

1 *Review*

2 **Impacts of Salinity Intrusion in Community Health:** 3 **A Review of Effectiveness of Adaptation Measures to** 4 **Decrease Drinking Water Sodium (DWS) from** 5 **Coastal Areas of Bangladesh**

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

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

27

28 **1. Introduction**

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

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

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

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

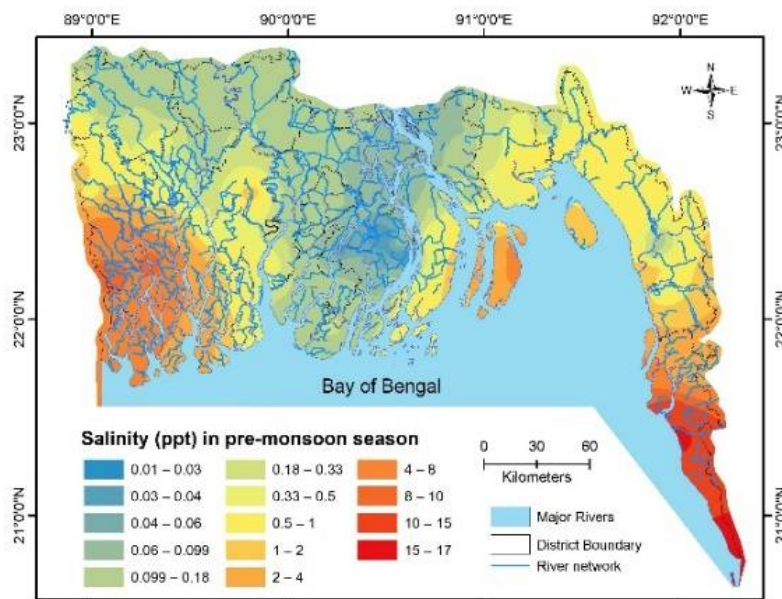
63 Increased dietary sodium ingestion contributes to rise the proven risk of hypertension,
64 nonetheless it remains unidentified whether sodium ingesting in potable water could have parallel
65 impacts on human health [15]. Drinking water sodium (DWS) is a significant basis of critical source
66 of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

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

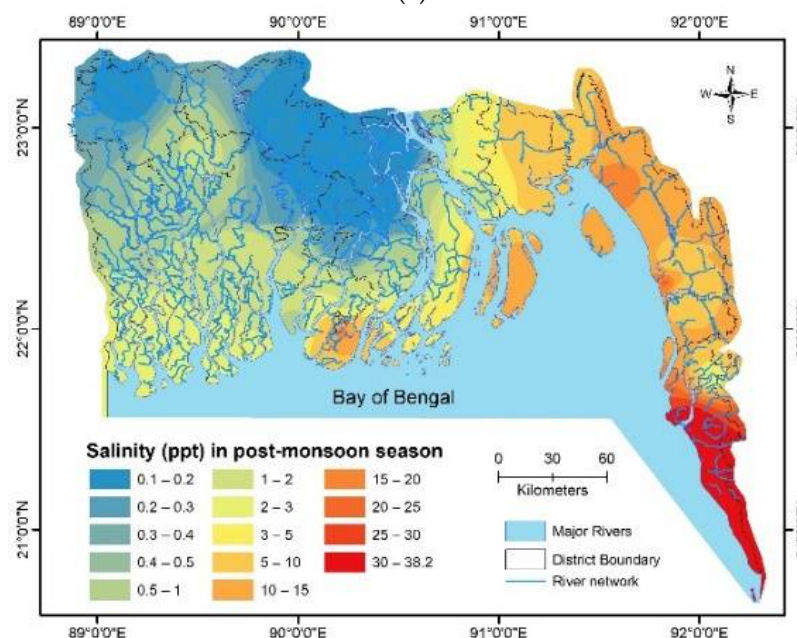
80 The interruption of salinity into surface water and aquifer constitutes a significant risk to
81 people's access to potable water [2]. The likely effects of climate alter on coastal zone districts
82 comprise a regular immersion from the Bay of Bengal, increased storm surges, damage of coastal
83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

