The Effect of Water, Sewage and Hand Hygiene on Waterborne Diseases in Saudi Arabia

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Master thesis 15 credits
Infectious Disease Control Program | 2021

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List of Abbreviations

ANOVA	Analysis of Variance
E. coli	*Escherichia coli*
E. histolytica	*Entamoeba histolytica*
HAV	Hepatitis A virus
WHO	World Health Organization

Popular Summary

Waterborne diseases are illnesses caused by microscopic organisms, like viruses, bacteria and parasites, that transmitted either by contaminated water or food or by direct person to person contact such as diaper changing or sexual activity. Most waterborne diseases are characterized by diarrhea, which involves excessive stooling, often resulting in dehydration and possibly death. According to the World Health Organization, diarrheal disease is responsible for the deaths of 1.8 million people every year. The transmission cycle of waterborne disease can be broken through safe water supplies, maintaining standards of sanitation and proper handwashing practices. Two waterborne diseases are considered in this study: hepatitis A and amebic dysentery.

This study aimed to understand the important factors for preventing waterborne diseases in order to improve public health. The study assessed the effect of different drinking water sources, sewage systems and different active practices of soap use for hand washing on incidence of waterborne diseases in different regions in Saudi Arabia. In comparison of different drinking water sources, this study showed borderline rise in incidence of waterborne diseases with the use of private well water. Whereas different sewage systems had no clear effect on the incidence of waterborne diseases. The study also revealed that not using soap for hand washing would increase the risk for hepatitis A infection. Moreover, the study showed significant decline in waterborne diseases incidence when access to filtered water combined with regular soap use in the same statistical test.

Abstract

Waterborne diseases are illnesses caused by microscopic organisms, like viruses, bacteria and parasites, that transmitted via the fecal-oral route through ingestion of contaminated water or food or by direct person to person contact. The transmission cycle can be broken through safe water supplies, maintaining standards of sanitation and proper handwashing practices. Two waterborne diseases are considered in this study: hepatitis A and amebic dysentery. The study aimed to understand the important factors for preventing waterborne diseases in order to improve public health. A descriptive cross-sectional study was conducted to assess the effect of different drinking water sources, sewage systems and different active practices of soap use for hand washing on incidence of waterborne diseases in different regions in Saudi Arabia. Data was obtained from Ministry of Health and Household Environment Survey provided by General Authority for Statistics. Statistical analysis performed by using general linear model and type II Analysis of Variance. In comparison of different drinking water sources, this study showed borderline rise in incidence of waterborne diseases with the use of private well water. Whereas different sewage systems had no clear effect on the incidence of waterborne diseases. The study also revealed that not using soap for hand washing would increase the risk for hepatitis A infection. Moreover, the study showed significant decline in waterborne diseases incidence when access to filtered water combined with regular soap use in the same linear model.

Introduction

Waterborne diseases are those diseases that are transmitted through the direct drinking of water contaminated with pathogenic microorganisms. Most waterborne diseases are often transmitted via the fecal-oral route, and this occurs when human fecal material is ingested through drinking contaminated water or eating contaminated food which mainly arises from poor sewage management and improper sanitation. Waterborne disease can be caused by bacteria, viruses and intestinal parasites.(1)

Most waterborne diseases are characterized by diarrhea, which involves excessive stooling, often resulting in dehydration and possibly death. According to the World Health Organization (WHO), diarrheal disease accounts for an estimated 4.1% of the total daily global burden of disease and is responsible for the deaths of 1.8 million people every year. Further estimates suggest that 88% of that burden is attributable to unsafe water supply, sanitation and hygiene and is mostly concentrated on children in developing countries.(2,3)

Examples of waterborne diseases include Cholera, Amebic dysentery, Cryptosporidiosis, Typhoid, Giardiasis, Paratyphoid, Salmonellosis, Campylobacter enteritis, Rotavirus diarrhea, *Escherichia coli* diarrhea, Hepatitis A, Leptospirosis and Poliomyelitis.(1) Two types of waterborne diseases are considered in this study: Hepatitis A and Amebic dysentery.

Background on Hepatitis A in Saudi Arabia

Hepatitis A virus (HAV) is a nonenveloped RNA virus belonging to the family *Picornaviridae*.(4) Humans are the only natural reservoir of the virus. HAV is transmitted via faecal–oral route through direct person to person contact or ingestion of contaminated food or water.(4) Infected people shed the virus 1–2 weeks before the onset of clinical symptoms while infants can shed virus up to 6 months after infection.(4)

Clinical manifestations include abrupt onset of fever, diarrhea, anorexia, nausea, vomiting and abdominal discomfort, followed within a few days by jaundice. Severe hepatic complications, including fulminant hepatitis and liver failure, are rare but more common in high risk population. The overall case fatality ratio varies according to the affected population.(4)

There is no appreciable seasonal variation in hepatitis A incidence. HAV is common in areas with inadequate sanitation and limited access to clean water. The diagnosis of acute hepatitis A requires the presence of HAV-specific IgM antibody. Treatment is generally supportive. Locating the primary source and preventing further outbreaks are paramount. HAV infection can be prevented with maintaining standards of sanitation, food and water precautions and vaccination or immune globulin (IG).(4) Saudi Arabia added hepatitis A vaccine to their childhood immunization schedules in 2008. It consists of inactivated virus and given in 2 shots 6 months apart. The first shot when infant is 18 months old and the second at 24 months old. Vaccination policy against HAV for adult is elective in Saudi Arabia.(5)

