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Water Scarcity and Challenges for Access to Safe Water: A Case of Bangladesh's Coastal Area Vulnerable to Climate Change

Mohammad Radwanur Rahman Talukder[1,2]*, Shannon Rutherford[3], Khairul Islam[4] and Cordia Chu[2]

[1]Baker Heart and Diabetes Institute, Alice Springs, NT, Australia
[2]Centre for Environment and Population Health, Griffith University, Brisbane, Queensland, Australia
[3]School of Medicine, Griffith University, Queensland, Australia
[4]WaterAid Bangladesh, House 97/B, Road 25, Block A, Banani, Dhaka, 1213, Bangladesh
✉ radwan.talukder@baker.edu.aum

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Abstract: Existing efforts to ensure safe water access in coastal Bangladesh are challenged by increasing freshwater salinity. This research explored/explores safe water consumption choices in coastal Bangladesh, which data are scarce to date, using a mixed-methods approach. In 2014, a cross-sectional survey was conducted in southwestern coastal Bangladesh (n=261) and data was generated on water supply and consumption. Data collection also involved 29 in-depth interviews of household care givers and focus group discussions were performed with three community groups. Descriptive statistics were applied to analyse quantitative data and thematic analysis was used for qualitative data. The survey showed that 60% of the study population used tube well water while 40% used pond water for drinking. It was observed that for cooking purposes, the use of pond water was slightly higher than the tube well water. Only 13% of the respondents mentioned that their drinking water tasted salty whereas 6% of the respondents reported health problem (diarrhoea, dysentery, gastric issues and skin problems) after using these water sources. The qualitative data reveals that water available for drinking and cooking is causing a serious threat to this coastal community, particularly during the dry season. In-depth assessments indicated that drinking water choices were less driven by concerns for health than practical issues such as travel distance and time taken and taste. The palatability of water was an important determinant of choice for drinking and other domestic uses. Furthermore, the utility of alternative options for safe drinking water is driven by beliefs and traditions and source maintenance. Given the increasing salinisation of freshwaters in many low-lying countries and likely exacerbation related to climate change-induced sea level rise, therefore, promotion of low saline drinking water along with salt reducing interventions consider that community beliefs and practices must be a made priority.

Key words: Salinity, coastal Bangladesh, water scarcity, safe water, water resource management.

Introduction

Coastal Bangladesh is exposed to extreme climatic conditions and frequent natural disasters (BanDuDeltas, 2015a). The coastal area suffers from extreme water scarcity, as well as from arsenic and saltwater contaminations in many places (Abedin et al., 2012). While the national coverage of access to improved water sources is 98% (Government of Bangladesh, 2015), in some areas of the coastal zone, this figure is even lower,

*Corresponding Author

dropping below 50% (BBS, 2011). Being able to afford fresh water supply for domestic and agricultural uses is already a challenge in for people living in these areas (BanDuDeltas, 2015b). Unimproved surface (pond) water often becomes a main source of water supply to households as the dry seasons intensify (Azam and Sarker, 2012; Islam et al., 2011). This leads to increasing water-borne diseases (CCC, 2009). However, there is limited knowledge on how much water scarcity affects water consumption and community choices for safe water in coastal Bangladesh.

Being a Ganges-dependent region, the southwest coastal region of Bangladesh suffers from dry season water shortage and saltwater intrusion. In the coastal zone, most shallow groundwater sources are saline and surface water salinity is also widespread (BanDuDeltAS, 2015b). Impacts of climate change and sea level rise are likely to compound the existing problems of salinity intrusion and concentration in freshwater water river areas in coastal Bangladesh (Dasgupta et al., 2014). A significant sea level rise of up to 52 centimeters is predicted until the year 2050 and this would mean that the freshwater zones in eight out of 19 coastal districts will be severely affected by the increase in river salinity. The total number of people affected by such changes in salinisation will increase from 2.9 to 5.2 million with a significant impact on the poor population (BanDuDeltAS, 2015a).

