Understanding *Helicobacter pylori* Infection Prevalence and Associated Factors in slum and swampy areas of Narayanganj, Bangladesh: Findings from Medical Camps

By

Ismath Jarin
15226013
Tawsif Ahmed
15226003
Jamila Jannatun Nahar
15126024

A thesis submitted to the Department of Mathematics And Natural Science in partial fulfillment of the requirements for the degree of
B.Sc. in Microbiology

Department of Mathematics and Natural Science
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Declaration

It is hereby declared that

1. The thesis submitted is my/our own original work while completing a degree at BRAC University.
2. The thesis does not contain material previously published or written by a third party, except where this is appropriately cited through full and accurate referencing.
3. The thesis does not contain material which has been accepted, or submitted, for any other degree or diploma at a university or other institution.
4. We have acknowledged all main sources of help.

Student's Full Name and Signature:

Ismath Jarin
15226013

Tawsif Ahmed
15226003

Jamila Jannatun Nahar
15126024

Approval

The thesis/project titled "Understanding *Helicobacter pylori* Infection Prevalence and Associated Factors in slum and swampy areas of Narayanganj, Bangladesh: Findings from Medical Camps" submitted by

1. Ismath Jarin (15226013)
2. Tawsif Ahmed (15226003)
3. Jamila Jannatun Nahar (15126024)

As of Spring, 2024 has been accepted as satisfactory in partial fulfillment of the requirement for the degree of B.Sc. in Microbiology on 23 May, 2024..

Examining Committee:

Supervisor:
(Member)

Fahim Kabir Monjurul Haque, PhD
Associate Professor
Department of Mathematics And Natural Sciences
BRAC University

Program Coordinator:
(Member)

Nadia Sultana, PhD
Associate Professor
Department of Mathematics And Natural Sciences
BRAC University

Department Head:
(Dean)

A F M Yusuf Haider, PhD
Dean
Department of Mathematics And Natural Sciences
BRAC University

Ethical Considerations:

The study strictly maintained the principles and guidelines of the Helsinki declarations. Ethical clearance was obtained from the departmental review board of BRAC University, Dhaka, Bangladesh. Informed consent was obtained from the respondents before data collection. During data collection, the privacy of the respondents and confidentiality of the data were maintained strictly. Participation in the survey was completely voluntary, and the collected data was anonymously used only for this current study.

Abstract

Helicobacter pylori (H. pylori) infection is a significant global health concern, implicated in the pathogenesis of peptic ulcer disease and gastric cancer. To assess the prevalence and potential determinants of *H. pylori* infection in Narayanganj, Bangladesh, we conducted four medical camps in the Hrisipara slum areas of Nitaiganj and swampy areas of Haziganj. A total of 40.5% of the tested population were found to be positive for *H. pylori,* with a slightly higher prevalence observed among men (41.5%) compared to women (39.6%). Our findings suggested that poor socioeconomic conditions, characterized by inadequate access to clean water sources, proximity to sewage lines and drainage systems, and frequent consumption of food from roadside vendors might contribute to the high prevalence of *H. pylori* among these people. These environmental and behavioral factors likely contribute to the high prevalence of *H. pylori* infection observed in the study population. These results underscore the urgent need for targeted interventions aimed at improving water sanitation, promoting hygienic food practices, and addressing socioeconomic disparities to effectively combat *H. pylori* infection in Narayanganj, Bangladesh.

Key Words: *Helicobacter pylori,* prevalence, peptic ulcer, gastric cancer, medical camp, swampy and slum area, poor hygienic practice, untreated water, socioeconomic disparities, rapid kit test.

Dedication

Our research project is dedicated to our parents, some of whom we have lost during this course of research period.

Acknowledgement

Firstly, all praise to the Almighty Allah for whom our thesis has been completed without any major interruption.

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Last but not the least, we are eternally grateful to our parents and family members without whose support it may not be possible. With their kind support and prayer we are now on the verge of our graduation.

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List of Acronyms:

1. PPI: Proton Pump Inhibitor
2. WHO: World Health Organization
3. WASA: Water Supply and Sewerage Authority
4. PCR: Polymeric Chain Reaction
5. CNG: Compressed Natural Gas
6. NGO: Non-Governmental Organization
7. RT-PCR: Real-time Polymeric Chain Reaction
8. ELISA: Enzyme-Linked Immunosorbent Assay
9. Ab: Antibody
10. Ag: Antigen
11. IgG: Immunoglobulin G
12. IgA: Immunoglobulin A
13. IgM: Immunoglobulin M
14. ICT: Immunochromatographic Assay
15. ISO: International Organization for Standardization
16. IARC: The International Agency for Research on Cancer

Chapter 1

Introduction

1.1 *Helicobacter pylori*:

Helicobacter pylori (previously known as *Campylobacter pylori*) is a gram-negative, microaerophilic bacterium which is the primary cause of peptic ulcer and an infectious substance that develops gastric cancer (Duck et al., 2004; Parikh & Ahlawat, 2024) . Infections with *Helicobacter pylori* are mostly found in densely populated areas with limited access to clean water (van Duynhoven & de Jonge, 2001; Zamani et al., 2017). Several studies show that this bacterium can be transmitted from person to person through direct contact with saliva, vomit, or fecal matter, as well as through contaminated food and water (Parikh & Ahlawat, 2024) .

1.2 Worldwide prevalence:

Several studies show that the gram negative, spiral shaped bacterium *H. pylori* affect 50% of the population around the world (Parikh & Ahlawat, 2024; Rahman et al., 2021) and the prevalence ratio is comparatively higher in developing countries which is 80%-90% and lower in the developed countries, around 30%-40% (Duck et al., 2004) . Some other studies were previously done in Bangladesh where in one study it was found that around 67% of the population under study was positive for *H. pylori* infection in Chittagong (Habib et al., 2016), another study shows that anti-*H. pylori* antibodies were found in 54.5% of study subjects in Charcharia of Dhaka district and Kharrah of Munshiganj district (Rahman et al., 2021) .

1.3 Diseases caused by *H. pylori*:

Symptoms of a *Helicobacter pylori* infection typically include burning abdominal pain, nausea, vomiting, loss of appetite, sudden weight loss, bloating and dyspepsia (Parikh & Ahlawat, 2024) . However, it is worth nothing that many individuals may be infected without exhibiting any signs or symptoms. Individuals often seek medical attention when they experience severe abdominal pain, difficulty swallowing, or the presence of bloody or black vomit and stools. Many people remain asymptomatic for extended periods, and the infection is often acquired during childhood (Jones et al., 2017; Jones & Sherman, 1998).

In underdeveloped countries, there is often a lack of awareness about *Helicobacter pylori* infection and its associated symptoms. As a result, many individuals do not receive proper treatment for prolonged periods. During this time, *Helicobacter pylori* can colonize the human body for an extended duration, leading to damage to the gastric mucosa and the development of various gastrointestinal diseases, including chronic or atrophic gastritis, peptic ulcer, gastric lymphoma, and gastric carcinoma (Iannone et al., 2018) . The International Agency for Research on Cancer has recognized *H. pylori* as a Class 1 carcinogen ("Schistosomes, Liver Flukes and Helicobacter Pylori.," 1994) . This bacterium is also responsible for causing several malignancies and non-malignant conditions including non-ulcer dyspepsia, recurrent peptic ulcer bleeding, unexplained iron deficiency anemia, idiopathic thrombocytopenia purpura, and colorectal adenomas (Best et al., 2018) . This poses a significant threat to public health, particularly in countries like ours. Researchers have said that the eradication of *Helicobacter pylori* infection can reduce the occurrence of gastric cancer (Takenaka et al., 2007) . Globally gastric cancer is the second most common cause for cancer-related deaths (Yeh et al., 2009)

and around 89% of all gastric cancer is caused by *H. pylori* infection (Khoder et al., 2019) .