Understanding the epidemiological shift in HAV seropositivity is crucial to develop a strategic plan for healthcare system. There is marked decline in prevalence of hepatitis A in Saudi children and adolescents from 52% in 1989, to 25% in 1997, to 18.6% in 2008, which indicates that more than 82% of the young population during 2008 were susceptible to symptomatic HAV infection. This high susceptibility of the young population means that they lack the immunity against HAV due to vaccination or natural infection.(5) The intermediate HAV endemicity in Saudi Arabia is closely linked to the socioeconomic conditions of sanitation and hygiene.(6) Prevalence patterns of HAV infection vary among regions within Saudi Arabia reflecting the different stages of economic development of these regions. Regions where the prevalence of HAV infection is decreasing have growing numbers of susceptible people and are at risk for outbreaks of hepatitis A. The current low prevalence rates call for strict adherence to vaccination policies in high risk patients and raises the question of a universal HAV vaccination program.(5)

Background on Amebic Dysentery in Saudi Arabia

Amebiasis is caused by the parasite *Entamoeba histolytica* that exists in two distinct life stages.(7) Infection by *E. histolytica* occurs by ingestion of mature cysts through the fecal-oral route either by fecally contaminated food or water or person-to-person contact such as by diaper changing, or sexual activity.(7) The ingested cysts develop into trophozoites inside the human host. The trophozoites multiply by binary fission in the colon and produce new cysts that will be dispersed through the feces.(7) Because of the protection conferred by their walls, the cysts can survive days to weeks in the external environment and remain infective in fecal matter, water, sewage, and moist soil at low temperatures. Whereas trophozoites passed in the stool are rapidly destroyed once outside the body.(7)

Most infected people are asymptomatic cyst carrier. The symptomatic form of the disease has gradual onset and characterized by cramps, watery or bloody diarrhea and weight loss, and may last several weeks.(7) Occasionally, the parasite may spread to the liver (extraintestinal amebiasis) causing amebic liver abscesses.(7) People at higher risk for severe disease include pregnant, immunocompromised and patients with chronic liver disease. Also, associations with diabetes and alcohol use have been reported.(7)

Immunoassays that detect *E. histolytica* antigens in stool are sensitive and specific to confirm the diagnosis.(7) Amoebic dysentery treated with antiprotozoals like metronidazole for eradication in combination with paromomycin to prevent the recurrence. Asymptomatic carrier who pass *E. histolytica* cysts should be treated to prevent development of invasive disease and spreading disease to others.(7) Hand hygiene, food and water precaution are essential to prevent infection.(7)

Among all the parasitic diseases, amoebiasis is the third most frequent infectious disease related cause of mortality after malaria and schistosomiasis.(8) It is highly endemic throughout poor and socio-economically deprived communities in the tropics and subtropics. In Saudi Arabia, amebic dysentery still must be notified locally at regional level within a diarrheal disease surveillance program.(9) Surveillance data in Saudi Arabia from 1993-2008 were analyzed and during this period 63583 amoebic dysentery cases were reported with an annual rang of 2328 to 8185 cases (incidence: 10.5 to 43.8/100,000).(9) In 1993, the incidence of amoebic dysentery was high (23.6/100,000), then resumed its rise to its highest level in 1996 (43 .8/100,000), after which a dramatic decline began to take place until it reached its lowest value in 2003 (10.5/100,000), then started to rise again to reach (13.2/100,000) in 2008.(9) Through this period, the seasonal trend showed a slight decline of reported rates from the 1st quarter of the year to the 2nd quarter then a steady rise up to the 4th quarter.(9)

In Southwestern region, high prevalence of intestinal parasitic infections (70.5%) was reported. *E. histolytica* was found to be one of the common intestinal parasites.(10)

Rationale

Draw the attention to current situation of Sustainable Development Goals (SDGs) in Saudi Arabia especially Goal 6, ensure access to safe water and sanitation for all.

Disease burden that leads to high morbidity and mortality in extreme ages. Furthermore, no specific treatment is available for some viral diseases and increasing anti-microbial drug resistance is being recorded for some bacterial diseases. Outbreaks could cause panic in the community and negative media coverage.

Research Aim

To understand which factors that are important for preventing waterborne diseases and potential outbreaks in order to improve public health.

Research Objectives

1- Assess the effect of different drinking water sources and sewage systems on incidence of waterborne diseases in different regions in Saudi Arabia, 2019.

2- Determine the effect of different active practices of soap use for hand washing on incidence of waterborne diseases in different regions in Saudi Arabia, 2019.

Based on the objectives of this study, the main hypotheses are:

1- Low water quality and poor sanitation could affect the incidence of waterborne diseases in different regions in Saudi Arabia.

2- Variation in soap use for hand washing might affect the incidence of waterborne diseases in different regions in Saudi Arabia.

Literature Review

Estimates from the WHO indicate that 1.1 billion people worldwide are without access to safe potable water and 2.4 billion people do not have access to adequate sanitation. Approximately 900 million people suffer from diarrheal diseases worldwide each year from exposure to or consumption of contaminated water.(11) The safe water access in Saudi Arabia is 99.84% and the sanitation access is 100 % which has improved since the establishment of the National Water Company. (12) However, the increase of urbanization and the population growth rate in Saudi Arabia have aggravated the demand for water and sanitation service.(13) There is a growing amount of literature on waterborne diseases and the preventive measures. The overall outcome from the literature review highlighted the role of safe water supply and improved sanitation to prevent infection and encouraged proper handwashing technique.

Alomran et al. (14) conducted a study in different zones in Riyadh, Saudi Arabia to assess drinking water quality. They found that the microbial levels in some of their samples were higher than the United States Environmental Protection agency's standard for is which 500 colonies forming unit/mL.(15) Further, Saati and Faidah (16) assessed the prevalence of pathogens in 36 drinking water wells and another 36 non drinkable sources in Makkah city, Saudi Arabia. They found E.coli in seven of the wells that contained potable water and in five of the wells that had non-drinkable water.

