CITY OF AUBURN
Pet Waste and Water Quality

University of Washington ○ Department of Environmental and Occupational Health Services
Environmental Health 545: Water, Wastewater and Health

Instructor: Dr. Scott Meschke
Teaching Assistant: Erika Keim, M.S.
Post- Doctoral Researcher: Nicolette Zhou, PhD

Report Authors: Meagan Deviaene ○ Joanna Harrison

Fall 2016

SPECIAL THANKS TO:

We have many people to thank for their input and support in generating this report. We would first like to thank our contacts at the City of Auburn, including Tim Carlaw, Shannon Howard, Melanie May and Chris Thorn. We deeply thank our class teaching assistants Erika Keim and Nicolette Zhou for their support, as well as our professor Scott Meschke. We would also like to thank each and every one of our classmates in ENVH Water, Wastewater and Health for their valuable feedback and poignant questions. Finally, we thank all pets, large and small.

PET WASTE AND WATER QUALITY

ABOUT LIVABLE CITY YEAR

The UW Livable City Year program (LCY) is an initiative that enables local governments to tap into the talents and energy of the University of Washington to address local sustainability and livability goals. LCY links UW courses and students with a Washington city or regional government for an entire academic year, partnering to work on projects identified by the community. LCY helps cities reach their goals for livability in an affordable way while providing opportunities for students to learn through real-life problem solving. LCY has partnered with the City of Auburn for the 2017-2018 academic year, the inaugural year of the program.

The UW's Livable City Year program is led by faculty directors Branden Born with the Department of Urban Design and Planning, and Jennifer Otten with the School of Public Health, in collaboration with UW Sustainability, Urban@UW and the Association of Washington Cities, and with foundational support from the College of Built Environments and Undergraduate Academic Affairs. For more information contact the program at uwlcy@uw.edu.

LIVABLE CITY YEAR: ONE YEAR. ONE CITY. DOZENS OF UW FACULTY AND HUNDREDS OF STUDENTS, WORKING TOGETHER TO CATALYZE LIVABILITY.

LCY.UW.EDU

ABOUT THE CITY OF AUBURN

The City of Auburn is well-positioned to take advantage of many of the opportunities in the Puget Sound region. Centrally located between Seattle and Tacoma, Auburn is home to more than 77,000 residents. It is the land of two rivers (White & Green), home to two nations (Muckleshoot Indian Tribe & City of Auburn) and spread across two counties (King & Pierce).

Auburn was founded in 1891 and has retained an historic downtown while also welcoming new, modern development. Known for its family-friendly, small-town feel, Auburn was initially an agricultural community; the city saw growth due to its location on railroad lines and, more recently, became a manufacturing and distribution center. Auburn is situated near the major north-south and east-west regional transportation routes, with two railroads and close proximity to the Ports of Seattle and Tacoma.

Auburn has more than two dozen elementary, middle and high schools, and is also home to Green River College, which is known for its strong international education programs. The city is one hour away from Mt. Rainier, and has many outdoor recreational opportunities.

The mission of the City of Auburn is to preserve and enhance the quality of life for all citizens of Auburn, providing public safety, human services, infrastructure, recreation and cultural services, public information services, planning, and economic development.

WWW.AUBURNWA.GOV

01 EXECUTIVE SUMMARY

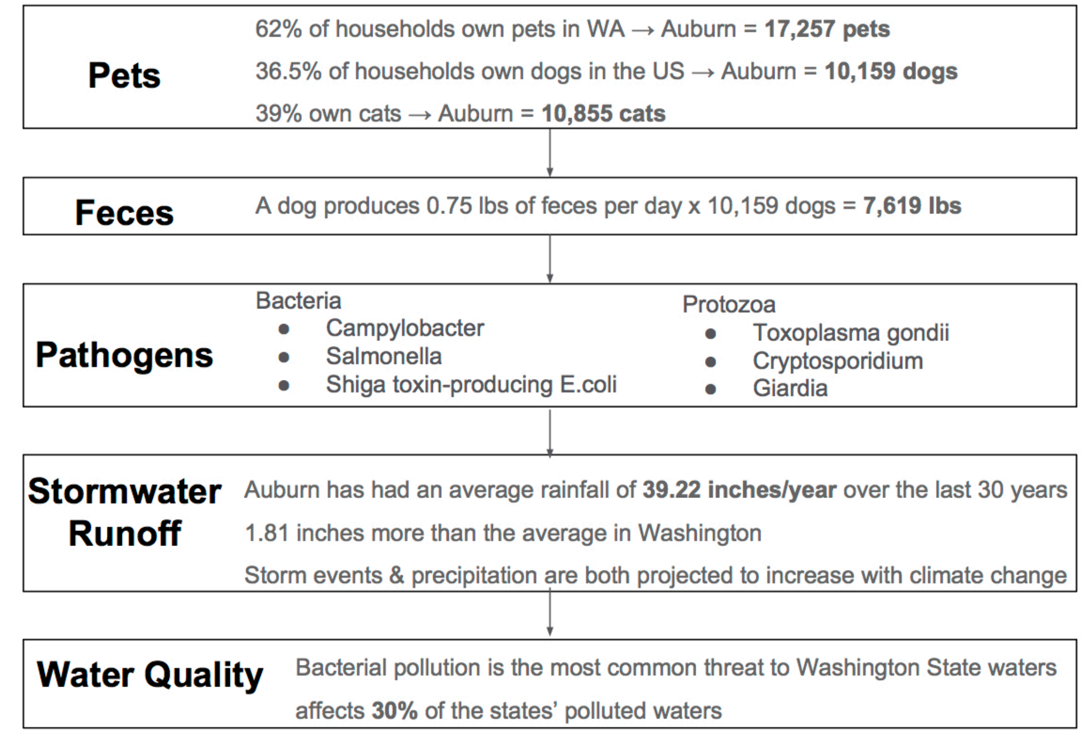
Bacterial pollution is a significant issue concerning water quality impairment in the state of Washington. Recently, pet waste as nonpoint source pollution (i.e. of diffuse origin) have received attention as a potential significant contributor to bacterial pollution in water bodies, especially those in urban areas. Pet feces carry many pathogens, which can cause illness in humans and animals; as well as being high in nutrient content, which leads to eutrophication of lakes.

This report will detail a project undertaken to characterize the issue of pet waste and water quality in the City of Auburn. The project was completed as a collaborative effort between two environmental health students, their professor and teaching assistants, as well as several support staff at the City of Auburn. This report will introduce the subject of pet waste and water quality, detail health issues associated with this subject and suggest several recommendations towards characterizing and remediating this issue. These remediation strategies include microbial source tracking, infrastructure implements, and pet waste disposal options, as well as behavior change strategies.

02 INTRODUCTION

Bacterial pollution is cited as the most common threat to Washington waters, affecting up to 30% of the state's polluted waters (Washington State Department of Ecology 2008). This type of pollution can be derived from many sources. Some bacteria such as *Legionella* are environmentally stable, but a large portion of bacteria come from animals including: sylvatic organisms, domestic pets, and humans, and are also transmitted via the fecal-oral route, meaning that what is excreted from feces eventually ends up being ingested. In urban areas, the Washington State Department of Ecology (WSDOE) has stated that bacteria from pet wastes may be a major contributor to surface water pollution (WSDOE). Due to the inherent connectedness of bodies of water in a watershed, deposition of pet wastes occurs much more in urban areas as compared to rural zones; however, pet waste pollution can affect the overall water quality in a watershed and can also affect downstream communities.

Contaminants from pet wastes most commonly enter water systems through stormwater runoff. This encompasses water from rain or snow that transports contaminants from grass, sidewalks, and roads. This water will run downhill until it reaches a lake, river or marine waterway, carrying residuals of contaminants picked up along the way. Even when a potential source of contamination is distant from a water source, runoff from pet feces could be conveyed into a storm sewer, a structure which releases collected untreated water directly into a water body (WSDOE). "Nonpoint source" source pollution is a particularly important aspect of stormwater runoff. Nonpoint source pollution encompasses contaminants from diffuse sources which may accumulate in water bodies. The term is often used in contrast with point source pollution, which derives from a single, definable origin.



