White Paper: Contaminants of Emerging Concern and Reclaimed Water

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Introduction

The growing concern about the public and environmental health impacts from pharmaceuticals and personal care products (PPCPs) or contaminants of emerging concern (CECs) in water supplies has fueled a multitude of research on this topic. Reclaimed water that is reused for both potable and non-potable purposes is known to contain such chemicals, and there is concern about the adverse health effects from exposure to these water sources. De facto water reuse (incidental exposure, but after treatment) means that many water intakes are downstream of a wastewater treatment plant. Therefore, constituents that humans and businesses excrete after conforming to their discharge permit to waters of the state may contain CECs (https://www.epa.gov/dwucmr/learn-about-unregulated-contaminant-monitoring-rule).This paper summarizes research on the potential health effects from exposure to CECs, what is known and further research needs.

CEC Presence

Scientists and health officials are concerned about whether concentrations of CECs are statistically different in reclaimed water than in other water sources (e.g. drinking water sources). The WateReuse Foundation assessed CEC levels in non-potable reclaimed water, groundwater and surface water at 12 separate locations for 244 CEC analytes (pharmaceuticals, hormones and steroids, volatile organics, semi volatile organics, nutrients, micro biologicals and synthetic organic chemical constituents). The samples were taken from distinct water matrices: groundwater, groundwater under the influence of surface or reclaimed water, surface water, surface water under the influence of reclaimed water, and reclaimed water effluent (non-potable). The reclaimed water treatment processes included six secondary and five tertiary treatment processes, each using sand filtration with nine of the sites having deep bed sand filters, and three sites having traveling bridge sand filters. Chlorine disinfection was used at 11 of the treatment plants and the other plant used chloramine. None of the treatment trains included membrane filtration. Appendix A (figures taken from (WateReuse Foundation, 2009) shows graphical representations of the distribution of concentrations of all constituents tested. The figures show that reclaimed water is slightly higher in hormonal and steroidal constituents, most inorganics and significantly higher in many organic constituents (WateReuse Foundation, 2009).

The data revealed that 39% of the 244 analytes were not detected in *any* of the water sources in the wet and dry season samples. The samples also revealed that reclaimed water was within the drinking water standards for trihalomethanes and haloacetic acids (HAAs), and samples of chemicals that exceeded drinking water standards were within three times the recommendations set for drinking water. Salinity concentration was similar in reclaimed water effluents, and groundwater had slightly higher concentrations of metals (arsenic, barium, calcium, selenium, iron and copper). Reclaimed water had higher concentrations of aluminum, potassium and mercury in addition to nutrients. PPCPs were found in all water sources in most of the samples (e.g. DEET and Caffeine). Overall, the constituents present in all of the water sources were detected at the microgram or nanogram per liter range (WateReuse Foundation, 2009).

The results from the WateReuse Foundation study are similar to findings in other research on CECs in water sources. For example, the United States Geological Survey (USGS) and Environmental Protection Agency) EPA assessed source and product water from 25 drinking water treatment plants in the United States and found pharmaceuticals in both the source and product water samples, although fewer were detected in product water samples indicating drinking water treatment is effective at removing some CECs (Furlong et al., 2017). Additionally, an assessment of residual chemicals in wastewater influent, reclaimed water (Class A per state of Washington requirements) and ground and surface water also revealed that many CECs were present, although in most cases less concentrated in ground and surface water (LOTT, LOTTa & LOTTb, 2017). Results from these assessments indicate the influence that wastewater effluent (e.g. the public contribution through urination, and other disposal methods from consuming and using CECs) has on water sources.

