The health impacts of groundwater salinity among household members with different wealth indexes in coastal Bangladesh

Miss Shayan Ara Amin

A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Science in Health Economics and Health
Care Management
Common Course
FACULTY OF ECONOMICS
Chulalongkorn University
Academic Year 2019

ผลกระทบจากความเค็มในน้ำบาดาลที่มีต่อสุขภาพของสมาชิกในครัวเรือน ณ ระดับความแตกต่างของดัชนีความมั่งคั่ง ในแถบชายฝั่งของประเทศบังคลาเทศ

น.ส.ชาญาน อารา อามีน

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต
สาขาวิชาเศรษฐศาสตร์สาธารณสุขและการจัดการบริการสุขภาพ
ไม่สังกัดภาควิชา/เทียบเท่า
คณะเศรษฐศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย
ปีการศึกษา 2562

Thesis Title	The health impacts of groundwater salinity among household members with different wealth indexes in coastal Bangladesh
By	Miss Shayan Ara Amin
Field of Study	Health Economics and Health Care Management
Thesis Advisor	Assistant Professor Dr TOUCHANUN KOMONPAISARN, Ph.D.

Accepted by the FACULTY OF ECONOMICS, Chulalongkorn University in Partial Fulfillment of the Requirement for the Master of Science

.... Dean of the FACULTY OF ECONOMICS

(Associate Professor SITTIDAJ PONGKIJVORASIN, Ph.D.)

THESIS COMMITTEE

.... Chairman

(Professor Dr SIRIPEN SUPAKANKUNTI, Ph.D.)

.... Thesis Advisor

(Assistant Professor Dr TOUCHANUN KOMONPAISARN, Ph.D.)

.... External Examiner

(Assistant Professor Dr Sasiwimon Warunsiri Paweenawat, Ph.D.)

ชาญาน อารา อามีน : ผลกระทบจากความเค็มในน้ำบาดาลที่มีต่อสุขภาพของสมาชิกในครัวเรือน ณ ระดับความแตกต่างของดัชนีความมั่งคั่ง ในแถบชายฝั่งของประเทศบังคลาเทศ. (The health impacts of groundwater salinity among household members with different wealth indexes in coastal Bangladesh) อ.ที่ปรึกษาหลัก : ธัชนันท์ โกมลไพศาล

ผลกระทบต่อสุขภาพในระดับปัจเจกบุคคลและระดับครัวเรือนมีความสัมพันธ์กับความมั่งคั่ง อ้างอิงจากการสำรวจเรื่องความยากจนของชาวบังคลาเทศและความเค็มของน้ำบาดาลในปี พ.ศ. 2559 การศึกษานี้ศึกษาความสัมพันธ์ระหว่างระดับความเค็มของน้ำบาดาลกับผลกระทบทางสุขภาพซึ่งเป็นอาการร่วมของโรคความดันโลหิตสูงโดยพิจารณาถึงความมั่งคั่งในระดับครัวเรือนด้วย การศึกษานี้บ่งชี้ความสัมพันธ์ระหว่างสุขภาพกับความมั่งคั่งสำหรับกลุ่มเปราะบางที่อ่อนไหวกับการเปลี่ยนแปลงของสภาพอากาศในแถบชายฝั่งตะวันตกเฉียงใต้ของบังคลาเทศอย่างชัดเจน การศึกษาในอดีตมักมุ่งศึกษาในประเด็นผลกระทบโดยตรงของความเค็มในน้ำดื่มต่อสุขภาพและความยินดีจ่ายเพื่อซื้อน้ำดื่มและการรักษาพยาบาล งานศึกษานี้ใช้การวิเคราะห์เชิงปัจจัยเพื่อจัดกลุ่มความมั่งคั่งในกลุ่มตัวอย่างและพบความเชื่อมโยงที่มีนัยสำคัญทางสถิติระหว่างอาการของโรคความดันโลหิตสูง (ใช้การวิเคราะห์สมการถดถอยปัวซอง Poisson regression, กับจำนวนอาการต่อไปนี้ อาการปวดศีรษะอย่างรุนแรง, อาการเลือดออกทางจมูก, อาการวิตกกังวลอย่างรุนแรง, อาการหายใจถี่) กับตัวแปรหุ่นแสดงระดับความมั่งคั่ง โดยพบว่าอาการของโรคความดันโลหิตสูงจะเพิ่มขึ้นในกลุ่มที่มีความมั่งคั่งน้อยลง นอกจากนี้การศึกษายังพบความสัมพันธ์ที่เป็นเชิงบวกอย่างมีนัยสำคัญทางสถิติระหว่างจำนวนอาการที่สนใจกับระดับการปนเปื้อนของน้ำเค็มที่รายงานโดยบุคคล อายุ การเป็นเพศหญิง ระดับการบริโภคน้ำและระยะทางไปยังแหล่งน้ำมีความสัมพันธ์เชิงบวกอย่างมีนัยยะสำคัญต่อจำนวนอาการ การศึกษานี้จะมีความถูกต้องมากขึ้นหากมีข้อมูลค่าความดันโลหิตที่ถูกต้องและมีการวัดระดับความเค็มหรือองค์ประกอบของน้ำในแหล่งน้ำของผู้ตอบแบบสอบถาม ยังคงมีความจำเป็นที่ต้องศึกษาให้ละเอียดยิ่งขึ้นเพื่อจะศึกษาผลกระทบของความเค็มในน้ำดื่มต่อสุขภาพของประชากรกลุ่มเปราะบางที่มีระดับความมั่งคั่งที่แตกต่างกัน

สาขาวิชา	เศรษฐศาสตร์สาธารณสุขและการจัดการบริการสุขภาพ	ลายมือชื่อนิสิต ....
ปีการศึกษา	2562	ลายมือชื่อ อ.ที่ปรึกษาหลัก ....

6185653629 : MAJOR HEALTH ECONOMICS AND HEALTH CARE MANAGEMENT
KEYWORD: health-wealth, drinking water, hypertension, salinity, health, wealth, Bangladesh, economics

Shayan Ara Amin : The health impacts of groundwater salinity among household members with different wealth indexes in coastal Bangladesh. Advisor: Asst. Prof. Dr TOUCHANUN KOMONPAISARN, Ph.D.

Individual and household level health impacts are related to their wealth, a connection that expands into impacts from drinking water quality. Using the Bangladesh Poverty and Groundwater Salinity Survey 2016, this study examines the relationship of self-reported groundwater salinity on self-reported health impacts that are common symptoms of hypertension among individuals for an association with household-level wealth quintiles. This study is unique in substantiating the health-wealth relationship for the climate-change vulnerable people of southwest coastal Bangladesh, where so far studies on the impact of drinking water salinity have focused on direct health impacts and willingness-to-pay for drinking water and healthcare. After using a factor analysis to form wealth quintiles, a statistically significant link between the summation of hypertension symptoms (the outcome variable in a Poisson regression; severe headaches, nosebleeds, severe anxiety, shortness of breath) and the bottom four quintiles was found, positively associated and progressively larger as wealth diminished. Additionally, there was a statistically significant positive association found with the health impacts on individuals and both households' self-reported salinity contamination and water tasting highly saline. Age, being female, average water consumption and distance to water sources were also significantly and positively associated with health outcomes. This study would be improved by accurate blood pressure measures and scientific testing of respondents' water sources for salinity levels and composition. Further study is necessary to look into the health impact of drinking water salinity on vulnerable populations in different wealth strata.

Field of Study:	Health Economics and Health Care Management	Student's Signature ....
Academic Year:	2019	Advisor's Signature ....

ACKNOWLEDGEMENTS

My cousins have been a bedrock of support, I do not know how I would have gotten through this without them. My friends have propped me up, encouraged me to be brave and sent snacks when I was despairing, helping me in whatever capacity they could. Dr Touchanun allowed me to continue this degree and complete, where otherwise I would not have had the opportunity. There are numerous kind souls who have been both significant and insignificant touch points throughout this journey, and I hope that I can be the same for them. This paper has been a serendipitous combination of my personal interests and I am grateful to have been able to write it.

Shayan Ara Amin

TABLE OF CONTENTS

Page

1. Introduction

1.1. Drinking water, salinity and hypertension

What does salinity mean for drinking water?

To achieve a sustainable water future, the United Nations Sustainable Development Goal 6 branches out from the Millennium Development Goal focus on drinking water and basic sanitation to “include water, wastewater and ecosystem resources”. The purported target is a sustainable water future. According to the UN’s 2030 Agenda, “water is a key factor in managing risks related to famine, disease epidemics, migration, inequalities within and between countries, political instability and natural disasters”.

As of 2017, there were 2.2 billion people worldwide who did not have safely managed drinking water services (World Health Organization: WHO, 2019). With this in mind, the goal from drinking water, specifically, is to achieve “universal and equitable access to safe drinking water for all” by the year 2030.

Freshwater makes up only 3% of water on the globe. Of this, 70% is frozen in the North and South poles. Groundwater makes up 27% of freshwater and surface water on rivers and lakes makes up less than 1% (Ayyam, Palanivel, & Chandrakasan, 2019, p. 165). In coastal areas, groundwater is the most crucial source of freshwater that can be used for multiple purposes, all key for lives and livelihoods. Coastal aquifers (that supply groundwater) are vulnerable to being totally obliterated by the ongoing increase in sea levels caused by climate change, the most obvious impact coming from the submersion of low-lying areas (Ayyam, Palanivel, & Chandrakasan, 2019, p. 167). In 2000, 189 million people were living in low-elevation coastal zones that were vulnerable to being flooded by 2100. By 2030, an estimated 268-286 million people are projected to be at risk of coastal flooding (Neumann, Vafeidis, Zimmermann, & Nicholls, 2015b), and access to drinking water will be one of their many problems.

In the World Health Organization's 2011 *Guidelines for drinking-water quality*, safe drinking water is defined as that which "does not represent any significant risk to health over a lifetime of consumption, including different sensitivities that may occur between life stages" (World Health Organization, 2011, pp. 1).

This report continues to focus on diseases derived from drinking water as a major burden on human health. The logical conclusion is actions that improve drinking-water quality provide significant benefits to health.

Climate change has brought about rising frequencies of extreme weather across the globe and rising sea levels from melting icebergs and ice are expected impacts from climate change. These changing sea levels, compounded with over-abstraction can result in the salinisation of coastal groundwater (World Health Organization & World Health Organization, 2011, pp. 94). The resulting changes in groundwater levels could alter mineral composition that could tap into aquifers at deeper levels, which are a specific health concern in that they raise salinity.

> **"**The salinity of water is defined as the sum of dissolved inorganic ions and molecules. The major components of salinity are the ions Ca, Mg, Na, Cl, SO_4 and HCO**,"** (Suarez & Lebron, 1993, p. 390).

In coastal areas, the tidal influence of the sea can make surface water resources saline, as the inward migration during high tide of seawater changes the quality of water in streams, drainage canals, aquifers and groundwater, bringing salt content above the threshold of 500mg/l required for drinking and irrigation water (Rhoades, Kandiah, & Mashali, 1992, pp. 10–13).

The World Health Organisation's recommendation for total dissolved solids (encompassing salts among other components) is less than 600mg/L, and levels of over 1000mg/L are "significantly and increasingly unpalatable" (World Health Organization, 2011, pp. 3-5).

The overall issue of climate change is receiving increasing levels of global attention, yet the impact on drinking water in coastal areas from salinity is not often discussed. The economic magnitude of the impact has not been studied and there is scant information on exactly how many people drink saline water to the detriment of their health, or the economic impact of greater drinking water salinity.

While Bangladesh can be cited as a "model country" to study these effects, the problem of salinity is not exclusive to delta regions or even coastal areas across the world (Vineis, Chan, & Khan, 2011, p. 5). Man-made freshwater lakes in the Netherlands are at risk of seawater intrusion, in the US state of California the Sacramento and San Joaquin rivers form a delta that bears geographical similarities with Bangladesh, with periods of delta inflow in the autumn and early winter resulting in peak salinities. Halfway across the globe, deforestation in Australia has seen groundwater becoming more saline, which has perpetuated further changes to ecosystems. Western Australia has the most widespread deterioration of ecosystems, creating burgeoning salinity and water quality problems (Vineis, Chan, & Khan, 2011, p. 7).

This study aims to gauge the health impact drinking water salinity causes to coastal populations of varying wealth status in Bangladesh. Similar studies have looked into the impact of soil salinity on food security (Szabo et al, 2015) , as well as the differential impact of salinity salinity levels on health costs (Das et al, 2019). These analyses have established that wealth can mitigate the impact of soil salinity among farmers (Szabo et al, 2015) and that increasing drinking water salinity raises health costs (Das et al, 2019). This study looks to take these findings a step further and show that greater wealth results in reduced health impact from drinking water salinity.

What is the health burden?

The WHO defines hypertension “or elevated blood pressure” as a serious medical condition “that significantly increases the risks of heart, brain, kidney and other diseases” (World Health Organization: WHO, 2019b). That is to say, the presence of high blood pressure as a comorbidity indicates a predilection for other chronic systemic diseases. The WHO also notes that around 1.3 billion people are estimated to have hypertension, with the 2010 Global Burden of Disease report finding high blood pressure to be the single leading risk factor for the global burden of disease as assessed by disability-adjusted life year (Bromfield & Muntner, 2013, p. 134). Hypertension is also difficult to track down and diagnose without regular monitoring of blood pressure, making most people with the condition unaware that they are at risk (World Health Organization: WHO, 2019b). Symptoms include headaches, nosebleeds, irregular heart rhythms, vision changes for milder hypertension and more severe hypertension can manifest with fatigue, nausea, vomiting, confusion, anxiety, chest pain, and muscle tremors (World Health Organization: WHO, 2019b). Development, sedentary lifestyles, ageing populations and a Westernised diet (read: more salt and fat) seem to be the main contributors towards the rising prevalence of hypertension. The increase of 594 million adults with hypertension to 1.13 billion over 1975-2015 mostly came about from low- and middle-income countries (World Health Organization: WHO, 2019b).

1.2. Objectives

General research objectives

A. Determine the extent to which wealth plays a role in health status.

B. Provide an economic perspective for the health impact groundwater salinity has on coastal residents in southwest Bangladesh.

C. Determine the factors that most influence the health impact from drinking groundwater salinity.

Hypotheses

There are two hypotheses for this research:

I. Wealth has an inverse relationship with health impacts from groundwater salinity.

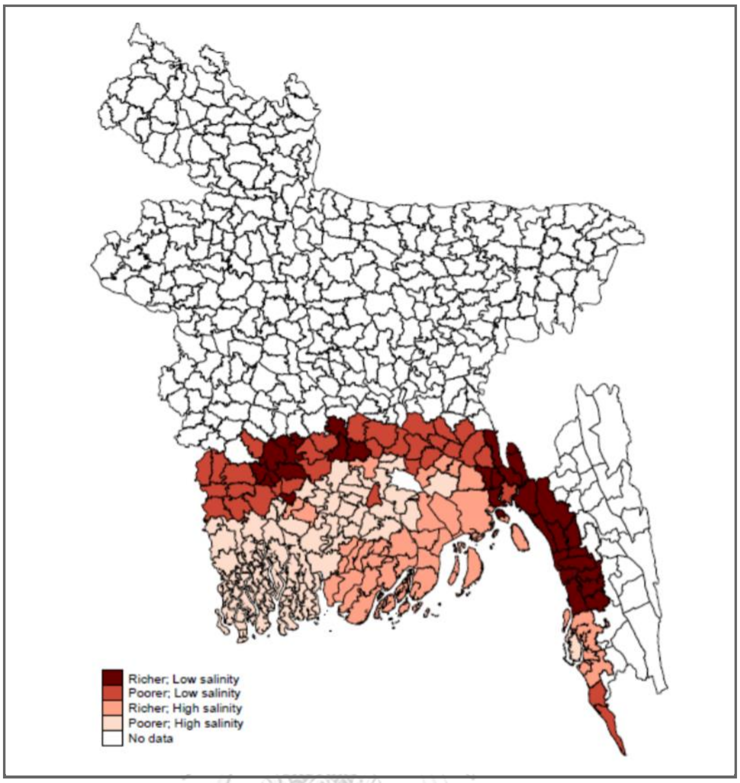
II. Higher groundwater salinity has a negative impact on health; lower salinity has lower overall symptoms and diagnosis of hypertension.

Scope of the study

The main contribution from this study is the analysis of the health impact from salinity contamination across different socioeconomic segments, represented by wealth quintiles.

This analysis of the health-wealth gradient for hypertension symptoms and diagnoses uses data from the World Bank’s Poverty and Groundwater Salinity Survey 2016. The aim of the survey is stated as twofold: to assess how much high drinking water salinity is associated with poor health outcomes and to provide better understanding about the links between poverty and groundwater salinity in coastal Bangladesh. The three subdistricts were chosen after categorising 146 coastal subdistricts according to salinity and poverty levels, after which three subdistricts were chosen based on discussions with a groundwater expert. The data gathered in this study covers 1502 households with 7047 individuals. The household characteristics and assets can be used to generate a factor analysis that can divide all households into quintiles instead of subdistricts and predetermined poverty status to create an indicator for the health-wealth gradient of the entire coastal population of Bangladesh.

Map 1: Survey categorisation for the 146 coastal subdistricts



Source: World Bank Microdata Library, 2007.

2. Background

2.1. Bangladesh’s economy, demography and geography

The overall population density of Bangladesh stands at 1,000 people per km^2 on average, with variances depending on flatland distribution. Dhaka city has the highest density, while Chittagong in the southeast has the lowest. With a total population of over 160 million, Bangladesh is one of the least urbanised countries in the region, with only a third of the population living in urban areas as of 2010 (Tinker & Husain, 2020). In the same year, 25% of the population was under 15, indicating a wide-based population pyramid.

Half the population is in the agricultural sector, growing rice, jute and tea, with the later two a significant export. However, farming leaves huge segments of the population seasonally unemployed, and thus incapable of maintaining a standard of living.

Despite these obstacles, Bangladesh has averaged 8% GDP growth since 2018. Income per capita has risen as well, helped along by falling population growth (World Economic Forum, 2019). The proportion of workers living under the poverty line fell to 10.4% in 2018 from 73.5% in 2010.

The United Nations classifies Bangladesh as a “least-developed country” expected to break out of the category by 2024, indicating that a country’s infrastructure, income per capita and resources are at a point where sustainable development is possible.

Table 1: Bangladesh's demographic, economic and development indicators

Category/Year	1990	2000	2010	2018
Demography				
Population, total (millions)	103.17	127.66	147.58	161.36
Population growth (annual %)	2.4	2	1.1	1.1
Surface area (km^2) (thousands)	148.5	148.5	148.5	147.6
Population density (people per sq. km of land area)	792.6	980.7	1,133.70	1,239.60
Poverty headcount ratio at national poverty lines (% of population)	..	48.9	31.5	24.3
Poverty headcount ratio at $1.90 a day (2011 PPP) (% of population)	44.2	34.8	19.6	14.8
Health and education				
Income share held by lowest 20%	9.6	8.6	8.9	8.6
Life expectancy at birth, total (years)	58	65	70	72
Fertility rate, total (births per woman)	4.5	3.2	2.3	2.1
Births attended by skilled health staff (% of total)	..	12	27	50
Mortality rate, under-5 (per 1,000 live births)	144	87	49	30
Prevalence of underweight, weight for age (% of children under 5)	61.5	42.3	36.8	..

Immunization, measles (% of children ages 12-23 months)	65	74	88	97
Primary completion rate, total (% of relevant age group)	47	..	68	..
School enrollment, primary (% gross)	83.8	..	106	116.5
School enrollment, secondary (% gross)	21	50	52	73
School enrollment, primary and secondary (gross), gender parity index (GPI)	1	..	1	1
Economy				
GDP (current US$) (billions)	31.6	53.37	115.28	274.02
GDP growth (annual %)	5.6	5.3	5.6	7.9
Inflation, GDP deflator (annual %)	6.5	3.4	7.1	5.6
Agriculture, forestry, and fishing, value added (% of GDP)	30	23	17	13
Industry (including construction), value added (% of GDP)	20	22	25	29
Exports of goods and services (% of GDP)	6	12	16	15
Imports of goods and services (% of GDP)	13	17	22	23
Mobile cellular subscriptions (per 100 people)	0	0.2	46	100.2
Individuals using the Internet (% of population)	0	0.1	3.7	15
Net migration (thousands)	-814	-1,493	-2,307	-1,848

Personal remittances, received (current US$) (millions)	779	1,968	10,850	15,562

Source: Times series World Development Indicators for Bangladesh, World Bank

2.2 Local government organisation in Bangladesh

Under the military governments of the 1980s and 1990s, a decentralisation effort was carried out. At the first level, this resulted in seven major divisions that have since become eight divisions: Barisal, Chittagong/Chattogram, Dhaka, Khulna, Mymensingh, Rajshahi, Rangpur and Sylhet. According to the 2011 National Census, Dhaka division had the largest population at over 47 million people living in 31,026km^2 ("Banglapedia," 2015). Barisal, Chittagong and Khulna cover the 580km coastline with the Bay of Bengal.

Map 2: Bangladesh's international borders and eight administrative divisions.

Source: Maps of World website.

Each division has 4-13 second-level administrative districts, totalling 64 for the whole country. Districts are then divided into third-level *upazilas* or 'subdistricts'. There are a total of 492 subdistricts, further divided into 4,554 union council areas, which are the lowest tier in the regional administrative system ("Banglapedia," 2015). Each union council area is made up of nine wards, and a ward is typically a village.

This study will focus on three subdistricts: Morrelganj in Bagerhat district and Shyamnagar in Satkhira district under Khulna Division, and Taltali in Barguna district under Barisal Division.

Map 3: Bangladesh's 64 administrative districts, with Satkhira, Bagerhat and Barguna districts in the southwest highlighted in purple.

Source: Aziz, 2007, Creative Commons.

Morrelganj subdistrict covers 460.9km^2 and has a population of 349,551 ("Banglapedia," 2015), of which 322,199 people are rurally located.

Shyamnagar subdistrict is located on 1,968km^2 and has 318,254 people as of the 2011 Census. Taltali subdistrict is relatively miniscule, with 88,004 people on 258.9km^2.

Morrelganj, Shyamnagar and Taltali: coastal context

Bangladesh's coastal area is poorer than the rest of the country, especially in terms of income. There is hardly any industrial development and investors stay away from the poor infrastructure and low-skilled labour. In a mixed method study covering 27 coastal subdistricts (including Morrelganj, Shyamnagar and Taltali), the majority of people are characterised as living in disadvantaged communities, and the issues of coastal development have been increasingly been addressed by the election manifestos of both the government and opposition political parties (Mamun Rashid, 2014, p. 30). The most frequently high-ranked recommendation for the government by the 400 respondents was protections for fishermen from pirates. This was followed by policy to develop environmentally-friendly industries in coastal areas.

The exposed coastal area especially depends on agriculture, mainly rice. Farmers of these areas face difficulty in availing good quality agricultural inputs, especially as prices increase. This precarious economic situation is underlined by the study's findings that 8.89% of farmers are landless, while 77.78% of farmers operate under share-cropping and one-year leasing systems (Mamun Rashid, 2014, p. 30). Saline intrusion of croplands makes fodder for farm animals scarce and dysfunctional sluice gates prevent use of low-lying lands. Furthermore, the study found that 82.22% of farmers do not use the appropriate methods to be able to work with salt-tolerant crop varieties, nor do they have the knowledge to do so. Poor transport to and within these areas, no marketing or storage makes life for farmers even worse.

Fishermen may be worse off than farmers, and are overwhelmingly dependent on loan sharks, with 78% of them caught in the vicious cycle. Pirates have victimised 71% of fishermen at least once (Mamun Rashid, 2014, p. 30). During seasons when fishing is banned, the government provides 120kg of rice to each family (for a total of four months), but only 58.82% of these families receive this (Mamun Rashid, 2014, p. 30).

The Sundarbans is the world's largest mangrove forest, and the people (including fishermen) dependent on the forest for subsistence are not only indebted to loan sharks, but are effectively held hostage by local mobs, to whom they have to pay regular tithes to. Mamun Rashid's (2014) interviewees said, predictably, that their livelihoods are sensitive to changes in climate, further exacerbated by the vulnerability of the region to natural hazards.

Remote coastal areas do not seem to be fully receiving the benefits of Bangladesh's progress towards the Millennium Development Goals, especially in the area of healthcare. Retaining doctors, as one would expect for remote areas with poor infrastructure, is a huge struggle. Mamun Rashid (2014) says the health for these coastal communities is "severely deplorable" due as poverty and malnutrition continue to persist. Hazards such as "tube-well water, pollution, unhygienic latrine, changes of climate, increasing water salinity, water-logging" are cited as persistent vulnerabilities (Mamun Rashid, 2014, p. 31). The health burden from these ecological travails are close to impossible to ameliorate in the face of poor staffing and equipment, low funding, overcrowding, consuming gender norms that disproportionately harm women and poor hygiene. There is an unregulated private health sector in these exposed coastal regions that charge exorbitant high fees that yet again play into the loan sharking cycle (Mamun Rashid, 2014, p. 31).

Poor access to education, with an almost impossible path to high education contributes to poverty, child labour, child marriage, as agricultural and fishery dependent households need to pull their children out of school periodically or permanently to help earn income. Poor staffing and funding again creates a market for private actors who charge high fees for tutoring.

In the dataset used in this study, 26.63% of respondents have had no schooling and 23.8% have had some form of primary schooling.

3. Literature review

The materials for the literature review for this topic were gathered from Chulalongkorn University's Office of Academic Resources, JSTOR, Springer Link, Elementa Science, the National Center for Biotechnology Information's search database, The Lancet, Google search and Google Scholar. Keywords used include "drinking water salinity", "groundwater salinity", "Bangladesh" and "economic impact of groundwater salinity". Reports from the World Health Organization, the World Bank and UNICEF, along with textbooks on geography and demographics have been key.

3.1. Theoretical framework: the relationship between wealth and health outcomes

According to the WASH report, people living in poverty are the most impacted by salinity intrusion of drinking water in Bangladesh. Three coastal subdistricts surveyed were found to have poorer areas less likely to have deep tube wells and tap water, the type of infrastructure that circumvents salinity. In a predictable contrast, piped water, rarely troubled by arsenic or salinity, seems to be exclusively owned by rich urban populations (World Bank, 2018, pp. 2-49).

Wealth tends to have positive associations with health outcomes. In a study on the impact of inequality in low and middle-income countries on population health, van Deurzen et al. (2014) used individual-level data from Demographic and Health Surveys spanning 2000-11. The health outcomes of anaemia in women, anaemia in children and experiences with child mortality were proxies for population health. Explanatory variables of assets and material wealth were used to form a Gini Index of household wealth for inequality and run in three binary logistic multilevel models (one for each health outcome). They found in countries where household wealth inequality is higher, there was higher correlation of anaemia and child mortality. Measles vaccinations had a negative correlation with the Gini Index of household wealth. van Deurzen et al. (2014) concluded that increasing wealth among the poor would be an effective way to improve population health in lower and middle income countries.

Similarly, in a paper that has been cited a whopping 706 times, Deaton (2002) makes a systematic review that looks into whether policy designed to address health inequalities “make sense”. After mulling what appears to be a cherry-picked selection of studies, he concludes that directly providing incomes to address poverty is a more effective policy direction than actually funding healthcare systems.

Given the general trend seen in societies of health improving as income improves, begetting the question of whether population health improves when wealth is redistributed, Deaton (2002) argues that the combination of poverty and poor health creates a more pressing need for policy solutions, but policies targeting to resolve health inequities are “inappropriate”.

This is a good point to note that Deaton does not seem to consider the differences between inequalities and inequities. In cycling through arguments for and against the causation of income on health and health on income and considering the interplay of education, all applied to abstract “rich countries” and “poor countries”, Deaton settles on the principle that individual welfare is dependent on both health and wealth. With this, he warns against policies that create a tradeoff between income and health. The second principle he chooses to apply is Pareto criterion, using the example of health technology as a key area where the rich get ahead faster because they are more educated and are faster to take up advancements.

He then goes on to argue against policies that aim to provide healthcare to the poor alone, making that point that the most effective way is to target people who need care, regardless of health status. This general principle is further underlined by stressing the need to protect the process that ensures healthcare for those who need it: "We should not deny people care because their social status is too high, any more than we should deny them care because their status is too low". This same logic is somehow applied to the focusing on diseases that are prevalent among lower income groups, which Deacon extends to apply to the inequality of men living shorter lives than women.

On a broader scale than van Deurzen et al (2014), Ray & Linden (2018) conducted a global study questioning the impact of inequality on GDP and health outcomes for 194 countries with data spanning 1990-2014. Using Kuznet's hypothesis, an instrumental variable estimation approach was applied for three models, with GDP per capita, health status (infant mortality as a proxy) and health expenditures as dependent variables. The countries were divided into three categories: GDP per capita under $1000, GDP per capita of $1000-10000 and GDP per capita of over $10,000. They found that health status (infant mortality) has a negative impact on GDP per capita. Rich countries had a greater decrease in infant mortality as GDP per capita rises. Only poor countries saw nonlinear inequality impacts on GDP per capita.

Studies on the impact of wealth or inequality on health outcomes for Bangladesh focus on childhood nutrition, a common trend among the literature on impoverished countries. Szabo et al (2015) investigate the impact to food security from soil salinity and household socioeconomic characteristics in Bangladesh's Ganges-Brahmaputra coastal delta, and found that soil salinisation has a negative impact on food security. However, this impact is negated once household wealth is accounted for.

The study selected 993 households from two secondary datasets: the 2010 Household Income and Expenditure Survey and the Soil Resource Development Institute's sub-district level soil salinity data. Households that spent more than 75% of expenditure on food were categorised as food insecure and/or if daily caloric requirements were greater than total energy intake (binary).

For the logistic regressions, household food security was an outcome variable, with household characteristics of wealth, education, gender, agricultural engagement as explanatory variables, along with soil salinity. Principal component analysis was applied to form the asset indices.

Five regression models were applied: (1) The relationship between household food security and soil salinity, (2) the inclusion of socioeconomic explanatory variables, (3) the inclusion of households' wealth status, (4) unadjusted and (5) adjusted relations between dependent and independent variables.

From these papers several key points can be applied to this research. Wealth and health have a positive association, yet the impact seems to differ among countries in accordance with levels of inequality within a country. This is especially relevant to Bangladesh, where income inequality is high. According to Table 1, in 2018 the poorest 20% of people had a 8.6% share of the country's income, a fall from 9.6% in 1990 (The World Bank, 2020). This indicates growing inequality and a higher impact of wealth on health can be inferred. Furthermore, we can expect that even with income and education, individuals will still face wealth-determined disparities in health levels/impacts. Income is not an explanatory variable in this study, but education is.

.

Summary table: the health-wealth relationship

Title	Year	Author	Research question	Data	Methodology	Findings
Policy Implications Of The Gradient Of Health And Wealth	2002	Angus Deaton	What are the reasons for increases in income having proportionate decreases in mortality in the US? Can redistributing income improve population health?	NA	Review of evidence indicating a "gradient" between health and income (health on income, income on health), healthcare access, life-saving technology, health-related behaviour, education (relation between education and income), impact of wealth redistribution on health, primarily focused on UK policy	Economic policy should be separate from health policy. Low income and education is the best way to address poverty. Healthcare delivery systems are key for ensuring population health. Where systems are weak, funding should be directed at improving poor people's incomes instead of trying to address 'health inequities'

Soil salinity, household wealth and food insecurity in tropical deltas: evidence from south-west coast of Bangladesh	2015	Sylvia Szabo, Md. Sarwar Hossain, W. Neil Adger, Zoe Matthews, Sayem Ahmed, Attila N. La´za´r, Sate Ahmad	How do soil salinity and wealth impact household food security?	2010 Household Income and Expenditure Survey + subdistrict-level soil salinity data -> 1000 PSUs, 993 households in sample. Dependent variable: household level food security. 5 logistic regression models: relationship between salinity affected area and households' food security; socioeconomic characteristics added; adjusted; unadjusted.	One-way ANOVA for mean salinity scores between secure and insecure households.PCA applied to survey response. Logistic regression outcomes interpreted by odds ratios and CI.	Positive association between salinity and food insecurity. Education and agricultural involvement are negatively associated with food insecurity. Education is a strong predictor of food security. Household size is positively associated with food insecurity. When household wealth is accounted for, salinity is no longer significant. Socioeconomic characteristics alter the nature of the association between salinity and food security.
Inequality and Health among Low and Middle Income Countries	2014	Ioana van Deurzen, Wim van Oorschot, Erik van Ingen	Does lower inequality improve health in lower and middle income countries?	Individual level, DHS, eligible women, 2000-11 + contextual data. Dependent variables: anemia status of women and of their children and the women's experience of child mortality. Independent: material resources. Three samples: anemia, child anemia, experience of child mortality.	Gini Index of household wealth for inequality, binary logistic multilevel models (once for each sample)	higher levels of household wealth inequality were positively correlated with higher prevalence of anemia and of experience of child mortality; Gini Index of Household Wealth was negatively and significantly correlated with the coverage of measles vaccination. Higher Gini Index of Household Wealth was significantly related with higher chance to be tested with anemia or to the chance of women to experience the death of a child.