Credit: Meagan Deviaene

PATHOGEN TRANSFER CHART

Summary of the issues surrounding pet waste in Washington state waters.

Current trends in population size, accompanying land use and climate changes affect several of the factors that contribute to the consequences of pet waste runoff. Without appropriate intervention, it is likely that the public health threat of pet wastes will intensify. Climate change is projected to cause an increase in storm events and precipitation in Western North America, which could intensify runoff (van Oldenborgh et al. 2013). Urbanization, or concentration of human populations into specific areas has increased across the United States over the past 200 years and is projected to continue to increase (United States Environmental Protection Agency (USEPA); U.S. Census Bureau). This process involves the concentration of infrastructure systems serving growing human populations, which inherently involves land use changes favoring more impervious surfaces such as concrete roads. A study investigating the effects of land use on fecal coliform (FC) levels in water found that impervious surface was the major explanatory variable correlated to higher FC levels and further indicated that urban land uses decrease opportunity for filtration that could reduce pathogen levels (Buchino 1970).

The comprehensive water treatment and monitoring facilities through which many people in the United States receive their drinking water fortunately minimizes the threat of infection due to pet waste contamination. However, recreational waters are inherently more at risk to this type of contamination, as recreational water bodies such as lakes and rivers are typically not subject to the same treatment processes as drinking water. These differences in risk are illustrated from the most recent water related illness reports issued by the Centers for Disease Control and Prevention (CDC), in which *Legionella* introduced downstream from treatment facilities was the principal cause of illness in drinking water compared to toxins released by cyanobacteria that have grown in the recreational water (Beer et al., 2015; Hlavsa et al., 2015). In Washington State, about one third of water bodies are listed as not meeting their water quality criteria for their designated use, recreation being one of the uses (WSDOE). Auburn has many recreational water bodies and deterioration of these could have an impact on the quality of life for Auburn's residents.

03 IN THE CONTEXT OF AUBURN

This report will endeavor to detail the subject of pet wastes and water quality with special attention paid to the issue in the context of the city of Auburn, Washington. In Auburn, it is estimated that there are over 10,000 dogs that could generate over 7,600 pounds of wastes each day (WSDOE; Nemiroff and Patterson 2016). Approximately half of all dog owners walk their dogs in public areas and a survey done in Washington found that up to 31% do not clean up their dog's waste (Hardwick, 1997). Additionally, Auburn has 1.81 more inches of average annual precipitation volume than the state of Washington, creating more opportunities for runoff from undisposed wastes to occur (NOAA).

There is reason to believe that pet wastes may be an issue in Auburn. As required by the Clean Water Act Action Plan, in 2011 the Washington State Department of Ecology performed monitoring in the Puyallup River watershed and found several sites in the City of Auburn failing to meet acceptable water quality criteria. The standards require a geometric mean of less than 100 colonies per 100 ml of fecal coliforms, and less than 10% of total samples exceeding 200 colonies per 100 ml. Sampling at Bowman creek consistently yielded FC counts over 100 colonies per 100 ml. In the report they hypothesized that urban runoff from pet wastes may be a contributing factor to the contamination observed at this site and other sites in Auburn (WSDOE 2011).

In response to the state, City of Auburn completed their own sampling at four municipal separate storm sewer systems (MS4) outflows located around mill pond. The results from their sampling was somewhat inconclusive. Of the four sites sampled, only one site met both water quality criteria, the second site only met one part of the criteria, the third site met either both or neither of the criteria depending on the point at which sampling occurred, and at the final site they were unable to sample sufficiently to make any conclusions (City of Auburn, Washington 2012). As a part of this endeavor, sampling geared towards identifying the source of this microbial contamination is being planned. Elaboration about this effort is described in the remediation section of this document.

Site Code	Site Description	State/City	Geometric Mean (FC colonies/100ml)	90th Percentile Standard
10-TAS-.0.01	Auburn High	State	39	Exceeded
10 - BOW - 0.3	Bowman Creek	State	37	Exceeded
1309 - T1134	MS4 discharges into the tributary to the White River that runs through Roegner Park	City	49	Exceeded
1309 - T1C		City	20	Met
1309 - T2		City	110	Exceeded
1309 - T333		City	29	Met
1309 - T299		City	33	Exceeded

TABLE 1.

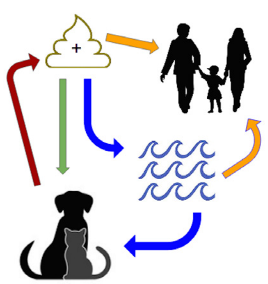
Results of both the WSDOE and City of Auburn sampling. Geometric mean to fit the water quality criteria, a water body must have both a geometric mean of less than 100 colonies per 100mls and less than 10% of all samples exceeding 200 colonies per 100mls.

04 EPIDEMIOLOGICAL EVIDENCE

Despite a supposed link between stormwater pollution and pet wastes, studies and reports specifically linking fecal pollution in water directly to pet wastes are sparse. This could be attributed to several factors. First, the CDC's Waterborne Disease and Outbreak Surveillance System is responsible for collecting data on waterborne disease outbreaks. The system further subcategorizes outbreaks into recreational water and drinking water outbreaks. In this system, the microbial etiologic agent associated with outbreak, and not the upstream cause, requires reporting; thus, there may not be a concerted effort to isolate these original sources especially in the case of nonpoint source pollution (CDC 2015). Additionally, identification is usually accomplished by molecular characterization of pathogens which are found in the wastes of many different types of animals. Consequently, this method is not sufficient to determine the animal source of fecal contamination. (Harwood et al. 2014; Colford et al. 2007). Furthermore, in Washington State, yearly water quality assessment reports are produced which dictate categorization of water bodies; however, this data is compiled after a call for data from the public, therefore the interval of sampling of different water bodies may be irregular (Washington State Department of Ecology 2016). Also, only water bodies classified as category 5 (polluted) require a total maximum daily load (TMDL) or water quality index (WQI) project, mandating their regular surveillance. Finally, while contamination of waters with pet waste are occurring, health effects may not be seen or are not being reported. Due to these factors, the extent to which pets contribute to contamination is unclear. However, some studies of areas where fecal pollution has been linked to domestic animals are summarized below.

- Ervin et al. (2014) used microbial source tracking to characterize elevated levels of fecal indicator bacteria (*E. coli* and *Enterococci*) at frequently contaminated beaches. Sampling took place over two years and canine sources were found to be the most important contributor to contamination.
- Wright et al. (2010) collected feces at a recreational beach in Florida with frequent closures due to contamination events. They worked to ascertain which source contributed the highest concentration of enterococci, and found that dog feces were the largest contributor.
- Nnane et al. (2011) used bacteriophage based microbial source tracking in the River Ouse catchment (UK) to distinguish sources of fecal pollution. The results showed that the greatest contributors to fecal pollution were non-human sources. Additionally, variable factors such as climate, storm events, and animal and anthropogenic influences were found to contribute directly or indirectly to fecal contamination.