Health Impacts

CEC Exposure from Fields Irrigated with Reclaimed Water

A risk assessment conducted in 2012 revealed that exposure to tertiary treated, non-potable reclaimed water from recreating on areas irrigated with recycled water (both children and adults) and working in agricultural fields irrigated with recycled water is highly unlikely to pose adverse health effects. The study employed the EPA's risk assessment method that included hazard identification, exposure assessment, dose-response relationship and risk characterization. Concentrations of PPCPs in recycled water were below the acceptable concentrations of daily intake levels for each PPCP. Furthermore, exposures to PPCPs from recycled water for the above mentioned uses were compared to other exposure pathways (e.g. taking an aspirin for a headache) and showed that it would take anywhere from a few to 190 million years of exposure to equal a single day of exposure for the same PPCP for normal, day-to-day uses. For example, according to the study a child would have to play once a week during the nice-weather months for 160,000 years on a playground irrigated with recycled water before being exposed to the equivalent of one dose of the prescription hormone replacement 17-beta estradiol (Kennedy et al., 2012). These results coincide with findings from a large group of similar studies that assessed the daily dose of PPCPs from ingestion of vegetables irrigated with reclaimed water and bio solids as documented in Xiaoqin et al. 2015.

Fate and Transport from Irrigated Landscapes

Adverse health effects from exposure to endocrine disrupting compounds (EDCs) are also of concern. One study spiked recycled water with five different EDCs and irrigated landscapes near ponds to determine the fate and transport of these chemicals in the environment. All five EDCs were not detectable six hours after the irrigation event, and EDC concentrations were generally lower in the ponds after irrigation, indicating attenuation during drainage and runoff (Sidhu et al., 2015). Snyder et al. 2003 concluded that exposure to EDCs from consuming seafood was likely a greater risk than exposure to the low concentrations found in drinking water.

Risk of CECs in Drinking, Surface and Groundwater

The World Health Organization (WHO) conducted a project to determine the public health risk associated to pharmaceuticals in drinking water. They reviewed published literature on studies that assessed concentrations of pharmaceuticals in surface and ground water

impacted by wastewater effluent and found them to be typically less than 0.1 microgram per Liter in the surface and groundwater, and well below 0.05 micrograms per Liter for treated drinking water. The WHO concluded that trace quantities of pharmaceuticals in drinking water are very unlikely to pose risks to human health, however that the combined risks from the "cocktail" of contaminants and long term exposure need to be assessed to truly understand the health impacts (WHO, 2011). They suggested "that concern over pharmaceuticals should not take away focus and resources from more immediate threats to water quality such as disease-causing microorganisms and high levels of arsenic and fluoride" (Raghav, M. et al., 2013).

CEC Accumulation in Plant Tissue

An interesting study in 2015 assessed the accumulation of CECs into different tissue portions (root, shoot and fruit) of edible crops (lettuce and strawberries). They measured nine structurally diverse chemicals (tris1-chloro phosphate, tris2-propyl phosphate, tris2-chloroethyl phosphate, carbamazepine, diphenhydramine, sulfamethoxazole and trimethoprim) and found that affinity to plant tissue compartments vary. Accumulation of some CECs into the shoots and roots showed a linear relationship to concentration of CECs in reclaimed water, and accumulation in plants decrease in the order of root, leaf, stem and fruit. The authors measured the concentration of chemicals in the edible portions of the plants and found that all of the targeted chemicals ingested per day were less than the acceptable ingestion limits for the chemicals, and many were magnitudes lower. Physiochemical properties of chemicals such as hydrophobicity, charge, solubility, molecular weight and size impact how plants uptake CECs and further research is needed to draw conclusions and classify chemical uptake (Hyland et al., 2015, Hyland et al., 2015a). Additionally, chemical structure and physio-chemical properties affect how CECs persist and/or degrade in soils and in turn, affects their bioavailability to crops (Xiaoqin et al., 2015).

Effectiveness of CEC Removal by Conventional WWTFs

Conventional, biological wastewater treatment shows a range of effectiveness in removing pharmaceuticals (for those that have been studied) ranging from less than 20% to greater than 90%. Factors that affect removal include sludge age, activated sludge tank temperature and hydraulic retention time. Free chlorine has been shown to remove up to 50% of pharmaceuticals that have been investigated in drinking water treatment, and chloramines have lower removal efficiency. Treatment employed to treat wastewater for potable reuse purposes (e.g. indirect and direct potable reuse) show much higher removal rates. Ozonation, advanced oxidation, activated carbon and nanofiltration and RO membranes have pharmaceutical removal rates up to 99%. The WHO recognizes that there are challenges to monitor, treat and evaluate risks from these contaminants and recommend that trace concentrations of these chemicals do not warrant installation of costly treatment to completely remove them from drinking water at the time of their assessment (WHO, 2011).

