatings	nt	nt	nt	yes	yes
Perfluoro-N-Heptanoic Acid (PFHpA)		Oil and water repellent coatings for carpets, textiles, leather, paper, cardboard, etc.	nt	nt	nt	yes	yes
Perfluorooctanesulfonic acid (PFOS)	CCL	Key ingredient in Scotch Gard, a fabric protector made by 3M, and numerous stain repellents	nt	nd	yes	nt	yes
Perfluorooctanoic acid (PFOA)	CCL	Surfactant and used in the manufacture of Teflon and Gore-Tex	nt	yes	yes	nt	yes

Emerging Contaminant	Legal Status*	Common Uses	Presence in the Colorado River and CAP Canal	Presence in Treated Wastewater and Reclaimed Water	Presence in Ground-water	Presence in Other Surface Waters	Presence in Drinking Water
Polychlorinated Naphthalene		Used in insulating coatings for electrical wires, in wood preservatives, as rubber and plastic additives, and in lubricants.	yes	yes	yes	nt	yes
Primidone		Anticonvulsant	yes	yes	yes	yes	yes
Progesterone		Natural steroid hormone	yes	yes	nd	nt	nd
Prometon		Herbicide	yes	nt	yes	yes	nd
n-Propylbenzene	CCL	In crude oil - solvent and used in dues and printing applications	nt	nt	nt	yes	yes
Propylparaben		Natural plant ester and synthetic cosmetic, pharmaceutical, and food additive	yes	nt	nt	nt	nt
Pseudoephedrine		Decongestant	nd	yes	nd	nt	nd
Quinoline	CCL	Chelating agent, used in the production of dyes	yes	nt	nt	nt	nt
Simazine	MCL	Triazine class herbicide - inhibits photosynthesis	yes	nd	yes	yes	yes
Sucralose		Artificial sweetener	yes	yes	yes	yes	yes
Sulfamethoxazole		Antibiotic	yes	yes	yes	yes	yes
Tris(2-carboxyethyl)phosphine (TCEP)		Flame retardant	yes	yes	yes	yes	yes
Tris (1-chloro-2-propyl) phosphate (TCPP)		Flame retardant	yes	yes	yes	yes	yes
Testosterone		A male steroid hormone used to treat breast cancer in women	yes	yes	nd	nt	nd
Theophylline		Bronchodilator	nt	nt	yes	nt	yes
1,2,3-Trichlorobenzene		Solvent, precursor to dye and the pesticides	nt	nt	nt	yes	yes
Trichlorofluoromethane		Formerly a refrigerant, solvent, used in styrofoam, propellant	nd	nt	nt	yes	yes
Triclocarban		Antibacterial agent in personal care products	yes	yes	nt	nt	nt
Triclosan		Antibacterial and antifungal agent in personal care products	yes	yes	yes	yes	yes
Trimethoprim		Antibiotic	yes	yes	yes	yes	nd
1,2,4-Trimethylbenzene	CCL	Liquid scintillator. sterilizing agent, in dyes, perfumes, and resins, gasoline additive	nt	nt	nt	yes	yes
1,3,5-Trimethylbenzene		Solvent and colorant	nt	nt	nt	yes	yes
Inorganic Chemicals			nd = not detected; nt = not tested				
Chlorate	CCL	Oxyanion salt of chloric acid - industrial applications	nt	nt	nt	yes	yes
Chromium	MCL	Natural element geologically leached and mined for use in multiple manufacturing systems	yes	yes	yes	yes	yes
Cobalt	CCL	Natural element geologically leached and mined for use in multiple manufacturing systems	yes	yes	yes	yes	yes
Hexavalent chromium (Chromium-6)	MCL-R	Used in the manufacture of paints, stainless steel, textile dyes, and wood preservatives	yes	nt	yes	nt	yes
Molybdenum	CCL	Natural element geologically leached and mined for use in multiple manufacturing systems	yes	yes	yes	yes	yes
Perchlorate	CCL	Ingredient of explosives and fertilizers	yes	yes	nt	nt	yes
Strontium	CCL	Natural element used in multiple manufacturing systems	yes	nt	nt	yes	yes
Vanadium	CCL	Natural element geologically leached and mined for use in multiple manufacturing systems	nd	yes	yes	yes	yes
Microorganisms			nd = not detected; nt = not tested				
Aeromonas	CCL		nt	nt	nt	nt	yes
Cryptosporidium	MCL-TT		yes	nt	nt	yes	nd
Cyanobacteria (blue-green algae)	CCL		yes	nt	nt	yes	nt

