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Analysis of the Stringency of Drinking Water Quality Standards of Bangladesh in Comparison to the USA, EU, Japanese, and Indian Standards

Islam, K.[1*], Zahra, F. T.[2], Chowdhury, M. A.[2] and Biswas, S. M.[3]

1. Department of Systems Innovation, Graduate School of Engineering, The University of Tokyo, Hongo 7-3-1, Bunkyo-ku, Tokyo 113-8656, Japan

2. Institute of Water and Flood Management, Bangladesh University of Engineering and Technology, Dhaka 1000, Bangladesh

3. College of Environmental Science and Forestry, State University of New York, 1 Forestry Drive, Syracuse, NY 13210, USA

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ABSTRACT: Water is one of the most crucial substances for life. In order to maintain their public health, each and every country has defined standards of drinking water quality, beyond which the water is considered harmful for human health. The current study compares physical, chemical, and biological standards of drinking water quality for the USA, EU, Japan, India, and Bangladesh, considering 4 physical parameters (namely, color, odor, taste, and turbidity), 36 chemical parameters (such as Calcium (Ca), Magnesium (Mg), Phosphate (PO_4^{3-}), Sodium (Na), Phenolic compounds, Nitrite (NO^{2-}), Arsenic (As), Aluminum (Al), etc.) and 2 biological parameters (i.e., Coliform (Fecal) and Coliform (Total)). The data has been collected from several secondary sources and since processes of data collection for water quality differ from one another, this aspect has been ignored. No variation has been found in biological water quality standards along with physical quality standards of the considered regions. In order to find out the differences in chemical parameters, standard ANOVA and pair-wise F-test have been conducted. There was no disparity among chemical parameters in ANOVA test. Moreover, thanks to the few excessive values of the standards (as in case of Bangladesh), the COD value is 4 mg/L, whereas in other countries this parameter is much less. However, the chemical parameters of water quality standards in Bangladesh vary significantly from other countries. Besides, there has been no variation among the standards of other countries, even though they are located in different continents. Most interestingly, despite being neighbors, Bangladesh and India differ significantly in this regard.

Keywords: Water, Quality, Management, Resources; Environment, Health, Sanitation, Standards

INTRODUCTION

Only the rare things of the earth are valuable; water which is the best of all things is the cheapest - once said by the great philosopher, Plato (Hanemann, 2006). Human beings are particularly interested in water quality as poor quality may put their health at risk (Rahman et al., 2017). According to World Health Organization (WHO), there should be some legally-established national standards for drinking water quality (WHO, 2001 & 2009). Ensuring drinking water quality is

[*] Corresponding author, Email: ksujonifescu@gmail.com; kamrul-islam@g.ecc.u-tokyo.ac.jp

very obligatory, continuously practiced by legally-binding standards in both EU and USA (EC, 2016; Holeck et al., 2015). Similarly, Japan follows WHO guidelines to sustain its water quality management; although, there was some contamination due to heavy metals like lead, nitrate and nitrite, bromate, chlorate, etc. in its water supply system (Hattori, 2006). India, too, is concerned about reclaiming drinking water supply system, thanks to the considerable costs, charged for the treatment of various water-borne diseases, such as typhoid, viral hepatitis, etc. Due to the presence of pathogens, India does routine examination to avoid risk of health issues and defines appropriate control processes (BIS, 2012). As for Bangladesh, the country has its own water quality standards for relevant parameters, which are supposed to be closely followed by any water supply system (e.g. DoE (Department of Environment) has set water quality standards for consumption purpose (Islam, 2017)).

Surface water systems, like rivers, lakes, reservoirs, estuaries, and coastal waters, are crucial sources of drinking water, directly influencing public health. Hence, it is of enormous importance to assess systems' water quality which requires development of optimal water monitoring networks (Tavakol et al., 2017a). Increased agricultural practices, urbanization, and climate change enhance direct and indirect possibilities of drinking water contamination in physical, chemical, and biological ways (Silva & Dubé, 2017; Hargalani et al., 2014; Pejman et al., 2011).