1.4 Transmission route:

The transmission of *H. pylori* is closely associated with socioeconomic status, contaminated water and personal hygiene, with routes including fecal-oral, gastric-oral, oral-oral and sexual routes transmission (Parikh & Ahlawat, 2024; Queralt et al., 2005; van Duynhoven & de Jonge, 2001; Zamani et al., 2017)

1.5 Importance of diagnosis:

According to the International Agency for Research Cancer (IARC), *H. pylori* is a Class I carcinogen and it is the most potent known risk factor for gastric malignancies worldwide, accounting for approximately 89% of all gastric cancers (Khoder et al., 2019; "Schistosomes, Liver Flukes and Helicobacter Pylori.," 1994). American cancer society also include *H. pylori* among the "Group 1: Carcinogenic to humans" (Known and Probable Human Carcinogens, n.d.). Additionally, *H. pylori* can cause extra-digestive diseases such as iron-deficiency anemia. Therefore, controlling *H. pylori* infection is crucial in reducing the risk of gastric ulcers and peptic cancer. It is necessary to have up-to-date information to implement strategies for eradicating *H. pylori* in populations where its prevalence is high.

1.6 Types of *H. pylori* diagnosis:

The diagnosis of *H. pylori* infection can be performed through both invasive and non-invasive methods. Invasive methods include endoscopy and biopsy, while non-invasive methods include serological tests, stool antigen tests, and urea breath tests (Vaira et al., 2001) . However, invasive tests have a disadvantage as they require endoscopic examinations, making them more challenging to perform.

1.7 Objective

The objective of this survey based descriptive cross-sectional study is to help understand prognosis of *Helicobacter pylori.* This study will mainly concentrate on the prevalence of *Helicobacter pylori* in the swampy slum areas where the access of clean water is limited. It is anticipated that the proposed study will provide the information required for the raise of awareness about being caution against *H. pylori* infections. Additionally, it will provide a revelation of the prevalence of *H. pylori* infection among the residents of swampy slum areas in Narayanganj, Dhaka, Bangladesh to ensure better response against this bacterium.

Chapter 2

Materials and methods:

2.1 Study design and site:

A cross-sectional study was conducted from May to December 2019 to analyze the prevalence of *Helicobacter pylori* in the blood sample of a target population living in swampy slum areas of Narayanganj, Bangladesh, where the water source is compromised. In between the period four campaigns were held in two sites, two on 3rd and 5th October 2019 at Nitaiganj, focusing Hrishipara slum area and another two on 9th and 13th November 2019 at Haziganj Rail Line Bazar, a swampy and waterlogged place in Narayanganj.

Figure 1: Medical camp team

2.1.1 Environment at Hrishipara slum area:

Hrishipara slum is situated at Nitaiganj area in Narayanganj. This was originally a playground known as “Hrishipara Math” which was later occupied by poor people. Math (মাঠ) is Bengali for Field. This information was important to mention because this makes it understandable that this area was not a planned residential community. For this reason, there were a lot of problems regarding basic rights establishment i.e. healthcare, sanitation facility, water supply facilities, government provided fossil fuel facilities etc. Like most other slum areas this establishment was congested, unhygienic and overpopulated. Most of the people used deep tube wells and shallow tube well facilities to get water but most of them were built near latrines, sewage facilities or garbage drainage systems. Apart from some houses, most of them did not have government distributed gas lines. The open drainage system went across the whole facility and was clogged and full of waste.

Figure 2: Dirt and garbage pile at Hrishipara Slum

Figure 3: Bathhouse near drainage system

Figure 4: Tube well beside open toilet

2.1.2 Environment at Haziganj Rail Line Bazar:

Haziganj is a residential area in Narayanganj. An abandoned rail-line had gone across this community. Due to the presence of this abandoned rail line the proper water regulation and circulation system was not established. During the monsoon period many of Haziganj's areas went under water. This makes a lot of areas swampy. Many of the residents use this swamp to dispose of their daily waste which also has worsened the situation.

Figure 5: Arial view of the Swampy area and garbage pile of Haziganj Railway Area

2.2 Study population:

2.2.1. Number of Study Participants and Campaign

A total of 294 study participants' blood samples were collected from the four campaigns. Among these people we got cases from different backgrounds.

2.2.2 Socio-economic status of the study population:

Among the two studied areas the study participants were from different aspects of life and generally lived under the poverty line. But there were also some interested study participants who were from well-established backgrounds. In a comparison among the two areas, study participants from Haziganj were more affluent than the Hrishipara slum dwellers. But both of their environmental aspects were similar, and the two mentioned areas faced harsh environmental challenges.

Among the studied population, there were day laborers, housewives, students, street vendor owners, street performers, teachers, rickshaw pullers, CNG auto-rickshaw drivers, NGO workers etc. This proves that the analysis had a diverse study population.

2.3 Sample collection:

A total of 294 study participants' blood samples were collected from the four campaigns. The blood samples were collected by following the Finger-Stick method. The process involves to put on powder-free gloves, turn study participant's hand upward, massage the participant's hang and lower part of the finger to increase the blood flow, scrub the study participant's middle finger or ring finger with an alcohol swab and let it dry, hold the finger in an upward position and lance the palm-side surface of the finger with proper-size lancet (adult/child), press firmly on the finger when making the puncture, doing so will help to obtain the amount of blood needed, take one to two drops of blood into the specimen loading area of the test kit. Apply a sterile adhesive bandage over the puncture site. Then the blood sample was diluted by adding diluent and kept for an initial 15 minutes for the result to be seen.

Within these 15 minutes the study participant was asked a few questions. A questionnaire was structured to gather information from the people on whom the survey was done about sociodemographic characteristics and gastrointestinal symptoms. The questionnaire includes hygiene system, health inquiries, general history, age, medical history, food habit, physical checkup (height, weight, and blood pressure), source of drinking water, water purification method (if applied), drug taking history, medi-clinical history etc.

2.4 Test Kit:

For the diagnosis "Aria *H. Pylori* Ab Combo Rapid Test" kit was used. The Aria *H. Pylori* Ab Combo Rapid Test is a sandwich lateral flow immunochromatographic assay (ICT) which is used for the qualitative detection of antibodies (IgG, IgM and IgA) against *Helicobacter pylori*. Serum, plasma or whole blood samples all can be used in this test kit, for our investigation we used whole blood samples.

One of the reasons behind using this rapid kit device is it does not need to avoid any medication. Again, it is non-invasive and easy to perform procedures and can produce results in 15 minutes which align with our core purpose of examining the highest number of volunteers within a short period of time.

With the test kits there are cassette devices, desiccants, sample diluent and plastic dropper for adding diluent. An instruction manual is also given inside the box. This test kit is ISO certified, CE marked, and quality assured by MedTek, a leading technology provider.

2.5 Screening of *H. pylori* IgG antibodies:

The color development on the internal device of the rapid test kit indicates the result. IgG, IgM and IgA antibodies specific to *Helicobacter pylori* can be detected by the *H. pylori* Ab Combo Rapid Test device through visual interpretation of color development in the test region (T) and the control region (C). On the control region (C) of the device both *H. pylori* antigens and antibodies against *H. pylori* antigens are precoated which are conjugated with some pigmented particles. When the blood sample along with the diluent reaches the control region it develops a color band which indicates that the device is in good condition. After that due to capillary action

the sample travels through the membrane to the test region (T) where *H. pylori* antigens are kept fixed. These antigens in test region (T) are also conjugated with some colored particles. During the process, when the blood sample reacts with the *H. pylori* antigens fixed with the test region and develops a colored band it indicates a positive result. That means antibodies against *H. pylori* are present in the blood sample that is being tested. If the test region does not produce any color band it indicates that the blood sample absents *H. pylori* antibodies, or the result is negative.