APPENDIX A
LIST OF EMERGING CONTAMINANTS
Emerging Contaminants in Arizona Water
Prepared by the Advisory Panel on Emerging Contaminants
Sponsored by the Arizona Department of Environmental Quality

Emerging Contaminant	Legal Status*	Common Uses	Presence in the Colorado River and CAP Canal	Presence in Treated Wastewater and Reclaimed Water	Presence in Ground-water	Presence in Other Surface Waters	Presence in Drinking Water
Legionella pneumophila	MCL-TT		nt	nt	yes	nt	yes
Mycobacterium avium	CCL		yes	yes	yes	yes	yes
Naeglaria fowleri	CCL		yes	nt	yes	yes	yes
Vibrio cholerae			nt	nt	nt	yes	nd

NOTES:
**EPA Safe Drinking Water regulatory status as follows:*
MCL: Numerical Maximum Contaminant Level (MCL) published
MCL-TT: Non-numerical Treatment Technology MCL published
MCL-R: Under review by EPA for potential MCL standard setting (not on CCL)
CCL: Listed on EPA Candidate Contaminant List 1, 2, 3, Draft CCL4, or more than one list
CCL-N: EPA determination that no regulatory action for this CCL constituent is appropriate or necessary

APPENDIX B

SELECTED EMERGING CONTAMINANT MONITORING LISTS COMPILED BY WATER AND WASTEWATER UTILITIES

List 1. Tucson Water Emerging Contaminant Analyte List

List 2. Scottsdale Water Campus Compounds of Potential Concern List

List 1. Tucson Water
Emerging Contaminant Analyte List
2015

Analyte

1,7-DIMETHYLXANTHINE
2,4-D
4-NONYLPHENOL- (SEMI-QUANT)
4-TERT-OCTYLPHENOL
ACESULFAME-K
ACETAMINOPHEN
ALBUTEROL
AMOXICILLIN (SEMI-QUANT.)
ANDROSTENEDIONE
ATENOLOL
ATRAZINE
AZITHROMYCIN
BENDROFLUMETHIAZIDE
BEZAFIBRATE
BIS PHENOL A (BPA)
BROMACIL
BUTALBITAL
BUTYLPARABEN
CAFFEINE
CARBADOX
CARBAMAZEPINE
CARISOPRODOL
CHLORAMPHENICOL
CHLORIDAZON
CHLOROTOLURON
CHROMIUM, HEXAVALENT/DISSOLVED
CIMETIDINE
CLOFIBRIC ACID
COTININE
CYANAZINE
DACT
DEA
DEET
DEHYDRONIFEDIPINE
DIA
DIAZEPAM
DICLOFENAC
DILANTIN
DILTIAZEM
DIURON
ERYTHROMYCIN
ESTRADIOL
ESTRONE
ETHINYL ESTRADIOL-17 ALPHA
ETHYLPARABEN
FLUMEQUINE
FLUOXETINE
GEMFIBROZIL
IBUPROFEN
IOHEXAL
IOPROMIDE
ISOBUTYLPARABEN
ISOPROTURON
KETOPROFEN
KETOROLAC
LIDOCAINE
LINCOMYCIN
LINURON
LOPRESSOR
MECLOFENAMIC ACID
MEPROBAMATE
METAZACHLOR
METHYLPARABEN
METOLACHLOR
NAPROXEN
NIFEDIPINE
NORETHISTERONE
OXOLINIC ACID
PENTOXIFYLLINE
PERFLUORO BUTANOIC ACID - PFBA
PERFLUORO OCTANESULFONIC ACID - PFOS
PERFLUORO OCTANOIC ACID - PFOA
PERFLUORO-1-BUTANESULFONIC ACID - PFBS
PERFLUORO-1-HEXANESULFONIC ACID - PFHxS
PERFLUOROHEPTANOIC ACID - PFHpA
PERFLUORO-N-DECANOIC ACID
PERFLUORO-N-HEXANOIC ACID
PERFLUORO-N-NONANOIC ACID - PFNA
PERFLUOROPENTANOIC ACID
PHENAZONE
PRIMIDONE
PROGESTERONE
PROPAZINE
PROPYLPARABEN
QUINOLINE
SIMAZINE
SUCRALOSE
SULFACHLOROPYRIDAZINE
SULFADIAZINE
SULFADIMETHOXINE
SULFAMERAZINE
SULFAMETHAZINE
SULFAMETHIZOLE
SULFAMETHOXAZOLE
SULFATHIAZOLE
TCEP
TCPP
TDCPP
TESTOSTERONE
THEOBROMINE
THEOPHYLLINE
TRICLOCARBAN
TRICLOSAN
TRIMETHOPRIM
WARFARIN

Note: The Tucson list emphasizes detection and assessment occurrence of a wide variety of ECs in source and treated waters.