95 season in Bangladesh's surface water is easily distinguishable (Figure 1). Increased anions and cations
 96 such as Cl^- , Na^+ , SO_4^{2-} , HCO_3^- etc. throughout the post-monsoon shows the inward movement of salt-
 97 water [19]. The extreme seasonal distinction of anions and cations is, therefore, ascribed to the
 98 upstream freshwater deliberation and plummeting currents in the downstream followed by swelling
 99 invasion of seawater in the land [19]. The more prominent the entrance of marine impact into the
 100 terrestrial inland, the lower is the accessibility of freshwater, that by its combination with salt water
 101 tends to be brackish [20]. In addition of the total dissolved solids (TDS) and the electrical conductivity
 102 (EC), the abundance of the key anions and cations in the surface water was confirmed in the
 103 subsequent directive of $\text{Na}^+ > \text{Ca}^{2+} > \text{K}^+ > \text{Mg}^{2+}$ and $\text{Cl}^- > \text{SO}_4^{2-} > \text{HCO}_3^- > \text{NO}_3^- > \text{CO}_3^{2-}$ [19].

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(a)



(b)

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

111 As described in earlier section Gopalganj Sadar Upazila is one of the salinity prone vulnerable
112 coastal zones of Bangladesh. The risk of salinity hazard was investigated for the surface water (ponds
113 and river) and the groundwater samples from the shallow tube wells (STW) and the deep tube wells
114 (DTW) [21]. Correlation matrices as well as the principal component analysis (PCA) established the
115 higher electrical conductivity (EC) and total dissolved solids (TDS) in relation to the salinity stress
116 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.
117 (2017) further examined an entire of 46 groundwater samples from pre- and post-monsoon periods
118 to evaluate the likely risk to human consumption among adults and children of the Gopalganj
119 district. Maximum hydrochemical parameters corresponding to pH, EC, TDS, Na^+ , Cl^- , HCO_3^- , As,
120 Mn, Fe, B, NO_3^- , CO_3^- etc. surpassed the limits of various potable water standards. The spatial
121 extensions of EC, Cl^- , As, Fe, and Mn varied considerably. The exponential semivariogram model
122 was overriding in the analysis of the best model for both pre-monsoon and post-monsoon seasons.
123 Furthermore, mean values of the hazard quotient and hazard index constructed on As, Fe, Mn, B,
124 NO_3^- and F^- specified that the groundwater varied seasonally and carries a considerable health and
125 wellbeing hazard to the grown-ups as well as to the children [22].

126 Molar proportion of the $\text{Cl}^-/\Sigma\text{anions}$ and $\text{Na}^+/\text{Na}^++\text{Cl}^-$ specified that the groundwater in the
127 south- central part of Bangladesh, in particular, Barguna and Patuakhali, was affected by the
128 intrusion of seawater. The groundwater of Barguna and Patuakhali was clearly dominated by the
129 cations and anions of Na^+ , Mg^{2+} , Ca^{2+} , Cl^- , and HCO_3^- amid the both wet and dry-monsoon seasons
130 [23]. While the maximum sodium intake according to WHO (2011) is 200 mg/L, the Na^+
131 concentrations in the groundwater reported were 863 mg/L and 825 mg/L in the pre-monsoon and
132 post-monsoon seasons, respectively [23]. In another research works, 18 groundwater samples were
133 collected from the tube wells of Chittagong district, located in the Southeastern coastal region of
134 Bangladesh. The depths of the tube wells shifted from 244 to 365 meters and the tests indicated
135 that the 75% of the groundwater samples were Na^+ subjugated. Whereas, the average salinity of the
136 shallow tube wells ranged from 5.11 to 6.48 dS/m, while the pondwater salinity ranged from 0.11 to
137 3.12 dS/m [24].