Solutions to water scarcity and safe water supply in coastal Bangladesh are complex and not readily evident (BanDuDeltAS, 2015d, Benneyworth et al., 2016). Though some technical solutions such as the construction of large, community operated, rain-fed reservoirs and de-salinisation of seawater and recharge aquifer are on trial in these areas, the success of such types of resource management requires long-term investments and good local-level governance (Benneyworth et al., 2016). Furthermore, while rainwater harvesting (RWH) and pond sand filters (PSFs) have long been identified as potential alternative to safe water supply options in coastal areas of Bangladesh (Islam et al., 2011), the adoption of these technologies is still low and limited by storage capacity, water quality, poor maintenance and water availability (Harun and Kabir, 2013; Islam et al., 2011). Although local community participation is identified as a key part of successful and sustained implementation of water sector activities (Safiuddin and Karim, 2003) in coastal areas, knowledge and practice adapted by the local people with regard to water use have received insufficient attention in the promotion of safe water supply. To better understand potential health risks and assistance for developing future response options, a more in-depth analysis of the water supply situations and factors influencing consumption and choices in the coastal region is imperative. This research aimed to explore water consumption and community choices for safe water in coastal Bangladesh.

Methods

This research utilised a mixed-method approach in a cross-sectional survey in Koyra, a rural sub-district of Khulna district in southwestern coastal Bangladesh during May-June 2014. This sub-district belongs to the exposed coast. It is prone to salinity intrusion and has reported the highest salinity concentration in freshwater among the other sub-districts of Khulna (Abedin et al., 2013).

Household Quantitative Survey

The study area and quantitative methods used for this research have been detailed elsewhere (Talukder et al., 2016a). In brief, we selected two unions, that is, Koyra Sadar and Amadi (lowest administrative unit in Bangladesh), out of 7 in Koyra, based on the diversity of potable water uses. In these unions, both surface water (e.g., pond) and groundwater (e.g., tube well) were used for domestic purposes. In four selected villages (two from each union), trained research staff made household visits for data collection. They identified and listed eligible participants aged 19-25 year old as per study objective (Talukder et al., 2016a). Of the 340 respondents available for interviews during the household listing, we excluded multiple eligible participants from the same household (n=49), pregnant women (n=21) and participants who declined to participate (n=4). Of them, 261 participants (77% of the total available) with completed data on water supply and use were included in the analyses. Information on drinking and cooking water sources, collection and travel time, distance travelled, duration of use, amount of water consumed for drinking daily and taste of drinking water were collected using a structured questionnaire.

Qualitative Data Collection

In-depth interviews (IDI) and focus group discussions (FGD) were conducted in two of four villages of Amadi union. In total, 29 IDIs and 3 FGDs were conducted purposively. A male researcher with Masters-level education, experienced in qualitative data collection,

was recruited to assist the IDIs and FGDs for note-taking and transcription of the interviews.

The respondents for IDIs were selected purposively from the listing of household members prepared for the quantitative survey but independent of their participation to survey. To obtain a wider perspective on the water supply and consumption-related behaviours, we also included elderly female members (mothers or mothers-in-law as appropriate) from the same household. Preference was given to the inclusion of more female members because of their involvement as caregivers in the family, and their known role in water collection and preparing food. Each interview took about 30-45 minutes depending on the participants' involvement with the subject matter.

Focus group discussions were conducted with three community groups representing caregivers of the family, young adults and the local level water management authority from Amadi union, where surface (e.g., pond) water is the major source of drinking water. This was done in order to develop a better understanding of the impact and challenges of water scarcity in the community. These groups were involved with NGO-led water, sanitation and hygiene (WASH) interventions in the area. In each group, 6-8 participants gathered at their regular meeting place with NGO staff.

In both the IDIs and FGDs, respondents were asked about water sources, water quality, collection of water, time and distance to travel to collect water, salinisation of water sources, impacts of changing water quality due to salinity on their health, perceptions about safe water and possible solutions related to water salinity. The IDIs and FGDs were conducted in Bangla language, noted manually and audiotaped and transcribed by the investigator and research staff after the interview. All the data from IDIs and FGDs were transcribed in Bangla and then translated to English by the research assistant. The investigator checked the accuracy of the translation with the original transcript and hand-notes before data analyses.

This research was approved by the ethics committee of Griffith University, Australia and International Centre for Diarrhoeal Disease Research, Bangladesh (icddr,b). All participants provided written consent at the beginning of data collection.

