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Review

Impacts of Salinity Intrusion in Community Health: A Review of Effectiveness of Adaptation Measures to Decrease Drinking Water Sodium (DWS) from Coastal Areas of Bangladesh

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Abstract: Increasing salt intake has substantial negative impacts on health and well-being. This review article focusses on the effect of salinity intrusion (SI) on the water quality and community health of coastal Bangladesh and to find out the effectiveness of interventions for reducing the negative effects of salinity. Saline water is a noteworthy reason for hypertension or high blood pressure in the coastal areas. Health status of women especially the pregnant women are vulnerable because of drinking water sodium (DWS) prompting to pre-eclampsia, high blood pressure and hypertension as well as infant mortality. Several interventions such as rainwater harvesting and Pond sand filter (PSF) system as well as managed aquifer recharge (MAR) usage and the integration of mixed sources were reviewed on the content of drinking water sodium (DWS). Although rainwater has the positive impact of low or no sodium intake on human health, it still possesses negative impacts from not having vital minerals. Despite what might be expected, in MAR a steady increment in sodium concentration through the span of the dry season was observed. It is, subsequently, important to increase awareness about drinking water sodium (DWS) intake by providing and adopting correct technological interventions.

Keywords: Salinity; drinking water sodium (DWS), High blood pressure; maternal health; Pond sand filter (PSF)

1. Introduction

Seawater intrusion (SI) is an extensive issue in the coastal aquifers worldwide. Surface water resources, like rivers and canals, is astringently affected by the intrusion of saline water [1, 2]. In the mega-delta coastal areas of Vietnam, Bangladesh and India, surface and near-surface drinking water are the most susceptible to contaminate by saline water intrusion, pushing more than 25 million people at jeopardy of drinking saline water. Climate change is liable to intensify this quandary and have adverse health consequences, such as the prevalence of hypertension and cardiovascular diseases [3]. The scarcity of safe drinking water caused by the cumulated effects of salinity, arsenic and drought is one of the most solemn resources and health quandaries in Bangladesh's coastal communities [2] contaminated by varying degrees of salinity from rising sea levels, cyclone and storm surges, and upstream withdrawal of freshwater [4].

High salt intake is a major risk factor for increased blood pressure. Approximately 20 million people in Bangladesh are at high risk of hypertension due to the intrusion of saline water caused by climate change [5]. The physical geography of the coastal region of Bangladesh is more diverse and dynamic than it is usually known. Disappointment to acknowledge this has driven to genuinely mistaken assumptions around the conceivable impacts of rising ocean levels on Bangladesh with

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worldwide warming [6]. Most of Bangladesh's coastal towns are located on the banks of low tidal areas at an average elevation of 1.0–1.5 m from the sea level [7]. The southern portion of coastal Bangladesh covers about 32% of the entire zone of the country [8] and are significantly susceptible to the results of temperature due to climate change [9]. Water salinity is a consistent peril to numerous districts of southern Bangladesh. For instance, Batiaghata Upazila, located within the southwestern Khulna District of Bangladesh, is the frequently saline affected area, within which agricultural activities principally depend on precipitation [10]. The earlier study on groundwater in southwestern Bangladesh established that the zone was prevailing in Na-Cl category of brackish waters [11] because of the stimulus effect of seawater and the hydrogeochemical progressions [12]. Anthropogenic such as the upstream freshwater removal, as well as the biophysical factors such as cyclones originated outside the topographical frontier of the coastal Bangladesh contribute to the cumulative increase in salinization in the southwestern region [13].

Groundwater in Bangladesh is the main and safer source for drinking water collection compared to other sources of water. The rural population depends heavily on drinking water for tube wells [14]. Millions of populations of the coastal Southeast Asia experience cumulative sodium concentrations in their sources of potable water, probably partly because of climate change [15]. The long-term consumption of substantial amounts of sodium by drinking water remains unknown on population health [15]. About 20 percent of adults and 40-65 percent of elderly people in Bangladesh suffer from hypertension (HTN), which is an increasingly important medical and public health problem [16].

Increased dietary sodium ingestion contributes to rise the proven risk of hypertension, nonetheless it remains unidentified whether sodium ingesting in potable water could have parallel impacts on human health [15]. Drinking water sodium (DWS) is a significant basis of critical source of every-day sodium admissions in human health in the salinity-affected zones as well as a hypertension hazard. In view of the prospective upsurge in salinization, swift courses of activities are required in the affected zones. Since managed aquifer recharge (MAR) has varying outcomes, innovations for the arrangement of dependable, secure and low-sodium containing potable water, together with the improvements in MAR, should be developed and evaluated in "real-life" salinity settings. The prescribed nutritional sodium ingestion is 2 g/day (< 85 mmol/day) concurring to the World Health Organization (WHO) and the Food and Agriculture Organization (FAO) (2002) of the joint expert consultation [17]. However, drinking water sodium (DWS) intake has exceeded in many parts of Coastal Bangladesh triggered by salinity intrusion, climate change, storm surges etc. in the soil and in the existing water resources. The aim of this review article is therefore to identify the impacts of sodium in the drinking water from coastal areas of Bangladesh, how it is affecting the health status of men women and children and the positive and negative effects of the associated intervention mechanisms available.