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

144 2.1. Drinking water Sodium (DWS) and health of coastal people

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

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

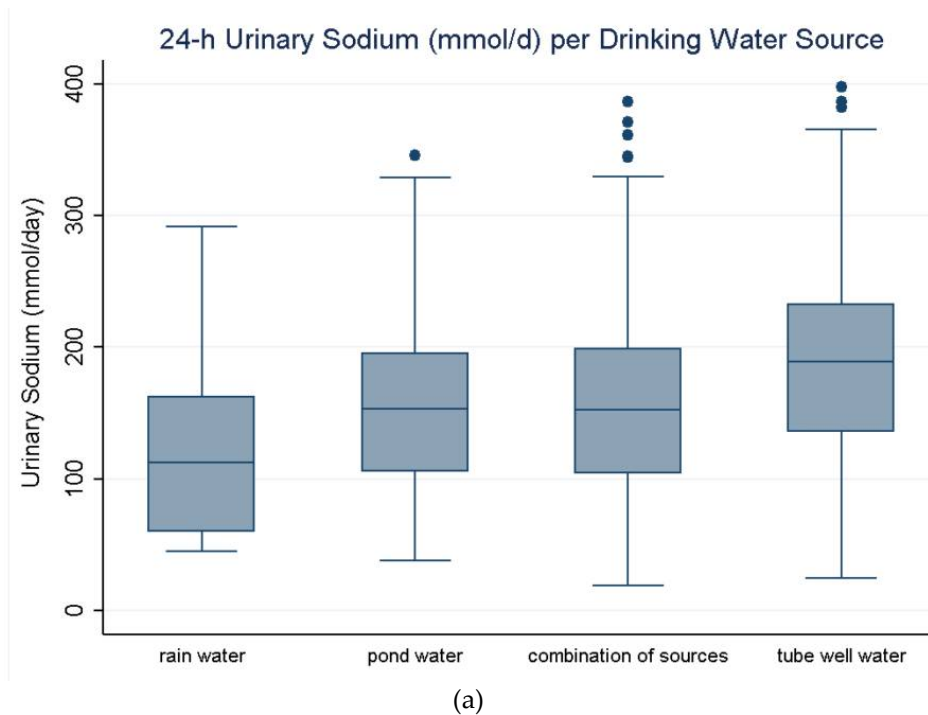
161 The neglected existence of salt in potable water will en course to an unsatisfactory and risky
162 level of salt ingestion among the population. Such over the top salt intake, in turn, can put numbers
163 of individuals together with pregnant women, at a risk of hypertension and even death [5].

164 Khan et al. (2011) identified an estimated average DWS of 5 -16 g/day amid the dry season
165 compared to 0.6–1.2 g/day within the wet season. The daily sodium concentration in the urine was
166 found 3.4 g/day (range 0.4 to 7.7 g/day) [4]. Women relied on STSs for potable water were more likely
167 to have urine sodium >100 mmol/day compared to the women consuming rainwater [OR= 2.05; 95%
168 confidence interval (CI), 1.11–3.80] (Figure 2(a)). The yearly hospital incidence of hypertension amid
169 the pregnancy period was greater within the dry period (OR= 12.2%; 95% CI, 9.5–14.8) than within
170 the wet season (OR= 5.1%; 95% CI, 2.91–7.26%). A substantial relation among DWS and for each of
171 the (pre)eclampsia and gestational hypertension was distinctly delineated [27]. It was clearly found
172 in the Dacope Upazila of Khulna District the potable water sources had remarkably high-levels of
173 sodium concentration (mean 516.6 mg/L, \pm 524.2) (Figure 2(b)). The women dependent on the tube-
174 well or groundwater were more susceptible to disease risk than the rainwater consumers (p,0.001).
175 Adjusted risks for (pre)eclampsia and gestational hypertension considered together increased in a
176 dose-response manner for increasing sodium concentrations (300.01–600 mg/L, 600.1–900 mg/L,
177 900.01 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]
178 and 5.48 [3.30–9.11] (p-trend,0.001) [27]. People exposed to slightly saline (1000–2000 mg/l) and
179 moderately saline (\geq 2000 mg/l) concentration drinking water had respectively 17% (p < 0.1) and 42%
180 (p < 0.05) higher chance of being hypertensive than those who consumed freshwater (<1000 mg/l). It
181 was further found that the females were 31% higher probable to be hypertensive than the males. In
182 addition, interviewees of 35 years old and above were approximately 2.4 times tend to be
183 hypertensive compared to the interviewees of under 35 years. Moreover, it was found that, among
184 the age of 35 years and above, pre-hypertension and hypertension were 53.8% higher for the slightly
185 saline water and 62.5% higher for the moderate saline water. In total, the disease risks were higher
186 than national rural statistics by 50.1% for saline water groups. For a modest salinity exposure, the
187 pervasiveness of hypertension among the interviewees was 21%, 60% and 48% higher than national
188 statistics (23.6%), respectively. Although there was a slight periodical difference in the salinity of
189 potable water, during the dry season it showed an increasing trend and maximum levels of the blood
190 pressure. Average salinity as well as the relevant pervasiveness of hypertension were greater among
191 the consumers of deep aquifer water (21.6%) than for the users of shallow aquifer waters (20.8%) [15].