05 POTENTIAL EFFECTS ON HUMAN HEALTH



PATHOGEN PATHWAYS

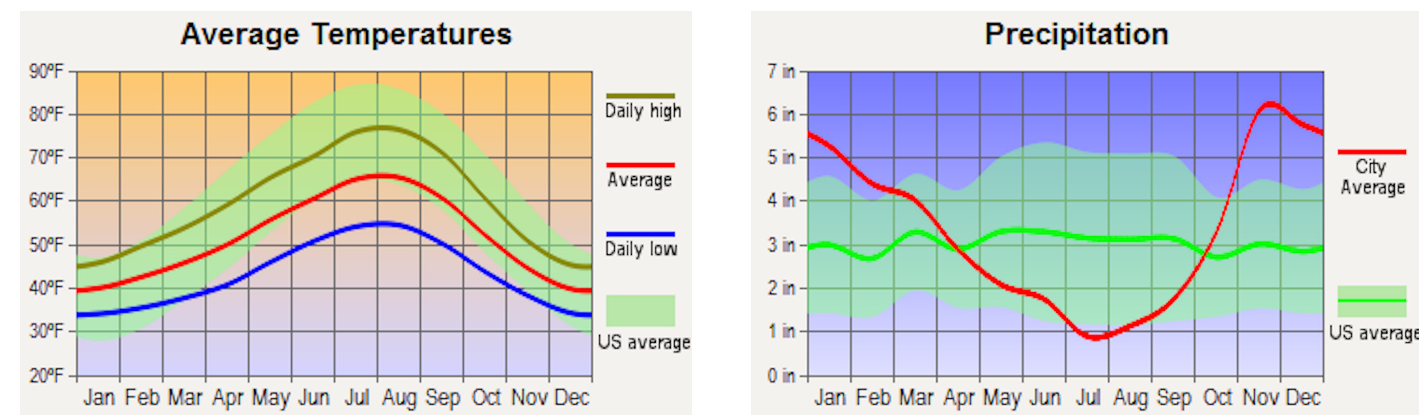
Cycle of pathogen travel via direct and indirect (water) routes from feces positive with pathogens.

Credit: Joanna Harrison

Not only is fecal waste in water aesthetically displeasing and foul-smelling, there are also a wide array of human diseases that can be caused by exposure to pet waste. The organisms that cause disease are called "pathogens" and are transmitted from animal feces to humans through direct contact (i.e. touching waste, tracking waste into the home, or contact with vector surfaces called "fomites"), or can travel through other routes such as water and soil (Gashaw et al. 2015; Boone & Gerba 2007).

Some pathogens present in the Pacific Northwest that can come from fecal contact with pet waste and can also be waterborne include: *Campylobacter*, *Giardia*, *E. coli*, *Cryptosporidium*, and *Salmonella* (CDC 2016; Little et al. 2009). These pathogens were present in cases in either Pierce County or King County in 2015. The list may not include those that are hard to detect or not looked for due to the expensive nature of environmental pathogen testing, pathogens that were not reported to the Washington State Department of Health (WSDOH), or those that are not considered to be present in the Pacific Northwest and are therefore not looked for (WSDOH 2015). From previous research, we think it is also important to include *Toxoplasma gondii* as a potentially transported pathogen for reasons discussed later in the report.

When a pet defecates outside, the pathogens in their feces can "sink" into the soil or water, and either be transported to other locations via downstream water flows, or can persist in the location until ingested by animals or humans (Jamieson, Gordon, Sharples, Stratton & Madani 2002). If the waste is defecated onto concrete, it can still end up in water or soil due to stormwater runoff, as mentioned in the previous section. Many environmental conditions impact the survival factors of these pathogens, including: soil type, moisture, temperature, pH, nutrient availability, and competition with other microorganisms (Meschke 2016; Food Pathogen Control Data Summary 2011; Mihaljevic, Sikic, Klancnik, Brumini, Mozina, & Abram 2007; John & Rose 2005). Consequently, not all pathogens will survive and their survival rates may vary depending on the time of year; typically, survival is better in milder temperatures because pathogens cannot proliferate during extreme cold or hot temperatures, but transmission increases during hotter temperatures, generally in the summer, as more people and pets go outside and access community parks and recreational water (Boxall et al. 2009; Craig, Hall & Russell 2008). However, studies have shown that when animal waste is applied to the ground, pathogenic organisms can persist and spread to other locations regardless of time of year. While the number of cases tend to increase in the summer due to increased outdoor activity and recreational water usage, if a pet defecates outside in the winter, the pathogens in feces can still persist in the cold (Jamieson, Gordon, Sharples, Stratton & Madani 2002; Jones & Martin 2003). If there is snow coverage during the winter, the feces can melt into the snow, giving the illusion that it is not



Credit: City-Data.com

WEATHER CYCLES

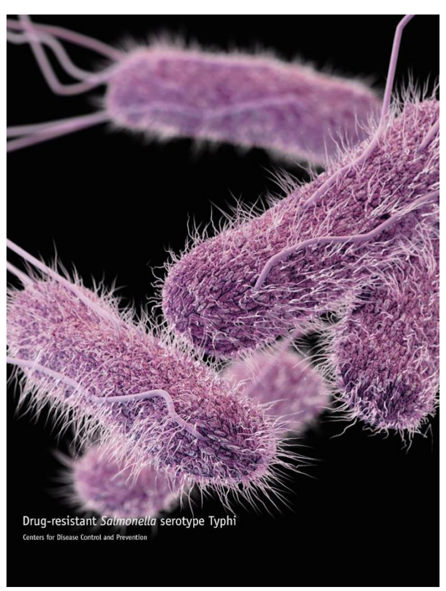
Average temperature and precipitation per year in Auburn, Washington based on data reported by over 4,000 weather stations.

there. When temperatures warm and the snow starts to melt, the waste can move to new locations with the melting water. If this transport method does not move the waste, large quantities of feces from the winter can persist in a location which can then sink into the soil or be moved during rainfall (Johnson 1999; Rosen 2000).

According to the City of Auburn website, Auburn has a climate that may promote the survival of pathogenic organisms. The temperate climate does not have drastically cold winters or extremely hot summers. Instead, winter temperatures range from about 33-51 degrees Fahrenheit, with an annual snowfall of about 12 inches (varying by altitude), and summers are a pleasant 49-78 degrees Fahrenheit. This relatively mild range of temperature is ideal for many pathogenic organisms, as they cannot tolerate the extreme freezing or hot temperatures (United States Environmental Protection Agency 2000; King, Keegan, Monis & Saint 2005; Food Pathogen Control Data Summary 2011). Additionally, like many other cities in the Pacific Northwest, Auburn experiences a sizeable amount of precipitation for an extended period of time every year, with an average annual precipitation of 39.39

inches. This rainfall promotes the introduction of fecal pathogens into the soil and into stormwater runoff throughout the year (Sidhu, Hodgers, Ahmed, Chong & Toz, 2012; Edge et al. 2013).

Pathogenic organisms' survival capabilities, inconsistent monitoring, environmental characteristics and occasional difficulty in identifying clear point sources creates potential concern over larger outbreaks because a contamination source may not be easily determined (i.e. a nonpoint source). Additionally, a contamination problem may not even be clearly identified until cases start to increase. Some of these downstream contamination problems include the contamination of drinking water when deficiencies in treatment processes are present, compromising the quality and safety of public water resources (Wright, Solo-Gabriele & Elmira 2010; Betancourt & Rose 2004; Edge et al. 2013). Illness from recreational water can result from skin contact and ingestion of contaminated water, while drinking water contamination is primarily from ingestion only.



Top: *Campylobacteria*
Bottom: *Salmonella*
Credit: Center for Disease Control and Prevention

Some pathogens have life-stages that are resistant to chlorine, such as *Cryptosporidium* and *Toxoplasma gondii* (Effect of Chlorination on Inactivating Selected Pathogen 2012). The treatment that the city provides may not remove these harmful pathogens from the drinking water system, which could potentially result in a large outbreak as akin to the *Cryptosporidium* outbreak in Milwaukee in 1993 where over 400,000 residents became sick from ingesting contaminated drinking water and resulted in an economic loss of almost $100 million (Kenzie et al. 1994; Corso, Kramer, Blair, Addiss, Davis, Haddix 2003).

Private wells have also been implicated in waterborne outbreaks. Wells can be vulnerable to pathogens after rain events, especially if they are shallow and have been submerged by water (*Cryptosporidium* (Crypto) and Drinking Water from Private Wells 2015; USEPA 2002). Because the city does not regulate, sample or treat these wells, if the owners are not regularly testing for pathogens, they could get sick (WSDOH: Testing Your Water). The CDC classifies the pathogens mentioned above as both "waterborne disease[s]" and "drinking water contaminants", and the extent to which the pathogens cause disease varies, as does the number of cases they cause. The WSDOH keeps records of cases of the pathogens and tracks an increase or decrease in case number by year.