Statistical analysis is very useful to test goodness of fit of the data, used in water quality assessments as well as monitoring plan development. Especially, multivariate statistical techniques such as CCA (Canonical Correspondence Analysis), PCA (Principal Component Analysis), and PFA (Principal Factor Analysis) are effective tools for assessment of water health in a variety of Iranian rivers like Haraz River, Gorgunrud River, etc. (Fataei et al., 2010; Noori et al., 2012; Tavakol, et al., 2017b).

Drinking water quality also depends on the groundwater quality. As such, groundwater chemistry and Water Quality Index (WQI) are important tools utilized to find out drinking suitability of water conditions (Varol & Davraz, 2015). As WQI does not focus on aquatic life or human health regulation, proper formation of various water quality indices can be found in various studies (Hargalani et al., 2014; Karbassi et al., 2011; Semiromi et al., 2011). Using Analytical Hierarchy Process (AHP), WQI has been formed and Fuzzy Water Quality Index (FWQI) has been developed to give proper weight to parameters such as DO (Dissolved Oxygen), BOD, and fecal coliform, used to monitor river water quality in Iran by integrating of physical, chemical and biological water parameters (Karbassi et al., 2011; Semiromi et al., 2011). This comparative study is quite important to formulate an effective WQI for drinking water quality in Bangladesh, wherein the pairwise statistical comparison has been never done before.

The study analyzes water quality standards of Bangladesh, the United States, the European Union, Japan, and India in order to find the overall condition, pertaining to it. Various studies in the past have used different amounts of parameters, according to their own requirements (Noori et al., 2012; Tavakol et al., 2017a). Moreover, the main aim of this study is to compare water quality parameters, e.g. Ca, Cl, DO, $CaCO_3^-$, Mg, NO_3^-, PO_4^-, Na, suspended solids, sulphates, total dissolved solids, Zn, Fluoride, etc. (see table 1 for the detailed list), of Bangladesh with the other four abovementioned countries (Holeck et al., 2015; Kumar & Puri, 2012; Schernewski et al., 2015; Tsuzuki, 2015). As a result, the study will help decision makers develop a monitoring plan by maintaining stringency, as offered by WHO guidelines and similar to other countries as well.

MATERIALS AND METHODS

This study is based on the data about water quality parameters, collected from relevant government authorities. While going through the data collection process, we found that availability of the data, regarding the number of water quality parameters, differed among the studied regions (namely, Bangladesh, India, Japan, EU, and USA). In order to solve this problem, we decided to collect the data that targeted Bangladeshi water quality parameters as the basis. If the parameter to be studied was found in all regions, only then did we include it in our database. This process helped comparing water quality parameters without any further complexity. The parameters were sub-divided into physical, chemical, and biological water quality parameters, in accordance with their characteristics. They are shown in Table 1.

Table 1. Studied water quality parameters

Physical water quality parameter
Color, Odor, Taste, Turbidity
Chemical water quality parameter
Calcium (Ca), Chloride (Cl^-), Dissolved Oxygen (DO), Hardness as $CaCO_3$, Magnesium (Mg), Nitrate (NO_3^-), Phosphate (PO_4^{---}), Sodium (Na), Suspended solids, Sulphate (SO_4^{--}), Total Dissolved Solid (TDS), Zinc (Zn), Fluoride (F^-), Silver (Ag), Selenium (Se), Phenolic compounds, Nitrite (NO_2^-), Nickel (Ni), Mercury (Hg), Manganese (Mn), Lead (Pb), Iron (Fe), Cyanide (CN^-), Copper (Cu), Chemical Oxygen Demand (COD), Chromium (Cr) (Total), Chloroform ($CHCl_3$), Chlorine (Cl_2) (Residual), Cadmium (Cd), Boron (B), Biochemical Oxygen Demand (BOD_5), Benzene (C_6H_6), Barium (Ba), Arsenic (As), Aluminum (Al), Potential of Hydrogen (pH)
Biological water quality parameter
Coliform (Fecal), Coliform (Total)

Our main goal was to compare water quality parameters in Bangladesh with aforementioned regions to see whether these parameters were in conformity with others or not. It is worth mentioning here that the specific water quality parameters had the same unit across all studied regions, making it possible to have a comparison among them. We hypothesized that the value of different water quality parameters across the studied regions were the same and conducted ANOVA (Analysis of Variance) and F-test for chemical water quality parameters to test this hypothesis. In case of physical and biological water quality parameters, we simply compared it with cross-tabulation.

