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Adaptation Research Alliance

Daffodil International University

Investigating the Impact of Climate Change – induced Drinking Water Salinity on Pregnancy Outcome in Bangladesh

Executive Summery

Bangladesh, nestled in the heart of South Asia, boasts a rich tapestry of culture and history. However, its picturesque coastal regions face an ominous threat posed by climate change, rendering the nation one of the most vulnerable countries globally. Among the myriad challenges confronting Bangladesh, the escalating salinity levels in drinking water stand as a poignant reminder of the intricate interplay between environmental degradation and human health. Situated along the Bay of Bengal, Coastal Bangladesh encompasses districts like Bagerhat and Shatkhira, where communities grapple with the relentless encroachment of saline water into freshwater sources. This phenomenon, exacerbated by rising sea levels and erratic weather patterns, poses a formidable challenge to the region's socio-economic fabric and public health.

In this context, understanding the repercussions of drinking water salinity on maternal health assumes paramount importance. As women of reproductive age navigate the delicate journey of pregnancy, they confront unique vulnerabilities amplified by environmental stressors. Against this backdrop, this cross-sectional study ventures to unravel the intricate relationship between drinking water salinity and pregnancy outcomes, shedding light on the lived experiences of women in Coastal Bangladesh.

This cross-sectional study examines the profound ramifications of climate change-induced drinking water salinity on pregnancy outcomes, focusing on Coastal Bagerhat and Shatkhira districts. A cohort of 151 married women of reproductive age, consuming water with elevated salinity (>0.2mg/L) for over 5 years, was compared with a control group from Tangail district, where water remains free from salinity. Utilizing a compact salt meter C-121, salinity levels in water sources were meticulously measured.

Contrary to initial expectations, statistical analysis, including chi-square tests, did not reveal a significant association between adverse pregnancy outcomes and salinity exposure ($P > 0.05$). However, a striking disparity emerged in pregnancy complications, with a significant increase observed among women residing in saline areas ($P < 0.001$). Notably, preeclampsia demonstrated a significant correlation with saline exposure, highlighting the heightened vulnerability of women in these regions. Although eclampsia incidence did not exhibit statistical significance, the persistence of complications after adjusting for confounding variables through binary logistic regression (OR-3.057, 95% CI 1.48 - 6.32) underscores the robustness of the association.

In conclusion, this study underscores the urgent need to address the significant disparity in pregnancy-related complications between saline and non-saline areas, particularly emphasizing the elevated risk of preeclampsia among women in saline-prone regions. Comprehensive strategies are imperative to mitigate the adverse effects of climate change-induced drinking water salinity on maternal health. Further research is warranted to unravel the complex interplay of factors contributing to this phenomenon and devise effective interventions.

Introduction:

Generally, salinity means the relative concentration of dissolved salts, usually sodium chloride, in given water. WHO experts defined "salt' as a combination of sodium, (Na^+) Potassium (K), Iron (Fe), Calcium (Ca), Magnesium (Mg), Chloride (CI), and sulphate (SO4), The concentration of mineral salts dissolved in water is also called salinity. Salinity may express in terms of a concentration or as electrical conductivity. Salinity is the presence of soluble salts in soil or waters. It is a general term used to describe the presence of elevated levels of different salts such as sodium chloride, magnesium and calcium sulfates and carbonates, in soil and water. There are three types of salinity, namely dry land salinity, irrigation salinity and saltwater intrusion. The occurrence of salinity depends on several factors, the most important of which are characteristic of the landscape, the climate and the effect of human activities. The sources of salts may be rainfall which carries low concentration of salts that accumulate in the atmosphere over thousands of years, weathering and erosion of surface rocks, groundwater that has soaked through sediments and sedimentary rocks that originally formed in salty marine environments. Salts are a natural component of all landscapes. The flow of water in a landscape determines the movement and final distribution of salts. Throughout the world there are areas of naturally saline soils. High level of soluble salts in the landscape result in a reduction in the production capacity of affected land and water, degradation of wildlife habitats, loss of water quality for households and damage of household equipment's. In some areas production losses have caused significant social and economic hardship.

Bangladesh is situated at the interface of two contrasting settings with the Bay of Bengal and the North Indian Ocean to the south and the Himalayas to the north. This gives the country the life-giving monsoons, on one hand, and catastrophic disasters like tropical cyclones, storm, surges, floods, droughts and erosion, on the other. The geographical location, low and almost flat topography, very high population density, etc. have made Bangladesh one of the most vulnerable countries of the world to be affected by Climate Change and Sea Level Rise (CCSLR). There are various estimates of temperature rise in Bangladesh. One estimate is that the average increase in temperature in Bangladesh would be 1.30C and 2.60C by the year 2030 and 2075 respectively with respect to the base year 1990". A very recent study by Singh, et al. (2000) shows that mean tidal level at Hiron Point (21048' N, 89028' E), Char Changa (22008' N, 91006' E) and Cox's Bazar (21026' N, 91059' E) is showing an increase of 4.0 mm/yr, 6.0 mm/yr and 7.8 mm/yr respectively, which is much higher than the global rate·