APPENDIX B
List 2. Scottsdale Water Campus Compounds of Potential Concern (CPC) List

N-Nitrosodiethylamine (NDEA)	Disinfection byproduct
N-Nitrosodiethylamine-1,1,1-d3	Disinfection byproduct
N-Nitrosodi-n-butylamine (NDBA)	Disinfection byproduct
N-Nitrosodi-n-propylamine (NDPA)	Disinfection byproduct
N-Nitrosomethylamine (NDMA)	Disinfection byproduct
N-Nitrosomethylethylamine (NMEA)	Disinfection byproduct
N-Nitrosomorpholine (NMOR)	Disinfection byproduct
N-Nitrosopiperidine (NPIP)	Disinfection byproduct
N-Nitrosopyrrolidine (NPYR)	Disinfection byproduct
Acetaminophen	Analgesic
Dichlofenac	Analgesic
Ibuprofen	Analgesic
Naproxen	Analgesic
Ciprofloxacin	Antibiotic
Erythromycin	Antibiotic
Sulfamethoxazole	Antibiotic
Triclosan	Antibiotic
Trimethoprim	Antibiotic
Gemfibrozil	Heart medicine
Caffeine	Psychoactive
Carbamazepine	Psychoactive
Fluoxetine (Prozac)	Psychoactive
Meprobamate	Psychoactive
Primidone	Psychoactive
Estradiol	Steroid
Estrone	Steroid
17-α-Ethinylestradiol	Steroid
Progesterone	Steroid
Testosterone	Steroid
Oxybenzone	Sunscreen
N,N-Diethyl-meta-toluamide (DEET)	Pesticide

Note: This CPC list emphasizes a limited set of ECs that are diagnostic to monitoring the effectiveness of Scottsdale's advanced treatment processes in removing the ECs.

APPENDIX C

APEC SURVEY

APEC SURVEY Public Perception Working Group

SurveyMonkey

1. Please indicate the category that best descibes your utility.

	Response Percent	Response Count
Potable Water Utility	28.6%	6
Waste Water Utility	9.5%	2
Both Potable and Waste Water Utility	**61.9%**	**13**
Other (please specify)		5
answered question		**21**
skipped question		**5**

2. Rate your current level of concern related to Emerging Contaminants in your water system.

	Not Concerned	Somewhat Concerned	Concerned	Very Concerned	Rating Average	Rating Count
	0.0% (0)	**53.8% (14)**	30.8% (8)	15.4% (4)	2.62	26
answered question						**26**
skipped question						**0**