Korfali and Jurdi (17) assessed the domestic water profile in the city of Beirut. Water samples were collected from three types of household water sources (municipality, private wells, and vended water bottles) and tested for physiochemical and microbial profile. In parallel, they conducted a cross-sectional survey assessing water consumption patterns and the prevalence of waterborne diseases. The tests showed a deficient water quality profile in all three water sources. The measured parameters reflected the high frequency of waterborne diseases. The study recommended upgrading the existing water quality control program and planning for more consumers awareness activities.

In a study conducted in rural area of Asir region of Saudi Arabia by Omar et al. (18) stool samples were collected and examined for intestinal parasites. Overall, the prevalence rates of infection with the common waterborne parasites, Giardia lamblia and Entamoeba histolytica were 18.9% and 9.2%, respectively. The sociodemographic factors were found to be non-significant. The highest prevalence of infection was found among householders who drank well water or jar water (potable water sold in private shops). In contrast, the use of desalinated water had a significant protective effect against contracting infections with both parasites.

A questionnaire-based survey was used by Hamner et al. (19) to estimate waterborne and enteric disease incidence and study Ganges River use patterns among residents in India where untreated human sewage is discharged into the river. The study revealed significant associations between waterborne/enteric disease occurrence such as (acute gastrointestinal disease, cholera, dysentery, hepatitis A, and typhoid) and use of the river. Also showed significant associations between waterborne disease outcome and lack of sewerage and toilets at residence.

In trial done by Burton et al. (20), 20 volunteers contaminated their hands deliberately by touching door handles and railings in public spaces. They were then allocated at random to handwashing with water, handwashing with non-antibacterial soap and no handwashing. Each volunteer underwent this procedure 24 times, yielding 480 samples overall. Pathogens were found after no handwashing in 44% of samples. Handwashing with water alone reduced the presence of contamination to 23%. Handwashing with plain soap and water reduced the contamination to 8%. The study concluded that handwashing with non-antibacterial soap and water is more effective for the removal of pathogen from hands than handwashing with water alone and should therefore be more useful for the prevention of transmission of diarrheal diseases.

Another study by Luby et al. (21) to assess the relationship between observed handwashing behavior and subsequent diarrhea. They conducted a 5-hour structured observation of handwashing behavior and a cross-sectional survey to collect demographic information followed with monthly surveillance for 2 years to ask whether household residents had diarrhea during the preceding 48 hours. At the end of 2 years follow, the result showed that handwashing before preparing food is a particularly important opportunity to prevent diarrheal diseases.

In a six-month randomized control trial in Bolivia by Clasen et al. (22), ceramic water filters were distributed randomly to half of the 50 participating households while the remaining households continued to use customary water handling practices and served as controls. In four rounds of sampling following distribution of the filters, 100% of the 96 water samples from the filter households were free of coliforms compared with 15.5% of the control household samples. Diarrheal disease risk for individuals in intervention households was 70% lower than for controls. The study results showed that affordable ceramic water filters enable low-income households to treat and maintain the microbiologic quality of their drinking water.

Another randomized controlled trial in Cambodia by Brown et al. (23) to evaluate the microbiologic effectiveness and impact on diarrheal disease of a promising household water treatment technology. After collecting four weeks of baseline data on household water quality, diarrheal disease and water handling practices households were randomly assigned to one of three groups of 60 households: those receiving a ceramic water purifier (CWP), those receiving a second filter employing an iron-rich ceramic (CWP-Fe), and a control group receiving no intervention. Households were followed for 18 weeks post-baseline with biweekly follow up. They found that households using either filter reported significantly less diarrheal disease compared with control group.

Contrary to Clasen et al. (22) and Brown et al. (23) studies, the study carried out in Qatar by Nriagu et al. (24) revealed unexpected result. They collected water samples from 32 housing units and survey instrument was used to gather information on maintenance and care of the water filters. They showed that filters can induce significant deterioration of the quality of tap water by functioning as reservoirs for sludge or rust deposits which promote microbial growth and biofilm formation in the household water distribution system.

Method

Study Design

A descriptive cross-sectional study design was conducted to assess the effect of different drinking water sources, sewage systems and soap use for hand washing on incidence of waterborne diseases in different regions in Saudi Arabia.

Data

The data covers 13 administrative regions of the Kingdom of Saudi Arabia, which are: (Riyadh, Makkah, Madinah, Qassim, Eastern Province, Asir, Tabuk, Hail, Northern Borders, Jazan, Najran, Al-Baha, and Al-Jouf). Regional data for incidence (per 100,000) of waterborne diseases in 2019 was obtained from Ministry of Health.(25) The data for incidence counts as the proportion of inhabitants in each region who newly diagnosed with waterborne diseases in the year 2019. The waterborne diseases included in this study are hepatitis A and amebic dysentery only because there were zero reported cases of cholera and typhoid during 2019.

The regional data on different drinking water sources, sewage systems and active practices of soap use for hand washing for the year 2019 were obtained from the Household Environment Survey provided by General Authority for Statistics.(26)

The data on different drinking water sources counts as the proportion of inhabitants in each region who have access to (public network, filters, tank, private well, bottles or other). Data on different sewage systems counts as the proportion of inhabitants in each region who have access to (public network or private network). Data on active practices of soap use for hand washing counts as the proportion of inhabitants in each region who use soap and water to clean hands with different levels of using soap (regularly, when needed, rarely or not used). Full data is found in the appendix.