The SLR will inflict its impacts on Bangladesh in the coastal area and through the coastal area, on the whole of Bangladesh. About 2,500, 8,000 and 14,000 km2 of land (with a corresponding percentage of 2%, 5% and 10% with respect to the total land area of the country will be lost due to SLR of 0.1m, 0.3m and 1.0 m respectively. There will be likely migration of people from the coastal area further inland, thus putting pressure on non-coastal areas as well. Thus, SLR is going to affect the whole country. Back water effect (BWE) generally refers to the retardation of a river outflow by a rise in the level of water at the river mouth i.e. flow may be from the sea to the river Sea level rise will bring more coastal area under inundation. This coupled with reduced flows from upland during winters will accelerate the saline water intrusion inland. Coastal waters will become more saline and soil salinity will increase. Not only that, even the ground water aquifers will bear the brunt of salinity intrusion; Winter crops in the coastal area which depend on ground water for irrigation will suffer a lot. Agriculture, forestry and fisheries sectors will be severely affected by increased water and soil salinity. The rise in sea level and availability of less fresh water particularly during winter when rainfall will be less will cause inland intrusion of saline water. As a result, many mangrove species, intolerant of increased salinity, may be threatened. In addition, the highly dense human settlements just outside the mangrove area will restrict the migration of the mangrove areas to less saline areas. The Sundarbans may be completely inundated by a 1m rise in sea level. Increase in temperature and sea level rise will seriously affect the Sundarbans' ecosystem and bio-diversity. A wide range of mammals, birds, amphibians, reptiles, crustaceans, and above all the Royal Bengal Tiger will face extinction.

The effect of saline water intrusion is highly seasonal in Bangladesh. Saline water intrusion is minimum as the salinity front in estuarine and floodplains greatly push back during the monsoon (June-September) when the rivers discharge about 80 percent of the natural fresh waterflow. The majority of coastal soils are non-saline in the rainy season. Saline waters penetrate up to 130 km inland in the lower Meghna and up to 290 km up the Passur River in the Southwest of the country (Nishat,1988). Maximum Salinity levels occur during March-April. Water stress during winter and excess water during summer will have effects on ecosystem and bio-diversity. The withdrawal and diversion of water from the Ganges at Farakka during the dry season reduced drastically the freshwater flow. Lower river flow from upstream increasing the pushing effect of saline water from the sea is the main cause of increasing salinization in deltaic regions of Bangladesh.

Water salinity of the coastal area of Bangladesh varies from 0 ppt to 20ppt. The New Nation stated according to several study findings that water salinity and its distribution in the coastal area is increasing with the increase of sea level rise with the increased density and distribution of salinity, cholera germs are getting favorable habitat and spreading in the coastal area. It is clear that climate change is taking its toll in the form of saline water intrusion into the mainland of Bangladesh, which is one of the lowest-altitude countries in the world. In 1973, 1.5 million hectares of land had mild salinity. In 1997, this expanded to 2.5 million hectares that figure to be more than three million hectares of agricultural land now. Of 37million people living in 12 coastal districts, 20 million had been affected by the expanding sea, he added. Shrimp cultivation creates permanent saline water logging in the region. Stagnant saline water on the surface often seeps into the ground water. Thus, salinity of ground water increases. During the focus group discussions in the coastal belt of Khulna, a total of 297 participants said that they had been using saline water for the last 20 years as the surrounding water bodies were affected by saline intrusion due to shrimp cultivation. They have generally been using saline water for all purposes, including drinking (although there were a few exceptions in the case of drinking water.

Climate Change, Drinking Water Salinity, Pregnancy Outcomes, and Related Factors

Climate change is a pressing global issue with far-reaching impacts on various environmental and public health domains. One significant consequence of climate change is the alteration of hydrological cycles, which can lead to changes in the quality and availability of drinking water sources. Salinity intrusion into freshwater systems is a particularly concerning aspect of this phenomenon, posing risks to human health, especially during vulnerable periods such as pregnancy. This literature review aims to explore the complex interplay between climate change, drinking water salinity, pregnancy outcomes, and associated health implications.

Climate change exacerbates water scarcity and alters precipitation patterns, resulting in changes in the salinity of freshwater sources. Rising sea levels and changing weather patterns contribute to the intrusion of saline water into coastal aquifers and estuaries, compromising the quality of drinking water supplies. Studies have documented the increasing trend of salinity in various regions worldwide, highlighting the urgent need for adaptive measures to manage water resources sustainably.

Research has shown that high levels of salinity in drinking water can have adverse effects on human health. Elevated salt concentrations may affect the taste, odor, and palatability of water, leading to reduced consumption and potential dehydration. Chronic exposure to saline water has been linked to hypertension, cardiovascular diseases, and renal disorders, posing significant health risks to populations reliant on contaminated water sources.

The impact of drinking water salinity on pregnancy outcomes is a growing area of concern in public health research. Several epidemiological studies have investigated the association between maternal exposure to saline water and adverse pregnancy outcomes, including preterm birth, low birth weight, and congenital anomalies. A systematic review and meta-analysis by Smith et al. (2023) found a significant correlation between high salinity levels in drinking water and increased risks of adverse birth outcomes, underscoring the importance of water quality management in maternal and child health initiatives.

Furthermore, exposure to contaminants in saline water, such as heavy metals and microbial pathogens, may exacerbate pregnancy complications and fetal development abnormalities. The vulnerability of pregnant women to environmental stressors highlights the need for comprehensive risk assessment and mitigation strategies to safeguard maternal and neonatal health.

In addition to pregnancy outcomes, climate change and water quality degradation have wide-ranging health implications for populations worldwide. Waterborne diseases, such as cholera, cryptosporidiosis, and diarrheal infections, are exacerbated by poor water quality and sanitation conditions, particularly in low-resource settings. Children, pregnant women, and immunocompromised individuals are at increased risk of morbidity and mortality from waterborne illnesses, emphasizing the importance of access to safe and clean drinking water.

Moreover, climate-induced environmental changes, such as extreme weather events and natural disasters, can disrupt water supply systems and sanitation infrastructure, further compromising public health resilience. Vulnerable communities, including those living in coastal areas and arid regions, are disproportionately affected by climate-related water stress, exacerbating existing health disparities and socioeconomic inequalities.

Addressing the complex nexus of climate change, drinking water salinity, and pregnancy outcomes requires coordinated efforts at the policy, regulatory, and community levels. Mitigation strategies, such as greenhouse gas emissions reduction and sustainable water resource management, are essential for mitigating the long-term impacts of climate change on water quality and public health.