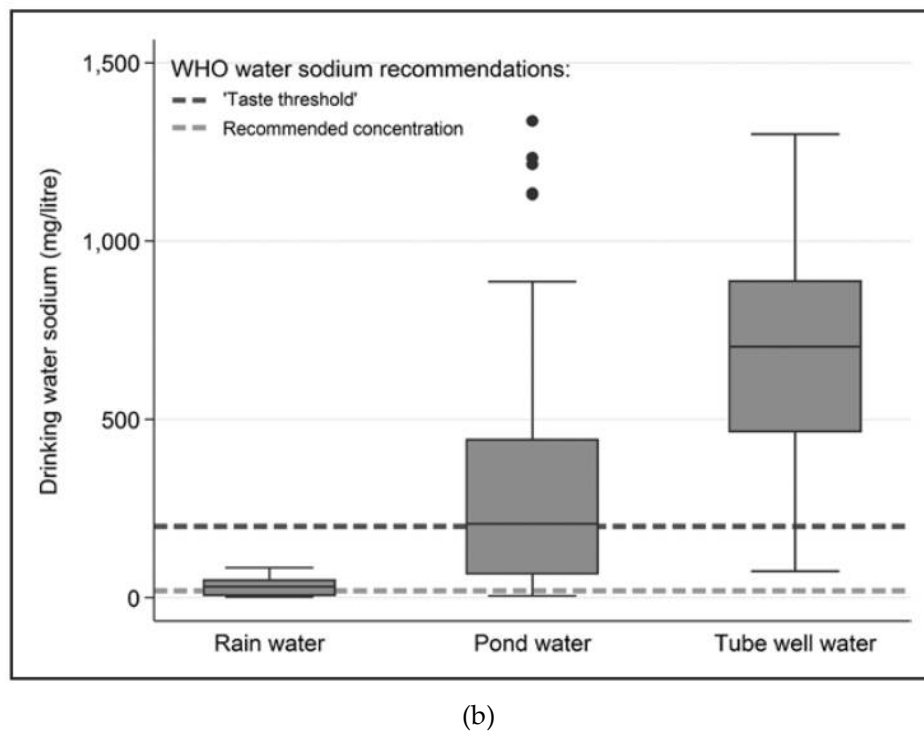
192 Consequent modifications for the puzzling aspects found that DWS concentrations were
193 significantly associated with BP. In addition, systolic and diastolic BP was lesser typically by 0.95/0.57
194 mmHg for each 100 mg/L decline in DWS and the probabilities of hypertension were lesser by 14%
195 [15]. Scheelbeek et al. in another study (2017) examined the effects of DWS on pregnant women's
196 blood pressure. Research has shown that increased blood pressure can have a serious impact on
197 maternal and fetal health. Comprehensive linear mixed regression models further examined the
198 relationship of systolic and diastolic BP of healthy females according to their sources of drinking
199 water. Subsequent tuning of the several other factors revealed that high saline sources such as tube-
200 wells as well as well as the pond water consumers had expressively higher average systolic (+ 4.85
201 and +3.62 mmHg) and diastolic (+2.30 and +1.72 mmHg) BP than the rainwater consumers [28].
202 Analogous characteristics have also shown by 24-hour urinary sodium (mmol/day) from drinking
203 water sources [28]. Higher concentration of DWS from salt water contamination was linked with
204 higher BP in normotensive pregnant women of the coastal regions. Variations may result at pre-
205 pregnancy stage as the DWS levels may vary before they conceive or may be induced amid pregnancy
206 when a woman is enforced to transform the source of potable water from rainwater-based-system to
207 an even higher-saline substitute source owing to the depletion of storing [28].