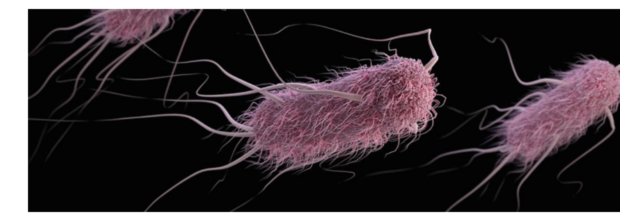
From the aforementioned pathogens, *Campylobacter*, a bacterium, caused the greatest number of cases in both King County and Pierce County in 2015, with 604 cases and 250 respectively, giving an incidence rate of 29.4 and 30.1 per 100,000 people respectively

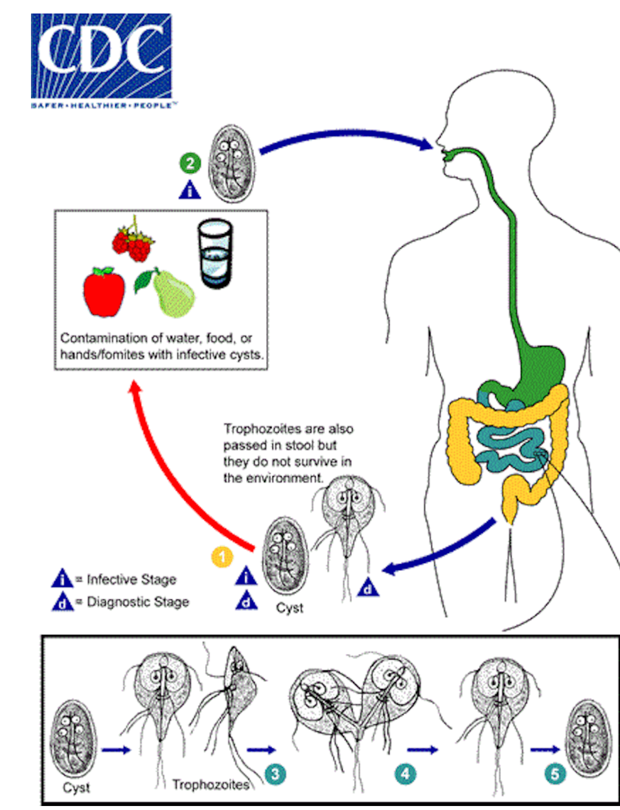
(Washington State Communicable Disease Report 2015). According to the CDC, *Campylobacter* is one of the most common causes of diarrhea in the United States (WSDOH reports it as the most commonly reported enteric illness in Washington, with up to 1,850 reports of campylobacteriosis every year) and although the illness usually resolves within a week, sometimes it can lead to reactive arthritis, Guillain-Barre syndrome, or, in immunocompromised patients, the bacteria can spread to the bloodstream and cause life-threatening problems. The highest risk groups are the young, elderly, pregnant, and immunocompromised

Salmonella bacteria comes in second with the number of cases in 2015; 435 in King County and 95 in Pierce County, with 21.2 and 11.4 incidence rate per 100,000 people respectively (Washington State Communicable Disease Report 2015). Although there is an increase in cases during the spring and summer, cases do occur year round. In Washington State, the 2015 reported cases reached 1,034 with one death (Washington State Communicable Disease Report 2015). Symptoms and risk groups are similar to that of *Campylobacter*, as well as the possibility of reactive arthritis being a long term condition of the disease (Washington State Communicable Disease Report 2015).

For *Giardia*, a protozoan parasite, there were 219 cases in King County and 42 in Pierce County during the 2015 year; a 10.7 and 5.1 cases per 100,000 population incidence rate respectively (Washington State Communicable Disease Report 2015). This parasite also mainly causes diarrhea and the most at risk group are children under the age of five. Although the state reports that there has been a declining trend in the number of cases in Washington (604 reported cases in 2015), it remains one of the most common waterborne diseases in the country (Washington State Communicable Disease Report 2015; CDC). The cysts - a protective life stage - can survive several months in cold water and are also resistant to mild chlorination, meaning routine water treatment may not kill the cysts (Jarroll, Bingham, & Meyer 1981; CDC). Although symptoms usually last one to two weeks, if untreated the symptoms can last for months at a time. Research also shows that giardiasis in children can, "delay physical and mental growth, slow development, and cause malnutrition" (CDC).

The bacteria Shiga toxin-producing *E. coli* (STEC) had 113 cases in King county and 26 in Pierce county in 2015, giving a 5.5 and 3.1 cases per 100,000 population incidence rate respectively (Washington State Communicable Disease Report 2015). There are many different kinds of *E. coli*, but those recorded by the WSDOH were STEC due to their ability to cause serious illness in people. The number of cases in



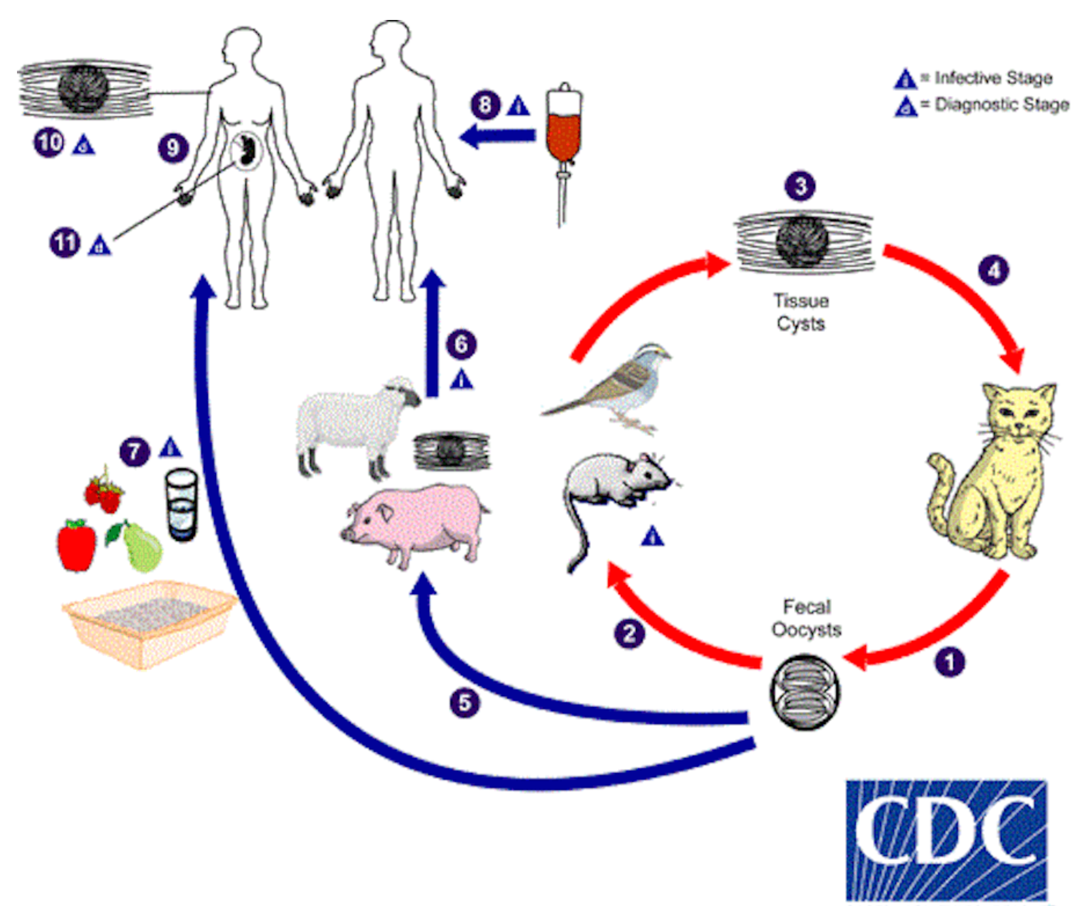


Top: *E.Coli*
Bottom: *Cryptosporidium* Life Cycle
Credit: Center for Disease Control and Prevention

Washington every year has ranged from 150-250 but in 2015 there were two outbreaks that lead to 419 reported cases (Washington State Communicable Disease Report 2015). Again, the main symptom of STEC is diarrhea, which can be bloody. More serious cases can develop a kidney complication called hemolytic uremic syndrome (HUS) and these serious cases occur mostly in children under the age of five, a serious problem because of their developing immune system (Public Health - Seattle & King County 2015).