Research Needs

The fate and transport of CECs in the environment need further investigation to determine the toxicological impacts from exposure to trace levels in water (Snyder et al., 2003). Researchers also recommend that health effects from the combined mixture of chemicals found in drinking water and the environment be assessed (WHO, 2011). Additionally, the impacts of exposure to these chemicals to sensitive populations need to be assessed with

regards to lifetime exposure (per the standard EPA risk assessment of consumption.) The WHO has acknowledged that because there are data gaps due to the fact that these constituents are fairly new to the environment and water sources, there is a need to constantly review new data and update their *Guidelines to Drinking-water Quality* to include pharmaceuticals, when necessary (Raghav et al., 2013). The EPA continues to address these concerns with drinking water standards, and the water reuse, academic community continues to address these concerns for uses of reclaimed water for both potable and non-potable uses.

References

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Appendix A

Figures of Concentrations of CECs in Ground, Surface and Reclaimed Water*

*WateReuse Foundation. (2009) *A Reconnaissance-Level Quantitative Comparison of Reclaimed Water, Surface Water, and Groundwater.* IBSN: 978-1-934183-12-0.

FIGURE 11
Concentrations of organic constituents (µg/L)

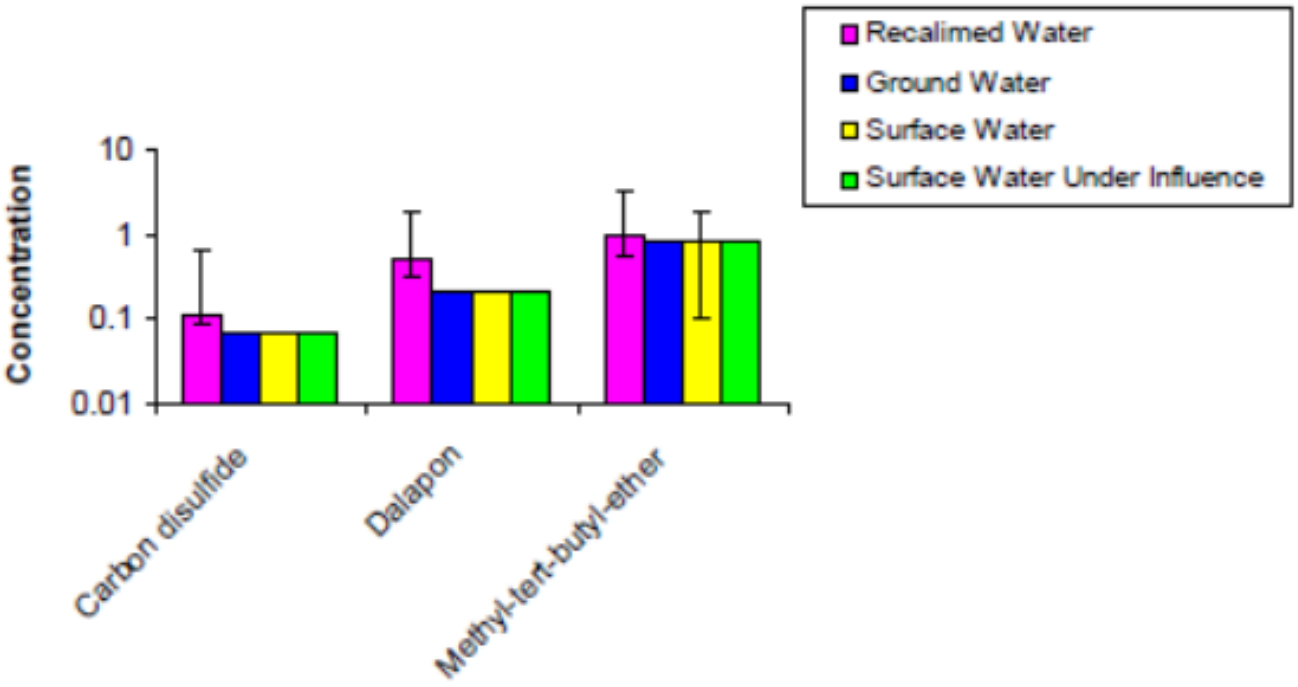

FIGURE 12
Concentrations of hormonal and steroidal constituents (ng/L)