Health, inequality and income: a global study using simultaneous model	2018	Devdatta Ray and Mikael Linden	How does income inequality impact health statuses and GDP?	Data set of 194 countries, 1990-2014.	Health–income simultaneous equations model for GDP per capita level, infant mortality (health status) and health expenditures per capita. Nonlinear Kuznets' GDPc effects with income inequality depending on the level of GDPc specified. Instrumental variable estimation approach because some variables are endogenously determined.	Health status measured with infant mortality has a negative effect on the level GDPc. GDPc decreases infant mortality in rich countries most effectively. Nonlinear inequality effects on GDPc found only in poor countries. Health expenditures elastic when GDPc and drs per capita summed.

3.2. Economic impact from groundwater salinity: tangible and intangible aspects

Das et al (2019) found that for the three sub districts of southwest Bangladesh studied, acute diseases came about from salinity exposure and caused workday losses at the household level. They found salinity exposure results in a health cost of $28.38 per year (1.44% of annual income), made up of $9.76 in wages lost, $12 to avert the health impact and $6.63 to mitigate the health impact.

To find the willingness-to-pay (WTP) for health costs in three southwest districts in Bangladesh, Das et al (2019) conducted a survey where they collected multiple samples of water from 270 households to account for seasonal changes and multiple water sources, and gathered information on WTP through a questionnaire of both open- and close-ended questions. With regards to salinity, questions were asked about workdays lost, actions taken to avoid saline water sources and actions taken to deal with the impact of salinity ailments.

In their model, the marginal willingness to pay (derived from utility) was a dependent variable resulting from the sum of changes in wages lost and changes in mitigating costs (together the marginal cost of illness) and the marginal avertive cost.

The dependent variables of working day loss, avertive expenditures and mitigation expenditures were composed from salinity exposure, household head characteristics and household characteristics. They found that an average of 19 working days were lost per household every year due to the health impact of salinity, average avertive expenditures of approximately $80 and $43 for average mitigation expenditures in the year the study took place. Furthermore, costs of illness were found to be positively associated with sodium chloride concentrations in water, indicating that higher salinity resulted in higher health costs. The concentration of sodium chloride was also found to have huge impact on mitigation expenditures: to the tune of 100mg/L increases showing a rise in workdays lost of 0.2 and annual avertive expenditures of $1.44 per household. The same rise in salinity has a lower impact of $0.76 in mitigation costs.

In a study conducted across four villages in Satkhira district (also in Southwest Bangladesh and chosen for having high salinity) to gauge the correlation between salinity and "livelihood strategies", Haider & Hossain (2013), found the one positive impact of rising salinity – shrimp culture activity. The regular negative impacts from salinity intrusion were found on income, expenditure and employment. Interestingly, salinity intrusion was found to be positively related to shrimp farming, independent shrimp farming, rainwater harvesting and "business as an occupation". Salinity intrusion was found to negatively related to rice cultivation, income, expenditure, river water, groundwater and "day labor as an occupation". A logit model was used to estimate employment and land use patterns, and salinity was found to reduce employment opportunity.

Data on income, expenditure, employment and land use were gathered through a survey of 150 farmers formed the "livelihood strategy" and soil samples were gathered to test farms' salinity. Four regressions were run with the "livelihood strategy variables" as dependent variables and a combination of individual demographic data (age, education, occupation), assets (income, land) and key data pertaining to salinity (salinity level, pH, distance to fresh water source) as dependent variables. This paper did not clarify why income was both a dependent and independent variable for the regression, nor was there any distinction between the incomes used for either end of the equation, or any kind of fix for endogeneity. This leads to the assumption that income was an independent variable for three regressions, but not for when income was an independent variable. Interestingly, the farmers surveyed did fall into two categories with regards to salinity: farmers in low salinity areas (over 75% of those surveyed) used groundwater and river water while farmers in high salinity areas used tube well water mostly. Farmers in low salinity areas were also a further distance (within one kilometre) from their water sources than their counterparts in high salinity areas (within 500 metres). High salinity areas were found to be used almost exclusively for shrimp cultivation, as farmers had little other option. Low salinity farmers were able to work with greater variety: rice, white fish and shrimp, among others.

Establishing that salinity exposure causes losses in employment and income is key: while this study is considering wealth in terms of assets and not income or employment, the impact of having lost income or employment can be expected to present in household assets. Secondly, in learning that farmers living in lower salinity areas have higher incomes, we can expect that surveyed residents of areas with relatively lower wealth

Summary table: economic impact from groundwater salinity

Title	Year	Author	Research question	Data	Methodology	Findings
Health cost of salinity contamination in drinking water: evidence from Bangladesh	2018	Debasish Kumar Das, Md. Sariful Islam, Sheikh Hadiujjaman, Champa Bati Dutta, Md. Manjur Morshed	What is the health cost of drinking water salinity in 3 southwest districts?	Survey of 270 household heads in districts with severe salinity, 266 kept. 38 questions: household socioeconomic details, water demand and source; sickness and health expenditure, mitigation and averting costs, workdays lost; awareness of salinity contamination. Household-specific 1L water samples gathered and tested for salinity thrice (in different seasons).	WTP approach based on revealed preference data: U = U(X, L, S). Tobit model for predicting averting and mitigating expenditure. Zero-inflated regression for dependent variable. NPV calculation for pond sand filters.	19 working days lost per household per year + 1.44% of the annual household income. Richer households spend more on AE and ME, education reduces costs. Salinity exposure induces the spreading of acute diseases that causes workday loss. Average salinity: 3.47 times higher than WHO safety standard. 86% of respondents aware of salinity. Reducing salinity to permissive level would save 71% of health costs, $2.12 million for entire study area. Pond sand filter installations would yield higher benefits than costs over 10 years.

Impact of salinity on livelihood strategies of farmers	2013	M. Z. Haider, M. Z. Hossain	How does salinity intrusion impact farmers' income, expenditure and employment? (in coastal Bangladesh).	Livelihood data on income, expenditure, employment, and land-use pattern from 150 respondents. Soil samples from respondents' plots.	Frequency distribution, correlation, t-test, and regression analysis. Dependent variables: income, expenditure, employment and land-use pattern. Independent variables: age, education, land holdings, income, expenditure, distance from freshwater source, salinity level, pH, land-use for shrimp, water source and occupation.	Yearly income and expenditure for the people in the high saline area are relatively lower than that of the low saline area. Farmers in low saline areas use land for multiple purposes. Farmers in high saline areas use land for shrimp cultivation alone. Income and expenditure for shrimp cultivators are lower. Salinity intrusion encourages shrimp culture/independent farming, constrains rice cultivation, restricts water collection, requires tubewell or rain water, reduces employment. decreases income and expenditure.

Water Quality and Willingness to Pay for Safe Drinking Water in Tala Upazila in a Coastal District of Bangladesh	2019	Nepal C. Dey, Mahmood Parvez, Ratnajit Saha, Mir Raihanul Islam, Tahera Akter, Mahfuzar Rahman, Milan Barua, Akramul Islam	What is the state of water quality in Tala subdistrict? What are people willing to pay for safe drinking water?	April-May 2015: questionnaire for 4500 households; 500 samples from 12 "severe" unions and 250 from six "less severe" unions. Level of salinity, arsenic, iron tested at drinking water sources with high dependency. Average family size, education level, economic condition based on 2011 PPP (ultra-poor 63%, 33% poor, 4% non-poor).	Logistic regression	Monthly household income, tubewell ownership, distance of drinking water source found to be determinants of willingness to pay for safe drinking water. For safe drinking water, 75% were willing to pay BDT 20.0 (0.25 USD) per week for 20L or to 2–6% of monthly income. 14% of respondents had experience with water-borne diseases in the last 15 days. Arsenic: 74% of tested drinking water sources were unsafe in the study area. 14% of deep tubewells in the study area are contaminated by high levels of arsenic, unsafe for drinking. Salinity: all sources had electric conductivity values above permissible limits in respect to Bangladesh (94%) and WHO (99%) standards.

3.3. Drinking water salinity and health

The 1997 INTERSALT study is considered a seminal contribution to establishing the relationship between electrolyte excretions (an indicator of salt consumption) and blood pressure. By monitoring over 10000 individuals aged 20-59 across the globe in what was an immense venture in quality control through highly standardised protocol, data on potassium and sodium excretions, blood pressure and blood pressure over age/time were gathered from 1984 until 1997. The key findings were a positive relationship between sodium excretion and both systolic and diastolic blood pressure and between sodium-potassium ratios and blood pressure. This bolsters evidence that higher sodium intake causes higher blood pressure and higher potassium intake acts towards mitigating the impact of higher sodium ("Intersalt: an international study of electrolyte excretion and blood pressure. Results for 24 hour urinary sodium and potassium excretion. Intersalt Cooperative Research Group.," 1988, p. 324).

Across subgroups, the key findings that are relevant to this study are as follows:

i) Sodium excretion was associated with the slope of blood pressure with age. This means that as participants aged, their blood pressure was higher.

ii) Low sodium excretion (which means there was low sodium intake) was associated with low median blood pressure. This means lower sodium consumption results in lower blood pressure, and lower hypertension prevalence.

iii) Body mass index was strongly, positively and independently associated with blood pressure. This means subsections of people who have higher body mass indexes tend to have higher blood pressure and are more likely to have hypertension.

3.3.1. The coastal health crisis in Bangladesh

Caritas Development and the Government of Bangladesh reported that coastal populations who were highly likely to be exposed to increased salinity (i.e, sodium chloride among other salts) had greater propensities of hypertension (which is essentially very high blood pressure), miscarriages among pregnant women, skin diseases, acute respiratory infection and diarrhoeal diseases (Vineis, Chan, & Khan, 2011, p. 8).

Bangladesh's dry season, November to April, sees major rivers with drastically lower discharge, water channels drying, falling water tables and salinity encroachment, particularly in the southwest region (Chowdhury, 2009, p. 40).

Das et al. (2019) found that the average salinity in three districts surveyed (Khulna, Satkhira, and Bagerhat) to be 868mg/L, over triple the World Health Organisation recommendation of 250mg/L, indicating a major public health concern. The acuteness of this problems is underlined by the fact that almost 90% of the population use some variation of tubewells, even as they are ineffective in filtering out faecal bacteria, arsenic, salinity among other adulterants (World Bank, 2018, pp. 2). Quite obviously, tubewells are not a sustainable source for water (Das et al., 2019, p. 374).

A 2016 longitudinal study published in *The Lancet* found that drinking water sodium concentrations are highly associated with blood pressures (Scheelbeek et al., 2016). At a 95% confidence level, every 100mg/L decrease in sodium concentration for drinking water, the odds of hypertension were 16% lower, with blood pressure falling 0.95/0.57 mmHg on average. The multistage sampling process was carried out in three sub districts in coastal Bangladesh (chosen for being frequently inundated by rising sea levels) and the authors suggested alternative low-sodium drinking sources could prevent hypertension-related morbidity and mortality for the large number of people living in these coastal areas. Participants consumed water mostly from saline drinking sources such as ponds and tubewells, the baseline salinities of which were recorded. Baseline blood pressures were also recorded and a questionnaire was carried out for "personal, lifestyle, and environmental characteristics". Water salinity samples, blood pressure measures and the questionnaire were carried out a total of three times, after which generalised linear mixed methods were applied with blood pressure as an independent variable against the dependent variable of drinking water salinity.

A population-based cross-sectional study between September 2016 and January 2017 in three rural coastal sub-districts located in the south and southwest regions of Bangladesh used a survey and water samples found consistently higher health risks for the fourth quartile of drinking water salinity when compared with the lowest quartile after accounting for the potential covariates' education and annual household income (Chakraborty et al., 2019, p. 3746). This study also highlighted the lack of awareness as more than half the population from high salinity areas did not think salinity posed a health threat. This was a sharp contrast to the low salinity area, where 71.8% thought that drinking water salinity could harm health. The study also found a significant association between hospital visits due to cardiovascular disease, diarrhea, and abdominal pain and with high salinity and total dissolved solids in drinking water.

In a longitudinal survey of 1,500 households representing four types of ecological systems in coastal Bangladesh, Nahian et al. (2018) gathered drinking water samples, dietary information, blood pressure to find the linkage between drinking water salinity concentration and blood pressure. The four ecological systems resulted in four types of drinking water categories: ground water sources, surface sources, rainwater and others such as bottled water. Using a multi-level binomial logistic regression model on panel data and bivariate analysis, they found that high blood pressure is significantly associated with drinking water salinity, with women having a 31% higher chance of hypertension. Of respondents aged under 35 exposed to drinking water of 1000mg/L salinity concentration, 34.3% had hypertension or prehypertension, which rose to 42.6% for the same age group exposed to salinity concentration of 2000mg/L. They found that there was no significant association between hypertension and food diversity. Importantly, hypertension was found to gradually increase with higher educational attainment, even though participants who had secondary education had 26% lower hypertension than those with no education.

The driving forces of climate change cause seawater intrusion pressures that result in higher drinking water sodium that then causes health impacts (specifically, hypertension, strokes, pre-eclampsia during pregnancy and infant mortality), which need possible responses (pond sand filters, rainwater harvesting among others). The use of the Driver-Pressure-State-Impact-Response (DPSIR) framework (created by the Organization for Economic Cooperation and Development and the European Environmental Agency) allows stakeholders to better cite and organise the challenges that exist in coastal systems, specifically those in Bangladesh (Shammi, Rahman, Bondad, & Bodrud-Doza, 2019, p. 50). The framework created was supported by a review of literature and secondary data, but the main contribution from this research was the use of inverse distance weighting (a geostatistical method) to form a map that predicts proximity to saline drinking water through estimation of sampled points. Furthermore, the authors of this study gathered 120 user opinions on rainwater harvesting and solar desalination plants in Patuakhali district, a "severely salinity-affected area from the south-central part of Bangladesh". This adds an element of qualitative analysis and contributes to the "response" aspect of the framework. Rainwater harvesting was found by 50% of respondents to be moderately effective, with the remaining 46% finding it "very effective" or "highly effective". Reverse osmosis was much less popular (65.8% of respondents saying "not effective at all"), which bears added weight as the survey area has four solar-powered reverse osmosis plants.

In a study that investigated the state of drinking water safety towards calculating how much households are willing to pay for safe drinking water in Tala subdistrict (this is in Satkhira district, as is Shyamnagar subdistrict, which is one of the three subdistricts in this study), Dey et al. (2019) gathered data through a questionnaire at 4,500 households and also studied water quality for arsenic, salinity and iron contamination. The explanatory variables were monthly income, tubewell ownership, distance from drinking water source, self-reported arsenic contamination, difficulty during disasters to access water in a logistic regression with the outcome variable of whether a household is willing to pay for safe drinking water. The results found that monthly household income, ownership of a tubewell and distance to drinking water were statistically significant determinants of willingness to pay. Of respondents, 75% were willing to pay for safe drinking water in the range of 2-6% of their incomes. Dey et al (2019) also found that of the 649 wells tested, 99% did not meet the WHO safety threshold of 250µS/cm for electric conductivity.

From these studies we establish that drinking saline water has detrimental health impacts in coastal Bangladesh due to salinity encroachment resulting from climate change. High blood pressure/hypertension is significantly associated with hypertension and is more prevalent in women. Awareness of drinking water salinity seems to be important for populations, but the extent of this is not fully explored. This same awareness may play a part in households being willing to spend on safe drinking water. Local populations' understanding of salinity may be low and the effectiveness of responsive measures (both policy and non-policy) is in question.

Summary table: the coastal health crisis in Bangladesh

Title	Year	Author	Research question	Data	Methodology	Findings
High concentrations of sodium in drinking water and raised blood pressure in coastal deltas affected by episodic seawater inundations	2016	Pauline F D Scheelbeek, Muhammad AH Chowdhury, Andy Haines, Dewan S Alam, Mohammad A Hoque, Adrian P. Butler, Aneire E Khan, Sontosh K Mojumder, Marta A G Blangiardo, Paul Elliott, Paolo Vineis	What is the effect of drinking water with high levels of sodium on blood pressure? Is the impact of high salinity drinking water on blood pressure reversible?	Baseline concentrations of sodium in drinking water; participants' blood pressure; and personal, lifestyle, and environmental characteristics recorded in March 2013, March 2014, May 2014 from participants aged over 18 in coastal Bangladesh (multistage sampling process). Low saline water provided in last sampling.	Generalised linear mixed methods to model the effect of drinking water sodium on blood pressure and track changes from drinking low-saline water.	Drinking water sodium concentrations highly associated with blood pressures, even after controlling for lifestyle and environment. for a 100 mg/L decrease in sodium concentration in drinking water, blood pressure was reduced, on average, by 0.95/0.57 mmHg and the odds of hypertension reduced by 16% (95% CI 8%–26%)

Health Implications of Drinking water salinity in Coastal Areas of Bangladesh	2019	Rishika Chakraborty, Khalid M. Khan , Daniel T. Dibaba , Md Alfazal Khan, Ali Ahmed and Mohammad Zahirul Islam	Is high drinking water salinity associated with increased hospital visits?	Population-based cross-sectional study (September 2016-January 2017) in three rural coastal sub-districts with established high salinity. 60 households from each subdistrict selected, questionnaire and two water samples gathered. Questionnaire: sociodemographic, water use, perception of health impact from water salinity, BMI. Health outcomes: CVDs, diarrhea, abdominal pain, gastric ulcer, dysentery, skin diseases, typhoid. **Only head of household interviews.** Inspection of tubewells, cut off of 150m.	Water samples tested three times and salinity level averaged. Participants in two groups: high or low salinity. Bivariate analysis to compare differences in proportions. Comparison of hospital visits over 12 months. Multivariate logistic regression models to examine the associations between quartiles of water salinity and hospital visits.	Significant association found between hospital visits due to high salinity and TDS in drinking water with CVD, diarrhea, and abdominal pain. Population from high salinity areas had a higher frequency of hospital visits. 71.8% of the participants from low salinity area believed that drinking water salinity has a negative effect on health, while more than half the population from high salinity area did not think salinity posed a health threat.

Intersalt: an international study of electrolyte excretion and blood pressure. Results for 24 hour urinary sodium and potassium excretion	1988	Intersalt Cooperative Research Group	How do high electrolyte excretions related to blood pressure?	52 centres in 32 countries recruited 200 men and women aged 20-29: data from 10648 people was included. Sitting blood pressure was measured twice. Participants were given jars to collect urine for 24 hours. Height and weight measured twice.	Centre linear regressions of blood pressure on sodium, potassium, and sodium to potassium ratio were calculated, adjusted for age and sex.	Sodium excretion positively associated to blood pressure. Sodium significantly related to blood pressure slope with age. Potassium excretion was negatively correlated with blood pressure.
Drinking Water Salinity Associated Health Crisis in Coastal Bangladesh	2018	Mahin Al Nahian, Ali Ahmed, Attila N. Lázár, Craig W. Hutton, Mashfiqus Salehin, Peter Kim Streatfield	What are the health effects of high drinking water salinity?	longitudinal survey on equal numbers of representative households for 4 types of ecological systems. Three rounds of household survey (cross sectional), four months apart from Feb 2014 to Feb 2015. Drinking water samples, dietary information, blood pressure from over 1,500 households.	multi-level binomial logistic regression model on panel data. bivariate analysis.	High blood pressure significantly associated with drinking water salinity. Women 31% higher chance of hypertension. Dry season increased trend and showed maximum blood pressure.

Summary table: hypertension symptoms

Title	Year	Author	Research question	Data	Methodology	Findings
Headaches and the Treatment of Blood Pressure Results From a Meta-Analysis of 94 Randomized Placebo-Controlled Trials With 24 000 Participants	2005	Malcolm Law, FRCP; Joan K. Morris, PhD; Rachel Jordan, MPH; Nicholas Wald, FRS	Does blood pressure reducing medication treat headaches?	94 randomized placebo-controlled trials of 4 different classes of blood pressure–lowering drugs	systematic review, odds ratio, tests for heterogeneity using the I2 test statistic	One third fewer people on average reported headache in the treated groups. 1 in 30 treated persons benefited by having headache prevented. Indication that high blood pressure is a cause of headache.
Hypertension and Migraine in the northern Manhattan study	2016	Hannah Gardener, ScD1; Teshamae Monteith, MD1; Tatjana Rundek, MD, PhD1; Clinton B. Wright, ScD1; Mitchell S.V. Elkind, MD; Ralph L. Sacco, MD,	What is the association between migraine and hypertension?	1338 participants, self-report questionnaire , two blood pressure checks	Cross-sectional cohort study, logistic regression models, multinomial logistic regression models for categories of migraine aura	Hypertension was associated with migraine (OR: 1.76, 95% CI: 1.21-2.54), both with and without aura.

Prevalence of hypertension-attributed symptoms in routine clinical practice: a general practitioners-based study	2008	M Middeke, B Lemmer, B Schaaf and L Eckes	What is the prevalence of symptoms generally attributed to hypertension? What is the relationship between symptoms and blood pressure categories?	questionnaire, gender, age; symptoms: dizziness/vertigo, headache/tension, angina pectoris/chest pain, dyspnoea. 64,644 patients from2934 genera practitioners	Cross-sectional analysis; unpaired Student's t-test for comparison across subsegments; Spearman's correlation coefficient for blood pressure and corresponding prevalence.	Strong correlation between the severity of blood pressure and reported symptoms, higher in women and in patients with concomitant diseases. Headache frequently reported symptom. Dizziness was the most prevalent. Symptoms warn of inadequate control of blood pressure.
Association between Hypertension and Epistaxis: Systematic Review and Meta-analysis	2017	Hyun Jin Min, Hyun Kang, Geun Joo Choi, and Kyung Soo Kim,	What is the association between hypertension and epistaxis? Is hypertension an independent risk factor for epistaxis?	2768 studies from MEDLINE, EMBASE, and Cochrane Library databases, 10 chosen for study based on inclusion criteria of peer-reviewed cohort study, nested case control study, case-control study, or cross-sectional study. 9574 patients total.	Systematic review, meta-analysis; pooled OR with 95% CI for binary data. Mantel-Haenszel random-effect model. Sensitivity analysis to study the effect of individual studies.	Risk of epistaxis significantly increased for patients with hypertension (OR, 1.532 [95% CI], in case-control studies, not cohort studies. Epistaxis is also not dependent on the magnitude of either SBP or DBP.

Relationship between epistaxis and hypertension: A cause and effect or coincidence?	2015	Nabil Abdulghany Sarhan, Abdulsalam Mahmoud Algamal	What is the relationship between epistaxis and hypertension?	80 patients divided into two groups and monitored for ambulatory blood pressure for three months. Blood pressure, ambulatory blood pressure and blood pressure at three months was recorded. Nosebleed patient group treated with four methods.	t-test, chi-squared test, Pearson's correlation coefficient, one-way anova	No association found between hypertension and epistaxis; epistaxis was not initiated by high BP.
Epistaxis and hypertension	1977	RICHARD CHARLES, ELIZABETH CORRIGAN	Is epistaxis a symptom of hypertension?	case-notes of 194 patients from 1973-75	Student's t-test	26 patients with a factor predisposing to nasal bleeding had age- and sexadjusted systolic and diastolic scores similar to those of the general population. 168 patients with no predisposition to nasal bleeding formed a different population with significantly higher age- and sex-adjusted systolic and diastolic scores. Epistaxis is a true symptom of hypertension.

Association between anxiety and hypertension: a systematic review and meta-analysis of epidemiological studies	2015	Yu Pan Wenpeng cai Qi cheng Wei Dong Ting an Jin Yan	What is the association between anxiety and hypertension?	21 studies selected from body of 4072 English and 237 Chinese studies. 231,535 participants covered.	Systematic review and meta-analysis (Chinese + English); pooling measure (DerSimonian and Laird random effect model) or fixed-effect model; sensitivity analysis; maximum likelihood estimation; Egger's regression asymmetry test.	13 cross-sectional studies (n=151,389) final pooled odds ratio 1.18 (95% CI); Eight prospective studies (n= 80,146) pooled adjusted hazard ratio 1.55 (95% CI)
Mental health in hypertension: assessing symptoms of anxiety, depression and stress on anti-hypertensive medication adherence	2014	Irene A Kretchy, Frances T Owusu-Daaku, Samuel A Danquah	What is the role of mental health (anxiety, depression, stress) on taking hypertension medication?	400 patients' data on socio-demographic characteristics, anxiety, depression and stress symptoms, spiritual beliefs, and medication adherence	Chi-square tests, logistic regression, Depression Anxiety Stress Scale	Hypertensive patients experienced symptoms of anxiety (56%), stress (20%) and depression (4%). Stress among patients increased their likelihood of medication non-adherence [OR = 2.42 (95% CI), p = 0.035]

The Relationship Between Dyspnea and Blood Pressure in Chronic Obstructive Pulmonary Disease	2007	Patricia C Jenkins	What is the relationship between dyspnea and blood pressure?	60 adults diagnosed with chronic obstructive pulmonary disease, dyspnea recorded with visual analog scale and arterial blood pressures continuously recorded	omnibus parametric repeated-measures analysis of variance, Bonferroni correction, Pearson product-moment correlation coefficient	evidence of an inverse relationship between dyspnea and blood pressure patterns
Dyspnea, depression and health related quality of life in pulmonary arterial hypertension patients	2015	Arunabh Talwar, Sonu Sahni, Eun Ji Kim, Sameer Verma and Nina Kohn	What is the interrelationship of dyspnea, depression and HRQOL in pulmonary arterial hypertension patients?	46 pulmonary arterial hypertension patients' psychosomatic health quantitative measurements of dyspnea, depression and health related quality of life	correlation with SF-36 scale	Patients with PAH suffer from diminished HRQOL correlating with their dyspnea and underlying depression.

3.3.2. The symptoms of hypertension

The questionnaire for data used in this study asked participants to self-report whether they had severe headaches, nosebleeds, severe anxiety and shortness of breath. The survey design states that these are common symptoms of hypertension, and this section of the literature review will establish the relations between the four symptoms and hypertension.

Severe headaches

Overall, the medical community seems to be at odds over whether headaches and hypertension have any relation and/or whether the relationship that may or may not exist is causational in either direction. In a meta-analysis of 94 randomised placebo-controlled trials, Law, Morris, Jordan, & Wald (2005, p. 2302-06) analysed the effects of four different blood pressure reducing drugs. There were 17,641 participants who were allocated blood
pressure–lowering drugs and 6603 given placebos.

On average across the 94 trials, a third fewer people in treatment groups reported lower headaches than in placebo groups. Each of the four types of blood pressure reducing drug reduced the prevalence of headaches in the trials at a highly significant level. The study notes that the headaches could be attributable to either blood pressure reduction or other effects of the drugs. Further cross-sectional analysis showed that headaches were 17% less prevalent for 5-mm Hg lower diastolic blood pressure, but only at the 10% significance level and systolic blood pressure displayed no association with headaches (Law et al., 2005, p. 2305). In essence this study proves that blood pressure medication relieves headaches for those with high blood pressure, and indicates that blood pressure is a cause of headaches, but does not prove conclusively that hypertension causes headaches.

The research for migraines being caused by hypertension seems to be more substantial than for headaches alone. In a cross-sectional analysis of a multi-ethnic urban population sample of 1338 participants, hypertension was found to be positively associated with migraine, both with and without aura at an odds ratio of 1.76 at 5% significance (Gardener et al., 2016, p. 323). This was with 80% of participants having no migraines, 6% having migraines with aura and 15% having migraines without aura. Hypertension was present in 76% of the study population, with various durations of having treated ("controlled") the disease. Controlled or uncontrolled hypertension among individuals who had the condition for a long duration (greater than nine years) had more than double the odds of having migraines with aura compared with participants with no hypertension (Gardener et al., 2016, p. 323). This is particularly pertinent to this study, where residents are likely to be living with hypertension for longer periods of time, and "severe headaches" are the most common ailment.

Lastly, a 2007 cross-sectional study aimed to catalogue the treatment and control rates for hypertensive symptoms in German primary care settings, recruiting patients through 2934 general practitioners in 2001. A total of 64,644 patients were questioned about dizziness, headache, chest pain, dyspnoea or other symptoms, all related to hypertension. Biometric information was also gathered. Of all symptoms, dizziness was most prevalent among hypertensive patients, along with headache, chest pain and shortness of breath. Normotensive patients in the study reported greater tiredness, which was helpful in ascertaining that headaches and dizziness were due to hypertension (Middeke et al., 2007, p. 257). This is because hypertensive patients reported markedly lower tiredness than normotensive, as opposed to dizziness and headaches, which also did not come with increasing severity of tiredness. Middeke et al. (2007) conclude that symptoms such as headache, dizziness, chest pain or shortness of breath indicate that a patient's blood pressure is not sufficiently controlled.

Nosebleeds

In a systematic review on the association between hypertension and epistaxis (the medical name for nosebleeds) 10 studies were selected from 2768 studies on the topic, Min, Kang, Choi, & Kim (2017, p. 925) found that hypertension is significantly associated with the risk of epistaxis, but evidence for a causal relationship was not found. The 10 studies totalled 9574 patients, and the authors noted that the definition of hypertension and the methods for blood pressure measurement were not standardised (Min et al., 2017). They also found that men had nosebleeds more commonly than women. They recommended the use of ambulatory blood pressure to gauge the association with nosebleeds according to hypertension severity and based on separate systolic and diastolic blood pressure measurements.

In this vein, Sarhan & Algamal (2015) studied two groups of 40 patients: one with nosebleeds and the second without. The patients were measured for blood pressure and ambulatory blood pressure in the three month study, as Min et al. (2017) recommended. Nosebleeds in patients were managed by first aid, nasal packing with Merocel (a type of compressed sponge), electrocautery (application of a heated electrode) and nasal balloons for the study period. The final dataset was analysed to compare the mean values between the two patient groups, using *t*-test, and χ^2 test was applied to compare between the groups. One-way ANOVA was used for comparisons between more than two groups (between treatment methods). The study found 45% of patients in the nosebleed group presented with hypertension, with eight patients previously being unaware of the condition. In the control group, 42.5% of patients were found to have hypertension, with four having been unaware. Regarding nosebleeds specifically, this study found no correlation over the three month period with age, sex, smoking or BMI. The findings indicated that uncontrolled hypertension is associated with higher nosebleed instances and nosebleeds are harder to control when patients have uncontrolled hypertension. However, despite all this, a "definite association" with hypertension and nosebleeds were not found (Sarhan & Algamal, 2015, p. 83). The authors did substantiate that recurring nosebleeds were higher among patients with hypertension, and nosebleeds were harder to control among hypertensive patients.

In the context of Min et al. (2017) and other studies comprising this literature review, Sarhan & Algamal (2015, p. 83) have a relatively small sample size and short period of study, and as such their results are best considered in the context of the larger body of studies on this topic. Charles & Corrigan (1977, p. 260) took on a much simpler task than Sarhan & Algamal: proving that nosebleeds are a symptom of hypertension. By gathering patient cases from October 1973 to October 1975, data for 194 patients was compared using the Student's *t*-test for nosebleeds or conditions predisposing nosebleeds. Measures were taken to account for variances in blood pressure due to nosebleeds and blood pressures were converted to account for age and sex by adjusting systolic and diastolic scores. Patients with no predispositions for nosebleeds were found to have significantly higher (at the 1% significant level) blood pressure than patients with no predisposing factors for nosebleeds (Charles &

Corrigan, 1977, p. 260). The study concluded there is an association between nosebleeds and hypertension, and nosebleeds are a “true symptom” of hypertension.

