Association between salinity and hospital admission for hypertension: An ecological case-control study in the Mekong Delta Region in Vietnam

Association between salinity and hospital admission for hypertension: An Ecological Case-Control Study in the Mekong Delta Region in Vietnam

Mohammad Radwanur Rahman Talukder* [1,2], Dung Phung*[1], Shannon Rutherford[1], Cordia Chu[1]

[1] Centre for Environment and Population Health, School of Environment, Griffith University, Brisbane, Queensland, Australia

[2] International Centre for Diarrhoeal Disease Research, Bangladesh, Mohakhali, Dhaka, Bangladesh

Email: Mohammad Radwanur Rahman Talukder: radwan.talukder@griffithuni.edu.au, Dung Phung: d.phung@griffith.edu.au, Shannon Rutherford: s.rutherford@griffith.edu.au, Cordia Chu: c.chu@griffith.edu.au

***** Both contributed equally

Corresponding author:

Mohammad Radwanur Rahman Talukder
Centre for Environment and Population Health
School of Environment, Griffith University, Nathan campus
170 Kessels Road, Nathan, Brisbane, Queensland 4111, Australia
Phone: +61 (0) 737353698 (office)
Fax: +61 (0) 737357459
Email: radwan.talukder@griffithuni.edu.au

Co-corresponding author:
Dung Phung

Phone:	+61(07) 37355078
Fax:	+61(07) 37355318
Email:	d.phung@griffith.edu.au
Address:	Centre for Environment and Population Health Nathan campus, Griffith University 170 Kessels Road, Nathan Brisbane, Queensland 4111, Australia

Short Title: Drinking water salinity and hypertension

Acknowledgements

Mohammad Radwanur Rahman was awarded Griffith University Postgraduate Research Scholarship to pursue his doctoral study and Dr Dung Phung was awarded Griffith Post-doctoral Fellowship Award.

Competing interests

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

Word count:

Abstract: 182 words

Text: 2153 words (excluding references and table)

Abstract

Drinking water in the Mekong Delta Region (MDR) is highly vulnerable to salinity intrusion and this problem is expected to increase with the projected climate change and sea level rise. Despite this, the evidence on health effects of saline contaminated water is scarce in this region. This research examines the risk of hospital admission for hypertension in salinity affected areas of the MDR. Of the 13 provinces in the MDR we identified seven as 'salinity exposed' and the remaining as 'non-exposed' areas. Cases and controls were obtained from national/provincial hospital admission records for 2013. A multi-level logistic regression model was used to examine the association between salinity exposure and hypertension outcome. Of the total 573,650 hospital admissions, 22,382 (~3.9%) were hypertensive cases. The multi-level logistic model combining both individual and ecological factors showed a 9% increase in risk (95% CI: 3-14%) of hypertension among individuals in exposed areas compared to those in non-exposed areas. In order to develop and promote appropriate adaptation strategies, further research is recommended to identify the salt exposure pathways and consumption behaviours in the salinity affected areas.

Background

Drinking water sources in Asian deltas, more particularly the Ganges, the Mekong and the Red River deltas are highly vulnerable to saltwater contamination (Hoque et al., 2016). In the Mekong Delta number of studies has reported significant saline contamination of groundwater affecting drinking water supply (Buschmann et al., 2008, CGIAR, 2016). According to Buschmann et al. (2008) water sodium concentration in southern Vietnam i.e. in the Mekong Delta ranges from 0.01-4g/L. This poses significant health concerns for the large populations living and working in these areas. The few relevant studies from the coastal Bangladesh-Ganges region indicate that saline contaminated drinking water sources (0.6-8.2g/L) result in salt consumption above the WHO recommended level and is associated with elevated blood pressure in young adults (Talukder et al., 2016a) and pregnant women (Khan et al., 2011; Khan et al., 2014). Substantial evidence suggests that high salt intake and elevated blood pressure (BP) are linked with cardiovascular and kidney diseases (Koliaki & Nicholas, 2013, WHO, 2013). However little is known about the health consequences of living in high salinity vulnerable deltas such as the Mekong Delta Region (MDR).