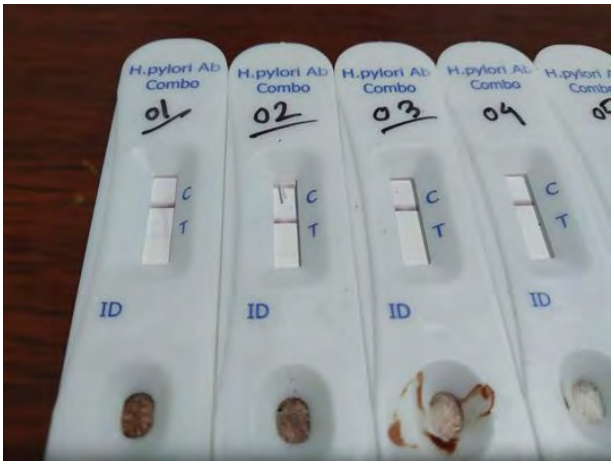

Figure 6: Test kits while performing Rapid test

2.6 Data analysis:

For our data analysis, we utilized IBM SPSS Statistics 20. We conducted a descriptive analysis to investigate a variety of factors that are related to Helicobacter pylori infection.

Chapter 3

Result:

Table 1: Distribution of Sex			
		Frequency	Percent
Valid	F	164	55.8
	M	130	44.2
	Total	294	100.0

A total of 294 Volunteers attended the medical camp. Among the respondents 55.8% (n= 164) were female and 44.2% (n=130) were male (figure 7) (Table 1). The minimum age of volunteers is 4 years old, whereas the maximum was 72 years old.

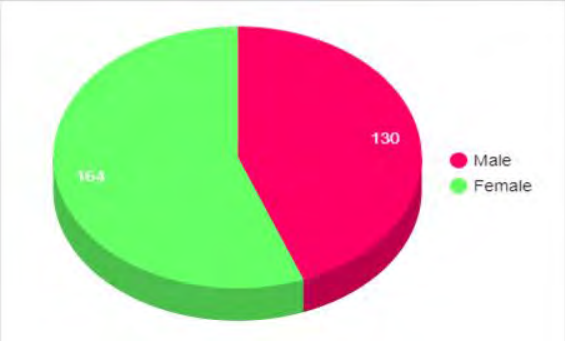

Figure 7: Pie Chart distribution of sex among the participants

Participants had a mean age of 31.70 years. Their age ranges from 4 years to 72 years. The median and mode of their age is respectively 29.50 and 35 (Table 2)

Table 2: Distribution of sex among the volunteers		
Total number of participants	Valid	294
	Missing	0
Mean		31.70
Median		29.50
Mode		35

Among the respondents, *H. pylori* IgG antibody was detected in 119 persons which is 40.5% of the total test population. The rest of the population 175 individuals (59.5%) are screened as *H. pylori* antibody test negative (Table 3).

Table 3: Result of Rapid test

		Frequency	Percent
Valid	N	175	59.5
	P	119	40.5
	Total	294	100.0

An analysis was conducted to find out the distribution of negative and positive test result according to the participant's sex. 60.4% (n=99) of total females are test negative and 39.6% (n=65) of females are found test positive. 58.5% (n=76) male were screened test negative where 41.5% (n=54) were test positive. (Table 4) (Figure 8)

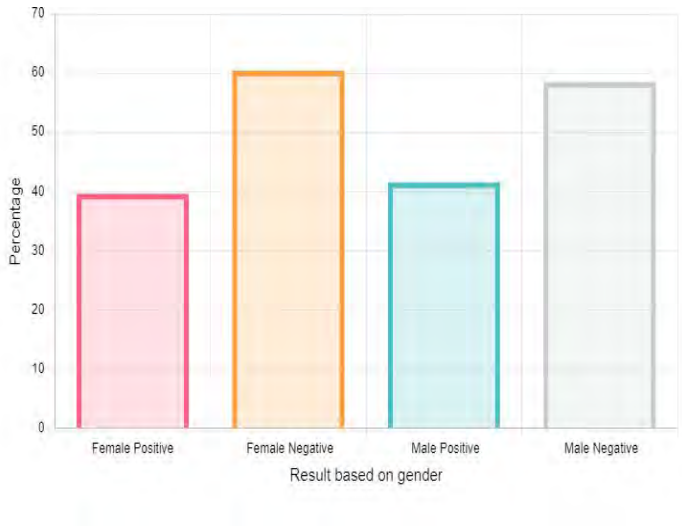

Figure 8: Bar diagram of Result Vs Gender distribution

Table 4: Cross tabulation between Result and Sex

			Sex		Total
			F	M	
Result	N	Count	99	76	175
		% within Sex	60.4%	58.5%	59.5%
	P	Count	65	54	119
		% within Sex	39.6%	41.5%	40.5%
Total		Count	164	130	294
		% within Sex	100.0%	100.0%	100.0%

From the survey, it was observed that the volunteering population used various sources for drinking water. They drink water from various sources like deep tube wells or groundwater, filter bottles, tube-wells and water supply from WASA. Their numbers are respectively 17, 1, 169 and 107. (Figure 9)

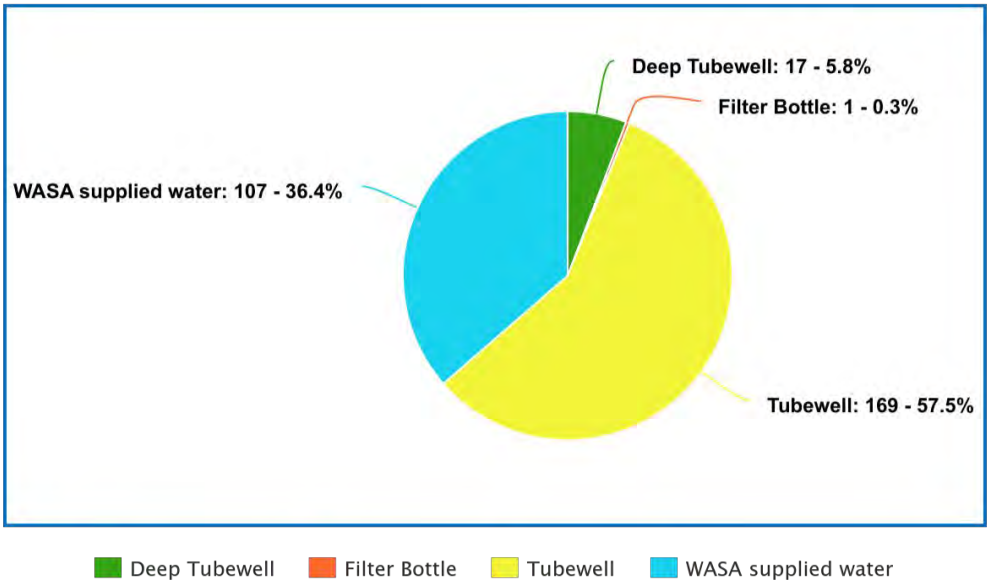

Figure 9: Sources of Drinking water

17 people used ground water as their source of drinking water. Among them, 64.7% of people (n=11) were found test positive and 35.3% people (n=6) were tested negative. People using tube-well water as their drinking water were 169 in number. Among them 42.6%people (n=72) carried *H. pylori* IgG antibody. 107 people used water from WASA for drinking purposes and 32.7% (n=35) of them carried H. pylori IgG antibody (Table 5).