2. Drinking water Sodium (DWS): from the saline water intrusion

The interruption of salinity into surface water and aquifer constitutes a significant risk to people's access to potable water [2]. The likely effects of climate alter on coastal zone districts comprise a regular immersion from the Bay of Bengal, increased storm surges, damage of coastal swamps and wetlands, as well as expanded salinity [18, 2] amid the monsoon with the tides through rivers and estuaries [2]. Moreover, ascendant or lateral movement of the groundwater amid the post-monsoon as well as the direct flooding with the saline or brackish water for shrimp cultivation is the anthropogenic basis of salinization in the south [2]. Spatial and temporal inclination of surface water salinity investigation in the coastal zones of Bangladesh showed that the maximum salt encroached areas in the monsoon is: (i) Khulna, Satkhira, Bagerhat, Jessore and Gopalganj- the districts located in the extreme southwestern zones; (ii) Bhola, Noakhali and Feni- the districts positioned in the lower Meghna River floodplain and the Meghna estuarine floodplain; (iii) Chittagong and Cox's Bazar- the districts located in the southeastern portion of the Chittagong coastal plains adjacent to the Bay of Bengal; and (iv) Barisal, Jhalkathi, Patuakhali and Barguna- the slightly-saline-diverged mid-south zone districts. All these districts are also affected during the dry season [19]. The critical seasonal difference in the salinity of the pre-monsoon season and the salinity outcome of the post-monsoon

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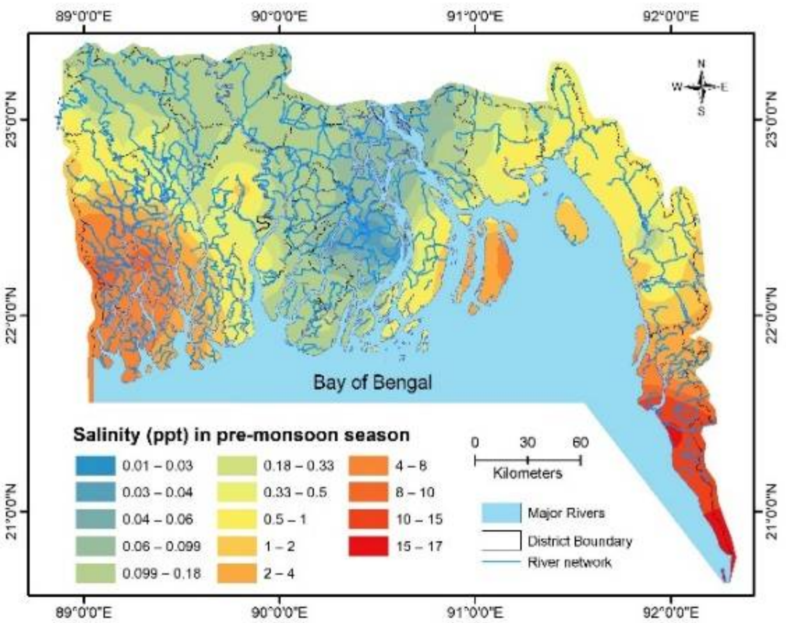
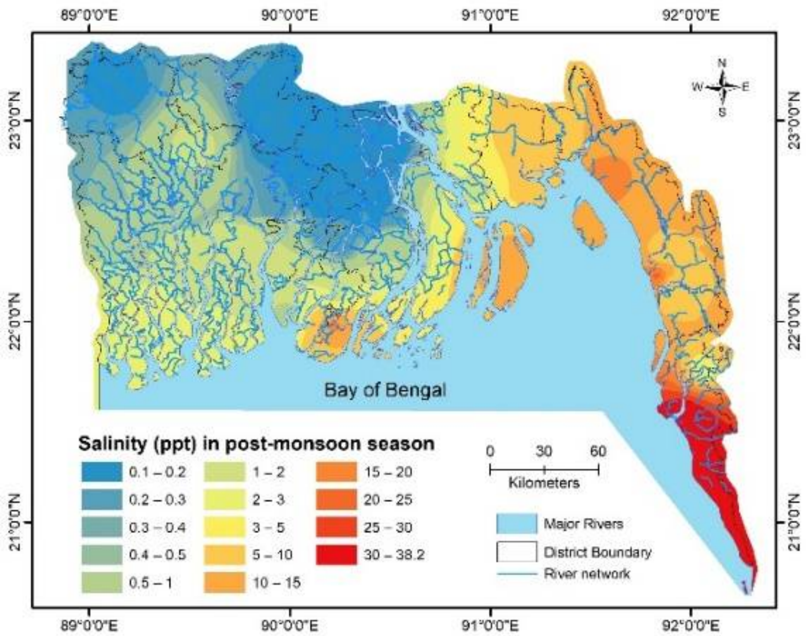
season in Bangladesh's surface water is easily distinguishable (Figure 1). Increased anions and cations such as Cl^-, Na^+, SO_4^{2-}, HCO_3^-etc. throughout the post-monsoon shows the inward movement of salt-water [19]. The extreme seasonal distinction of anions and cations is, therefore, ascribed to the upstream freshwater deliberation and plummeting currents in the downstream followed by swelling invasion of seawater in the land [19]. The more prominent the entrance of marine impact into the terrestrial inland, the lower is the accessibility of freshwater, that by its combination with salt water tends to be brackish [20]. In addition of the total dissolved solids (TDS) and the electrical conductivity (EC), the abundance of the key anions and cations in the surface water was confirmed in the subsequent directive of $Na^+ > Ca^{2+} > K^+ > Mg^{2+}$ and $Cl^- > SO_4^{2-} > HCO_3^- > NO_3^- > CO_3^{2-}$ [19].