In developed countries, salt consumption is dominated by food consumption that is related to processed food (Brown et al., 2009). In contrast, in developing countries, salt consumption predominantly relates to salt added during food preparation and at the table (Campbell et al., 2012). The contribution of water to total salt consumption has historically been considered insignificant (World

Health Organization, 2004). However in low resource settings where natural water sources are commonly used without any treatment and where salt contamination of freshwater has occurred, potable water can significantly contribute to high salt consumption. For example, in coastal Bangladesh a mean saline (sodium) concentration of 800 mg/L through drinking water alone was estimated to contribute 1.6g sodium (assuming 2 liters of water via drinking) representing 75% of the WHO recommended level of sodium (<2g/day) consumption (Talukder et al., 2016b). As pointed out by Talukder et al. (2016b), given the established relationship between high salt consumption and hypertension (He et al., 2013, Aburto et al., 2013), consumption of high saline water is more likely to have similar health effects, and this requires further investigation in different contexts and for different salt exposure pathways.

The existing salinity problem in these areas will be aggravated further with climate change induced sea level rise. For example a 30cm SLR by 2050 is predicted to increase the extent and the intensity of salinity intrusion in the MDR (Smajgl et al., 2015). Similarly a 50% decline in freshwater river areas in coastal Bangladesh is projected by 2050 (Dasgupta et al., 2014). The resulting changes in water quality leading to high salt exposure and elevated BP imply significant health burdens for large populations in these areas that heavily rely on natural groundwater for their drinking and domestic purposes. Nonetheless evidence of health effects is limited across the most affected salinity areas including the MDR. In order to promote appropriate adaptation actions and strategies for these areas, context specific evidence is important though to date, few studies have been conducted for this purpose in the MDR. To begin to address this

deficit, this research examines the risk of living in a salt exposed area of the MDR on hypertension.

Methods

We conducted an ecological case-control study to examine if the risks of hospital admissions were higher in salinity-affected areas than in non-salinity affected areas. The research location was the Mekong Delta region (MDR), which comprises 13 provinces in the south of Vietnam with a total population of 17.5 million people (GSO 2012). The MDR has experienced increased salinity intrusion due to rising sea level, and this is anticipated to spread further inland and affect wider areas of the region (CGIAR 2016). Each province is served by a provincial hospital. We selected the cases and controls from the 2013 hospital admission records obtained from 13 national/provincial hospitals in the MDR. The cases were adult patients whom hypertension (ICD10-code: I10-I15) was primary diagnosis for admission and included both the new and pre-existing hypertension conditions. The controls were randomly selected from adult patients who were diagnosed with one of the following conditions or diseases: mental and behavioral disorder (ICD10: F00-F99), respiratory diseases (ICD10: J00-J99), disease of nervous system (ICD10: G00-G99), and disease of the musculoskeletal system (ICD10: M00-M99). The cases and controls were selected with a ratio of 1:1 in each province. Available data on residential location and age were obtained from admission records for each case and control. Besides individual data, aggregated provincial level data on population, % of males, % of literacy among persons above 15 years, and average household income were also obtained from the General Statistic Office 2012 (GSO 2012).

We defined the areas as 'exposed to salinity' if they were affected by salinity at any level based on the map of salinity intrusion provided by the Institute for Hydro-Meteorology and Climate Change (Figure 1A). On this basis, seven provinces; Tien Giang, Ben Tre, Tra Vinh, Soc Trang, Bac Lieu, Ca Mau and Kien Giang, were defined as exposed areas, whereas, the rest of provinces were selected as non-exposed areas (Figure 1B). The salinity concentration was measured as total dissolved solids in gram per liter of water where sodium (Na) shared the major concentration (Buschmann et al., 2008). The salinity concentration in the exposed areas range from 1g/L to above 24g/L while that of in the non-exposed areas is less than 1g/L.