Table 5: Cross tabulation between Result and Source of drinking water

			Source of Drinking water				
			DEEP TUBEWELL	FILTER BOTTLE	TUBEWELL	WASA	Total
Result	N	Count	6	0	97	72	175
		% within Source of Drinking water	35.3%	0.0%	57.4%	67.3%	59.5%
	P	Count	11	1	72	35	119
		% within Source of Drinking water	64.7%	100.0%	42.6%	32.7%	40.5%
Total		Count	17	1	169	107	294
		% within Source of Drinking water	100.0%	100.0%	100.0%	100.0%	100.0%

Among 294 people, 158 people do not purify their drinking water. 42.5% of them (n=68) test positive and 57.5% (n=92) of them test negative. The rest of the 134 people purify their drinking water by using various purification methods. 38.1% (n=51) of these people were still detected with *H. pylori* IgG antibody test positive. Surprisingly 160 individuals among the total participants (n=294) do not purify their drinking water. Among the test positive volunteers (n=119), 57.4% (n=68) do not purify their drinking water which is more than half of the total test positive count. (Table 6)

Table 6: Cross tabulation between Result and Purification of drinking water

			Purification of drinking water		Total
			NO	YES	
Result	N	Count	89	86	175
		% within Result	50.9%	49.1%	100.0%
		% within Purification of drinking water	56.3%	63.2%	59.5%
		% of Total	30.3%	29.3%	59.5%
	P	Count	69	50	119
		% within Result	58.0%	42.0%	100.0%
		% within Purification of drinking water	43.7%	36.8%	40.5%
		% of Total	23.5%	17.0%	40.5%
Total		Count	158	136	294
		% within Result	53.7%	46.3%	100.0%
		% within Purification of drinking water	100.0%	100.0%	100.0%
		% of Total	53.7%	46.3%	100.0%

Among those 134 individuals who purify their drinking water, the majority of them (87 individuals) use boiling as their purification method. Among these 87 individuals 33.3% (n=29) were having *H. pylori* IgG antibody and 66.7% (n=58) were test negative. 50 people among those 134 individuals used filtration as a purification method, 44.0% (n=22) of filtered water users were found test positive and 56.0% (n=28) were test negative. There were 2 persons who used both boiling and then filtration for water purification, among them one was test positive and the other one was test negative. One person used halogenation as a water purification method and he was not detected with any *H. pylori* IgG antibody in blood samples.

Table 7: Cross tabulation between Result and Purification system

			Purification System					Total
			BOIL	BOIL+FILTER	FILTER	HALOGEN	NO	
Result	N	Count	56	1	28	1	89	175
		% within Result	32.0%	0.6%	16.0%	0.6%	50.9%	100.0%
		% within Purification Syster	67.5%	50.0%	56.0%	100.0%	56.3%	59.5%
		% of Total	19.0%	0.3%	9.5%	0.3%	30.3%	59.5%
	P	Count	27	1	22	0	69	119
		% within Result	22.7%	0.8%	18.5%	0.0%	58.0%	100.0%
		% within Purification System	32.5%	50.0%	44.0%	0.0%	43.7%	40.5%
		% of Total	9.2%	0.3%	7.5%	0.0%	23.5%	40.5%
Total		Count	83	2	50	1	158	294
		% within Result	28.2%	0.7%	17.0%	0.3%	53.7%	100.0%
		% within Purification System	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
		% of Total	28.2%	0.7%	17.0%	0.3%	53.7%	100.0%

Among 294 participants 284 individuals washed their hands before eating. 41.2% (n=117) of them were test positive and 58.8% (n=167) were test negative. Only 10 people of the total population (n=294) do not wash their hands before eating and 2 of them tested positive (20%) (Table-8)

Table 8: Cross tabulation between Result and Habit of Washing hands

			Habit of hand washing		Total
			NO	YES	
Result	N	Count	8	167	175
		% within Habit of hand washing	80.0%	58.8%	59.5%
	P	Count	2	117	119
		% within Habit of hand washing	20.0%	41.2%	40.5%
Total		Count	10	284	294
		% within Habit of hand washing	100.0%	100.0%	100.0%

Among the volunteers, 76.5% (n=91) of the total 119 *H. pylori* IgG antibody positive people have the habit of eating outside and 23.5% (n=28) of them do not eat from outside sources. Among the test negative people (n=175), 26.3% (n=46) do not eat from outside sources and 73.7% (n=129) have the habit of eating from outside. (Table 9)

Table 9: Cross tabulation between Result and Habit of eating outside

			Habit of eating outside		
			NO	YES	Total
Result	N	Count	46	129	175
		% within Habit of eating outside	62.2%	58.6%	59.5%
	P	Count	28	91	119
		% within Habit of eating outside	37.8%	41.4%	40.5%
Total		Count	74	220	294
		% within Habit of eating outside	100.0%	100.0%	100.0%

Among the participants, 114 had a habit of drinking water from outside which is not properly treated and 180 people did not drink water from an unhygienic outside source. Among the people who drank water from outside, 43.0% (n=49) of them were test positive and the percentage of test positive among people who did not drink water from outside was comparatively low 38.9% (n=70). (Table 10)

Table 10: Cross tabulation between Result and Habit of drinking water from outside

			Habit of drinking water from outside		Total
			NO	YES	
Result	N	Count	110	65	175
		% within Habit of drinking water from outside	61.1%	57.0%	59.5%
	P	Count	70	49	119
		% within Habit of drinking water from outside	38.9%	43.0%	40.5%
Total		Count	180	114	294
		% within Habit of drinking water from outside	100.0%	100.0%	100.0%

There were many people who used tube well water but ate outside from the road vendors. Among the people who drank tubewell water (n= 169), 75.7% ate outside (n= 128). But among these people who normally drank tubewell water had a considerably low percentage of drinking water from outside sources 34.9% (n=59). This percentage was quite high among the people who drank water from WASA (n= 107) supply and that is 46.7% (n=50). People who drank water from WASA supply also had a high rate of eating outside 78.5% (n = 84). People who used deep tube well as a source of water (n= 17) had a lower percentage of eating outside and drinking water from outside sources. They are respectively 41.2% (n= 7) and 29.4% (n=5). 220 people have the habit of eating outside and the rest 74 individuals take only homemade foods. A total of 134 people who purify their drinking water 84.3% (n=113) of them have the habit of eating from outside and 15.7% (n=21) do not have the habit. 160 people do not purify their drinking water and 33.1% (n=53) among them do not eat from outside source but the rest 66.9% (n=107) eat from outside source. (Table 11 and Table 12)

Table 11: Cross tabulation between Source of Drinking water and Habit of eating outside					
			Habit of eating outside		Total
			NO	YES	
Source of Drinking water	DEEP Tube well	Count	10	7	17
		% within Source of Drinking water	58.8%	41.2%	100.0%
		% within Habit of eating outside	13.5%	3.2%	5.8%
		% of Total	3.4%	2.4%	5.8%
	FILTER BOTTLE	Count	0	1	1
		% within Source of Drinking water	0.0%	100.0%	100.0%
		% within Habit of eating outside	0.0%	0.5%	0.3%
		% of Total	0.0%	0.3%	0.3%
	TUBEWELL	Count	41	128	169
		% within Source of Drinking water	24.3%	75.7%	100.0%
		% within Habit of eating outside	55.4%	58.2%	57.5%
		% of Total	13.9%	43.5%	57.5%
	WASA	Count	23	84	107
		% within Source of Drinking water	21.5%	78.5%	100.0%
		% within Habit of eating outside	31.1%	38.2%	36.4%
		% of Total	7.8%	28.6%	36.4%
Total		Count	74	220	294
		% within Source of Drinking water	25.2%	74.8%	100.0%

	% within Habit of eating outside	100.0%	100.0%	100.0%
	% of Total	25.2%	74.8%	100.0%

Table 12 : Cross tabulation between Source of Drinking water and Habit of drinking water from outside