Severe anxiety

The impact hypertension has on mental health covers a range of symptoms (anxiety, depression, stress) that are difficult to track due the complexity of the physiological and psychological connections. A systematic review published in 2015 sifted through 4,072 studies in English and 237 in Chinese that covered anxiety and hypertension, of which 21 studies were used for meta-analysis. Odds-ratios of the results were extracted from the articles, of which 13 were cross-sectional studies on the association between anxiety and hypertension (Yan et al., 2015, p. 11233). The 13 studies covered 151,398 participants and the DerSimonian and Laird random effect model was applied to account for the significant heterogeneity between the studies. A publication bias was detected (statistical significance of 1.6%), and upon adjustment the final result of an odds ratio of 1.18 was significant within the 95% confidence interval, indicating a significant positive association with hypertension.

The remaining eight studies were prospective studies that looked into the role of anxiety in predicting hypertension, totalling 80,146 participants that together had a pool-adjusted hazard ratio by random effect model of 1.55, also with strong heterogeneity. The authors found that the heterogeneity in both sets of studies was not a result of location, diagnostics, age, sex, sample size or quality of the studies (Yan et al., 2015, p. 1126) and concluded that anxiety has an association with increased risk of hypertension.

A cross-sectional study in Ghana took a different approach in examining this relationship by considering the mental health impact on adherence to hypertension medication. The 400 participants were already diagnosed with hypertension and had been prescribed medication for at least two months. Anxiety was found to be the most common among the sample, with 57% of patients experiencing the symptom according to the Depression Anxiety Stress Scale, but despite this no significant association between anxiety and adherence was found (Kretchy et al., 2014, p. 4). Only stress (experienced by 20% of participants) was found to have a significant association with medical non-adherence.

Shortness of breath

The association between shortness of breath and hypertension has a more limited number of studies, with little to no research looking at the relationship specifically. The symptom is defined as “Chronic dyspnea is shortness of breath that lasts more than one month” (Wahls, 2012). One small study of 60 adults diagnosed with chronic obstructive pulmonary disease found an inverse relationship between shortness of breath and blood pressure patterns (Jenkins, 2007, p. 355), but did not look specifically at hypertension.

Another similarly small study of 46 pulmonary hypertension patients looked into dyspnea and depression as they pertained to health-related quality of life (Talwar et al., 2015, p. 264). The study used the Modified Medical Research Council Dyspnoea Scale to quantify the severity of shortness of breath, which is a patient-reported scale. There were significant negative associations found between self-reported shortness of breath and physical health summary scores as well as mental health summary scores. Talwar et al. (2015) concluded that dyspnea impacts pulmonary hypertension patients mental and physical health.

To summarise simply, severe headaches and nosebleeds have extensive research that substantiates their use as a symptom for hypertension. Anxiety and shortness of breath do not have the same breath of research as proxies or indicators for hypertension, but do play a role as a comorbidity.

4. Methodology

4.1. Conceptual framework

The structure of this research is based on the frameworks used by Das et al. (2019) and Szabo et al (2015). Both studies looked into the same region as this one and separately represent the unique facets of this study. Szabo et al (2015) used a wealth index to study the impact of soil salinity on health status (food security), while Das et al (2019) looks into the health cost of salinity contamination in drinking water. This study looks into the impact of wealth and salinity contamination on health status, which is proxied by symptoms of hypertension (and are also symptoms of other diseases). In effect, this study's structure can be approximated by overlapping Das et al (2019) and Szabo et al (2015).

Participants of the Poverty and Groundwater Salinity Survey 2016 were asked whether they had any of the four symptoms of hypertension (severe headaches, nosebleeds, severe anxiety, shortness of breath) and whether they had been diagnosed by a health provider with hypertension. These were framed as yes/no questions in the questionnaire, making them binary categorical variables. For the purposes of this study, each symptom retains a count value of 1, and they are summed up to form the aggregate dependent variable. This is structured as follows:

$$Total\ symptoms = \sum Headaches_{0}^{1} + \sum Nosebleeds_{0}^{1} \sum Anxiety_{0}^{1} + \sum Breath_{0}^{1},$$

which in this study would range 0-4, integers only.

The main methodologies from the two studies that will be applied are displayed in the table below:

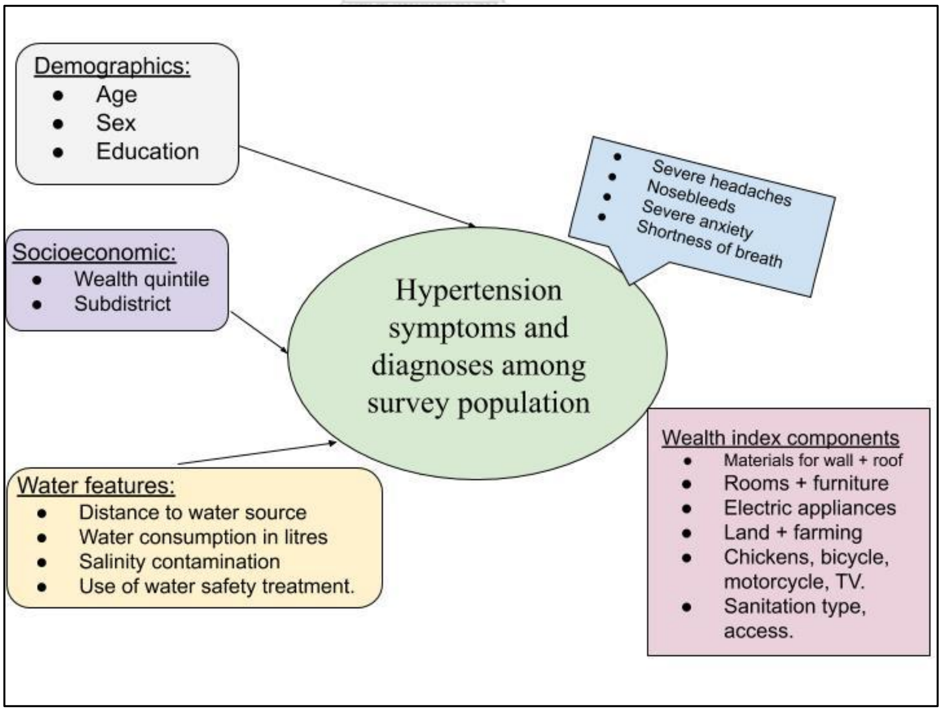
Table 2: Main methodologies from previous literature

Research paper	Dependent variable(s)/Output	Independent variables	Model/method
Szabo et al (2015)	Household food insecurity	Number of household members, years of education of HH head, age of HH head, HH head is female, HH head worked during last 7 days, HH engaged in crop cultivation, HH raises livestock, HH has been receiving remittances, religion, wealth quintile	Logistic regression
Szabo et al (2015)	Wealth index	HH has electricity, HH has sanitary toilet, HH has access to improved water sources, Wall material, Roof material, HH owns a computer, HH has a bicycle, HH has a motorcycle/scooter, HH occupancy status	Principal component analysis
Das et al (2019)	(1) Total workday lost by household members in a year, (2) total avertive expenditure incurred by household members in a year, (3) total mitigation expenditure incurred by household members in a year	Income, age, family size, years of schooling, frequency of diseases, awareness, sodium chloride (mg/L).	(1) Zero-inflated regression (Poisson); Tobit model for (2) and (3)

Das et al (2019) only surveyed household heads, gathering the characteristics of age, education and awareness (of salinity issues). Given that we are looking for the determinants of hypertension symptoms/diagnoses among populations as part of our model, we will use age, sex and education. The addition of participants' sex is to account for both differences in diagnoses (as women and men have different healthcare utilisation in different age brackets, as per Mannan et al [2013], see Appendix) and to see if the global trend for men having greater hypertension prevalence holds up in this study.

Household features, structures, appliances, resources are used to compile a wealth index by using factor analysis because all of these features are connected and result from whether individuals/households have wealth. This has the practical effect of compacting the number of variables in the model and generating factor weights for wealth that allow to form the health-wealth gradient for the survey population.

Figure 1: Conceptual framework for study design



4.2. Constructing the wealth index

The World Food Programme's VAM Guidance Paper on "Creation of a wealth index" was used as the template for using the information at hand to form a wealth index. In lieu of income, expenditure and consumption data (the most common measures of wealth), a wealth index acts as a proxy indicator. The use of asset ownership gives a better sense of a household's long-term economic status that does not fluctuate with short-term economic changes (World Food Programme, 2017). The index acts as a proxy indicator for household wealth. This varies from a poverty line in that the index measures relative wealth and there are no absolute measures for who is "poor" and who is not. The households in this study therefore, will be poorer or richer than each other and the survey population will be divided into five equally large groups based on their wealth rank (World Food Programme, 2017). The quintiles will be used to identify the impact of wealth status on health outcomes, which in this case are hypertension symptoms and diagnoses for individuals. As all 1500 households in the Poverty and Groundwater Salinity Survey 2016 are rural, there is no need to make adjustments to the wealth index to account for differing characteristics between urban and rural households.

The variables selected fall into three broad categories: productive, non-productive and household utilities. For this survey dataset, we are including variables such as employment status, occupancy status and education.

While this study is using the aforementioned guideline, the use and data are those that are applied to Demographic and Health Surveys. Across the world, wealth indexes use different variables that represent the context of the society and/or community, and are not a measure of poverty, income or consumption (Filmer & Pritchett, 2001, p. 117). There are two main approaches to using wealth index rankings: using quintiles/terciles or comparing entire distributions. This study is using the first method, and studies have found this “moderately approximates” consumption or income (Poirier, Grépin, & Grignon, 2019, p. 25). As the wealth index uses household assets, this cannot be broken down into per person values, and as such is not highly exact (Poirier et al., 2019, p. 25). While there is much use of wealth indexes in health and education outcomes, there are indications that they exaggerate social health inequalities, but seem to be relatively accurate for health-seeking behaviours (Poirier et al., 2019, p. 25).

In a study towards attaining comparability among DHS wealth indexes, the writers concluded that indexes can proxy as a type of permanent income, especially in developing countries where actual income is unreliable and/or seasonal (Rutstein, Shea &Sarah Staveteig, 2014). This same study used the Universal Basic Needs framework for anchor points, which entailed inadequate walls, crowding, toilets, children who do not attend school and “high economic dependency” (defined as a household head having less than primary education and more than three dependents) (Rutstein et al., 2014). The first three points are accounted for in this study, with the remainder being based on the VAM guidance paper’

Initially, the following 20 variables from the dataset were selected to be included the wealth index:

Table 3: Preliminary variables for wealth index composition

No.	Variable name/lab	Category	Variable description	Variable type	Reference

	el				
1	rooms	Household utilities	Number of rooms in the household.	Continuous.	Filmer & Pritchett (2001)
2	occupancystatus	Other	Whether home is owned, rented, provided by the government or relatives or respondents are squatting.	Categorical: owned, rented, provided by relatives, squatting, government provided.	(World Food Programme, 2017)
3	landsize1	Other	Household's total cultivable land (for agriculture) in acres.	Continuous.	Filmer & Pritchett (2001); World Food Programme (2017)
4	landsize2	Other	Size of the plot home is on in acres.	Continuous.	Filmer & Pritchett (2001); World Food Programme (2017)
5	landsize3	Other	Size of household's total uncultivable land in acres.	Continuous.	Filmer & Pritchett (2001); World Food Programme (2017)
6	chickens	Productive assets	Household owns a chicken.	Binary.	World Food Programme (2017)
7	bicycle	Non-productive assets	Household owns a bicycle.	Binary.	Filmer & Pritchett (2001); World Food Programme (2017)

8	motorcycle	Non-productive assets	Household owns a motorcycle.	Binary.	Filmer & Pritchett (2001); World Food Programme (2017)
9	refrigerator_freezer	Non-productive assets	Households own a refrigerator or a freezer.	Binary.	Filmer & Pritchett (2001); World Food Programme (2017)
10	fans	Non-productive assets	Household owns a fan	Binary.	World Food Programme (2017)
11	television	Non-productive assets	Household owns a television.	Binary.	Filmer & Pritchett (2001); World Food Programme (2017)
12	drawing_room_furniture	Non-productive assets	Household owns drawing room furniture.	Binary.	World Food Programme (2017)
13	dining_room_furniture	Non-productive assets	Household owns dining_room_furniture.	Binary.	World Food Programme (2017)
14	boat	Productive assets	Household owns a boat.	Binary.	World Food Programme (2017)
15	Walls	Non-productive assets	The construction material of the walls of the house.	Categorical: Brick/ cement; C.I. Sheet/wood; Mud brick; Hemp/hay/bamboo.	Filmer & Pritchett (2001); World Food Programme (2017)
16	Land1	Productive assets	Household has cultivated land in the past 12	Binary.	World Food Programme (2017)

			months.		
17	latrine	Non-productive assets	Type of toilet household has.	Categorical: sanitary; water seal; pit; permanent; temporary; other.	World Food Programme (2017)
18	land8	Productive assets	Whether the household has farmed shrimp.	Categorical: yes; no, don't know.	World Food Programme (2017)
19	roof	Non-productive assets	Construction material of the roof of the main room.	Categorical: Brick/ cement; C.I. Sheet/wood; Mud/brick; Hemp/hay/bamboo; other.	Filmer & Pritchett (2001); World Food Programme (2017)
20	toiletshare	Non-productive assets	Whether the toilet is shared with other households.	Binary.	World Food Programme (2017)

The first rule of thumb applied is frequency. If 95% of households do not have an asset, the DHS guidance is to not include the asset in the index. For this, ownership of a boat was immediately dropped: only 5.12% of the survey population owned a boat, therefore it is not an asset indicative of relative wealth of the entire population. Refrigerator/freezer ownership at 1.36% and motorcycle ownership at 4.15% were also dropped.

Secondly, continuous variables are recoded into binary/categorical ones: education is divided into 0-5 (no education to primary school), 6-11 (middle school to completed secondary school) and 12-13 (complete university/first degree) and 13-18 (postgraduate and technical/professional training). This yields three main groups for education, dummies for which are generated.

For land holding, first all three land categories are totalled into one variable. (Making a wealth index is an iterative process; trial and error has shown that, for this dataset, having three separate categories for land ownership is less useful and they each have little to no loading within factors separately.) This summed variable is then divided into four groups of 0-0.1 acres, 0.1-0.36 acres, 0.36-1.2 acres and over 1.2 acres. Dummy variables are generated for these too. This same process is applied for "rooms". The variable for how many rooms a household has is categorised into four groups: 1 room, 2 rooms, 3 rooms and more than 3 rooms.

All the dummy variables are then tested for correlation. Variables that have correlation values of over 0.6 are dropped (Filmer & Pritchett, 2001), to ensure the factors that are generated are more robust and have limited overlap from variables. A factor analysis is then run to compress the variables and to see how they load into the factors that are generated. According to Schildernick (1969), "Factor analysis is based on the assumption that there are a number of general causal factors which give rise to the various relationships between the variables under examination".

The aim is to reduce the number of variables into a set of 'dimensions' that grasp the connections/correlation between the variables and can act as a proxy. The components generated by the principal component analysis or factor analysis process are each a linear weighted combination of the initial variables (Vyas & Kumaranayake, 2006, p. 460). For hypothetical variables X_1 to X_n, principal components generated would be as follows:

$$PC_1 = a_{11}X_1 + a_{12}X_2 + ... + a_{1n}X_n$$

$$\vdots$$

$$PC_m = a_{m1}X_1 + a_{m2}X_2 + ... + a_{mn}X_n$$

Where a_{mn} is the weight for the *n*th variable and the *m*th principal component/factor (Vyas & Kumaranayake, 2006, p. 460). The weights come from the covariance matrix eigenvectors, and the eigenvalue from the eigenvector makes up the variance of each principal component/factor.

For the square matrix ***A***, being multiplied by vector ***x*** creates the vector ***Ax***. The vector ***x*** is an eigenvector if it moves in the same direction as ***Ax***. When the eigenvector ***x*** is multiplied by matrix ***A***, the resulting ***Ax*** is ***λ*** times the original vector ***x***. The eigenvalue of the matrix ***A*** is the number ***λ***. Eigenvalues are the variances of the principal components. Eigenvectors represent directional orientation for a matrix, while eigenvalues represent magnitude for the same matrix.

The DHS directions for factor analysis use eigenvalues of greater than one (implying that each factor accounts for the variances of more than one variable, which are then rotated orthogonally in a varimax rotation. This maximises the variance of the squared loadings of a factor on all the variables to ensure that each factor has large or small loadings from each variable. Factor analysis was chosen over principal component analysis because the latter does not measure latent variables. Wealth is the criteria that is being gauged through an agglomeration of assets. However, this is not a linear combination. The variables/assets do not create wealth, and are instead both created by pre-existing wealth and contribute to forming household wealth. This means that there is a latent variable at hand, for which factor analysis is the more appropriate instrument.

As mentioned previously, variables that have higher correlation with others are cleared out from the factor analysis. From there dummies for different categories are tested in an iterative process to ensure that factor loadings, which are the correlation coefficient between the variables and the factor are above 0.3 and the Kaiser-Meyer-Olkin measure of sampling adequacy is as high as possible.

The Kaiser-Meyer-Olkin test measures the proportion of shared variance between pairs of variables. The result runs from 0 to 1 and a higher value indicates that the variables used are better suited to factor analysis.

Third, to judge whether the use of factors is justified, and to check for redundancies, Bartlett's test of sphericity is used. This tests the null hypothesis that the correlation matrix is an identity matrix. An observed correlation matrix is compared to the identity matrix (where the values along the diagonal are 1 and all of the other values are 0) to check redundancy and help decide if the number of variables used needs to be reduced.

Significance levels of under 5% indicate that the factor analysis is useful for the data at hand. The p-value for the final variable list is 0.000, indicating that the variables used do not form an identity matrix, and the null hypothesis is rejected.

Table 4: Results for KMO and Bartlett's test

Determinant of the correlation matrix
Det = 0.081
Bartlett test of sphericity
Chi-square = 17484.497
Degrees of freedom = 105
p-value = 0.000
H_0: variables are not intercorrelated
Kaiser-Meyer-Olkin Measure of Sampling Adequacy

KMO = 0.785

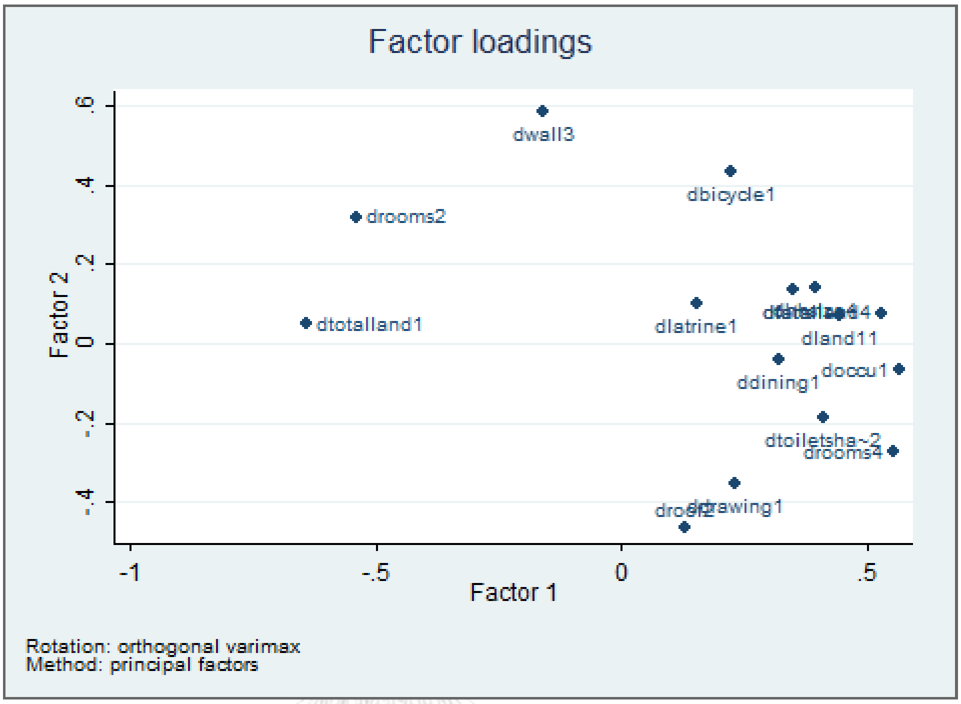
Starting with the 27 variables that are indicative of or related to household wealth, the best set of variables for the factor analysis are a set of 15, listed in the following table:

Table 5: Final components for wealth index

Variable label	Description	KMO
drooms2	Dummy variable for 2 rooms	0.8192
dwall3	Dummy variable for mud/brick walls	0.7228
ddrawing1	Dummy for drawing room furniture	0.8024
ddining1	Dummy for dining room furniture	0.8422
dbicycle1	Dummy for owning a bicycle	0.6802
dfans1	Dummy for having at least one fan in house	0.7809
dland11	Dummy for land cultivated in past 12 months	0.8223
droof2	Dummy for roof being made of metal sheet/wood	0.7646
dtoiletshare2	Dummy for not sharing a toilet with other households	0.8607
dtotalland1	Dummy for owning up to 0.1 acre of land	0.7564
dtotalland4	Dummy for owning more than 1.2 acres of land	0.8180
dlatrine1	Dummy for having a sanitary latrine	0.6510
dhhsize4	Dummy for more than 7 members in household	0.7640
drooms4	Dummy for 3 or more rooms in the house	0.8157
doccu1	Dummy for home ownership	0.7577
	Overall KMO	0.7854

The resulting factors are generated and the factor that has the most variables loaded is used to generate wealth quintiles. In the factor loadings plot below, the factor that has the most variables positively loading is clearly “Factor 1”.

Figure 2: Loadings plot for variables in factor analysis



Sensitivity analysis for wealth index components

To judge the impact/contribution of each component on the overall wealth index, a simple sensitivity test was applied to see the difference in the KMO sampling adequacy value with the addition/removal of individual components.

Table 6: Sensitivity analysis for wealth index

Component removed	Resulting KMO value	Difference from completed index KMO value
two rooms	0.7466	-0.04
mud/brick walls	0.7684	-0.02

drawing room furniture	0.7679	-0.02
dining room furniture	0.7685	-0.02
owning a bicycle	0.7745	-0.01
having at least one fan in house	0.7678	-0.02
land cultivated in past 12 months	0.7646	-0.02
roof being made of metal sheet/wood	0.7677	-0.02
Not sharing a toilet with other households	0.7570	-0.03
Owning up to 0.1 acre of land	0.7649	-0.02
Owning more than 1.2 acres of land	0.7571	-0.03
Having a sanitary latrine	0.7797	-0.01
More than 7 members in household	0.7713	-0.01
Three or more rooms in the house	0.7509	-0.03
Home ownership	0.7700	-0.02

The table shows the differences made to the wealth index's sampling adequacy for the survey population with the removal of each component. That is, each component adds 0.01 to 0.04 to the identity correlation matrix that makes up the wealth index used in this study. Having two rooms in a household is the variable with the most impact on the matrix, while bicycle ownership, over seven members in a household and a household having a sanitary latrine have the lowest impact.

4.3 Tables of variables

Table 7: Dependent variable

	Description	Type/Range of values
Y	Number of hypertension symptoms: headache, nosebleeds, severe anxiety, shortness of breath.	Count; 0-4.

Table 8: Independent variables

	Variable name	Description and variable coefficient	Expected sign	Type/Range of values	Reference
	Demographic/Individual level				
β_4	Age	Age of participants. Blood pressure tends to rise as people get older (Intersalt, 1988)	+	Continuous; 0-100	Das et al. (2019), Chakraborty et al., (2019)
β_5	Female	Hypertension has been found to be more prevalent in females.	+	Binary. 0=male, 1=female	Chakraborty et al., (2019), Nahian et al. (2018)
β_6	Years of education	Education has significant associations with determinants of health	+	Continuous; 0-18	Nahian et al. (2018)
	Socioeconomic				
β_{10-13}	Q_{2-5}	Factor analysis score divided into quintiles. Four dummy variables are used in the	-	Binary	Szabo et al., (2015)

		model specification, with the reference being the top quintile.			
β_{14-15}	Subdistrict	Dummy variables for Morrelganj and Taltali subdistricts	+	Both subdistricts have greater salinity levels than Shyamnagar	Shamsudduha et al. (2019)
	Water features				
β_1	Primary drinking water tastes slightly saline.	Subjective test of drinking water salinity, with low salinity being detected.	-	Binary; 0=option not chosen, 1=option chosen.	Nahian et al. (2018)
β_2	Primary drinking water tastes moderately saline.	Subjective test of drinking water salinity, with moderate salinity being detected.	-	Binary; 0=option not chosen, 1=option chosen.	Nahian et al. (2018)
β_2	Primary drinking water tastes highly saline.	Subjective test of drinking water salinity, with high salinity being detected.	+	Binary; 0=option not chosen, 1=option chosen.	Nahian et al. (2018)
β_9	Distance to water source in feet	How far the household's water source is in feet. Longer distance implies poor access to water.	+	Continuous, up to 2,640,000 feet. The ln of this variable is used to stabilise variance.	Ziaul Haider & Zaber Hossain, (2013)
β_8	Water consumption in litres per person.	How much water a household consumes per day. Drinking more water could help reduce	+	Continuous	Scheelbeek et al., (2016); (Shammi et al, 2019)

		hypertension symptoms (Shammi et al, 2019), but drinking more saline water could do the opposite (Scheelbeek et al., 2016)			
β_7	Salinity contamination is a problem.	Responses for top three water quality problems. Whether salinity is one of the top three problems for water quality according to respondents. Accounts for respondents who have had water source tested for salinity	+	Binary; 0=no salinity in water source. 1=salinity in water source.	Das et al. (2019)

4.4. Theoretical basis and study model

Regression model for dependent count variable

The output variable in this study can only be counted in non-negative integers. Individuals can have zero symptoms, but cannot have negative 2 or 1.7 symptoms. Das et al. (2019) used the zero-truncated Poisson regression (ZTP). However, the symptoms in this study range 0-4, not exclusively positive integers. The zero-inflated version is used when the outcome variable cannot be zero. In this case, the basic Poisson regression suffices because the random variable for symptoms does present values of zero.

The Poisson regression models how the count variable (non-negative integers) depends on explanatory variables, based on expected frequencies. Salinity-induced symptoms are a count data variable. As a generalised linear model, the Poisson regression models canonically have the logarithm as the link function. Should a dependent/respondent variable have a Poisson distribution, the logarithm of its expected value can be modelled by a linear combination of unknown parameters.

The Poisson model has the density:

$$P(Y = y_i) = (e^{-\mu} \mu^{y_i})/y_i!, \quad y_i = 0,1,2\ldots,$$

Where the expected value of Y equals the variance of Y and the parameter μ is the mean incidence rate of an event per unit of exposure (equidispersion assumption). In this study, the unit of exposure is population size and the exposure period is unity (Cameron & Trivedi, 1998, pp. 3–4).

The regression model based on this distribution conditions the distribution of y_i on a k-dimensional vector of covariates, $\mathbf{x}_i` = [x_{1i}, \ldots, x_{ki}]$, and the parameters $\boldsymbol{\beta}$, based on a continuous function $\mu(\mathbf{x}_i, \boldsymbol{\beta})$ to allow for $\mathrm{E}[y_i \mid x_i] = \mu(\mathbf{x}_i, \boldsymbol{\beta})$. For a given $\mathbf{x}_i$, y has the density:

$$f(y_i \mid x_i) = (e^{-\mu_i} \mu_i^{y_i})/y_i!, \quad y_i = 0,1,2\ldots.$$

The log-linear version of the model parameterises the mean parameter as

$$\mu_i = \exp(x_i`\boldsymbol{\beta}),$$

ensuring $\mu > 0$. This is the exponential mean function (Cameron & Trivedi, 1998, pp. 61–63) Together the two models define the Poisson log-linear regression model.

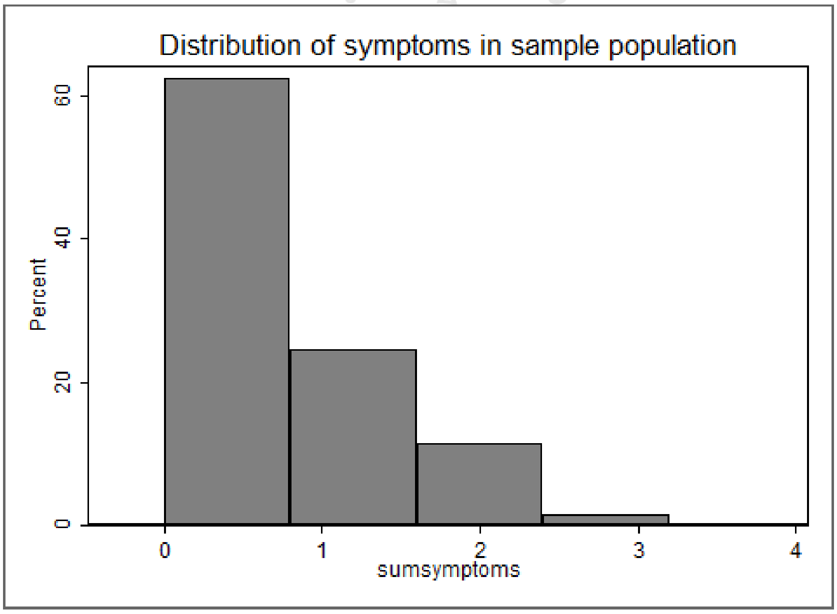
If an event may occur in a large number of trials but the probability of the event occurring in a trial is small, the law of rare events dictates that the events that do occur will approximate the Poisson distribution (Cameron & Trivedi, 1998). For a set of explanatory variables, the dependent variable has a Poisson distribution. The distribution of the dependent data in this study meets the requirements and assumptions of the Poisson distribution.

The Poisson model estimated by maximum likelihood $\boldsymbol{\beta}_P$^ is found through the first-order condition:

$$\sum(y_i - \exp(\mathbf{x}_i`\boldsymbol{\beta})\mathbf{x}_i = 0$$

Consistency requires the left-hand side of the first order condition to have an expected value of zero. This means consistency holds for the maximum likelihood estimator of a linear exponential family such as the Poisson as long as the conditional mean function is correctly specified (Cameron & Trivedi, 1998, pp. 61–63).

Figure 2: Histogram of symptoms experienced by respondents



In the histogram for symptoms among the population, 60% of the population (6971 total observations) have one of the symptoms, and only one person has all four symptoms.

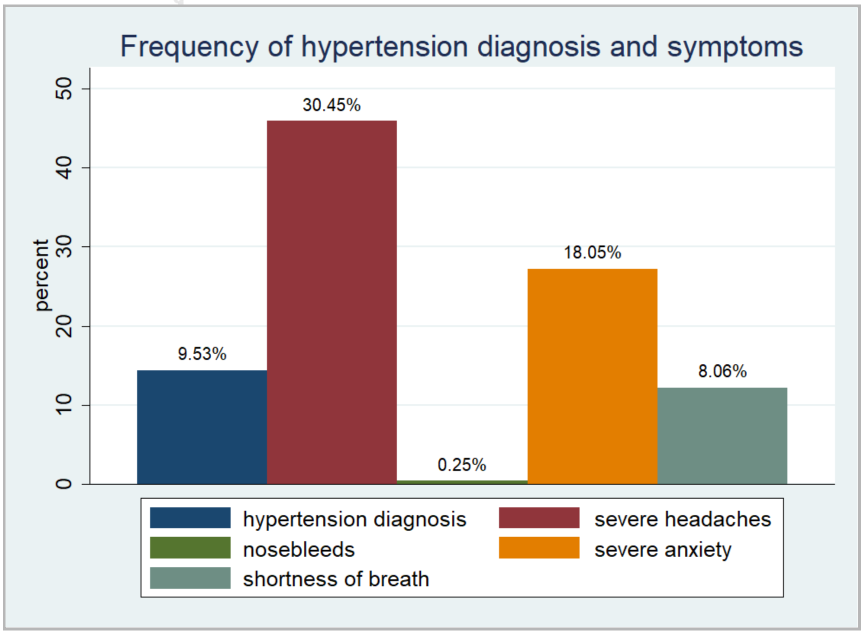
When the data generating process for the response/dependent variable is Poisson, the maximum likelihood theory yields:

$$V_{ML}[\boldsymbol{\beta}_P\hat{}] = (\sum \mu_i \mathbf{x}_i \mathbf{x}_i`)^{-1}.$$

Regression model for dependent binary variables

The responses for each of the four hypertension symptoms and hypertension diagnoses can also be studied under logit regression. Each of these responses involves only two alternatives, making them all dichotomous choice models (Dhrymes & Guerard, 2017, pp. 527-529). This model is being used to predict the probability of outcome successfulness, or the probability of the study model's independent variables in successfully causing the four symptoms and hypertension diagnoses.