(a)



(b)

Figure 1. Spatial salinity distribution in parts per thousand (ppt) in the pre-monsoon season (a) and post-monsoon season (b) in Bangladesh's coastal rivers and estuaries. Pre-monsoon (n=96) and post-monsoon (n=44) sampling points [author's study].

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As described in earlier section Gopalganj Sadar Upazila is one of the salinity prone vulnerable coastal zones of Bangladesh. The risk of salinity hazard was investigated for the surface water (ponds and river) and the groundwater samples from the shallow tube wells (STW) and the deep tube wells (DTW) [21]. Correlation matrices as well as the principal component analysis (PCA) established the higher electrical conductivity (EC) and total dissolved solids (TDS) in relation to the salinity stress with Na^{+}, K^{+}, Cl^{-} and total hardness (TH) in relation to Ca^{2+}, Mg^{2+}, PO_4^{3-} and SO_4^{2-} [21]. Rahman et al. (2017) further examined an entire of 46 groundwater samples from pre- and post-monsoon periods to evaluate the likely risk to human consumption among adults and children of the Gopalganj disctrict. Maximum hydrochemical parameters corresponding to pH, EC, TDS, Na^{+}, Cl^{-}, HCO_3^{-}, As, Mn, Fe, B, NO_3^{-}, CO_3^{-} etc. surpassed the limits of various potable water standards. The spatial extensions of EC, Cl^{-}, As, Fe, and Mn varied considerably. The exponential semivariogram model was overriding in the analysis of the best model for both pre-monsoon and post-monsoon seasons. Furthermore, mean values of the hazard quotient and hazard index constructed on As, Fe, Mn, B, NO_3^{-} and F^{-} specified that the groundwater varied seasonally and carriages a considerable health and wellbeing hazard to the grown-ups as well as to the children [22].

Molar proportion of the Cl^{-}/Σanions and $Na^{+}/Na^{+}+Cl^{-}$ specified that the groundwater in the south- central part of Bangladesh, in particular, Barguna and Patuakhali, was affected by the intrusion of seawater. The groundwater of Barguna and Patuakhali was clearly dominated by the cations and anions of Na^{+}, Mg^{2+}, Ca^{2+}, Cl^{-}, and HCO^{3-} amid the both wet and dry-monsoon seasons [23]. While the maximum sodium intake according to WHO (2011) is 200 mg/L, the Na^{+} concentrations in the groundwater reported were 863 mg/L and 825 mg/L in the pre-monsoon and post-monsoon seasons, respectively [23]. In another research works, 18 groundwater samples were collected from the tube wells of Chittagong district, located in the Southeastern coastal region of Bangladesh. The depths of the tube wells shifted from 244 to 365 meters and the tests indicated that the 75% of the groundwater samples were Na^{+} subjugated. Whereas, the average salinity of the shallow tube wells ranged from 5.11 to 6.48 dS/m, while the pondwater salinity ranged from 0.11 to 3.12 dS/m [24].

It is, therefore, clear from the above recent studies that the salinity of the surface water as well as the groundwater resources of the coastal districts varies significantly. The level of salinity within the shallow and deep tube wells varied in keeping with the profundity of the wells and the distance from the Bay of Bengal. In addition, the groundwater in the coastal districts was categorized by a higher level of non-carcinogenic and cancer risk vulnerability of arsenic and other elements from groundwater.

2.1. Drinking water Sodium (DWS) and health of coastal people

Confirming passage to secure potable water is one of the foremost serious questions for the wellbeing and sustainable financial improvement of the residents living within the coastal zones [2]. Salt was depicted as a fundamental component of nourishment with solid social and devout roots, which was reported in a study on the perception, practice and belief of Bangladesh's vulnerable salt intake and health risks in climate change. [5]. People described both health benefits and salt ingestion risks. The inclusive risk insight for disproportionate salt ingesting was truncated among the respondents. The respondents further believed that the cooking procedure made the salt harmless and opined that the salt was added to many foods even if they were not tasted salty. Nevertheless, they could not distinguish that salt can naturally occur in both food and water [5].

