Title: Spatio-temporal patterns of pre-eclampsia/eclampsia (PE/E) and low birthweight births in relation to drinking water salinity at the district level in Bangladesh from 2016-2018

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Abstract (150 words)

Bangladesh is one of the most climate-vulnerable countries. This analysis explores spatio-temporal patterns of PE/E in relation to drinking water salinity and risk factors for this exposure. National DHIS2 data was extracted to the district level (n=64), for monthly reporting of total deliveries, PE/E cases, low birthweight births, and maternal and neonatal deaths. These were overlaid with the low elevation coastal zone, proximity to rivers, electrical conductivity of groundwater, and monthly rainfall data. Controlling for total population, referrals, and other factors, spatial and cluster detection analysis methods were implemented to measure the association between drinking water salinity and PE/E. Hypertensive disorder in pregnancy is one of the leading causes of maternal and perinatal death in low-income countries and may increase as drinking water salinity increases due to flooding and coastal intrusion. This study will identify spatio-temporal trends using surveillance data to potentially inform targeting of interventions to improve maternal outcomes.

Background

There is sufficient epidemiological evidence associating high salt intake with risk of hypertension in children and adults.[1, 2] However, the link between salt intake and hypertensive disorders in pregnancy (HDP) is less clearly defined, according to a 2005 Cochrane Review.[3] HDPs are among the leading causes of maternal and perinatal death in low-income countries.[4] These include pre-eclampsia, which occurs when a woman experiences a rapid elevation in blood pressure (hypertension) and increased levels of protein in the urine after 20 weeks of gestation; if untreated, this can lead to eclampsia, a disorder characterized by seizures and other complications that can ultimately lead to the death of the woman and/or her fetus.[5] Perinatal death is due to increased risk of preterm birth and intrauterine growth? restriction.[6] Globally about 10-20% of maternal deaths are associated with eclampsia; Bangladesh reports PE/E are the second leading direct cause of death nationally (20% of maternal deaths).[5] Recent studies in Bangladesh have linked salt intake and hypertensive disorders in pregnancy specifically in coastal regions (Dacope Upazila, Khulna).[6]

Bangladesh's coastal population, comprising approximately 40 million people, relies heavily on natural water sources such as ponds, rivers and tube-wells for drinking water. In Bangladesh, salinity has already encroached more than 100km inland from the Bay of Bengal, and the impacts are projected to rise. Two-thirds of Bangladesh's land area is less than five meters above sea-level.[7] This low-elevation coastal zone (LECZ) is vulnerable to coastal threats including progressive inundation from sea level rise, heightened storm damage, loss of wetlands, and increased salinity from saltwater intrusion.[7] Although groundwater is abundant in coastal Bangladesh, saline water intrudes into the aquifer system due to reductions of upstream freshwater flow and exacerbation by shrimp farming and over abstraction of groundwater for irrigation.[8] Groundwater typically contains higher sodium than surface water. A recent study found mean sodium concentrations in drinking water in coastal Bangladesh of 700 mg/L, in some areas exceeding 1500 mg/L; the WHO recommends a maximum sodium intake of 2000 mg that can be easily exceeded in this region between dietary salt intake and drinking water.[9]

Some studies in Bangladesh have worked to isolate the link between drinking water salinity and adverse pregnancy outcomes including pre-eclampsia and post-natal mortality, specifically. Two studies reported women who drank tubewell water during the dry season had significantly higher urinary sodium levels, which is assumed to be linked with hypertension.[10] This seminal work is critical but restricted in its geographic coverage, limited temporal span and limited environmental data. The authors later published a case-control study in Dacope, Bangladesh, supporting initial findings.[6] A third World Bank paper increases the geographic coverage and time frame by overlaying Bangladesh Demographic and Health Survey (BDHS) data (2004 and 2007) with proxies for drinking water salinity from 41 monitoring stations collected (2001-2009). However, the BDHS does not collect hypertension measures for the women surveyed, so the focus is on mortality events for children during their first 2 years of life.

This study aims to measure a link between PE/E, low birthweight births, maternal and neonatal mortality as reported in national level surveillance data, exploring seasonal and spatial trends across the country (not just in coastal areas). This will allow for exploration of spatio-temporal trends in PE/E and related adverse pregnancy outcomes in association with the geographic distribution of drinking water salinity at the district level across Bangladesh between 2016-2018.