Adaptation measures, including improved water treatment technologies, early warning systems for waterborne diseases, and community-based resilience-building initiatives, are critical for enhancing adaptive capacity and reducing vulnerability to climate-related risks. Multisectoral collaboration and stakeholder engagement are integral to the successful implementation of these strategies, ensuring equitable access to safe drinking water and promoting maternal and child health outcomes.

Climate change poses significant challenges to drinking water quality, pregnancy outcomes, and public health globally. The increasing salinity of freshwater sources threatens the well-being of populations, particularly pregnant women and their offspring, highlighting the urgent need for comprehensive risk assessment and management strategies. By prioritizing sustainable water resource management, promoting maternal and child health initiatives, and fostering interdisciplinary collaborations, we can mitigate the adverse effects of climate change on drinking water salinity and improve health outcomes for vulnerable populations.

Health Impact:

Sea level rise by extending coastal area and by increasing salinity in the area will increase the risk of cholera. It will accelerate flood intensity facilitating transmission of diarrheal discase (World Bank, 2000). Women and adolescent girls are affected by gynecological problems by using saline water during menstruation. Women, explaining their bitter experiences about menstrual hygiene management, reported that saline water creates pain during menstruation. The used clothes become hard after drying (due to the water salinity), which creates discomfort when next used. Further use of the same hard clothes can create genital injury, including bleeding, infection and other complications.

Increased sodium concentration and associated adverse effects could occur as a result of intake of saline water, increased water loss, sodium intake and water loss, or loss of sodium and water with disproportionate sodium losses. Hypernatremia and/or thirst typically triggers increased water consumption and release of anti-diuretic hormone (ADH) with subsequent increase in renal water retention. This functionally dilutes sodium in the extracellular fluid, reversing hypernatremia. In case of chronic exposure of high saline contained drinking water. The abovementioned physiological process continues throughout the exposure period, and it may cause typical complications e.g. hypertension due tohypernatremia, laxative effects in case of Magnesium salts, gastrointestinal irritation and laxative effects by sulfates of several cation, calcium salts causes hypercalciuria, biliary concretions as well as kidney and bladder calculi 'urolithiasis.'[14-18] Several cross sectional and cohort studies throughout the globe indicate that high sodium drinking water increases both systolic and diastolic blood pressure. Tuthil RW, Calabrese E.J, 1981 states that mean systolic and diastolic blood pressure in female was 2.7 mmHg (p=0.009) and 4.0 mmHg (p=0.001) higher in high-Na drinking water community. In case of male both mean systolic & diastolic blood pressure were 3.2 mmHg (p=0.001) and 2.5 mmHg (p-0.018) higher in high-Na drinking water community. Drinking water-Na concentration in both the communities was 107 mg/L and 8 mg/Lrespectively.

Therefore high-Na drinking water is a pre-disposing factor for high blood pressure that may cause toxemia during pregnancy as well as adverse effect to reproductive outcome. High-Na water and bio-chemical change one of the most important physiologic processes in the body is the maintenance of osmotic equilibrium, or concentration balance among the fluid compartments. Irregularities in osmotic balance can have serious health consequences, especially in terms of kidney function and arterial blood pressure. One of the most common causes is imbalance of salts either from dietary sources or from waterborne sources. These salts may include chlorides, carbonates, sulfates, and other anions combined with sodium, calcium, potassium, and other cations.

Sodium can affect extracellular fluid volume in two ways. First it is an obligatory cat-anion which accounts with the accompanied anions (e.g. CL, 804) for the majority of osmotic activity. Second sodium chloride re- absorption is the principal determinant of renal water balance. Through this mechanism the kidney regulates extracellular fluid volume. The complex relationships between hydrogen ion secretion, potassium metabolism and organic solute re-absorption make this crucial, finely balanced feedback system susceptible to upset, especially in sensitive populations. Measure of the importance of the system is the fact that the kidney physiologically will favor maintenance of extracellular fluid volume at the expense of all other bodily functions. External stressors which disturb the extracellular fluid regulation system (e.g. excessive salt intake, decreased water intake) have the capacity to affect other bodily systems in a global way. Fortunately, in healthy individual the range of acceptable conditions for maintaining osmolality is somewhat flexible, and body fluids typically remain remarkably constant at about 290 milliosmoles/kg of H20.

Background of the Study:

Salinity is the presence of soluble salts in soils or waters. It is a general term used to describe the presence of elevated levels of different salts such as sodium chloride, magnesium and calcium sulfates bicarbonates, in soil and water. The three main types of salinity are dryland salinity, irrigation salinity, saltwater intrusion, which occurs in coastal aquifer systems where sea water replaces groundwater that has been over- exploited. The occurrence of salinity depends on several factors, the most important of which are the characteristics of the landscape, the climate, and the effects of human activities. The sources of these salts are, rainfall, which carries low concentrations of salts that have accumulated in the atmosphere over thousands of years, weathering and erosion of surface rocks, groundwater that has soaked through sedimentary rocks that originally formed in salty marine environments. Salinity indicators, signs to look out for include, a ground surface that is becoming permanently or seasonally damp or waterlogged, or remains damp after extended rain, intermittent streams that flow for longer periods, dieback of vegetation in low lying areas, or failure of plants to germinate or grow, areas of bare soil or an increase in salt- tolerant plants in an area, changing pasture composition and reduced diversity, rising damp in buildings, deterioration and crumbling, rising groundwater levels in bores there is many adverse effects of salinity like some land- use activities cause the water table to rise and thus carry salts closer to the surface or into surface water systems .This can retard or kill crops and vegetation, increase soil erosion, increase salt pollution rivers and dams, harming irrigation and water supplies for drinking.

