Emerging Chemical Contaminants of Concern in the State of Arizona's Water

Prepared by the Chemical Emerging Contaminants Subcommittee of the Advisory Panel on Emerging Contaminants

20 December 2013

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1.0 INTRODUCTION

1.1 Background

The Advisory Panel on Emerging Contaminants (APEC) was formed by the Arizona Department of Environmental Quality (ADEQ) to advise ADEQ, water utilities, and the general public on matters concerning unregulated chemicals and pathogens in water (otherwise known as contaminants of emerging concern or CECs). The Chemical contaminant subcommittee of APEC was tasked with identifying and providing guidance on unregulated chemical contaminants found in Arizona waters. The subcommittee is comprised of members of ADEQ, professors and researchers from the University of Arizona, Arizona State University, and Northern Arizona University, and members from cities and municipalities, water utilities, law firms, and environmental consulting firms.

The purpose of this white paper is to provide water providers, utilities and the public current information about CECs with respect to human consumption and/or contact. This paper also will provide recommendations on how they are currently being addressed and how to minimize the use of these chemicals, as well as references to numerous publications on the subject. Emerging chemical contaminants listed in this document are compounds that have been found in Arizona waters and are not currently being considered by the United States Environmental Protection Agency (EPA) for proposed regulation, or they are being considered at a very preliminary level.

1.2 Water Sources in Arizona

There are many distinct water sources within Arizona that yield various volumes of water. The following information is a general overview of the sources of water that may be available in many parts of Arizona.

1.2.1 Ground water

The state of Arizona contains a variety of geological settings that contribute to the formation and retention of various groundwater scenarios. The southern and western parts of the state are generally characterized with basin and range type deposits. These deposits consisting of various mixtures of loose sediments and gravel have been known to produce vast amounts of groundwater in many areas. The water has accumulated within these basins over many thousands of years. The ability of groundwater wells to remove significant quantities of water from the aquifer during the past 100 years has allowed overland irrigation, the expansion of agriculture, and municipal growth. Many basin and range groundwater systems in Arizona typically are in a condition of historical "overdraft". This is when a particular aquifer is depleted of its water resources faster than it is replenished. Mountain front recharge is the primary natural mechanism to replenish basin aquifers.

In other parts of the state that do not exhibit the basin and range province characteristics, groundwater systems are much different. The central highlands, rim country, and the northern areas of the state commonly have groundwater systems based in rock formations. Water bearing units associated with permeable sandstones and fractured bedrock generally provide the groundwater base for many of these areas. Natural recharge of these aquifers can be limited due to the steep topography and high water runoff which may occur (ADWR, 2010). Groundwater surfacing as springs and flowing as surface water is not uncommon.

1.2.2 Surface water

Arizona's surface water systems fall into several categories: perennial, intermittent, ephemeral and effluent dependent. Perennial and intermittent streams and rivers dominate most areas in central and northern Arizona. Groundwater systems that produce outflows to a surface water body usually maintain flow in response to precipitation and groundwater storage throughout the year. The state's major continual flow is the Colorado River. The Colorado River watershed covers multiple states and is continually fed by rain or snowmelt. Other major perennial flows within the state include the Salt and Verde River systems.

Ephemeral water systems generally only respond to precipitation events and do not last. Ephemeral stream systems are more common in the basin and range areas of the state, as well as canyons and washes in areas with steep surface topography. Historically, Arizona had many perennial and intermittent streams and rivers in the basin and range areas, but over pumping of groundwater caused once gaining streams to become losing streams. The Santa Cruz River outside of Tucson is an example of a surface water system changing due to a change in the groundwater condition.

Effluent dependent surface waters are generally those water systems that would be an ephemeral water system if not for the discharge of treated wastewater into the surface water body. The Santa Cruz River near Nogales, and further downstream in Tucson and Marana, is the state's best example of an effluent dependent waterway. During dry periods, the surface flows within the river are 100% effluent dominated.

Harvested water is another temporary use of surface water. Harvested storm water appears in macro systems (community storm water retention basins) or in micro systems (household storm water retention). Each of these systems generally is temporary. In a macro system, a storm water retention basin is designed to collect water and limit damage from a large precipitation event to a community's roads and infrastructure. In a micro system, individuals are retaining harvested storm water for a secondary use as irrigation for landscaping. This system allows a homestead to retain precipitation to keep vegetation irrigated until the next storm water event.

The final potential usable surface water source in Arizona is reclaimed water. Reclaimed water systems directly use water produced by a constructed wastewater facility. Many communities across the state have developed a system to capture the wastewater effluent for beneficial use throughout their community. This can be done through a direct delivery network for industrial or irrigation applications. In addition, reclaimed water systems can divert what would be a surface water flow to a groundwater replenishment program. In this application, reclaimed water is stored underground for aquifer augmentation. Underground storage allows water to be recovered from the groundwater system when it is needed.

1.3 Water Usage in Arizona

Water usage in Arizona may include: drinking and food preparation, domestic uses (laundry, etc.), agriculture applications, industrial applications, recreation (surface water augmentation, irrigation for parks and golf courses, etc.), and general landscape irrigation. All of these applications can take advantage of either surface water or groundwater sources.

1.4 The Urban Water Cycle

The traditional water cycle taught in schools is based on the planetary water cycle. This is the description of water evaporation from the earth's oceans, precipitation of water on the land masses, the formation of groundwater and surface waters on those land surfaces, and the eventual return of that water to the world's oceans to begin the cycle over again. Recent concerns over the amount and access to water by people has created a new way of describing the water cycle on a community wide basis. This water cycle is often called the urban water cycle.

The urban water cycle has gained in popularity in states like Arizona where access to water is becoming increasingly important as the population continues to grow and access to water in many areas remains limited. The urban water cycle has a distinct focus on water that is utilized for potable water production, as well as how water is returned to the cycle from wastewater processes (Figure 1).

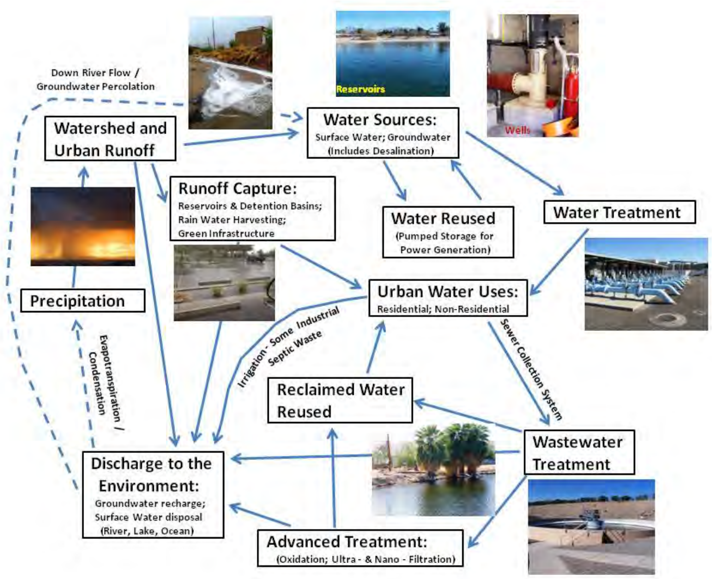

Figure 1: Generalized Urban Water Cycle that includes reuse of water.