Figure 3: Bar chart for symptom and diagnosis responses



For the event E, if p is the probability that it occurs, the complement $\bar{E}$ is $q = 1 - p$. For if the standard logistic distribution function $F(\cdot)$, the logit of $p_{i^\wedge}$ can be defined by

$$\text{Logit}(p_{i^\wedge}) = ln\,[p_{i^\wedge}/(1 - p_{i^\wedge}) = t_{i^\wedge}$$

and the logistic cumulative distribution function/standard logistic distribution is found by,

$$F(t) = 1/(1 + e^{-t}).$$

By rearranging with respect to t,

$$\ln\,〖F(t)/[1 - F(t)]〗 = ln\,(e^{t}) = t,$$

the inverse for which is,

$$t_i = \ln\,〖F(t_i)/[1 - F(t_i)]〗.$$

For the logit analysis model,

$$z_i = t_i,$$

which gets written as,

$$z_i = x_i\beta + error.$$

Maximum likelihood methods are the most commonly used means of estimating the parameters of the binary choice model (Dhrymes & Guerard, 2017, pp. 538-540). The log likelihood function for the dichotomous choice model is,

$$\angle = \Sigma^{n}_{i=1} \{ y_i \ln F(x_i\,\beta) + (1 - y_i) \ln [1 - F(x_i\,\beta)] \}.$$

The first-order partial derivative for this model is,

$$\partial\angle/\partial\beta = \Sigma^{n}_{i=1} [y_i\, f/F - (1 - y_i)\, f/(1 - F)]\, x_i.$$

The maximum likelihood estimator comes from $\beta^{\wedge}$ being a solution of $\partial \mathcal{L} / \partial \beta = 0$, which also implies that the log likelihood function for the model is strictly convex (Dhrymes & Guerard, 2017, pp. 550-551). The marginal effects need to be calculated to find the magnitude of the independent variables' impact on the probability of the dependent outcome occurring.

With the Poisson regression and the outcome and explanatory variables established, the study model is as follows:

log(hypertension symptoms) = β_0 + β_1(water tastes slightly saline) + β_2(water tastes moderately saline) + β_3(water tastes very saline) + β_4(respondent is female) +β_5(age) + β_6(years of education) + β_7(salinity contamination is a problem) + β_8(water consumption in litres per person) + β_9(natural log of distance to water distance in feet) + β_{10}(dummy variable for Q_2) + β_{11}(dummy variable for Q_3) + β_{12}(dummy variable for Q_4) + β_{13}(dummy variable for Q_5) + β_{14}(dummy variable for Taltali) + β_{15}(dummy variable for Morrelganj)

The above specification holds men in Shyamnagar subdistrict (in Satkhira district) who drink water that tastes like rainwater as the reference case.

With the top wealth quintile as the reference, $Q_{2\text{-}5}$ are dummy variables for wealth quintiles, where, Q_2 = second quintile, 20.05%;

Q_3 = third quintile, 20.07%;

Q_4 = fourth quintile, 19.90%;

Q_5 = bottom quintile, 20.20%.

4.5. Assessments and measures

In the Poisson regression, the output coefficients each represent the expected increase in log count for a one-unit increase in the explanatory variables. For binary variables, the coefficient displays the expected difference in log count between the group where the variable = 1 and the reference group (where the variable = 0). Robust standard errors, z-scores, p-values and 95% confidence intervals are also generated in the output.

To assess the fit of the model, two goodness-of-fit ^{2} tests are used to assess whether the data meets the Poisson model form. The Pearson and deviance statistics are the weighted sum of residuals and are approximately chi-squared distributed with n - k degrees of freedom, where n is the sample size and k is the number of parameters (Cameron & Trivedi, 1998, pp. 151–153).

The Pearson statistic, for the model of y_i with mean μ_i and variance ω_i is as follows:

$$\boldsymbol{P} = \sum (y_i - \hat{\mu}_i)^2 / \hat{\omega}_i,$$

where $\hat{\mu}_i$ and $\hat{\omega}_i$ are estimates of μ_i and ω_i. For the Poisson model, where mean and variance are equal, this amounts to:

$$\boldsymbol{P_P} = \sum (y_i - \hat{\mu}_i)^2 / \hat{\mu}_i.$$

The deviance statistic for the Poisson model is as follows:

$$\boldsymbol{D_P} = \sum \{ y_i \ln(y_i / \mu_i) - (y_i - \mu_i) \},$$

where $y\ln y = 0$ if $y = 0$. When an intercept is included (as the model in this study does) and the exponential mean function is used, the Poisson residuals sum to zero, the G-squared statistic $\boldsymbol{D_P}$ can be calculated with $\sum y_i \ln (y_i / \hat{\mu}_i)$.

The χ^2 goodness-of-fit test is a generalisation of the Pearson statistics to compare fitted probabilities with actual frequencies (that is, the ascribed model), comparing observed and expected predicted probabilities for each count (Cameron & Trivedi, 1998, pp. 155–156). If the χ^2 goodness-of-fit tests for both the Pearson and the deviance statistics are insignificant, the null hypothesis of the dependent variable having a Poisson distribution is accepted.

Interpreting regression results for Poisson models differs from linear regression models. Given the exponential conditional mean,

$$E[\, y \mid \mathbf{x} \,] = \exp(\mathbf{x}`\boldsymbol{\beta}),$$

that on differentiation becomes,

$$\partial E[y \mid \mathbf{x}] / \partial x_j = = \boldsymbol{\beta}_j \ \exp(x_i{'}\boldsymbol{\beta}).$$

In effect, the coefficient $\boldsymbol{\beta}_j$ equals the proportionate change in the conditional mean if the *j*th regressor changes by one unit (Cameron & Trivedi, 1998, pp. 80–82). This can be obtained by differentiating $\ln E[\, y \mid \mathbf{x} \,] = (\mathbf{x}`\boldsymbol{\beta})$ with respect to **x**.

The logistic regression model will also be assessed with a Pearson χ^2 goodness-of-fit test. Output coefficients of independent variables represent an increase in log-count for the binary dependent variable equalling one from zero. Robust standard errors, z-scores, p-values and 95% confidence intervals are also generated in the output.

5. Data

The Bangladesh Poverty and Groundwater Salinity Survey 2017 surveyed 1502 households with 7047 individual respondents, which was divided into two datasets. There were 29 individual-level variables and 240 household-level variables to work with. The datasets were merged, and after cleaning missing responses for the variables used in the study model, 6062 observations remained at the individual level from 1438 households. The wealth index was generated from 15 asset-related variables that were coded to be binary.

The survey covered three subdistricts in southwest coastal Bangladesh:

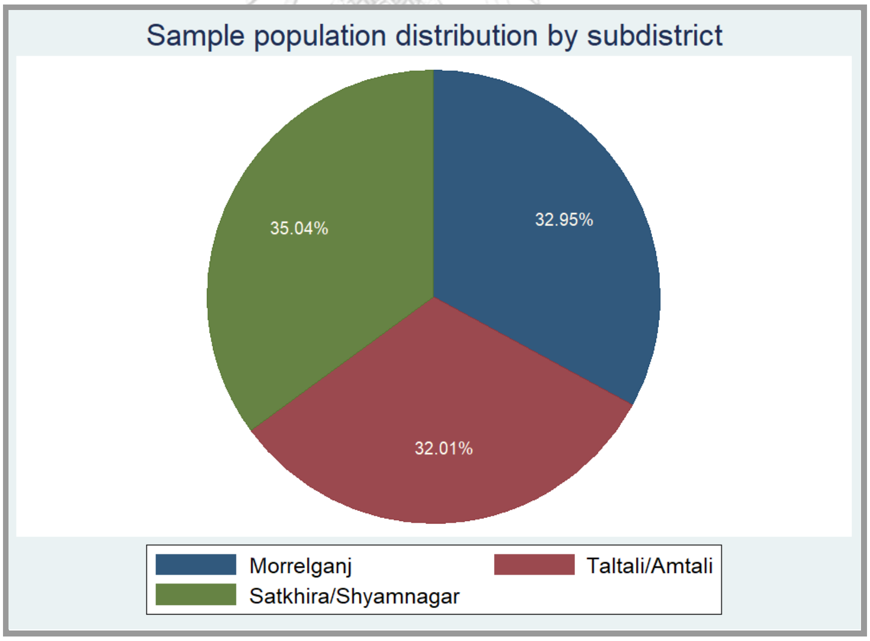
(i) Taltali subdistrict, Barguna district, Barisal division, 32.01% of participants;

(ii) Morrelganj subdistrict, in Bagerhat district, Khulna division, 32.95% of participants;

(iii) Shyamnagar subdistrict, Satkhira district, Khulna division, 35.04% of participants.

The poverty rate in Bangladesh is determined on the division level (i.e., the highest administrative level) and differs for urban and rural areas. In the early stages of the survey, five variables were used to predict households' per capita expenditure and poverty status: household size, number of rooms in dwelling, refrigerator ownership, at least one bicycle owned, and ownership of at least one fan. The households within each of the 50 primary sampling units across the three subdistricts were then sorted from richest to poorest according to these predictions. Using systematic equal probability sampling, five households were selected from "poor" and "non-poor" subgroups. Under the survey's sampling design, the "poor" were oversampled, as the subdistricts in question have poverty rates of under 50% (according to the 2010 Bangladesh Poverty Maps) and the "poor" subdistricts, Morrelganj and Shyamnagar, make up 68.45% of participants. Given the focus of this study and the fact that there is sufficient data at hand to compile a wealth index, the categorisation made by the survey for "poor" and "non-poor" are both redundant and do not contribute any additional information. The focus of this study is the health-wealth gradient as it pertains to hypertension caused by groundwater salinity, and the data collected by the Bangladesh Poverty and Groundwater Salinity Survey 2016 is sufficient to determine that relationship.

Figure 4: Respondents' location in the three subdistricts



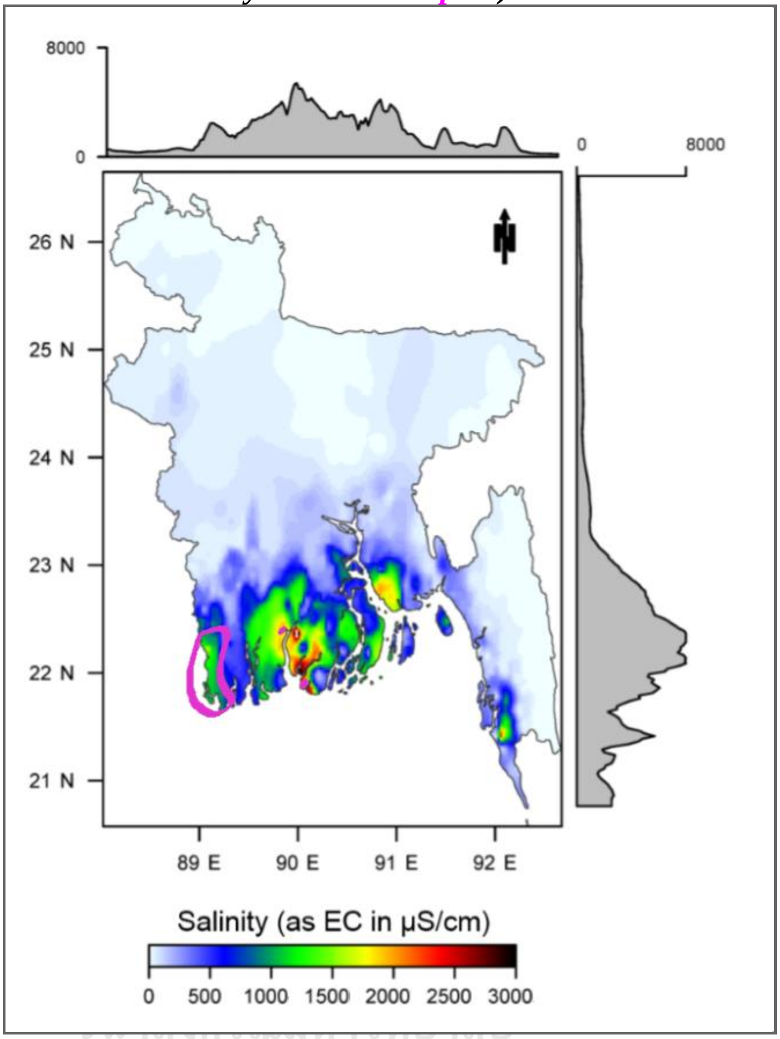
Among the subdistricts, Taltali had the lowest percentage (24.33%) of respondents who said their water source was saline.

Table 9: Salinity contamination by subdistrict

	Salinity contamination		
Upazila	0	1	Total
Morrelganj	746	1,253	1,999
	37.32%	62.68%	100%
Taltali/Amtali	1,477	465	1,942
	76.06%	23.94%	100%
Shyamnagar	1,289	837	2,126
	60.63%	39.37%	100
Total	3,512	2,555	6,067
	57.89%	42.11%	100

The salinity levels of each subdistrict were not specified in the World Bank Microdata Library. The sampling design selected coastal subdistricts based on salinity information from the Bangladesh Water Development Board and the Institute of Water Modelling (IWM). Specific salinity information is found in a working paper for the World Bank Group's Water Global Practice that looks into groundwater risks to drinking water supply across Bangladesh (Shamsudduha et al., 2019).

Map 4: Bangladesh's groundwater salinity by electric conductivity (subdistricts surveyed marked in pink)



Source: World Bank Group, 2009.

In the map, Shyamnagar subdistrict is both the largest (as mentioned in the introduction), and has the lowest groundwater salinity with electric conductivity ranging 1000-1250µS/cm. Morrelganj has 1800µS/cm and Taltali has 2000µS/cm. Easily, we can see that Morrelganj and Taltali have higher salinity in groundwater, with Taltali almost doubling some areas of Shyamnagar. The same study uses a ratio of 0.65 for electric conductivity to dissolved solids, giving Shyamnagar approximately 650-813mg/L, Morrelganj 1170mg/L and Taltali 1300mg/L

(Shamsudduha et al., 2019). The latter two subdistricts close to double the thresholds set by the WHO for safe and palatable drinking water, while Shyamnagar is only slightly above the recommended 600mg/L. These salinity values are averaged across seasons.

Table 10: Hypertension diagnosis against hypertension symptoms

	Presence of hypertension symptoms		
Diagnosed with high blood pressure by a doctor or nurse	Yes	No	Total
No	2,045	3,444	5,489
	37.26%	62.74%	100%
Yes	430	148	578
	74.39%	25.61%	100%
Total	2,475	3,592	6,067
	40.79%	59.21%	100%

From the data, we can see that while 59.21% of the sample population do not have hypertension symptoms, 25.61% of that subsample do have a diagnosis for hypertension. This could be because they received treatment. What is also of note is of the 40.79% who do have one of the four symptoms, 37.26% of the subsample have not been diagnosed by a healthcare provider as having hypertension.

Outcome variable: hypertension symptoms

The survey framed the question "Have you suffered from any of the following health problems in the past 2 weeks?" with five possible options:

1. Severe headaches
2. Nosebleeds
3. Severe anxiety
4. Shortness of breath
5. None of these problems.

The responses for the 6,067 responses in the cleaned dataset were as follows:

Table 11: Self-reported symptoms among sample population

Symptoms	Frequency	Percentage	Cumulative %
None of the problems	3,592	59.21	59.21
Severe headaches	1,018	16.78	75.98
Severe headaches and nosebleeds	2	0.03	76.02
Severe headaches, nosebleeds and severe anxiety	2	0.03	76.05
All four symptoms	1	0.02	76.07
Severe headaches, nosebleeds and shortness of breath	2	0.03	76.1
Severe headaches and shortness of breath	598	9.86	85.96
severe headaches, severe anxiety and shortness of breath	97	1.6	87.56
Severe headaches and shortness of breath	128	2.11	89.67

Nosebleeds	6	0.1	89.76
Nosebleeds and severe anxiety	1	0.02	89.78
Nosebleeds and shortness of breath	1	0.02	89.8
Severe anxiety	359	5.92	95.71
Severe anxiety and shortness of breath	37	0.61	96.32
Shortness of breath	223	3.68	100

The majority of respondents, 59.21% had no symptoms. Of the remainder, severe headaches were the most common symptom, with 16.78% having headaches alone and a total of 13.68% having severe headaches together with at least one other symptom. Severe anxiety was the second most common single symptom, with 5.92% of respondents reporting that they experienced it and a total of 12.13% having severe anxiety with another symptom.

Shortness of breath was experienced by 8.06% of respondents, and nosebleeds were the least common symptom, experienced by 15 people in total.

When totalling the binary responses for each symptom, a variable that is at least 0 and at most four in value is created for regression analysis. As the presence of a symptom can only be an integer, this means there are only five unique values for the dependent variable in this study: 0-4.

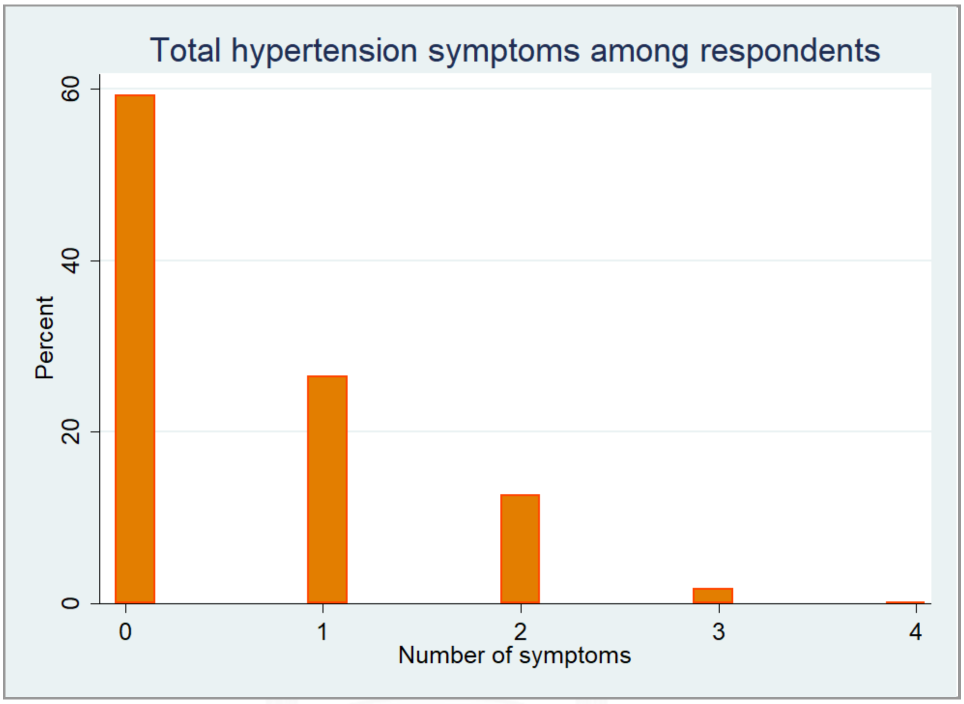
Table 12: Frequency of symptom(s) presence

Number of symptoms	Frequency	Percentage
0	3592	59.21%
1	1606	26.47%
2	767	12.64%

3	101	1.66%
4	4	0.066%

This can also be represented in a histogram:

Figure 5: Number of symptoms among respondents

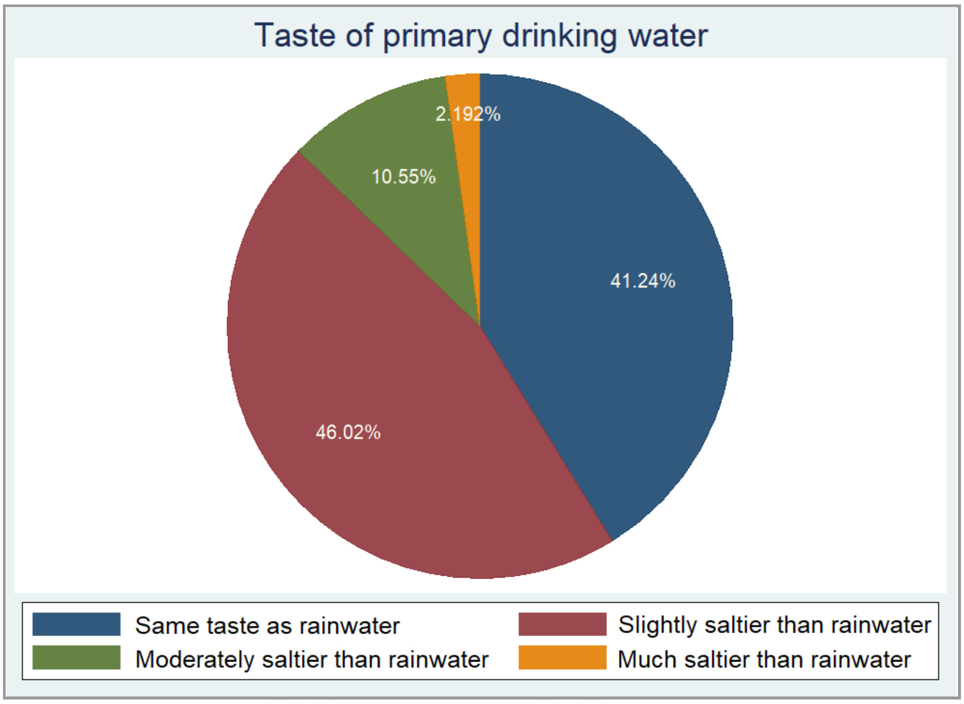


Explanatory variables

Taste of drinking water

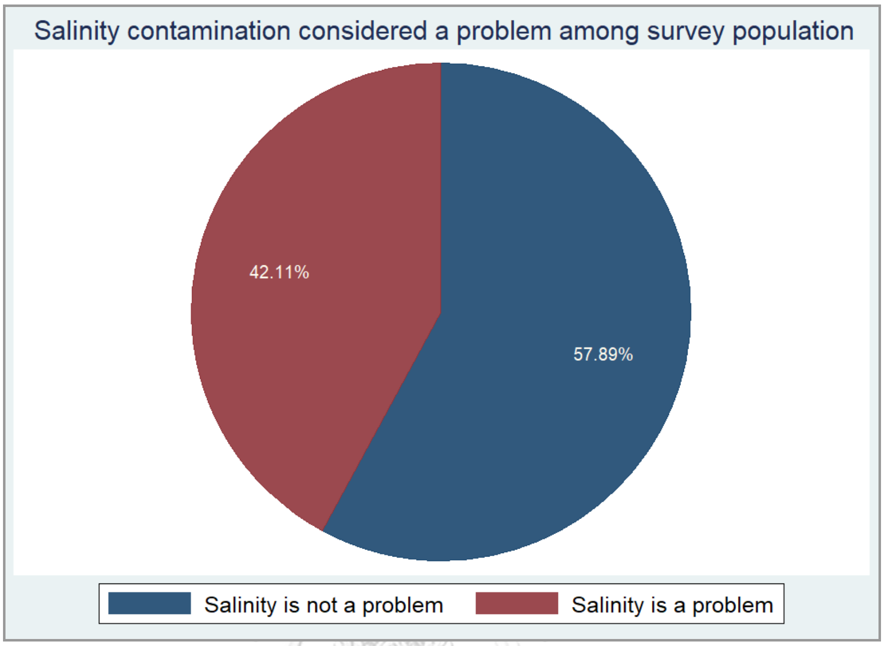
Respondents were asked to describe the taste of their drinking water, with four options for answers. In the model, "same taste as rainwater", which 41.24% of respondents experienced was the reference case. The other three options of varying levels of salinity are included as binary variables in the regression model. The most popular response was "moderately saltier than rainwater". Previous literature has indicated that low-salinity drinking water is associated with lower levels of blood pressure and hypertension. The literature mostly indicates that drinking water that is "much saltier" than rainwater will cause negative health impacts. In this sample, 2.19% of respondents say their water tastes highly saline.

Figure 6: Subjective description of drinking water taste



Salinity contamination

Figure 7: Pie chart for self-reported salinity contamination



In the sample population, 42.11% reported that their water source had salinity contamination. This was in response to the survey question “what are the top three problems you find in your drinking water service quality?”. In the cleaned dataset, 1,839 respondents (30.31%) reported no problems. The most popular water problem was “funny taste, smell or colour”, which 45.92% of participants reported.

Table 13: Crosstab of salinity contamination and drinking water taste

	Taste of primary drinking water				
Salinity contamination is a problem	Same as rainwater	Slightly saline	Moderately saline	Highly saline	Total
0	2,188	1,181	122	21	3,512
	62.30%	33.63%	3.47%	0.60%	100%
1	314	1,611	518	112	2,555
	12.29%	63.05%	20.27%	4.38%	100%
Total	2,502	2,792	640	133	6,067
	41.24%	46.02%	10.55%	2.19%	100%

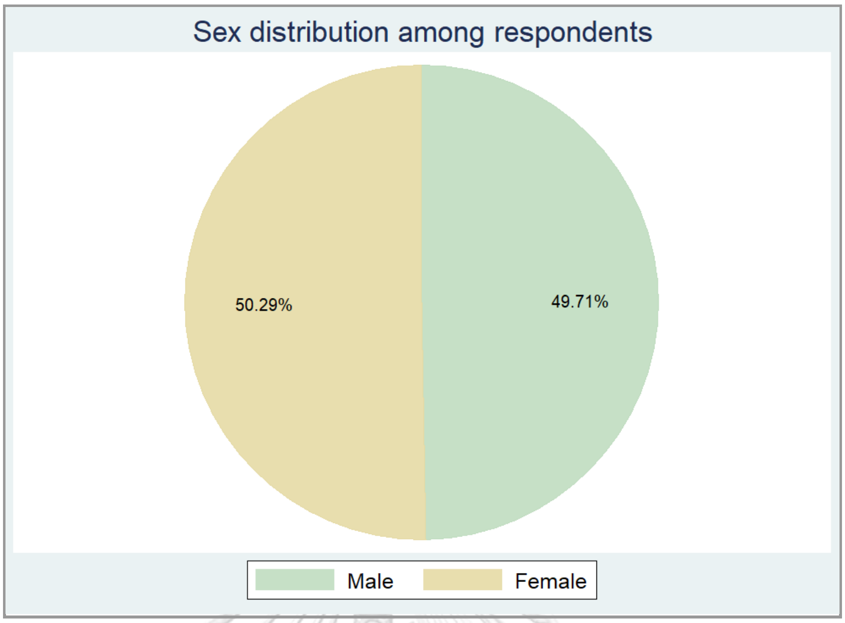
Participant age

The mean age of participants in the cleaned dataset was 30.63 years, with the youngest 130 being five years of age and the oldest 14 registering at the upper limits of 99 years. The standard deviation was 19.04 years and the most common age was 35 years of age, which 308 respondents said they were (5.08%).

Participant sex

The questionnaire allowed only for “male” and “female” as respondent options. There were 3016 male respondents and 3,051 female respondents, making up 49.71% and 50.29%, respectively.

Figure 8: Pie chart for sex distribution

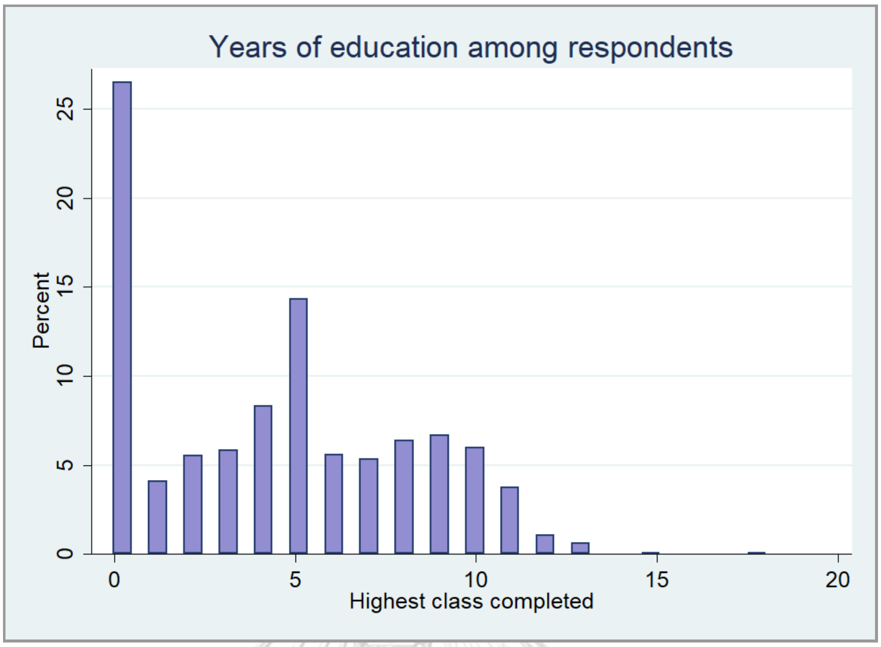


Education

The survey questionnaire asked individual respondents "What is the highest class that you completed?'. For options such as "Nursing" or "SSC/Equivalent" the value was replaced with years. Nursing school in Bangladesh lasts for three years and a secondary school certificate is required for entry. The values for "Graduate", "Post graduate", "Medical", "Engineering" were similarly replaced with integers for years. Participants who did not know how many years of education they had were dropped from the dataset.

The average for years of education was 4.42. The most frequent response was no education, which 26.50% of participants had. The next most frequent education level was "Class 5" or five years of education, which 14.31% of the sample population had. The maximum years of education were 18, which two respondents had.

Figure 9: Histogram for respondent education level

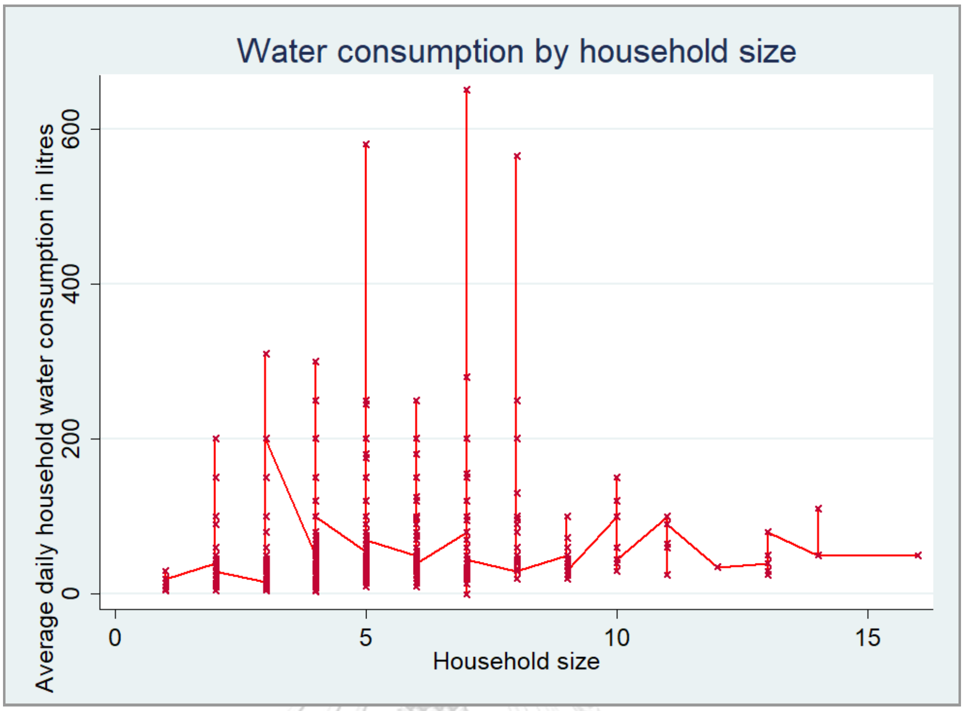


Water consumption per person

The responses for the question "On average, how much water does your household consume daily?" was recorded in litres. The average consumption was 49.318 litres. The most common answer was 30 litres, the response for 18.92% of participants. The standard deviation was 48.605 litres. Oddly enough, six respondents (0.1%) came from households where the response was zero litres, while another six respondents reported consuming 650 litres per day.