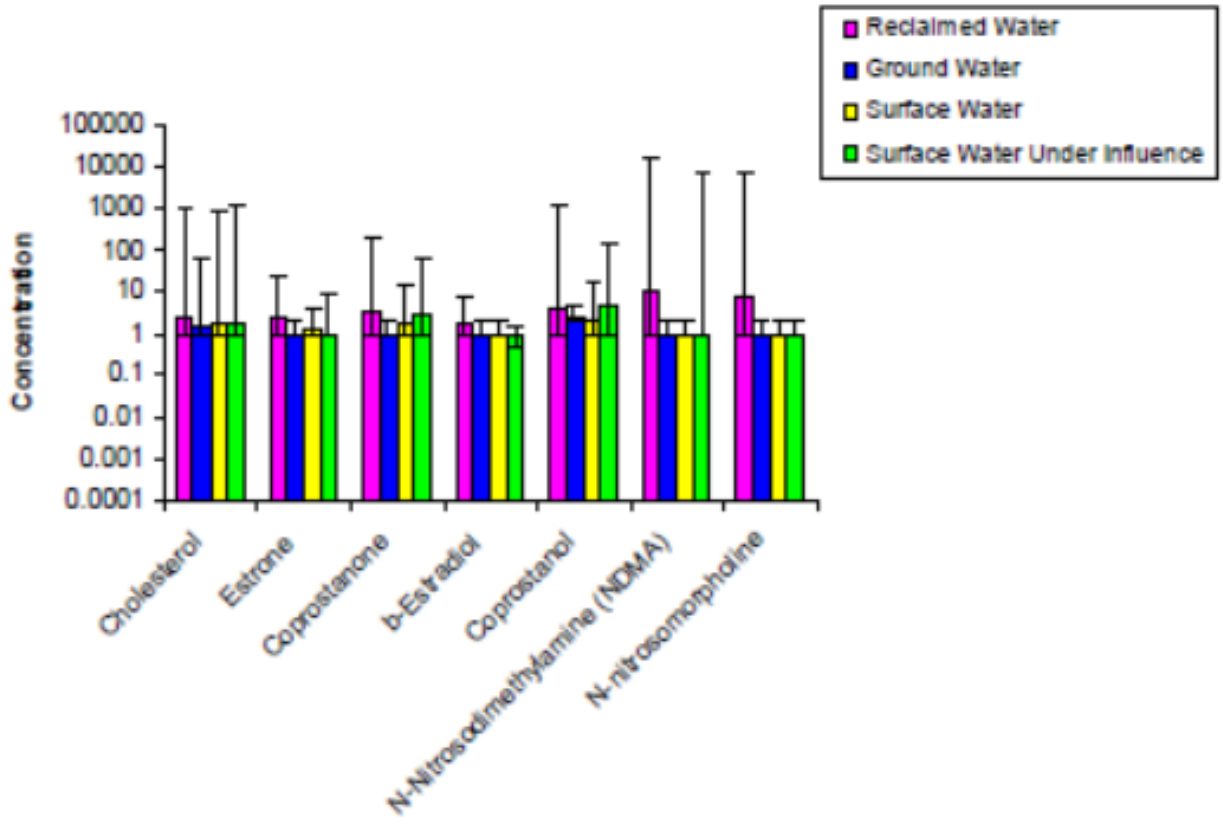

FIGURE 13
Concentrations of inorganic constituents (mg/L)