1.5 Human Contact Pathways

Humans may be exposed to non-regulated chemical compounds in a variety of ways. The most direct way a person may come into contact with an unregulated drinking water compound is by directly using that compound in their daily environment. Most of these compounds are created for some type of beneficial use. Once the compounds are used, they can enter the environment, particularly the water environment.

Comment [A1]: See also http://www.docstoc.com/docs/592684/Origins-and-Fate-of-PPCPs-in-the-Environment

for a comprehensive view of pathways

Another direct way a person may come into contact with unregulated compounds is through a potable water supply. The likelihood for discovery of unregulated compounds is high if potable water is developed from groundwater that may have had historic contact with surface waters or directly under influence from wastewater discharges; or groundwater replenishment programs. Groundwater or surface water basins that have human-derived water discharges have the potential to contribute these compounds to the drinking water supply of a community or individual. The most direct pathway is through a wastewater effluent discharge program. Unregulated compounds that make it through a wastewater treatment process usually are released to the environment, where they can enter the urban water cycle and potentially make it into a future potable supply.

Direct body contact with dispersed CECs could occur through intentional recreation activities in surface water or routine bathing A reclaimed water program within a community may provide a way to disperse CECs that are not removed by a conventional wastewater treatment facility in the form of irrigation, industrial, or recreational waters.

If chemical compounds are used in the environment, precipitation can release and make mobile compounds on the ground. These compounds can end up in a surface water or groundwater system and eventually into a potable water supply. Unregulated compounds can be present in storm water retention basins and water harvesting programs. .

Comment [A2]: *1.Concentration of Trichloroethylene in Breast Milk and Household Water from Nogales, Arizona* Paloma I. Beamer, Catherine E. Luik, Leif Abrell, Swilma Campos, María Elena Martínez, and A. Eduardo Sáez *Environmental Science & Technology* **2012** *46* (16), 9055-9061

2.0 EMERGING CHEMICAL CONTAMINANTS FOUND IN ARIZONA WATERS

2.1 The List

Selected compounds that represent a variety of unregulated contaminants of emerging concern are presented in Table 1. Compounds are listed under categories of pharmaceuticals (divided into classes of use), endocrine disrupting compounds (EDCs), steroids, illicit drugs, compounds used in plastics, other industrial compounds and nanoparticle technology. Table 1 briefly describes each compound’s use, toxicity or health effects, detection in Arizona waters by water type, inclusion in the Water Research Association’s 2008 Toxicology Report, appearance on the EPA’s CCL3 list, the best treatment removal technology from wastewater or effluent dominant waters, and selected references related to toxicity. Complete references are cited in the appendix.

This list only scratches the surface of the many thousands of constituents in use and in our waters, but they represent some that are persistent in the environment with the capability to enter drinking water supplies. Agricultural, medical and industrial chemical technology continues to increase the number of synthetic compounds. Many of these compounds enter the environment via wastewater streams and others are applied in agriculture and industrial practices that extend pathways of entrance into the environment. Increased diversity in constituent types, awareness of some of the physiological actions of low dose exposure and the ability to increasingly detect smaller concentrations of these compounds has heightened the awareness of these compounds in all waters.

2.2 Defining Emerging Contaminants

Recognizing that analytical detection limits are getting lower and lower as technology is improving, potentially thousands of chemicals can be detected at trace levels. Typically when developing methods and monitoring programs, groups of indicator compounds are selected to determine the transport and fate through the environment and/or treatment processes. One indicator compound can represent a group of organic chemicals thereby eliminating analysis of hundreds of compounds. The chosen indicator represents the physical, chemical and biodegradable attributes of the group. Ideal indicator compounds should meet the following criteria:

(a) Presence in water sources of concern. A useful indicator compound should be detectable in a much higher percentage of the waters sampled than other trace organics. Also, if the indicator compound is not detected in a sample, the absence should strongly suggest that the water is free of all or nearly all wastewater-derived trace organic contaminants in that group.

(b) Analytical convenience. A reliable method must exist for each indicator compound.

(c) Ability to measure at concentrations encountered in water sources of concern. The compounds selected should be present in impacted waters at concentrations well above their respective detection or quantification limits.

(d) Persistence across typical water or wastewater treatment processes. Some of the compounds selected should survive processes used to prepare water for potable use. That is, they should survive these processes at least as well as trace organics that are not routinely measured. However, to use analytical results as a diagnostic tool—to analyze the performance of specific treatment processes—the full list should include compounds with a wide range of treatment-dependent removal efficiencies such as in the case of sulfamethoxazole. Sometimes there are few data with which to develop such expectations, so that physical data must be used to anticipate or predict the likelihood of compound removal during water treatment or attenuation in the environment.

(e) Potential Human and Ecological Effects (capacity to adversely affect physiological function). In this area, judgment is likely to be handicapped by a lack of data. For some trace organics, there are observable effect levels (non-carcinogens) or reference doses (carcinogens) that can be compared to concentrations in surface waters or wastewater effluent in order to establish relative risk. Furthermore, the list of indicators can be amended as more trace organics come under public and scientific scrutiny or additional toxicity information becomes available.

2.3 Where they have been found in Arizona

Studies concerning CECs around the world indicate that they are ubiquitous in urban wastewater streams wherever medicines are taken or household / personal care products are flushed. They are also present in surface water and groundwater supplies that have some connections to raw or treated wastewater disposal, agricultural or storm runoff, leaching refuse sites, or through spills/leaks/dumping of refined products such as perchlorate and hexavalent chromium plating solution.

Arizona is no different. The sampling of available data from the Phoenix metropolitan area, Tucson, Lake Havasu City, and Flagstaff indicates most of the pharmaceuticals and many of the EDCs, steroids and illicit drugs on this report's accompanying list of CEC examples are expected to be found in centralized sewer collection systems of the majority of Arizona's cities and towns. Several other compounds on the list occur only where they have been used for specific industrial purposes, such as those listed under the explosives and corrosion inhibitors categories.

Rural areas are not isolated from the presence of CECs in Arizona. Work on the Colorado, San Pedro, Santa Cruz, and Verde rivers shows CECs can be carried for many miles without decomposing with some potentially ending up in the source water for a downstream drinking water system. Section 3.1 presents examples of monitoring work conducted for known occurrences of CECs in Arizona's waters.