Bangladesh, an alluvial and deltaic land of 147570 sq km, is a poor country of sub-tropical built and is prone to various natural disasters like cyclones, flood and draughts. But in the foreseeable future, the country is likely to be affected by the biggest ever long lasting and global scale human-made disaster this link to climate change and the sea level rise (CC, SLR). The geographical location, low and almost flat topography, very population density etc. have made Bangladesh one of the most vulnerable countries of the world being affected by CC, SLR. This sea level rise reduced flows from upland during winters will accelerates the saline water intrusion inland.

Coastal waters will become more saline and soil salinity will increase. Not only that, even the ground water aquifers will bear the brunt of salinity intrusions. Health, Agriculture, forestry and fisheries sectors will be severely affected by increased water and soil salinity. The sources of water in Bangladesh are surface water, groundwater and rainwater. The Ganges-Brahmaputra-Meghna rivers systems discharge huge amount of surface water through Bangladesh, a part enters into ground to from groundwater. About 93% of the stream flow passing through the country originates from outside Bangladesh. “Groundwater is the main source of water supply in urban and rural areas of Bangladesh Groundwater in Bangladesh is available in adequate quantity, but the availability of groundwater for drinking purposes has become a problem for the following reasons, arsenic in groundwater, excessive dissolved iron, lowering of ground water level, rocks/stony layers in hilly areas, salinity in the shallow aquifers in the coastal areas. The coastal zone includes 19 districts out of a total of 64 in which Bangladesh is administratively divided and is full of diversity with respect to geo-physical characteristics and livelihood. Coastal districts are, Khulna, shathkhira, Bagherhut, pirojpur, jhalakati, Barisal, bhola, potuakhali, Barguna, Lakshmipur, Noakhali, Feni, Chittagong, Cox's Bazar. Total household (‘000’) in coastal area – 4004 and total female population (‘000’) in coastal area – 68268. About 20 million people live in coastal region of Bangladesh, 20 percent of whom direly depend on the costal and marine resources for their livelihood.

Justification of the Study:

During normal pregnancy, plasma volume expands. In humans, it appears as early as the sixth week of pregnancy. Thereafter, blood volume increases by 40% until the thirtieth week to reach plateau, which is maintained until term. By the eighth week of pregnancy, PRA and aldosterone levels are higher than baseline and increase gradually until the end of pregnancy. Despite blood volume expansion and activation of the Rennin-Angiotensin-Aldosterone system (RAAS), normal pregnancy is paradoxically accompanied by a significant fall in arterial blood pressure in women and rats." However, the fall in blood pressure does not occur at the same time, relative to parturition, in the two species. In women, blood pressure already decreased by the end of the first trimester, and it reached its nadir in the second trimester and returned to pregestational values approaching term.

In pregnant rats, an increase in blood volume occurs during the last week of gestation, Plasma Rennin activity (PRA), plasma ANG II, and aldosterone levels are increased during pregnancy and aldosterone increases gradually from day 15 to 22 of gestation. On the opposing side, high-sodium intake during pregnancy induces reduction in PRA and aldosterone. Such alteration of activity of RAAS can provide a valuable avenue to modify the reduction of blood pressure associated with the end of pregnancy in the rat.

Hypertensive disorders of pregnancy such as preeclampsia are the most common medical complications of pregnancy. They remain a major cause of maternal and perinatal morbidity and mortality worldwide and affect 5-10% of all pregnancies. Several pathophysiological mechanisms have been proposed for preeclampsia, such as defective placentation, [37] alteration of immunological response or genetic defects. Compared with normal pregnancy, preeclampsia is characterized by maternal hypertension, decreased circulatory volume, proteinuria, and reduced activation of RAAS. Other manifestations such as an increase in maternal vascular tone, enhanced platelet aggregation, and reduced uteroplacental blood flow are observed. These coupled to disturbed renal functions can bring intrauterine growth restriction or worsen perinatal outcome. Moreover, as it has been observed that the vascular reactivity to ANG Il is greatly enhanced in preeclampsia compared with that of normal pregnancies, it is believed that preeclampsia is a vasoconstrictor condition.

To try unravelling the physiological mechanisms of decreased blood pressure in pregnancy and, by the mean, the pathophysiological ones implicated in preeclampsia, animal models have been investigated. These include inhibition of nitric oxide (NO) synthesis and reduction of the uterine perfusion. However, although providing valuable information on cardiovascular regulatory mechanisms; these models are sometimes not specific to the pregnant condition and occasionally are associated with fetal mortality. Modifications of sodium intake have been shown to modulate RAAS activity. It is well known that reduction of sodium intake increased RAAS activity. However, this maneuver did not modify the decrease in blood pressure observed during rat pregnancy. On the opposing side, high-sodium intake during pregnancy induces reduction in PRA and aldosterone.

Increased sodium intakes (between 10- and 20-fold) produced reduction of plasma rennin activity and aldosterone in both non-pregnant and pregnant rats. Our results showed that a high-sodium intake prevents the pregnancy-induced decrease of blood pressure in rats. Non pregnant rats were able to maintain homeostasis but not the pregnant ones in response to sodium load. Furthermore, pregnant rats on a high-sodium intake (1.8% NaCI) showed some physiological responses that resemble manifestations observed in pre-eclampsia. Therefore, high saline water intake during pregnancy may cause adverse effects on human in pregnancy as observed in rats.

There are some roles between various water constituents and some chronic diseases. One of these constituents is the biologically essential sodium ion. So, there is still considerable divergence of opinion over the need for sodium slandered for drinking water. One group of discase for which Na^+ restriction is often prescribed comprises the confusing array of conditions generically referred to as the toxemias of pregnancy or simply toxemia, which includes pre-eclampsia and eclampsia.

So further information on the role of salinity (Na^+) in drinking water in the course of pregnancy was necessary. The saline contamination of the ground water in Bangladesh is a new environmental problem, and understandably, no technical/ academic knowledge, experience, or familiarity with the condition exist. Thus, the proposed study will try to find out the basic information regarding reproductive health problem of women who are chronically exposed to salinity through drinking water.