While the intrusion of salinity in fresh groundwater, directly and indirectly, affects human well - being [25], very few studies on intake and related health effects of DWS have been obtained. Salinity intrusion on the coast of Bangladesh has serious implications for population health, which must still be clearly understood [26]. Jabed et al. (2018) identified the public discernment of the water salinity effects on human health in the Chittagong South-Eastern coastal region. Owing to the use of saltwater, villagers suffered from numerous diseases including skin ailments, hair fall, diarrhoea, gastric and high blood pressure [25].

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The neglected existence of salt in potable water will en course to an unsatisfactory and risky level of salt ingestion among the population. Such over the top salt intake, in turn, can put numbers of individuals together with pregnant women, at a risk of hypertension and even death [5].

Khan et al. (2011) identified an estimated average DWS of 5 -16 g/day amid the dry season compared to 0.6–1.2 g/day within the wet season. The daily sodium concentration in the urine was found 3.4 g/day (range 0.4 to 7.7 g/day) [4]. Women relied on STSs for potable water were more likely to have urine sodium >100 mmol/day compared to the women consuming rainwater [OR= 2.05; 95% confidence interval (CI), 1.11–3.80] (Figure 2(a)). The yearly hospital incidence of hypertension amid the pregnancy period was greater within the dry period (OR= 12.2%; 95% CI, 9.5–14.8) than within the wet season (OR= 5.1%; 95% CI, 2.91–7.26%). A substantial relation among DWS and for each of the (pre)eclampsia and gestational hypertension was distinctly delineated [27]. It was clearly found in the Dacope Upazila of Khulna District the potable water sources had remarkably high-levels of sodium concentration (mean 516.6 mg/L, ±524.2) (Figure 2(b)). The women dependent on the tube-well or groundwater were more susceptible to disease risk than the rainwater consumers (p,0.001). Adjusted risks for (pre)eclampsia and gestational hypertension considered together increased in a dose-response manner for increasing sodium concentrations (300.01–600 mg/L, 600.1–900 mg/L, 900.01 mg/L, compared to ,300 mg/L) in drinking water (ORs 3.30 [95% CI 2.00–5.51], 4.40 [2.70–7.25] and 5.48 [3.30–9.11] (p-trend,0.001) [27]. People exposed to slightly saline (1000–2000 mg/l) and moderately saline (≥2000 mg/l) concentration drinking water had respectively 17% ($p < 0.1$) and 42% ($p < 0.05$) higher chance of being hypertensive than those who consumed freshwater (<1000 mg/l). It was further found that the females were 31% higher probable to be hypertensive than the males. In addition, interviewees of 35 years old and above were approximately 2.4 times tend to be hypertensive compared to the interviewees of under 35 years. Moreover, it was found that, among the age of 35 years and above, pre-hypertension and hypertension were 53.8% higher for the slightly saline water and 62.5% higher for the moderate saline water. In total, the disease risks were higher than national rural statistics by 50.1% for saline water groups. For a modest salinity exposure, the pervasiveness of hypertension among the interviewees was 21%, 60% and 48% higher than national statistics (23.6%), respectively. Although there was a slight periodical difference in the salinity of potable water, during the dry season it showed an increasing trend and maximum levels of the blood pressure. Average salinity as well as the relevant pervasiveness of hypertension were greater among the consumers of deep aquifer water (21.6%) than for the users of shallow aquifer waters (20.8%) [15].

Consequent modifications for the puzzling aspects found that DWS concentrations were significantly associated with BP. In addition, systolic and diastolic BP was lesser typically by 0.95/0.57 mmHg for each 100 mg/L decline in DWS and the probabilities of hypertension were lesser by 14% [15]. Scheelbeek et al. in another study (2017) examined the effects of DWS on pregnant women's blood pressure. Research has shown that increased blood pressure can have a serious impact on maternal and fetal health. Comprehensive linear mixed regression models further examined the relationship of systolic and diastolic BP of healthy females according to their sources of drinking water. Subsequent tuning of the several other factors revealed that high saline sources such as tube-wells as well as well as the pond water consumers had expressively higher average systolic (+ 4.85 and +3.62 mmHg) and diastolic (+2.30 and +1.72 mmHg) BP than the rainwater consumers [28]. Analogous characteristics have also shown by 24-hour urinary sodium (mmol/day) from drinking water sources [28]. Higher concentration of DWS from salt water contamination was linked with higher BP in normotensive pregnant women of the coastal regions. Variations may result at pre-pregnancy stage as the DWS levels may vary before they conceive or may be induced amid pregnancy when a woman is enforced to transform the source of potable water from rainwater-based-system to an even higher-saline substitute source owing to the depletion of storing [28].