2.4 Potential Human and Ecological Effects

Numerous studies have evaluated the effects of many contaminants of emerging concern listed in Table 1. The studies looked at effects in various organisms and environments: humans, organisms under laboratory conditions, aquatic and marine environments, and in soils that can be leached. Understanding the biochemical effects on organisms exposed to compounds at concentrations found in the environment is important in determining the potential effects of CECs.

Research indicates many of the listed compounds exhibit varying levels of effects on human health and aquatic and terrestrial organisms (Kim et al., 2007; Martin-Diaz et al., 2009; Pal et al., 2010). Some chemicals have evidence of endocrine disrupting capabilities and other harmful effects. Antibiotics have the potential to cause changes in bacterial resistance. Still, other compounds have been shown to be harmless at all explored levels. The Arizona Nature Conservancy recently published a review of the effects of exposure to wastewater effluent on wildlife, demonstrating that the effects of exposure are not unique to the state of Arizona (Quanrud and Propper, 2010). Most studies have evaluated the effects of exposure to aquatic vertebrates such as fish, and the findings vary, but the most consistent effects suggest that mixes of CEC's in wastewater effluent may act as estrogens and ultimately affect sexual development. Again, the long-term health effects on these organisms at either the individual or population level have not been investigated.

Comment [CRP3]: ADEQ: do you want to expand on the wildlife/human literature effects or leave this section more generic as it is now? There is some new literature since Quanrud and Propper, but what has been found is not too dramatically different from the summary as written here.

Research on the transport and fate of emerging contaminants is essential to fully understand the environmental impact. The compounds can be diluted, undergo photolysis (react to sunlight), and can be oxidized (react to the atmosphere) as they are carried for miles in surface water. As the compounds change in the environment, by-products may be produced. These by-products can have varying effects on ecology and human health. In addition, some compounds may be taken up by organisms and stored in their tissue. Animals at the top of the food chain can accumulate not only the compounds and by-products found in the environment, but also in the food they eat. The higher the organism is in the food chain, typically the higher the concentrations of compounds in its tissues. This process is called bioaccumulation.

Emerging contaminants present in groundwater may be broken down by bacteria or be adsorbed (attached) onto mineral surfaces as the water migrates underground. Some compounds are quickly removed, but others persist in the groundwater after traveling several miles to potential water diversion locations. The latter case may include by-products formed during the bacterial decay process. Evaluation of the effects of these by-products on aquatic systems and to human health is in its infancy. Further research will continue to clarify the overall impact of CECs on the environment and to drinking water supplies.

The study of the effects of compound mixtures on organisms is well rooted in toxicological chemistry, yet investigations to determine actual toxicity of CEC mixtures in the environment are uncommon. Studies on the harmful effects from compound mixtures in laboratory settings, which could carry over to the aquatic environment, have supported two long standing principles: concentration addition and independent action (Cleuvers, 2003). Concentration addition means the compounds in the mixture affect an organism in similar ways or locations within the organism. Independent action means the compounds in the mixture can affect different areas or biochemical pathways (processes that happen at the cell level) within an organism. These two concepts, as applied to pollutants in conceptual aquatic environments, show that both have potential in predicting toxicological effects (Altenburger et al., 2000 and Backhaus et al., 2000).

However, some studies have shown there are exceptions to this rule. The combination of carbamazepine and clofibrinic acid (a lipid lowering agent) is an example of when drugs with two different actions follow the predicted path of concentration addition (Cleuvers, 2003). In the same study, a mixture of diclofenac and ibuprofen, compounds from the same class of anti-inflammatory compounds, would be expected to have similar effects on different organisms, but in actuality, they had differing effects on different organisms. Exposing this mixture to green algae followed the predicted concentration addition path, but had a much stronger than predicted effect on the common water flea *Daphnia*.

Pomati et al. (2006) investigated effects on human embryonic cells from a mixture of 13 compounds known to be environmentally persistent and common in receiving waters. The mixture concentration was equal to that found in environmental settings. The major effect noted by the mixture, which included sulfamethoxazole, carbamazepine and ibuprofen from Table 1, was inhibited cell growth. The study did not determine the underlying cause of the cell growth

Comment [CRP4]: ADEQ: Again, this is a section that can be expanded upon with more detail and literature. Would you like me to add to it?

changes. Understanding interactions among contaminants of emerging concern in the environment is important to determining relationships between mixture concentrations in water and causes of effects on organisms, including humans.

Whole animal exposures to complex mixes also demonstrate effects on several endocrine pathways. For example, in amphibians, where developing from a tadpole to a frog is a model for thyroid hormone activity, exposure to wastewater effluent affects thyroid-hormone dependent developmental processes (Searcy et al., 2012). In other aquatic vertebrate species, exposure to wastewater effluent affects development of reproductive organs (Sowers et al., 2009; Vajda et al., 2008; Woodling et al., 2006), and leads to expression of egg yolk protein in males (e.g. (Barber et al., 2011) *In vivo e*xposure of fish to sediment off of the Southern California coast, which receives significant wastewater effluent outfall, induces estrogenic responses that could not be predicted by those found from any one given extract fraction (Schlenk et al., 2005). These studies suggest that there may be unpredictable environmental health consequences of exposure to complex mixes.

2.5 Associated Compounds

Some compounds known to be associated with each other in the environment can harm certain organisms. Other compounds decompose to generate by-products with deleterious effects as mentioned in Section 3.2. Examples include: 1,4-Dioxane, a probable carcinogen according to the EPA, which has been found with trichloroethylene (TCE) and trichloroethane (TCA) groundwater plumes in several remediation locations around the United States, including Tucson; and Triclosan which breaks down into dichlorodibenzo-*p*-dioxin (DCDD) when it is exposed to heat, sunlight (in aqueous environments) or ultraviolet disinfection during water treatment (Doudrick et al., 2010). DCDD can be further decomposed in the presence of polyvinyl chloride to toxic dioxin-like congeners.

Along with perfluorinated contaminants (e.g. PFOS and PFOA) introduced to ground water at many Department of Defense facilities through the use of flame retardant mixtures, chlorinated degreasing solvents and jet fuel components occur as co-contaminants, represented by TCE, heptane, undecane and *m*-xylene (1,3-dimethylbenzene) (Moody et al., 1999).

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3.0 RECOMMENDATIONS FOR UTILITIES

3.1 Background

Several communities in Arizona have conducted studies identifying, monitoring, and mitigating unregulated compounds of concern. The mitigation aspect mostly has been concerned with potential water and wastewater treatment processes that reduce or eliminate CECs in the respective water streams. The following case histories are presented to give water and wastewater utilities around the state possible approaches to understanding their CEC situation.