3. Please rank the following Emerging Contaminants that are of greatest concern or priority fo responses.)

	1	2	3	4	5	6	7	8	9	10
Microbials	**20.8% (5)**	**20.8% (5)**	16.7% (4)	12.5% (3)	4.2% (1)	4.2% (1)	4.2% (1)	12.5% (3)	0.0% (0)	0.0% (0)
Nitrosamines	4.2% (1)	20.8% (5)	12.5% (3)	4.2% (1)	8.3% (2)	**25.0% (6)**	12.5% (3)	0.0% (0)	0.0% (0)	4.2% (1)
DBPs (other than nitrosamines)	**29.2% (7)**	4.2% (1)	20.8% (5)	12.5% (3)	4.2% (1)	8.3% (2)	12.5% (3)	4.2% (1)	0.0% (0)	0.0% (0)
Algal Toxins	0.0% (0)	0.0% (0)	4.2% (1)	12.5% (3)	16.7% (4)	4.2% (1)	**20.8% (5)**	**20.8% (5)**	12.5% (3)	0.0% (0)
Pharmaceuticals	20.8% (5)	12.5% (3)	4.2% (1)	8.3% (2)	8.3% (2)	**25.0% (6)**	4.2% (1)	8.3% (2)	8.3% (2)	0.0% (0)
Personal Care Products	4.2% (1)	4.2% (1)	0.0% (0)	12.5% (3)	8.3% (2)	16.7% (4)	16.7% (4)	12.5% (3)	**20.8% (5)**	4.2% (1)
Pesticides	8.7% (2)	8.7% (2)	13.0% (3)	**17.4% (4)**	8.7% (2)	4.3% (1)	8.7% (2)	13.0% (3)	4.3% (1)	4.3% (1)
Industrial Chemicals	4.2% (1)	8.3% (2)	4.2% (1)	4.2% (1)	**25.0% (6)**	4.2% (1)	8.3% (2)	16.7% (4)	12.5% (3)	12.5% (3)
Fire Retardants	0.0% (0)	8.3% (2)	0.0% (0)	0.0% (0)	4.2% (1)	4.2% (1)	8.3% (2)	4.2% (1)	**29.2% (7)**	**29.2% (7)**
Nanomaterials	0.0% (0)	4.2% (1)	4.2% (1)	0.0% (0)	4.2% (1)	0.0% (0)	0.0% (0)	8.3% (2)	4.2% (1)	**33.3% (8)**
Naturally-Occurring Hormones	0.0% (0)	0.0% (0)	4.2% (1)	0.0% (0)	4.2% (1)	4.2% (1)	0.0% (0)	0.0% (0)	4.2% (1)	8.3% (2)
Inorganics	8.3% (2)	8.3% (2)	16.7% (4)	8.3% (2)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	4.2% (1)	4.2% (1)
Pipe & Tank Liners	0.0% (0)	0.0% (0)	0.0% (0)	8.3% (2)	4.2% (1)	0.0% (0)	4.2% (1)	0.0% (0)	0.0% (0)	0.0% (0)

4. Has your utility participated in research studies, directly or as project advisory members or done in-house monitoring for any of the Emerging Contaminants listed above?

	Response Percent	Response Count
Yes	**60.9%**	**14**
No	39.1%	9
Other (please specify)		2
answered question		**23**
skipped question		**3**

5. If you selected 'Yes' to question 4, which Emerging Contaminants does your utility monitor and how were they selected for monitoring?

	Response Count
	12
answered question	**12**
skipped question	**14**

6. Has your utility been contacted by your customers about concerns related to Emerging Contaminants?

	Response Percent	Response Count
Yes	47.6%	10
No	**52.4%**	**11**
Other (please specify)		3
answered question		**21**
skipped question		**5**

7. Rate your customers' level of concern related to Emerging Contaminants in your water system.

	Not Concerned	Somewhat Concerned	Concerned	Very Concerned	Rating Average	Rating Count
	22.2% (4)	**61.1% (11)**	11.1% (2)	5.6% (1)	2.00	18
					answered question	**18**
					skipped question	**8**

8. If your utility has been contacted by your customers with concerns, specifically which Emerging Contaminants have you been contacted about? (Check all that apply.)

	Response Percent	Response Count
Microbials	35.3%	6
Nitrosamines	0.0%	0
DBPs (other than nitrosamines)	23.5%	4
Algal Toxins	0.0%	0
Pharmaceuticals	**70.6%**	**12**
Personal Care Products	47.1%	8
Pesticides	11.8%	2
Industrial Chemicals	5.9%	1
Fire Retardants	0.0%	0
Nanomaterials	0.0%	0
Naturally-Occurring Hormones	5.9%	1
Inorganics	29.4%	5
Pipe & Tank Liners	0.0%	0
	Other (please specify)	1
	answered question	**17**
	skipped question	**9**

9. If/when your utility is contacted about Emerging Contaminants by the public, does your utility have a standard protocol for providing information to your customers?

	Response Percent	Response Count
Yes	33.3%	6
No	**66.7%**	**12**
Other (please specify)		1
answered question		**18**
skipped question		**8**

10. Which of the following resources do you currently provide to customers containing information about Emerging Contaminants? (Check all that apply.)

	Response Percent	Response Count
Local Utility Website	56.3%	9
Other Utility Website	6.3%	1
Regulatory Agency Website (EPA, ADEQ, other)	**81.3%**	**13**
WateReuse Association Publications/Website/Resources	18.8%	3
WateReuse AZ Publications/Website/Resources	6.3%	1
AZ Water Publications/Website/Resources	25.0%	4
Fact Sheets/Brochures	37.5%	6
Bill Insert	12.5%	2
University Publications/Website/Resources	12.5%	2
	Other (please specify)	1
	answered question	**16**
	skipped question	**10**

11. Considering your communication with the public, what are the most common term(s) that you use when communicating about Emerging Contaminants?