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

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



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225 **Figure 2.** (a) Urinary sodium excretion (mmol/day) of healthy pregnant women recruited in the dry
 226 season (n=645) and (b) Dry season DWS concentrations measured by water source type in Dacope
 227 2009 to 2010 (mg/L) [28].

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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]

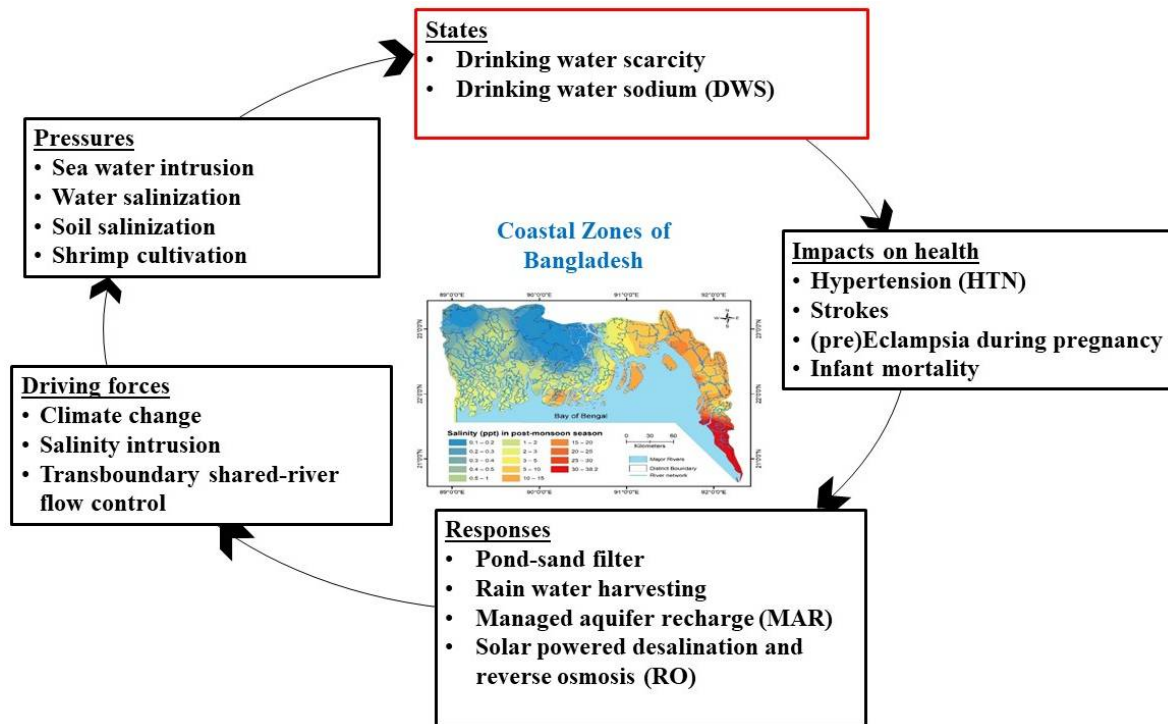
The post-natal impact of pre-natal salinity exposure	Bangladesh Demographic and Health Surveys (BDHS) for 2004 and 2007, Monthly soil salinity data for 2001–2009; spatial interpolation of infant mortality that lie within 40km of the BDHS clusters.	DWS consumed during gestation lead to hypertension, (pre)eclampsia and post-partum infant mortality.	Four coastal regions of southern Bangladesh: Barisal, Chittagong, Dhaka and Khulna.	[18]
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230 2.3. Drivers, Pressures, State, Impact, Response (DPSIR) model for drinking water sodium (DWS)