The least reported pathogen in 2015 was *Cryptosporidium*, with 25 cases in King County and 24 in Pierce County; a 1.2 and 2.9 cases per 100,000 population incidence rate respectively (Washington State Communicable Disease Report 2015). *Cryptosporidium*, a protozoan parasite, results in diarrhea and dehydration. Immunocompromised patients are at greater risk of more serious outcomes. (CDC) The CDC reports that during 2001-2010, *Cryptosporidium*, "was the leading cause of all waterborne disease outbreaks, linked to recreational water in the United States." This pathogen is very pernicious because of its ability to survive standard disinfection methods such as chlorination in its oocyst life-stage (CDC). For this reason, the WSDOH reports that it, "may occur in municipal water systems, home filtered water, or bottled water." This is one of the reasons why it is so pertinent that the pathogen does not get into water sources.

TOXOPLASMA GONDII LIFE CYCLE



Credit: Centers for Disease Control and Prevention

DISEASE CASES BY PATHOGEN IN 2015

Report does not specify location in county or route of transmission. Numbers are based on those reported to the WSDOH.

Pathogen	King County (number of cases)	Pierce County (number of cases)	Combined Number of Cases
Campylobacter	604	250	854
Salmonella	435	95	5330
STEC	113	26	139
Cryptosporidium	25	24	49
Giardia	219	95	315

Credit: Washington State Department of Health (WSDOH)

We have decided to include *Toxoplasma gondii* (*T. gondii*) in this report even though it is not reported by the WSDOH, because approximately 39% of the population in Auburn owns cats, which is about 10,855 cats (American Veterinary Medical Association). *T. gondii* is a protozoan parasite that matures inside cats, meaning that cats are the definitive host for the parasite (CDC; T & I 2005). Infected cats will shed the oocyst stage of the parasite in their feces, at which point the oocysts can be ingested by other animals, humans, or contaminate the soil and water (CDC; Black & Boothroyd 2000). Unlike the other pathogens, the symptoms of *T. gondii* are more flu-like, such as muscle pains and swollen lymph nodes, that can last months (CDC). A big problem occurs in immunocompromised patients or pregnant women. *T. gondii* can pass from mother-to-child in the womb and if this occurs, the baby can have blindness or mental disability later in life (CDC; Many & Koren 2006). The CDC reports that 60 million people may be infected; however, most do not show symptoms because their immune system can combat it, but they can still spread the disease. We believe that although the WSDOH does not have available data on case numbers, the pathogen should still be considered a potential pathogen from pet waste that contaminates water.

All the pathogens mentioned above are preventable. If contaminated pet waste does not continue to persist in the soil or water, then exposure to the pathogen will go down, resulting in a reduction in the number of cases. It is also important to note that the case number given by the WSDOH is grouped by county, not city, and that these are the number of cases reported to the department. It is likely that cases go unreported, meaning the numbers given above are, in all likelihood, under-representative. For example, a 2015 CDC Morbidity and Mortality Weekly Report estimated that there are 748,000 cryptosporidiosis cases per year in the United States, but that less than 2% are reported (Painter, Hlavsa, Collier, Xiao & Yoder 2015).

The United States Department of Agriculture (USDA) has an agency that looks at the potential economic health burden caused by the pathogens above, except for *Giardia*. This agency is called the Economic Research Service (ERS) and produces reports on the cost estimates of foodborne illnesses. Unfortunately, they do not

	ACUTE ILLNESS					CHRONIC ILLNESS
	Non-hospitalized		Hospitalized	Post-hospitalization outcomes		
	Didn't Visit physician; recovered	Visited physician; recovered	Hospitalized	Post-Hospitalization Recovery	Hospitalized; Died	
TOTAL NUMBER OF CASES						
Low: 12,060	10,603	1,339	58	58	0	
Mean: 57,616	50,723	6,683	210	206	4	
High: 166,771	146,908	19,345	518	499	19	
MEDICAL COSTS						
Physician office visits						
Average visits per case	0	1.4	0.7	1.0		0
Average cost per visit	$136	$136	$136	$136	$0	$136
Emergency Room Visits						
Average visits per case	0	0.1	0.3	0		0
Average cost per visit	$573	$573	$573	$573		$573
Outpatient clinic visits						
Average visits per case	0	0.3	0.2	0		0
Average cost per visit	$659	$659	$659	$659		$659

Credit: Center for Disease Control and Prevention

	ACUTE ILLNESS					
	Non-hospitalized		Hospitalized	Post-hospitalization outcomes		
	Didn't Visit physician; recovered	Visited physician; recovered	Hospitalized	Post-Hospitalization Recovery	Hospitalized; Died	
MEDICAL COSTS (CONTINUED)						
Hospitalizations						
Average admissions per case	0	0	1	0	0	0
Average cost per hospitalization	0	0	$22,464	0	0	0
Total medical costs per case	$0	$445	$22,862	$136	$0	$0
PRODUCTIVITY LOSS, NON-FATAL CASES						
Proportion of cases employed	0.44	0.46	0.43	0.43		0.44
Average number of work days lost	1.00	2.00	4.56	3.04		1
Average daily earnings	$254	$256	$263	$263	$0	$258
Total productivity loss per case	$113	$235	$516	$344		$113
PREMATURE DEATH						
Low value per death					$1,574,065	
Mean value per death					$8,657,357	
High value per death					$15,740,649	

have economic impact data of these pathogens when waterborne, but the health outcomes of the same amount of the same pathogen being ingested via food or water is the same. The most recent data they have are from 2013, so economic health burden might have changed in the past four years; however, we think it is still important to report this data because economics plays a role in the changing of laws and implementation of prevention strategies that could reduce the cases of disease. We have included a picture of some of the report for *Cryptosporidium*, but all the data for each pathogen can be found on the USDA ERS Cost Estimates of Foodborne Illness website (USDA 2014). These reports take into account the differences in hospitalization costs; if the person did or did not go to the hospital; acute versus chronic illness; and fatal versus non-fatal deaths. The reports also have low, mean, high and per case assumptions costs. In the United States in 2013, the ERS's mean estimate of the total annual cost of foodborne illness from the pathogens is as follows:

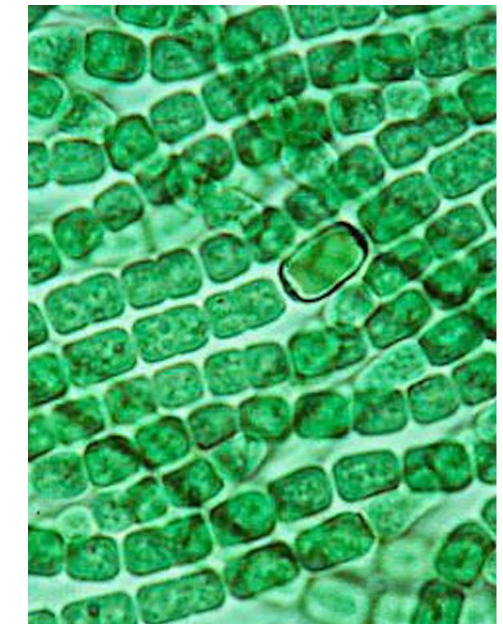
- *Salmonella*: $3,666,600,031
- *Toxoplasma gondii*: $3,303,984,478
- *Campylobacter*: $1,928,787,166
- *E. coli* O157: $271,418,690
- *Cryptosporidium*: $51,813,652

It is important to note that the number of reported cases for some of these diseases are much higher than others (*Salmonella* has a mean estimated number of 1,027,561 cases, while *Cryptosporidium* has 57,616 estimated cases. Also in the picture below, you can see how many people do not visit a physician when sick, and so the number of cases of a disease can be under-represented. The estimated economic health burden of these pathogens is not insignificant, and ought to be considered when determining why and how to prevent waterborne illness from pathogen-contaminated pet waste.