	Response Percent	Response Count
Emerging Contaminants (ECs)	25.0%	4
Contaminants of Emerging Concern (CEC)	25.0%	4
Trace Organic Contaminants (TOrCs)	12.5%	2
Constituents of Concern (COC)	12.5%	2
Endocrine Disrupting Compounds (EDCs)	18.8%	3
Pharmaceuticals & Personal Care Products (PPCPs)	**62.5%**	**10**
	Other (please specify)	1
	answered question	**16**
	skipped question	**10**

12. Does your utility have plans to develop a comprehensive approach to dealing with Emerging Contaminants currently or in the future? (Including but not limited to monitoring, treatment, and communication.)

	Response Percent	Response Count
Yes, we have a plan.	5.6%	1
No, we do not have a plan.	**94.4%**	**17**
	Other (please specify)	0
	answered question	**18**
	skipped question	**8**

13. What type of information/format would be most useful in helping you address concerns related to Emerging Contaminants?

	Not Useful	Somewhat Useful	Useful	Very Useful	Rating Average	Rating Count
Websites	0.0% (0)	10.5% (2)	**47.4% (9)**	42.1% (8)	3.32	19
Fact Sheets/Brochures	0.0% (0)	22.2% (4)	**38.9% (7)**	**38.9% (7)**	3.17	18
University Publications/Website/Resources	0.0% (0)	27.8% (5)	**44.4% (8)**	27.8% (5)	3.00	18
Template PowerPoint Presentations	11.8% (2)	**41.2% (7)**	35.3% (6)	11.8% (2)	2.47	17
Continuing Education/Trainings on Public Communication	5.6% (1)	**33.3% (6)**	27.8% (5)	**33.3% (6)**	2.89	18
Continuing Education/Trainings on Water Quality and Treatment	5.6% (1)	27.8% (5)	**50.0% (9)**	16.7% (3)	2.78	18
Scientific Publications	5.6% (1)	**44.4% (8)**	33.3% (6)	16.7% (3)	2.61	18
					Other (please specify)	1
					answered question	**19**
					skipped question	**7**

14. If there was a clearinghouse of resources (fact sheets, publications, other) available for your utility to use to aid in communication with your customer about Emerging Contaminants, how likely would you be to use these resources?

	Not Likely	Somewhat Likely	Likely	Very Likely	Rating Average	Rating Count
	0.0% (0)	10.5% (2)	**47.4% (9)**	42.1% (8)	3.32	19
					Other (please specify)	0
					answered question	**19**
					skipped question	**7**

15. Considering the questions above, do you believe that your utility is adequately prepared to provide information to customers about Emerging Contaminants related to your water system?

	No, we are not prepared.	We are somewhat prepared.	Yes, we are prepared.	Yes, we are very prepared.	Rating Average	Rating Count
	22.2% (4)	**66.7% (12)**	11.1% (2)	0.0% (0)	1.89	18
					Other (please specify)	0
					answered question	**18**
					skipped question	**8**

16. If a free, full-day workshop at central AZ location (e.g. Maricopa, AZ) were offered on how to communicate to your customers about Emerging Contaminants, would your utility make a best effort to send a representative?

		Response Percent	Response Count
Yes		**100.0%**	**19**
No (If not why?)		0.0%	0
		answered question	**19**
		skipped question	**7**

Page 2, Q1. Please indicate the category that best descibes your utility.

1	W & WW Consultant	Oct 19, 2013 5:30 PM
2	Consultant	Oct 17, 2013 1:27 PM
3	Academic	Oct 7, 2013 3:44 PM
4	Consultant	Oct 7, 2013 1:45 PM
5	I work for a state agency	Oct 7, 2013 1:39 PM

Page 2, Q4. Has your utility participated in research studies, directly or as project advisory members or done in-house monitoring for any of the Emerging Contaminants listed above?

1	N/A	Oct 19, 2013 5:30 PM
2	Worked with some research with previous employer. Also have conducted several literature reviews of EC removal via membranes	Oct 7, 2013 1:45 PM

Page 3, Q5. If you selected 'Yes' to question 4, which Emerging Contaminants does your utility monitor and how were they selected for monitoring?