Statistical Analysis

The prevalence of the two waterborne diseases (hepatitis A and amebic dysentery) were analyzed with a set of different general linear models testing if the incidence of the two diseases are affected by the proportional access to the different types of drinking water sources, or the proportional access to the different types of sewage systems, or the proportion of different levels of soap use during handwashing. The data is available as proportions in the 13 different regions for the different levels of all categories of drinking water sources (public network, filters, tank, private well, bottles or other), sewage systems (public network or private network), and degree of soap use (regularly, when needed, rarely or not used). Therefore, all different categories were analyzed separately in general linear models. As an example, the disease incidence was analyzed as a function of the type of disease and the percentage of the population that had access to public network water supply. In a second model the disease incidence was analyzed as a function of the type of disease and the percentage of the population that had the access to filters, and so on for all different categories for all explanatory variables. All models also included two-way interactions.

I also constructed models analyzing the disease incidence as a function of disease type, one of the drinking water sources, and one of the different levels of soap use and the interaction between the water source and soap use. For all models, diagnostic diagrams were used to assess normality, linearity and homoscedasticity. To improve homoscedasticity and normality, the incidence of waterborne diseases was log transformed in all models. All effects were assessed with a type II Analysis of Variance (ANOVA) to get the most accurate p-values. All statistical tests were performed using R and RStudio version 4.0.2.

Results

In comparison of different drinking water sources, there is a borderline significant positive effect of the access to private well water on incidence of waterborne diseases with p-value = 0.051, slope b = 0.284 and adjusted R-squared = 0.32. The adjusted R-squared indicates how large the proportion of the variation in the response (incidence) that is explained by access to private well water. (Table 1, 2 and Figure 1).

Table 1. Results from the linear models analyzing the effect of different drinking water sources on incidence of waterborne diseases.

Drinking water source	Estimate	t-value	p-value	Adjusted R-squared
Public network	0.019	0.79	0.437	0.21
Filters	-0.023	-1.63	0.117	0.27
Tank	0.003	0.33	0.744	0.19
Private well	0.284	2.06	**0.051**	0.32
Bottles	0.002	0.22	0.828	0.19
Other	-0.227	-1.09	0.289	0.23

Table 2. ANOVA results on the effect of different drinking water sources on incidence of waterborne diseases. It is important to note that each drinking water source was analysed with separate ANOVA model.

Drinking water source	P-value of waterborne diseases (hepatitis A, amebic dysentery)	P-value of drinking water source	P-value of the interaction between waterborne diseases and drinking water source
Public network	0.009	0.437	0.706
Filters	0.007	0.117	0.527
Tank	0.010	0.744	0.947
Private well	0.006	**0.051**	0.990
Bottles	0.010	0.828	0.569
Other	0.009	0.289	0.582

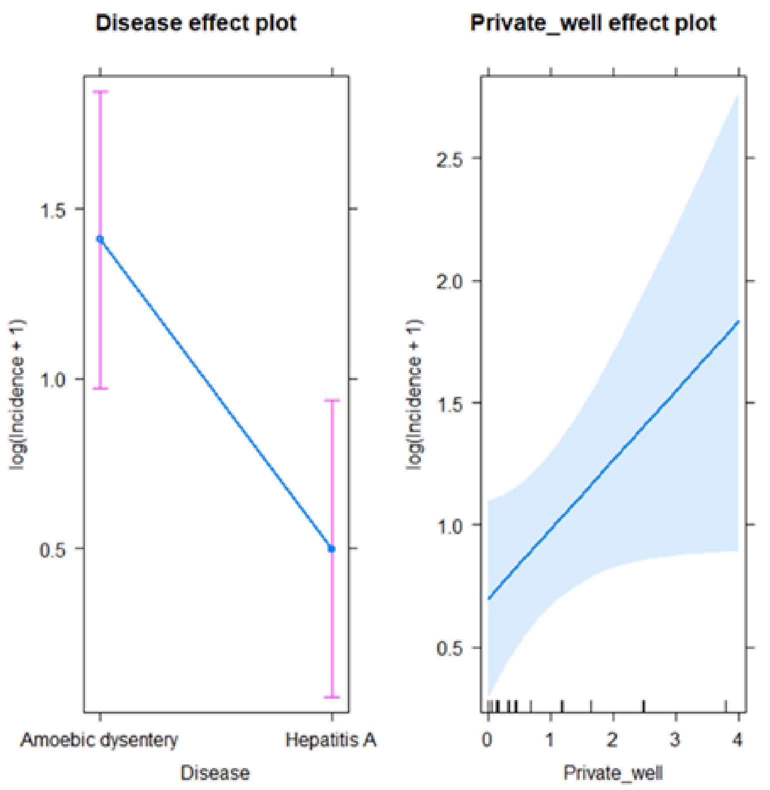

Figure 1. Private well and waterborne diseases effect plots at log scale.

To assess the effect of different sewage systems on incidence of waterborne diseases, linear models indicate that there is no clear effect of different sewage systems on incidence of waterborne diseases (Table 3 and 4).

Table 3. Results from the linear models analyzing the effect of different sewage systems on incidence of waterborne diseases.

Sewage system	Estimate	t-value	p-value	Adjusted R-squared
Public network	0.005	0.80	0.434	0.21
Private network	-0.005	-0.80	0.434	0.21

Table 4. ANOVA results on the effect of different sewage systems on incidence of waterborne diseases. It is important to note that each sewage system was analysed with separate ANOVA model.

Sewage system	P-value of waterborne diseases (hepatitis A, amebic dysentery)	P-value of sewage system	P-value of the interaction between waterborne diseases and sewage system
Public network	0.009	0.434	0.711
Private network	0.009	0.434	0.711

For the second research objective, linear models show a statistically significant interaction between active practice of not using soap for hand washing and waterborne diseases (hepatitis A, amebic dysentery). This interaction indicates that if soap is not used for hand washing there is a significant effect on incidence of hepatitis A, but no significant effect on incidence of amebic dysentery. (Table 5, 6 and Figure 2).