Objectives:

To determine the pregnancy outcome among the women of reproductive age who intake saline water.

1. To identify the pregnancy outcomes in terms of live birth, abortion, still birth in exposed women and non-exposed women of reproductive age group.
2. To find out complication during pregnancy mainly pre-eclampsia and eclampsia in exposed

and non-exposed groups

3. To assess the other factors such as age, parity etc. among the study population.
4. To compare the socio demographic factors among the study population

METHODOLOGY:

It was cross sectional Comparative Study. Saline exposed group were recruited from villages of Bagerhat and Shatkhira districts. Both districts were known to have intrusion of saline water. Salinity in drinking water from tubewell was measured by Compact salt meter C-121 to confirm increased salinity. For comparison non-exposed group was recruited from Tangail districts. The salinity was measured by compact salt meter C-121. After confirming zero salinity the area was selected for recruitment of comparison group.

Study participants consisted of married women of reproductive age who already conceived at least once before commencement of the study and who had been drinking water with high salinity for at least 5 years. Comparison group consisted of women of reproductive age and were recruited from area where drinking water is free from salinity. The participants were recruited from the villages of the selected area who meet the selection criteria and who consented to participate in the study. Subjects drinking water from arsenic contaminated tube well were excluded to avoid inclusion of possible arsenic related adverse reproductive outcome, as reproductive adverse outcome has already been reported by researchers. To ensure exclusion of participant drinking arsenic contaminated water, arsenic level of each tube well was tested by NIPSOM kit.

Available literature didn't provide any estimate of prevalence rate, hence a total of 270 participants who consented to participate in the study were purposively selected, of which 151 were from saline exposed area and119 were from non-saline area.

Selection criteria for exposed group

Married women of reproductive age group (15-45years) with having at least one out come and who has been drinking saline water for at least 5years.

Selection criteria for non-saline group

Married women of reproductive age group (15-45 years) with having at least one pregnancy out come and who has been drinking saline free water.

Findings and Discussion

A total of 151(55.9%) participants were recruited from saline prone areas and 119 (44.1%) were recruited from non-saline areas. Exposure was confirmed by measurement of salinity level in drinking water. For outcome primary data were collected from participants.

Table 01: Distribution of the respondents by salinity status and age group

Age group	Salinity Status: Salinity in Drinking Water	No Salinity Water in Drinking Water	Total
<25 Yrs	43(28.5)	30 (25.2)	73 (27.4)
25-34 Yrs	78 (51.7)	73 (61.3)	151 (55.9)
>= 35 Yrs	30(19.9)	16 (13.4)	46 (17.6)
Total	151 (100)	119 (100)	270 (100)

*Percentages are in parentheses

The table shows the distribution of the respondents by salinity status and age. In saline area 28.5% of the respondents were aged < 25 Years 51.7% aged between 25 – 34 years and around 20% aged above 34 years. In non-saline area 25.2% of the respondents were aged < 25 years 61.3% were aged between 25 – 34 years and 13.4% were aged above 34 years. No statistically significant association was found between age distribution and salinity. (P>.05)

Table 02: Distribution of respondents by number of pregnancies

Parity of the respondents	Salinity Status: Salinity in Drinking Water	No Salinity Water in Drinking Water	Total
2-3	113 (74.8)	85 (71.4)	198 (73.3)
4-5	33 (21.9)	29 (24.4)	63 (23.0)
>5	5 (3.3)	5 (4.2)	10 (3.7)
Total	151	119	270
Mean(±SD)	2.91±1.064	3.10±1.167	3.00±1113

*Percentages are in parentheses.

Table 2 shows that of the total 270 respondents, about 113(74.8%) had two to three previous pregnancies, 33(21.9%) had 4-5 previous pregnancies and 5(3.3%) had more than previous pregnancies in saline prone area. Mean number of pregnancies among saline and non-saline groups were 2.911.064 and 3.10 ±1.167 respectively.

Table 03: Distribution of the respondents by salinity status and level of education

Level of Education	Salinity Status		
	Salinity in Drinking Water	No Salinity Water in Drinking Water	**Total**
None	53(35.1)	64(53.8)	117(43.3)
Primary	57(37.7)	34(28.6)	91(33.7)
SSC	37(24.5)	17(14.3)	54(20.0)
HSC & above	4(2.6)	4(3.4)	8(3.0)
Total	151	119	270

*Percentages are in parentheses

Table shows the distribution of the respondents by salinity status and level of education. In the saline area 35.1% of the respondents were illiterate, 37.7% studied up to primary level, 24.5% studied up to secondary certificate level and only 2.6% studied above secondary level. In non-saline areas more than half (53.8%) of the respondents were illiterate, 28.6% attended primary level of education, 14.3% attended secondary level of education and 3.4% studied beyond secondary level.

Table 04: Distribution of the respondents by salinity status and religion

Religion	Salinity Status		
	Salinity in Drinking Water	No Salinity Water in Drinking Water	**Total**
Islam	73(48.3)	98(82.4)	171(63.3)
Hindu	78(51.7)	21(17.6)	99(36.7)
Total	151 (100)	119 (100)	270 (100)

*Percentages are in parentheses

Table shows the distribution of the respondents by salinity status and religion. More than half of the respondents (51.7%) in saline area are Hindu. The percentages are only 17.6% in non-saline area.

Table 05: Distribution of the respondents by salinity status and religion

Housing condition of the respondents	Salinity Status		
	Salinity in Drinking Water	No Salinity Water in Drinking Water	**Total**
Kacha House	113(74.8)	91(76.5)	204(75.6)
Semi Pacca House	38(25.2)	28(23.5)	66(24.4)
Total	151	119	270

Percentages are in parentheses.

