RECLAMATION
Managing Water in the West

Water Reuse and Agriculture

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Mission Statements

The U.S. Department of the Interior protects America's natural resources and heritage, honors our cultures and tribal communities, and supplies the energy to power our future.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

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14. ABSTRACT *(Maximum 200 words)* Water reuse and agriculture is an important area of research because of the possible presence of contaminates of concern and their impacts on the environment. This scoping project has several goals where several different literature reviews were performed on various aspects of water reuse. First to find the webpages that list each states regulations on water reuse and agriculture. Second, to gather general background information on water reuse and agriculture, and find areas where further research would be useful. Finally, to focus on the area that was of great interest to the author which was the issue of antibiotic resistance bacteria and genes in reuse water. This topic is one that impacts human health and wellness. From this scoping project an area of future research on antibiotic resistant bacteria was identified.

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Executive Summary

In the Western United States, drought is an ongoing issue that will only continue to increase in the upcoming years. The population in the western US is predicted to continue to grow over the next century. Water reuse and recycling is going to become a way of obtaining water for the US population in the future. One area where water reuse can be of great importance is for agricultural needs. The effects of water reuse on both the soil and plants is important to understand because of the possible long term health effects.

This goal of this scoping project was to perform a literature search to identify areas of potential research. This report is divided into three sections. The first section includes websites that document each states regulations for the amount of contaminates allowed in agriculture. The second section was a literature survey to assess the current research on water reuse and agriculture. The third section focuses on the development of antibiotic resistant bacteria, and the impact that these organisms might have on water reuse and agriculture.

Agricultural water reuse is a broad topic with many different aspects to study. The impact of the reused water on soils, plants, and human health are all areas where there is already a great deal of ongoing research. One topic of interest is the presence of antibiotic resistant bacteria in water reused on agricultural crops. Antibiotics are heavy used in agriculture, particularly in locations where animals are being raised for human consumption. The movement of antibiotic resistant genes among bacteria is of serious concern to us all.

The next step following this scoping project was to submit a research proposal for 2017 that will examine antibiotic resistance in the environment in more detail. If funding is granted in 2017, a detailed literature review will be conducted, along with a list of currently recognized antibiotic resistant genes. Additionally, polymerase chain reaction (PCR) assays will be developed to test Reclamation waters for the presence of antibiotic resistance genes.

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Introduction

Worldwide, 70% of freshwater supplies are used for irrigation [1]. In the western United States, drought is an ongoing issue that will only continue to increase in the upcoming years. The population in the western US is predicted to continue to grow over the next century. Water reuse and recycling is going to become a way of obtaining water for the US population in the future. One area where water reuse can be of great importance is for agricultural needs. The long term effects of water reuse on both the soil and plants is important to understand because of the potential health effects. The goal of this project was to perform a literature review investigate areas that need more research or understanding.

This report is divided into three sections. First, the current regulations and requirements for water reuse and agriculture were researched. The second part was to perform a literature search to assess the current research in agriculture and water reuse. The third second focuses on the issue of antibiotic resistance and agriculture. The movement of antibiotic resistant genes among bacteria is of serious concern to us all. This is an area of interest for the author because of the potential impact to human, animal, and plant health that antibiotic resistance genes and bacteria could have on our society.

In the coming years agricultural water reuse will continue to be a major concern. The long term effects of using reused and recycled water on both the soils and crops will be of great interest to both scientists and the general public. The use of antibiotics in agriculture is of concern because of the potential development of antibiotic resistant bacteria.

State, Federal, and International Regulations

The environmental protection agency (EPA) does not set the standards for reused water in agriculture, this organization offers suggestions for regulation (Table 1). This means that it is up to each state to develop their own laws and regulations. The list of regulated chemicals and organisms is large, and in addition there are lists of contaminants of emerging concern. Each state sets their own priorities. There are also chemicals and biological agents that have not yet made it on to a regulatory list, but could cause potential human health impacts.