U.S. Geological Survey

The U.S. Geological Survey (USGS) has been sampling the groundwater, surface water, and aquatic biota across Arizona for emerging chemical contaminants of concern (CECs) since the early 1970's. The earliest detections were for Diazinon, a general purpose insecticide, in 1972 in the Gila River at Gillespie Dam (U.S. Geological Survey National Water-Information System).
The USGS has been sampling the Colorado River for CECs since the late 1970's. CECs were first detected in the aquatic biota of the Lower Colorado River in 1986-87 (Radtke et al., 1988), and again in 1995 (Tadayon et al., 1997). CEC's have been detected in the river water samples since the 1990's at locations at Lee's Ferry, above Diamond Creek, above Imperial Dam, and at the northern International boundary with Mexico (U.S. Geological Survey National Water-Information System). In 2003, CECs were detected in the aquatic biota from several regions of the Colorado River and its tributaries (Hinck et al., 2006).

In northern Arizona, CECs were detected in aquatic biota in the Verde River and Granite Creek in 1996 (Gebler, 2000). Groundwater samples in Prescott from 1999 contained CECs (U.S. Geological Survey National Water-Information System). The Rio de Flag in Flagstaff contained CECs when sampled in 2004 (U.S. Geological Survey National Water-Information System). CECs were detected at several locations in Lake Powell in 2010-2011 (U.S. Geological Survey National Water-Information System).

In central Arizona, the USGS first detected CECs in streams, aquatic biota, and groundwater throughout the West Salt River Valley, including the areas of Phoenix, Peoria, Surprise, Goodyear, and Buckeye, in 1996-98 (Gebler, 2000; Gellenbeck and Anning, 2002). Detections of CECs were widespread during this time period in shallow groundwater affected by agricultural activities in the western part of the West Salt River Valley, near Buckeye (Edmonds and Gellenbeck, 2002). In the mid- to late-2000's, groundwater in the West Salt River Valley was sampled again in similar areas as in 1996-98, and CECs were again detected (U.S. Geological Survey National Water-Information System). CECs were found in the water and aquatic biota at the Tres Rios Demonstration Constructed Wetlands in 1998-2000 (Barber et al., 2003), and in the water at the outfall from the 91st Avenue wastewater treatment plant (WWTP) in 1999 (Barnes et al., 2002; Kolpin et al., 2002). Finally, CECs have been detected in urban runoff throughout the Phoenix region since 2002 (U.S. Geological Survey National Water-Information System).

In south-central Arizona, the USGS first detected CECs in streams and groundwater throughout the Upper Santa Cruz Basin, including the areas of Oro Valley, Tucson, Green Valley, and Nogales, in 1998 (Gellenbeck and Anning, 2002). CECs have been detected in the Santa Cruz River at Cortaro Road in 1999 (Barnes et al., 2002; Kolpin et al., 2002), downstream of the Roger Road WWTP in 2004-05 (Walker et al., 2009), at Tubac from 1997-2010 (U.S. Geological Survey National Water-Information System), near Rio Rico in 1999 (Barnes et al., 2002; Kolpin et al., 2002), at Santa Gertrudis Lane from 1997-2012 (U.S. Geological Survey National Water-Information System), and downstream of the Nogales International WWTP in the late 1990s (Petty et al., 2000) and in 2012 (U.S. Geological Survey National Water-Information System). CECs were detected in aquatic biota in the Santa Cruz River at Tubac in 1996 (Gebler, 2000) and in the Santa Cruz River downstream of the Roger Road WWTP in 2004-05 (Walker et al., 2009). In addition, the USGS detected CECs in 2002 in the Santa Cruz River downstream of the Ina Road WWTP and in wells adjacent to the river in this area (Cordy et al., 2002). Finally, the USGS has been monitoring CECs in south Tucson since the 1980's (Leake and Hanson, 1987; Graham and Monical, 1997; Tillman, 2009; Tillman, 2010).

In southeastern Arizona, the USGS detected CECs in groundwater throughout the San Pedro Basin, including the areas of Sierra Vista, Bisbee, Tombstone, and Benson, in 1996-97 (Gellenbeck and Anning, 2002). In 2008, CECs were detected in a spring located east of Sierra Vista (U.S. Geological Survey National Water-Information System).

Tucson Area: Tucson Water has been investigating and evaluating the presence of emerging contaminants 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:

a) Literature searches on emerging contaminants, occurrence, monitoring, analyses, regulations and treatment.
b) Participation in local, regional and national research studies.
c) Developing and implementing a monitoring program for groundwater, surface water, recharged surface water, recharged wastewater and reclaimed water. Annually an expanding suite of compounds are measured at locations representing drinking water, recharged surface water and groundwater sources. The data is compiled and evaluated for trending compounds that are found at each location and used as baseline data in research efforts.

Tucson water has collaborated with the USGS, the University of Arizona, Water Research Foundation and numerous other entities to determine the presence and influence of CECs. Section 6.3 lists several references to studies that the Tucson Water has been involved with. In addition, Tucson Water is an active member of the Pima County Dispose-A-Med (Take Back) Program.

Lake Havasu City: A town of 53,000, Lake Havasu City sits on the shores of Lake Havasu with surface and subsurface water flow toward the lake. In late 2008, the city initiated a treated wastewater 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 CECs and monitor the fate as the effluent migrated away from the recharge site. The analyzed group of 40 CECs were restricted to available analytical suites provided by the Southern Nevada Water Authority River Mountains Operations Center Laboratory and EPA National Exposure Research Laboratory, both in Las Vegas. Most of the compounds are well known for their persistence in the environment and many are included on the list given in Section 2 of this report.

Water samples were collected, beginning in 2007, on the Colorado River and Lake Havasu, from the city's raw source water (a horizontal collector well) and subsequent treated water, from treated wastewater streams and from the Colorado River Aquifer down gradient from the recharge site and down gradient from more than 25,000 septic tanks in the city. Monitoring of groundwater at the recharge site and one WWTP continues to date. Ultra-low concentrations (parts per trillion or ng/L) of certain CECs were detected in all of the water types, but the wastewater streams had by far the highest concentrations and the most diverse detection of compounds (33 out of 40). Eighteen compounds were detected in the river/lake system, but only six compounds were detected in the raw source water, atrazine, carbamazepine, meprobamate, phenytoin, primidone and sulfamethoxazole. Only one of those, sulfamethoxazole, did not survive chlorine gas disinfection, although all six compounds survived short, high intensity ultraviolet radiation prior to chlorination.

Although the recharged treated wastewater is intended for seasonal storage, water can migrate away from the recharge site and eventually end up as return flow into the lake two miles away. Monitoring wells up to 2000 feet down gradient from the recharge site reveals only a few constituents; sulfamethoxazole, carbamazepine, N,N-Diethyl-meta-toluamide (DEET), meprobamate, phenytoin, primidone, gemfibrozil and sucralose (in the parts per billion or µg/L range) survive above detection limits. The results compliment earlier studies.

