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The Effects of Flood Irrigation on Groundwater *E. coli*/coliform Contamination

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ABSTRACT

Recent field observations raise the question of a connection between flood irrigation and groundwater *E. coli* contamination. Previous studies have shown that total coliform and *E. coli* serotype O157:H7 are capable of transmission in a freshwater medium. The most common water sources associated with human outbreak are irrigation, wastewater, recreational, and drinking. Further investigation of water as a growth medium revealed that *E. coli* can survive in sterile water with low carbon concentrations. These studies show only the transmission of *E. coli* in water and the growth of *E. coli* in sterile fresh water. At present no literature can lead one to say that flood irrigation has an impact on domestic water wells. A statistically significant correlation of contamination by total coliform bacteria with irrigation has been found (P = 0.014).

Keywords: *Escherichia coli,* coliform bacteria

INTRODUCTION

Total coliform and fecal coliform are monitored regularly in domestic water wells. Total coliform bacteria are typically found in the environment including soil and vegetation. Fecal coliform are a sub-group that are normal flora in mammalian intestines. Contamination of domestic water wells by either of these may indicate that there is a risk of pathogens entering the system, which could present many health risks (Michigan Department of Environmental Quality). *Escherichia coli* (*E. coli*) are mostly harmless but there are pathogenic strains that can cause illness. There are five pathogenic classes of *E. coli* including enterotoxigenic *E. coli* (ETEC), enteroinvasive *E. coli* (EIEC), enteropathogenic *E-coli* (EPEC), enteroaggregative (EAggEC), and enterohemorrhagic *E. coli* (EHEC). Previous studies have shown that total coliform and EHEC serotype O157:H7 (a sub class of *E. coli*) are capable of transmission in a freshwater medium. The most common water sources linked with human outbreaks are irrigation, wastewater, recreational, and drinking. Water transmission of *E. coli* O157:H7 is the third greatest known route following food-borne and person-to-person transmission. (Muniesa, 2006)

Further studies on *E. coli* O157:H7 have revealed that it can grow in sterile freshwater that contains low carbon concentrations. This finding goes against the most commonly accepted idea that *E. coli* concentrations will decline after introduction to a freshwater medium. It is also important to note that increasing temperature resulted in higher growth rates of *E. coli* O157:H7 (Steel, 2004).

There is also evidence suggesting that the vector for pathogenic contamination of fruits and vegetables is by irrigation using poor-quality water. Typically, surface water irrigation is of variable microbial water quality and groundwater irrigation is of good microbial quality (Vital, 2006).

These studies highlight the transmission of *E. coli* in water, transmission from water to fruit and vegetables, and the growth of *E. coli* in sterile fresh water. Recent field observations by Lynn Fector of Four Corners Geoscience, raise the question of a connection between flood irrigation and groundwater *E. coli* contamination. At present the author has found no literature that can lead one to say that flood irrigation has an impact on domestic water wells. My intention is to show the impact of flood irrigation water on the water quality of domestic water wells.

MATERIALS AND METHODS

Two types of wells were sampled; wells located in a flood irrigated plain and wells in a non-irrigated plain. Wells were selected at random, for a total of 26 water samples. Testing took place in LaPlata County, Colorado, in townships T34N and T35N and range 6W. To ensure a random sample I assigned a number to each well located in the area of testing and then used random number generation to select my sample sites. There were 13 irrigated and 13 non-irrigated wells tested. The testing was completed in two days. On the first day all 13 samples were collected from the irrigated region. I tested temperature, conductivity, dissolved oxygen, and salinity using an YSI Model 85 handheld oxygen, conductivity, salinity, and temperature system. I also measured the pH with a hand held pH meter. Following the manual's recommendation, each instrument was recalibrated every 2 hours to ensure accurate readings. Separate samples (from each of the sample sites) were taken in sterile vials I received from the San Juan Basin Health Department (SJBHD). All samples were collected from exterior sources in order to prevent sample contamination. In order to clear the system, water was run for 5