RESULTS AND DISCUSSION

Although biological parameters of water quality, as some agents, are very important, they can pose a serious threat to human health, if they are present in drinking water. Only 2 such parameters were found (i.e. Faecal Coliform, and Total Coliform) in Bangladeshi standard, while the other regions' list is very comprehensive in this case. For comparison purposes, only these two parameters were considered. It is of high account that there was no variation among these two parameters (Table 2).

The government of Bangladesh is aware of the scarcity of safe drinking water, especially in local areas. To ensure sustainable supply of safe drinking water and combat diarrheal diseases, GoB (Government of Bangladesh) published the national water policy in 1999. Additionally, Water Act of Bangladesh (2013) identified several zones for water, e.g. industrial water, agricultural water, brackish water for aquaculture, and hatchery water. Like Bangladesh, National Water Policy of India (2012), EU water directive (2000), and Federal water pollution control act (2002) in the US also focused on sustainable supply of safe drinking water for all (Ministry of Law, Justice and Parliamentary Affairs, 2013; MoWR, 2012; Ministry of Water Resources, 1999; Federal water pollution control act, 2002; Water Directive, 2000).

Table 2. Comparison of biological water quality parameters

Water Quality Parameters	Bangladesh Standard	US Standard	EU Standard	Japanese Standard	Indian Standard
Coliform (Fecal) CFU (N/100 mL)	0	0	0	0	0
Coliform (Total) CFU (N/100 mL)	0	0	0	0	0

In case of chemical water quality parameters, it is possible to analyze from a comprehensive list with as many as 35 of such parameters being considered. Because the number of parameters is big, they cannot be nicely accommodated in one figure to present the status. Hence, Figs. 1 and 2 show these 35 parameters only for the sake of representation.

From Fig. 1, it is clear that there had been hardly any difference in the concentration limit of calcium, chloride, dissolved oxygen (DO), magnesium, nitrate, suspended solid, etc. among the studied regions' water quality parameters. Bangladeshi guideline permits a maximum of 1000 mg/L total dissolved solid in its drinking water, whereas the remaining 4 studied regions allow 500 mg/L of this parameter.

Both Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) are permissible to a certain extent (0.2 and 4 mg/L respectively) in case of Bangladeshi standard, while the other nations do not permit either of them in their drinking water. There is almost no variation in parameters such as silver, selenium, phenolic compounds, nitrite, mercury, manganese, lead, iron, cyanide, chromium, boron, etc. (Figure 2).

Since the unit of pH differs from all other 35 parameters, it is not shown is figure. There is a slight change is this parameter among the studied regions. The pH range for Bangladeshi, US, EU, Japanese, and Indian standard are (6.5-6.8), (6.5-6.8), (6.5-8.5), (5.8-8.6), and (6.5-6.8), respectively, which shows that Japanese pH range surpass the others.

It is difficult to find any significant difference among the countries chemical water quality standards. As such a two-factor ANOVA without any replication can be used to observe the variation. Again a pair-wise F-test can be useful to find the variation of standards between two studied regions.

It is clear from the findings that there was no significant variation in water quality standards among the regions, yet the parameters, themselves, differed significantly (Table 3).

Based on Table 4, it can be inferred that there was a significant difference in water quality standards between Bangladesh and the US, Bangladesh and the EU, Bangladesh and Japan, and Bangladesh and India. On the other hand, there was no pairwise significant variation in chemical water quality parameters among the American, European, Japanese, and Indian standards. It can be concluded that Bangladeshi standard differs significantly from the rest of the four studied regions in terms of chemical water quality parameters (Table 4).

According to WHO (2008), several surveillance aspects are needed to be considered (e.g. the ratio of sick people to total population, the characteristics of water to impose health risk, identification of an outbreak, and geographical and socio-economic characteristics analysis) to maintain drinking water security. In addition, catchments, surface water, and groundwater are considered to assess drinking water system of a country (WHO, 2008). Furthermore, in case of chemical parameters, the location of main water sources, dietary, and instability have to be considered. These two factors of Bangladesh varies from those of the other regions under study (WHO, 2008). All of these issues of Bangladesh were different from the EU, US, Japan, and

India. Perhaps since all of these geographical and social aspects have been considered, the limits of dissolved solids, BOD, COD, and pH are higher than other regions.