Methods

Health Data

District level monthly data were extracted from the national DHIS2 surveillance system for Bangladesh for 2016-2018. DHIS2 is the platform used by the Bangladesh national health information system. Facilities upload monitoring data on various health outcomes related to pregnancy, maternal, and child health indicators. For this analysis, number of pregnancies, number of births, number of complicated births, number of PE/E cases, low birthweight births (<2000 grams), number of maternal deaths and number of neonatal deaths were all aggregated to the district level (n=64 districts in Bangladesh). Since DHIS2 is only surveillance data and not linked to individual level information, additional variables will be controlled for including referrals for complicated pregnancy, and number of facilities per district. The DHIS2 is the national health surveillance

reporting system for Bangladesh, but potentially there are missing data errors and variation in reporting by facilities and regions that may impact this analysis. These will be explored in more detail, and if possible, accounted for in the analysis.

Environmental Data

Two environmental data sources were overlaid on the district level health outcome data using R statistical software to determine potential exposure to high salinity drinking water. The first is presence in the LECZ, defined as the contiguous and hydrologically connected zone of land along the coast and below 10m elevation.[11, 12] The LECZ bands of elevation per meter were categorized into three risk zones, 0-5m (high risk), 5-10m (medium risk), and 10-20m elevation (low risk). Below 5 meters is commonly considered to be presently at high risk of coastal flooding and related seaward hazards.[13] Being geographically located in the high risk LECZ category is predicted to increase risk of exposure. The methods used to overlay spatial demographic data with LECZ exposure has been described previously.[11]

The second environmental dataset is groundwater salinity at shallow depth (<150m below ground level, bgl) at the national-scale in Bangladesh. High levels of groundwater salinity are commonly recorded in coastal aquifers of southern Bangladesh; groundwater salinity is generally defined by total dissolved solids (TDS) or Electrical Conductivity (EC), sometimes chemical constituent such as chloride (Cl) is also reported.[14] Groundwater with greater concentration of dissolved ions has higher EC and hence higher salinity. In this study, groundwater salinity is expressed by its EC level, which has a unit of micro-Siemens per centimeter or µS/cm. This study applies district-level groundwater EC values, extracted from an interpolated, national-scale groundwater EC dataset.[15]

Statistical Analysis

LECZ values were categorized into high risk (0-5m), medium risk (5-10m) and low risk (10-20m), and no risk (>20m). Districts were overlaid with the LECZ categories and the proportion of the district in each LECZ risk zone was calculated. Next, the average, minimum and maximum EC value per district was extracted from the hydrogeological

dataset. Monthly PE/E reported cases were tabulated per month to explore any seasonal variation by monthly rainfall.

Univariate analyses were conducted to explore the associations between EC values and LECZ categories, as well as reported PE/E, low birthweight births, and maternal or fetal deaths. A full model will be constructed to explore seasonal and environmental risks associated with increased numbers of pre-eclampsia cases reported controlling for population, number of health facilities per district, referrals, and rainfall.

Preliminary Results

Model building and analysis are still in progress.

Maps of LECZ and EC values are presented, highlighting the spatial pattern of environmental risk of exposure to high salinity drinking water. Risk is particularly high in coastal areas, due to coastal intrusion and chronic flooding (Figure 1).

A figure of monthly rainfall and monthly pre-eclampsia/eclampsia reports suggest an inverse relationship; in the dry season months the number of PE/E reports increases (Figure 2). This is consistent with previous reports.

A third figure highlights the distribution of total PE/E reports per district between January 2017-July 2018, over total births at EmOC facilities (Figure 3).

Next steps will include generating maps and models of the distribution of PE/E cases, low birthweight births, and deaths controlling for season, district population, number of hospitals or EmOC facilities per district, referrals of complicated pregnancies, and other factors to isolate the association between environmental risks and PE/E risks. High levels of referral may mask the relationship as the spatial location is of where the woman delivered not where she was exposed to drinking water during her pregnancy. This will be explored and where possible, controlled for.

We hypothesize that the final model will result in an association between PE/E and other adverse pregnancy outcomes with proximity to high salinity drinking water, with peaks in the dry season.

To reduce complications and death due to hypertensive disorders in pregnancy, climate change and coastal flooding must be addressed, alternative sources of drinking water made available, and improved early detection and management of hypertensive

disorders in pregnancy (HDPs) through quality antenatal, delivery and postnatal care for pregnant and postpartum women particularly in these at risk regions.