Table 5. Results from the linear models analyzing the effect of different active practices of soap use for hand washing on incidence of waterborne diseases.

Active practice of soap use for hand washing	Estimate	t-value	p-value	Adjusted R-squared
Regularly	-0.012	-0.96	0.350	0.22
When needed	0.011	0.87	0.394	0.22
Rarely	0.106	0.72	0.479	0.21
Not used	1.636	2.17	**0.041**	0.32

Table 6. ANOVA results on the effect of different active practices of soap use for hand washing on incidence of waterborne diseases. It is important to note that each active practice of soap use for hand washing was analysed with separate ANOVA model.

Active practice of soap use for hand washing	P-value of waterborne diseases (hepatitis A, amebic dysentery)	P-value of active practice of soap use for hand washing	P-value of the interaction between waterborne diseases and active practice of soap use for hand washing
Regularly	0.009	0.350	0.830
When needed	0.009	0.394	0.755
Rarely	0.009	0.479	0.689
Not used	0.006	0.430	**0.041**

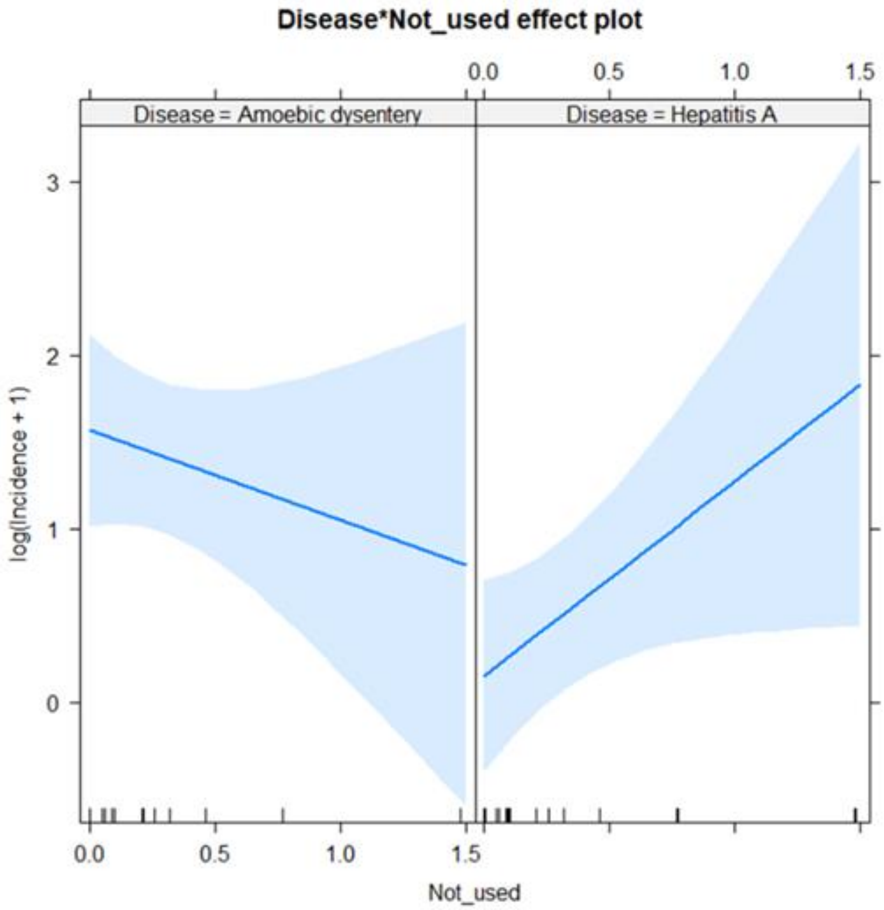

Figure 2. Effect plot at log scale for the interaction between active practice of not using soap for hand washing and waterborne diseases (hepatitis A, amebic dysentery).

In addition, the disease incidence was assessed as a function of disease type, filtered water, and the different levels of soap use. The result showed a statistically significant negative effect of the access to filtered water on incidence of waterborne diseases with p-value = 0.022, slope b = -0.036 and adjusted R-squared = 0.36. Also, there is a borderline negative effect of regular soap use for hand washing on incidence of waterborne diseases with p-value = 0.054, slope b = -0.026 and adjusted R-squared = 0.36 (Table 7, 8 and Figure 3).

Table 7. Results from the linear models analyzing the effect of active practices of soap use for hand washing and access to filtered water on incidence of waterborne diseases.

Active practice of soap use for hand washing	Active practice of soap use for hand washing			Filtered water			
	Estimate	t-value	p-value	Estimate	t-value	p-value	Adj. R^2
Regularly	-0.026	-2.04	**0.054**	-0.036	-2.46	**0.022**	0.36
When needed	0.025	1.90	0.071	-0.035	-2.38	0.027	0.35
Rarely	0.159	1.11	0.280	-0.026	-1.83	0.081	0.28
Not used	0.118	0.28	0.780	-0.022	-1.43	0.167	0.24

Table 8. ANOVA results on the effect of active practices of soap use for hand washing and access to filtered water on incidence of waterborne diseases. It is important to note that each active practice of soap use for hand washing was analysed with separate ANOVA model.