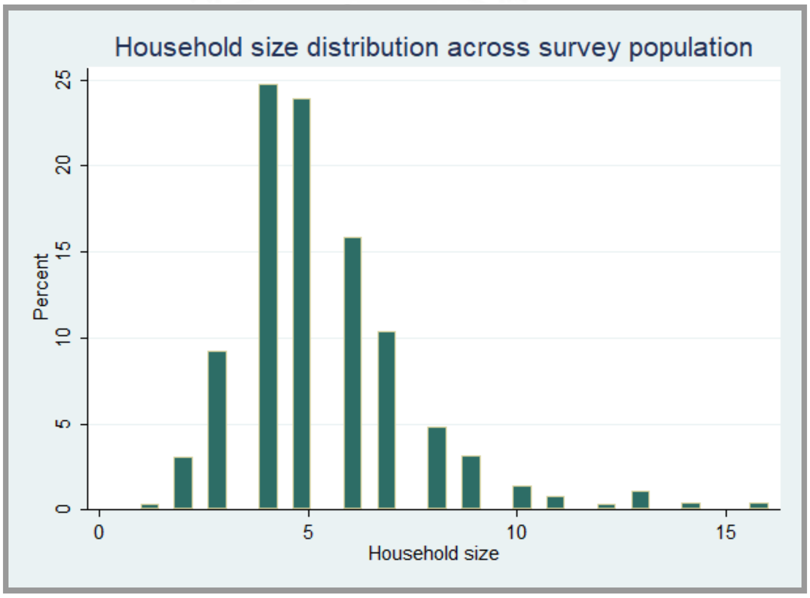
To be able to gauge the impact of water consumption per person on the presence of hypertension symptoms, average household water consumption is divided by household size to create a per person water consumption value. The resulting variable has an average of 9.75 litres, with the most frequent consumption at five litres per person per day (12.94%).

Figure 10: Scatterplot of average water consumption (litres) and household size



Household size was determined by the number of people living in the same residence who eat together:

Figure 11: Histogram for headcount in households



As the histogram shows, the most common household size was four individuals per home, closely followed by five individuals per home. For the cleaned dataset, the mean household size was 5.4 people, with a standard deviation of 2.15.

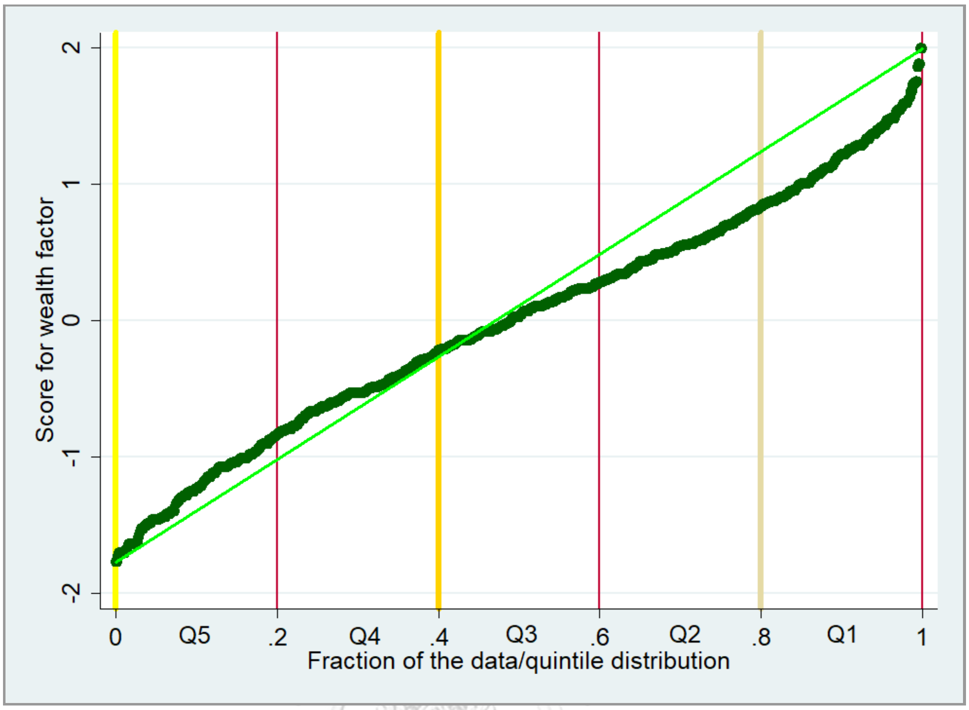
Distance to water source

For the question “How far (distance) does it take to go to your main drinking water source, get water, and come back?”, 86.43% of respondents gave their answers in feet and 13.57% gave their answer in miles. The values given in miles were converted to feet. This created a mean distance of 6020.5 feet to get water (answers were registered on a household basis, with the smallest distance being zero and the farthest coming to 2.64 million feet (converted from 500 miles). The most common distance was 200 feet, which is the distance 6.12% of participants need to travel to get drinking water. The standard deviation for this variable was 107,771, which is likely to create a poorly-fitted model. To this end, the natural logarithm of the variable is taken. Otherwise the relationship with the dependent variable becomes close to exponential.

Wealth quintiles

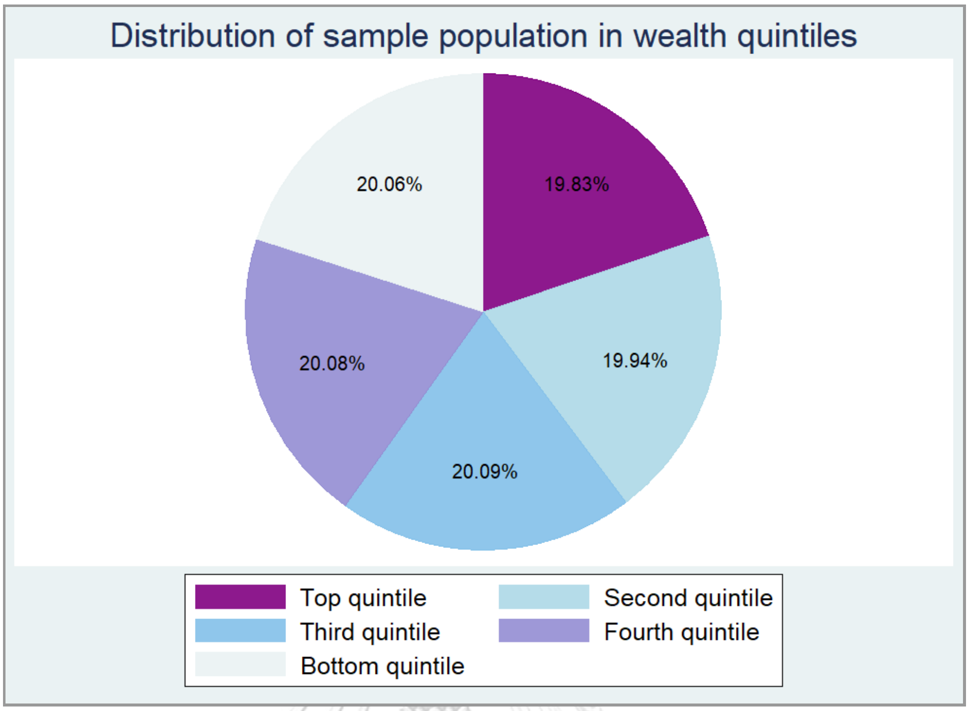
With the top quintile as the reference case for the model, the remaining four quintiles are dummy variables. Each quintile represents approximately 1200 people. The wealth factor ranges in value from -1.771 to 1.991 and has a mean of $-7.80e^{-10}$. The standard deviation is 0.8798. A graph of the factor shows an upward-sloping curve.

Figure 12: Wealth factor score across quintiles



Dummy variables for each quintile were generated, resulting in one non-zero quintile value for each individual in the sample.

Figure 13: Percentage of respondents in each wealth quintile



6. Results

6.1. Poisson regression output

To determine the relationship between self-reported salinity contamination and the prevalence of hypertension symptoms across different wealth quintiles, the coefficients of the independent variables in the model have coefficients that are also interpreted in terms of incidence rate ratios (IRRs). The reference case was Shyamnagar district and the wealthiest quintile. More precisely, the males from the wealthiest quintile in Shyamnagar district who say their drinking water tastes like rainwater and do not have salinity contamination as a problem for their drinking water.

Table 14: Poisson regression output, IRR and conditional marginal effects

					Number of obs = 6062	
Log pseudolikelihood = -5548.5259					Wald $\chi2(15)$ = 1435.55	
					Prob > $\chi2$ = 0	
					Pseudo R2 = 0.0916	
	Coefficient	Robust standard errors for coefficient	**IRR**	Robust standard errors, IRR	**Conditional marginal effects**	Delta method standard errors
Water tastes slightly saline***	**-0.205**	0.040	**0.814**	0.033	**-0.100**	0.020
Water tastes moderately saline***	**-0.579**	0.067	**0.560**	0.037	**-0.282**	0.032
Water tastes very saline***	**0.416**	0.087	**1.516**	0.132	**0.203**	0.043
Salinity contamination***	**0.153**	0.040	**1.166**	0.046	**0.075**	0.019

age***	**0.024**	0.001	**1.025**	0.001	**0.012**	0.000
Female***	**0.404**	0.034	**1.498**	0.050	**0.197**	0.016
Years of education***	**0.019**	0.005	**1.019**	0.005	**0.009**	0.002
Average water consumption per person***	**0.008**	0.002	**1.008**	0.002	**0.004**	0.001
Distance to get drinking water***	**0.037**	0.007	**1.037**	0.007	**0.018**	0.003
Second quintile*	**0.091**	0.052	**1.095**	0.057	**0.044**	0.025
Third quintile**	**0.118**	0.053	**1.126**	0.059	**0.058**	0.026
Fourth quintile***	**0.134**	0.054	**1.144**	0.061	**0.065**	0.026
Fifth quintile***	**0.221**	0.057	**1.247**	0.071	**0.107**	0.028
Morrelganj subdistrict***	**0.125**	0.040	**1.133**	0.046	**0.061**	0.020
Taltali subdistrict***	**-0.183**	0.047	**0.832**	0.039	**-0.089**	0.023
constant	**-2.038**	0.089	**0.130**	0.012	•	•
(***significant at 1%; **significant at 5%, *significant at 10%)						

Salinity contamination

The results show that for the entire sample population an increase of salinity contamination results in an increase in the number of hypertension symptoms by a factor of 1.165 compared with the reference case of no salinity contamination; every response of salinity contamination entails 16.5% more hypertension symptoms. The average predicted number of symptoms resulting from salinity contamination, holding all variables at their means, is 0.0747, or 7.47% more.

Drinking water taste

Water that tastes slightly saline and moderately saline see a decrease in the number of salinity symptoms by factors of 0.814 and 0.560, respectively. The average predicted number of symptoms resulting from water tasting mildly saline or moderately saline when compared with the reference case of water that tastes like rainwater is 10% and 28.21% fewer, respectively.

Age

The incidence rate ratio for years in age among respondents is 1.024, meaning that for every year a participant ages their symptoms rise by 2.4%. The predicted number of symptoms resulting from each year of age, holding all other variables at their means is 0.0118, or 1.18%.

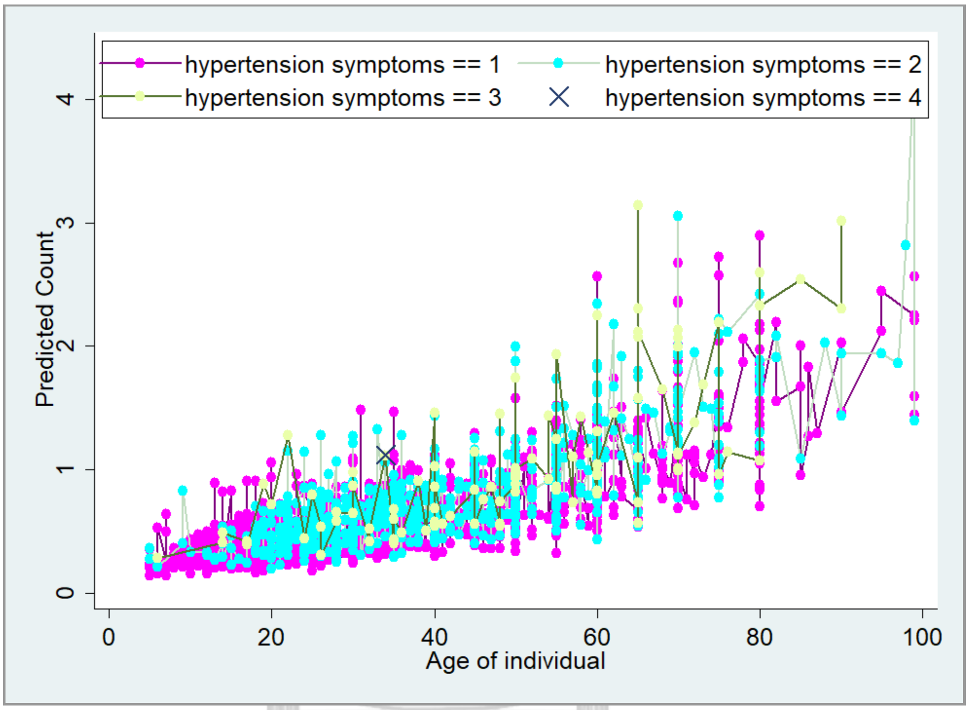
To take a better look at the breakdown among adults, the observed values for hypertension symptoms from age 18 to age 98 are held at 10-year intervals for all observations to isolate the average predicted counts:

Table 15: The marginal effect from age 18-98 at 10-year intervals

age	Margin	Delta method standard errors
18	0.377	0.009
28	0.481	0.009
38	0.612	0.010
48	0.780	0.014
58	0.995	0.022
68	1.267	0.036
78	1.615	0.056
88	2.058	0.086
98	2.622	0.129

As expected, the average predicted count increases with age, with people from age 58 and above having one or more symptoms of hypertension and the number of hypertension symptoms predicted to rise with age.

Figure 14: Predicted counts for hypertension symptoms by age



Sex

Being a female increases the incidence of hypertension symptoms by 1.498 times, with the predicted number of symptoms that occur when a respondent is female, when holding all other variables at their means, is 0.1969 or 19.69%. This is expected, as Nahian et al (2018) found in their research of the same general coastal area that females had greater prevalence of hypertension (not symptoms) by 31% compared with men.

Education

The IRR for education is 1.0194, which means every year of education increases the number of hypertension symptoms by 1.94%. The predicted number of symptoms for every additional year of education is 0.0094 or 0.94%. This echoes the trend found by Nahian et al. (2018), where overall increases in years of education resulted in greater hypertension or prehypertension.

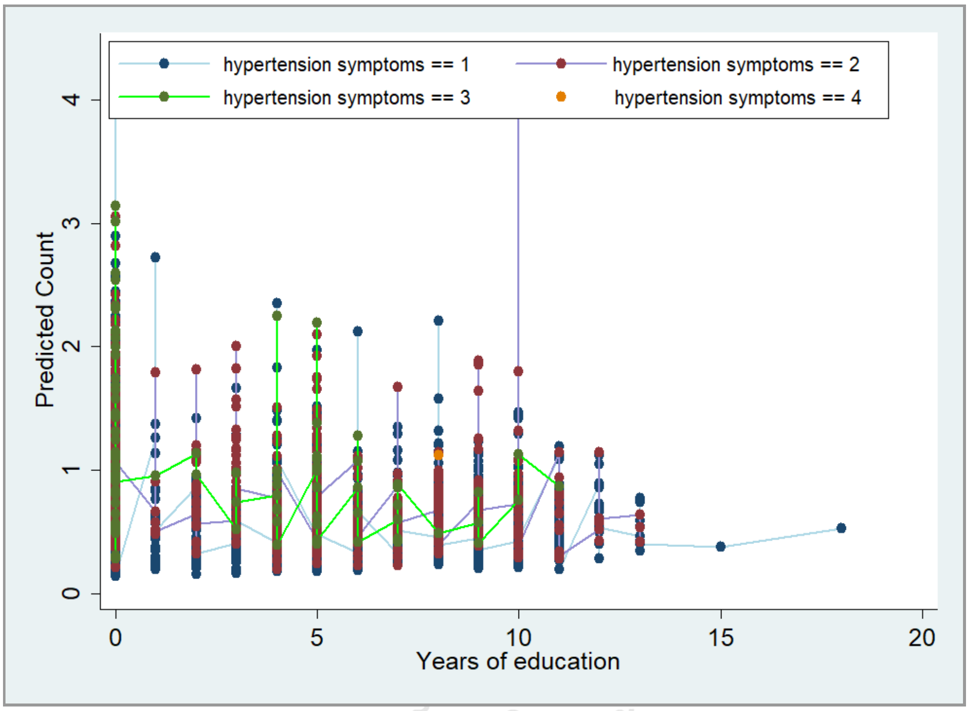
A better understanding of the observed values for hypertension symptoms for different educational attainment, years of education are held at five-year intervals for all observations to isolate the average predicted counts for no education (zero years), primary education (five years), high school education (10 years) and university education (15 years).

Table 15: Predicted counts for symptoms for stages of education

Years of education	Margin	Delta-method standard errors
0	0.527	0.013
5	0.580	0.010
10	0.639	0.021
15	0.703	0.039

The results show that the predicted counts for hypertension symptoms rise with years of education, albeit those with no education and those with primary education having very close average predicted counts at 0.53 and 0.58, respectively. The two-way scatterplot indicates further insight: the uneducated have a high concentration of people with three hypertension symptoms, while people with two symptoms become more common as education attainment increases, along with one symptom. This explains what would otherwise be an unexpected trend.

Figure 15: Predicted symptom counts by education attainment



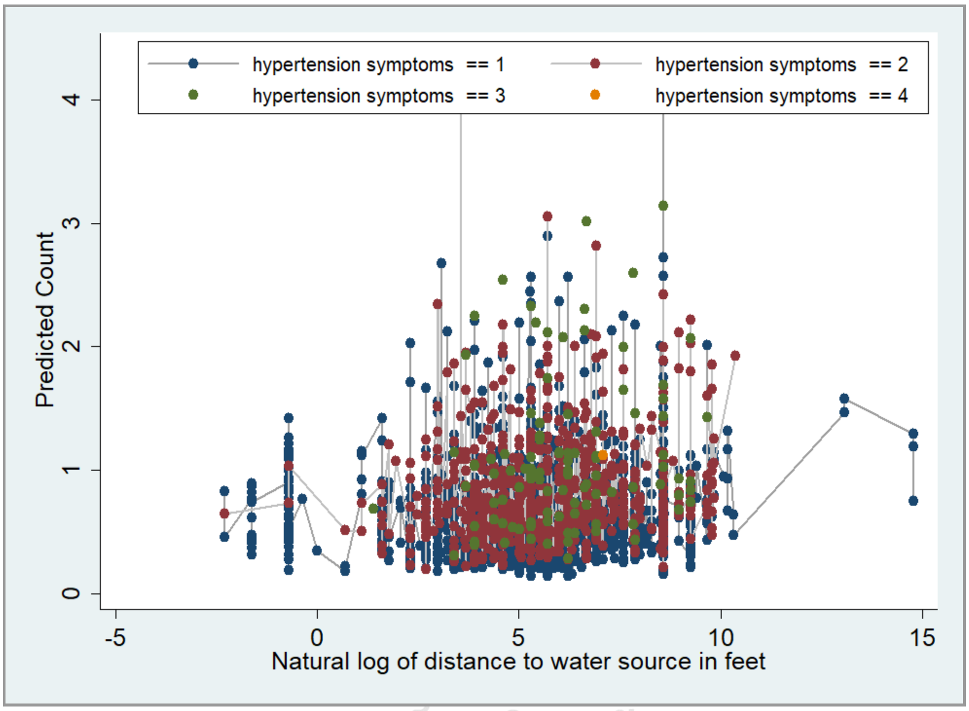
Water consumption

Every litre of water consumed increased the incidence of hypertension symptoms by a factor of 1.0077, or 0.77%. The predicted number of symptoms for litre of water drunk when holding all other variables at their means is 0.37% more. This indicates that on average the water being drunk by participants has a level of salinity that is contributing to hypertension symptoms

Distance to water source

The IRR of 1.0077 means the logarithm of every foot travelled to access drinking water increases the incidence of hypertension symptoms by 0.7%. Every log of a foot predicts 0.38% more symptoms when all other variables are held at their means.

Figure 16: Predicted symptom counts by log of distance to water source in feet



For the range of values below zero, the most common number of hypertension symptoms is zero. For 0-10, two symptoms become the most common, interspersed with some predicted counts of three symptoms, after which one symptom is the only average predicted count of symptoms.

Second wealth quintile

The IRR for the second quintile is 1.095, implying that being in this wealth group raises the probability of having hypertension symptoms by 9.5% more compared with the reference group of the wealthiest quintile.. With all other variables held at their means, the second quintile predicts 4.42% more symptoms compared with the richest quintile.

Third wealth quintile

The IRR for the third quintile is 1.1256, implying that being in this wealth group raises the probability of having hypertension symptoms by 12.56% compared with the reference group of the wealthiest quintile. With all other variables held at their means, the third quintile predicts 5.77% greater probability of hypertension symptoms in this population sample.

Fourth wealth quintile

The IRR for the fourth quintile is 1.1436, implying that being in this wealth group raises the probability of having hypertension symptoms by 14.36% compared with the reference group of the wealthiest quintile.. With all other variables held at their means, the fourth quintile predicts 6.54% greater probability of hypertension symptoms in this population sample.

Fifth wealth quintile

The IRR for the third quintile is 1.2468, implying that being in this wealth group raises the probability of having hypertension symptoms by 24.68% compared with the reference group of the wealthiest quintile.. With all other variables held at their means, being in the poorest quintile predicts 10.75% more hypertension symptoms in this population sample compared with the reference group of the top quintile.

Subdistrict dummy variables

With Shyamnagar district as the reference case, Morrelganj had an IRR of 1.1329 and Taltali had an IRR of 0.8325. This means being in Taltali reduced the probability of a respondent having hypertension symptoms by 16.75% and being in Morrelganj increased the probability by 11.2%. Being a resident of Taltali predicts 8.93% fewer symptoms, while being a resident of Morrelganj predicts 6.08% more hypertension symptoms.

Including interaction terms for wealth and salinity contamination

The initial model for this study was:

log(hypertension symptoms) = $\boldsymbol{\beta}_0$ + $\boldsymbol{\beta}_1$(water tastes slightly saline) + $\boldsymbol{\beta}_2$(water tastes moderately saline) + $\boldsymbol{\beta}_3$(water tastes very saline) + $\boldsymbol{\beta}_4$(respondent is female) +$\boldsymbol{\beta}_5$(age) + $\boldsymbol{\beta}_6$(years of education) + $\boldsymbol{\beta}_7$(salinity contamination is a problem) + $\boldsymbol{\beta}_8$(water consumption in litres per person) + $\boldsymbol{\beta}_9$(natural log of distance to water distance in feet) + $\boldsymbol{\beta}_{10}$(dummy variable for Q_2) + $\boldsymbol{\beta}_{11}$(dummy variable for Q_3) + $\boldsymbol{\beta}_{12}$(dummy variable for Q_4) + $\boldsymbol{\beta}_{13}$(dummy variable for Q_5) + $\boldsymbol{\beta}_{14}$(dummy variable for Taltali) + $\boldsymbol{\beta}_{15}$(dummy variable for Morrelganj)

The inclusion of interaction terms to capture the relation and relative impact of wealth and salinity contamination within the model requires the addition of four interaction terms (one for each quintile):

log(hypertension symptoms) = β_0 + β_1(water tastes slightly saline) + β_2(water tastes moderately saline) + β_3(water tastes very saline) + β_4(respondent is female) +β_5(age) + β_6(years of education) + β_7(salinity contamination is a problem) + β_8(water consumption in litres per person) + β_9(natural log of distance to water distance in feet) + β_{10}(dummy variable for Q_2) + β_{11}(dummy variable for Q_3) + β_{12}(dummy variable for Q_4) + β_{13}(dummy variable for Q_5) + β_{14}(dummy variable for Taltali) + β_{15}(dummy variable for Morrelganj) + β_{16}(interaction term for salinity contamination and Q_2) + β_{16}(interaction term for salinity contamination and Q_3) + β_{16}(interaction term for salinity contamination and Q_4) + β_{16}(interaction term for salinity contamination and Q_5)

Table 16: Poisson regression with interactions output IRR and conditional marginal effects

					Number of obs = 6062	
		Log pseudolikelihood = -5541.7913			Wald χ2(19) = 1476.72	
					Prob > χ2 = 0.0000	
					Pseudo R2 = 0.0927	
hypertension symptoms	Coefficient	Robust standard errors for coefficient	Incidence rate ratio	Robust standard errors, IRR	Average marginal effects	Delta-method standard errors
Water tastes slightly saline***	-0.202	0.040	0.817	0.033	-0.098	0.020
Water tastes moderately saline***	-0.566	0.067	0.568	0.038	-0.275	0.032

Water tastes very saline***	0.437	0.087	1.548	0.134	0.212	0.042
Salinity contamination	-0.075	0.080	0.928	0.075	-0.036	0.039
age***	0.024	0.001	1.025	0.001	0.012	0.000
Female***	0.404	0.033	1.498	0.050	0.197	0.016
Years of education***	0.020	0.005	1.020	0.005	0.010	0.002
Average water consumption per person***	0.008	0.002	1.008	0.002	0.004	0.001
Distance to get drinking water***	0.037	0.007	1.038	0.007	0.018	0.003
Second quintile	-0.009	0.061	0.991	0.061	-0.005	0.030
Third quintile	0.048	0.069	1.049	0.072	0.023	0.033
Fourth quintile	-0.009	0.069	0.991	0.069	-0.004	0.034
Fifth quintile*	0.133	0.071	1.142	0.081	0.065	0.034
Morrelganj subdistrict***	0.118	0.040	1.125	0.046	0.057	0.020
Taltali subdistrict***	-0.187	0.047	0.830	0.039	-0.091	0.023
Interaction Q2 and salinity contamination***	0.292	0.094	1.339	0.126	0.142	0.046
Interaction Q3 and salinity contamination**	0.207	0.100	1.230	0.123	0.101	0.048
Interaction Q4 and salinity contamination***	0.365	0.102	1.440	0.147	0.177	0.050
Interaction Q5 and salinity contamination**	0.235	0.108	1.265	0.136	0.114	0.052
_constant	-1.962	0.092	0.141	0.013	•	•

(***significant at 1%; **significant at 5%, *significant at 10%)		

For this output, the focus is on salinity contamination, the wealth quintiles and the interaction terms that have been added. The first major observation is that the coefficient for salinity contamination goes from positive in the first Poisson regression to negative with the addition of interaction terms. This is interpreted as 7.2% *fewer* hypertension symptoms in the event of respondents having the problem of salinity contamination with their water compared with the reference case. This, of course, is highly unexpected given the hypotheses of these studies and the context the literature reviewed have established. However this, as well as the marginal effect of 3.64% fewer predicted symptoms, are statistically insignificant.

When looking at the output for the wealth quintiles, the inclusion of interaction terms makes the first three wealth quintiles statistically insignificant and the fifth (poorest) wealth quintile statistically significant only within the 90% confidence interval. The second and fourth wealth quintiles bear negative coefficients, entailing that people in these quintiles have lower incidence of hypertension symptoms by 0.009% and 0.008%, respectively. The marginal effects come out to 0.46% and 0.42% fewer predicted symptoms, respectively. The third quintile is also statistically insignificant, bearing an incidence of 4.9% more symptoms than the reference case and a marginal effect of 2.33% more predicted symptoms. The only statistically significant quintile is the poorest quintile, with an incidence of 14.21% more symptoms and a marginal effect of 6.46% more predicted symptoms than the reference case.

The interaction terms all pass the 5% significance threshold. The interaction term for the fourth quintile has the largest incidence of 43.99% more symptoms and a marginal effect of 17.73% more predicted symptoms compared with the reference case. This is followed by the second quintile with 33.9% more incidence and 14.19% more predicted symptoms. The poorest (fifth) quintile sees 26.53% more incidence and 11.44% more predicted symptoms. The interaction term with the lowest magnitude is the third quintile, which has an incidence of 23.03% more symptoms and a marginal effect of 10.08% more predicted symptoms.

The cumulative interaction between salinity contamination and wealth quintiles from is calculated using the following template:

$$Q_x = [\partial\, E(number\ of\ symptoms)]/[\partial[salinity\ contamination]$$

$$= (\beta_7)\ \cdot e^{(\beta 0\ +\ \beta 7\ +\ \beta quintile\ +\ \beta interaction\ term)},$$

Where Q_x is a quintile, β_0 is the constant (-1.962), β_7 is the coefficient for salinity contamination (-0.0748), $\beta_{quintile}$ is the coefficient for the quintile at hand and $\beta_{interaction\ term}$ is the coefficient for the interaction term at hand. This yields the following cumulative effects:

Q_2 = -0.012942733

Q_3 = -0.012589519

Q_4 = -0.013929444

Q_5 = -0.014100106.

This means the cumulative effect for people being in the second quintile and having salinity contamination on hypertension symptoms is 1.29% fewer symptoms.

For the third quintile the effect is 1.26% fewer symptoms, the fourth quintile is 1.39% fewer symptoms and the poorest quintile sees 1.41% fewer symptoms when accounting for the interaction between wealth and salinity contamination.

6.2. Logistic subsample regressions

Hypertension diagnosis and each of the four symptoms can be modelled as binary dependent variables to further explore the impact of wealth in the form of dummy variables for quintiles as well as other independent variables. This entails five separate logistic regressions.

Logistic regression output for hypertension diagnosis

Out of all respondents, 578 (9.53%) were diagnosed by a medical professional with hypertension.

Table 18: Logistic regression output OR and conditional marginal effects for hypertension diagnoses

Number of observations = 6062		LR $\chi2(15)$ = 643.13	Prob > $\chi2$ = 0.0000	Log likelihood = -1586.3847	Pseudo R2 = 0.1685	
	Coefficient	Standard errors for coefficient	Odds ratio	Standard errors for odds ratio	Average marginal effects	Delta-method standard errors
Water tastes slightly saline*	0.218	0.119	1.244	0.148	0.012	0.007

Water tastes moderately saline	0.211	0.178	1.235	0.220	0.012	0.010
Water tastes very saline***	1.327	0.273	3.769	1.028	0.075	0.016
Salinity contamination	0.065	0.116	1.067	0.124	0.004	0.007
age***	0.055	0.003	1.057	0.003	0.003	0.000
Female***	0.462	0.098	1.587	0.155	0.026	0.005
Years of education***	0.048	0.014	1.049	0.015	0.003	0.001
Average water consumption per person***	-0.003	0.006	0.997	0.006	0.000	0.000
Distance to get drinking water***	0.072	0.022	1.075	0.024	0.004	0.001
Second quintile**	-0.347	0.150	0.707	0.106	-0.020	0.009
Third quintile	-0.040	0.147	0.961	0.141	-0.002	0.008
Fourth quintile	-0.112	0.152	0.894	0.136	-0.006	0.009
Fifth quintile	0.108	0.154	1.114	0.171	0.006	0.009
Morrelganj subdistrict***	-0.299	0.116	0.742	0.086	-0.017	0.007
Taltali subdistrict***	-0.610	0.135	0.543	0.073	-0.035	0.008
constant	-5.052	0.278	0.006	0.002	•	•
(***significant at 1%; **significant at 5%, *significant at 10%)						

Respondents who say their water tastes mildly saline are 1.24 times more likely to have a hypertension diagnosis than those who say their water tastes like rainwater, but those who say their water tastes highly saline have 3.77 times higher odds of having a hypertension diagnosis. Salinity contamination is not statistically significant, but has an odds ratio of 1.067 more hypertension symptoms than the reference case of no salinity contamination, with a marginal effect of 0.37% greater predicted probability of hypertension symptoms.