Tables/Figures

Figure 1: Maps of environmental risks in Bangladesh; a) Low elevation coastal zone and b) electrical conductivity (salinity) measures for Bangladesh

a) b)

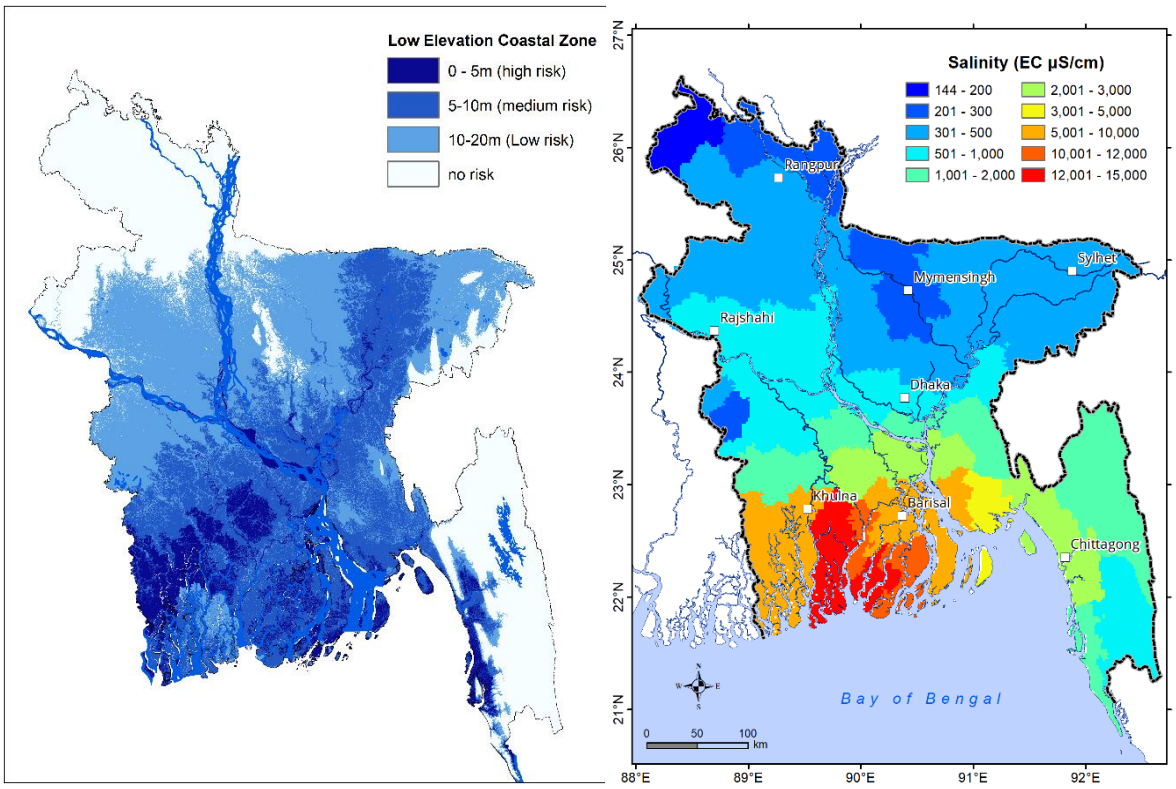


Figure 2: Average monthly rainfall and total PE/E cases reported, Jan 2016- July 2018