Phoenix Area: Drewes et al. (2003) made an early attempt to delineate CEC fate in groundwater in the Phoenix area and found some compound concentrations (caffeine, diclofenac, ibuprofen, naproxen and gemfibrozil) decreased to below detection levels within six months and others (carbamazepine and primidone) persisted for more than eight years.

The Arizona State University School of Sustainability conducted several studies in the mid to late 2000’s on a variety of focus topics concerning CECs in the environment (references given in section 2.5). Surface water tested included the Verde River, Salt River and the Central Arizona Project canal system (Chiu and Westerhoff, 2010). 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, contained CEC concentrations at levels near those collected at the treated wastewater outflow.

Modeling efforts have been made to better understand wastewater treatment CEC removal techniques for individual compounds (Weir et al., 2010).

Flagstaff: The City of Flagstaff has used reclaimed treated wastewater for 20 years and today recycles more than 700 million gallons of water each year for conservation purposes. In

January 2013, the City Manager convened an Advisory Panel of local, state and national experts to discuss what CECs mean to Flagstaff. The initial focus of the panel discussions has been around "human health impacts" and the panel has recommended the City focus on four compounds detected in the City's reclaimed water; 17-beta estradiol, N-nitrosodimethylamine (NDMA), triclosan and caffeine. The first two compounds are on the EPA's Contaminant Candidate List #3.

Additionally, the City of Flagstaff has been proactive at managing its water supplies and voluntarily conducted four sampling events dating back to 2002 that tested for a variety of unregulated CECs within its drinking water and reclaimed water. A 2002-2006 study by Northern Arizona University detected CECs in the City's reclaimed water. Sampling events also took place from 2010 through 2012 in the City's drinking water and reclaimed water. CECs detected in the raw and finished drinking water supply were caffeine, DEET, Theobromine, Triclosan, Iohexal and Acesulfame-K. The Lake Mary water source had Bisphenol-A (BPA), diaminochlorotriazine (DACT), Naproxen and Theobromine above detection limits. Reclaimed water samples yielded 33 compounds out of 87 analyzed above detection limits, including acesulfame-K, Iohexal, sucralose and aldicarb sulfone. Like other sample sites within the state, all concentrations from the Flagstaff sources varied from parts per trillion (ng/L) to a few at the parts per billion level (µg/L).

Last, the City of Flagstaff contracted with the USGS and NAU to do the first evaluation of CEC's in both the reclaimed and direct release wastewater effluent (Propper, 2006). The results demonstrated that while CEC's were in the wastewater effluent, the types of compounds and their concentrations were similar to those found in other studies throughout the United States. Furthermore, the study evaluated the potential for the wastewater effluent to affect thyroid hormone activity in a model amphibian system. The results demonstrated that exposure to the wastewater may affect thyroid hormone-dependent development. However, the results of this study could not predict whether exposure during development would lead to long-term adverse outcomes on health (Searcy et al., 2012).

3.2 Current Treatment Techniques

Research has shown that using conventional water and wastewater treatment methods alone have limited capability of significantly removing CECs. Additional steps are necessary to greatly reduce concentrations of these compounds. Those processes examined, but found of limited value, are coagulation, lime softening, biofiltration and ultraviolet photolysis (UV). However, other processes, such as chlorination, powder activated carbon, ozonation, and membrane filtration, including reverse osmosis, have been shown to essentially remove many constituents (up to >99%).

There are drawbacks to some of the effective processes. For example, reverse osmosis is expensive to install and operate and it creates brine that must be carefully disposed of. Chlorination generates chlorinated by-products, such as trihalomethanes and haloacetic acids, that are regulated and their generation must be minimized.

Powdered active carbon (PAC) and granular activated carbon (GAC) can be used either in drinking water or wastewater treatment processes to improve odor and taste and promote adsorption of compounds to the carbon particle surfaces. This technology is used extensively in European drinking water treatment systems as shown in Figure 2. PAC is particularly known to remove significant percentages of many CECs (Westerhoff et al., 2005). PAC can be dosed directly to existing flocculent tanks at a prescribed rate followed by flocculation or mechanical filtration.

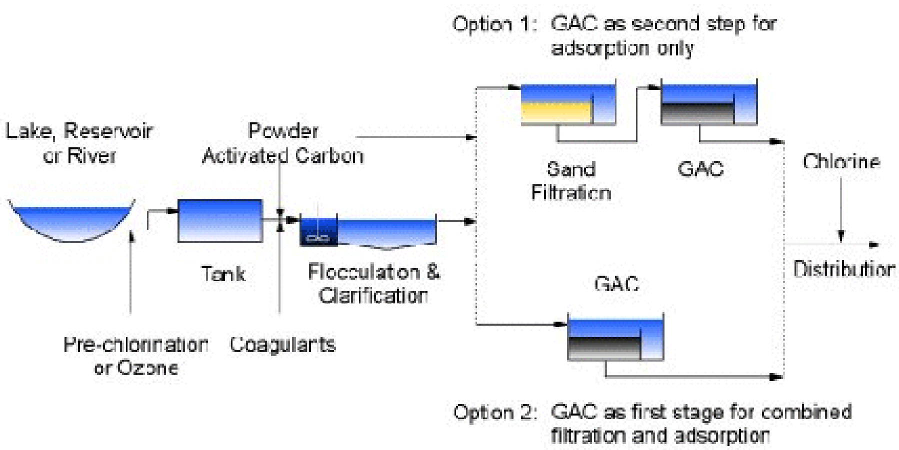

Figure 2: Schematic flow chart of drinking water treatment steps involving PAC and GAC (http://www.chemvironcarbon.com/en/applications/drinking-water-treatment/municipal-and-industrial).

Chlorination and ozonation involve oxidizing compounds to transform them. Briefly, free chlorine gas and more effectively, chlorine dioxide, react particularly with phenolic compounds by adding chlorine to the aromatic ring structure and cleaving the ring (Snyder et al., 2003). Molecular ozone and the hydroxyl radicals produced during ozone injection react with amines, phenols and double bonds in aliphatic structures. Yet to yield the most effective transformation of CECs, advance oxidation processes (AOP) may be required. AOP involves combining either ozone with hydrogen peroxide, UV treatment with hydrogen peroxide or ozone with UV treatment. (Snyder et al., 2003; Acero and Von Gunten, 2001).

Membrane filtration – Nanofiltration (<0.001 – 0.01 μm) and reverse osmosis filtration techniques in wastewater treatment have shown success in removing substantial percentages of CECs (up to >95%) (Kim et al., 2007). The nanofiltration process to remove CECs from water is dominated by hydrophobic adsorption and size exclusion on the membranes (Yoon et al., 2007). Molecules with molecular weights <100 can generally pass through nanofilters if not adsorbed, but reverse osmosis can block much smaller molecules, including most CECs.