Data Analysis

Descriptive statistics were used to describe water supply and consumption-related variables – drinking and cooking water sources, duration of use (in months), distance (in kilometres-km), collection time (in hours), frequency of collection, the taste of water and estimated daily amount of water consumed for drinking (in Litres–L). A cumulative estimate for total distance travelled daily was constructed by multiplying the frequency of collection per day with travel distance for each collection. For the estimation of total time spent collecting water, the frequency of collection per day was multiplied by the sum of travel and collection time for each collection. We used mean and standard variation for continuous variables (e.g., duration of use, frequency of water collection), proportions for categorical variables (e.g. water source, distance categorized into 1 km, 1-2 km, >2 km), and compared them between groups using Student's t-test or Pearson's chi^2 test, as found appropriate.

Thematic analyses were conducted with a focus on water sources, seasonal differences, water salinity and health impacts, and community perceptions towards safe water (as per Liamputtong and Ezzy, 2005). The data were searched and coded for differences and similarities between behaviours and practices related to water supply and consumption in the community, then grouped into categories. Subsequently, categories and sub-categories were examined for connections and unified around themes. Besides this, the participants' views obtained from FGD were also compared with individual views expressed during in-depth interviews. All the data analyses were conducted manually.

Results

Household Survey – Characteristics of Water Consumption

Table 1 presents the water consumption characteristics based on survey data. Tube wells and ponds are the two major sources of drinking water whereas for cooking the use of pond water was higher than tubewell water. The average distance travelled to collect drinking water was around 0.3 km, which was significantly higher for pond than tube well users ($p<0.001$) (Table 1).

On average, respondents collected water three times per day from sources. The daily average time spent on water collection was 50 minutes. Approximately, one third (31%) of respondents spent at least one or more hours while about 40% of the population had to travel one or more kilometers daily for water collection (Table 1). Only 13% of the respondents mentioned that their drinking water tasted salty.

Whereas 6% of the respondents reported for any health problem from using these water sources. The self-reported health problems were dominated by diarrhoea

Table 1: Water supply and consumption characteristics of the respondents in Koyra, Bangladesh, 2014 (N=261)

Features[a]		*n*
Drinking water sources		
Pond (%)	60.1	104
Tubewell (%)	39.8	157
Cooking water sources (n=255)		
Pond (%)	50.6	129
Tubewell (%)	49.4	126
Months used water sources in a year		
Mean (sd)	11.1 (1.7)	245
Distance travelled for collection of water (kilometers)		
[overall] Mean (sd)		
By sources	0.28 (0.26)	261
Pond [Mean (sd)]		
Tubewell [Mean (sd)]	0.41 (0.26)	104
	0.21 (0.22)*	157
Frequency of drinking water collection (number of times daily]		
[overall] Mean (sd)		
By sources	2.8 (1.4)	261
Pond [Mean (sd)]		
Tubewell [Mean (sd)]	2.2 (1.0)	104
	3.2 (1.4)*	157
Total daily time spent collecting water (hours) (frequency*[travel time +collection time for each collection])		
Mean (sd)		
By hours	0.6 (0.5)	261
Less than 1 hour (%)		
1 – 1.5 hours (%)	77.8	203
More than 1.5 hours (%)	19.1	50
	3.1	8
Total daily distance travelled collecting water (kilometers) (frequency*distance for each collection)		
Mean (sd)		
By distance categories	0.7 (0.9)	261
Less than 1 kilometer (%)		
1-2 kilometers (%)	59.0	154
2+ kilometers (%)	36.8	96
	4.0	11
Estimated daily consumption of water (litre)[b] Mean (sd)	3.0(0.9)	259
Taste of drinking water		
Normal/not salty (%)	87.0	227
Salty (%)	13.0	34

*p<0.001

[a]data presented as mean (standard deviation) or percentage

[b]estimated assuming 250 ml per glass; mean (sd) number of glasses water drunk daily- 11.9 (3.5)

and dysentery (n=11), followed by gastric issues (n=4) and skin problems (n = 2). None of the respondents reported high blood pressure or hypertension as a result of drinking water.