			Habit of drinking water from outside		Total
			NO	YES	
Source of Drinking water	DEEP Tubewell	Count	12	5	17
		% within Source of Drinking water	70.6%	29.4%	100.0%
		% within Habit of drinking water from outside	6.7%	4.4%	5.8%
		% of Total	4.1%	1.7%	5.8%
	FILTER BOTTLE	Count	1	0	1
		% within Source of Drinking water	100.0%	0.0%	100.0%
		% within Habit of drinking water from outside	0.6%	0.0%	0.3%
		% of Total	0.3%	0.0%	0.3%
	TUBEWELL	Count	110	59	169
		% within Source of Drinking water	65.1%	34.9%	100.0%
		% within Habit of drinking water from outside	61.1%	51.8%	57.5%
		% of Total	37.4%	20.1%	57.5%
		Count	57	50	107

	WASA	% within Source of Drinking water	53.3%	46.7%	100.0%
		% within Habit of drinking water from outside	31.7%	43.9%	36.4%
		% of Total	19.4%	17.0%	36.4%
Total		Count	180	114	294
		% within Source of Drinking water	61.2%	38.8%	100.0%
		% within Habit of drinking water from outside	100.0%	100.0%	100.0%
		% of Total	61.2%	38.8%	100.0%

The number of people who purify their drinking water and do not have the habit of drinking water from outside is 92, which is 68.7% among the total number of people who purify drinking water (n=134). People who purify water, also have the habit of drinking water from outside were 42 in number and 31.3% among people using purification (n=134). On the other hand, the number of people who do not purify their water and alongside drink water from outside is comparatively greater which is 72 individuals and they are 45.0% among those people who do not purify drinking water (n=160) (Table 13)

Table 13: Cross tabulation between Habit of drinking water from outside and Purification of drinking water

			Purification of drinking water		Total
			NO	YES	
Habit of drinking water from outside	NO	Count	88	92	180
		% within Purification of drinking water	55.0%	68.7%	61.2%
	YES	Count	72	42	114
		% within Purification of drinking water	45.0%	31.3%	38.8%
Total		Count	160	134	294
		% within Purification of drinking water	100.0%	100.0%	100.0%

Among the participants there were14 people who did not have the facility of a sanitary toilet and were using an open toilet. Only 3 among the 14 people who did not use sanitation facilities were detected test positive (Table 14)

Table 14: Cross tabulation between Result* Use of sanitation system					
			Sanitation system		
			OPEN TOILET	SANITARY TOILET	Total
Result	N	Count	11	164	175
	P	Count	3	116	119
Total		Count	14	280	294

Among the total 294 participants, n=17 individuals had ulcers. Among the *H. pylori* IgG test positive people, the number of people diagnosed with ulcer was 3.4% which was (n=4). A total of 7.4% of the 175 test negative people had ulcer which is (n=13) (Table 15).

Table 15: Cross tabulation between Volunteer with diagnosed ulcer and Result					
			Result		
			N	P	Total
Ulcer	NO	Count	162	115	277
		% within Result	92.6%	96.6%	94.2%
	YES	Count	13	4	17
		% within Result	7.4%	3.4%	5.8%
Total		Count	175	119	294

Among the participants (n=294), 12.2% people (n=36) had ulcer in family history. From the studied participants, 10.9% (n=13) of the *H. pylori* IgG test positive people (n=119) had family members who had ulcer or previously diagnosed with ulcer. Among the IgG negative people (n=175), 13.1% participants had someone in the family diagnosed with ulcer (n=23) (Table 16).

Table 16: Cross tabulation between Number of Volunteers with family history of ulcer diagnosis and Result

			Result		Total
			N	P	
Ulcer in family history	NO	Count	152	106	258
		% within Result	86.9%	89.1%	87.8%
	YES	Count	23	13	36
		% within Result	13.1%	10.9%	12.2%
Total		Count	175	119	294

Study participants who were diagnosed with ulcer (n=17), had 52.9% cases where their family members were diagnosed with ulcer as well (n=9). Among those who were not diagnosed with ulcer (n= 277), the percentage of family members diagnosed with ulcer is considerably low, only 9.7% (n= 27) (Table 17).

Table 17: Cross tabulation between Ulcer infected volunteer and Ulcer in family history

			Ulcer in family history		
			NO	YES	Total
Ulcer	NO	Count	250	27	277
		% within Ulcer	90.3%	9.7%	100.0%
	YES	Count	8	9	17
		% within Ulcer	47.1%	52.9%	100.0%
Total		Count	258	36	294
		% within Ulcer	87.8%	12.2%	100.0%

Among the studied population(n=294), 33.7% people do not take any gastritis medication (n=99). Among the positive results (n = 119), 53.7% people intake Proton Pump Inhibitor (PPI) drugs (n = 64). Among the negative results (n = 175) the rate of PPI intake is 47.6% (n=82). (Table 18)

Table 18: Cross tabulation between Result and Gastritis drug intake

			Result		Total
			N	P	
Type of Medicine	Antacid	Count	12	4	16
		% within Result	6.9%	3.4%	5.4%
	Esomeprazole	Count	22	16	38
		% within Result	12.6%	13.4%	12.9%
	N/A	Count	67	32	99
		% within Result	38.3%	26.9%	33.7%
	Omeprazole	Count	54	40	94
		% within Result	30.9%	33.6%	32.0%
	Pantoprazole Sodium	Count	5	8	13
		% within Result	2.9%	6.7%	4.4%
	Rabeprazole Sodium	Count	1	0	1
		% within Result	0.6%	0.0%	0.3%
	Ranitidine	Count	14	19	33
		% within Result	8.0%	16.0%	11.2%
Total		Count	175	119	294

Chapter 4

Thesis discussion

A total of 294 individuals volunteered in our study among them 164 were female and 130 were male. They had a mean age of 31.70 years. From the result, there were 119 individuals who were tested positive with a percentage of 40.5%.

This result is significantly similar with some other studies which were previously done in Bangladesh. For example, in a study on 1021 subjects, 54.5% contain anti-*H. Pylori* antibodies (Rahman et al., 2021) . The prevalence of *H. pylori* was found 92% in a study on 181 subjects in Bangladesh in 1995 (Ahmad et al., 1997; Bardhan, 1997) . In another test in 2016 in Chittagong Bangladesh 67% of the population was found *H. pylori* positive (Habib et al., 2016) . Again, in another study the result was 47% with no difference between gender and age group (Aftab et al., 2018) . So, there is no significant change in result if we compare it with other studies done in the nearby time period. The reason behind this might be the prevalence scenario at different regions of Bangladesh are relatively similar. The difference found between different similar research might be related to period of testing, demographic and age distribution. In a study on global *H. pylori* prevalence over time it was found that *H. pylori* infection decreased from 58.2% in the 1980-90 period to 43.1% in the 2011-22 period (Li et al., 2023) .

The present study focuses on the prevalence of *H. pylori* contamination among the residents of a slum and swamp area in Narayanganj, Bangladesh. 40.5% (n=119) of the 294 subjects were *H.*

pylori antibody positive where the females were 39.6% of the total female population and males were 41.5% of the total male population. Among the total *H. pylori* antibody positive population (n=119) 54.6% (n=65) were female and 45.4% (n=54) were male. So, it is noticeable that the number of male and female test positive for *H. pylori* are remarkably close, these similarities ask for further studies. This discussion aims to explore the implications of these findings and contextualize them within the socio-cultural and environmental aspects of the study area.

Among several aspects, one of the most noteworthy is gender-based role division in the population. Most males in the area were engaged in professional work outside the household whereas females primarily managed domestic responsibilities. This gender division might prove vital in understanding the sources of *H. pylori* contamination. These different responsibilities might expose different sources of contamination. For example, there was a chance that males might encounter H. pylori through their professional interactions at their work environment while females could be more exposed to sources within the household.