3.2.1 – Selected Advanced Treatment Facilities

The following examples of advanced water treatment for wastewater and raw source water showcase the above mentioned technologies, but also indicate subtle local preferences in the treatment train.

Singapore – Wastewater

The Singapore Public Utilities Board is in charge of four water reclamation facilities that generates NEWater, a brand name given to treated wastewater that has been purified using the following steps: conventional wastewater treatment, microfiltration, reverse osmosis, ultraviolet disinfection and pH balance. The primary function of the microfiltration step is to remove surface suspended solids, colloidal particles, disease-causing bacteria, some viruses and protozoan cysts. The reverse osmosis step blocks most other contaminants in the water. However, for redundancy, UV disinfection is applied to make sure any microorganisms present are inactive. The resulting water is essentially at a distilled state, but an alkaline addition step is included at the end of the entire process to adjust pH balance for human consumption and for industry requiring high purity water. NEWater production meets 30% of the population's water demand , currently 114 Million Gallons Per Day (MGD), and plans are to expand operations to meet 55% of the demand by 2060.

Orange County, California – Wastewater

Groundwater Replenishment System by Orange County Water District recharges treated wastewater at the Fountain Valley Water Purification Facility. The purification process includes microfiltration, reverse osmosis and oxidation with ultraviolet light and with hydrogen peroxide, and treats the water almost to a distilled state, similar to the Singapore process. The largest single facility for water purification at 70 MGD processed, this facility will be expanded by 30 MGD to supply a total of 850,000 residents by 2014. Treated water is sent to recharge wells and percolation basins along the Santa Ana River for eventual reuse after blending with groundwater.

Scottsdale Water Campus, Arizona – Wastewater

Scottsdale's primary Water Reclamation Plant (WRP), 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 associated with the City's Reclaimed Water Distribution System. The WRP process includes nitrification/denitrification followed by tertiary treatment and disinfection which provides Class A+ reclaimed water, as defined by the Arizona Department of Environmental Quality (ADEQ). The city also conducts groundwater recharge at the Water Campus as part of the assured water supply program. The primary source water for this effort is Class A+ reclaimed water from the WRP further treated through the Advanced Water Treatment (AWT) Plant located at the Water Campus. The AWT consist of microfiltration, reverse osmosis (RO), UV, post treatment stabilization and vadose zone recharge wells.

Originally designed for treating 20 MGD, the Water Campus was expanded to 24 MGD in 2013. This expansion also included the addition of ozonation prior to microfiltration and UV following RO. In addition to providing disinfection, the ozone oxidizes the precursors for nitrosamine formation resulting in lower nitrosodimethylamine (NDMA) production and also reduces other CECs. The UV was added to further reduce NDMA to below 10 ppt. and remove the remainder of chemical contaminants not removed through RO.

Queensland, Australia - Wastewater

The Bundamba Advanced Water Treatment Plant (AWTP) is part of the largest recycled water scheme in the Southern Hemisphere and the third-largest in the world. The Bundamba facility, one of three AWTP facilities planned, was built in two main stages for a total capacity of 17.4 MGD. The main treatment steps include ultrafiltration membranes, reverse osmosis membranes followed by advanced oxidation using UV and hydrogen peroxide. The ultrafiltration step goes one step further than microfiltration (0.1 – 3 μm) as the pore size range is 0.01 -0.1 μm. The plant also uses 18 x 61 inch spiral wound reverse osmosis membranes, instead of the more conventional 8 x 40 inch membranes, which reduced the number of required membranes (585 membrane elements), lowered capital cost and construction time, resulted in less maintenance and required a smaller plant footprint.

Cincinnati, Ohio – Potable Water

The Richard Miller Treatment Plant in Cincinnati, Ohio, is a 240 MGD capacity potable water treatment facility owned and operated by the city under the Greater Cincinnati Water Works Department. The primary water source for the city is the Ohio River, which is mostly polluted with various organic compounds. The facility uses coagulation and high rate sedimentation processes to remove large solids as a preliminary pre-filtration step and then sends the water to biologically active rapid sand filtration basins to remove particles and impurities. The water is then subject to a granular activated carbon (GAC) adsorption process to remove many organic compounds and finally is taken through ultraviolet disinfection. The GAC process uses adsorption contactors that hold 3.5m of GAC and take 15 minutes of empty bed contact time to get rid of organic materials from the water. Prior to supplying to consumers, the GAC treated water is chlorinated to meet primary disinfection requirements for *Giardia lamblia* and virus inactivation. Though the chlorinated water fulfills all the existing drinking water standards, it is not effective against *Cryptosporidium*, a chlorine-tolerant protozoan now regulated under the Long-Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR, or LT2 rule). The ultraviolet disinfection system provides an additional inactivation barrier to protect against harmful protozoa.

3.3 Sampling and Analysis

For entities interested in monitoring for CECs, there are certain things to consider when developing a monitoring program; proper sampling technique, choosing an analytical method and choosing a laboratory.

3.3.1 Sampling

The goal of sampling water for CECs should be to obtain samples representative of the environment being sampled. Samples should be handled in a manner that does not alter how well the results represent the environmental water conditions. The time and place of sampling, the equipment used to collect and filter samples, the bottles used, the preservation methods, how samples are stored, and how samples are shipped for analysis can all potentially affect sample CEC concentrations. In order to minimize error introduced during sampling for CECs, precise repeatable procedures should be followed. Many of these procedures have been thoroughly described in guidelines authored by the U.S. Environmental Protection Agency (2007) and by the U.S. Geological Survey (variously dated).

Following quality-assurance (QA) procedures and collecting quality-control (QC) data are vital steps to verifying a sample represents the environmental water being studied. QA procedures are used to manage un-measurable components of sampling, such as sampling at the right time and place, using the correct equipment, and following the proper techniques. QC data is generated by collecting QC samples, such as blanks, replicates, and spikes, to quantify bias and variability introduced during the sample collection and handling. Chapter A4 of the USGS National Field Manual for the Collection of Water-Quality Data (USGS, 2006) gives guidance on preparing for and collecting QC samples.

Passive samplers, such as the semipermeable membrane device (SPMD) and the polar organic chemical integrative sampler (POCIS) are becoming more widely used to sample water for CECs. Guidelines for the use of passive samplers, including guidance on QA and QC, are available in Alvarez (2010).