A one year increase in age raises the odds of a hypertension diagnosis by 1.057 times and raises the predicted probability by 0.31%. Women have 1.587 greater odds than men of being diagnosed. Every year of education raises the odds of a hypertension diagnosis by 1.049 and the predicted probability by 0.27%. Every litre of water consumed on average reduced the odds of a diagnosis by a factor of 0.997, but while this is statistically significant the marginal effect is only 0.017% less. The natural log of every foot required to travel to the source of drinking water raises the odds of a hypertension diagnosis by 1.075 and has a marginal effect of 0.041% greater probability. The second wealth quintile is the only one that is statistically significant: being in this quintile lowers the odds of being diagnosed with hypertension by a factor of 0.707, with the predicted probability of a hypertension diagnosis falling by 1.97% (when all other variables are held at their means). Unlike the coefficients and marginal effects for the Poisson regression of all symptoms, the marginal effects of the wealth quintiles in this model do not increase in magnitude as wealth decreases. A respondent in Morrelganj district has lower odds by a factor of 0.74 of being diagnosed while a respondent in Taltali has an odds ratio of 0.543 relative to a respondent in Shyamnagar, with marginal effects of 1.7%and 3.47% lower predicted probabilities, respectively.

Logistic regression output for severe headaches

Of all respondents, 1,848 (30.46%) reported to experience severe headaches.

Table 19: Logistic regression output OR and conditional marginal effects for severe headaches

					Number of obs = 6062	
		Log likelihood = -3415.6978			LR $\chi 2(15) = 623.87$	
					Prob > $\chi 2 = 0.000$	
					Pseudo R2 = 0.0837	
Severe headaches	Coefficient	Standard errors for coefficient	Odds ratio	Standard errors for odds ratio	Average marginal effects	Delta-method standard errors
Water tastes slightly saline***	-0.274	0.073	0.760	0.055	-0.056	0.015
Water tastes moderately saline***	-0.646	0.118	0.524	0.062	-0.132	0.024
Water tastes very saline*	0.352	0.198	1.422	0.282	0.072	0.040
Salinity contamination***	0.327	0.073	1.387	0.102	0.067	0.015
age***	0.031	0.002	1.031	0.002	0.006	0.000
Female***	0.847	0.060	2.334	0.141	0.173	0.012
Years of education***	0.031	0.009	1.031	0.009	0.006	0.002

Average water consumption per person	0.004	0.003	1.004	0.003	0.001	0.001
Distance to get drinking water**	0.028	0.014	1.028	0.014	0.006	0.003
Second quintile	0.148	0.094	1.159	0.109	0.030	0.019
Third quintile**	0.213	0.095	1.237	0.117	0.043	0.019
Fourth quintile	0.124	0.096	1.131	0.109	0.025	0.020
Fifth quintile**	0.242	0.099	1.274	0.126	0.049	0.020
Morrelganj subdistrict	0.078	0.076	1.081	0.082	0.016	0.015
Taltali subdistrict	-0.129	0.080	0.879	0.070	-0.026	0.016
constant	-2.710	0.163	0.067	0.011	•	•
(***significant at 1%; **significant at 5%, *significant at 10%)					•	•

Severe headaches, as previously mentioned, were the most common symptom among respondents. Respondents describing their drinking water as tasting mildly or moderately saline reduced the odds of experiencing a headache by factors of 0.76 and 0.52, respectively, and decreased the probability by a margin of 5.58% and 13.2%, respectively, compared with those who describe their water as having no salinity in taste (same as rainwater). Respondents who described their water as tasting highly saline experienced a 7.17% greater predicted probability of severe headaches, at the 10% significance level. Salinity contamination had a marginal effect of 6.66% greater predicted probability of severe headaches. Every year of age adds a 0.63% marginal probability of experiencing the symptom, while being female had a marginal effect of 17.26% greater probability than males of experiencing severe headaches. The natural log of the distance in feet to drinking water was statistically significant at the 5% level, with an added marginal effect of 0.57% per unit.

The third and fifth quintiles were statistically significant, with marginal effects of 4.33% and 4.94% greater predicted probability, respectively. The second quintile had 3% greater marginal effect than the reference case of the richest quintile and the fourth quintile had a 2.52% greater predicted probability of severe headaches.

Logistic regression output for nosebleeds

Only 15 people (0.25%) experienced nosebleeds. None of these people experienced moderately saline drinking water, so that variable becomes omitted. Only the variable for water consumption is statistically significant, likely because there were not sufficient responses to detect differences. This could mean that nosebleeds are not a good indicator of hypertension within the sample population, or even that hypertension may not be significant.

Table 20: Logistic regression output OR and conditional marginal effects for nosebleeds

					Number of obs = 6062	
		Log likelihood = -89.939631			LR χ2(14) = 26.78	
					Prob > χ2 = 0.0205	
					Pseudo R2 = 0.1296	

Nosebleeds	Coefficient	Standard errors for coefficient	Odds ratio	Standard errors for odds ratio	Average marginal effects	Delta-method standard errors
Water tastes slightly saline	0.070	0.591	1.073	0.634	0.000	0.004
Water tastes moderately saline	0.000	(omitted)	1.000	(omitted)	0.000	(omitted)
Water tastes very saline	0.671	1.235	1.957	2.416	0.000	0.037
Salinity contamination	0.098	0.672	1.102	0.740	0.000	0.005
age	0.008	0.015	1.008	0.015	0.000	0.000
Female	-0.127	0.522	0.881	0.460	0.000	0.007
Years of education	0.080	0.077	1.084	0.084	0.000	0.004
Average water consumption per person*	0.035	0.016	1.036	0.017	0.000	0.002
Distance to get drinking water	0.1852916**	0.151	1.204	0.182	0.000	0.010
Second quintile	13.857	3020.342	1042518.000	3150000000	0.001	0.492
Third quintile	13.218	3020.342	550277.900	1660000000	0.001	0.457
Fourth quintile	14.819	3020.342	2727914.000	8240000000	0.001	0.546
Fifth quintile	15.623	3020.342	6096174.000	1840000000	0.001	0.590
Morrelganj subdistrict	-1.076	1.113	0.341	0.379	0.000	0.060
Taltali subdistrict	0.807	0.633	2.242	1.418	0.000	0.045

_constant	-22.722	3020.343	0.000	0.000		
(***significant at 1%; **significant at 5%, *significant at 10%)						

Only the coefficients for average water consumption per person (litres) and the natural log of the distance travelled to the water source in feet were within the 95% confidence interval. This only indicated a positive association with nosebleeds as the marginal effects were not statistically significant.

There were no respondents who both had nosebleeds and thought their water tasted moderately saline so the variable is omitted. The marginal effects for salinity contamination, water tasting mildly saline and water tasting slightly saline were at most six thousandth of a percentage in magnitude (0.0062%), both statistically significant and practically too small to report on.

The wealth quintiles did not have any statistically significance for people who reported experiencing nosebleeds. The marginal effects, from second quintile to poorest quintile were 0.127%, 0.122%, 0.136% and 0.144% larger than the wealthiest quintile, indicating greater occurrence at the poorest quintile. However, the expectation of larger marginal effects as wealth diminished did not hold as the magnitude of the third quintile was a hair smaller than the second quintile.

Logistic regression output for severe anxiety

Severe anxiety was experienced by 1,095 or 18.05% of respondents.

Table 21: Logistic regression output OR and conditional marginal effects for severe anxiety

					Number of obs = 6062
		Log likelihood = - 2444.708			LR $\chi^2(15)$ = 834.36

					Prob > χ^2 = 0.0205	
					Pseudo R^2 = 0.1458	
Severe anxiety	Coefficient	Standard errors for coefficient	Odds ratio	Standard errors for odds ratio	Average marginal effects	Delta-method standard errors
Water tastes slightly saline***	-0.521	0.091	0.594	0.054	-0.062	0.011
Water tastes moderately saline***	-1.608	0.171	0.200	0.034	-0.193	0.020
Water tastes very saline***	1.269	0.211	3.558	0.752	0.152	0.025
Salinity contamination*	0.165	0.092	1.180	0.108	0.020	0.011
age***	0.041	0.002	1.042	0.002	0.005	0.000
Female***	0.357	0.074	1.429	0.105	0.043	0.009
Years of education***	0.035	0.011	1.036	0.011	0.004	0.001
Average water consumption per person***	0.018	0.004	1.018	0.004	0.002	0.000
Distance to get drinking water***	0.114	0.017	1.121	0.019	0.014	0.002
Second quintile	0.091	0.117	1.095	0.128	0.011	0.014
Third quintile	0.100	0.119	1.105	0.132	0.012	0.014
Fourth quintile**	0.294	0.118	1.341	0.159	0.035	0.014
Fifth quintile***	0.474	0.121	1.606	0.194	0.057	0.014

Morrelganj subdistrict***	0.550	0.089	1.734	0.155	0.066	0.011
Taltali subdistrict***	-0.676	0.106	0.509	0.054	-0.081	0.013
_constant	-4.062	0.205	0.017	0.004	•	•
(***significant at 1%; **significant at 5%, *significant at 10%)						

Respondents who said their drinking water tasted mildly saline had a marginal effect of 6.25% lower predicted probability of severe anxiety. Those who said their water tasted moderately saline experienced an average marginal effect of 19.28% lower predicted probability of severe anxiety. Lastly, those who said their water tasted highly saline experienced 15% higher predicted probability of severe anxiety than the reference group of those who set their water tasted like rain water. All three of these variables were significant at the 1% level. Salinity contamination had a predicted probability of 1.9% more severe anxiety at the 10% significance level.

The average marginal effect of each year of age was 0.49% greater probability of severe anxiety. Women had a 4.28% greater probability of experiencing severe anxiety than men at the 1% significance level. On average, every year of education added 0.42% predicted probability of experiencing severe anxiety.

Every litre of average water consumption had a marginal effect of 0.22% greater predicted probability of experiencing severe anxiety, and the natural log of every foot had a marginal effect of 1.37% greater predicted probability of severe anxiety.

The two poorest quintiles had a statistically significant impact on respondents reporting severe anxiety. The second and third quintiles were not statistically significant, but had a marginal effect of 1.09% and 1.19% greater probability of the symptom, respectively. The fourth and fifth quintiles had a marginal effect of 3.52% and 5.68% greater predicted probability of severe anxiety, respectively. This symptom displayed increases in marginal effects as wealth diminished across quintiles, as expected by the hypotheses of this paper.

Logistic regression output for shortness of breath

Shortness of breath was experienced by 498 or 8.06% of respondents.

Table 22: Logistic regression output OR and conditional marginal effects for shortness of breath

					Number of obs = 6062	
		Log likelihood = -1511.0413			LR χ^2 (15) = 377.41	
					Prob > χ^2 = 0.0205	
					Pseudo R^2 = 0.1110	
Shortness of breath	Coefficient	Standard errors for coefficient	Odds ratio	Standard errors for odds ratio	Average marginal effects	Delta-method standard errors
Water tastes slightly saline	0.031	0.120	1.032	0.123	0.002	0.007
Water tastes moderately saline	-0.057	0.194	0.945	0.184	-0.003	0.011
Water tastes very saline**	0.707	0.278	2.028	0.563	0.040	0.016

Salinity contamination	0.037	0.121	1.038	0.125	0.002	0.007
age***	0.041	0.003	1.042	0.003	0.002	0.000
Female**	0.213	0.100	1.237	0.124	0.012	0.006
Years of education*	-0.028	0.015	0.972	0.015	-0.002	0.001
Average water consumption per person***	0.014	0.005	1.015	0.005	0.001	0.000
Distance to get drinking water*	0.007	0.024	1.007	0.024	0.000	0.001
Second quintile	0.117	0.156	1.125	0.175	0.007	0.009
Third quintile	0.120	0.159	1.128	0.179	0.007	0.009
Fourth quintile	0.075	0.163	1.077	0.176	0.004	0.009
Fifth quintile	0.112	0.169	1.118	0.189	0.006	0.010
Morrelganj subdistrict*	-0.224	0.132	0.800	0.105	-0.013	0.007
Taltali subdistrict	-0.005	0.130	0.995	0.130	0.000	0.007
_constant	-4.212	0.280	0.015	0.004	•	•
(***significant at 1%; **significant at 5%, *significant at 10%)						

Of the four salinity-related variables, only the dummy variable for drinking water tasting highly saline is statistically significant (5%), with an average marginal effect of 3.99% greater probability of shortness of breath over the reference case of water tasting like rainwater (no salinity).

Every added year of age on average raises the probability of experiencing severe shortness of breath by 0.23%. Women have a 1.2% greater predicted probability over men of experiencing this symptom. This is the only symptom that displays what one would intuitively expect from education: every added year of education on average reduces the predicted probability of experiencing shortness of breath by 0.16%.

Average water consumption per person of every litre has the marginal effect of 0.08% greater probability of experiencing this symptom. Every unit of the natural logarithm of the distance in feet to get to drinking water has a marginal effect of 0.04% added likelihood of severe shortness of breath.

None of the wealth quintiles are statistically significant. However, they do have increasingly larger marginal effects as wealth diminished for the second to fourth quintiles at 0.66%, 0.68% and 0.42%, respectively. The poorest (fifth) quintile has the second-lowest marginal effect of 0.63% greater probability of experiencing the symptom.

For this symptom, being located in Morrelganj subdistrict is statistically significant for respondents, displaying an average marginal effect of 1.23% lower probability of respondents experiencing shortness of breath.

6.3. Subsample analysis of household heads

There are 1481 household heads in the database. One detail that needs to be at the forefront while reading this study is that while individual respondents have varying age, education, gender and hypertension symptoms, their position in the wealth index, their sub district and their water consumption and distance to their water source are information collected at the household level. This necessitates applying the model to household heads alone, which is what Szabo et al. (2015) did in their study. This makes the sex breakdown a lot more lopsided: only 73 (4.93%) of household heads are female. The factor analysis is rerun to account for varying household sizes and divided into quintiles.

Table 23: Poisson regression output IRR and conditional marginal effects for household heads only

					Number of obs = 1480	
		Log pseudolikelihood = -1563.7293			Wald $\chi^2(15)$ = 191.73	
					Prob > χ^2 = 0.0000	
					Pseudo R^2 = 0.0428	
Household head symptoms	Coefficient	Robust standard errors for coefficient	Incidence rate ratio	Standard errors for IRR	Average marginal effects	Delta-method standard errors
Water tastes slightly saline*	-0.137	0.071	0.872	0.062	-0.091	0.047
Water tastes moderately saline***	-0.522	0.114	0.593	0.068	-0.346	0.075
Water tastes very saline***	0.497	0.133	1.643	0.218	0.329	0.088
Salinity contamination**	0.168	0.068	1.183	0.081	0.112	0.045
age***	0.010	0.002	1.010	0.002	0.007	0.001
Female***	0.357	0.097	1.429	0.139	0.236	0.064
Years of education**	-0.018	0.008	0.982	0.008	-0.012	0.006

Average water consumption per person***	0.009	0.003	1.009	0.003	0.006	0.002
Distance to get drinking water***	0.049	0.012	1.050	0.012	0.033	0.008
Second quintile	0.123	0.093	1.131	0.105	0.081	0.061
Third quintile	0.054	0.094	1.055	0.099	0.036	0.062
Fourth quintile	0.063	0.102	1.065	0.109	0.041	0.068
Fifth quintile	-0.048	0.116	0.953	0.111	-0.032	0.077
Morrelganj subdistrict**	0.179	0.077	1.195	0.092	0.118	0.051
Taltali subdistrict***	-0.371	0.091	0.690	0.062	-0.246	0.059
_constant	-1.086	0.186	0.338	0.063	•	•
(***significant at 1%; **significant at 5%, *significant at 10%)						

The key contribution of this study, the wealth quintiles, are insignificant when considering household heads alone. What is also strange is that the poorest quintile has a negative coefficient: being in the fifth quintile reduces the count rate of symptoms by 4.69% compared with the reference group of household heads, with a marginal effect of 3.18% lower predicted probability. Given the insignificance, however, this aberration can be dismissed. There could simply not be sufficient sample size for each quintile to power acceptable significance levels.

Regarding the four dummy variables on salinity, the coefficients and marginal effects are largely consistent with the first Poisson regression carried out on the entire sample population: household heads who said their water tastes slightly or moderately saline experience lower counts of symptoms by 12.82% and 40.68%, respectively, with 9.086% and 34.58% lower predicted counts, respectively. Those who described their water as tasting highly saline (10.87% of this subsample) experienced 64.32% more symptoms and 32.89% greater predicted probability of a symptom. Household head respondents who reported salinity contamination as a problem they experienced with their drinking water saw 18.34% more hypertension symptoms and a marginal effect of 11.16% greater predicted counts of symptoms.

Another result of note for this Poisson regression is that for education, exhibiting 0.85% fewer symptoms for every year gained on average and 1.21% lower predicted counts with every year gained.

7. Discussion and conclusions

Using the Bangladesh Poverty and Groundwater Salinity Survey 2016, this study has explored the impact of wealth on the probability of having hypertension symptoms in Taltali, Morrelganj and Shyamnagar subdistricts in the southwest coast of the country, as well as associated determinants explored by established literature on the topic within the area. Individual responses are elicited from the questionnaire (see Appendix) as well as household-level responses. This study's main contribution is the perspective and understanding generated through the application of wealth quintiles (the use of which has been established through a broad expanse of research done by international institutions) to the problem of health impacts derived from drinking water salinity. Secondary to this are the results found for the impact of age, education, sex, average water consumption and distance to water sources, which have been explored and established by previous research (most predominant being Szabo et al, 2015; Chakraborty et al., 2019; Das et al., 2019; Dey et al., 2018; Nahian et al., 2018; Shammi et al., 2019; and Szabo et al., 2015), and are reiterated in this study. The consistency of these latter measures with existing literature grants credence to the novel contribution of this paper.

The focus is on the impacts of the four quintiles relative to the richest quintile. The Poisson regression that covered all respondents and all symptoms displayed the expected progression of positive coefficients and marginal effects that increased in magnitude from the second to the fifth quintiles. This trend was also seen in the household head subsample Poisson regression and the logistic regression for severe anxiety, albeit the latter two outputs did not meet the significance threshold. The results for the wealth quintiles are summarised in the table below:

Table 24: Comparison of estimation results across quintiles

	Main Poisson regression		Poisson regression with interaction terms		Hypertension logistic regression	Severe headache logistic regression	Nosebleeds logistic regression	Severe anxiety logistic regression	Shortness of breathe logistic regression	Household head subsample Poisson regression	
Quintile	Percentage difference from richest quintile	Marginal effect	Percentage difference from richest quintile	Marginal effect	Marginal effect	Marginal effect	Marginal effect	Marginal effect	Marginal effect	Percentage difference from richest quintile	Marginal effect
Second quintile	9.5***	-0.005	-0.9	-0.005	-0.0197**	0.030	0.001	0.011	0.007	0.131	0.081
Third quintile	12.6***	0.023	0.490	0.023	-0.002	0.043**	0.001	0.012	0.007	0.055	0.099
Fourth quintile	14.4***	-0.004	-0.090	-0.004	0.006	0.025	0.001	0.035**	0.004	0.065	0.109
Poorest quintile	24.7***	0.065	14.2*	0.065*	0.006	0.049**	0.001	0.057***	0.006	0.047	0.111
		Second quintile interacting with salinity contamination***	33.89	0.142							
		Third quintile interacting with salinity contamination**	23.04	0.101							
		Fourth quintile interacting with salinity contamination***	43.99	0.177							
		Poorest quintile interacting with salinity contamination**	26.53	0.114							

The inclusion of interaction terms is normally expected to capture how one variable changes when another variable changes: in this case the interaction terms would be hoped to capture how the presence of salinity contamination among respondents changes impact wealth quintiles have on the number of hypertension symptoms. However, the use of interaction terms under log-linear models such as the Poisson cannot be interpreted as difference in semi elasticities as under OLS regression. The coefficients of interaction terms do not provide a consistent estimate of the interaction effect for two dichotomous variables (Shang et al., 2017), instead varying depending on which of the two coefficient estimates (salinity contamination or the quintile) is used as the base variable. This makes the model more complex, as it requires choosing and adhering to a base variable, none of which were statistically significant.

Despite the lack of statistical significance, the cumulative effects for the quintiles and the interaction terms were considered and they seemed to connote the polar opposite of what the hypotheses of this study indicated: all of the quintiles had negative impacts relative to the richest quintile on the number of hypertension symptoms, with the poorest quintile having the largest impact of -1.41% and the second-richest quintile having 1.29% fewer symptoms. While the model that includes interaction terms could be interpreted quite alarmingly, the lack of statistical significance renders the model largely meaningless.

When comparing the same quintiles across the regressions, we can see more clearly that statistical significance is only consistent in the main Poisson regression. The interaction terms are significant, implying that the health impact created by wealth compounded with the presence of salinity contamination bears the largest magnitude seen across all regressions, with 43.99% greater symptoms should respondents be in the fourth wealth quintile and report that their water is contaminated by salinity. The interaction terms do not rise in magnitude as wealth diminishes, however, which implies that there is more than a direct relationship at hand.

The fifth quintile was statistically significant across four regressions: severe headaches, severe anxiety and both Poisson regressions. This could be interpreted as the symptoms of hypertension being more significantly borne across the lowest wealth tier.

Delving further into the health-wealth relationship requires considerations of context. The entirety of the survey population were rural, and within the sample while there was a clear spectrum of wealth, there were no indications of gross wealth disparities. As the literature indicated, higher inequality is a trend that accompanies health inequalities (van Deurzen et al, 2014) , and this sample population did not have deep inequality, which may explain why the logistic regression output for hypertension diagnosis did not see higher marginal effects as wealth diminished.

However, despite all this, the increasing marginal effects as wealth diminished across wealth quintiles for the Poisson regression of all symptoms (for the entire sample and the household head subsample) and the logistic regressions for nosebleeds and severe anxiety indicate the realisation of the health-wealth relation for the symptoms of hypertension in these three coastal subdistricts, thereby satisfying this thesis.

Salinity contamination consistently bore a positive association with hypertension symptoms, with the exception of the model where interaction terms were used (and salinity contamination was rendered insignificant). Salinity contamination was also insignificant where fewer people had a symptom: nosebleeds and shortness of breath. This may be attributed to there being insufficient power for there to be significance, or that nosebleeds and shortness of breath have no real relation to salinity contamination in drinking water. By and large, self-reported salinity contamination was proven to be a significant determinant of anxiety and severe headaches as well as the totality of all four hypertension symptoms for the entire sample population and the household head subsample.

A few other trends were confirmed through the numerous regressions carried out: distance to a water source is a consistent determinant of the health symptoms of hypertension, confirming Ziaul Haider & Zaber Hossain (2013) and Dey et al. (2019), bearing a positive association. Water consumption was also consistently statistically significant, cementing a positive association with the four symptoms at hand and confirming Das et al. (2019) and Nahian et al. (2018) findings. This also grants credence to the supposition that the households surveyed by and large were drinking water that was saline beyond healthy thresholds, the consumption of which contributed additively to the manifestation of hypertension symptoms. This can be concluded on despite the variations in respondents' descriptions of what their drinking water tasted like. Regardless, water tasting highly saline was a significant determinant of severe headaches and anxiety as well as all four symptoms across the whole sample and the household head subsample.

Education, age and sex were also consistently statistically significant across all regressions. While age is proven yet again to be a reliable predictor for hypertension symptoms, as per Intersalt (1988) and Nahian et al. (2018) along with any and all hypertension studies, being female being a significant predictor of hypertension, albeit for marginal effects ranging from as low as 0.65% to as high as 19%, this contradicts Intersalt (1988) findings, but research specific to Bangladesh, such as Nahian et al. (2018), indicate that hypertension is more prevalent in women and Chakraborty et al. (2019) underlines the heightened vulnerability of pregnant women to saline water consumption. Chakraborty et al. (2019) also links farther distances required to access drinking water to higher hypertension in women, a connection that is not apparent in this study, but may very well exist among the survey population.

Limitations and policy implications

The results of this study have several limitations. Firstly, the very fact that all answers are self-reported puts this study into question. The water respondents were drinking was not tested for salinity, nor was their blood pressure measured in order to actually pinpoint whether a respondent was hypertensive or not. While the self-reported presence of a symptom is sufficient to account for a health impact, asking respondents what their water tastes like or whether their water has salinity contamination are not good proxies for actually taking water samples and testing them. Water that is highly saline can taste uncontaminated or vice versa. People may very well not know whether their water is contaminated, or may know their water is contaminated and still insist it is not a problem for them: subjectivity does not bode well for accuracy. The placebo effect may also be in effect: people think their water tastes very saline so they think they have severe headaches as a result of that, as opposed to say, poor eyesight, or people experience severe anxiety and decide that their water source must have salinity contamination. This is underlined by the inconsistencies with the coefficients for the subdistrict dummy variables and the actual research that tested the water (Shamsudduha et al., 2019). Taltali and Morrelganj are both confirmed to have more saline water by twofold over the reference case of Shyamnagar subdistrict. However, where the p-values are significant, Morrelganj keeps to a higher count of symptoms, but Taltali tends to have a negative coefficient. This, however, reverses for the logistic regression for hypertension diagnosis, where Morrelganj has a negative coefficient and Taltali has a positive one. This may indicate that self-reported symptoms have a cause other than salinity contamination, one that results in

Shyamnagar respondents reporting the symptoms at higher counts than Taltali respondents.

The key policy implications of this study are derived from lower wealth resulting in higher health impacts: national development and health policies should take into account the poor who live in coastal areas who are clearly more vulnerable to the vagaries of climate change and require better access to healthcare, especially at the union level. Furthermore, the full implementation of the Driver-Pressure-State-Impact-Response (DPSIR) framework developed by Shammi et al. (2019) may be more critical than ever. This study confirms that there is a significant self-reported salinity contamination that is a determinant of hypertension symptoms (regardless of hypertension the four symptoms are unto themselves capable of deteriorating quality of life) that require responses in the form of improved water treatment and access (distance to water sources are a significant determinant) that are in no way going to resolve themselves. The over abstraction of groundwater (see Appendix) is a pressure that in combination with climate change raising salinity encroachment through rising sea levels are threatening livelihoods and health simultaneously across the coast of Bangladesh.

As mentioned in the results and discussion chapters, the results across the board indicated that women were more likely to experience hypertension symptoms than men, at 49% more for the main Poisson regression, and at varying levels for the logistic regressions (marginal effect of 2.6% for hypertension diagnoses and 17% and 4% for headaches and severe anxiety, respectively). This implies a need for better health policy focused on women. While maternal care has fairly good utilisation (see Appendix), healthcare for women who are not in the process of reproducing seems to be in crucial need. Contrary to the Intersalt global study, the women in this survey are experiencing more hypertension and hypertension symptoms than men are.

Given that the existing Bangladesh Delta Plan 2100 (see Appendix) does not have sufficient action for salinity encroachment, the findings of this study shed further light on the inequality that exists for health impacts from drinking unhealthy saline water. This requires policy responses on two levels, especially given the insights from Deaton (2002). Firstly the issue of water quality needs to be addressed. Shammi et al. (2019) found that reverse osmosis was not a popular option despite being and pond sand filters were much more popular. Das et al. (2019) found that pond sand filters were cost-effective in comparison to reverse osmosis, the latter requiring more time and use to “earn” the cost of the technology. Given the poverty of the area and especially those who are more likely to be impacted by drinking water salinity and other losses from rising sea level, pond sand filters may be the optimal solution. This is further underlined by the fact that many areas are not expected to exist beyond the next decade, implying greater need for policy that focuses on migration and relocation of these vulnerable populations.

REFERENCES

Abhyankar, L. N., Jones, M. R., Guallar, E., & Navas-Acien, A. (2012). Arsenic Exposure and Hypertension: A Systematic Review. *Environmental Health Perspectives*, *120*(4), 494–500. https://doi.org/10.1289/ehp.1103988

Ahmad, H. (2019). Bangladesh Coastal Zone Management Status and Future Trends. *Journal of Coastal Zone Management*, *22*(1), 1. https://www.longdom.org/open-access/bangladesh-coastal-zone-management-status-and-future-trends.pdf

Ahmed, S. M. (2015). *Bangladesh Health System Review* (3rd ed., Vol. 5). World Health Organization.

Ahmed, S., Siddique, A. K., Iqbal, A., Rahman, P. K. M. N., Islam, M. N., Sobhan, M. A., Islam, M. R., & Sack, R. B. (2010). Causes for Hospitalizations at Upazila Health Complexes in Bangladesh. *Journal of Health, Population and Nutrition*, *28*(4), 399–404. https://doi.org/10.3329/jhpn.v28i4.6047

Alam, S. (2019, March 23). Bangladesh Delta Plan 2100: Implementation challenges and way forward. *The Financial Express*. https://thefinancialexpress.com.bd/views/reviews/bangladesh-delta-plan-2100-implementation-challenges-and-way-forward-1553354695

Ayyam, V., Palanivel, S., & Chandrakasan, S. (2019). Water Resources and the Changing Needs. *Coastal Ecosystems of the Tropics - Adaptive Management,* 153–173. https://doi.org/10.1007/978-981-13-8926-9_8

Aziz, A. (2007, July 30). *Administrative Map of Bangladesh* [Illustration]. https://commons.wikimedia.org/wiki/File:BD_Map_admin.svg

Bangladesh Political map showing the international boundary, divisions boundaries with their capitals and national capital. (2020, February 22). [Illustration]. https://www.mapsofworld.com/bangladesh/bangladesh-political-map.html

Banglapedia. (2015). Banglapedia. http://en.banglapedia.org/index.php?title=Main_Page

Boretti, A., & Rosa, L. (2019). Reassessing the projections of the World Water Development Report. *Npj Clean Water*, *2*(1), 1–5. https://doi.org/10.1038/s41545-019-0039-9

Bromfield, S., & Muntner, P. (2013). High Blood Pressure: The Leading Global Burden of Disease Risk Factor and the Need for Worldwide Prevention Programs. *Current Hypertension Reports*, *15*(3), 134–136. https://doi.org/10.1007/s11906-013-0340-9

Cameron, C. A., & Trivedi, P. K. (1998). *Regression Analysis of Count Data (Econometric Society Monographs)* (0 ed.). Cambridge University Press.