Despite their gender-based differences in roles and exposure, the relatively close numbers of infected males and females asks for a consideration. It suggests that there can be a possibility that both genders can get contaminated by *H. pylori* from common sources. Such sources likely include shared activities such as cooking, washing, and drinking water. Moreover, sexual activities might be responsible for intrafamilial transmission of *H. pylori* (Parikh & Ahlawat, 2024) .

The possibility of contamination via a common source and shared activity elucidates findings regarding water sources and treatment. These might have potential connection to the transmission of *H. pylori* within the investigated community.

For the investigation, the primary sources of water used by the residents for drinking and cooking were inquired. The responses revealed a variety of sources. Most of them relied on tubewell water (169 individuals) and WASA's supply (107 individuals) as water source. Notably, these water sources are widely utilized, even though recent studies have shown that shallow tubewells in Bangladesh can be contaminated with fecal matter from nearby sewage systems (Dey et al., 2017; Howard et al., 2006; van Geen et al., 2011) . An on-site inspection further revealed that many of the tubewells were situated near sewage or drainage systems, reinforcing the potential contamination risk. The number of people who used alternative water sources such as deep tubewell and filter bottle water were respectively 17 and 1, which proves them very insignificant.

In this study the practice of water treatment within the community was also explored. It was illuminating to discover that a substantial portion of the residents (58%) did not treat their water by any means. This lack of water treatment was primarily attributed to the cost. Comparatively boiling can be considered the cheapest water treatment method for the volunteer population. According to some of the volunteers, dry wood was too expensive to waste on treating water. Another reason was the limited availability of government-distributed gas lines for that particular community. This finding was particularly significant because treating water is known to be crucial in reducing and eliminating microorganisms (Clasen et al., 2008; Juran & MacDonald, 2014; Psutka et al., 2011; Rana et al., 2024) . The absence of water treatment highlights a potential vulnerability to the transmission of microorganisms, such as *H. pylori.*

Given that most residents draw water from the same sources for different purposes, there was a plausible scenario in which they might be getting infected from the same contaminated water source. This has raised concerns about the quality and safety of the water sources.

To validate the suspicions about the role of water quality in *H. pylori* transmission, it is imperative to conduct rigorous testing of different water sources through Real Time PCR (McDaniels et al., 2005; Yáñez et al., 2009) . This will help confirm whether the water sources themselves are reservoirs of H. pylori or if they play a role in its transmission. Such an investigation is vital for the development of strategies to improve water quality and mitigate the risk of H. pylori infection in this community.

Most of the participants used boiling as a purification method (n=87) and after that 50 participants used filtered water, only 2 purified water by both boiling and then filtration and 1 used halogenation for water purification. Boiling seemed to be effective as among the total 175 test negative volunteers 33.1% used boiling for water purification and 16.0% used filtration method. The number of other two purification system users was too low to process the statistical count.

H. pylori contamination might not only come from home. Eating and drinking from outside might also prove responsible. Among them 220 individuals had a habit of eating from outside, among them a significant 41.4% tested positive for *H. pylori,* slightly exceeding the overall prevalence in the volunteered population. This observation might prove significant because it is considered as one of the potential sources for *H. pylori*.

When people eat or drink from roadside restaurants or sources, there is a chance that they might get contaminated. The outside drinking water is collected mostly from government water supply which has the possibility to be infected with different microorganisms (Haider et al., n.d.) . From the on-field inspection it came to light that many of the vendors collected water from

nearby ponds, cannels, rivers and poorly facilitated public toilets and used them without treatment.

Additionally, factors such as cooking methods and hygiene practices played a significant role in this context. Many of these external food vendors might not adhere to proper hygiene standards, increasing the likelihood of contamination. Therefore, it was imperative to acknowledge that these factors contribute to a complex web of potential risks associated with *H. pylori* transmission.

The study involved 294 individuals, and among them, 114 individuals reported drinking water from external sources. Notably, 43% of those who consumed water from external sources tested positive for *H. pylori*. This finding suggests a potential association between external water consumption and *H. pylori* infection.

Again, among the people who drink water from a safe source might also get infected from *H. pylori* if they have a habit of eating outside or drinking water from outside sources. To further investigate the volunteers were asked several questions. Some facts came to us which may provide light to some of the questions. Like “if so, many people are using tube wells or treating water how come they are still infected?”. Around 75.7% of people drank water from tube wells yet they ate outside. Among tube-well using population drinking water from outside sources were considerably low 34.9%. But outside food prepared with unhygienic methods and untreated water can also be responsible for *H. Pylori* infections.

Among the study population 107 people used water supplied by WASA for drinking purposes. Among them 46.7% of people drank water from outside and 78.5% ate outside foods. Among the deep tube well users these rates were quite low. The percentage of eating outside was 41.2%

and drinking outside water was 29.4%. These percentages might showcase the health consciousness of the targeted population. Ranking the ones who used deep tube well water as most health conscious to those who used supplied water to less health-conscious ones.

According to the overall scenario, among the volunteers 220 people had a habit of eating outside and 74 people did not eat outside food. Among the 134 people who purified their drinking water, 84.3% of them had a habit of eating outside. This is a significant discovery because the infected people had chances to get infected from an outside source.

An intriguing discovery was the presence of *H. pylori* in water sources that did not exhibit coliform indicators (Queralt et al., 2005; Vesga et al., 2019) , which are commonly used as an indicator of water quality. This implies that *H. pylori* can persist in water sources even when they meet certain microbial quality standards.

The well-established association between *Helicobacter pylori* infection and peptic ulcers is a fundamental premise of this study (Duck et al., 2004; Nurgalieva et al., 2002; Parikh & Ahlawat, 2024; Zamani et al., 2017) . Within the cohort, an analysis of individuals previously diagnosed with peptic ulcers revealed that 23.5% of them tested positive for *H. pylori*. This observation underscores the significance of *H. pylori* as a causative agent in the development of peptic ulcers. It is important to note that peptic ulcers can result from various etiological factors, and our findings provide support for the role of *H. pylori* in this regard.

The substantial 36.1% positive *H. pylori* infection rate among individuals with a familial history of ulcers further strengthens this correlation. However, it is imperative to recognize that *H. pylori* exposure does not uniformly lead to peptic ulcer formation, suggesting that additional factors and individual susceptibility contribute to the pathogenesis of this condition.

Another pivotal aspect of this study revolves around the utilization of Proton Pump Inhibitor (PPI) drugs, including esomeprazole, omeprazole, pantoprazole, and rabeprazole. These drugs are known to potentially yield false negative results when using whole blood samples for *H. pylori* detection (Gatta et al., 2004; Sharara, 2005; Syrjänen et al., 2016) . Our findings indicate that 49.6% of participants were taking PPI drugs as a preventive measure against acidity, raising concerns about the risk of false negative *H. pylori* test results. Patients taking PPI drugs are often diagnosed with *H. pylori* false negative test results in Blood Test, Stool Test and Urea Breath Test because PPI drugs decrease the microbial load in stomach mucosa (Syrjänen et al., 2016) . To mitigate this issue and ensure the accuracy of *H. pylori* diagnosis, it is recommended to consider alternative sample types, such as serological tests Real Time PCR and biopsy, which have been documented as more reliable for this purpose (Vaira et al., 2001) .

In conclusion, this study illuminates the possibility that *H. pylori* might spread from contaminated water sources and foods. We could provide surety if the volunteer population was larger. Alternate test methods can mitigate the plausible irregularities of the investigation. But it is evident from the study that the correlation between water and food source with *H. pylori* contamination is not far-fetched and there is definite connection between *H. pylori* and peptic ulcer.

Chapter 5
Future Work

For our future endeavor, we aim to explore in greater depth the enhancement of diagnostic methodologies, particularly the utilization of stool tests for more precise detection of H. pylori infection among the populace. By refining and optimizing this diagnostic approach, we can potentially improve detection rates and ensure more accurate diagnoses, thereby facilitating timely intervention and treatment.