A multi-level logistic regression model (Equation 1), which combined both individual and ecological data, was used to examine the association between salinity exposure and hypertension outcome. The dependent variable was a binary of health outcome (case, hypertension=1; control, other diseases=0), and the main exploratory variable is a binary of exposure (exposure, salinity province=1; and non-exposure, non-salinity province=0). The adjusted variables included individual variables (age group) and ecological variables (% males, % illiterate, and % having supply water connection). The Odds Ratio (OR) and 95%CI were estimated to evaluate the risk of hypertension among cases in comparison with controls, and a statistically significant level representing a p value <0.05 was used.

$$\log\left(\frac{case}{control}\right) = \alpha + \beta_1 Exposure + \beta_2 Age + \beta_3 Male\% + \beta_4 Illiterate\% + \beta_5 having\ supply\ water\ connection\%$$

(Equation 1)

Results

The distribution of population, gender, household income, and literacy rate are presented in Figure 2. The population of the provinces ranged from 769,700 to 2,153,700 people with the population density ranging from 230 to 862 persons/km^2. The average household income ranged from $60 to $100/month with a mean of $80 (±$12.50). The percentage of males was 49.0 to 50.5%, and the rate of illiteracy among people aged 15+ ranged from 3.4 to 11.8% (±2.2%). A total number of 573,650 hospital admissions were observed across 13 national/provincial hospitals in 2013, of which the number of hypertensive cases was 22,382 with a range of 549 to 3,858 cases (mean, 1,722±894). The average age of cases (64.4±17) was significantly higher than that of controls (38.4±31).

The univariate logistic regression indicated no difference in the risk of hypertension between individuals' from exposed and non-exposed areas (OR, 0.99; 95%CI: 0.96-0.99, p=0.9) (Table 1). However after controlling for age, a 13% (8-18%) increase in risk of hypertension was found among those in the exposed area compared to those in the non-exposed area. This result confirms the strong confounding factor of age in the relationship between salinity and hypertension. The multi-level logistic model with involvement of both individual and ecological factors identified a 9% (95%CI: 3-14%) increase in risk of hypertension among individuals from exposed areas compared with those from non-exposed areas (Table 1).

Discussion

Main finding of this study

We have shown an increased risk of hospital admissions for hypertension in salinity affected provinces of the MDR. To the best of our knowledge this is the first study reporting potential health effects of salinity exposure in the MDR.

What is already known on this topic

Number of studies has reported significant saline contamination of groundwater affecting drinking water supply in the Mekong Delta (Buschmann et al., 2007,). According to Buschmann et al. (2008) water sodium concentration in southern Vietnam i.e. in the Mekong Delta ranges from 0.01-4g/L. But little is known about salt exposure in population living in this area. Studies in coastal Bangladesh (Talukder et al., 2016, Khan et al., 2011) already demonstrated significant association between drinking water salinity, salt consumption, and blood pressure. Cooking in high sodium water can also contribute to total salt consumption as absorbed in food (Rowan and Calabrese, 1984). Research in coastal Bangladesh also showed that people drinking highly saline water (~800mg/L) without being aware of salty taste of water (Talukder et al., 2017, unpublished data). Therefore it is highly likely that people in the Mekong Delta are having similar exposure and health risks from saline drinking water.

The findings of this research are consistent with the observations from salinity affected coastal Bangladesh. In coastal areas of Bangladesh high water salinity was associated with elevated BP in the exposed populations (Talukder et al., 2016a) including in pregnant women (Khan et al., 2014). Research also reported that people in the affected areas were consuming high salt above the WHO

recommended level (Talukder et al., 2016b). The adverse effects of high salt consumption on cardiovascular health are well established (Aaron and Sanders, 2013). Until now food has been considered as the major contributor to salt consumption (World Health Organization, 2016), mainly based on studies from developed country settings. However in developing countries, particularly in rural areas, highly saline drinking water can contribute to a significant proportion of the total salt consumption (Talukder et al., 2016b). These results imply that the salinization of freshwater in coastal areas where people utilize untreated water presents an important health risk.