Qualitative Research Findings

Water Supply and Consumption

Type of Water Source

Similar to the survey findings, the IDIs and FGDs revealed that surface (pond) and ground (tube well) water were the main sources of domestic water supply. Very few residents used rainwaters, and those that did, only used it for a short-term, i.e., during the wet season. The majority of the respondents collected and consumed water from a single source. However, in some households, especially during the dry season as the water availability declines and the quality of water deteriorates, respondents used water from multiple sources and travelled to another source (either pond or tube well) for water collection:

> *"During the dry season (starting from January-February) we face lot of problems [---] we have to collect water from several sources e.g. X pond, X school tube well and pond)"* (IDI respondent)

People tend to drink water from those ponds where they perceive water is of good quality (e.g. clear, taste normal, having no smell). In these areas, the taste of water was an important determining factor for its use as drinking water. Despite having tube wells nearby, or even in their households, these sources were abandoned or used for other purposes such as washing rather than for drinking and cooking for meeting daily requirements, as water from these sources had become salty:

> *"In our area, pond is the source of drinking water. In some houses there are tube wells, which are used for cooking, washing and bathing"* (FGD respondent of mothers' group).

Water Salinity and Impacts

Both men and women in this community recognised the problem of salinity in their water sources and described that issue of salinity was highly impacting their livelihoods. The young respondents mentioned that they had been exposed to the salinity problem since their birth. Because of salinity, the sinking of tube wells was unsuccessful in most parts of the area. According to respondents, groundwater was more saline than surface water. Also, most of the groundwater was not suitable for drinking, cooking or other purposes e.g., irrigation.

> *"We do not have any alternative to the pond water for low saline water. In our area, boring a tube well only yields saline water, we cannot use this water. We cannot boil our rice with this water and cooked curry becomes unsuitable for eating".* (FGD respondent of Mothers' group)

During the dry season as the water sources become scarce and salty, the water crisis worsens. Respondents mentioned that they have to drink poor quality water i.e. saltier or foul smelling or travel long distances to collect water to meet their daily requirements. Travelling long distances often means they are unable to collect enough water for all uses and have to compromise with the water quality.

> *"We can collect only one pitcher from this far, which is not sufficient. Then we mix and dilute this water with water from other nearby sources (ponds in this case, where water becomes foul smelling and bluish or greenish during summer) and drink"* (IDI respondent).

Women are responsible for the collection of water in all households that were interviewed. These women reported that they have to travel the maximum distance of 1 km by foot to collect drinking water, taking approximately one hour and translating to approximately 2 kilometers of walking and 2 hours spent on drinking water collection daily. These results suggest that if they were to collect more water, they would have to travel long distances and spend more time on water collection.

Similar to the quantitative survey results, there was little awareness among the respondents about health problems due to high saline (salt) water. Further probing during in-depth interviews revealed that in every household, diarrhoea, dysentery and heart burn were common health problems among family members. During the dry period, as the water quantity reduced, people frequently suffered enteric problems such as diarrhoea. Some respondents also mentioned haemorrhoids (piles) and skin diseases. Awareness relating to the consequences of consuming saline water or increased salt consumption on blood pressure appears to be less. Some respondents mentioned that travelling long distances or carrying water containers lead to muscular pain and sometimes numbness of the limbs.

Possible Solutions

Many respondents indicated that salinity in water was widespread and they considered it a major problem in their area. However, existing efforts to tackle this salinity problem generally focussed on short-term

solutions, most of which were inadequate to ensure safe water supply throughout the year. According to the Community Disaster Management Committee (CDMC), local administrative bodies (Union Parishad) were mainly responsible for the maintenance of water sources. Some NGOs were involved with the promotion of preservation and maintenance of ponds for freshwater supply by engaging the local administrative bodies and forming a local management committee for water resources. NGOs also provided logistical support to excavate ponds, establish filtration systems in ponds, water treatment plants and boring tube wells.

Pond sand filter (PSF) and tube wells were perceived to be the safest water options and almost all the IDI and FGD informants mentioned that establishment of filters in ponds or building new mobile treatment plants could solve their problem. However, none of the few available PSFs in the study area were functioning at the time of the study. This raised questions about the sustainability of PSFs as an efficient and reliable source of safe water.