Table 1. The mean values of dissolved oxygen (DO), conductivity (Cond), salinity, H^+ concentration, and temperature (temp) for (Irrigated) and (Non-irrigated) are reported ± 1 S.E.. The only significant difference, assuming equal variance, found was concentration of H^+ between irrigated and non-irrigated plains.

	n	DO (mg/L)	Cond (µs)	Salinity	[H+]	Temp ºC
Irrigated	13	1.7 ± 0.5	426.9 ± 46.8	0.3 ± 0.04	3.2E-07 ± 8.2E-08	16.6 ± 0.6
total coliform	7	0.9 ± 0.5	352.6 ± 60.2	0.2 ± 0.04	3.7E-07 ± 1.0E-07	16.6 ± 1.1
E. coli	2	0.5 ± 0.5	282.8 ± 173.3	0.2 ± .01	1.1E-07 ± 3.3E-08	17.9 ± 2.4
no contamination	6	2.7 ± 0.9	513.8 ± 61.1	0.4 ± 0.06	2.8E-07 ± 1.3E-07	16.7 ± 0.6
Non-irrigated	13	4.9 ± 0.5	462.3 ± 54.1	0.3 ± 0.03	7.8E-08 ± 1.7E-08	17.7 ± 0.7
total coliform	0					
E. coli	0					
no contamination	13	4.9 ± 0.5	462.3 ± 54.1	518.9 ± 0.03	7.8E-08 ± 1.7E-08	17.7 ± 0.7

minutes prior to taking the sample. Sample vials going to SJBHD water lab were filled to within 1 inch from top of vial. Samples were not taken from faucets with strainers or aerators. Collector used caution when collecting sample and made sure not to touch inside the bottle or lid to avoid sample contamination. Samples were then taken into the SJBHD water quality lab for further testing on the absence/presence of total coliform and *E. coli*. Absence is determined to be less than 1.1 coliform per 100 mL. Anything above that indicates an unsafe sample and water should be treated and re-tested. After the samples were collected, they were placed in a cooler, at approximately 16º C, to remain cold. It is important to note any samples over 24 hours old were discarded. The second day the same procedure was followed for the non-irrigated region.

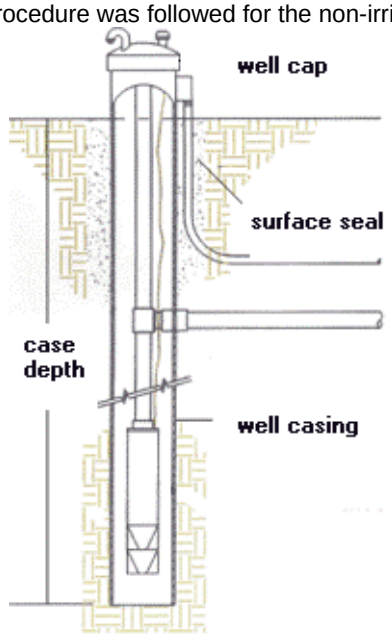

Figure 1: Representation of normal well construction showing case depth, well cap, surface seal, and well casing. Insufficient well casing depth, improper sealing of space between casing and bore hole, corroded or cracked well casings, poor well seals or caps, and unplugged/abandoned wells are common sources of coliform contamination.

Presence/absence data were converted into a Z-score so that I could find the point on the Z distribution that corresponds to the *x* on the binomial distribution. This was done by using the following equation:

$$Z = \frac{x - np}{\sqrt{np(1-p)}}$$

where p equals the probability of *x* outcomes and *n* is the sample size (Kuzma and Bohnenblust, 2005). Two sample t-tests, assuming equal variances, were run on temperature, conductivity, dissolved oxygen, salinity and pH data between irrigated and non-irrigated plains. Mann-Whitney Rank Sum tests were used if data were not normal. Data were also categorized into coliform present and coliform absent and same tests were performed with critical value of a = 0.05.