Active practice of soap use for hand washing	P-value of waterborne diseases (hepatitis A, amebic dysentery)	P-value of active practice of soap use for hand washing	P-value of filtered water
Regularly	0.005	**0.054**	**0.022**
When needed	0.005	0.070	0.027
Rarely	0.007	0.280	0.081
Not used	0.008	0.780	0.167

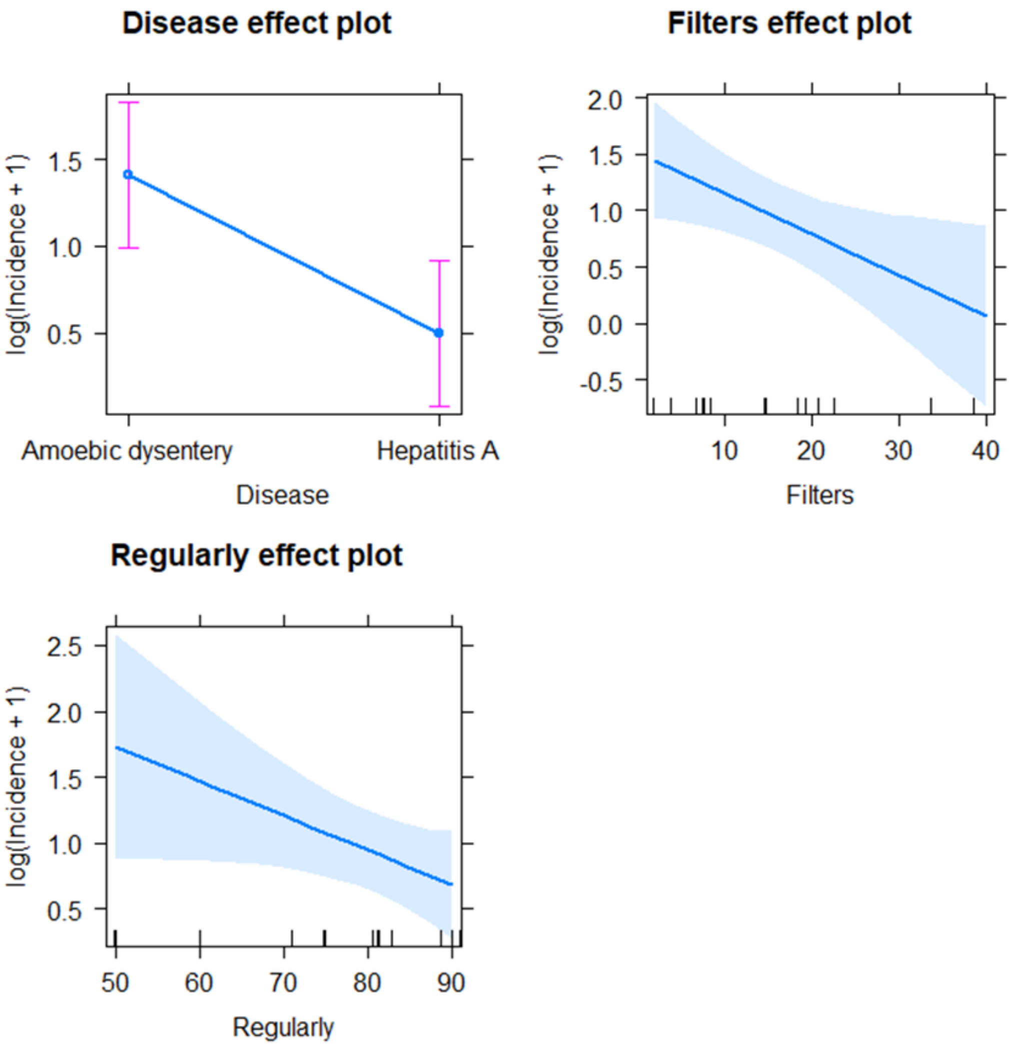

Figure 3. Effect plot at log scale for active practice of regular soap use for hand washing and access to filtered water.

Finally, the disease incidence was assessed as a function of disease type, well water, and the different levels of soap use. The result showed a borderline positive effect of the access to private well water on incidence of waterborne diseases with p-value = 0.058, slope b = 0.280 and adjusted R-squared = 0.30. However, the effect of access to private well on incidence of waterborne diseases is not strong enough to be seen with active practice of rarely soap use for hand washing in the same model (Table 9, 10 and Figure 4).

Table 9. Results from the linear models analyzing the effect of active practices of soap use for hand washing and access to private well water on incidence of waterborne diseases.

Active practice of soap use for hand washing	Active practice of soap use for hand washing			Private well water			
	Estimate	t-value	p-value	Estimate	t-value	p-value	Adj. R^2
Regularly	0.006	0.39	0.703	0.330	1.80	0.086	0.29
When needed	-0.007	-0.45	0.658	0.335	1.86	0.077	0.29
Rarely	0.093	0.67	0.512	0.280	1.10	**0.058**	0.30
Not used	-0.087	-0.20	0.846	0.210	1.87	0.076	0.29

Table 10. ANOVA results on the effect of active practices of soap use for hand washing and access to private water on incidence of waterborne diseases. It is important to note that each active practice of soap use for hand washing was analysed with separate ANOVA model.

Active practice of soap use for hand washing	P-value of waterborne diseases (hepatitis A, amebic dysentery)	P-value of active practice of soap use for hand washing	P-value of private well water
Regularly	0.007	0.703	0.086
When needed	0.007	0.658	0.077
Rarely	0.006	0.512	**0.058**
Not used	0.007	0.846	0.076