Being low-lying, with a mean elevation of less than 1 meter above sea level (CGIAR, 2016), the Mekong Delta is seriously affected by salinity intrusion (Smajgl et al., 2015; Buschmann et al., 2008). From the end of 2015 to mid 2016, 11% of the total agricultural land in 8 coastal provinces has been affected by salinization, which is anticipated to grow significantly in the days to come (Vietnam National Committee on Large Dams & Water Resources Development, 2016). Safe water scarcity is an existing problem and salinization of water has made the situation worse (Buschmann et al., 2008). Only 60-65% of the urban population in this area has a safe water supply and this figure is believed to be even lower for rural populations (WUR and DeltaRes, 2013). Salinity intrusion is also seasonal with the concentration becoming highest in the dry season. A simulation study for 2010-2020 shows a salinity concentration of 4g/liter in the dry season in 70-85% of coastal Bac Lieu province in the MDR (Hoang et al., 2012) revealing significant implications for salt consumption via drinking water.

The evidence on salt consumption in Vietnam including in the MDR is scarce (Batcagan-Abueg et al., 2013). A survey in rural Vietnam indicates that average salt consumption (11g/day) was two times higher than the recommended value 5g/day of WHO (Do, H.T.P., 2014). Increased salinization of the environment results in high salt exposure from direct consumption through water and possibly via indirect accumulation in the food either during cooking or during production (Talukder et al., 2016b). According to the Vietnam National Institute of Nutrition (NIN, 2011) the uses of condiments during food preparation and cooking, and additional use at the table are the main sources (81%) of sodium in the diet (NIN, 2011). The resulting changes in the environment (e.g. water and soil) following salinity intrusion are more likely to intensify this salt exposure, therefore increasing related chronic health risks of the populations in these areas if not addressed adequately.

What this study adds

Consuming excess salt leads to high blood pressure or hypertension and greatly increases the risk of heart diseases and stroke (World Health Organization, 2013b). High BP is also the single leading risk factor for global burden of disease (Lim et al., 2013). In Vietnam every one in four individuals aged 25 and older is reported to be hypertensive (Son et al., 2012) and cardiovascular disease is the leading cause of death (WHO, 2014). To tackle the burden of non-communicable diseases, Vietnam has adopted WHO's nine global action plans including reducing salt intake by 30% by 2025 (WHO, 2013b). Given the changes in the environment due to salinity intrusion the proposed measures to reduce salt intake solely based on dietary changes (WHO, 2013b) are unlikely to be

adequate to reduce total salt consumption, particularly in salinity vulnerable areas in the MDR. Further exacerbation of salinity intrusion as a result of climate change induced sea level rise (Smajgl et al., 2015) points to an increasing problem.

This is a preliminary research examining the potential health risks from exposure to high salinity in the MDR. In order to adopt appropriate intervention strategies, further research is recommended to identify and estimate the contribution of different salt exposure pathways (e.g. food, crop, water). In addition population-based studies need to be conducted to investigate the potential influence of salinization of environments on health, more specifically on salt consumption, hypertension and related chronic health risks in the MDR.

Limitations of this study

Ours is the first study to demonstrate the increased risk of hospital admissions due to hypertension in salinity-affected areas of the MDR. However the study has some limitations, which require noting. First, we had a lack of individual level exposure data on salinity and related confounding factors (e.g. age, sex, socioeconomic condition and other confounders like smoking, overweight etc), which might have introduced ecological bias. Second, the cases that we included are more likely to be those individuals with 'severe hypertension' requiring admission in hospital. We might have missed minor cases that had sought care at the outpatient or lower-level hospitals (i.e. district hospitals) hence under-estimating the effect of salt exposure. We also assumed everyone in high salinity

areas have high exposure, hence not considering the variation of salinity consumption within the high exposure areas.

Conclusion

This research has shown an increased risk of hospital admission for hypertension among populations in the salinity affected region of the MDR. Climate change and sea level rise projections indicate further aggravation of salinity in such environments and hence the existing food-based strategies to reduce salt consumption are unlikely to be sufficient to prevent chronic health problems such as hypertension and cardiovascular diseases associated with elevated salt exposure. More detailed data on salt exposure pathways, salt consumption behaviours and subsequent chronic health outcomes are particularly important in order to plan and promote appropriate intervention strategies and as such more research focus is urgently needed in this area.

Reference:

Aaron, K. J., & Sanders, P. W. (2013, September). Role of dietary salt and potassium intake in cardiovascular health and disease: a review of the evidence. In Mayo Clinic Proceedings (Vol. 88, No. 9, pp. 987-995). Elsevier.