Similar to biological water quality parameters, there was no significant variation among the physical water quality parameters. Table 5 compares physical water quality parameters among Bangladeshi, US, EU, Japanese, and Indian standards.

Table 3. ANOVA of chemical water quality parameters of Bangladesh, US, EU, Japan, and India

Source of Variation	SS	df	MS	F	P-value	F-critical
Parameters	2455889	35	70168.25	34.08	$1.14*10^{-52}$	1.51
Country standards	7763.414	4	1940.854	0.94	0.441355	2.44
Error	288276.8	140	2059.12			
Total	2751929	179				

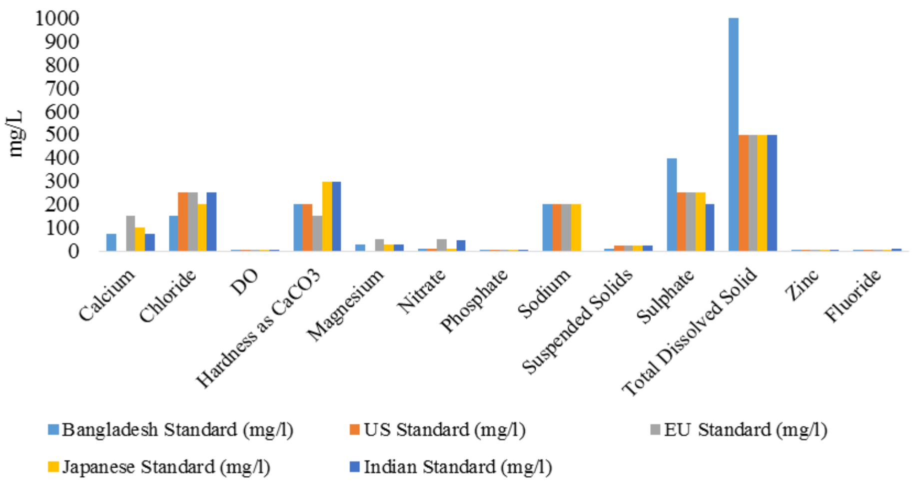

Fig. 1. Chemical water quality parameters of Bangladesh, US, EU, Japan, and India

Table 4. Pairwise F-test for comparison of chemical water quality standard in Bangladeshi, US, EU, Japanese, and Indian standards

Country standard (mg/L)	Mean	Variance	F-value	p-value	F-critical
Bangladeshi US	58.56 40.68	32740.53 11322.38	2.89	0.001	1.76
Bangladeshi EU	58.56 45.88	32740.53 11142.77	2.94	.0009	1.76
Bangladeshi Japanese	58.56 45.65	32740.53 11978.92	2.73	0.001	1.76
Bangladeshi Indian	58.56 40.55	32740.53 11220.13	2.92	0.001	1.76
US EU	40.68 45.88	11322.38 11142.77	1.01	0.48	1.76
Japanese US	45.65 40.68	11978.92 11322.38	1.06	0.43	1.76
US Indian	40.68 40.55	11322.38 11220.13	1.009	0.49	1.76
Japanese EU	45.65 45.88	11978.92 11142.77	1.07	0.42	1.76
Indian EU	40.55 45.88	11220.13 11142.77	1.007	0.49	1.76
Japanese Indian	45.65 40.55	11978.92 11220.13	1.07	0.42	1.76

Table 5. Comparison of physical water quality parameters

Water Quality Parameters	Bangladesh Standard	US Standard	EU Standard	Japanese Standard	Indian Standard
Color	15 Hazen	15 color units	No abnormality	5 degree	3 Hazen
Odor	Odorless	3 threshold odor number	No abnormality	Not abnormal	Unobjectionable
Taste	----	Not abnormal	No abnormality	Not abnormal	Agreeable
Turbidity	10 NTU	1 NTU	No abnormality	2 degree	5 NTU