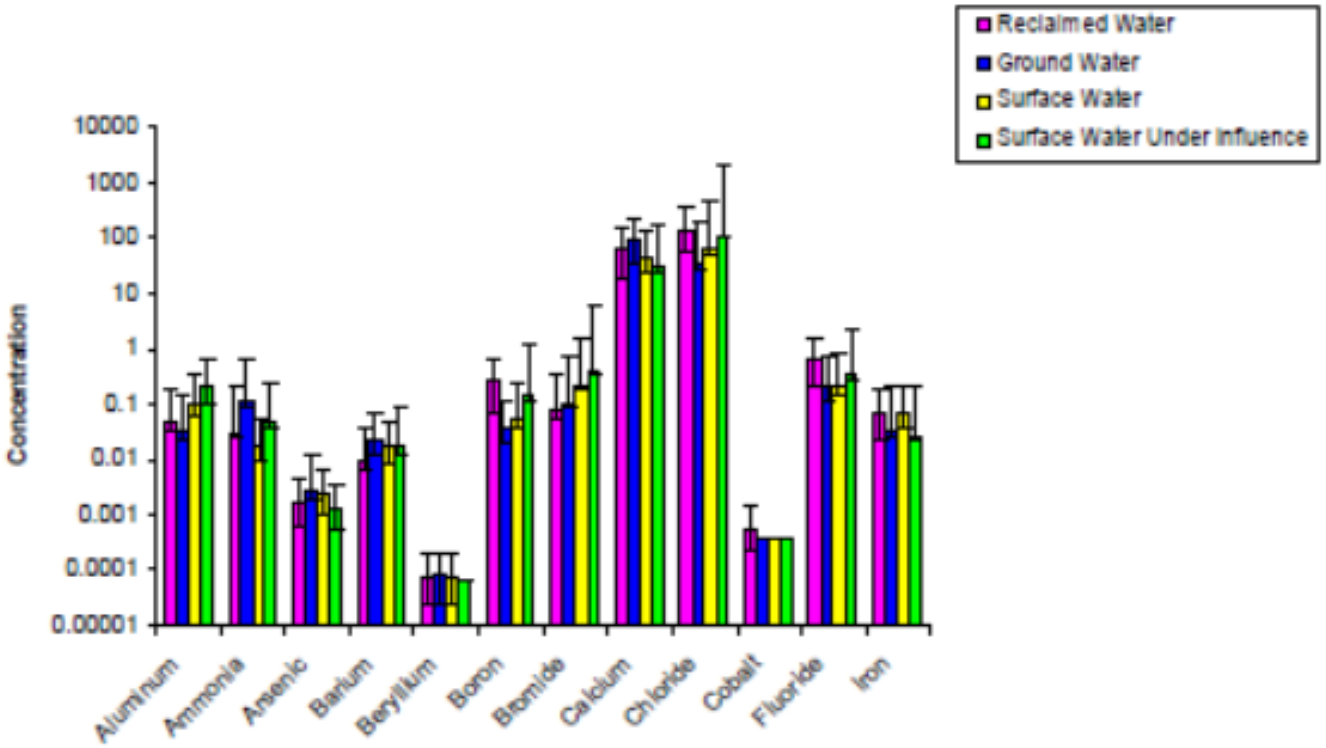

FIGURE 14
Concentrations of inorganic constituents (mg/L) (continued)