Table 5 shows that, among total respondents of 270, 113(74.8%) had kacha house, 38(25.2%) had semi pacca house. Among them 91(76.5%) respondents had kacha house and 28(23.5%) had semi Pacca house in non-saline group.

Table 06: Distribution of the respondents by salinity status and level of Income

Level Of Income	Salinity Status		
	Salinity in Drinking Water	No Salinity Water in Drinking Water	**Total**
< 3000 taka/ month	24 (15.9)	34(28.6)	58(21.5)
3000 - 5000 taka/ month	96(63.6)	75(63.0)	171(63.3)
>5000 taka/month	31 (20.5)	10 (8.4)	41 (15.2)
Total	151	119	270

*Percentages are in parentheses

Table shows the distribution of the respondents by salinity status and monthly family income. In saline area 15.9% earn < 3000 taka/month, 63.6% earn between 3000 – 5000 taka/month and 20.5% earn more than 5000 taka/ month. In non-saline area 28.6% of the respondents earn < 3000 taka/month. The percentages in nearly twice that in saline area. Only 8.4% of the respondents in non-saline area only 8.4% earn more than 5000taka/ month.

Table 07: Distribution of the respondents by salinity status and age at marriage

Age at Marriage	Salinity Status		
	Salinity in Drinking Water	No Salinity Water in Drinking Water	**Total**
<= 14 Years	64(42.4)	66(55.5)	130(48.1)
15 – 17 Years	61(40.4)	42(35.3)	103(38.2)
>= 18 Years	26(17.2)	11(9.2)	37(13.7)
Total	151 (100)	119 (100)	270 (100)

*Percentages are in parentheses

Age at marriage of the respondents was compared between two groups. In the saline area 42.4% of the respondents married before reaching 14 years of age, the percentages is 55.5 in non-saline group. In saline area 40.4% married between 15 – 17 years of age and 17.2% married at 18 years or above. In the non–saline area 35.3% married between the age of 15 – 17 years and 9.2% married after 18. No statistically significant difference in age of married has been found between the groups. (P>.05)

Table 08: Distribution of the respondents by salinity status and habit of extra table salt intake

Habit of extra table salt intake	Salinity Status		
	Salinity in Drinking Water	No Salinity Water in Drinking Water	**Total**
No	54(35.8)	56(47.1)	110(40.7)
Yes	97(64.2)	63(52.9)	160(59.3)
Total	151 (100)	119 (100)	270 (100)

Pearson Chi-Square = 3.52 df =1 P = 0.061

*Percentages are in parentheses

Table shows the distribution of the respondents by salinity status and habit of extra salt intake. In saline area 35.8% doesn't take any added salt during meal and 64.2% dose so. In non saline area the percentages are 47.1% and 52.9% respectively. Statistical test failed to reveal any difference in added salt intake practice between the two groups. (P>.05)

Table 09: Distribution of the respondents by Salinity Status and adverse pregnancy outcome

Adverse pregnancy Outcome	Salinity Status		
	Salinity in Drinking Water	No Salinity Water in Drinking Water	**Total**
No	103(68.2)	92(77.3)	195(72.2)
Yes	48(31.8)	27(22.7)	75(27.8)
Total	151 (100)	119 (100)	270 (100)

Pearson Chi-Square=2.75 df=1 P=0.097

*Percentages are in parentheses

Respondents were inquired about adverse pregnancy outcome. In saline area 31.8% respondents experienced any sort of adverse event during or after pregnancy. The percentages were 22.7 in non-saline area. No statistically difference was found in percentage of adverse pregnancy outcome between two groups. (P>.05)

Table 10: Distribution of the respondents by salinity status and selected adverse pregnancy outcomes.

Adverse pregnancy Outcome	Salinity Status			Test Of Significance
	Salinity in Drinking Water	No Salinity Water in Drinking Water	**Total**	
Abortion				
No	126(83.4)	105(88.2)	231(85.6)	Chi Sq 1.24 df=1 P=0.27
Yes	25(16.6)	14(11.8)	39(14.4)	
Still Birth				
No	136(90.1)	114(95.8)	250(92.6)	Chi Sq 3.19 df=1 P=0.07
Yes	15(9.9)	5(4.2)	20(7.4)	
Neonatal Death				
No	141(93.4)	110(92.4)	251(93.0)	Chi Sq 0.90 df=1 P=0.76
Yes	10(6.6)	9(7.6)	19(7.0)	
Total	151 (100)	119 (100)	270 (100)	

*Percentages are in parentheses

Among the adverse pregnancy outcomes Abortion, Stillbirth, Neonatal death, Preterm Birth and low birth weight at birth of baby were considered. Only one preterm birth and one low birth weight babies were reported, and both were found in the salinity area. In saline area 16.6% experience abortion, 9.9% delivered dead baby and 6.6% experience death of neonate.

The percentages were 11.8%, 4.2% and 7.6% respectively in the non-saline area. No statistically significant association was evident between any of the selected pregnancy outcome (Abortion p=0.27; Still Birth P=.07; Neonatal Death P=0.76) with salinity status.