Aburto Nancy J, Ziolkovska Anna, Hooper Lee, Elliott Paul, Cappuccio Francesco P, Meerpohl Joerg J et al. Effect of lower sodium intake on health: systematic review and meta-analyses BMJ 2013; 346 :f1326

Buschmann, J., Berg, M., Stengel, C., Winkel, L., Sampson, M. L., Trang, P. T. K., & Viet, P. H. (2008). Contamination of drinking water resources in the Mekong delta floodplains: Arsenic and other trace metals pose serious health risks to population. Environment International, 34(6), 756-764.

Brown, I. J., Tzoulaki, I., Candeias, V., & Elliott, P., 2009 Salt intakes around the world: implications for public health. Int J Epidemiol, 38(3), 791-813.

Campbell, N. R. C., Johnson, J. A., & Campbell, T. S. (2012). Sodium Consumption: An Individual's Choice? International Journal of Hypertension, 2012

Dasgupta, Susmita; Kamal, Farhana Akhter; Khan, Zahirul Huque; Choudhury, Sharifuzzaman; Nishat, Ainun. (2014). River salinity and climate change: evidence from coastal Bangladesh. Policy Research working paper; no. WPS 6817. Washington, DC: World Bank Group. http://documents.worldbank.org/curated/en/2014/03/19299368/river-salinity-climate-change-evidence-coastal-bangladesh

Hoque, M. A., Scheelbeek, P. F. D., Vineis, P., Khan, A. E., Ahmed, K. M., & Butler, A. P. (2016). Drinking water vulnerability to climate change and alternatives for adaptation in coastal South and South East Asia. Climatic Change, 136(2), 247-263.

CGIAR 2016. The drought and salinity intrusion in the Mekong Delta of Vietnam: Assessment Report. Accessed 7 September 2016 In: https://cgspace.cgiar.org/rest/bitstreams/78534/retrieve.

GSO 2012. General Statistics Office (2012): Statistical Yearbook of Vietnam 2011. Statistical Publishing House, Hanoi.

He Feng J, Li Jiafu, MacGregor Graham A. (2013). Effect of longer term modest salt reduction on blood pressure: Cochrane systematic review and meta-analysis of randomised trials BMJ; 346 :f1325

Hoang, H. N., Huynh, H. X., & Nguyen, T. H. (2012, February). Simulation Of Salinity Intrusion In The Context Of The Mekong Delta Region (Viet Nam). In Computing and Communication Technologies, Research, Innovation, and Vision for the Future (RIVF), 2012 IEEE RIVF International Conference on (pp. 1-4). IEEE.

Khan, A. E., Scheelbeek, P. F. D., Shilpi, A. B., Chan, Q., Mojumder, S. K., Rahman, A., ... & Vineis, P. (2014). Salinity in drinking water and the risk of (pre) eclampsia and gestational hypertension in coastal Bangladesh: a case-control study. PloS one, 9(9), e108715.

Khan, Aneire Ehmar, Ireson, Andrew, Kovats, Sari, Mojumder, Sontosh Kumar, Khusru, Amirul, Rahman, Atiq, & Vineis, Paolo. (2011). Drinking water salinity and maternal health in Coastal Bangladesh: implications of climate change. *Environmental Health Perspectives*, 119(9), 1328.

Koliaki, C., & Katsilambros, N., 2013 Dietary sodium, potassium, and alcohol: key players in the pathophysiology, prevention, and treatment of human hypertension. Nutr Rev, 71(6), 402-411.

Lim, S. S., Vos, T., Flaxman, A. D., Danaei, G., Shibuya, K., Adair-Rohani, H., ... & Aryee, M. (2013). A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010. The Lancet, 380(9859), 2224-2260.

National Institute of Nutrition. (2011). Investigation of dietary sodium intake and sources in the adults aged 25-64 years 2010, Vietnam

Rowan, C. A. & Calabrese, E. J. (1984). The effect of cooking with water having elevated sodium levels upon the concentration of sodium and potassium in vegetables. Journal of Environmental Science and Health. Part A: Environmental Science and Engineering 16, 125–137.