3.3.2 Analysis

For many of the compounds listed in Table 1 there are standard EPA methods available to determine if they are present and at what amount. Many commercial and several utility laboratories have the instrumentation and capabilities to run these tests. Table 2 below lists some of the readily available methods and corresponding compounds:

EPA Method	Title	CEC detected
218.7	Determination Of Dissolved Hexavalent Chromium In Drinking Water, Groundwater And Industrial Wastewater Effluents By Ion Chromatography	Hexavalent Chromium
331	Determination Of Perchlorate In Drinking Water By Ion Chromatography With Suppressed Conductivity And Electrospray Ionization Mass Spectrometry	Perchlorate
521	Determination Of Nitrosamines In Drinking Water By Solid Phase Extraction And Capillary Column Gas Chromatography With Large Volume Injection And Chemical Ionization Tandem Mass Spectrometry (MS/MS)	Nitrosodimethylamine (NDMA)
522	Determination Of 1,4-Dioxane In Drinking Water By Solid Phase Extraction (SPE) And Gas Chromatography/ Mass Spectrometry (GC/MS) With Selected Ion Monitoring (SIM)	1,4 Dioxane
524.3	Measurement Of Purgeable Organic Compounds In Water By Capillary Column Gas Chromatography/Mass Spectrometry	1,2,3-Trichloropropane
527	Determination Of Selected Pesticides And Flame Retardants In Drinking Water By Solid Phase Extraction And Capillary Column And Solid Phase Extraction And Capillary Column Gas Chromatography/Mass Spectrometry	Atrazine, Chlorpyrifos, Malathion, Parathion, PDBE and PBB
537	Determination Of Selected Perfluorinated Alkyl Acids In Drinking Water By Solid Phase Extraction And Liquid Chromatography/Tandem Mass Spectrometry (LC/MS/MS)	PFOS, PFOA
539	Determination Of Hormones In Drinking Water By Solid Phase Extraction (SPE) And Liquid Chromatography Electrospray Ionization Tandem Mass Spectrometry	Testosterone, Ethinylestradiol, Estradiol
614	The Determination of Organophosphorus Pesticides in Municipal and Industrial Wastewater	Diazinon
1694	Pharmaceuticals and Personal Care Products in Water, Soil, Sediment, and Biosolids by HPLC/MS/MS	Various EDCs and Pharmaceuticals
8095	Explosives By Gas Chromatography	Hexahydro-1,3,5-trinitro-1,3,5-triazine and 2,4,6-Trinitrotoluene

More information regarding available EPA approved methods can be found at the following EPA websites: http://water.epa.gov/scitech/drinkingwater/labcert/analyticalmethods.cfm and http://water.epa.gov/scitech/drinkingwater/labcert/analyticalmethods_ogwdw.cfm.

A study sponsored by the Water Research Foundation (#4167) and completed in 2012 evaluated analytical methods for EDCs and pharmaceuticals (Vanderford, 2012). The objective of the project was to evaluate sampling, preservation and various methods for the analysis of CECs at low detection levels in various water matrices and provide analytical guidelines for future work. Twenty five laboratories analyzed a suite of twenty two compounds using fifty different methods. Unsilanized glass amber bottles, ascorbic acid for dechlorinating and sodium azide for preservation were shown to have the least effect on compound recoveries. A combination of Liquid Chromatography/Tandem Mass Spectrometry (LC/MS/MS) and isotope dilution was determined to be the method of choice for 18 of the 22 compounds. For this method, isotopically labeled versions of each compound are added to the samples prior to extraction. The results for the unlabeled compound (what is present in the sample) are corrected for matrix effects based on the recovery of the labeled versions.

Analyzing for CECs, for most laboratories, is a relatively new endeavor. There are commercial laboratories that are able to analyze for CECs but because the methods are not approved by regulatory agencies the following items should be considered when choosing a laboratory:

- Does the laboratory have an independent quality assurance (QA) department? Is the lab accredited with any organization? If so, which one(s)? Do they follow any published standard of good laboratory practices?
- Will any of the sample testing be outsourced to another lab?
- How do they handle samples from the time of receipt, through lab analysis, report issuance and data archiving?
- Do they have written procedures and schedules for instrument and equipment maintenance and calibration?
- Does the laboratory have written standard operating procedures for the non-standard methods? How does the lab assure the test result(s) is both accurate and precise?
- Is raw data in bound books (laboratory notebooks) or in other laboratory information systems? Is there a way to track a final report to the original raw data? What is the time period for retaining raw data can such data be provided upon request?

- What is the typical turn-around- time for results?
- If unexpected results are received, what policies and procedures does the lab follow to assure those results are valid?
- How much experience does the lab (including the analyst working on the samples) have analyzing emerging contaminants with non-standard methods?
- If the lab is analyzing for CECS with non-standard methods do they use stable isotopically labeled internal standards in their quality control (QC) measures?

Currently there is research being conducted on the use of bioanalytical tools to screen for CECs. Instead of analyzing for specific compounds, the toxicological effects of an entire sample can be determined by incubating cells with the water sample and observing metabolic changes. Therefore, in the future, in addition to the chemical and analytical techniques, bioassays that use both cell culture and animal assays may help identify potential exposure outcomes. Assays that can be applied may include those developed by the USEPA through Toxcast and the Endocrine Disruptor Screening Program (http://www.epa.gov/ncct/toxcast/; http://www.epa.gov/endo/).

The Arizona Department of Health Services Lab Licensure, ADEQ, USGS and the universities listed in this white paper can provide information about laboratories available to provide analysis for compounds of emerging concern using non-standard methods. Commercial laboratories who analyze for compounds listed in Table 2 may also analyze for CECs or be able to provide contact information for laboratories who do.

Comment [llm5]: Guidance from ADEQ on what information to provide regarding labs available to analyze for CECs

4.0 RECOMMENDATIONS FOR THE PUBLIC

Our detection capabilities and our understanding of CECs are improving every day. CECs may be new substances or old substances that only recently have been detected in the environment (Arroyo, 2013). Substances we use every day, flush or wash, or otherwise discard, end up in our water supplies. CECs found in our water supply are there because of our exposures through many other routes. As federal and state governments begin to formulate approaches in addressing these difficult-to-regulate contaminants, we all can do our part in reducing our exposure and that of others by taking the following simple steps.

4.1 Chemical usage in Your Home: Better Decisions

The fewer chemicals we use, the fewer will end up in the water cycle. GoodGuide, Inc. (www.goodguide.com), an organization led by a team of chemists, toxicologists, nutritionists, sociologists, and lifecycle analysis experts, rates products and companies on their health, environmental, and social performance. Goodguide, Inc.'s 0 to 10 rating system helps consumers quickly evaluate and compare products. Another useful site is from the Environmental Working Group's Consumer Guides (http://www.ewg.org/consumer-guides) which also provides information on many different types of products. Many homes have a variety of chemicals used for house projects that have, over time, have become "stale" or are no longer useful for projects. These chemicals can range from solvents, to pesticides, to paint and varnish, spot removers, bleach, fertilizers, etc. Because wastewater now is recycled, any and all of these chemicals should be properly disposed of. There are neighborhood hazardous chemical collection drives (see Section 4.3) that individuals and communities should use as opposed to pouring any of these chemicals down drains or in the storm drains. Practice helps keep these chemicals from making their way back into our drinking water supplies.