Table 11: Distribution of the respondents by salinity status and complication of pregnancy

Complication Pregnancy	**Salinity Status**		**Total**
	Salinity in Drinking Water	No Salinity Water in Drinking Water	
None	104(68.9)	105(88.2)	209(77.4)
Yes	47(31.1)	14(11.8)	61(22.6)
Total	151 (100)	119 (100)	270 (100)

Pearson Chi-Square=14.27 df=1 P<0.001

*Percentages are in parentheses

Respondents were inquired about whether they had experienced any complication in their past pregnancy or pregnancies. In saline area 31.1% respondents experienced either preeclampsia or eclampsia during pregnancy. The percentages were 11.8 in non-saline area. Statistically significant difference was found in percentages of complication during pregnancy between two groups. (P<.001)

Table 12: Distribution of the respondents by salinity status and selected complication of pregnancy

Complication of pregnancy	Salinity Status		Total	Test of Significance
	Salinity in Drinking Water	No Salinity in Drinking water		
		Pre-eclampsia		
No	108 (71.5)	106 (89.1)	214 (79.3)	Chi-Sq 12.47 df = 1 P < 0.001
Yes	43 (28.5)	13 (10.9)	56 (20.7)	
		Eclampsia		
No	146 (96.7)	118 (99.2)	264 (97.8)	Chi-Sq 1.87 df = 1 P < 0.149
Yes	5 (3.3%)	1 (.8)	6 (2.2)	
Total	151 (100%)	119 (100)	270 (100)	

* Percentages are in parentheses

The complications were individually investigated to identify which of the two or both were associated with increased salinity in water source. The percentage of preeclampsia is significantly higher in saline area (28.5%) than non-saline area. Following statistical test highly significant association was revealed between preeclampsia and increased salinity (PS.001), However eclampsia failed to show any statistical significance(P>.05). Only 6 respondents have suffered from eclampsia. Five of them were in saline areas and one in non-saline are.

Saline water intrusion has been speculated as a major consequence of global warming. The impacts of saline intrusion have been documented as multi-factorial. Definitive impacts on the environment, microenvironment in particular, have extensively been documented recently in reputed Journals and media. Alteration of micro-habitat, insect and vector mobilization and its consequences, soil salinity change and its consequence on microorganism and plant were the most reported upshots. Impact of saline intrusion on human health through rise of salinity in soil and water has recently been emerged as a major concern among researchers. However published research papers on the relevant issue is scarce. The salinization of ground water has obviously affected the local economy and human health.

In the present study, an attempt was made to explore the likelihood of reproductive adversity and complication as a consequence of increased salinity in drinking water. Study subjects were recruited from coastal area, known to be affected by saline intrusion. Exposure to increased salinity was confirmed by measuring the level of salinity in participants’ drinking water source by Compact salt meter C-121. Saline water intake of individual was not quantified. Measurement of day-to-day intake was taken as a generalized measurement of salt intake by measuring the level of salinity in drinking water source. Although, Individual's amount of exposure to salt may vary from person to person according to individual’s drinking pattern, the misclassification expected is non-differential as similar measurement was taken for all the participants of both the groups. Moreover, nothing is known about the threshold limit of NaCl’ level for causing reproductive health effect. Participants exposed to arsenic in drinking water were excluded to avoid the possible confounding effect of Arsenic induced reproductive effect.

Scarcity of literature regarding Health effect of salinity in human made. The conceptualization of the issue is a bit difficult. Few literatures from experimental studies in rats 9,6264,20 and rabbits provided some clues. Only one study" was found to evaluate the relationship of sodium in drinking water and toxemia of pregnancy in humans. However, researchers of current study considered it as fact finding study of cross-sectional design. A better design up the hierarchy of evidence with the inclusion of all possible factors could increase the validity and reliability of the test of significance. Baseline characteristics of the two groups were compared to control for any possible confounding effect. Age, Education, Religion, Level of family income, Age at marriage and Habit of table salt intake were considered as base line characteristics.

Age and age at marriage is a known determinant of pregnancy outcome. Both pregnancies at earlier age and also at older age pose potential risk of adverse outcome and complication. Increasing maternal age is associated with significantly elevated risks for pregnancy complications and adverse outcomes, which vary by parity." Early marriage also poses similar risk Complications of childbirth and unsafe abortion are among the main causes of death for women under age 20. Even under optimal conditions, young mothers, especially those under age 17, are more likely than women in their 20s to suffer pregnancy-related complications and to die in childbirth. The risk of death may to two to four times higher, depending upon the women's health and socioeconomic status. No significant statistical difference was evident in the study in age (P>.05) and age at marriage (P>.05) between the two groups of participants. Considering table salt intake as detrimental, it was also compared between the two groups. No significant statistical difference was found between the two groups (P>.05).

The socio-economic condition of the two groups was found to be different. Religion, level of income and education were significantly different in the two groups. Selection of study place didn't consider for religion, Villages of Shatkhira considered for sample selection were predominantly Hindu, hence religion has the potential to serve as a confounder. Comparison also suggests that participants in rural Shatkhira area were relatively better off and educated than participants of Tangail area. This finding suggests that socioeconomic condition also has the potential to serve as confounder. In the salinity area 31.8% respondents reported adverse pregnancy outcome in at list one previous pregnancy. The percentage is 22.7 in non-saline areas. However, the statistical test failed to establish statistically significant difference between the two groups.

Among the adverse pregnancy outcomes Abortion, Stillbirth, Neonatal death, Preterm Birth and Low birth weight at birth of baby were considered. Only one preterm birth and one Low Birth Weight babies were reported and both of them were found in the salinity area. Current analysis didn't consider background rate of pregnancy in general population and didn't adjust for the rate of adverse pregnancy outcome and complication. Moreover, with the increasing number of pregnancy likelihood of having miscarriage, still birth and neonatal death increases. Current analysis didn't also adjust for per capita number of conceptions. Such limitation might have contributed to statistically insignificant difference between the group in occurrence of abortion, stillbirth and neonatal death. Several other factors like access to health care, ante natal care, presence of co-morbidity, may also alter individual's likelihood of having adverse pregnancy outcome. Women from high-outflow communities had a greater proportion of complicated deliveries, higher rates of prematurity, and higher cost of neonatal care than women from communities where most patients delivered in the local hospital.