Smajgl, A., Toan, T. Q., Nhan, D. K., Ward, J., Trung, N. H., Tri, L. Q., ... & Vu, P. T. (2015). Responding to rising sea levels in the Mekong Delta. Nature Climate Change, 5(2), 167-174.

Son, P. T., Quang, N. N., Viet, N. L., Khai, P. G., Wall, S., Weinehall, L., ... & Byass, P. (2012). Prevalence, awareness, treatment and control of hypertension in Vietnam—results from a national survey. Journal of human hypertension, 26(4), 268-280.

Talukder, M. R. R., Rutherford, S., Phung, D., Islam, M. Z., & Chu, C. (2016a). The effect of drinking water salinity on blood pressure in young adults of coastal Bangladesh. Environmental Pollution, 214, 248-254.

Talukder, M. R. R., Rutherford, S., Phung, D., Malek, A., Khan, S., & Chu, C. (2016b). Drinking water contributes to high salt consumption in young adults in coastal Bangladesh. Journal of Water and Health, 14(2), 293-305.

Vietnam National Committee on Large Dams & Water Resources Development. (2016). Salinization situation in 2015-2016 Mekong Delta region, the drought in Central Highlands and propose remedies, Available online at:

http://www.vncold.vn/web/content.aspx?distid=4061, accessed on September 13, 2016

World Health Organization. (2016). Salt reduction, Available online at: http://www.who.int/mediacentre/factsheets/fs393/en/, accessed on October 6, 2016

World Health Organization. (2014). World Heart Day 2014: Salt Reduction saves lives, Available online at: http://www.wpro.who.int/vietnam/mediacentre/releases/2014/worldheartday2014/en/
Accessed on: October 6, 2016

World Health Organization, 2013a A global brief on hypertension. Geneva, Switzerland.

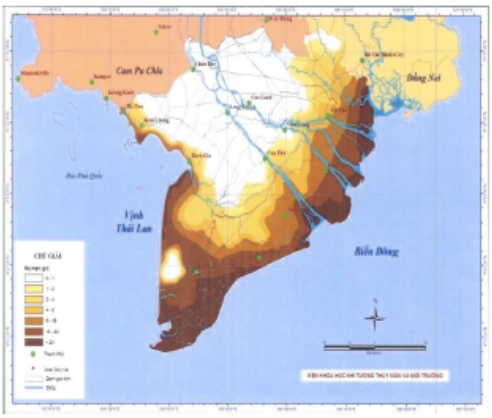
World Health Organization. (2013b). Global action plan for the prevention and control of noncommunicable diseases 2013-2020. Geneva, Switzerland

World Health Organization. (2004). Guidelines for drinking-water quality: recommendations (Vol. 1). World Health Organization, Geneva, Switzerland

WUR and DeltaRes. (2013). Mekong Delta Plan, Netherlands

A. Salinity intrusion in the Mekong Delta Region, Vietnam
(Source: Vien Khoa Hoc Khi Tuong Thuy Van va Moi Truong
In: http://www.vncold.vn/Web/Content.aspx?distid=4061)

B. Hospitalization for hypertension in 2013 by the provinces



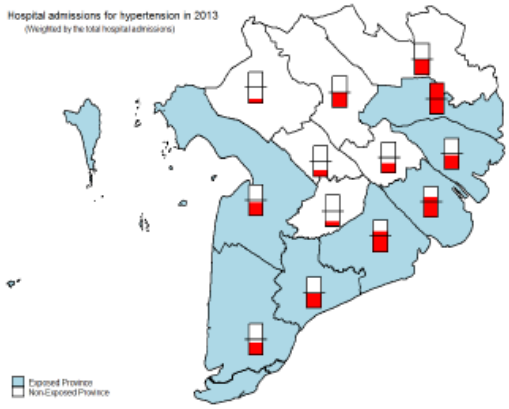


Figure 1A Map showing salinity intrusion in the Mekong Delta Region (MDR);
Figure 1B Number of cases with hypertension admission weighted by total number of hospital admission in 13 provinces of the MDR