Chakraborty, R., Khan, K. M., Dibaba, D. T., Khan, M. A., Ahmed, A., & Islam, M. Z. (2019). Health Implications of Drinking Water Salinity in Coastal Areas of Bangladesh. *International Journal of Environmental Research and Public Health*, *16*(19), 3746. https://doi.org/10.3390/ijerph16193746

Chan, N., Roy, R., & Chaffin, B. (2016). Water Governance in Bangladesh: An Evaluation of Institutional and Political Context. *Water*, *8*(9), 403. https://doi.org/10.3390/w8090403

Charles, R., & Corrigan, E. (1977). Epistaxis and hypertension. *Postgraduate Medical Journal*, *53*(619), 260–261. https://doi.org/10.1136/pgmj.53.619.260

Chowdhury, N. T. (2009). Water management in Bangladesh: an analytical review. *Water Policy*, *12*(1), 32–51. https://doi.org/10.2166/wp.2009.112

Das, D. K., Islam, M. S., Hadiujjaman, S., Dutta, C. B., & Morshed, M. M. (2019). Health cost of salinity contamination in drinking water: evidence from Bangladesh. *Environmental Economics and Policy Studies*, *21*(3), 371–397. https://doi.org/10.1007/s10018-018-0234-9

Deaton, A. (2002). Policy Implications Of The Gradient Of Health And Wealth. *Health Affairs*, *21*(2), 13–30. https://doi.org/10.1377/hlthaff.21.2.13

Dey, N. C., Parvez, M., Saha, R., Islam, M. R., Akter, T., Rahman, M., Barua, M., & Islam, A. (2018). Water Quality and Willingness to Pay for Safe Drinking Water in Tala Upazila in a Coastal District of Bangladesh. *Exposure and Health*, *11*(4), 297–310. https://doi.org/10.1007/s12403-018-0272-3

Dhrymes, P., & Guerard, J. (2017). *Introductory Econometrics*. Springer Publishing. https://doi.org/10.1007/978-3-319-65916-9

Filmer, D., & Pritchett, L. (2001). Estimating Wealth Effects Without Expenditure Data--Or Tears: An Application to Educational Enrollments in States of India. *Demography*, *38*(1), 115–132. https://doi.org/10.1353/dem.2001.0003

Gardener, H., Monteith, T., Rundek, T., Wright, C. B., Elkind, M. S. V., & Sacco, R. L. (2016). Hypertension and Migraine in the Northern Manhattan Study. *Ethnicity & Disease*, *26*(3), 323. https://doi.org/10.18865/ed.26.3.323

Garg, A. X. (2005). Risk of hypertension and reduced kidney function after acute gastroenteritis from bacteria-contaminated drinking water. *Canadian Medical Association Journal*, *173*(3), 261–268. https://doi.org/10.1503/cmaj.050581

Giannoccaro, G., Scardigno, A., & Prosperi, M. (2017). Economic analysis of the long-term effects of groundwater salinity: bringing the farmer’s perspectives into policy. *Journal of Integrative Environmental Sciences*, *14*(1), 59–72. https://doi.org/10.1080/1943815x.2017.1351993

Hansen, J. E., & Sato, M. (2012). Paleoclimate Implications for Human-Made Climate Change. *Climate Change*, 21–47. https://doi.org/10.1007/978-3-7091-0973-1_2

Howitt, R. E., Kaplan, J., Larson, D., MacEwan, D., Medellín-Azuara, J., & Horner, G. (2009). *The Economic Impacts of Central Valley Salinity* (No. 05-417-150–0). https://www.waterboards.ca.gov/rwqcb5/water_issues/salinity/centralvalley_salinity_alternatives_archives/committees_of_cvsalts_leadership_grp/social_economic_impact_committee/sec_12may08_howitt_pres.pdf

Intersalt: an international study of electrolyte excretion and blood pressure. Results for 24 hour urinary sodium and potassium excretion. Intersalt Cooperative Research Group. (1988). *BMJ*, *297*(6644), 319–328. https://doi.org/10.1136/bmj.297.6644.319

Jenkins, P. C. (2007). The Relationship Between Dyspnea and Blood Pressure in Chronic Obstructive Pulmonary Disease. *The Journal of Cardiovascular Nursing*, *22*(5), 351–358. https://doi.org/10.1097/01.jcn.0000287030.95370.d0

Kretchy, I. A., Owusu-Daaku, F. T., & Danquah, S. A. (2014). Mental health in hypertension: assessing symptoms of anxiety, depression and stress on anti-hypertensive medication adherence. *International Journal of Mental Health Systems*, *8*(1), 1–6. https://doi.org/10.1186/1752-4458-8-25

Law, M., Morris, J. K., Jordan, R., & Wald, N. (2005). Headaches and the Treatment of Blood Pressure. *Circulation*, *112*(15), 2301–2306. https://doi.org/10.1161/circulationaha.104.529628

Lee, J., & Kim, H. (2003). An Examination of the Impact of Health on Wealth Depletion in Elderly Individuals. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, *58*(2), S120–S126. https://doi.org/10.1093/geronb/58.2.s120

Mamun Rashid, M. (2014). Political Commitments and Aspirations of Grassroots Coastal Communities: a Micro-Level Study in Bangladesh. *American Journal of Rural Development*, *2*(2), 24–33. https://doi.org/10.12691/ajrd-2-2-2

Mannan, M. A., 2013. "Access to Public Health Facilities in Bangladesh: A Study on Facility Utilisation and Burden of Treatment," *Bangladesh Development Studies*, Bangladesh Institute of Development Studies (BIDS), vol. 36(4), pages 25-80, December.

Meer, J., Miller, D., & Rosen, H. (2003). Exploring the Health-Wealth Nexus. *Journal of Health Economics, Elsevier*, 713–730. https://doi.org/10.3386/w9554

Middeke, M., Lemmer, B., Schaaf, B., & Eckes, L. (2007). Prevalence of hypertension-attributed symptoms in routine clinical practice: a general practitioners-based study. *Journal of Human Hypertension*, *22*(4), 252–258. https://doi.org/10.1038/sj.jhh.1002305

Min, H. J., Kang, H., Choi, G. J., & Kim, K. S. (2017). Association between Hypertension and Epistaxis: Systematic Review and Meta-analysis. *Otolaryngology–Head and Neck Surgery*, *157*(6), 921–927. https://doi.org/10.1177/0194599817721445

Nahian, M. A., Ahmed, A., Lázár, A. N., Hutton, C. W., Salehin, M., & Streatfield, P. K. (2018). Drinking water salinity associated health crisis in coastal Bangladesh. *Elem Sci Anth*, *6*(1), 2. https://doi.org/10.1525/elementa.143

Neumann, B., Vafeidis, A. T., Zimmermann, J., & Nicholls, R. J. (2015a). Future Coastal Population Growth and Exposure to Sea-Level Rise and Coastal Flooding - A Global Assessment. *PLOS ONE*, *10*(3), e0118571. https://doi.org/10.1371/journal.pone.0118571

Neumann, B., Vafeidis, A. T., Zimmermann, J., & Nicholls, R. J. (2015b). Future Coastal Population Growth and Exposure to Sea-Level Rise and Coastal Flooding - A Global Assessment. *PLOS ONE*, *10*(3), e0118571. https://doi.org/10.1371/journal.pone.0118571

Poirier, M. J. P., Grépin, K. A., & Grignon, M. (2019). Approaches and Alternatives to the Wealth Index to Measure Socioeconomic Status Using Survey Data: A Critical Interpretive Synthesis. *Social Indicators Research*, *148*(1), 1–46. https://doi.org/10.1007/s11205-019-02187-9

Pollack, C. E., Chideya, S., Cubbin, C., Williams, B., Dekker, M., & Braveman, P. (2007). Should Health Studies Measure Wealth? *American Journal of Preventive Medicine*, *33*(3), 250–264. https://doi.org/10.1016/j.amepre.2007.04.033

Ray, D., & Linden, M. (2018). Health, inequality and income: a global study using simultaneous model. *Journal of Economic Structures*, *7*(1), 1–28. https://doi.org/10.1186/s40008-018-0121-3

Rhoades, J. D., Kandiah, A., & Mashali, A. M. (1992). *The Use of Saline Waters for Crop Production*. Food and Agriculture Organization of the United Nations.

Rich, V. I., & Maier, R. M. (2015). Aquatic Environments. *Environmental Microbiology*, 111–138. https://doi.org/10.1016/b978-0-12-394626-3.00006-5

Rutstein, Shea, and Sarah Staveteig. 2014. *Making the Demographic and Health Surveys Wealth Index Comparable*. DHS Methodological Reports No. 9. Rockville, Maryland, USA: ICF International

Sarhan, N. A., & Algamal, A. M. (2015). Relationship between epistaxis and hypertension: A cause and effect or coincidence? *Journal of the Saudi Heart Association*, *27*(2), 79–84. https://doi.org/10.1016/j.jsha.2014.09.002

Scheelbeek, P. F. D., Chowdhury, M. A. H., Haines, A., Alam, D. S., Hoque, M. A., Butler, A. P., Khan, A. E., Mojumder, S. K., Blangiardo, M. A. G., Elliott, P., & Vineis, P. (2016). High concentrations of sodium in drinking water and raised blood pressure in coastal deltas affected by episodic seawater inundations. *The Lancet Global Health*, *4*, S18. https://doi.org/10.1016/s2214-109x(16)30023-7

Schilderinck, J. (1969). *Factor analysis applied to developed and developing countries (Tilburg Studies in Economics)* (1970th ed.). Springer. https://doi.org/10.1007/978-94-015-7202-6

Shammi, M., Rahman, M., Bondad, S., & Bodrud-Doza, M. (2019). Impacts of Salinity Intrusion in Community Health: A Review of Experiences on Drinking Water Sodium from Coastal Areas of Bangladesh. *Healthcare*, *7*(1), 50–79. https://doi.org/10.3390/healthcare7010050

Shamsudduha, M., Joseph, G., Haque, S. S., Khan, M. R., Zahid, A., & Ahmed, K. M. U. (2019). *Multi-Hazard Groundwater Risks to the Drinking Water Supply in Bangladesh* (Policy Research Working Paper 8922). http://documentos.bancomundial.org/curated/es/797421561652185435/pdf/Multi-Hazard-Groundwater-Risks-to-the-Drinking-Water-Supply-in-Bangladesh-Challenges-to-Achieving-the-Sustainable-Development-Goals.pdf

Small, C., & Nicholls, R. (2003). A Global Analysis of Human Settlement in Coastal Zones. *Journal of Coastal Research*, 19(3), 584-599. Retrieved March 21, 2020, from www.jstor.org/stable/4299200

Shang, S., Nesson, E., & Fan, M. (2017). INTERACTION TERMS IN POISSON AND LOG LINEAR REGRESSION MODELS. *Bulletin of Economic Research*, *70*(1), E89–E96. https://doi.org/10.1111/boer.12120

Suarez, D. L., & Lebron, I. (1993). Water quality criteria for irrigation with highly saline water. *Towards the Rational Use of High Salinity Tolerant Plants*, 389–397. https://doi.org/10.1007/978-94-011-1860-6_45

Szabo, S., Hossain, M. S., Adger, W. N., Matthews, Z., Ahmed, S., Lázár, A. N., & Ahmad, S. (2015). Soil salinity, household wealth and food insecurity in tropical deltas: evidence from south-west coast of Bangladesh. *Sustainability Science*, *11*(3), 411–421. https://doi.org/10.1007/s11625-015-0337-1

Talwar, A., Sahni, S., Kim, E. J., Verma, S., & Kohn, N. (2015). Dyspnea, depression and health related quality of life in pulmonary arterial hypertension patients. *Journal of Exercise Rehabilitation*, *11*(5), 259–265. https://doi.org/10.12965/jer.150230

The World Bank. (2020). *Bangladesh | Data*. Bangladesh | Data. https://data.worldbank.org/country/BD

Tinker, H. R., & Husain, S. S. (2020, January 29). *Bangladesh*. https://www.britannica.com/place/Bangladesh

van Deurzen, I., van Oorschot, W., & van Ingen, E. (2014). The Link between Inequality and Population Health in Low and Middle Income Countries: Policy Myth or Social Reality? *PLoS ONE, 9*(12), e115109. https://doi.org/10.1371/journal.pone.0115109

Vineis, P., Chan, Q., & Khan, A. (2011). Climate change impacts on water salinity and health. *Journal of Epidemiology and Global Health*, *1*(1), 5. https://doi.org/10.1016/j.jegh.2011.09.001

Vyas, S., & Kumaranayake, L. (2006). Constructing socio-economic status indices: how to use principal components analysis. *Health Policy and Planning*, *21*(6), 459–468. https://doi.org/10.1093/heapol/czl029

Wahls S. A. (2012). Causes and evaluation of chronic dyspnea. *American family physician, 86(2)*, 173–182.

Wheeler, P. J., Peterson, J. A., & Gordon-Brown, L. N. (2011). Spatial Decision Support for Integrated Coastal Zone Management (ICZM) in Victoria, Australia: Constraints and Opportunities. *Journal of Coastal Research, 272*, 296–317. https://doi.org/10.2112/jcoastres-d-09-00150.1

World Bank. (2018). *Promising Progress: A Diagnostic of Water Supply, Sanitation, Hygiene, and Poverty in Bangladesh*. WASH Poverty Diagnostic.

World Economic Forum. (2019, November 19). *Bangladesh's economy is soaring - here's why*. https://www.weforum.org/agenda/2019/11/bangladesh-gdp-economy-asia/

World Food Programme. (2017). *Creation of a Wealth Index*. https://docs.wfp.org/api/documents/WFP-0000022418/download/?_ga=2.156326329.343949792.1543501988-1745710939.1423496269

World Health Organization & World Health Organization. (2011). *Guidelines for Drinking-water Quality* (Fourth ed.). World Health Organization.

World Health Organization: WHO. (2019a, June 14). *Drinking-water*. https://www.who.int/news-room/fact-sheets/detail/drinking-water

World Health Organization: WHO. (2019b, September 13). *Hypertension*. https://www.who.int/news-room/fact-sheets/detail/hypertension

Yan, J., Pan, Y., Cai, W., Cheng, Q., Dong, W., & An, T. (2015). Association between anxiety and hypertension: a systematic review and meta-analysis of epidemiological studies. *Neuropsychiatric Disease and Treatment*, 1121. https://doi.org/10.2147/ndt.s77710

Zahid, A., Rahman, A., & Hassan, M. R. (2016). Determining Source of Groundwater Salinity in the Multi-Layered AQUIFER SYSTEM OF THE BENGAL DELTA, BANGLADESH. *BRAC University Journal*, *XI*(2), 37–51. http://hdl.handle.net/10361/8386

Ziaul Haider, M., & Zaber Hossain, M. (2013). Impact of salinity on livelihood strategies of farmers. *Journal of Soil Science and Plant Nutrition*, *ahead*, 0. https://doi.org/10.4067/s0718-95162013005000033

Appendix

Goodness of fit for Poisson and logistic regressions

1. Main Poisson regression

To assess the fit of the model and to check if the Poisson model fits the data the deviance and Pearson goodness-of-fit tests are used . The results are:

Deviance goodness-of-fit = 5576.898

Prob > χ2(6046) = 1.00

Pearson goodness-of-fit = 5430.885

Prob > χ2(6046) = 1.00,

indicating the goodness-of-fit χ^2 test is not statistically significant and the Poisson model fits well.

2. Hypertension logistic regression

The goodness-of-fit test is not statistically significant, indicating that the model is a good fit:

Pearson χ2(6036) = 5105.62

Prob > χ^2 = 1.0000.

3. Severe headache logistic regression

The χ^2 goodness-of-fit test is not significant:

Pearson χ^2 (6036) = 5967.99

Prob > χ^2 = 0.7308

4. Nosebleeds logistic regression

The model was a good fit:

Pearson χ^2(5398) = 4859.18

Prob > χ^2 = 1.0000.

5. Severe anxiety logistic regression

The χ^2 test for goodness of fit was not significant:

Pearson $\chi^2(6036)$ = 5572.10

Prob > χ^2 = 1.0000

6. Shortness of breath logistic regression

This logistic regression's χ^2 test was also insignificant, indicating a good fit:

Pearson $\chi^2(6036)$ = 5906.52

Prob > χ^2 = 0.8812

7. Subsample analysis of household heads

The appropriateness of the Poisson model is confirmed with the goodness-of-fit tests being insignificant:

Deviance goodness-of-fit = 1466.091

Prob > $\chi^2(1464)$ = 0.4797

Pearson goodness-of-fit = 1299.198

Prob > $\chi^2(1464)$ = 0.9992

Groundwater salinity in Bangladesh

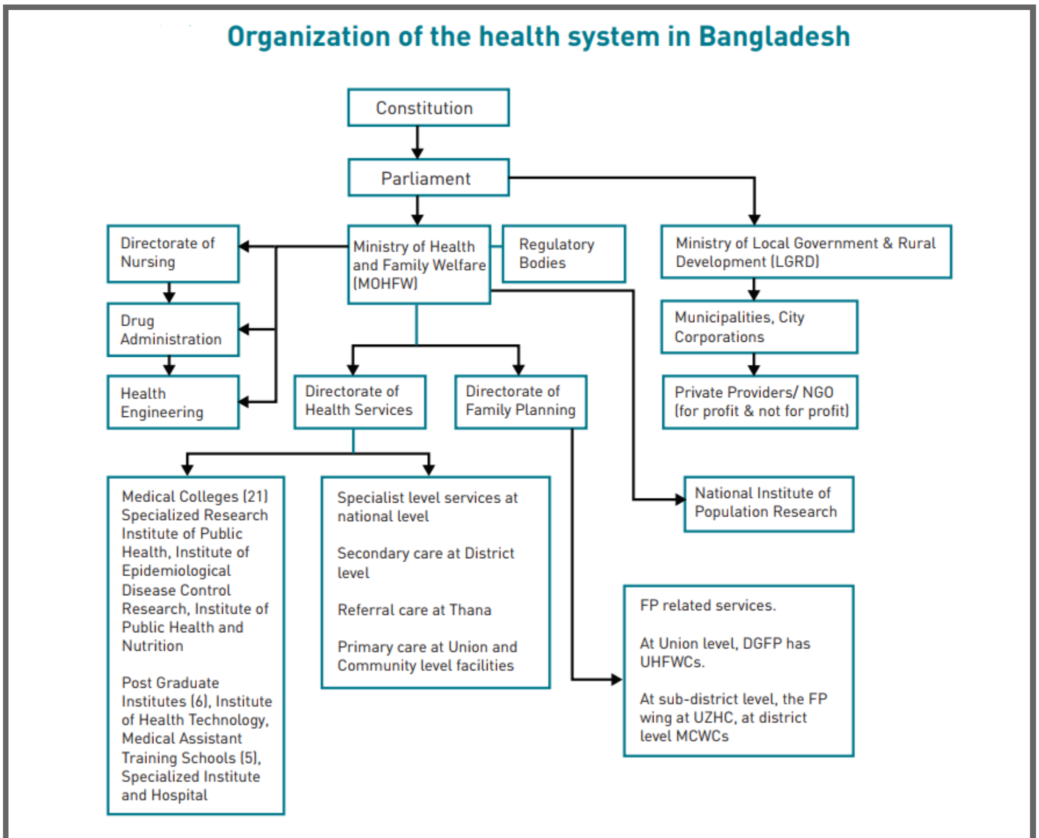
Bangladesh's coastal region makes up 32% of the country's land mass at 47,201 km^2, divided among 19 of the country's 64 districts (Ahmad, 2019, p. 1). Groundwater supplies 98% of drinking water and 80% of water for irrigation for the country, and people living in coastal areas are struggling to access safe drinking water as a result of salinity encroaching in the upper aquifer and in many areas salinity runs as deep as 250-300 metres underground into groundwater. The coastal delta aquifers are unpredictable in that they do not follow any pattern, but aquifers of all depths, even the deepest at 336m were found to be impacted by salinity. Furthermore, areas that have potable water are close to those with saline water, indicating that residents in the coastal region may not be able to distinguish between potable and saline water using geographical indicators (Zahid, Rahman, & Hassan, 2016, p. 43).

Healthcare in Bangladesh

The diagnosis and treatment of hypertension is highly dependent on access to and treatment from any form of healthcare system, especially because the disease does not manifest in an obvious manner. The rather lopsided structure and low utilisation of the existing healthcare system are likely to be key contributors to undiagnosed hypertension, risk of related diseases and comorbidities.

The system and structure

Image 1A: Bangladesh's healthcare system, according to the WHO



Source: Asia Pacific Observatory on Health Systems and Policies

Bangladesh's 2011 National Health Policy has three main goals (Ahmed, 2015, pp. 1–3):

a. Strengthening primary and emergency healthcare for all;

b. Expanding client-centred, equity-focused and high-quality healthcare services;

c. Motivating people to seek healthcare based on their rights.

The Health Care Financing Strategy (2012-32) aims to achieve universal coverage by focusing on pre-payment for risk pooling and recommends various mechanisms for people in different economic sectors.

In 1997, the Health and Population Sector Strategy (HPSS) generated the Fifth Five Year

Plan (1997–2002) and the National Health Policy in 2000. Among other facilities, these documents instituted Community Clinics (CCs) at the village level, which provide primary care. The CCs fall under the purview of both the Directorate-General of Health Services and the Directorate-General of Family Planning (within the Ministry of Health and Family Welfare) (Ahmed, 2015, pp. 10).

Ministry of Health and Family Welfare revenue and development budgets are prepared independently and on different timelines from the national budget, even while they both compartmentalise into revenue and development budgets (Ahmed, 2015, pp. 17).

With the implementation of national health policy in August 2000, CCs were set up on the *thana* (police station area, now recategorised as *upazila* or subdistrict) and village levels to replace the existing domiciliary services. From 1998-2001, around 11000 CCs were established. As of 2012, there were 12527 CCs, one for every 6,000 people.

The Ministry developed a Citizens' Charter of Rights, in line with goal (c). The charter has three main drawbacks (Ahmed, 2015, pp. 20):

- No institutional or legal mechanisms for the state or citizens;
- The vast majority do not know anything about these rights;
- They were developed without community involvement by government and health service personnel.

These drawbacks emphasise that in Bangladesh, the mere enactment of policy is not sufficient. This was underlined when local-level planning was implemented during HPSP. There proved to be inadequate capacity for aiding community leaders in planning, weak supervision and limited understanding of the objectives (Ahmed, 2015, pp. 24).

With limited healthcare workers and poor financing infrastructure, providers are more motivated to be in urban areas at secondary or tertiary facilities as opposed to working at the over 12000 CCs located across the countryside. This is exacerbated and encouraged by poor equipment and supplies at public sector health facilities (Ahmed, 2015, pp. 32).

In 2011, the National Health Policy was revised to emphasise primary and rural health. This was backed up by the introduction of a health insurance scheme for formal institutions and health cards for the "ultra-poor". Locally, the health administration is fully controlled by the Ministry. This means that CCs can apply for what they need to the central authority, but supply is dependent on the decision of the Ministry bureaucracy (Ahmed, 2015, pp. 32). Local government institutes are also responsible for providing health services at the local level and have the authority to supervise facilities in the event of irregularities or problems in delivery. However, local governments are also dependent on the central authorities for financing. This means financing is inefficient, especially given that the Bangladesh Government gives out funding in accordance with pre-determined regulations instead of needs or demand. This is separate from urban healthcare provision, the mandate for which is held by the Ministry of Local Government, Rural Development and Cooperatives.

Healthcare utilisation

As is evident from Table 1, Bangladesh has eked out progress in key health indicators. Life expectancy and the under-five mortality rate have risen consistently over 1990-2018. There are indicators that the ratio of healthcare workers are rising, and all this may be due to the public healthcare system, which is considered relatively advanced for a developing country. Under a hierarchical system, each of the 64 districts have a district-level hospital. However, there are only 460 subdistrict-level hospitals for the country's 492 subdistricts, called Upazila Health complexes, each with 31 beds (S. Ahmed et al., 2010, pp. 1–3). The 4,554 union council areas have 4,000 health and family welfare centres, and wards/villages have 11000-13000 CCs (Mannan, 2013, pp 27).

Healthcare utilisation comes about from the consideration of relative costs and benefits by decision makers, who may be making choices for themselves or for others (Mannan, 2013, pp 33). Costs are both direct and indirect: the cost of the health treatment as well as the opportunity cost of choosing to take the treatment. The latter is usually income lost, which rises with long and difficult commutes and wait times at healthcare service points.

In a study on hospital utilisation that interviewed 1,820 patients, men were found to make up 43% of total utilisation. Women dominated all levels of healthcare (district hospitals, Upazila Health complexes, CCs) at 57% of utilisation (Mannan, 2013, pp 42). The difference was mainly attributed to reproductive-aged women, without whom men would have much higher utilisation. The study found that female children under five were particularly at risk, with only 34% of utilisation of facilities, compared with 66% for male children under five. For elderly women aged over 65, utilisation was 38% compared with 62% for men over 65.

When it comes to the health-wealth gradient, the study found that poverty had the most significant impact in deterring utilisation of healthcare facilities and health-seeking behaviours, with patients who require hospitalisation in the most precarious situation. Even for treatment at government hospitals (where services are ostensibly free, but medicines and diagnostic tests range among a host of out of pocket expenditures), many households need to take on loans or liquidate assets to bring health treatments within reach. In poorer households, food takes up the bulk of expenditures, and health expenditures have the effect of leaving people hungry (Mannan, 2013, pp 56). Of respondents who faced negative impacts in their daily lives as a result of having to make health expenditures, food consumption was reduced or there was insufficient food among 57%, while 18% had trouble financing their childrens' education (Mannan, 2013, pp 56). This indicates that health expenditures are such that the vast majority of people in Bangladesh, especially the rural poor, are unlikely to seek out check-ups or treatments unless they are experiencing serious hindrances to their daily lives, further underlining that those who have illnesses that have mild to no symptoms such as hypertension are unlikely to be diagnosed or treated. Mannan et al. (2013) found that public hospital utilisation is dominated by the poor, with 84% of respondents choosing the healthcare facility because of no or low costs. Despite the convenience of cost, more than 60% of respondents were unsatisfied with the services provided. Even more damning is that less than 20% of patients who visited public health facilities were given physical exams by providers and only 35% received consultations with doctors or other providers (Mannan, 2013, pp 60). Patients surveyed indicated they were mostly there to avail medication (about 50%), and their perception of the healthcare facility revolved around availability of drugs. This becomes problematic, because only 23.9% of outpatient respondents received all the medication they were prescribed by providers, and inpatient respondents reported a tragic 7%.

The rarity of regular health checkups is also underlined by how infrequently respondents in Mannan et al. (2013) visited the public healthcare facilities. In a breakdown according to how much land the participants' household held, almost 75% of all respondents were found to have visited the facility one or more times in a space of six months. Respondents from land-poor households were found to have visited the public health facilities marginally more frequently than richer households. Whether richer households offset this by also visiting private healthcare facilities was not explored by the study.

Mannan et al. (2013) do a few analyses of informal and possibly corruption activities that also impact healthcare utilisation, but these findings are not germane to this study.

Bangladesh's policy on drinking water and climate change

Existing policy

The Bangladesh Delta Plan 2100 sets out national policy and regional strategy for the country, with a focus on flood protection, freshwater supply and development that is both sustainable and accounts for the changing climate. While Bangladesh's legislative bodies have passed this framework, the plan was drafted by Dutch companies and institutes in tandem with Bangladesh's General Economics Division, with funding from the Dutch Foreign Ministry, the World Bank and the Bangladesh government. The premise of the entire plan is Bangladesh's status as the largest delta in the world and there is a subsection that specifically addresses water resource management. Integrated water resource management connects the exogenous factors of climate change and natural disasters with economic growth and development (The Financial Express, 2019). This is an improvement to the provisions under the National Adaptation Plan 2005, which did not emphasise adaptation measures that focus on water management, even as the framework was formed to address fresh water scarcity, poor drainage, riverbank erosion, flooding, drought and salinity (Chan, Roy, & Chaffin, 2016, p. 403). However, specific policy has yet to be implemented under either plan at a level that sees actual results that address the rising urgency of salinity for the country.

The National Water Policy of 1999 made water usage management relatively low priority, listing salinity management as second-to-last within this area (Chowdhury, 2009, p. 36). In addition, inconsistent surface water availability has led to general national policy encouraging the use of tubewells, leading to the water table in many areas falling below suction level for these wells as overexploitation persists. This fall is what results in the rising salinity of aquifers in the coastal region (Chowdhury, 2009, p. 41).

Potential policy adaptations

Groundwater management, already an onerous and complex field, becomes even more difficult when salinity is thrown into the mix of problems. This is attributed to two main factors: (1) coastlines have fairly consistent groundwater depth relative to inland aquifers and (2) the effects of salinity require extended exposure to manifest (Giannoccaro, Scardigno, & Prosperi, 2017, p. 60).

Scheelbeek et al. (2016) found indications that the hypertension and high blood pressure that result from drinking saline water in seawater inundated areas may be reversible, and suggested "alternative low-sodium drinking water sources" as well as action to address microbial quality. Actual solutions in this vein, however, are not easily found and those that do exist have barriers in the form of cost or effectiveness.

The aforementioned WHO report recommends the development of new sources of water such as "recycled wastewater or desalinated brackish water or seawater" and setting up storage and recovery systems for aquifers. Rainwater harvesting is practiced at the household level and communities are scaling up this practice as well. Desalination systems used to remove salts from surface water and groundwater are advised to adopt stabilisation treatments for water or mineralised to reduce corrosiveness (World Health Organization & World Health Organization, 2011, pp. 98). This implies organisation at the local community level that may need to be funded and directed by the central government. However, these are all minor efforts that may not suffice against a backdrop of growing global populations, migration and rapid loss of groundwater as sea levels rise, particularly in coastal communities. The application of desalination methods such as reverse osmosis and water purification may offset the losses that are happening and have yet to come, but the struggle derived from the scarcity of water does not bode well.

More specific to this study are the wealth differentials in the health impact of groundwater salinity. Shedding light on this area would allow for more focused implementation of drinking water supplies to more vulnerable communities. In addition, this could create impetus for more thorough healthcare provision in this area. Lastly, where all options are not feasible, the need to migrate vulnerable populations from coastal areas will be further underlined by the disparities that exist between different wealth segments.

Desalinisation is the most effective process at hand to increase water supply to meet demand, but given the high cost, only 1% of the global coastal population depend on desalinisation (Boretti & Rosa, 2019, pp. 2).

In Bangladesh, pond sand filters have been found to be effective in removing 98% of bad odours, color and bacterial contamination (Das, Islam, Hadiujjaman, Dutta, & Morshed, 2019, p. 391), but are not a failsafe means of addressing salinity. What pond sand filters do effectively, however, is provide low salinity surface water. By meeting the Bangladesh government’s goal of 1752 pond sand filters for over 105,000 households in the coastal region that are subsequently maintained sufficiently, safe drinking water could be secured. Das et al (2019) calculated that the benefit would be 1.5 times the costs associated with installing pond sand filters in the coastal areas of southwestern Bangladesh.

The global perspective

Globally, coastal zones are acknowledged to be at particular risk due to high land subsidence (the gradual downward sinking of land that occurs when large amounts of groundwater have been withdrawn) that together with thermo-steric sea level rise results in relative rise of sea levels and the salinisation of aquifers. This is compounded by urbanisation and migration of populations to coastal areas seen across the globe (Boretti & Rosa, 2019, pp. 1–3). In addition to this, the impact on soils is one that threatens global food and agriculture, both in areas that are irrigated and those that are not. Boretti & Rosa (2019), in their rather acerbic review of the United Nations World Water Development Report (2018 edition), imply a cyclical impact:

the degradation of soils and ecosystems both contributes to and is caused by salinisation of water resources, and are also expected to negatively impact the water quality and access.

Delta regions face greater risks than most. The Mekong Delta, specifically, has been overwrought in supplying food, water and energy for over 20 million people in the immediate proximity as well as Southeast Asia's massive population of over 600 million. In the space of a few decades, the delta has sunk and shrunk, leading to coastal aquifers becoming saline, aquifers in general becoming depleted and poisoned by arsenic. Saline soil, floods, ruined harvests and collapsing the unique ecosystem have destroyed wild fish and other organisms both cause lower water availability and come about because of the unsustainable management of water resources (Boretti & Rosa, 2019, pp. 4). This paper includes, not incorrectly, that there is strong correlation with population and GDP growth and water scarcity.

As Vineis et al (2011) discuss in their systemic review, there is limited data and research on freshwater in coastal areas globally, the existing studies have two things in common: seasonal changes in salinity and the consistent prediction that salinity in coastal areas will increase as time progresses. Delta regions across the board are considered the most prominent victims to rising salinity, and the 11 mega-deltas in Asia are of particular concern. The papers that Vineis et al. (2011) discuss cover Bangladesh, California, Australia and Brazil, and despite the geographical diversity, the one health impact that is broad-reaching is hypertension. Across both developing and developed countries, higher blood pressure at the very least is projected to be a disease burden resulting from higher salinity in diet, drinking water and even wind-borne exposure.

n

Survey questionnaire: Bangladesh_WASH_SWIFTApril20

Field Question Answer

hhid Please enter the Household ID

intronote As-salamualaikum. My name is……… I have come from Nielsen Bangladesh. Currently The World Bank is

conducting a study on condition in coastal areas. In this regard, I wanted to talk to you about you and the

livelihood condition of your household. Could you please give us 30 minutes of your time? Please know, that you

can stop this interview at anytime

hhmember_name_respondent (required) Q4 What is your name?

sex_respondent (required) Q5 Are you a male or female? 1 male

2 female

age_respondent (required) Q6 How old are you?