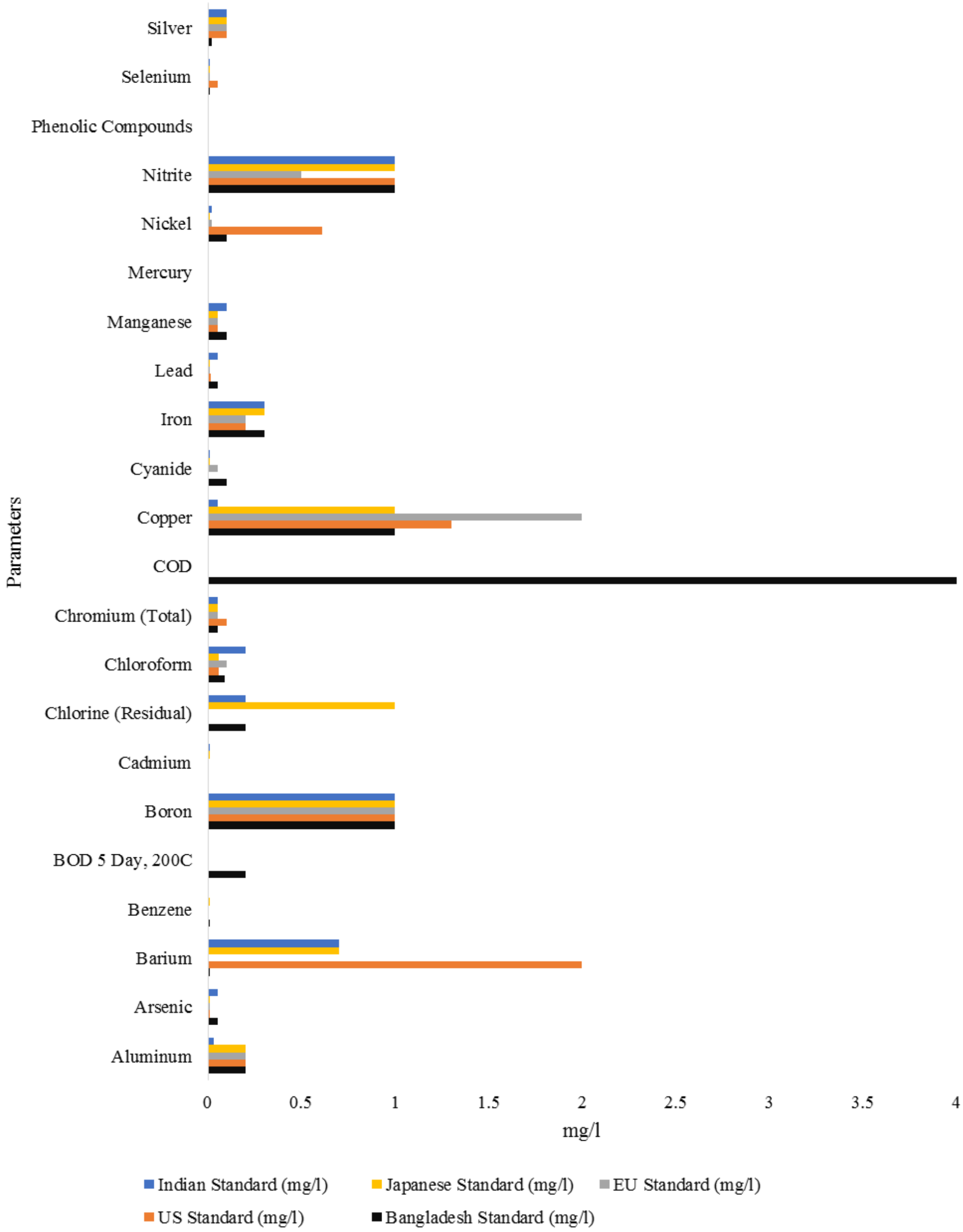

Fig. 2. Chemical water quality parameters (rest) of Bangladesh, US, EU, Japan, and India