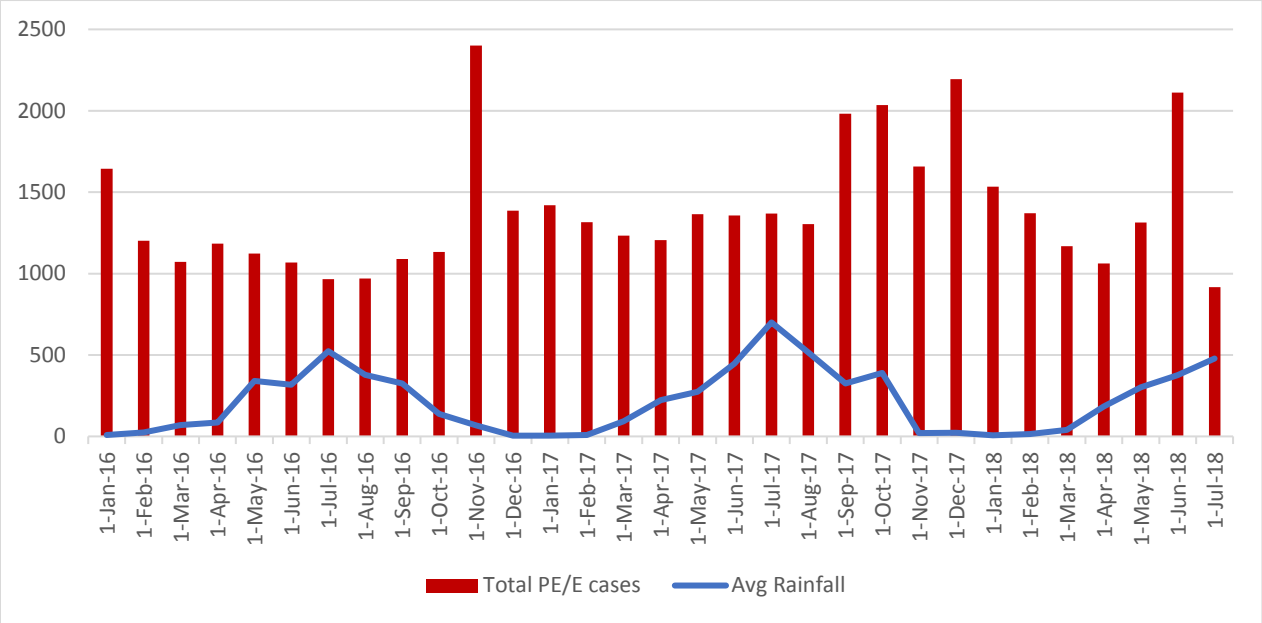
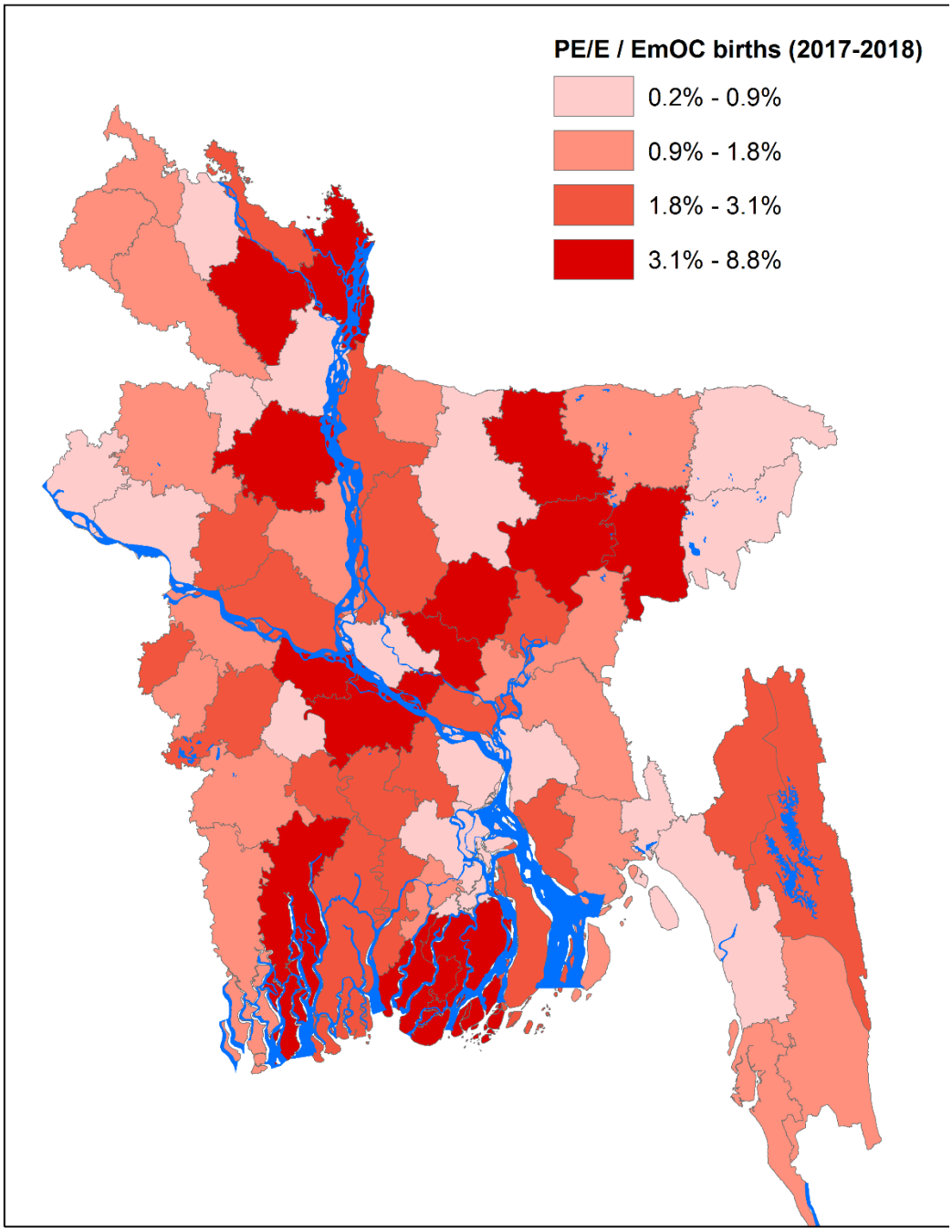


Figure 3: District level reports of average PE/E cases out of total births reported Jan 2017- July 2018



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