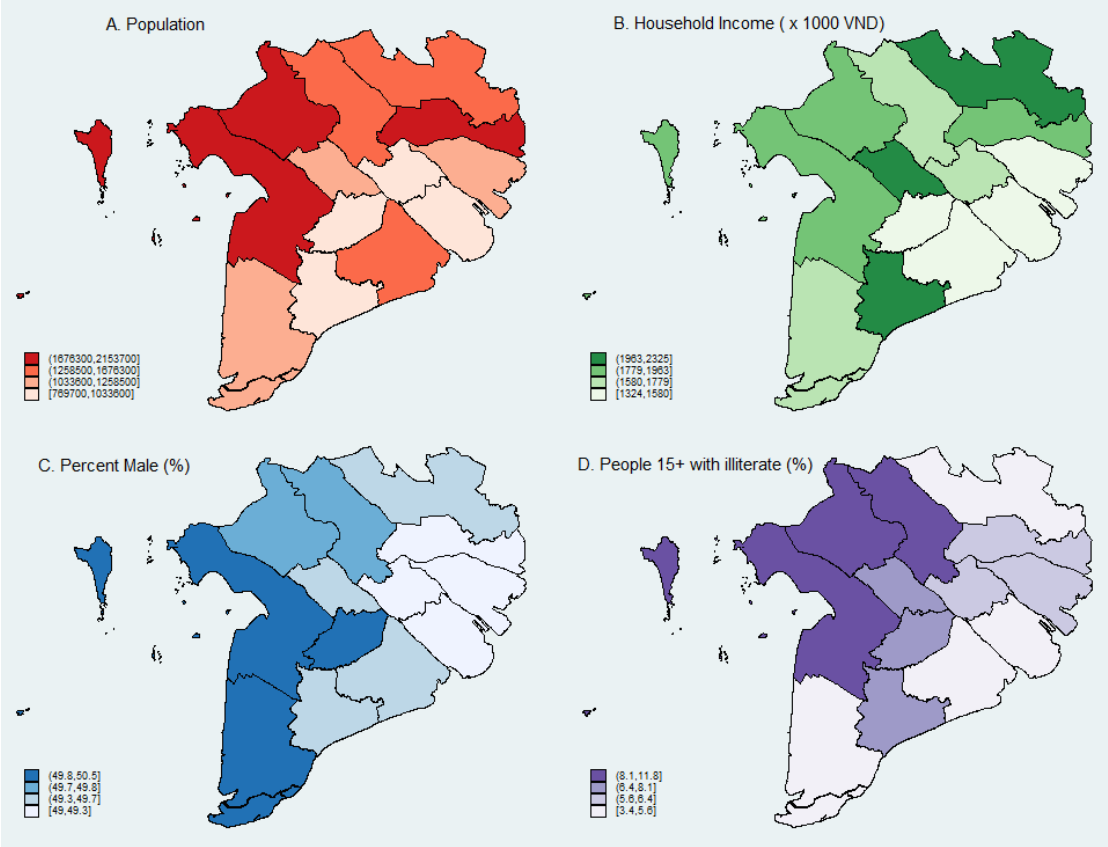


Figure 2 Distribution of selected variables (population, % of male, household income and % literate in population above 15 years) across 13 provinces in the MDR

Table 1 Logistic regression analyses showing unadjusted and adjusted odds ratio for admissions with hypertension in MDR

Model	Unadjusted OR	95% CI	p-value	Adjusted OR	95%CI	p-value
Salinity exposure						
Non-exposed	Ref					
Exposed	0.99	0.96-0.99	0.9	1.09*	1.03-1.14	0.001
Age						
Age group	1.45	1.44-1.46	<0.001	1.47	1.45-1.48	<0.001
Sex						
Male (%)	1.00	0.96-1.04	0.98	0.99	0.93-1.04	0.6
Education						
Illiterate (% of persons 15+)	1.00	0.99-1.01	0.99	1.03	1.01-1.04	<0.001
Income						
Income (x1000 VND)	1.00	0.99-1.00	1.00	0.99	0.99-0.99	<0.001

**Adjusted for both individual (age) and ecological factors (sex, education and income)*