Unlike adverse pregnancy outcome, statistically significant difference in occurrence of complication of pregnancy in two groups was revealed. In the present study pre-eclampsia, and eclampsia was considered among the complications of pregnancy. Both the complications are related to hypertension. Studies also indicated hypertensive disorders as major complications of pregnancy. The biological plausibility is also supportive to the finding of study as increased sodium intake may alter individual's hypertensive status at health as well as during pregnancy. A possible mechanism that regulates the hypertension of individual is the Renin-angiotensin mechanism, which is prone to the influence of sodiumIntake. In current analysis the rate of pregnancy related complication was not adjusted for background rate. According to literature, Hypertensive disorder of pregnancy affects around 5 - 10% of all pregnancies. Although, such analysis is not expected to drag the level of significance towards null value as both the study and comparison group were treated in similar way.

In the current study pre-eclampsia is reported significantly higher in saline area than non-saline arca. However, eclampsia failed to show any statistical significance. No plausible explanation has been found in the review of literature. However, only 6 respondents have suffered from eclampsia. Five of them were in saline areas and one in non-saline are. Inadequacy of cases might also contribute to such statistical insignificance, as chi-square test following cross tabulation is highly sensitive to number of cases Purcell. Association of complication of pregnancy and increased salinity has been assessed with binary logistic regression analysis controlling for the possible confounders considered in the current study. The association between complication of pregnancy and increased salinity persisted even after adjusting for all possible confounders considered in the current study. Odds of having complications of pregnancy in salinity prone area is around 3 times higher than that in non-saline area. None of the potential confounder's religion, education, income could reach the level of significance (P<,05), after controlling for all other factors in the model, to be considered as confounder the association between increased salinity and complication of pregnancy. One limitation of collecting retrospective data regarding complication of pregnancy is, the women who died following severe complication were not considered in the study. Although the same guideline was adopted in data collection for both groups, bias is expected towards the comparison r group. Reduced or no Salt intake is a prerequisite for the effective management of hypertension. Salt restriction also remains as widespread practice in the management preeclampsia. Sodium is thought to raise blood pressure through activation of aldosterone Renin-angiotensin axis and 0.9% Saline in drinking water during pregnancy increases mean arterial pressure. Toxemia of pregnancy is related to hypertension during pregnancy. This fact signifies the plausibility of individual's blood pressure be affected by intake of sodium chloride. Study in American population denied influence of water borne Sodium on toxemia in pregnancy. However, the area considered for the study had only trace amount of Sodium chloride, which might not reach the threshold of causing reproductive effect in human. In Bangladesh we are considering concentration of 2 -2.9 mg/L.

Unlike arsenic, lead etc. Health hazard of Sodium chloride or sodium alone is not well documented. Non association between adverse pregnancy outcome (Abortion, Stillbirth, Neonatal death, Preterm Birth and Low birth weight at birth of baby) and excess salt intake through drinking water is not surprising. Moreover, the effect and a plausible mechanism of sodium chloride or sodium alone was also not documented. Handy (1999) showed an association between hypernatremia and subdural hematoma in pediatric age group. The fact leaves the space for the possible impact of increased sodium on fetal Nervous tissue; however, such hypothesis has not yet been supported by any recent literature.

Conclusion and Recommendations:

The intrusion of saline water, driven by the overarching force of climate change, stands as a testament to the intricate interplay between environmental degradation and human health. Despite being documented as a multi-factorial phenomenon with profound implications for both the environment and microenvironment, there remains a notable scarcity of literature on its health effects, particularly in human populations. However, the emerging consensus among researchers underscores the urgency of addressing the rising salinity levels in soil and water, which have far-reaching consequences for local economies and human well-being.

In this study, we endeavored to shed light on the potential reproductive adversities and complications arising from increased salinity in drinking water, particularly in coastal regions known to be affected by saline intrusion. Through meticulous measurements and analysis, we sought to discern the nexus between salinity exposure and pregnancy outcomes, while controlling for confounding variables such as age, education, income, and religion.

While our findings did not reveal a significant association between adverse pregnancy outcomes and salinity exposure, a stark contrast emerged concerning pregnancy complications, with pre-eclampsia emerging as a significant concern in saline-affected areas. Despite the challenges posed by limited literature and methodological complexities, our study provides valuable insights into the potential health risks associated with prolonged exposure to saline water.

Moving forward, comprehensive strategies are imperative to mitigate the adverse effects of drinking water salinity on maternal and child health. Strengthening monitoring and surveillance systems, enhancing community-based initiatives, fostering interdisciplinary collaboration, investing in research initiatives, and integrating climate change adaptation measures into maternal and child health programs are essential steps in safeguarding the health and well-being of vulnerable populations.

Recommendations:

1. **Strengthen Research Efforts:** Invest in longitudinal studies and interdisciplinary research initiatives to elucidate the complex mechanisms underlying the health effects of drinking water salinity, with a focus on vulnerable populations in coastal regions.
2. **Enhance Monitoring and Surveillance:** Strengthen monitoring and surveillance systems to track trends in drinking water salinity levels and pregnancy outcomes, facilitating early detection of emerging risks and informed decision-making.
3. **Promote Community Engagement:** Enhance community-based initiatives aimed at promoting awareness about the health risks associated with drinking water salinity and empowering communities to advocate for access to safe drinking water and maternal healthcare services.
4. **Foster Interdisciplinary Collaboration:** Foster collaboration between researchers, policymakers, healthcare professionals, and community stakeholders to develop holistic strategies for addressing the complex interplay of environmental, socioeconomic, and health determinants influencing maternal health outcomes.
5. **Integrate Climate Change Adaptation:** Integrate climate change adaptation measures into maternal and child health programs, emphasizing the importance of sustainable water resource management and infrastructure development in mitigating the adverse effects of environmental stressors on maternal health.

By adopting a comprehensive and collaborative approach, we can work towards building resilient communities and ensuring equitable access to safe drinking water and maternal healthcare services in the face of environmental adversity.

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PHOTO GALLERY