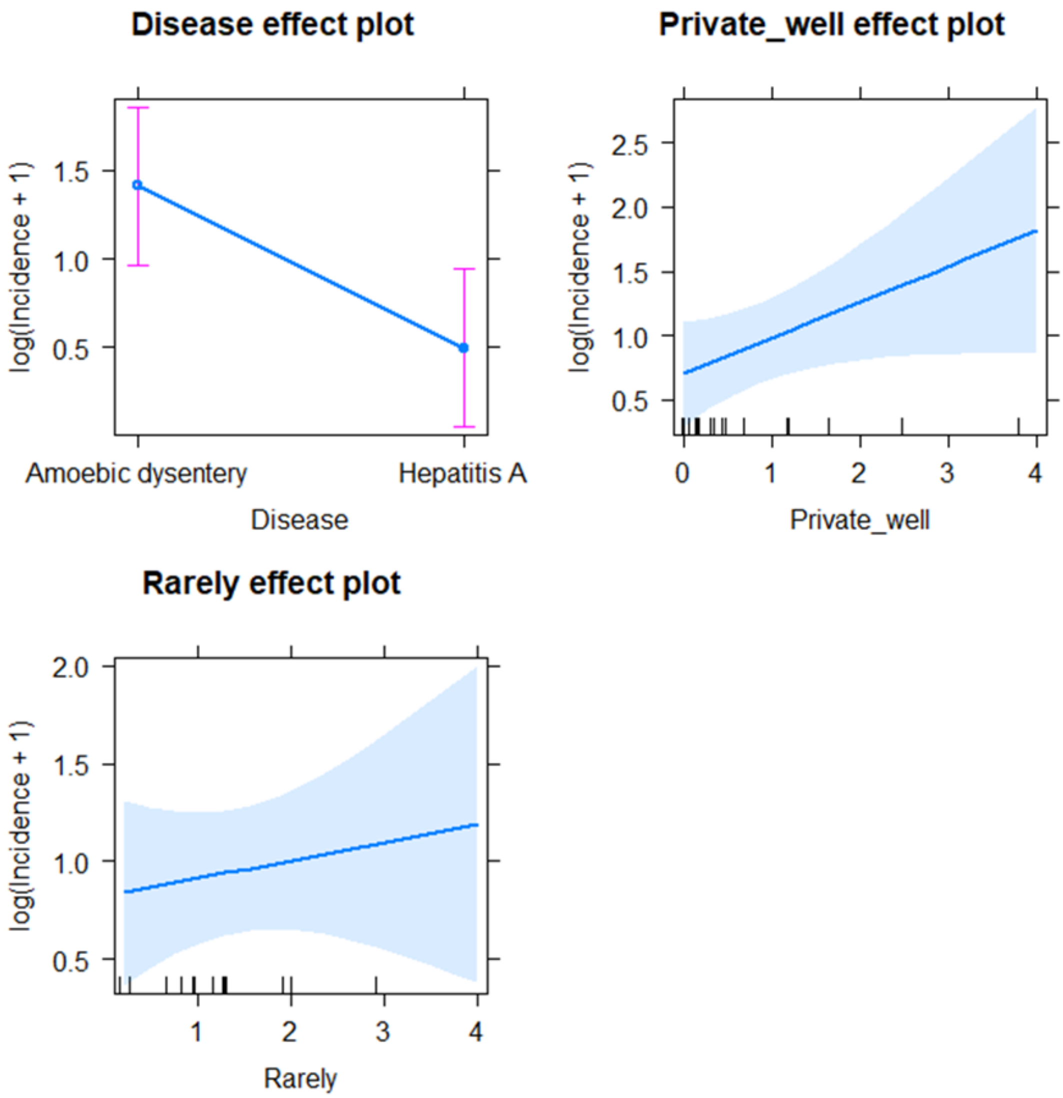

Figure 4. Effect plot at log scale for active practice of rarely soap use for hand washing and access to private well water.

Discussion

Drinking water from different water resources such as wells and tankers should be free from contamination with waterborne pathogens including bacteria, fungi, viruses and parasites to ensure proper health and wellness.(16) Worldwide, handwashing is one of the few practices that has been universally promoted by people of various religions and cultures throughout the ages. Handwashing is also influenced by the availability of soap or other agents.(27) The present study highlighted the effect of well water and not using soap for hand washing on incidence of waterborne diseases.

Drinking private well water had a borderline significant positive effect on incidence of waterborne diseases in this study. The positive effect in this situation means a higher risk for infection. This may be explained by contamination of wells water with different factors including sea water intrusion into aquifers, infiltration of wastewater into wells from the old deteriorating sewage network or septic tank and the cross-connection between domestic sewer pipes and domestic water pipes. The same result was found by Korfali and Jurdi (17) testing well water samples. They observed high mineral content and fecal coliform in well water and bottled water that originates from wells. They also found a statistically significant correlation between waterborne diseases and well water. Earlier study by Omar et al. (18) has also shown high prevalence of *E. histolytica* infection among householders who drinking well water.

According to the results of the current study there was no clear effect of sewage systems on incidence of waterborne diseases. Despite the positive trend of public sewage network and negative trend of private sewage network, the results are not statistically significant. Waterborne diseases could be associated with factors such as lack of proper sewerage, aging sewage infrastructure in the city or improper pipeline construction practices.(28) In contrast, the transmission cycle of waterborne diseases can be broken through effective collection, treatment and disposal of sewage. This finding might be related to high access to improved sanitation services which reached up to 100% according to Saudi Statistical Report of Sustainable Development Goals (SDGs). Also, Saudi Arabia started to invest in the fields of wastewater recycling and use. The percentage of treated wastewater out of total produced wastewater was 55%.(12)

The present study revealed a statistically significant interaction between not using soap for hand washing and waterborne diseases (hepatitis A, amebic dysentery). That indicates if soap is not used for hand washing there will be a significant positive effect on hepatitis A incidence i.e. positive effect means a higher risk for infection, but no significant effect on incidence of amebic dysentery. The reason might be related to intermediate endemicity of hepatitis A in Saudi Arabia and reflecting the growing numbers of susceptible people.(6) The non-existing effect on amebic dysentery may be explained by relatively high incidence in some regions and not using soap as a sole factor does not have effect on the current situation.(10) Probably with a longer perspective and high-resolution data, the linear model might be able to provide clearer effects of active practices of soap use for hand washing.