06 POTENTIAL EFFECTS ON ENVIRONMENTAL HEALTH

These parasites do not only affect humans, but the environment, pets, and wild animals as well. Although these health effects might not seem as important because they are not directly resulting in human illness, the spread between domestic animals, or pet to wild animals, can keep a pathogen continuously surviving in the population (Ervin, Van De Werfhorst, Murray & Holden 2014). This cycle is the same as was shown before in the Cycle of Pet Waste figure above: infected animals excrete waste, which can then come into direct contact with other animals who get sick, either transmitting the pathogen through their feces to other animals or resulting in death. The waste can also get into water sources, which other animals drink, resulting in new infection. If you extrapolate the average percent households across the Unites States which have dogs and cats, and use the number of households in Auburn, there would be about 21,014 dogs and cats in Auburn (American Veterinary Medical Association). Many of these animals use the same parks and go to the same locations, so when an infected pet drops feces and it is not picked up, there is an opportunity for another pet or wild animal to come in contact with those feces and continue the cycle.

The environment plays a role in the harboring of pathogens as well; Byappanahalli et al. (2012) stated that, “enterococci may be present in high densities in the absence of obvious fecal sources and that environmental reservoirs of these [Fecal Indicator Bacteria] FIB are important sources and sinks, with the potential to impact water quality”. Although the duration of survival depends on the pathogen and the previously-mentioned survival factors (soil type, moisture, temperature, etc.), this means that a disease-causing pathogen can persist in the environment until the right exposure vector leads to illness and/or potential outbreaks (Winfield & Groisman 2003). Also previously mentioned was the ability for pathogens to survive at different temperatures and in different media, such as in feces under snow. Auburn’s relatively high amount of precipitation and mild climate are good for the survival and dispersion of pathogens from feces (Sidhu, Hodgers, Ahmed, Chong & Toze 2012; Edge et al. 2013; United States Environmental Protection Agency 2000; King, Keegan, Monis & Saint 2005; Food Pathogen Control Data Summary 2011).



Cyanobacteria
Credit: Dwight Kuhn

Pet waste is also high in many nutrients, which can contribute to cyanobacterial blooms, also called blue-green algae blooms (Zabaleta & Rodic 2015; Loza, Perona & Mateo 2013). *Cyanobacteria* are single-celled organisms that live in all types of water, including fresh, brackish and marine water (CDC; USEPA). They use sunlight to make their food, similar to plants, but they are in fact a type of bacteria (Introduction to the Cyanobacteria; Echlin & Morris 1965). Although they prefer warmer temperatures, cyanobacteria are found all over the world and increase their reproduction in nutrient-rich waters (WSDOE; CDC). When pet waste gets into water sources, cyanobacteria have an abundance of nutrients they use to grow, and as the cyanobacteria replicate they deplete the water of oxygen (USEPA 2016). Without oxygen in the water, fish and other waterborne organisms are unable to survive. This destruction of the water ecosystem from cyanobacterial blooms is called eutrophication and it is harmful to the organisms living in the water, as well as those who rely on waterborne organisms to survive (WSDOE; U.S. Department of the Interior). The cascading consequences through the ecosystem are a result of the initial increase in nutrient levels in the water, which in some areas could be due to pet waste. The increased nutrient content causes an increase in cyanobacteria which decreases the amount of oxygen in the water, resulting in a decreased number

Dead fish resulting from eutrophication.

Credit: United States Geological Survey

of fish and other organisms. A decreased number of waterborne organisms can reduce the number of predators that eat them, such as bears, raccoons, larger fish and birds. An example of extreme eutrophication in Washington state occurred in Lake Washington around the 1930's until the 1950's. During this time the lake was acquiring increased amounts of treated sewage, which was full of nutrients like phosphorous, promoting cyanobacteria growth. The lake became rampant with blue-green algae, there were thick patches across the top of the lake and some even called it "Lake Stinko." Luckily there was not much reduction in the local wildlife population and when the treated sewage was diverted to another location the lake was restored approximate to its previous condition (Chislock, Doster, Zitomer. & Wilson 2013; The Lake Washington story 2016; Rescue of "Lake Stinko" 1996).

THE CASCADING CONSEQUENCES THROUGH THE ECOSYSTEM ARE A RESULT OF THE INITIAL INCREASE IN NUTRIENT LEVELS IN THE WATER, WHICH IN SOME AREAS COULD BE DUE TO PET WASTE

Some cyanobacteria can also produce toxins, and the WSDOH states that, "in their toxic form, blue-green algae can cause illness in humans, pets, waterfowl, and other animals that come in contact with the algae" (WSDOH). In the state of Washington, the two toxins of greatest concern are *Microcystin*, a hepatotoxin which damages the liver, and A*natoxin-A*, a neurotoxin which damages nerve tissues (USEPA 2016; Bláha, Babica & Maršálek 2009). When ingested, these toxins can have serious health effects on humans and animals, or even lead to death (Bláha, Babica & Maršálek 2009; WSDOE). From 2009-2016, three freshwater lakes in King County were found to have *Anatoxin-A* and 28 were found to have *Microcystin* (WSDOH). In the same years in Pierce county, *Anatoxin-A* was found in five freshwater lakes and *Microcystin* was found in 14 freshwater lakes (WSDOH).

Downstream effects also need to be considered. Dispersion to other locations via the water can result in illness in areas where the pathogen may not be present in the domestic or wild animal populations. When this happens it is extremely hard to pinpoint the source of the pathogen because the source may be upstream. Depending on the water source that the pathogen enters, potential areas that could be impacted downstream of Auburn include Lake Tapps, Sumner, and Puyallup, with risk persisting until the ocean. Consumption of shellfish growing downstream of the contamination release is another way of ingesting the pathogen that was in the environment, as shellfish are filter-feeders and will concentration the pathogen inside them (Cabral 2010).

When pet waste is not cleaned up properly, it continues the cycle to other animals and other locations, and can lead to cascading effects on the environment and wildlife. All the pathogens above, except for *Giardia* and *Cyanobacteria*, have had endemic rates in Washington state over the past years (Washington State Communicable Disease Report 2015). *Giardia* has shown a mild decline in cases and there is no data for cyanobacteria (Washington State Communicable Disease Report 2015). In order to reduce outbreaks or even eradicate a disease, the spread between hosts and the environment needs to be reduced.

07 REMEDIATION STRATEGIES

Because of the diffuse origins of pet wastes, the problem of controlling the waste is difficult to manage at the source. Stormwater is regulated through a series of pollution control measures referred to as Best Management Practices (BMP). These practices should be adopted for all properties excluding single-family homes. The goal of BMPs is to improve stormwater quality with the final destination of surface or groundwater in mind. Methods are either source control based or treatment based. The former method aims at preventing sources from contaminating storm water and includes structures that prevent stormwater from contacting potentially contaminating materials, as well as checking for leaks and drips. In contrast, treatment based methods aim to remove contaminants (Svrjcek 2003).

Below, we will summarize several recommendations to address the effect of pet waste on water quality. These are primarily source control based and can be further subcategorized into:

1) Surveillance strategies

2) Adoption of technologies and structural strategies

3) Behavior change strategies

Surveillance

In addition to, or preceding management strategies, surveillance could be adopted to 1) definitively attribute fecal pollution to a source organism, 2) characterize sites at risk for animal waste pollution, and 3) monitor at what level that contamination is occurring, if at all. Microbial source tracking (MST) is a method commonly used to identify sources of fecal contamination. This method employs molecular markers that are known to be associated with certain suspected hosts in order to link a sample to a given animal. Common molecular markers used include 16S rRNA, or housekeeping genes, such as the mitochondrial NADPH dehydrogenase 5 gene (Harwood 2014). MST has been used in source attribution in other geographic regions as well (Ervin 2014). Surveillance that describes the areas and the level to which animal wastes are affecting water quality could help guide interventions such as additional BMPs, including strategically placed structural strategies or public education and outreach strategies. It should be noted that surveillance is not intended as a remediation strategy, but in order to better direct other efforts.