While some use of rainwater during the wet season was reported, it was not a popular choice for drinking water in this area. None of the interviewed community members (IDIs or FGDs) mentioned rainwater harvesting systems (RWHS) as an alternative option. Water's sweet taste, perceptions of water as being colder, and the need for storing rainwater for long periods at the household were identified as the barriers for RWHS and continued use of rainwater. One of the respondents mentioned: *"In this (wet) season we sometimes use rainwater [---] it tastes sweet ('mistee'). We know rainwater is better, but we are used to drinking pond water"* (IDI respondent). The 'sweet' taste of rainwater is relative to the taste of available water sources and reflects the high purity of rainwater. This 'sweet' descriptor of rainwater was not considered a favourable feature. Sometimes respondents used rainwater for cooking rather than for drinking. Furthermore, it appears that there was a lack of knowledge about proper maintenance of rainwater storage. For example, observation throughout the study period indicated that the storage containers were sometimes not covered properly.

Discussion

Several challenges were observed with the availability of water for drinking and cooking in the coastal communities. These problems were more particular during the dry season, which are also consistent with previous studies in similar settings (Abedin et al., 2013; Karim et al., 2005). However, the quality of water from these sources, especially from surface water (i.e., pond), remains a big concern as a significant proportion of people in this community still rely on untreated surface water to meet their daily needs. Though we did not measure water quality in this research, direct observation of the pond water sources revealed the consumption of turbid water from unprotected sources, which are likely to be highly contaminated with pathogens. There have been very few published studies of microbiological water quality from sources available in coastal Bangladesh. One study in coastal Bangladesh showed that compared to PSF water, pond water had the highest amount of coliforms (*E. coli*) in water (Islam et al., 2011). Moreover, as the respondents are also required to collect water from distant sources, likely contamination of water even from safe water sources (e.g. tube well) during carrying cannot be ruled out (Hunter et al., 2010). A further assessment of water quality, particularly on microbiological aspects and sources of water contaminants, is recommended for appropriate identification of risks involved. This will empower communities to make informed choices about the water they drink and use for household purposes.

In this study, we observed direct use of surface water for drinking without any treatment. This practice is not uncommon in coastal Bangladesh. Recent research by Benneyworth et al. (2016) in a coastal sub-district in Bangladesh also showed high use of untreated water. This may effect the health adversely and also show nutritional deficiency among the local inhabitants. Almost all informants in this study commonly reported intestinal infections such as diarrhoea, dysentery, and indigestion in their families as a result of water consumption. Poor water, sanitation and frequent intestinal infections can reduce an individual's ability to absorb nutrients, which in turn affects growth and development (Kosek et al., 2014; Lin et al., 2013).

Given the widespread water salinity problem in coastal Bangladesh, there are limited options for drinking and cooking water sources and people tend to opt for the most available option; often from ponds, as it is assumed to be of good quality and taste. Scarcity of water sources and alternative safe options compel people to continue the consumption of untreated surface water (e.g. pond). The immediate and long-term health effects of continuous use of such water, especially for children and their development, need to be investigated and appropriate health promotion strategies should be adopted to reduce this health burden. Risk communication could be one strategy to reduce the health burden from drinking unsafe water (Islam et al.,

2011), however, this will only be successful if there are safe alternatives. This presents a serious dilemma for these communities as the evidence mounts that alternatives previously considered 'safe' – i.e., tube well water, now contain salt at levels that may lead to elevated blood pressure and in the long term increased CVD (Talukder et al., 2016).

Further, while the salinity concentration of both surface and groundwater was above the Bangladesh acceptable limit (≥600 mg/L) (Talukder et al., 2016), only a small proportion of the respondents recognised their water sources as salty. Similar observations have been made by several other studies in salinity affected coastal Bangladesh (Benneyworth et al., 2016; Grant et al. 2015). A study by Grant et al. (2015) in healthy volunteers revealed a threshold of 2100 mg/L for water salinity above which water became unpalatable (Grant et al., 2015). This indicates that people can be exposed to levels of salt from drinking saline water and it involves health risk even before it becomes unpalatable to them. Moreover, preference for the salty taste has been reported as a flexible trait—people exposed to a low-salt diet gradually get acclimatised to it and similarly those with a high salt diet become normalised to the taste of salt (Taylor and Henry, 2010). This indicates persistent exposure to high salt concentration is more likely among people in these areas, potentially starting early in life without any awareness of health risks. This implies that communities themselves cannot easily make informed and evidence-based choices about safe water use and scientifically based risk assessments are needed to help policymakers work with communities to identify the best options for them. This will require more regular salt monitoring in water sources and the development of appropriate communication strategies regarding saline-affected water sources to be utilised to reduce salt exposure in both the short and long-term.