1	DBP's, Organics, EPA mandated	Nov 27, 2013 7:25 AM
2	We selected a small group of contaminants that included pharmaceuticals, hormones and flame retardents. We have also monitored for Naegleria fowleri in our system and our sources.	Oct 23, 2013 1:15 PM
3	DBPs, NDMA, Pharmaceuticals, Personal Care Product, Hormones, Inorgancs. Based on detection in our effluents.	Oct 15, 2013 3:00 PM
4	pharmeceuticals, personal care products, antiobiotic resistance. compounds the community is concerned about	Oct 8, 2013 3:05 PM
5	perchlorate, hexavalent chromium, select pharmaceutcals, select personal care proeducts, select estrogens, select flame retardents, Legionella and Cryptosprodium. Items were selected based on occurrence data, specific research data, specific water quailty concerns and regulatory or potential regulatory needs.	Oct 8, 2013 1:10 PM
6	perchlorate	Oct 8, 2013 12:30 PM
7	Participated in a pesticide project with USDA and they also checked for a few of the pharmaceuticals and personal care products. Currently participating in EPA's UCMR3 study.	Oct 8, 2013 11:28 AM
8	DBP, Hexchrome	Oct 7, 2013 3:09 PM
9	I created a Emerging Compounds research program for Tucson Water. Use primarialy the list developed by MWH, now Eurofins Labs. Also review of CCL3.	Oct 7, 2013 2:00 PM
10	Pharmaceuticals were selected in areas where septice systems existed in close proximity to groundwater wells. This effort was incepted once our utility learned of USGS's efforts of testing for PCP and pharmaceuticals several years ago. This was a one time testing session. Low levels of ibuprofen, caffeine and a couple of hormones were detected.	Oct 7, 2013 2:00 PM
11	Via UCMR3	Oct 7, 2013 1:54 PM
12	THM, NDMA, EDCs.	Oct 7, 2013 1:48 PM

Page 4, Q6. Has your utility been contacted by your customers about concerns related to Emerging Contaminants?

1	general concern expressed	Oct 23, 2013 1:18 PM
2	A couple of calls following the media coverage in 2008	Oct 15, 2013 3:01 PM
3	Chromium VI	Oct 7, 2013 2:24 PM

Page 4, Q8. If your utility has been contacted by your customers with concerns, specifically which Emerging Contaminants have you been contacted about? (Check all that apply.)

1	Have not been contacted regarding Emerging Contaminants.	Oct 8, 2013 11:30 AM

Page 4, Q9. If/when your utility is contacted about Emerging Contaminants by the public, does your utility have a standard protocol for providing information to your customers?

1	Have not been contacted about Emerging Contaminants.	Oct 8, 2013 11:30 AM

Page 4, Q10. Which of the following resources do you currently provide to customers containing information about Emerging Contaminants? (Check all that apply.)

1	n/a	Nov 27, 2013 7:27 AM

Page 4, Q11. Considering your communication with the public, what are the most common term(s) that you use when communicating about Emerging Contaminants?

1	n/a	Nov 27, 2013 7:27 AM

Page 5, Q13. What type of information/format would be most useful in helping you address concerns related to Emerging Contaminants?