Structural Strategies

Low Impact Development

Currently the City of Auburn has 22 existing Low Impact Development zones, in both private and public areas. Low Impact Development (LID) strategies were adopted after urban land use and especially impervious surfaces such as concrete were found to increase stormwater runoff and pollution of waterways. The goal of LID strategies is to maintain pre-development land characteristics including soils, vegetation, and aquatic systems (Wulkan 2007). The most common LID strategies employed in Auburn, found in 17 of 22 zones, are bioretention or permeable pavements. Bioretention strategies include rain gardens and are generally depressions in the earth in which storm water can accumulate, whereas permeable pavements are pavement materials modified so that water may pass into the ground beneath. Both methods have been shown to reduce runoff and associated pollutant loads, with bioretention showing an average removal rate of 88% of fecal coliform bacteria in a laboratory study (Fassman and Blackbourn 2011, Dietz 2007).

Riparian Buffers

Riparian Buffers have been adopted in response to water quality impacts especially due to agricultural runoff (Anbumozhi and Yamaji 2001; Berka et al. 2001). Pet wastes have some similar pollutant characteristics, such as being high in nitrogen content and having some pathogens in common with livestock manure (Svrjcek 2003). A riparian buffer is strip of plant life along the river bed which provides the river with several benefits, including waste remediation. First, a properly designed buffer will inhibit wildlife and pets from accessing water and depositing feces near the water body. Second, roots and plants can filter pathogens and assimilate nutrients (Stormwater Management Office of Hilsboro, n.d.; Bode and Gray, n.d.). In fact, forested buffers can reduce nitrogen as much as 68% on their own and if accompanied by an upland grassed buffer can remove nitrogen loads in excess of 90%. Nutrient enrichment in a water body is one of the main factors in causing eutrophication, which favors growth of *Cyanobacteria*. Riparian buffers also slow flow of runoff into the water body which increases contact time of contaminants and improves the filtration effect the buffer provides. Buffers also have a shading effect which decreases water temperature of the adjacent river, and they have been reported to increase dissolved oxygen in an adjacent river, both of which can help mitigate eutrophication (Anbumozhi et al. 2005).

IN ORDER FOR THE PUBLIC TO CARE ABOUT THE IMPACT THAT PET WASTE HAS ON THE COMMUNITY, IT IS IMPORTANT FOR INDIVIDUALS TO KNOW HOW THEIR ACTIONS IMPACT THEIR OWN HEALTH AS WELL AS THE HEALTH OF CHILDREN, ANIMALS, AND THE ENVIRONMENT

Dog Bag and Disposal Stations

Many successful pet waste management programs across the country have introduced or increased the visibility and/or number of waste disposal stations. These stations occasionally include waste pickup implements; such as bags or the Mutt Mitt. The latter device was implemented in a program in Kitsap. In their program, they installed 350 mutt mitt stations over six years. Over that period, they estimated that as much as 256 tons of waste was diverted from waterways and over 900,000 bags were provided (Mills 2015).

Composting

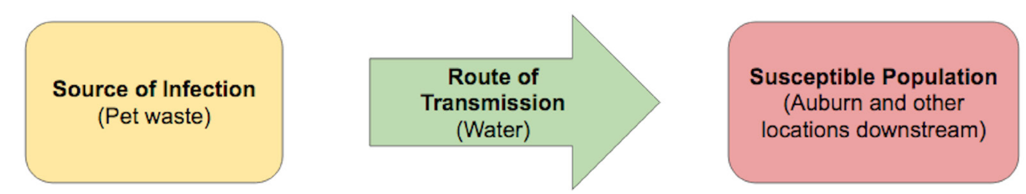
Encouraging pet owners to pick up waste and dispose of it in appropriate containers is an excellent step towards correcting the problem of water quality. However, the waste is not disappearing. A study by Gerba et al. (2011) found that pet feces was the leading contributor to several pathogen loads in landfills, comprising 97.27% of *Salmonella*, 95% of human enteroviruses and 97% of protozoan parasites. Though public health risk due to leachate from landfills is low, the volume of municipal solid waste is increasing and it remains possible that risks could change.

Composting is a strategy that not only diverts pet waste from water, but turns feces into a useable material. A study in Montreal looked at implementing a dog waste composting station in a dog park. They documented characteristics of the composting process and users' attitudes. Both outcomes were positive with almost a ton of dog waste and 7,000 plastic bags diverted from landfills over a year and about 1,700 lb of compost produced. Users attitudes were documented as enthusiastic (Nemiroff and Patterson 2016).

Behavior Change Strategies

Education

Public education is possibly the most important part of all of the methods for remediation. In order for the public to care about the impact that pet waste has on the community, it is important for individuals to know how their actions impact their own health as well as the health of children, animals, and the environment. At the same time, the city ought to attempt to make sure information is disseminated about how people can change their behavior to have a positive impact. This information needs to be easily understood by people from different backgrounds, so it is important that the information is clear and can also be easily discussed. A very simple diagram that can explain the ecology of transmission is the following:



Credit: Joanna Harrison

This diagram shows that three things are needed for transmission of an infectious disease (Meschke 2016). The above graphic is in the context of Auburn. By removing one of these factors, disease cases cannot occur via this specific route. In terms of Auburn, the susceptible populations cannot be removed, nor can the water. The only way to stop transmission of the pathogens is by removing the pet waste.

Easily understood educational material such as this is the best way of getting information out to a public with a diverse educational background. These diagrams can also be altered in order for children to more easily understand them. Educating the public with this information can be done at many different kinds of events, such as those hosted by the city, fairs, or pet-centric events. For example, the free Petpalooza event hosted by the City of Auburn where people can bring all kinds of pets and there is a run with your dog event is a good opportunity to have a booth describing what happens to pet waste when it is not picked up. Setting up educational booths at school functions is also a great way to get the next generation involved (Pet Waste n.d.). Games such as the "Poop toss game" from the City of Bellevue or the "Whatcom Water Week - Scoop The Poop Coloring Contest" from the City of Ferndale can get children engaged in learning. It is important to get children involved in cleaning up, because they tend to be very verbal with their parents resulting in behavioral modification of the parents (Gunawardena, Kurotani, Indrawansa, Nonaka, Mizoue, & Samarasinghe 2016).

ECOLOGY OF DISEASE TRANSMISSION:

For a disease to spread, it must have three factors involved: a host infected with the disease and shedding it, a way for a pathogen to get from where it is to a susceptible host, and a susceptible host (someone who does not already have the disease and can get sick from the pathogen).

PETAPALOOZA 2017 LOGO

Credit: City of Auburn

Another strategy for educating the public that we suggest, is to create a survey that the public can fill out that also deliberately educates them. Although the data from the survey might be usable in the future, the primary focus would be to include questions that get the participant thinking about their actions and the impact of those actions. We suggest a survey including the following questions (which can be modified):

- What is your zip code?
- How many times a week do you take your pet to the park?
- Are you carrying a poop bag for your pet?
- Have you or your pet ever been sick from any of the following?
    - *Cryptosporidium*
    - *Giardia*
    - *Campylobacter*
    - *Salmonella*
    - *E. coli*
    - Blue-green algae
    - *Toxoplasma gondii*
- Are you aware that these sicknesses can be passed from pet to human?
- Are you aware that these sicknesses get passed from feces (poop)?
- Are you aware that these sicknesses can get into water sources and be passed by water?

A note at the bottom of the survey may contain the following:

> "The above pathogens have been found in King and Pierce County waters. Picking up after your pet is the cheapest and simplest way to stop the spread of these sicknesses from your animal to water sources and eventually to humans, or to other animals. If you see someone leave their dog poop behind, let them know of the health concerns that pet waste can cause. A little change can go a long way."