An account of daily drinking water consumed is important to estimate the contribution of water to total salt exposure. In our research, it was found that on average people consumed about 3 litres of water daily (by number of glasses and assuming 250 ml per glass). This is also consistent with previous study observations regarding drinking water consumption in Bangladesh (Islam et al., 2011). It is important to note that this research was conducted during the hot summer when more consumption of water is likely. However, more conservatively, it is usually considered that 2 litres of water consumption directly through drinking can provide estimate exposure. This underestimation of the daily consumption of high salt drinking water has significant implications for derivations of exposure estimates and also estimating future health risks (for example, with a water salinity concentration of 800 mg/L based on our previous publication (Talukder et al., 2016b), 2 litres of water will lead to exposure to 1.6 g sodium/day while 3 litres will mean exposure to 2.4 g/L, which is already above the recommended daily level for sodium alone). Future health risk assessments should consider water consumption variability.

Coping with the scarcity of water due to widespread salinity problems in coastal Bangladesh is very challenging, as there appear to be few viable alternatives to finding safe water options. Recognising these challenges the Government of Bangladesh has adopted the water-centric Bangladesh Delta Plan 2100 with a multi-sectoral techno-economic plan for Bangladesh's delta region (Bangladesh Delta Plan, 2016) to ensure adequate water resources management. Filtering pond water (PSF) and rainwater harvesting (RWH) are two existing technologies, which have been promoted in coastal Bangladesh for a long time. While PSF is perceived to be one of the safe options and is efficient to reduce microbiological contaminants, it is less efficient in reducing salinity concentration in water (Harun and Kabir, 2013). Moreover, the maintenance of PSF in the community remains a challenge (Farhana, 2011). The reliability of safe water technologies to sustain water supply in the community is very important. If such technologies are not maintained, people may be forced to return to using unsafe water sources and may lose motivation to invest in them. Local leadership and governance play an important role in the maintenance of safe water technologies and ensuring the security of community water sources (Benneyworth et al., 2016). More in-depth assessments on enablers and barriers to maintaining available safe water technologies (such as PSF, community-based RWH etc.) in the community is critical for future scaling up of such technologies. In addition, the advancement of these technologies (e.g. PSF) to reduce salinity concentration in water should be the focus of more research.

The major strength of our research is a mixed method design where qualitative data strengthened survey findings and provided useful, more in-depth insights about community perspectives on water use safe water as they experience changes in water availability and quality following the salinisation of water in coastal Bangladesh. Data on water use and perceptions about safe water are likely to be applicable in other similar deltaic settings, which are exposed to water salinity.

However, the study has some limitations. First, the study explored water consumption issues at a time when water scarcity was intense (e.g. dry season). Given the common use of untreated surface water in these areas, hence, further in-depth assessments on seasonal influence on water consumption and perceptions about safe water are recommended. Second, qualitative research only demonstrated community perspectives related to water consumption behaviour and did not cover institutional and practitioners' in-depth views about water supply and resource management issues. However, it is believed that the data presented will make a useful contribution to further strengthen water resources management and promote safe water technologies in such vulnerable communities.

Conclusion

The existing safe water scarcity in coastal Bangladesh is more likely to be exacerbated in the days to come due to saltwater intrusion associated with projected climate change and sea level rise. In order to ensure safe water for large populations (about 40 million) in coastal Bangladesh, several new community based and household level technological solutions are on trial. Considering the geomorphology of the area and extent of the salinity, the combination of these solutions could be more appropriate to improve the access to safe water sources. An in-depth understanding of community behaviours and perceptions about water consumption and safe water is, therefore, essential to scale up such technologies and improve their long-term success. Studies on communities for habitual behaviour, safe water availability and community beliefs and perceptions regarding water quality were identified to play an important role in safe water use. In a climate-changing world, this problem is not unique to coastal Bangladesh. The findings of our research should be considered when planning for effective water resources management in similar deltaic settings where natural water sources are predominantly used. These areas being affected by water salinity, hence, community perceptions and behaviours must be better understood to ensure appropriate planning and sustained implementation of safe water supply options.

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Competing Interests

The authors declare no conflict of interest related to this research.

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Contents