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

252 Assuming that the coastal people in Bangladesh are antagonized with high content of salt in the
 253 drinking water, it is projected that the exposure to salinity will further rise as an outcome of climate
 254 change, sea level rise and different environmental stimuli [27]. Additionally, it is indispensable to
 255 promote and assess reasonable approaches to provide potable water with little or no salt content in
 256 an affordable manner. While there are several theoretical contexts for unfolding associations
 257 amongst the anthropogenic stresses and scenario deviations in marine and coastal ecosystems, the
 258 Drivers-Pressures-State change-Impact-Response (DPSIR) framework is the most extensively applied
 259 framework [32]. The framework is also flexible in numerous schemes, structures as well as in
 260 numerous geographic locations. The framework can further link the marine aquatic ecosystems to
 261 the adjoining terrestrial ecosystems [32]. The application of the DPSIR framework is substantially
 262 pertinent to link the existing gaps amongst the scientific disciplines and the sciences of the coastal
 263 development strategy as well as the integrated coastal zone management. However, the existing
 264 implications of the DPSIR framework in the coastal zones have been inadequate and novel innovative
 265 approaches are required to apply the model [33]. A Drivers-Pressures-State change-Impact-Response
 266 (DPSIR) framework for drinking water sodium (DWS) and its health problem in the coastal regions
 267 of Bangladesh is prepared from this review (Figure 3). Driving forces identified are climate change
 268 induced salinity problem, flow control of shared transboundary rivers etc. Pressures identified in the
 269 framework are sea water intrusion, salinization of soil and water resources and shrimp cultivation in
 270 the coastal zones leading to the states of drinking water scarcity and presence of sodium in drinking
 271 water (DWS). Impacts on health includes hypertension (HTN) or high blood pressures of adults in
 272 both male and female leading to the risks of strokes. Pregnant women have been found to be

273 particularly in risk of gestational hypertension, (pre)eclampsia and post-partum infant morbidity and
 274 mortality. Major interventions to reduce drinking water sodium in practice was identified as pond-
 275 sand filter (PSF), rainwater harvesting and Managed aquifer recharge (MAR). Advanced and
 276 expensive potable water solutions such as solar-powered desalination plants as well as the reverse
 277 osmosis and electro dialysis machines are amongst the options to lessen the salt from water which is
 278 also reported from some pilot scale study to yield secure consumable water.

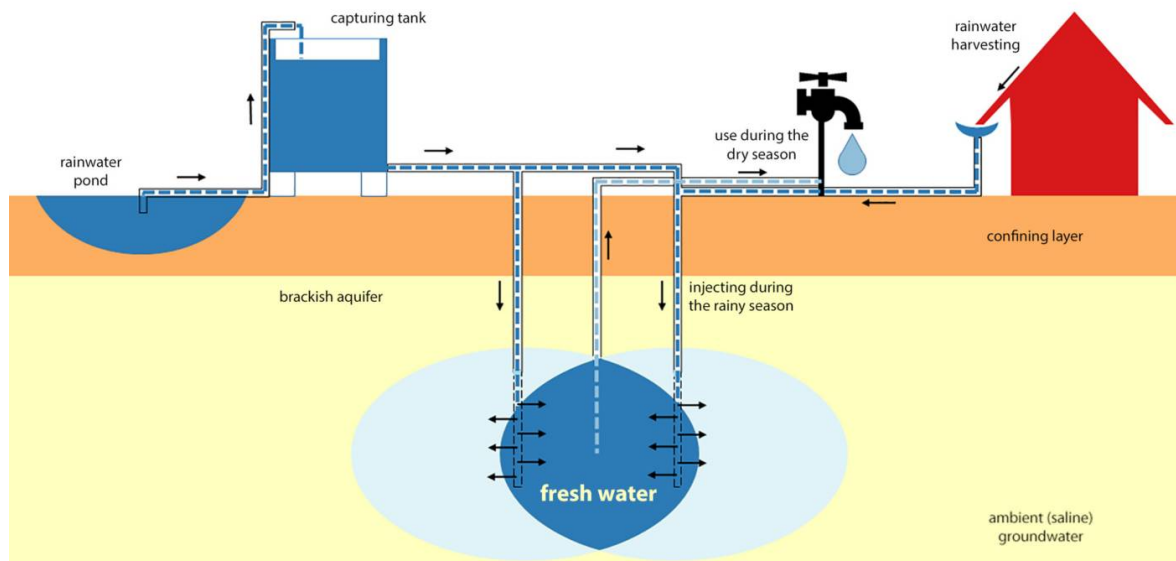


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280 **Figure 3.** Drivers, Pressures, State, Impact, Response (DPSIR) model for drinking water sodium
 281 (DWS) in the coastal areas of Bangladesh (this study).

282 *2.4. Interventions to decrease drinking water sodium (DWS): Are these interventions effective?*

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



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

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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].

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3. Conclusions

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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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