Most medications can be thrown in the household trash. Before throwing the medication in trash, mix it with undesirable substances like coffee grounds or kitty litter and place in an impermeable, nondescript container such as a sealable bag. Since water reuse has become standard for Arizona wastewater treatment plants, NO medicines should be flushed down the toilet. Some of the CECs can pass through sewage treatment plants and septic tanks and into surface water, soils, and groundwater. As noted earlier, no chemicals should be poured down your drains or allowed to enter the storm sewers. This will help keep these chemicals out of our water supply.

4.2 Treatment Devices

Multiple styles of water treatment devices are available on the market today. The most common styles are Point-of-Entry (POE) and Point-of-Use (POU) systems. POE devices typically treat water entering the residence or business and are usually installed after the water meter. A water softener is an example of a POE device. POU devices typically treat water in batches and deliver water to a single tap, such as the refrigerator.

It is important to note no POE or POU device has been certified to remove CECs. However, testing has shown them to reduce concentrations of CECs, with various degrees of effectiveness. The result of this testing, which was conducted by The Good Housekeeping Research Institute, partnering with the Arizona Laboratory for Emerging Contaminants at the University of Arizona, was documented in a March 2012 issue of Good Housekeeping Magazine at www.goodhousekeeping.com/tapwater. To test drinking water filters, municipal water was spiked with 15 CECs that have been discovered in drinking water. Then, to simulate the weeks or months of use that pitcher and fridge filters would get in a real home, researchers passed gallons of contaminated water through each device until it reached the manufacturer's estimated filter lifetime, then recorded the results. Table 2 below presents the 15 CECs tested and the range of the effectiveness of the tested filters:

CEC	Was the Filter Effective?	Percent Removed
Atrazine	Yes	60 - 92
BPA	Yes	60 - 95
Carbamazepine	Yes	60 - 92
DEET	Yes	60 - 92
Estrone	Yes	60 - 100
Fluoxetine	Yes	60 - 95
Ibuprofen	Yes	60 - 95
PFOA	Yes	55 - 95
PFOS	Yes	60 - 95
Primidone	Yes	60 - 92
Sucralose	Yes	49 - 92
Sulfamethoxazole	Yes	60 - 92
TCEP	Yes	60 - 92
Tonalide	Yes	60 - 92
Trimethoprim	Yes	60 - 92

The results of the testing suggests existing products are capable of reducing approximately one-half of the spiked concentration of the CECs, with some successful of removing more than 90 percent.

4.3 Take Back Programs

Periodic drug take back programs are available statewide. Because such programs fall under the authority of the Controlled Substance Act, contact your local law enforcement agency to find out if take back events are scheduled in your community. These programs not only assist the long term impact on the regional water cycle, but they also create an acute solution to drug abuse.

Pima County's "Dispose-A-Med" program at www.disposeamed.pima.gov has been especially effective in organizing and collecting unused or expired medication. Formed in 2009, Dispose-A-Med program includes representatives from a variety of community partners including law enforcement, fire departments, pharmacies, water and wastewater utilities, and community coalitions. Visitors to the website can search for upcoming collection dates and locations. Once collected, the medication is incinerated.

For additional information on take back programs consult the following websites:

- Arizona Department of Environmental Quality
  http://www.azrecycles.gov
- U.S. Department of Justice Drug Enforcement Administration
  http://www.deadiversion.usdoj.gov/drug_disposal/takeback/
- U.S. Environmental Protection Agency
  http://water.epa.gov/scitech/swguidance/ppcp/take-back.cfm

5.0 SUMMARY AND RECOMMENDATIONS

Understanding the relationship of chemicals within the environment will continue to be an area of focus for the world, not just Arizona. As chemical compounds are created and utilized by consumers, the ability of some of these compounds to enter the environment will always be present.

Of a positive note, many communities around Arizona are cognizant of the relationship between chemical use and the environment. Communities, research institutions, and other government entities have been conducting research for many years throughout the state to better understand this relationship and its possible effects on natural habitats or the human population.

This committee recommends the following activities to be initiated or continued in the future:

- Support of the State of Arizona University System to continue their world renown research in the fields of engineering, science, biology, etc., that support the advancement of knowledge in the world of emerging chemical compounds.
- Encourage community water and wastewater programs throughout the state to embrace and support research within their urban water cycle to fully understand the presence of unregulated compounds within their community.

- Communities should look for opportunities to jointly conduct research with research universities and other outside agencies like the United States Geological Survey, the U.S. Department of Agriculture, and U.S. Bureau of Reclamation.
- Encourage communities to share any research data obtained about their community with the Arizona Department of Environmental Quality.
- Encourage and educate communities on what local programs can support the reduction of unregulated compounds within their environment.
- Support the continuation of the state's Advisory Panel on Emerging Contaminants (APEC) to further collect information on unregulated contaminants and support educational efforts to minimize their introduction into the environment of Arizona.

This committee looks forward towards continuing the state-wide dialogue on this most important topic to the State of Arizona.

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Objective: This comprehensive report was prepared by the University of Arizona for Tucson Water in an effort to address the public and the scientific community concerns over PPCPs and EDCs by characterizing the current conditions in Arizona.

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Objectives: (a) to identify surrogates and indicators for wastewater-derived chemical contaminants that might be useful in the assessment of indirect potable reuse systems; (b) to identify and assess the performance of analytical methods for the chosen surrogates and indicators; and, (c) to validate the ability of chosen surrogates and indicators to predict the occurrence and removal of wastewater-derived contaminants in indirect potable water reuse systems.

Results of the Analyses for 1,4-Dioxane of Groundwater Samples Collected in the Tucson Airport Remediation Project Area, South-Central Arizona, 2006-2009
Objective: Assist in investigating the extent of groundwater contamination in the TARP area.

Water Research Foundation 4269, 2008, Detection and Quantification of EDC/PPCPs in Source Waters Containing Dissolved and Colloidal Organic Matter
Objectives:

- Assess the influence of dissolved and colloidal organic matter (DOM and COM) on standard practices of EDC/PPCP extraction from water and subsequent analysis (detection and quantification) using liquid and gas chromatography tandem mass spectrometry (LC-MSMS and GC-MSMS).
- Determine the effects of various watershed DOM/COM sources and constituent fractions on EDC/PPCP detection and quantification.
- Provide project partners with a preliminary assessment of EDC/PPCP levels in their source waters and treated wastewaters, including compound persistence in waters affected by wastewater effluent.

USGS 104b, 2010, Identifying PFOS sources to the Tucson Aquifer
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