1	You Tube videos?	Oct 23, 2013 1:21 PM

APPENDIX D

ARIZONA PRESCRIPTION DRUG DROP BOX LOCATIONS

Arizona Prescription Drug Drop Box Locations

Location	Address	City	Zip	County
Puerco Fire District	36750 Highway 191 South	Sanders	86512	Apache
Springerville Police Department	418 East Main Street	Springerville	85938	Apache
Apache County Sheriff's Office	370 South Washington St	St. Johns	85936	Apache
Benson Hospital	450 South Ocotillo Ave	Benson	85602	Cochise
Bisbee Police Department	1 West Highway 92	Bisbee	85603	Cochise
Douglas Fire Department	1400 East 10th St.	Douglas	85607	Cochise
Elfrida Fire Department	10293 N Central Hwy	Elfrida	85610	Cochise
Huachuca City Fire Department	500 N Gonzales Blvd	Huachuca City	85616	Cochise
Whetstone Fire District	2422 North Firehouse Ln	Huachuca City	85616	Cochise
Sunsites-Pearce Fire District	105 Tracy Road	Pearce	85625	Cochise
Fry Fire Department	4817 S Apache Ave	Sierra Vista	85650	Cochise
Sierra Vista Fire Station #1	1295 East Fry Blvd	Sierra Vista	85635	Cochise
Sierra Vista Fire Station #2	4127 Avenida Cochise	Sierra Vista	85635	Cochise
Sierra Vista Fire Station #3	675 Giulio Cesare Ave	Sierra Vista	85635	Cochise
Sierra Vista Police Department	911 North Colorado Dr	Sierra Vista	85635	Cochise
Tombstone Fire Department	315 E Fremont St	Tombstone	85638	Cochise
Willcox Police Department	320 West Rex Allen Dr.	Willcox	85643	Cochise
Flagstaff Police Department	911 E Sawmill Rd	Flagstaff	86001	Coconino
Page Police Department	808 Coppermine Rd	Page	86040	Coconino
Williams Police Department	501 West Rt. 66	Williams	86046	Coconino
Globe Police Department	175 North Pine Street	Globe	85501	Gila
Miami Police Department	740 West Sullivan	Miami	85539	Gila
Payson Police Department	303 North Beeline Highway	Payson	85541	Gila
Pima Police Department	136 West Center	Pima	85543	Graham
Graham County Sheriff's Department	523 South 10th Avenue	Safford	85546	Graham
Safford Police Department	525 South 10th Ave	Safford	85546	Graham
Thatcher Police Department	3700 West Main Street	Thatcher	85552	Graham
Clifton Police Department	210 Coronado Blvd	Clifton	85533	Greenlee
Canyonlands Health Center	227 Main Street	Duncan	85534	Greenlee
Gila Health Resources	118 5th Street	Morenci	85540	Greenlee
Chandler Police Department	250 East Chicago Street	Chandler	85225	Maricopa
Chandler Police Department Substation	4040 East Chandler Road	Chandler	85225	Maricopa
Chandler Police Department Substation	251 North Desert Breeze Blvd East	Chandler	85226	Maricopa
Gilbert Police Department	75 E. Civic Center Dr.	Gilbert	85296	Maricopa
Goodyear Fire Department - Station No. 183	3075 North Litchfield Rd	Goodyear	85338	Maricopa
Goodyear Police Department	144455 West Van Buren Street, Ste E101	Goodyear	85338	Maricopa
Mesa Police Department Central Station	120 North Robson	Mesa	85201	Maricopa
Mesa Police Department Fiesta/Dobson Station	1010 West Grove	Mesa	85210	Maricopa

Location	Address	City	Zip	County
Mesa Police Department Red Mountain Station	4333 East University	Mesa	85205	Maricopa
Mesa Police Department Superstition Station	2430 South Ellsworth	Mesa	85209	Maricopa
Paradise Valley Police Department	6433 East Lincoln Drive	Paradise Valley	85253	Maricopa
Peoria Police Department	8351 West Cinnabar Avenue	Peoria	85345	Maricopa
Peoria Police Department - North Pinnacle Peak Station	23100 West Lake Pleasant Parkway	Peoria	85382	Maricopa
Phoenix Police Department	620 West Washington Street	Phoenix	85003	Maricopa
Phoenix Police Department - Black Mountain Precinct	33355 North Cave Creek Rd	Phoenix	85331	Maricopa
Phoenix Police Department - Cactus Park Precinct	12220 North 39th Avenue	Phoenix	85029	Maricopa
Phoenix Police Department - Central City Precinct	1902 South 16th Street	Phoenix	85034	Maricopa
Phoenix Police Department - Mountain View Precinct	2075 East Maryland Avenue	Phoenix	85016	Maricopa
Phoenix Police Department - South Mountain Precinct	400 West Southern Avenue	Phoenix	85041	Maricopa
Phoenix Police Department - Desert Horizon Precinct	16030 North 56th Street	Scottsdale	85254	Maricopa
Scottsdale Police Department Foothills District	20363 North Pima Road	Scottsdale	85255	Maricopa
Scottsdale Police Department McKellips District	7601 East McKellips Road	Scottsdale	85257	Maricopa
Scottsdale Police Department Via Linda District	9065 East Via Linda	Scottsdale	85258	Maricopa
Phoenix Police Department - Estrella Mountain Precinct	2111 South 99th Avenue	Tolleson	85353	Maricopa
Wickenburg Police Department	155 North Tegner Street	Wickenburg	85390	Maricopa
Bullhead City Police Department	1255 Marina Boulevard	Bullhead City	86442	Mohave
Kingman Police Department	2730 East Andy Devine Avenue	Kingman	86401	Mohave
Lake Havasu City Police Department	2360 McCulloch Blvd North	Lake Havasu	86403	Mohave
Hualapai Police Department	103 Eagle Street	Peach Springs	86434	Mohave
Holbrook Police Department	120 E Buffalo St	Holbrook	86025	Navajo
Pinetop-Lakeside Police Department	1360 North Niels Hansen Ln	Lakeside	85929	Navajo
Heber-Overgaard Fire Department	2061 Lumber Valley Road	Overgaard	85933	Navajo
Show Low Police Department	150 North 6th St	Show Low	85901	Navajo
Snowflake-Taylor Police Department	602 South Main Street	Snowflake	85937	Navajo
Pinon Chapter House	Between Route 41 & N4, Business Loop 8031	Whiteriver	85941	Navajo
Winslow Police Department	708 West 3rd Street	Winslow	86047	Navajo
Pima County Sheriff's Substation - Green Valley	601 North La Canada Drive	Green Valley	85614	Pima
Sahuarita Police Department	315 West Sahuarita Center Way	Sahuarita	85629	Pima
Tucson Police Department Downtown Substation	270 South Stone Avenue	Tucson	85701	Pima
Tucson Police Department Midtown Substation	1100 South Alvernon Way	Tucson	85705	Pima
Tucson Police Department South Substation	4410 South Park Avenue	Tucson	85714	Pima
Tucson Police Department Westside Substation	1310 West Miracle Mile	Tucson	85705	Pima
Tucson Police East Substation	9670 East Golf Links Road	Tucson	85730	Pima
Apache Junction Police Department	1001 North Idaho Road	Apache Junction	85119	Pinal
Pinal County Sheriff's Office	13970 South Sunland Gin Road	Arizona City	85123	Pinal
Casa Grande Police Department	373 East Val Vista Blvd	Casa Grande	85122	Pinal
Casa Grande Police Department	520 North Marshall Street	Casa Grande	85122	Pinal
Healthcare Medical Waste Services	1305 North VIP Blvd.	Casa Grande	85122	Pinal
Pinal County Sheriff's Office	820 East Cottonwood Ln.	Casa Grande	85122	Pinal