Dasgupta et al. (2016) used probit and logit models to evaluate the likelihood of mortality for the newborns under two months of age from Bangladesh Demographic and Health Surveys (BDHS) in 2004 and 2007. Subsequently the BDHS data were spatially extrapolated on the monthly soil salinity data from 2001-2009. Since the household-specific drinking water salinity was not measured, soil data that fell within the 40km of the BDHS clusters were considered [18]. The study examined

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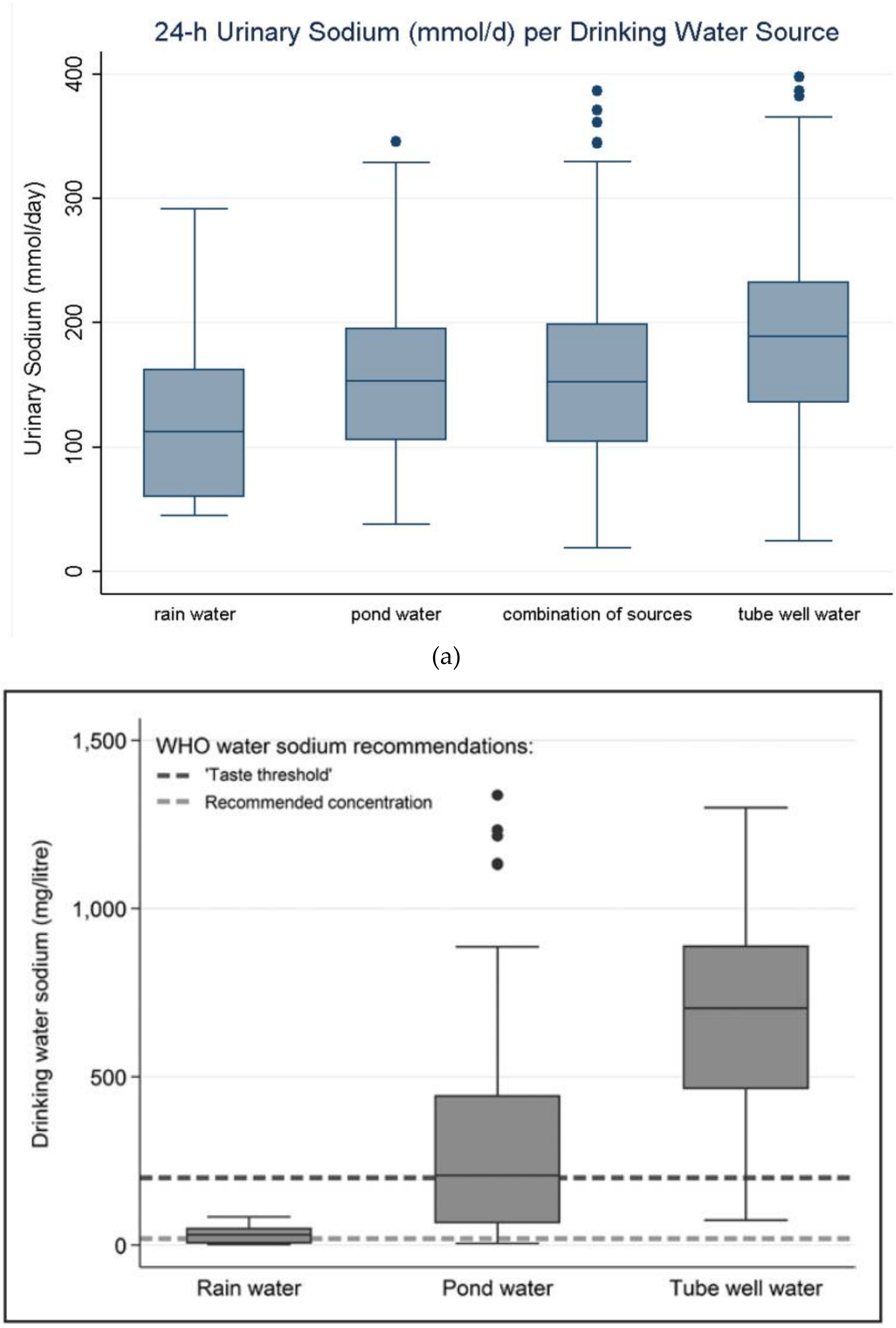
multiple factors of infant mortality and correlated that exposure to saltwater amid the last stages of gestation was highly significant. Nonetheless, the saltwater contact amid the earlier months of gestation was not significant. The implications are analogous to the projected paraphernalia of conventionally mentioned variables to a degree of maternal stage of development, schooling, household genders, assets, toilets, potable water sources, cooking fuels, etc. [18]. The modeling strongly suggested that DWS is a major factor of infant and newborn death in the coastal Bangladesh and further gave new insights into the relationship between post-natal influences and the pacing of prenatal ingestion of DWS [18].



(a)

(b)

Figure 2. (a) Urinary sodium excretion (mmol/day) of healthy pregnant women recruited in the dry season (n=645) and (b) Dry season DWS concentrations measured by water source type in Dacope 2009 to 2010 (mg/L) [28].

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228 229 **Table 1.** The effects of drinking water sodium (DWS) in the potable water and its associated health impacts reported from different coastal regions of Bangladesh.