RESULTS

Of the 13 wells in the irrigated regions, five wells were contaminated with coliform; two wells were contaminated with *E. coli.* The wells located in non-irrigated regions showed no presence of total coliform or *E. coli.* Table 1 shows the averages ± 1 S.E. of temperature, conductivity, dissolved oxygen, salinity and $[H^+]$ data collected in both plains.

DISCUSSION

Interpreting the data shows that there is statistically significant evidence suggesting that contamination due to surface irrigation is a possibility; however, further studies are needed. The probability of observing 7 total coliform and 2 *E. coli* contaminated samples was 0.01426 and 0.1492 out of 13 wells respectively. Table 1 shows that there were no statistically significant differences between temperature, conductivity, and salinity in the two plains. While there were statistically significant differences in $[H^+]$ and dissolved oxygen (P = 0.002) and (P = 0.028) respectively. No significant difference was found between the temperature,

conductivity, dissolved oxygen, salinity and pH / [H^+] between the 7 wells that showed presence of total coliform and the 6 that did not. The powers of the tests performed were all below the desired power of 0.800. In future studies a larger sample size would result in increased powers. Steel and colleagues found increasing water temperatures gave rise to increasing growth rates. It is interesting that no such correlation was found in the data. Overall, this study has produced evidence suggesting that there is a correlation between contaminated domestic water wells and being in an irrigated plain. Of the other water quality standards measured only differences in pH and dissolved oxygen were statistically significant between the Irrigated and Non-irrigated.

According to the Michigan Department of Environmental Quality's Water Division there are several common sources of coliform contamination. These include, insufficient well casing depth, improper sealing of space between casing and bore hole, corroded or cracked well casings, poor well seals or caps, and unplugged/abandoned wells (refer to Figure 1). All of these allow the introduction of sewage, surface water, and insects that can carry coliform into aquifers and other groundwater sources.

There is a possibility that groundwater can be contaminated by irrigation water that percolates back to the water table (aquifer). Further studies are needed to determine the exact causation of contamination. In order to determine if there is a surface water contribution one could look at ^{18}O:^{16}O and ^{2}H:^{1}H ratios. Stable isotope ratios of water are conserved in aquifers at low temperature but water becomes isotopically fractionated on the surface. Protium and deuterium fractionate more because of their larger percent relative mass difference (Borchardt et al, 2004). Water isotope analysis that Borchardt and colleagues used could be used. A tracing system (using KBr) could be used to determine if irrigation water was entering the well systems by sampling for bromide concentrations after introduction (Frye 2009). Another possible avenue would be to determine if any of the bacteria found in the wells were antibiotic resistant.

ACKNOWLEDGEMENTS

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LITERATURE CITED

Borchardt, MA, NL Haas, and RJ Hunt. 2004 Vulnerability of Drinking-Water Wells in La Crosse, Wisconsin, to Enteric-Virus Contamination from Surface Water Contributions, Applied and Environmental Microbiology 5937-5946.

Fector, L. 2008 Personal Interview (25 July 2009).

Frye, J. 2009 Personal Interview (4 Feb 2009).

Kuzma, JW, SE Bohnenblust. 2005. Basic Statistics for the Health Sciences. McGraw Hill Companies, Inc., New York, NY. 196 pp.

Michigan Department of Environmental Quality, Water Division-Ground Water Section. Environmental Health Fact Sheet. Coliform Bacterial and Drinking Water Oct 2004. Washtenaw County Michigan. http://www.michigan.gov/documents/deq/deq-wd-gws-wcu-coliformbactiwellwatersampling_270604_7.pdf (5 Nov 2008).

Muniesa, M, et al. Occurrence of Escherichia coli O157:H7 and Other Enterohemorrhagic Escherichia coli in the Environment. 2006 Environmental Science & Technology 40.23: 7141-7149.

Steel, M, and J Odumeru. 2004 Irrigation Water as Source of Foodborne Pathogens on Fruit and Vegetables. Journal of Food Protection 67.12: 2839-2849.

Vital, M, F Hammes, and T Egli. 2006 Esherichia coli 0157 can grow in natural freshwater at low carbon concentrations. Environmental Science & Technology 40.23: 7141-7149.