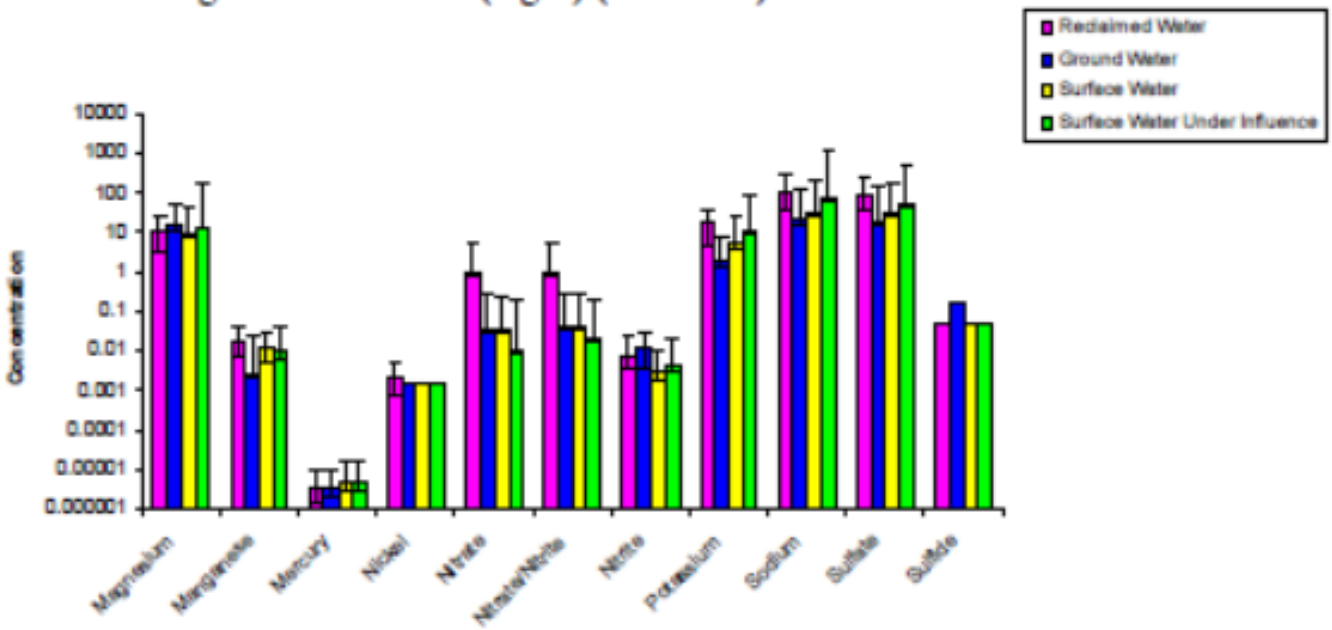

FIGURE 15
Concentrations of inorganic constituents (mg/L) (continued)