Health impacts reported	Data collection	Types of sampling	Location	Ref.
Skin diseases, hair fall, diarrhoea, gastric and high BP	Household random sampling (2016-2017)	Peoples' perception, 153 households	Two selected villages of Chittagong city corporation	[25]
Drinking water salinity and blood pressure measurements	DWS sampling, information on food intake and BP	1,500 households	21 unions from 9 coastal districts	[26]
People's perception, practice and belief in the intake of salt and health risks in Bangladesh, vulnerable to climate change	Cross-sectional mixed method study between April-June 2011	6 focus group discussions (FGD), 8 key informant interviews (KII), 60 free listing exercises, 20 ranking exercises, 10 observations, and 400 questionnaire survey of adults.	Chakaria, Southeastern coastal region of Bangladesh	[5]
The effect of DWS on the pregnant women's BP	Data on BP, potable water source, personal lifestyles, and environmental factors between January 2009 to June 2010	701 expectant females	Dacope, Khulna district, Southwestern coastal region	[28]
The effect of DWS on the BP	DWS, BP, and information on personal lifestyles, and environmental factors	581 expectant females	Dacope, Batiaghata and Paikghaccha; Khulna. Southwestern coastal region	[15]
The relationship of MAR water on BP	Participants' source of drinking and cooking water; salinity level and EC of household stored water; BP and urinary sodium and protein measurements.	A stepped- wedge cluster-randomised controlled community trial design. 16 communities over five monthly visits	Coastal regions of Bangladesh	[29]
DWS to elucidate the infrequent periodical pattern of hypertension	Water salinity data (1998–2000); Drinking water sources, 24-hr urine samples, BP (October 2009 through March 2010). The hospital data on the occurrence of hypertension amid gestation among 969 expectant females (July 2008 through March 2010).	343 expectant females	Dacope Upazila, Khulna. Southwestern coastal region	[4]
DWS and the risk of (pre)eclampsia and hypertension amid pregnancy	Case control study; epidemiological and clinical data; urinary sodium and sodium concentrations in drinking water	202 expectant females with (pre)eclampsia or gestational hypertension	Dacope Upazila, Khulna. Southwestern coastal region	[27]

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The post-natal impact of pre-natal salinity exposure	Bangladesh Demographic and Health Surveys (BDHS) for 2004 and 2007, Monthly soil salinity data for 2001–2009; spatial interpolation of infant mortality that lie within 40km of the BDHS clusters.	DWS consumed during gestation lead to hypertension, (pre)eclampsia and post-partum infant mortality.	Four coastal regions of southern Bangladesh: Barisal, Chittagong, Dhaka and Khulna.	[18]

2.3. Drivers, Pressures, State, Impact, Response (DPSIR) model for drinking water sodium (DWS)

Drinking water sources in rural Bangladesh, particularly in the rural areas of coastal regions varies. The sources of consumable waters incorporate deep and shallow groundwater from the aquifers, small ponds with or without the pond sand filters (PSF, sand and gravel filters), collected rainwater, bottled water, and streams etc. [30, 31]. The consumable water shortage issue is to a great extent regularly seasonal, with the most experience happening amid the dry season between November and early May. Owing to less precipitation and diminished river flow, the saltiness of surface water bodies such as waterways and canals increments amid the dry season. Furthermore, in the midst of the dry season, ponds repeatedly dried up leaving coastal population with few or no options but to extricate saline groundwater utilizing hand pumps for drinking and cooking, whereas amidst the monsoon (May to October), coastal population generally gather rainwater through household-or-community-level rainwater harvesting schemes [31]. It is, therefore, clear, that saltwater invasion as well as salinisation partakes consumable water shortages regionally and globally around the coasts, forcing the people to be dependent on the substitute sources for water consumption [29]. Coastal communities in Bangladesh, however, had little consciousness of the dangers related with superfluous salt consumption in their food. Moreover, reducing salt intake tactics were not very important to them [5]. The lower price of salt and the unidentified presence of salt in the potable water has shaped an environment leading to abundant salt intake unconsciously. Government organizations and NGOs have also reinforced public endeavors to manage with the issues by underlining mutually communal adaptation strategies as well as the institutional efforts [2]. This review article outlines a coordination of DWS and the combined community-based methods, which was intended to reduce potable water shortage in the coastal region of Bangladesh.

Assuming that the coastal people in Bangladesh are antagonized with high content of salt in the drinking water, it is projected that the exposure to salinity will further rise as an outcome of climate change, sea level rise and different environmental stimuli [27]. Additionally, it is indispensable to promote and assess reasonable approaches to provide potable water with little or no salt content in an affordable manner. While there are several theoretical contexts for unfolding associations amongst the anthropogenic stresses and scenario deviations in marine and coastal ecosystems, the Drivers-Pressures-State change-Impact-Response (DPSIR) framework is the most extensively applied framework [32]. The framework is also flexible in numerous schemes, structures as well as in numerous geographic locations. The framework can further link the marine aquatic ecosystems to the adjoining terrestrial ecosystems [32]. The application of the DPSIR framework is substantially pertinent to link the existing gaps amongst the scientific disciplines and the sciences of the coastal development strategy as well as the integrated coastal zone management. However, the existing implications of the DPSIR framework in the coastal zones have been inadequate and novel innovative approaches are required to apply the model [33]. A Drivers-Pressures-State change-Impact-Response (DPSIR) framework for drinking water sodium (DWS) and its health problem in the coastal regions of Bangladesh is prepared from this review (Figure 3). Driving forces identified are climate change induced salinity problem, flow control of shared transboundary rivers etc. Pressures identified in the framework are sea water intrusion, salinization of soil and water resources and shrimp cultivation in the coastal zones leading to the states of drinking water scarcity and presence of sodium in drinking water (DWS). Impacts on health includes hypertension (HTN) or high blood pressures of adults in both male and female leading to the risks of strokes. Pregnant women have been found to be particularly in risk of gestational hypertension, (pre)eclampsia and post-partum infant morbidity and mortality. Major interventions to reduce drinking water sodium in practice was identified as pond-sand filter (PSF), rainwater harvesting and Managed aquifer recharge (MAR). Advanced and expensive potable water solutions such as solar-powered desalination plants as well as the reverse osmosis and electrodialysis machines are amongst the options to lessen the salt from water which is also reported from some pilot scale study to yield secure consumable water.