To increase participation, the city can offer material incentives such as dog-poop-bag-dispensers. Studies have shown that by receiving these free incentives, people are more likely to participate in surveys (CDC 2010). The participant would receive the carrier after filling out the survey, or chose to donate it to the Auburn Valley Humane Society. By partnering with organizations like the Auburn Valley Humane Society, veterinary clinics in the city or Homeowners Associations, the city can reach a broader range of pet owners. The city can provide these partners with educational material that can then be disseminated to those organizations, such as the waste disposal pamphlets provided in the Appendix. These organizations also have events periodically - such as the Auburn Valley Humane Society Barktoberfest & Rover Romp - where education booths could be set up. A dialogue about what is currently happening, how it affects people individually, and what positive changes can be done is one of the most important remediation factors.

Increase Awareness

Positive-reinforcement control measures such as signs reminding park goers to pick up after their pet is another behavioral strategy change. According to the 2011-2015 U.S. Census survey of Auburn, Washington, 26.5% of people over the age of 5 speak a language other than English (United States Census Bureau). From the 2010 census, it was shown that although the vast majority of the population is white (70.5%) there is also a significant Latino and Asian population in Auburn (12.9% and 8.9% respectively) (United States Census Bureau). It also shows that of Latinos, 84.56% are Mexican and of Asians, 22.5% are Filipino. Because of this, we suggest that signage about picking up pet waste should have English, Spanish, and Tagalog present. We believe it is highly valuable to have someone fluent with these languages look over the signs before they are printed to ensure accurate and respectful communication. We have included a mock-up of a possible sign design in the Appendix that can be added to the parks.

DIALOGUE BETWEEN COMMUNITY MEMBERS ABOUT THE POTENTIAL HEALTH CONCERNS TO PETS, CHILDREN AND INDIVIDUALS IS AN IMPORTANT LEARNING TOOL

Another strategy is to mark pet feces left behind with flags or with bright paint as ways for the public to become aware of how much pet feces is left behind. This has been done by organizations and individuals in the past, with both positive and negative feedback from residents. While some say that the flags bring awareness to the amount of poop piles left, others consider the flags as "litter" and think they are "even more offensive than the piles of dog poop they mark" (Jensen, Kelly & Gonzalez 2016; Kennedy 2014; Chandler 2014). Although it does bring awareness to the number of fecal droppings left behind, this method only works if the flags are picked up after a period of time and also residents in the parks need to be informed of what the flags are for. Signs around the park can indicate the flags importance and the time period that they will be in the ground.

During the education of the public, the city can ask for their help to combat the problem. Individuals can call out those who they see leaving poop behind or be given "pick up your poop" signs to put in their lawn. Dialogue between community members about the potential health concerns to pets, children and individuals is an important learning tool, as participating in a discussion is a good way of remembering what we've learned (Benjes-Small & Archer 2014). Awareness of a problem can lead to community involvement in strategies to mitigate the problem, which can in turn lead to individuals correcting those who do not abide by the rules, creating a community that looks out for each other and corrects mistakes on their own, effectively reducing the city's burden.

Enforcement

If neither education or awareness is working to reduce the amount of pet waste left behind, fine-based reinforcement may need to be considered. The municipal code of Auburn provisions 6.02.132 A & B state that an individual may be fined up to $25.00 for either failing to remove animal waste or not possessing equipment to remove animal wastes. Information about level of enforcement of these ordinances in Auburn and other locations across the country with similar codes was not readily accessible, and in reality there are much more serious law issues that enforcement addresses, so this issue often gets overlooked (Levin 2011). The need for some enforcement does however exist, as people in cities all over the country complain about the waste left by other pet owners (Goodman 2008; Markovich 2016). Seattle has even devoted funds to a two-man enforcement team whose sole job is to go around the city parks and fine those who do not clean up after their pets or do not carry the proper equipment to clean up after their pets. Debate on what "proper equipment" includes is ongoing (Goodman 2008; Markovich 2016). This enforcement team focuses on parks which have a large number of pets visiting or where they get the most complaints about (Markovich 2016). Enforcement such as this, whose exclusive purpose is to enforce animal laws, is also occurring in other states across the country (Goodman 2008). It could instead be reasonable to have enforcement at the parks at random times throughout the year or to have enforcement campaigns during the rainy months of the year when spread of pathogens increases, to keep the public aware of their actions and uncertain when they could be caught not picking up pet waste.

IF NEITHER EDUCATION NOR AWARENESS IS WORKING TO REDUCE THE AMOUNT OF PET WASTE LEFT BEHIND, FINE-BASED REINFORCEMENT MAY NEED TO BE CONSIDERED

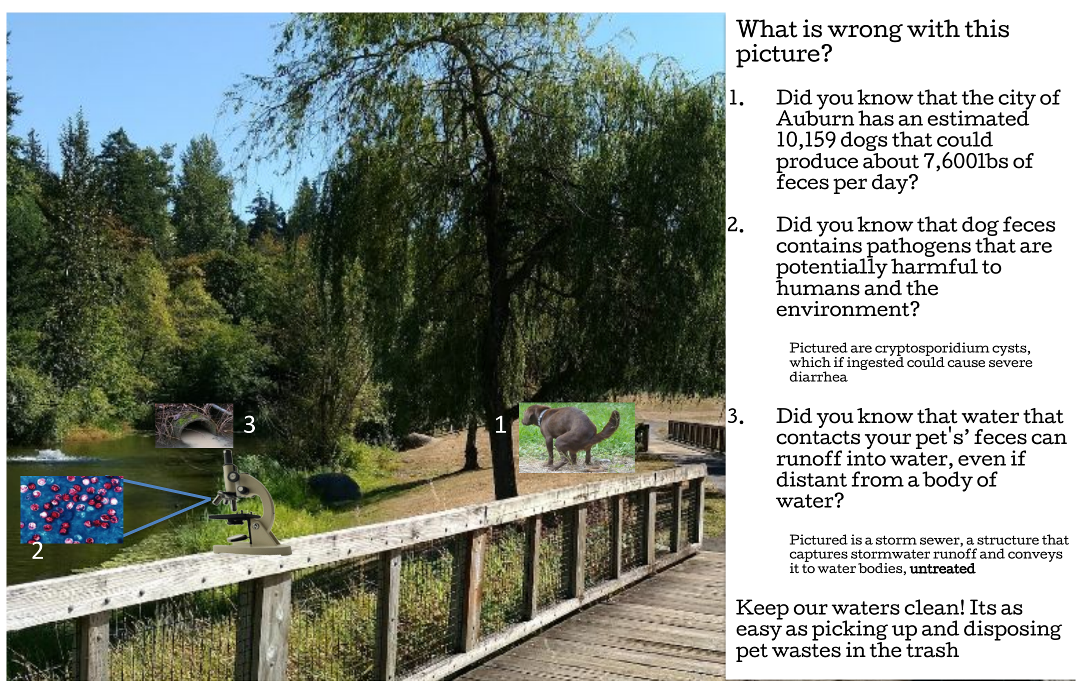
08 CONCLUSION

Pet waste can cause a variety of problems to humans, animals, and the environment that we live in by causing anything from unpleasing aesthetics to illness. The City of Auburn faces the problem of reduced water quality, possibly due to the entrance of pet waste into these sources. Pet waste also carries a variety of different types of pathogens, some of which have caused disease in King and Pierce Counties. Remediation strategies can target different aspects of the issue, from educating the public, to acquiring data about the contamination in their water, to providing materials necessary for the success of reducing pet waste. The long-term outcome would be for the community and individuals to understand the consequences of not picking up their pet waste and correct mistakes on their own; however, remediation efforts will need to begin at the government level in order to ensure acceptable water quality criteria.

APPENDIX

WASTE DISPOSAL PAMPHLET

Behavior Change Strategies



Credit: Meagan Deviaene

MOCK PARK SIGN

Credit: Joanna Harrison

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