Additionally, we intend to incorporate rtPCR analysis of water samples into our research endeavors. This extension could shed light on potential sources of H. pylori contamination in the environment, contributing to a more comprehensive understanding of transmission dynamics and aiding in the development of targeted prevention strategies.

Furthermore, our preliminary observations hint at a possible correlation between BMI (Body Mass Index) and H. pylori infection. This intriguing prospect warrants further investigation, as elucidating any such relationship could have significant implications for both our understanding of the pathogenesis of H. pylori-related diseases and the development of tailored therapeutic interventions.

To build upon these preliminary findings and address the complexities inherent in understanding the dynamics of H. pylori infection, a more elaborate research plan is imperative. Firstly, conducting a comprehensive assessment of water sources, including both potable and non-

potable water supplies, coupled with rigorous testing for the presence of H. pylori, will provide critical insights into potential environmental reservoirs and transmission routes.

Furthermore, expanding our investigation to encompass a wider array of food items commonly consumed within the study population, along with detailed dietary assessments, can shed light on the role of dietary habits in H. pylori transmission and infection. This could involve not only analyzing the microbiological quality of food samples but also exploring cultural and behavioral factors that may influence food hygiene practices and subsequent infection risk.

In addition to environmental and dietary factors, a more nuanced examination of socioeconomic determinants and their influence on H. pylori infection is essential. This may entail conducting socio-economic surveys, assessing housing conditions, and evaluating access to healthcare services among study participants. By integrating these multifaceted dimensions into our research framework, we can better elucidate the intricate web of factors contributing to H. pylori transmission and infection dynamics within underserved communities.

To substantiate and expand upon our initial findings, we aspire to collaborate on studies involving larger and more diverse populations spanning different age groups. By broadening the scope of our research to encompass a more extensive array of demographic variables, we can attain a deeper and more nuanced comprehension of the interplay between host factors and H. pylori infection, thereby informing more effective prevention and management strategies tailored to diverse population subsets.

Chapter 6:

Conclusion:

In conclusion, our research has provided valuable insights suggesting a potential correlation between Helicobacter pylori infection and both water and food sources. The possibility of external factors, such as the quality and source of food and water, influencing the prevalence and transmission of the infection is a compelling avenue for further investigation.

Moreover, our study population predominantly consisted of individuals from financially challenged backgrounds. This socioeconomic factor could potentially play a significant role in the susceptibility to and spread of H. pylori infection. The complex interplay between socioeconomic status, living conditions, and access to healthcare resources warrants deeper exploration to fully grasp the extent of their impact on the prevalence and outcomes of H. pylori infection within vulnerable communities.

In summary, our preliminary findings underscore the need for a comprehensive and multifaceted research approach to unravel the complexities surrounding H. pylori infection. By delving deeper into the interplay between environmental, dietary, and socioeconomic factors, we can advance our understanding of this pervasive pathogen and inform targeted interventions aimed at mitigating its impact on vulnerable populations.

References

1. Aftab, H., Yamaoka, Y., Ahmed, F., Khan, A. A., Subsomwong, P., Miftahussurur, M., Uchida, T., & Malaty, H. M. (2018). Validation of diagnostic tests and epidemiology of Helicobacter pylori infection in Bangladesh. *The Journal of Infection in Developing Countries*, *12*(05), 305–312. https://doi.org/10.3855/jidc.9841

2. Ahmad, M. M., Rahman, M., Rumi, A. K., Islam, S., Huq, F., Chowdhury, M. F., Jinnah, F., Morshed, M. G., Hassan, M. S., Khan, A. K., & Hasan, M. (1997). Prevalence of Helicobacter pylori in asymptomatic population--a pilot serological study in Bangladesh. *Journal of Epidemiology*, *7*(4), 251–254. https://doi.org/10.2188/jea.7.251

3. Bardhan, P. K. (1997). Epidemiological features of Helicobacter pylori infection in developing countries. *Clinical Infectious Diseases : An Official Publication of the Infectious Diseases Society of America*, *25*(5), 973–978. https://doi.org/10.1086/516067

4. Best, L. M., Takwoingi, Y., Siddique, S., Selladurai, A., Gandhi, A., Low, B., Yaghoobi, M., & Gurusamy, K. S. (2018). Non-invasive diagnostic tests for Helicobacter pylori infection. *The Cochrane Database of Systematic Reviews*, *3*(3), CD012080. https://doi.org/10.1002/14651858.CD012080.pub2

5. Clasen, T. F., Thao, D. H., Boisson, S., & Shipin, O. (2008). Microbiological Effectiveness and Cost of Boiling to Disinfect Drinking Water in Rural Vietnam. *Environmental Science & Technology*, *42*(12), 4255–4260.

https://doi.org/10.1021/es7024802

6. Dey, N. C., Parvez, M., Dey, D., Saha, R., Ghose, L., Barua, M. K., Islam, A., & Chowdhury, M. R. (2017). Microbial contamination of drinking water from risky tubewells situated in different hydrological regions of Bangladesh. *International Journal of Hygiene and Environmental Health*, *220*(3), 621–636. https://doi.org/10.1016/j.ijheh.2016.12.007

7. Duck, W. M., Sobel, J., Pruckler, J. M., Song, Q., Swerdlow, D., Friedman, C., Sulka, A., Swaminathan, B., Taylor, T., Hoekstra, M., Griffin, P., Smoot, D., Peek, R., Metz, D. C., Bloom, P. B., Goldschmid, S., Parsonnet, J., Triadafilopoulos, G., Perez-Perez, G. I., … Gold, B. D. (2004). Antimicrobial Resistance Incidence and Risk Factors among *Helicobacter pylori* –Infected Persons, United States. *Emerging Infectious Diseases*, *10*(6), 1088–1094. https://doi.org/10.3201/eid1006.030744

8. Gatta, L., Vakil, N., Ricci, C., Osborn, J. F., Tampieri, A., Perna, F., Miglioli, M., & Vaira, D. (2004). Effect of proton pump inhibitors and antacid therapy on 13C urea breath tests and stool test for Helicobacter pylori infection. *The American Journal of Gastroenterology*, *99*(5), 823–829. https://doi.org/10.1111/j.1572-0241.2004.30162.x

9. Habib, A. M., Alam, M. J., Rudra, B., Quader, M. A., & Al-Forkan, M. (2016). Analysis of Helicobacter pylori Prevalence in Chittagong, Bangladesh, Based on PCR and CLO Test. *Microbiology Insights*, *9*, 47–50. https://doi.org/10.4137/MBI.S39858

10. Haider, S., Mostafizur Rahman, M., Tasneem Towhid, S., & Abu Rus, A. (n.d.).

Health Risk Assessment of Municipal Supply Water from Dhaka 59.

11. Howard, G., Ahmed, M. F., Shamsuddin, A. J., Mahmud, S. G., & Deere, D. (2006). Risk assessment of arsenic mitigation options in Bangladesh. *Journal of Health, Population, and Nutrition*, *24*(3), 346–355.