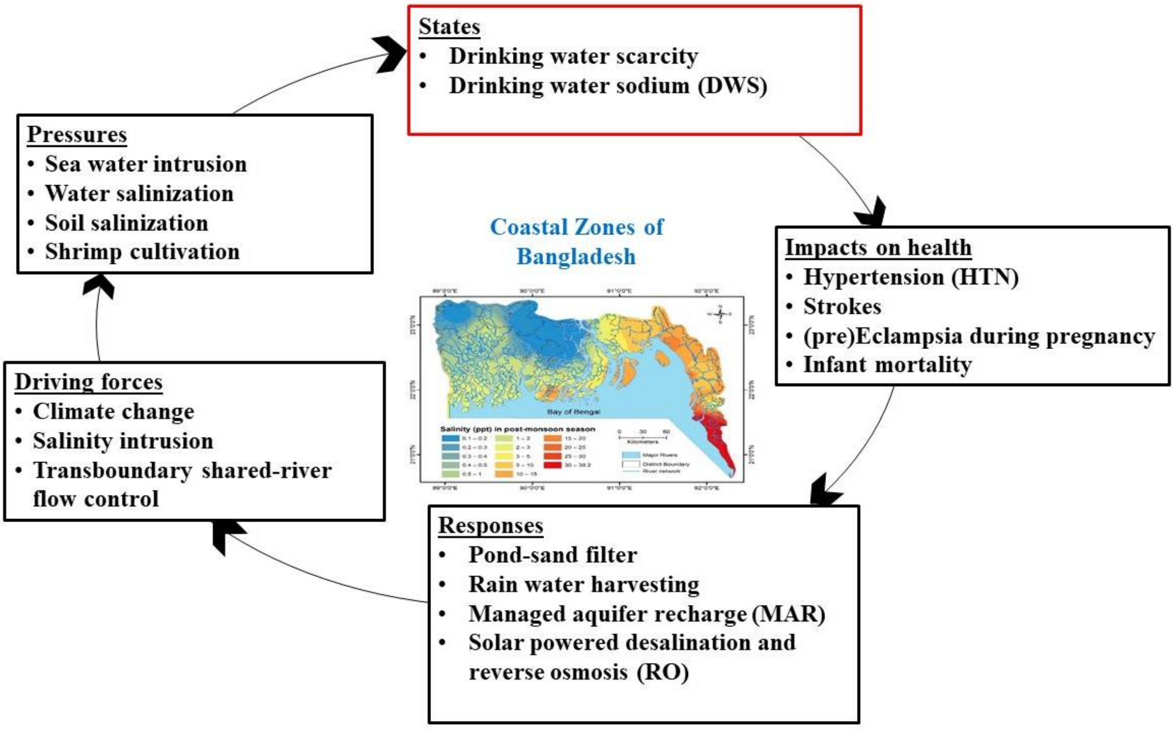

Figure 3. Drivers, Pressures, State, Impact, Response (DPSIR) model for drinking water sodium (DWS) in the coastal areas of Bangladesh (this study).

2.4. Interventions to decrease drinking water sodium (DWS): Are these interventions effective?

Several interventions have been taken to discourse the shortage of potable water owing to salt interruption in the coastal regions of Bangladesh. Rainwater harvesting is one such innovative approaches. Consuming rainwater discourses the salinity exposure by lowering sodium intake from consumable water and benefits cardiovascular health. Nevertheless, it decreases the ingestion of vital cardio-protective minerals such as magnesium and calcium [31]. The WHO acclaims addition of essential elements such as calcium and magnesium to mineralize the desalinated water to safeguard from cardiovascular risks [34]. Consequently, the rainwater also lacks essential elements important for the wellbeing of cardiovascular health of the coastal communities. Therefore, promotion of the rainwater is suggested with remineralization of the important elements [31]. Integrated holistic approaches such as the rainwater harvesting systems and pond sand filters (PFS) near rainwater-supplied surface ponds, and rainwater-supplied managed aquifer recharge (MAR) are being upgraded from a single rainwater or PSF system. These structures capture available rainwater during the monsoon and stock it for imminent usage in the dry season (Figure 3). While these interventions may be effective in reducing DWS exposure [31], MAR is a promising adaptive approach for increasing the accessibility of salt free potable water that sustains almost a yearly water supply. Since MAR storage of rainwater occur under confined conditions, it is further secured from evaporation as well as strong to tidal storms, cyclones and saltwater permeation (Figure 4) [29, 35]. In MAR, a freshwater lens is purposefully created amidst the brackish aquifers, to supply with the surface freshwater or rainwater to the aquifers to bring the hydrological equilibrium. It is a likely to be a key solution for salinity problem in the southwest coastal Bangladesh [29].