In Bangladesh, most people use both deep and shallow tube wells for managing their drinking water (Rahman & Paul, 2011). Also people from some districts use ponds and river as their sources of drinking water. Arsenic contamination, diarrhea, and cholera are considered the main water-borne diseases in Bangladesh (Esrey et al., 2000). National level assessment of drinking water does not depict the echo of local level vulnerability and physical diversity (Benneyworth et al., 2016). However, due to the vast infestation of arsenic (Smith et al., 2000), the government took several steps to increase public awareness, which was not seen for any other parameters. Despite numerous limitations, GoB developed water safety plan in 2011 to protect water sources from contamination and significantly reduced contamination via processing water, eliminating water pollution during further processing of the drinking water (Ministry of Local Government, Rural Development & Cooperative, 2011). Furthermore, Water Supply and Sewerage Authority (WASA) is responsible to supply purified water within the municipality, with the Department of Public Health and Engineering (DPHE) covering the rest of the area in Bangladesh. Water quality is monitored by DPHE, DoE, Bangladesh Standards and Testing Institution (BSTI), Atomic Energy Commission (AEC), and Community Based Organizations (CBOs). Local government division at Ministry of Local Government, Rural Development and Cooperative is responsible for working on these organizations' reports in order to control water quality throughout the country.

It is evident from this research that water quality parameters are different from other four regions. The European Commission has initiated water quality issue as a guideline among six guidelines (namely, water quality, waste management, air quality, environmental impact assessment, nature protection, and industrial pollution). After adoption of EU water legislation in 1973, two periods, one from 1975 to 1980 and the other from 1980 to 1991, passed so that it could be reformed, based on present demand through controlling pollution from the sources (Kampa et al., 2007). Although India does not have adequate drinking water sources, National water policy (2012) of India gives account to present institutions, formulating appropriate plans like appropriate legislative systems to ensure sustainable management of drinking water. On the other hand, the Japanese government has formulated several policies to promote better productivity of water through utilization of traditional rules as well as economic programs (The World Bank, 2006). In case of the US, the federal government has implemented a number of legislative documents, e.g. laws and programs, to improve water quality throughout the nation, while state and local government of the US also continue different forms of water policies to ensure water rights (Reimer, 2013).

Bangladesh set its standards in 1997. As time passed, WHO did update its guideline, though Bangladesh did not. In addition, all other countries defined their data collection, data processing, and data analysis procedures, whereas procedures, followed by Bangladesh is still not fair enough, despite being clearly defined in the protocol. The government of Bangladesh follows different methods to estimate water quality parameters, but updating and regular monitoring systems should be established with proper management. In this aspect, Bangladesh can follow WHO guidelines through analyzing the reports from 2009 field surveys of Bangladesh national drinking water quality (Minsitry of Planning, 2009). Furthermore, improper implementation of laws, policies, and action can also be a barrier to ensure adequate supply of drinking water in Bangladesh.

CONCLUSION

Drinking water quality standards are of great importance for maintenance of human beings' quality life. Safety of drinking-water is important as a health and development issue at national, regional, and local levels. The present study analyzed different drinking water quality parameters of Bangladesh, US, EU, Japan, and India to see their significant variations, using statistical techniques (ANOVA and pair wise F-test). In case of physical parameters, there were some differences in the standards for color and turbidity among the countries, while the rest were more or less the same. Surprisingly, the studied countries had fixed the same threshold levels for two biological parameters, e.g. fecal and total coliform bacteria. With regard to chemical water quality parameters, there were significant variations among the 36 chemical parameters. In addition, no difference was found in ANOVA test for country standards, as we used the average of total standard values of chemical parameters. In contrast, pair-wise testing of the parameters suggested that Bangladeshi standard varied significantly from parameters of the other four studied regions. Although most of the parameters' maximum concentrations limit was in conformity with Bangladeshi standard, maximum permissible limit of some parameters was higher or very lower than other four regions, e.g. Sulphate, COD, TDS, etc. The water quality standard of Bangladesh was settled in 1997 as a requirement of Environmental Conservation Act (1995). Those standards were set down, following the WHO guidelines of that time, which were appropriate back then; however, WHO upgraded its drinking water quality guidelines afterwards, which were published in 2011. We have to keep pace with the latest WHO guidelines, the most authentic and scientifically established to date. Bangladeshi standards need to be reviewed and modified as required. And as for other parameters, the units of which were not the same all over the world, WHO should fix the uniformity.

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