Location	Address	City	Zip	County
Coolidge Police Department	911 South Arizona Blvd.	Coolidge	85128	Pinal
Eloy Police Department	630 North Main Street	Eloy	85131	Pinal
Florence Police Department	425 North Pinal Street	Florence	85132	Pinal
Pinal County Sheriff's Office	971 North Jason Lopez Circle, Bldg C	Florence	85132	Pinal
Pinal County Sheriff's Office	5750 South Kings Ranch Rd	Gold Canyon	85118	Pinal
Kearny Police Department	355 Alden Road	Kearny	85137	Pinal
Mammoth Police Department	125 South Clark Rd	Mammoth	85681	Pinal
Maricopa Police Department	45147 West Madison Ave.	Maricopa	85139	Pinal
Pinal County Sheriff's Office	63701 East Saddelbrooke, Suite C	Saddlebrook	85739	Pinal
Pinal County Sheriff's Office	28380 South Veterans Memorial Highway	San Manuel	85631	Pinal
Pinal County Sheriff's Office	85 West Combs Rd, Ste 115	San Tan Valley	85142	Pinal
Superior Police Department	734 West Main Street	Superior	85173	Pinal
Nogales Police Department	777 North Grand Avenue	Nogales	85621	Santa Cruz
Camp Verde Marshal's Office	646 South 1st Street	Camp Verde	86322	Yavapai
Yavapai County Sherriff's Office	2830 North Commonwealth Drive, Ste 104	Camp Verde	86322	Yavapai
Chino Valley Police Department	1020 West Palomino Road	Chino Valley	86323	Yavapai
Clarkdale Police Department	49 North 9th Street	Clarkdale	86324	Yavapai
Cottonwood Police Department	199 South 6th Street	Cottonwood	86326	Yavapai
Jerome Police Department	305 Main Street	Jerome	86331	Yavapai
Prescott Police Department	222 South Marina	Prescott	86303	Yavapai
Yavapai County Sherriff's Office	255 East Gurly Street	Prescott	86301	Yavapai
Prescott Valley Police Department	7601 East Civic Circle	Prescott Valley	86314	Yavapai
Sedona Police Department	100 Roadrunner Drive	Sedona	86336	Yavapai
Somerton Police Department	455 East Main St.	Somerton	85350	Yuma
Yuma County Sheriffs Office	141 South 3rd Street	Yuma	85364	Yuma
Yuma County Sheriffs Office - District 1 Foothills Substation	13190 East South Frontage Road	Yuma	85367	Yuma
Yuma Police Department	1500 South 1st Avenue	Yuma	85364	Yuma

**Drop box coming soon*