12. Iannone, A., Giorgio, F., Russo, F., Riezzo, G., Girardi, B., Pricci, M., Palmer, S. C., Barone, M., Principi, M., Strippoli, G. F., Di Leo, A., & Ierardi, E. (2018). New fecal test for non-invasive Helicobacter pylori detection: A diagnostic accuracy study. *World Journal of Gastroenterology*, *24*(27), 3021–3029. https://doi.org/10.3748/wjg.v24.i27.3021

13. Jones, N. L., Koletzko, S., Goodman, K., Bontems, P., Cadranel, S., Casswall, T., Czinn, S., Gold, B. D., Guarner, J., Elitsur, Y., Homan, M., Kalach, N., Kori, M., Madrazo, A., Megraud, F., Papadopoulou, A., Rowland, M., & ESPGHAN, N. (2017). Joint ESPGHAN/NASPGHAN Guidelines for the Management of Helicobacter pylori in Children and Adolescents (Update 2016). *Journal of Pediatric Gastroenterology and Nutrition*, *64*(6), 991–1003. https://doi.org/10.1097/MPG.0000000000001594

14. Jones, N. L., & Sherman, P. M. (1998). Helicobacter pylori infection in children. *Current Opinion in Pediatrics*, *10*(1), 19–23. https://doi.org/10.1097/00008480-199802000-00005

15. Juran, L., & MacDonald, M. C. (2014). An assessment of boiling as a method of household water treatment in South India. *Journal of Water and Health*, *12*(4), 791–802. https://doi.org/10.2166/wh.2014.010

16. Khoder, G., Muhammad, J. S., Mahmoud, I., Soliman, S. S. M., & Burucoa, C. (2019). Prevalence of Helicobacter pylori and Its Associated Factors among Healthy Asymptomatic Residents in the United Arab Emirates. *Pathogens (Basel, Switzerland)*, *8*(2). https://doi.org/10.3390/pathogens8020044

17. *Known and Probable Human Carcinogens*. (n.d.). https://monographs.iarc.fr/cards_page/publications-monographs/

18. Li, Y., Choi, H., Leung, K., Jiang, F., Graham, D. Y., & Leung, W. K. (2023). Global prevalence of Helicobacter pylori infection between 1980 and 2022: a systematic review and meta-analysis. *The Lancet Gastroenterology and Hepatology*, *8*(6), 553–564. https://doi.org/10.1016/S2468-1253(23)00070-5

19. McDaniels, A. E., Wymer, L., Rankin, C., & Haugland, R. (2005). Evaluation of quantitative real time PCR for the measurement of Helicobacter pylori at low concentrations in drinking water. *Water Research*, *39*(19), 4808–4816. https://doi.org/10.1016/j.watres.2005.09.030

20. Nurgalieva, Z. Z., Malaty, H. M., Graham, D. Y., Almuchambetova, R., Machmudova, A., Kapsultanova, D., Osato, M. S., Hollinger, F. B., & Zhangabylov, A. (2002). Helicobacter pylori infection in Kazakhstan: effect of water source and household hygiene. *The American Journal of Tropical Medicine and Hygiene*, *67*(2), 201–206. https://doi.org/10.4269/ajtmh.2002.67.201

21. Parikh, N. S., & Ahlawat, R. (2024). *Helicobacter Pylori*.

22. Psutka, R., Peletz, R., Michelo, S., Kelly, P., & Clasen, T. (2011). Assessing the Microbiological Performance and Potential Cost of Boiling Drinking Water in

Urban Zambia. *Environmental Science & Technology*, *45*(14), 6095–6101. https://doi.org/10.1021/es2004045

23. Queralt, N., Bartolome, R., & Araujo, R. (2005). Detection of Helicobacter pylori DNA in human faeces and water with different levels of faecal pollution in the north-east of Spain. *Journal of Applied Microbiology*, *98*(4), 889–895. https://doi.org/10.1111/j.1365-2672.2004.02523.x

24. Rahman, M. M., Kibria, M. G., Sultana, N., Akhter, M., Begum, H., Haque, M. A., Haque, R., Sarker, S. A., Ahmed, F., & Hasan, M. (2021). Seroprevalence of Helicobacter pylori and its association with metabolic syndrome in a rural community of Bangladesh. *JGH Open : An Open Access Journal of Gastroenterology and Hepatology*, *5*(1), 64–72. https://doi.org/10.1002/jgh3.12448

25. Rana, V., Sheokand, M., Jain, K., Dhaka, S., Godara, S. K., Urmaliya, D. N., Madhav, S., Singh, K. P., & Dhaka, R. K. (2024). Effective and affordable water purification technologies for rural development. In *Water Resources Management for Rural Development* (pp. 91–106). Elsevier. https://doi.org/10.1016/B978-0-443-18778-0.00016-7

26. Schistosomes, liver flukes and Helicobacter pylori. (1994). *IARC Monographs on the Evaluation of Carcinogenic Risks to Humans*, *61*, 1–241.

27. Sharara, A. I. (2005). Rabeprazole: the role of proton pump inhibitors in Helicobacter pylori eradication. *Expert Review of Anti-Infective Therapy*, *3*(6), 863–870. https://doi.org/10.1586/14787210.3.6.863

28. Syrjänen, K., Author, C., & Kari, S. (2016). *False Positive and False Negative*

Results in Diagnosis of Helicobacter Pylori Infection Can be Avoided by A Panel of Serum Biomarkers (GastroPanel®). www.mathewsopenaccess.com

29. Takenaka, R., Okada, H., Kato, J., Makidono, C., Hori, S., Kawahara, Y., Miyoshi, M., Yumoto, E., Imagawa, A., Toyokawa, T., Sakaguchi, K., & Shiratori, Y. (2007). Helicobacter pylori eradication reduced the incidence of gastric cancer, especially of the intestinal type. *Alimentary Pharmacology & Therapeutics*, *25*(7), 805–812. https://doi.org/10.1111/j.1365-2036.2007.03268.x

30. Vaira, U., Gatta, L., Ricci, C., D'Anna, L., & Iglioli, M. M. (2001). Helicobacter pylori: diseases, tests and treatment. *Digestive and Liver Disease : Official Journal of the Italian Society of Gastroenterology and the Italian Association for the Study of the Liver*, *33*(9), 788–794. https://doi.org/10.1016/s1590-8658(01)80697-6

31. van Duynhoven, Y. T., & de Jonge, R. (2001). Transmission of Helicobacter pylori: a role for food? *Bulletin of the World Health Organization*, *79*(5), 455–460.

32. van Geen, A., Ahmed, K. M., Akita, Y., Alam, M. J., Culligan, P. J., Emch, M., Escamilla, V., Feighery, J., Ferguson, A. S., Knappett, P., Layton, A. C., Mailloux, B. J., McKay, L. D., Mey, J. L., Serre, M. L., Streatfield, P. K., Wu, J., & Yunus, M. (2011). Fecal contamination of shallow tubewells in Bangladesh inversely related to arsenic. *Environmental Science & Technology*, *45*(4), 1199–1205. https://doi.org/10.1021/es103192b

33. Vesga, F., Moreno, Y., Ferrús, M. A., Ledesma-Gaitan, L. M., Campos, C., & Trespalacios, A. A. (2019). Correlation among fecal indicator bacteria and physicochemical parameters with the presence of *Helicobacter pylori* DNA in raw

and drinking water from Bogotá, Colombia. *Helicobacter*, *24*(3). https://doi.org/10.1111/hel.12582

34. Yáñez, M. A., Barberá, V. M., Soria, E., & Catalán, V. (2009). Quantitative detection of *Helicobacter pylori* in water samples by real-time PCR amplification of the cag pathogenicity island gene, *cagE*. *Journal of Applied Microbiology*, *107*(2), 416–424. https://doi.org/10.1111/j.1365-2672.2009.04219.x

35. Yeh, J. M., Kuntz, K. M., Ezzati, M., & Goldie, S. J. (2009). Exploring the cost-effectiveness of Helicobacter pylori screening to prevent gastric cancer in China in anticipation of clinical trial results. *International Journal of Cancer*, *124*(1), 157–166. https://doi.org/10.1002/ijc.23864

36. Zamani, M., Vahedi, A., Maghdouri, Z., & Shokri-Shirvani, J. (2017). Role of food in environmental transmission of Helicobacter pylori. *Caspian Journal of Internal Medicine*, *8*(3), 146–152. https://doi.org/10.22088/cjim.8.3.146