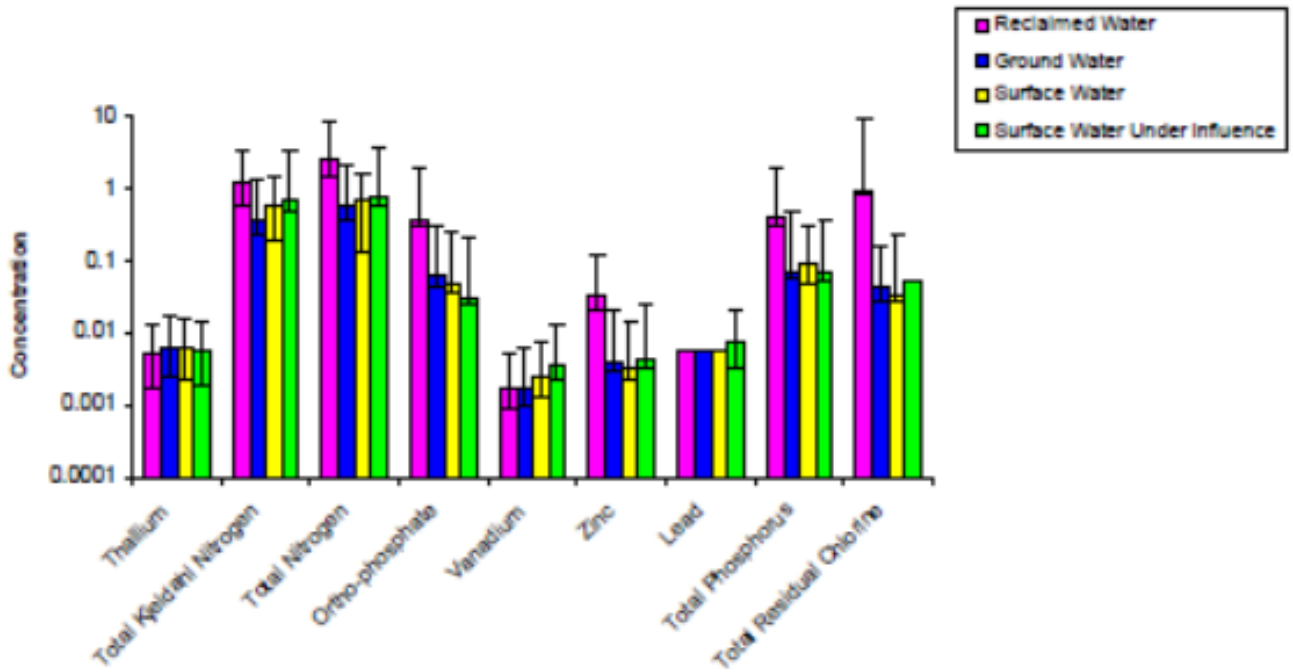

FIGURE 16
Concentrations of organic constituents (µg/L)