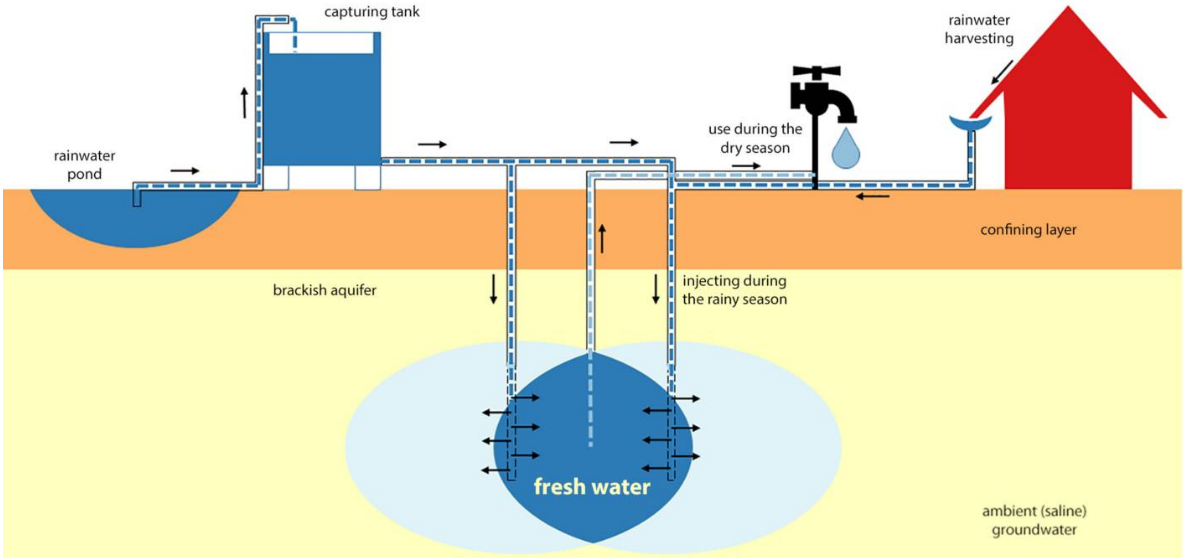

Figure 4. Schematic overview of a managed aquifer recharge (MAR) system in South-west Coastal Bangladesh [15].

However, a recent study by Scheelbeek et al. (2017) reported that a gradual increase in sodium concentration over the course of the dry season is observed in the MAR. Median sodium concentrations of the pond and MAR sources were ~400 mg/L toward the end of the dry season, whereas median sodium concentrations in tube wells exceeded 800 mg/L followed by extremes >1500 mg/L [15]. Some rainwater users mixed their rainwater with water from other sources to prolong the period of rainwater use. Toward the end of the dry season, only those with large amounts of storage space (and hence more likely to consume unmixed rainwater) still reported rainwater as the main drinking-water source, which explains the high outliers in sodium concentrations in "rainwater" in the early dry-season measurements. Although the potentiality of desalination plants such as reverse osmosis and electrodialysis are tremendous, due to high cost and energy it is still in the pilot scale level in many parts of coastal Bangladesh. During an academic survey it was found that a local NGO installed four solar-powered desalination plants and reverse osmosis in Kalapara Upazila, where most of the respondent (65.8%) thought that this measure was not effective at all where 12.5% think it as a low effective and 6.7% think it as a moderately effective measure [unpublished data by author in this study].

3. Conclusions

Drinking water sodium (DWS) is a burning issue in the present socio-economic, environmental and climatic condition of the coastal Bangladesh where salinity and seawater intrusion is a serious issue. Here, we reviewed several key intervention mechanisms recognized to manage saline water and DWS impact on the health of local people, particularly of pregnant women. The list of issues is inevitably extensive containing infant mortality, hypertension, high blood pressure, pre-eclampsia etc. leading to millions of affected people in heart diseases. Several interventions such as rainwater harvesting and PSF system as well as MAR usage and the integration of mixed sources were reviewed on the content of DWS. While rainwater has the positive impact of low or no sodium intake on human health, it still possesses harmful impacts on human health for not containing essential micronutrients such as calcium and magnesium. On the other hand, a gradual increase in sodium concentration over the course of the dry season was observed in MAR. It is therefore indispensable to increase consciousness amongst the coastal people regarding the impacts of DWS intake and help them providing and adopting correct technological interventions.

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