Using soap to wash hands is more efficient than using water alone because the surfactants in soap lift soil and pathogens from skin and the possibility that soap use may cause people to scrub their hands longer, which further removes germs.(29) Hand washing before preparing food is a particularly important opportunity to prevent diarrheal diseases.(21) The role of soap use for hand washing in improving health and preventing waterborne diseases has been extensively discussed in the literature.(20,21,27) Hand washing with water alone reduced the prevalence of pathogen substantially, but hand washing with soap is more effective in reducing the prevalence of contamination.(20) Similarly, the wide variety of hand cleansing means in poor settings (soil, ash, mud) are effective in reducing contamination. However, proper handwashing technique with soap as an agent is likely to be the best option.(27) Appropriate efforts should be undertaken to make soap available and affordable for all people.

The combination of filtered water effect with the effect of regular soap use in the same linear model showed that drinking filtered water had significant negative effect on waterborne diseases, whereas regular soap use for hand washing had borderline negative effect on incidence of waterborne diseases. The effect of regular soap use needs particular attention as there is a chance to make a type II error in stating that there is no effect when there is actually one. Probably there is a significant effect, but it is difficult to show the effect with few data points.

Water filters have been identified as one of the most promising and accessible technologies for treating water at the household level. This was seen in two randomized control trials which showed that water filters are an effective intervention in improving microbial water quality and reducing diarrheal diseases among a susceptible population.(22,23) Contrary to the current study and the mentioned randomized control trials, another study found that water filters can promote microbial growth and biofilm formation with lack of maintenance which lead to deterioration of the quality of tap water.(24, 30) This might explain the non-significant effect of filtered water when it was tested alone in linear model.

Further Studies

If a similar study was to be carried out in the future, high resolution data should be used to determine if the results are similar, and to increase generalizability. Additional factor such as water samples could also be added to study the water quality profile of different water sources.

Long-term and large-scale studies are needed to ensure that water filters can provide consistent, reliable, and low-cost access to safe drinking water.

Conclusion

In comparison of different drinking water sources, this study showed borderline rise in incidence of waterborne diseases with the use of private well water. Whereas different sewage systems had no clear effect on the incidence of waterborne diseases. The study also revealed that not using soap for hand washing would increase the risk for hepatitis A infection. Moreover, the study showed significant decline in waterborne diseases incidence when access to filtered water combined with regular soap use in the same linear model.

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Appendix

Table 1. Number of cases and incidence (per 100,000) of waterborne diseases in different regions in Saudi Arabia, 2019.

Administrative region	Hepatitis A		Amebic Dysentery	
	Number of cases	Incidence	Number of cases	Incidence
Riyadh	55	0.64	103	1.19
Makkah	44	0.49	800	8.86
Madinah	16	0.71	46	2.05
Qaseem	3	0.20	52	3.49
Eastern Region	53	1.03	1136	22.06
Asir	14	0.61	319	13.82
Tabuk	6	0.63	10	1.05
Hail	0	0	10	1.37
Northern Borders	0	0	4	1.04
Jazan	4	0.24	10	0.61
Najran	5	0.82	93	15.28
Al-Baha	0	0	3	0.60
Al-Jouf	52	9.78	6	1.13

Table 2. Percentage distribution of household drinking water source at the administrative region level in Saudi Arabia, 2019.

Administrative region	Public network	Filters	Tank	Private well	Bottles	Other
Riyadh	4.25	20.68	12.64	0.17	62.17	0.08
Makkah	9.56	6.63	6.63	0.68	76.38	0.12
Madinah	28.51	14.6	13.76	1.65	41.47	0.01
Qaseem	7.73	33.75	27.94	0.44	30.14	0
Eastern Region	12.42	3.82	31.39	0.06	52.3	0.02
Asir	10.17	1.76	26.8	1.18	60.09	0
Tabuk	11.36	38.61	5.47	0	44.56	0
Hail	18.65	19.16	32.54	0.47	29.18	0
Northern Borders	5.92	8.42	75.01	0.32	10.34	0
Jazan	2.58	7.36	20.11	0.14	66.94	2.86
Najran	8.84	18.41	31.46	3.78	37.51	0
Al-Baha	4.18	22.48	0.09	0.35	72.9	0
Al-Jouf	16.46	7.57	39.85	2.48	33.64	0

Table 3. Percentage distribution of household sewage systems at the administrative region level in Saudi Arabia, 2019.

Administrative region	Public network	Private network
Riyadh	80.41	19.59
Makkah	62.99	37.01
Madinah	52.34	47.66
Qaseem	62.15	37.85
Eastern Region	83.32	16.68
Asir	26.43	73.57
Tabuk	59.36	40.64
Hail	52.63	47.37
Northern Borders	49.32	50.68
Jazan	2.84	97.16
Najran	17.28	82.72
Al-Baha	0	100
Al-Jouf	42.64	57.36

Table 4. Percentage distribution of household active practices of soap use for hand washing at the administrative region level in Saudi Arabia, 2019.

Administrative region	Regularly	Rarely	When needed	Not used
Riyadh	71.04	0.94	27.92	0.09
Makkah	90.76	0.65	8.48	0.1
Madinah	81.27	1.99	16.69	0.05
Qaseem	60.05	0.96	38.88	0.1
Eastern Region	92.79	1.26	5.85	0.1
Asir	80.99	2.9	15.9	0.21
Tabuk	80.44	4.28	15.28	0
Hail	82.69	0.16	16.83	0.32
Northern Borders	88.52	0.82	10.6	0.06
Jazan	92.29	1.29	5.65	0.77
Najran	49.97	1.15	48.41	0.46
Al-Baha	89.99	0.26	9.49	0.26
Al-Jouf	74.78	1.9	21.84	1.48