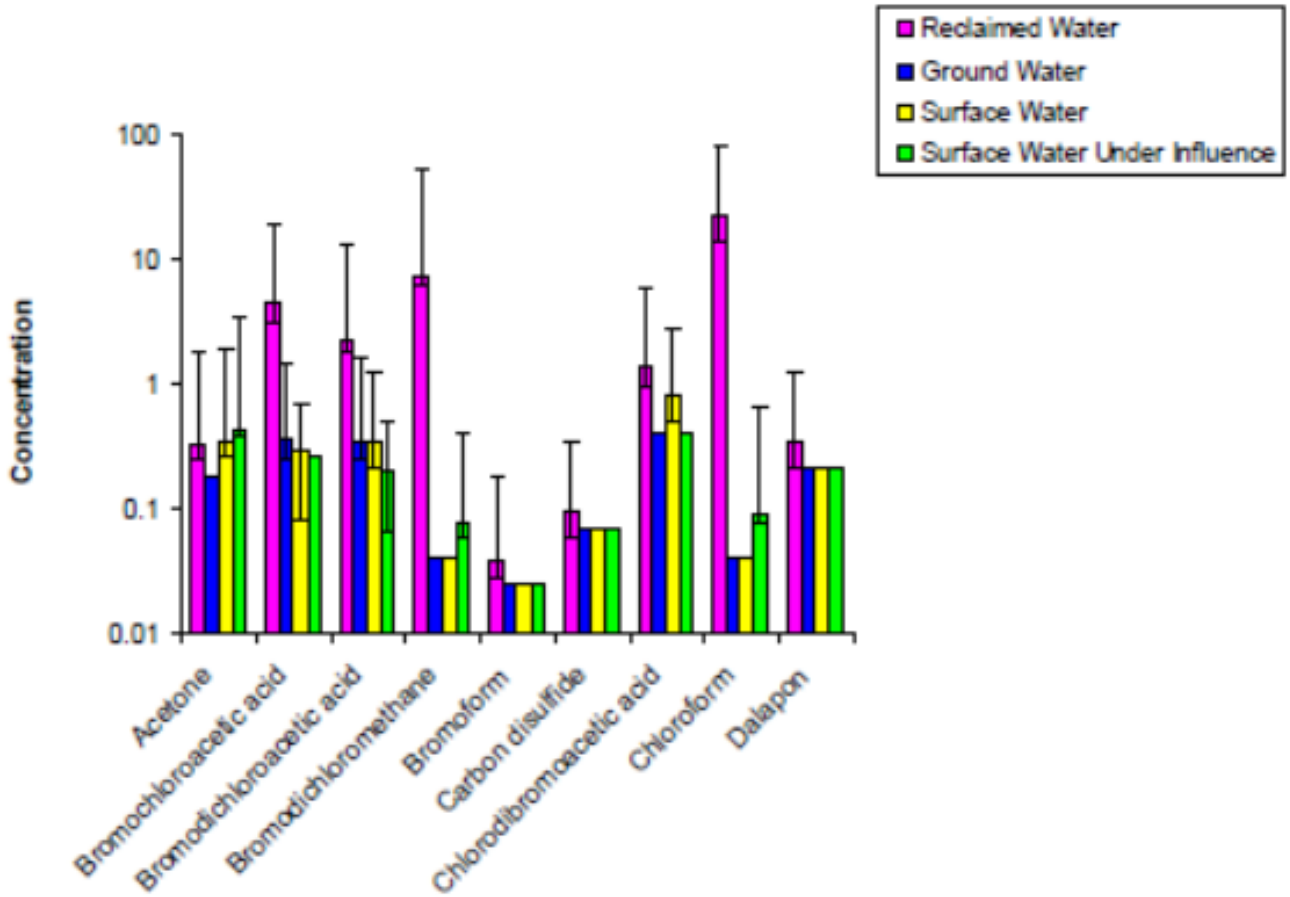

FIGURE 17
Concentrations of organic constituents (µg/L) (continued)

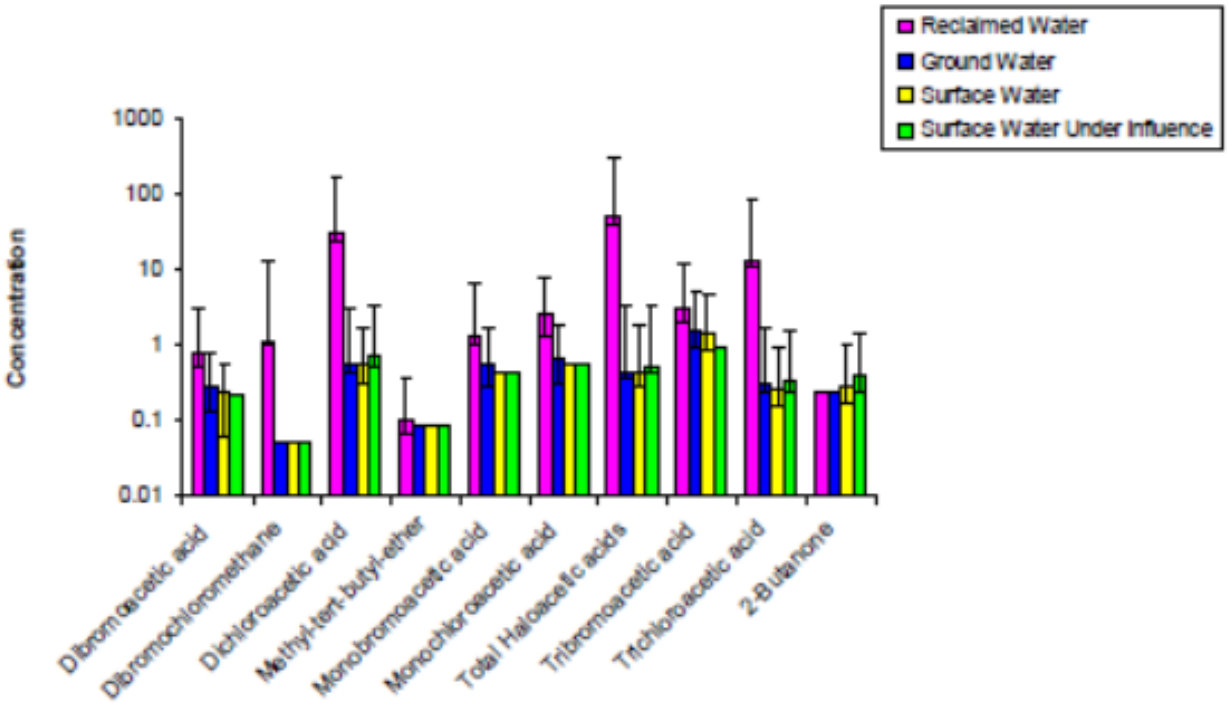

FIGURE 18
Concentrations of microbiological constituents
(Clositridium Perfringes CFU/100mL; Coliphage General PFU/100ml; Cryptosporidium oocysts/100L; Fecal Coliforms CFU/100mL; Free Residual Chlorine mg/L ; Giardia cysts/100L; Non-coliform colonies CFU/100mL; Enterococci CFU/100mL; Total Coliforms CFU/100mL; Enterviruses MPN/100L)