The EPA’s 2012 Guidelines for Water Reuse Appendix C [2] contains each states website which contains regulations and guidance on water reuse. This is a valuable resource because of the variation between each states regulations. In Table 2, the microbial standards for several states and different countries are listed. For example, the amount of fecal coliform per 100 mL allowed by Arizona and New Mexico is five-fold more than what Florida, Utah or Texas allows. The differences in regulations makes it important to research and know the allowances when new projects are planned.

Table 1: Summary of US EPA guidelines for irrigation (from http://pubs.ext.vt.edu/452/452-014/452-014_pdf.pdf, accessed 9/23/2016)

Reuse Type	Treatment	Water Quality	Setbacks	Monitoring
Public contact				
Irrigation for public areas: • Parks • Cemeteries • Golf courses • Other landscape areas with public access Agricultural irrigation for: • Food crops that will not be commercially processed • Any crop eaten raw	Secondary Filtration and Disinfection	• pH 6-9 • ≤ 10 mg/L BOD • ≤ 2 NTU • No detectable fecal coliforms/100 mL • At least 1 mg/L residual chlorine	• 50 feet to potable water wells	• Weekly: pH, BOD • Daily: Coliforms • Continuously: Turbidity, residual chlorine
Limited or no public contact				
Irrigation of restricted access areas: • Sod farms • Silviculture • Other areas with limited or no public access Agricultural irrigation for: • Food crops that will be commercially processed • Non-food crops and pastures	Secondary Disinfection	• pH 6-9 • ≤ 30 mg/L BOD • ≤ 30 mg/L TSS • ≤ 200 fecal coliforms/100 mL • At least 1 mg/L residual chlorine	• 300 feet to potable water wells • 100 ft. to areas accessible to public (if spray irrigation is used)	• Weekly: pH, BOD • Daily: Coliforms and TSS • Continuously: Residual chlorine

Table 2: Microbial standards, from EPA Water Guidelines 2012 (from [2]).

Microbial Standards or Guidelines by State, Country, Region	Total Coliform per 100 mL	Fecal Coliform or *E. coli* per 100 mL
Puglia (S. Italia)	≤ 10	
California, Italy	≤ 23	
Australia		≤ 10
Germany	≤ 100	≤ 10
Washington State	≤ 240	
Florida, Utah, Texas, EPA (Guidelines)		≤ 200
Arizona, New Mexico, Australia, Victoria, Mexico		≤ 1,000
Austria		≤ 2,000
Sicily	≤ 3,000	≤ 1,000
Cyprus		≤ 3,000
WHO, Greece, Spain		≤ 10,000

Literature Survey

The area of water reuse and agriculture is a wide one with many different approaches and topics of concern. The Mendeley reference server was used to perform a literature search and create a database of publications that are related to water reuse and agriculture. A list of these publications is available in Appendix 1, which is listed at the end of this report. Some of the key words that were used in the literature search include: water reuse, agriculture, soil, contaminates, Environmental Protection Agency, pathogens, and crops. Many of the publications detail efforts in the Middle East, Asia, and Africa. Over 100 publications are listed in Appendix 1. There are publications about the effects of reused water on soils and plants. But many of these publications are about bacteria and antibiotic resistance.

Antibiotic Resistance

There are many different chemical and biological contaminates of emerging concern. The development of drug resistant bacteria is a major concern in agriculture because antibiotics are commonly used in livestock production which enter the water system.

Antibiotics are used in hospitals, homes, and for animals. Approximately 50% of the antibiotics used in agriculture are for non-therapeutic reasons [1]. These antibiotics are used to enhance the growth and for disease treatment in pigs, poultry, and cattle. Antibiotic are also used in aquaculture. According to the Food and Drug Administration (www.fda.gov) antibiotics can be used for the following reasons in food-producing animals:

1. Treat diseases in animals that are sick.
2. Control the spread of disease in a group of animals when some become sick.
3. Prevent disease in animals that are at risk of becoming sick.
4. Promote growth or feed efficiency in a herd or flock to promote their weight gain.