Response constrained to: .<100

relation_hh_respondent (required) Q7 What is the relationship between you (the respondent) and the head of the household? 1 Head

2 Husband/ wife

3 Son/Daughter

4 Spouse of Son/Daughter

5 Grandchild

6 Father/Mother

7 Brother/Sister

8 Niece/Nephew

9 Father/Mother- in-law

10 Brother/Sister- in- law

11 Servant

12 Employee

p

97 Other

religion_respondent (required) Q8 What is your religion? 1 Islam

2 Hinduism

3 Buddhism

4 Christianity

97 Other

education_respondent (required) Q9 What was the highest class that you completed? 0 No class passed

1 Class 1

2 Class 2

3 Class 3

4 Class 4

5 Class 5

6 Class 6

7 Class 7

8 Class 8

9 Class 9

10 SSC/equivalent

11 HSC/equivalent

12 Graduate/equivalent

13 Post graduate/equivalent

14 Medical

15 Engineering

16 Vocational

17 Technical Education

18 Nursing

q

97 Other

hypertension_symptoms_respondent (required) Q10 Have you suffered from any of the following health problems in the past 2 weeks? READ RESPONSE

CHOICES ALOUD AND CHECK ALL THAT APPLY

Please select as many as needed

Response constrained to: (selected(., '0') and count-selected(.)=1) or not(selected(., '0'))

1 Severe headaches

2 Nosebleeds

3 Severe anxiety

4 Shortness of breath

0 None of these problems

hypertension_respondent (required) Q11 Have you ever been told by a doctor or nurse that you have high blood pressure? 1 Yes

0 No

98 Don't Know

99 Refuse/No Answer

pregnant_respondent (required) Q12 Have you been pregnant or given birth in the last 12 months?

Question relevant when: ${sex_respondent} =2 and ${age_respondent} >12 and ${age_respondent} <50

1 Yes

0 No

98 Don't Know

99 Refuse/No Answer

Field Question Answer

pregcomplications_respondent (required) Q13 Did you have any complications during pregnancy or delivery? READ RESPONSE CHOICES ALOUD AND r

CHECK ALL THAT APPLY

Please select as many as needed

Question relevant when: ${pregnant_respondent} =1

Response constrained to: (selected(., '0') and count-selected(.)=1) or not(selected(., '0')) 0 No

1 Yes- high blood pressure during

pregnancy

2 Yes- miscarriage of child during

pregnancy

3 Yes-pre-eclampsia

4 Yes- sepsis

5 Yes- death of child during

delivery

97 Yes- other (specify)

98 Don't Know

pregcomplications_other_respondent Q13_oth) Please specify "other."

Question relevant when: selected(${pregcomplications_respondent} , '97')

hhsize (required) Q3 Including you, how many people live in this household?

familynotefirst Now let's discuss each person in your household, starting with person number 1.

Question relevant when: ${hhsize} >1 and ${relation_hh_respondent} =1

Now let's discuss each person in your household, starting with the head of the household.

Question relevant when: ${hhsize} >1 and ${relation_hh_respondent} !=1

familynotefirsthead

Roster - Household Members (1) (Repeated group)

familynotenext Now let's discuss the next person in your family.

s

Question relevant when: ${hhmember} !=1

Q4 What is his or her name?

hhmember_name (required)

sex (required) Q5 Is [hhmember_name] a male or female? 1 male

2 female

age (required) Q6 How old is [hhmember_name] [WRITE "00" for less than 1 (one) YEAR]?

-

Response constrained to: .<100

relation_hh (required) Q7 What is the relationship between [hhmember_name] and the head of the household? 1 Head

2 Husband/ wife

3 Son/Daughter

4 Spouse of Son/Daughter

5 Grandchild

6 Father/Mother

7 Brother/Sister

8 Niece/Nephew

9 Father/Mother- in-law

10 Brother/Sister- in- law

11 Servant

12 Employee

97 Other

religion (required) Q8 What is [hhmember_name]'s religion? 1 Islam

2 Hinduism

3 Buddhism

4 Christianity

t

97 Other

education (required) Q9 What was the highest class that [hhmember_name] completed?

Question relevant when: ${age} >4

0 No class passed

1 Class 1

2 Class 2

3 Class 3

4 Class 4

5 Class 5

6 Class 6

7 Class 7

8 Class 8

9 Class 9

10 SSC/equivalent

11 HSC/equivalent

12 Graduate/equivalent

13 Post graduate/equivalent

14 Medical

15 Engineering

16 Vocational

17 Technical Education

18 Nursing

Field Question Answer

97 Other

hypertension_symptoms (required) Q10 Has [hhmember_name] suffered from any of the following health problems in the past 2 weeks? READ

RESPONSE CHOICES ALOUD AND CHECK ALL THAT APPLY

-

Response constrained to: (selected(., '0') and count-selected(.)=1) or not(selected(., '0'))

1 Severe headaches

2 Nosebleeds

3 Severe anxiety

4 Shortness of breath

0 None of these problems

hypertension (required) Q11 Has [hhmember_name] ever been told by a doctor or nurse that he/she has high blood pressure? 1 Yes

0 No

98 Don't Know

99 Refuse/No Answer

pregnant (required) Q12 Has [hhmember_name] been pregnant or given birth in the last 12 months?

Question relevant when: ${sex} =2 and ${age} >12 and ${age} <50

1 Yes

0 No

98 Don't Know

99 Refuse/No Answer

pregcomplications (required) Q13 Did [hhmember_name] have any complications during pregnancy or delivery? READ RESPONSE

CHOICES ALOUD AND CHECK ALL THAT APPLY

-

Question relevant when: ${pregnant} =1

Response constrained to: (selected(., '0') and count-selected(.)=1) or not(selected(., '0'))

0 No

1 Yes- high blood pressure during

pregnancy

2 Yes- miscarriage of child during

pregnancy

3 Yes-pre-eclampsia

4 Yes- sepsis

5 Yes- death of child during

delivery

97 Yes- other (specify)

98 Don't Know

pregcomplications_other Q13_oth) Please specify "other."

Question relevant when: selected(${pregcomplications} , '97')

diarrhea_child (required) Q14 Has [hhmember_name] had diarrhea in the last 2 weeks? ASKED ONLY TO CHILDREN BELOW FIVE

YEARS OF AGE 1 Yes

0 No

Question relevant when: ${age} <5

98 Don't Know

99 Refuse/No Answer

section3bnote Now, let me ask you a couple of questions about the household head

Question relevant when: ${relation_hh_respondent} !=1

Household head - respondent

Group relevant when: ${relation_hh_respondent} =1

work1 (required) Q15 Did you work for livelihood during the past 7 days? 1 Yes

2 No

work2 (required) Q16 Were you available for work during the past 7 days?

Question relevant when: ${work1} !=1

1 Yes

2 No

work3 (required) Q17 Did you look for work during the past 7 days? 1 Yes

2 No

work4 (required) Q18 If you were working, what was your employment status?

Question relevant when: ${work1} =1

1 Day labourer

2 Employer

3 Self employed

4 Employee

Household head - another person

Group relevant when: ${relation_hh_respondent} !=1

work1_other (required) Q19 Did the head of the household work for livelihood during the past 7 days? 1 Yes

2 No

work2_other (required) Q20 Was the head of the household available for work during the past 7 days?

Question relevant when: ${work1_other} !=1

1 Yes

2 No

work3_other (required) Q21 Did the head of the household look for work during the past 7 days? 1 Yes

2 No

work4_other (required) Q22 If the head of the household was working, what was the employment status?

Question relevant when: ${work1_other} =1

1 Day labourer

2 Employer

3 Self employed

4 Employee

other_members (required) Q23 Is there any former household member who is still alive and left the household in the past five years? 1 Yes

2 No

98 Don't Know

other_members_number (required) Q24 How many former household members left the household?

Question relevant when: ${other_members} =1

Field Question Answer

Roster - Former Household Members (1) (Repeated group)

familynotemigrantfirst Let's discuss the former household members.

Question relevant when: ${othermember} =1

familynotemigrantnext Let's discuss the next former household member.

Question relevant when: ${othermember} !=1

Q25 What is his or her name?

othermember_name (required)

sex_othermember (required) Q26 Is [othermember_name] a male or female? 1 male

2 female

age_othermember (required) Q27 How old is [othermember_name]?

-

Response constrained to: .<100

relation_hh_othermember (required) Q28 What is the relationship between [othermember_name] and the head of the household? 1 Head

2 Husband/ wife

3 Son/Daughter

4 Spouse of Son/Daughter

5 Grandchild

6 Father/Mother

7 Brother/Sister

8 Niece/Nephew

9 Father/Mother- in-law

10 Brother/Sister- in- law

11 Servant

12 Employee

97 Other

migrationstatus (required) Q29 Did [othermember_name] leave the village? 1 Yes

0 No

98 Don't Know

99 Refuse/No Answer

migrationreason (required) Q30 Why did [othermember_name] leave the village? DO NOT READ RESPONSE CHOICES ALOUD AND

CHECK ALL THAT APPLY

-

Question relevant when: ${migrationstatus} =1

Response constrained to: (selected(., '98') and count-selected(.)=1) or not(selected(., '98'))

1 Loss of Agricultural job

2 Loss of Non-agricultural job

3 Better job prospects

4 To obtain education

5 Marriage

6 Loss of land/property

97 Other - specify

98 Don't Know

migrationreason_other Q30_oth) Please specify "other."

Question relevant when: selected(${migrationreason} , '97')

section5note SECTION 5 - HOUSING - QUESTIONS ABOUT HOUSEHOLD

Now we are going to talk about your house

Q31 How many rooms does your household occupy (excluding rooms for business)?

rooms (required)

diningroom (required) Q32 Does your dwelling posses a separate dining room? 1 Yes

2 No

kitchen (required) Q33 Does your dwelling posses a separate kitchen? 1 Yes

2 No

walls (required) Q34 What is the construction material of the walls of the main room? 1 Brick/cement

2 C.I. Sheet/wood

3 Mud brick

4 Hemp/hay/bamboo

97 Other

roof (required) Q35 What is the construction material of the roof of the main room? 1 Brick/cement

2 C.I. Sheet/wood

3 Tile/wood

4 Hemp/hay/bamboo

97 Other

latrine (required) Q36 What type of latrine does the household use? 1 Sanitary

2 Pacca latrine (water seal)

3 Pacca latrine (pit)

4 Kacha latrine (perm)

5 Kacha latrine (temp)

97 Other

electricity (required) Q37 Does the household have an electricity connection? 1 Yes

2 No

Field Question Answer

electricity1 (required) Q37_b Is this connection provided through solar energy?

Question relevant when: ${electricity} =1 1 Yes

2 No

98 Don't Know

occupancystatus (required) Q38 What is your present occupancy status? 1 Owner

2 Renter

3 Squatter

4 Provided free by

relatives/employer

5 Government residence

97 Other

remittances (required) Q39 Did your household receive remittances from relatives during the past 12 months (CASH AND IN-KIND)? 1 Yes

2 No

remittanceslocation (required) Q40 Were the remittances received from relatives during the past 12 months from abroad or inside the country?

Question relevant when: ${remittances} =1

1 From inside the country

2 From abroad (outside the

country)

section6note SECTION 6: LANDHOLDING - QUESTIONS ABOUT HOUSEHOLD

landsize1 (required) Q41 In acres, what is your household's total cultivable agricultural land owned:

landsize2 (required) Q42 In acres, what is the size of the dwelling-house/Homestead land owned?

landsize3 (required) Q43 In acres, what is the size of the household's Total Non-cultivated Land?

Section7note SECTION 7: INVENTORY OF CONSUMER DURABLE GOODS - QUESTIONS ABOUT HOUSEHOLD

Household assets

labels Does your household own any of the following items? 1 Yes

2 No

chickens (required) Q44_a) Chicken 1 Yes

2 No

bicycle (required) Q44_b) Bicycle 1 Yes

2 No

motorcycle (required) Q44_c) Motorcycle or scooter 1 Yes

2 No

refrigerator_freezer (required) Q44_d) Refrigerator or freezer 1 Yes

2 No

fans (required) Q44_e) Fan 1 Yes

2 No

television (required) Q44_f) Television 1 Yes

2 No

drawing_room_furniture (required) Q44_g) Drawing room furniture 1 Yes

2 No

dining_room_furniture (required) Q44_h) Dining room furniture 1 Yes

2 No

boat (required) Q44_i) Boat 1 Yes

2 No

section8note SECTION 8- GENERAL QUESTIONS - QUESTIONS TO THE RESPONDENT

topthree (required) Q45 In your opinion, what are the top three most pressing topics that you think the government should address?

READ RESPONSE CHOICES ALOUD AND ONLY SELECT UP TO THREE 1 Agriculture and Irrigation

2 Shrimp farming

-

Response constrained to: ((selected(.,'96') or selected(.,'98')) and count-selected(.)=1) or (not(selected(.,

'96') or selected(., '98')) and count-selected(.)<=3)

3 Health and nutrition

4 Water access

5 Sanitation services and waste

disposal

6 Livelihood/Jobs

7 Crime and security

8 Flooding, water logging,

cyclones, storms, and other

environmental issues

9 Education

10 Roads/ transport

11 Electricity

12 Housing

97 Other, please specify

96 No opinion

98 Don't Know

topthree_other Q45_oth) Please specify "other"

Question relevant when: selected(${topthree} , '97')

Field Question Answer

season (required) Q46 What season are we in now? 1 Rainy

2 Dry

97 Other, please specify

98 Don't Know

season_other Q46_oth Please specify "other"

Question relevant when: ${season} =97

Section9note SECTION 9- ACESS TO SANITATION AND HYGIENE - QUESTIONS ABOUT HOUSEHOLD

toilet (required) Q47 What kind of toilet facility do members of your household usually use?
1 Flush to piped sewer system

2 Flush to septic tank

3 Flush to pit latrine

4 Flush to somewhere else

5 Flush, don't know where

6 Ventilated improved pit latrine

7 Pit latrine with slab

8 Pit latrine without slab/open pit

9 Composting toilet

10 Bucket toilet

11 Hanging toilet/hanging latrine

12 No facility/bush/field

97 Other, please specify

toilet_other Q47_oth) Please specify "other"

Question relevant when: ${toilet} =97

toiletshare (required) Q48 Do you share this toilet facility with other households? 1 Yes

2 No

toiletsharenumber (required) Q49 How many households use this toilet facility? IF "DON'T KNOW" WRITE 99

Question relevant when: ${toiletshare} =1

wash_observe (required) Q50 Please show me where members of your household most often wash their hands. 1 Observed

2 Not observed not in

dwelling/yard/plot

3 Not observed/No permission to

see

4 Not observed other reason

wash_observe_water (required) Q50_obs1 OBSERVATION ONLY: Observe presence of water at the place for handwashing

Question relevant when: ${wash_observe} =1

1 Water is available

0 Water is not available

wash_observe_soap (required) Q50_obs2 OBSERVATION ONLY: Observe presence of soap, detergent, or other cleansing agent

Question relevant when: ${wash_observe} =1

1 Soap or detergent bar, liquid,

powder, paste)

2 Ash, mud, sand

0 None

section10note SECTION 10 - ACCESS TO DRINKING WATER - QUESTIONS ABOUT THE HOUSEHOLD

water_source (required) Q51 What is the main source of drinking water for members of your household? 1 Piped into dwelling

2 Piped into compound, yard or

plot

3 Public tap / standpipe

4 Tubewell, Borehole

5 Protected well

6 Unprotected well

7 protected spring

8 Unprotected spring

9 Rain water

10 Tanker-truck or other vendor

11 Cart with small tank / drum

12 Surface water (river, stream,

dam, lake, pond)

13 Bottled water

97 Other, please specify

water_source_other Q51_oth) Please specify "other."

Question relevant when: ${water_source} =97

water_location (required) Q52 Where is that water source located? 1 In own dwelling

2 In own yard/plot

3 Elsewhere

water_source_depth Q51b Can you estimate the depth of your tubewell or borehole? (WRITE 9999 FOR DON'T KNOW)

Question relevant when: ${water_source} =4

water_source_depth_unit Q51b_unit) Is that in feet or meters? 1 Feet

Field Question Answer

Question relevant when: ${water_source_depth} !=9999 2 Meters

97 Other, please specify

water_source_depth_unit_other Q51b_unit_oth) Please specify "other."

Question relevant when: ${water_source_depth_unit} =97

water_source_tubewelltype Q51c What type of tubewell or borehole is it? (READ RESPONSE CHOICES ALOUD)

Question relevant when: ${water_source} =4 1 Deep tubewell or borehole

2 Shallow tubewell

97 Other, please specify

98 Don't Know

water_source_tubewelltype_other Q51c_oth) Please specify "other"

Question relevant when: ${water_source_tubewelltype} =97

water_source_pump Q51d) What type of pump does your tubewell or borehole use to extract water?

Question relevant when: ${water_source} =4 1 Hand pump

2 Motorized pump

97 Other, please specify

98 Don't Know

water_source_pump_oth Q51d_oth) Please specify "other."

Question relevant when: ${water_source_pump} =97

water_sourcebottle Q51_bottle1 What is the main source of water used by the household for other purposes such as cooking and handwashing? 1 Piped into dwelling

2 Piped into compound, yard or

Question relevant when: ${water_source} =13

plot

3 Public tap / standpipe

4 Tubewell, Borehole

5 Protected well

6 Unprotected well

7 protected spring

8 Unprotected spring

9 Rain water

10 Tanker-truck or other vendor

11 Cart with small tank / drum

12 Surface water (river, stream,

dam, lake, pond)

13 Bottled water

97 Other, please specify

water_sourcebottle_other Q51_bottle1) Please specify "other."

Question relevant when: ${water_sourcebottle} =97

water_locationbottle (required) Q51_bottle2 Where is that water source located?

Question relevant when: ${water_source} =13 1 In own dwelling

2 In own yard/plot

3 Elsewhere

water_time (required) Q53 How long does it take to go to your main drinking water source, get water, and come back? (ENTER 9999

FOR "DON'T KNOW")

time_unit (required) Q53_units Is that in minutes or hours?

Question relevant when: ${water_time} !=9999

2 Hours

1 Minutes

water_distance (required) Q54 How far (distance) does it take to go to your main drinking water source, get water, and come back?

ENTER 9999 FOR "DON'T KNOW"

distance_unit (required) Q54_units Is that in feet or miles?

Question relevant when: ${water_distance} !=9999 1 Feet

2 Miles

97 Other, please specify

distance_unit_other Q54_oth) Please specify "other."

Question relevant when: ${distance_unit} =97

water_person (required) Q55 Who usually goes to your main drinking water source to collect the water for your household? 1 Adult woman (over 15 years of

age)

2 Adult man (over 15 years of

age)

3 Female child (age 15 and

below)

4 Male child boy (age 15 and

below)

97 Other

water_share (required) Q56 Do you share your main drinking water source with other households? 1 Yes

2 No

water_share_number (required) Q57 With how many households do you share your main drinking water source?

Question relevant when: ${water_share} =1

howlongwater (required) Q58 How long has your household been using this water source? (ENTER 9999 FOR "DON'T KNOW")

howlongwater_unit (required) Q58_units) Is that in days, weeks, months or years?

- 1 Days

Field Question Answer

Question relevant when: ${howlongwater} !=9999 2 Weeks

3 Months

4 Years

hourswater (required) Q59 Typically, how many hours a day can water be obtained from this source?

Question relevant when: ${water_source} !=12

Response constrained to: .<25

daynumber (required) Q60 Typically, how many days a week can water be obtained from this source?

Question relevant when: ${water_source} !=12 0 Less than a day

1 1 day

2 2 days

3 3 days

4 4 days

5 5 days

6 6 days

7 Always- 7 days

98 Don't Know

whowaterinstall Q58b Who installed your tubewell or borehole?

Question relevant when: ${water_source} =4

1 Local Government

(UP/Pourashava)

2 Central Government (DPHE)

3 Private company or private

individual

4 NGO/community institution

97 Other, please specify

98 Don't Know

distance_unit_other_tubewell Q58b_oth) Please specify "other."

Question relevant when: ${whowaterinstall} =97

waterbeforeinstall Q58c Where did you get your drinking water from before the tubewell or borehole was installed?

Question relevant when: ${water_source} =4 0 Not applicable

1 Piped into dwelling

2 Piped into compound, yard or

plot

3 Public tap / standpipe

4 Tubewell, Borehole

5 Protected well

6 Unprotected well

7 protected spring

8 Unprotected spring

9 Rain water

10 Tanker-truck or other vendor

ll

11 Cart with small tank / drum

12 Surface water (river, stream,

dam, lake, pond)

13 Bottled water

97 Other, please specify

waterbeforeinstall_other Q58c_oth) Please specify "other."

Question relevant when: ${waterbeforeinstall} =97

waterfix (required) Q61 If your water source is not functioning and you or any of your neighbors cannot fix it, who would you report

the problem to? 1 Local Government

(UP/Pourashava)

2 Central Government (DPHE)

3 Private company or private

individual

4 Mosque/school/clinic/community

institution

5 NGO

6 Community leaders

7 No one

97 Other, please specify

98 Don't Know

0 Not applicable

waterfix_other Q61_oth) Please specify "other"

Question relevant when: ${waterfix} =97

waterpay (required) Q62 Do you pay to use your main drinking water source? 1 Yes

2 No

98 Don't Know

waterpayamount (required) Q63 What is the average amount of your monthly water bill (in TK)?

Field Question Answer

waterpaywho (required) Q64 To whom do you pay this amount? 1 Local Government

(UP/Pourashava)

2 Central Government (DPHE)

3 Private company or private

individual

4 Mosque/school/clinic/community

institution

5 NGO

6 Community leaders

97 Other, please specify

98 Don't Know

waterpaywho_other Q64_oth) Please specify "other"

Question relevant when: ${waterpaywho} =97

waterconsume (required) Q65 On average, how much water does your household consume daily?

watermetric (required) Q66 Is this in liters or another measure? 1 Liters

97 Other, please specify

watermetric_other (required) 66_oth) Please specify "other"

Question relevant when: ${watermetric} =97

watermakesafe (required) Q67 Do you do anything to the water to make it safer to drink?

- 1 Yes

2 No

98 Don't Know

watersafeaction (required) Q68 What do you usually do to make the water safer to drink? (DO NOT READ RESPONSE CHOICES ALOUD

AND CHECK ALL THAT APPLY)

Please select as many as needed

Question relevant when: ${watermakesafe} =1

Response constrained to: (selected(., '98') and count-selected(.)=1) or not(selected(., '98'))

1 Boil

2 Add bleach or chlorine

3 Strain through a cloth

4 Use water filter

(ceramic/sand/composite/etc)

5 Solar disinfection

6 Let it stand and settle

97 Other, please specify

98 Don't Know

watersafeaction_other (required) Q68_oth) Please specify "other"

Question relevant when: selected(${watersafeaction} , '97')

watertest (required) Q69 Has your main source of drinking water ever been tested for water quality issues? 1 Yes

2 No

98 Don't Know

watertestspecify (required) Q70 What was it tested for? (CHECK ALL THAT APPLY)

Question relevant when: ${watertest} =1

1 Arsenic

2 Iron

3 Salinity

4 Bacteria

97 Other

98 Don't Know

watertestresults (required) Q71 Were the results of any of the water quality tests communicated to you?

Question relevant when: ${watertest} =1

1 Yes, all results communicated

2 Only some results

communicated

98 Don't Know

section11note SECTION 11 - SALINITY IMPACT ON DRINKING WATER - QUESTIONS ABOUT HOUSEHOLD

waterproblems (required) Q72 In your opinion, what are the top three problems you find in your drinking water service quality? (READ

RESPONSE CHOICES ALOUD AND ONLY SELECT UP TO THREE RESPONSES) 1 Bacterial contamination

2 Arsenic or heavy metal

-

Response constrained to: (selected(., '0') and count-selected(.)=1) or (not(selected(., '0')) and count-selected

(.)<=3)

contamination

3 Salinity contamination

4 Funny smell, taste, or color

5 Not available throughout the

year

6 Not enough water to all the

demand

7 Too expensive

0 No problems

97 Other, please specify

waterproblems_other (required) Q72_oth) Please specify "other"

Question relevant when: selected(${waterproblems} , '97')

salinity1 (required) Q73 In your opinion, how would you describe the level of salinity taste of your primary drinking water source

compared to the taste of rainwater? 1 Same taste as rainwater (no

salinity)

2

Field Question Answer

Slightly saltier than rainwater

(slight salinity)

3 Moderately saltier than

rainwater (moderate salinity)

4 Much saltier than rainwater

(high salinity)

98 Don't Know

salinity2 (required) Q74 In your opinion, overall, have salinity levels in this drinking water increased, decreased, or stayed the same

in this water source in the past 5 years?

1 Increased

2 Decreased

3 Stayed the same

98 Don't Know

salinity2b Q74b) Do you know of any tubewells in this village that tap saline water? 1 Yes

0 No

98 Don't Know

99 Refuse/No Answer

salinity3 (required) Q75 Does drinking water from this source become more saline during certain times or events? 1 Yes

2 No

98 Don't Know

Salinity section - if salinity happens

Group relevant when: ${salinity3} =1

salinity4 (required) Q76 During when? (READ REPONSE CHOICES ALOUD AND CHECK ALL THAT APPLY)

Please select as many as needed 1 Dry season

2 Rainy season

3 Water logging

4 High tide

5 Cyclones

6 Drought

97 Other, please specify

salinity4_other (required) Q76_oth) Please specify "other"

Question relevant when: selected(${salinity4} , '97')

salinity5 (required) Q77 During any of these (high salinity) times, have you ever switched drinking water sources because the water

was too saline?

2 No

1 Yes

salinity6 (required) Q78 At what times did you switch drinking water sources when the water was too saline? (READ RESPONSE

CHOICES ALOUD AND CHECK ALL THAT APPLY)

Please select as many as needed

Question relevant when: ${salinity5} =1

1 Dry season

2 Rainy season

3 Water logging

4 High tide

5 Cyclones

6 Drought

97 Other, please specify

salinity6_other (required) Q78_oth) Please specify "other"

Question relevant when: selected(${salinity6} , '97')

salinity7 (required) Q79 During any of these (high salinity) times, what alternate drinking water sources have you switched to when

the water was too saline to drink? (CHECK ALL THAT APPLY) 0 Not different - same as usual

source

Please select as many as needed

Question relevant when: ${salinity5} =1 1 Piped into dwelling

Response constrained to: (selected(., '0') and count-selected(.)=1) or not(selected(., '0'))

2 Piped into compound, yard or

plot

3 Public tap / standpipe

4 Tubewell, Borehole

5 Protected well

6 Unprotected well

7 protected spring

8 Unprotected spring

9 Rain water

10 Tanker-truck or other vendor

11 Cart with small tank / drum

12 Surface water (river, stream,

dam, lake, pond)

13 Bottled water

97 Other, please specify

salinity7_other (required) Q79_oth) Please specify "other"

Question relevant when: selected(${salinity7} , '97')

salinity8 (required) Q80 Have you had to travel a further distance than usual to obtain any of these drinking water sources when the

water was too saline? 1 Yes

2 No

Question relevant when: ${salinity5} =1

98 Don't Know

Field Question Answer

salinity11 (required) Q81 Is your monthly expense for drinking water, more, less, or the same during periods of high salinity? 1 More

2 Less

3 Same

salinity9 (required) Q82 What drinking water source do you use the most during times of high salinity?

Question relevant when: ${salinity5} =1

1 Piped into dwelling

2 Piped into compound, yard or

plot

3 Public tap / standpipe

4 Tubewell, Borehole

5 Protected well

6 Unprotected well

7 protected spring

8 Unprotected spring

9 Rain water

10 Tanker-truck or other vendor

11 Cart with small tank / drum

12 Surface water (river, stream,

dam, lake, pond)

13 Bottled water

97 Other, please specify

salinity9_other (required) Q82_oth) Please specify "other"

Question relevant when: ${salinity9} =97

salinity10 (required) Q83 On average, can you estimate the number of days you rely on this source in a given year for drinking

water? (if none, write 0)

Question relevant when: ${salinity5} =1

water_time_salinity (required) Q84 How long does it take you to travel to and from this water source to collect drinking water? ENTER 9999

FOR "DON'T KNOW"

Question relevant when: ${salinity5} =1

Q84_units) Is that in minutes or hours? 1 Minutes

time_unit_salinity (required)

Question relevant when: ${salinity5} =1 and ${water_time_salinity} !=9999

2 Hours

water_distance_salinity (required) Q85 How far (distance) does it take to this water source, get water, and come back? ENTER 9999 FOR "DON'T

KNOW"

Question relevant when: ${salinity5} =1

distance_unit_salinity (required) Q85_units) Is that in feet or miles?

Question relevant when: ${salinity5} =1 and ${water_distance_salinity} !=9999 1 Feet

2 Miles

97 Other, please specify

watermakesafe1 (required) Q86 Do you do anything to the water to make it safer to drink during times of high salinity? 1 Yes

2 No

98 Don't Know

salinity13 (required) Q87 What do you usually do to make the water safer to drink? (CHECK ALL THAT APPLY)

-

Question relevant when: ${watermakesafe1} =1

Response constrained to: (selected(., '98') and count-selected(.)=1) or not(selected(., '98'))

1 Boil

2 Add bleach or chlorine

3 Strain through a cloth

4 Use water filter

(ceramic/sand/composite/etc)

5 Solar disinfection

6 Let it stand and settle

97 Other, please specify

98 Don't Know

salinity13_other (required) Q87_oth) Please specify "other"

Question relevant when: selected(${salinity13} , '97')

salinity14 (required) Q88 Overall, do you consume more, less, or the same amount of water when you use alternative drinking water

sources when your main drinking water source is too saline? 1 More

2 Less

Question relevant when: ${salinity11} >1

3 Same

salinity15 (required) Q89 During high salinity periods, was there ever a time your household could not obtain the amount of drinking

water it needed?

1 Yes

2 No

98 Don't Know

section12note SECTION 12: SALINITY IMPACT ON LAND AND AGRICULTURE

land1 (required) Q90 In the past 12 months, did you cultivate any land?

-

2 No

1 Yes

land2 (required) Q91 In the past year, was your crop production income more, same, or less compared to 5 years earlier?

Question relevant when: ${land1} =1

1 More

2 Less

3 Same

crops2 (required) Q92 Do you cultivate any of the following crops?

Please select as many as needed

1 Aus

2 Aman

Field Question Answer

Question relevant when: ${land1} =1

Response constrained to: (selected(., '0') and count-selected(.)=1) or not(selected(., '0')) 3 Boro

4 Wheat

5 Maize

6 Jute

7 Sugarcane

8 Pulses

9 Oil Seed

10 Shrimp

97 Other

0 None- Did not produce any of

these crop in the past five years

Asking about each crop (1) (Repeated group) crop_question42 (required) Q93 If you used to yield 100 kg of [crop_name2] five years ago, how much did you yield now in kg in the past 12

months?

Question relevant when: selected(${crops2} , ${crop_id2})

land3 (required) Q94 How did you use your crop production in the last 12 months? (SELECT ALL THAT APPLY)

Please select as many as needed 1 Household consumption

2 For sale

Question relevant when: ${land1} =1

3 Given to landlord

4 Feed for animals

5 Used as seed

6 Waste

7 For wages

97 Other, please specify

land3_other Q94_oth) Please specify "other"

Question relevant when: selected(${land3} , '97')

land4 (required) Q95 Has high salinity ever affected your crop production in the past 5 years?

Question relevant when: ${land1} =1 1 Yes

2 No

98 Don't Know

land5 (required) Q96 Has any cultivatable land become uncultivatable due to high salinity in the past 5 years?

Question relevant when: ${land1} =1

1 Yes

2 No

98 Don't Know

land5_howmuch (required) Q97 If yes, how much (in acres)?

Question relevant when: ${land5} =1

land6 (required) Q98 Have you ever had to switch irrigation water sources due to high salinity?

Question relevant when: ${land1} =1 1 Yes

2 No

98 Don't Know

land8 (required) Q99 Have you or anyone in your household taken up shrimp farming, shrimp farm labor, or fishing due to

increases in salinity in your locality?

1 Yes

2 No

98 Don't Know

section13note SECTION 12: FINAL SECTION - PHONE NUMBER AND GPS - FOR HOUSEHOLD CONTACT

phonenumber (required) Q100 In case we need to reach you, could you please provide your phone number?

Question relevant when: ${relation_hh_respondent} =1

Response constrained to: regex(.,'[0-9]{11}')

Q101 In case we need to reach you, could you please provide the phone number of the head of the household?

phonenumber_other (required)

Question relevant when: ${relation_hh_respondent} !=1

Response constrained to: regex(.,'[0-9]{11}')

location_gps Q102 Please record the location

GPS coordinates can only be collected when outside.

zz

problems The interview is over. Did you have any problems? Please explain.

VITA

NAME	Shayan Ara Amin
PLACE OF BIRTH	Tokyo, Japan