The issue is that as new antibiotics are brought to the market, very quickly antibiotic resistance can be found (Table 2). For example, penicillin was first used in 1943, and by 1946 there were bacteria that were resistant to this drug. This leads to an arms race between the development of new antibiotics and the bacteria as they develop resistance.

Table 3: Emergence of resistance to antibiotics (from [3])

Antibiotic	Year of Deployment	Onset of Resistance
sulfonamides	1930s	1940s
penicillin	1943	1946
streptomycin	1943	1959
chloramphenicol	1947	1959
tetracycline	1948	1953
erythromycin	1952	1988
vancomycin	1956	1988
methicillin	1960	1961
ampicillin	1961	1973
cephalosporins	1960s	late 1960s

Antibiotic resistance in bacteria is a worldwide issue that has to be addressed. Several publications focused on antibiotic resistance related to water reuse in agriculture were found in the literature search [4]–[8].

The use of antibiotics in agriculture can lead to high concentrations of antibiotics in water that could promote selection of antibiotic resistant bacteria. Bacteria that are already resistant to a particular antibiotic are able to transfer that resistance to other bacteria. Bacteria are able to acquire antibiotic resistance via three different methods: transformation, conjugation, and transduction (Figure 1). With transformation, DNA from a dead bacteria is transferred to another bacteria. Conjugation is where two bacteria are able to transfer plasmids that contain resistance genes between two cells. Finally, transduction is where the gene is delivered by a bacteriophage.

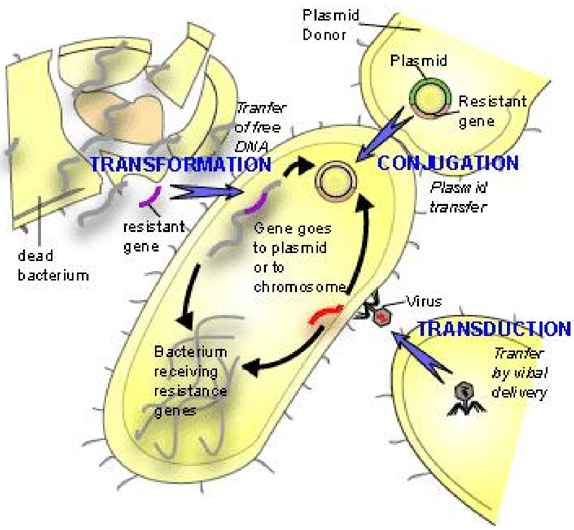

Figure 1: Ways that bacteria are able to acquire antibiotic resistance (from: http://mrsatopic.com/wp-content/uploads/2014/01/Gene-Transfer.jpg, accessed 9/26/2016)

Lessons Learned

There were several lessons learned during the course of this scoping project. First, the scope of the project was very broad, which made it difficult to focus on a particular aspect of this field. The range of potential areas of research that relate to water reuse and agriculture is huge. There are researchers worldwide who are studying this issue.

Second, there was a realization that it was important that the area of future research should be one that aligns to the skills and background of the researcher. In this case, studying antibiotic resistance and agriculture are an ideal fit. The skills need to perform analysis of water samples for the presence of antibiotic resistance genes already exist in the RDLES Laboratory. The main method used to study this issue will involve polymerase chain reaction (PCR) and the RDLES laboratory has a great deal of experience with analyzing water samples for the presence of genes of interest.

Summary and Future Directions

The area of water reuse and agriculture wide open area of research with many different issues and concerns that could be addressed. During the literature searches for this scoping project one area that captured the attention of the author was the antibiotic resistance bacteria and genes. For the authors this area would be one where future research would be of interest because the skills, such as polymerase chain reaction, are ones that the RDLES laboratory process. The tools needed to analyze for the presence of antibiotic resistance genes have been developed for PCR [9], [8]. Therefore, for the 2017 year, a project was proposed for looking at antibiotic resistance bacteria in water.

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Appendix 1: Publications relating to water reuse and agriculture.

A literature search was performed using the Mendeley program to create a database of publications related to water reuse and agriculture. These publications also include general background on water reuse. Many of the papers are from the Middle East and Africa and are examples of how water reuse and agriculture being performed and studied.

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