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Quality of packaged drinking water in Kolkata City, India and risk to public health

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ABSTRACT

In recent years, packaged drinking water (PDW) has become one of the major sources of drinking water and is very popular among consumers. The study was conducted to assess the bacteriological and physicochemical quality of PDW sold in Kolkata city, India, and its effects on public health. The quality of Indian PDW has been compared with that of Kolkata Municipal Corporation (KMC) supply water. Further, the quality of PDW and KMC supply water has been compared with an average quality of bottled water of some branded companies of advanced countries with respect to relevant Indian and international standards (World Health Organization, IBWA, US FDA and EPA). The samples of 27 types of bottled PDW, 10 types of bubble top can PDW of different Indian brands and 18 samples of KMC supply water have been collected from different locations of the city. Physicochemical and bacteriological parameters of collected samples have been tested at School of Water Resources Engineering, Jadavpur University, as per APHA guidelines and also some parameters have been obtained using different field kit instruments. In the study, no bacteria were found in the entire samples of either PDW or KMC supply water. The study also showed that at least 41% PDW had pH value below 6.5 and was acidic, whereas pH of KMC supply water was within the acceptable range (6.5–8.5). Both types of PDW were found to be soft, containing low concentration of minerals, total dissolved solids (TDS), calcium (Ca) and magnesium (Mg). All PDW showed low TDS values having the averages of 38.26 mg/l (bottled), 24.68 mg/l (bubble top can) and the maximum of 117 mg/l. Similarly, all PDW were found with very low "total hardness (TH)" with the maximum value of 76 mg/l, which is much below the standard limit. Likewise, all samples were also found to have low concentration of calcium (Ca), magnesium (Mg), chloride (Cl^-) and negligible concentration of fluoride (F^-) compared to bottled water of branded companies of some advanced countries, as per relevant Indian and international standards. On the other hand, municipal corporation supply water samples showed quite higher values of above-mentioned physicochemical parameters satisfying the said standards. Long-term consumption of low mineralised PDW may lead to potential risk on public health, like irritation to mucous membranes, increase in

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cardiovascular diseases, etc. Under this situation, municipal supply water can be a good alternative for drinking purposes. For this purpose, concerned municipal authorities should carry on regular and proper monitoring of supply water to ensure desired quality and encourage people to use the corporation supply water.

Keywords: Packaged drinking water; Physicochemical parameters; Bacteriological parameters; Kolkata Municipal Corporation; Low-mineralised water; Public health; Cardiovascular diseases

1. Introduction

Water is extremely essential for survival of all living organisms. With rapid urbanisation and increase in population, the water demand for drinking and domestic uses are being increased day by day. Drinking water (DW) needs to be safe from any type of contamination with respect to bacteriological and physicochemical parameters. World Health Organization (WHO) emphasises on protection of public health as per its guidelines. Hence, every effort should be made to achieve the DW as safe as possible without any risk to public health [1]. Kolkata Municipal Corporation (KMC) supply drinking water, and is the main source of drinking water for domestic use. Some people drink the KMC supply water directly and some people drink the same after some domestic purification by stand-alone filter. Yet, nowadays people are very conscious about the quality of drinking water with respect to different waterborne diseases. In this situation, people rely on different packaged drinking water (PDW) for consumption. The statistical study among the people of Kolkata city has not been conducted in this study regarding the tendency of consumption of PDW by the people. However, the use of PDW is increasing rapidly among the higher economic class people who can afford the high price of PDW rather than municipal supply water. PDW is mostly being used in social occasions, tourist spots, hotels, restaurants, etc. and it can be attributed, in part, to the higher standard of living. In India, many entrepreneurs are carrying on the business of PDW by means of production and vending to augment this demand. Most of the PDW available in market are ISI marked, produced based on Indian standard code of practice. As a consequence, the PDW becomes most popular among consumers owing to good marketing strategy, easy availability and, above all, prevalent faith on its quality. In India, PDW are mostly obtained from groundwater containing higher concentration of TDS, iron and hardness. PDW are manufactured and packaged from groundwater after microfiltration, ion exchange, reverse osmosis (RO) filtration, ultra-violet (UV) and ozonisation process. After filtration process, the concentration of different ions present in water will be reduced substantially. The major supply of PDW, which has become very popular among the common people, is company-sealed bottles and bubble top cans.

With the increase in demand among common people, many small entrepreneurs, other than renowned companies, have also launched PDW business. PDW is defined as the water for human consumption and may contain minerals, naturally occurring or intentionally added, may contain carbon dioxide, naturally occurring or intentionally added, but shall not contain sugar, sweetness, flavours or other food stuffs [2].

Many researchers carried out studies to assess the quality of PDW. It was reported that bubble top can PDW at Chennai city, India, was found to be contaminated compared to bottled water [3]. It was found that sachet-packed water sold in Nigeria did not meet microbiological standards for drinking water quality [4]. It was also found that quality of sachet-packaged water in Delhi city, India, was worse than bottled water and sachet water was unfit for consumption, due to presence of coliform bacteria [5].

This study was conducted to assess the quality of PDW available in Kolkata City and its surrounding areas, West Bengal, India. For this purpose, physicochemical and bacteriological parameters in PDW have been compared with Indian [2,6] and international (WHO, IBWA, USFDA and USEPA) standards [1,7]. In this study, 27 types of bottled PDW and 10 type of bubble top can PDW of different brands were analysed. Then, the results of PDW have been compared with that of the KMC supply water used for drinking. Further, a comparison has been done between the quality of Indian PWD and average quality of bottled water of some branded companies of advanced countries like USA, Canada and Norway [8].

In many countries including India, the maximum acceptable concentrations of inorganic and organic substances and micro-organisms have been specified to assure the safety of drinking water. The potential effects of totally demineralised and low-mineralised water have not generally been considered. In all cases, drinking water guidelines and standards have been

set without specifying the lower limits for different ionic concentrations. However, many emerging researches indicated that long-term consumption of low-mineralised water having low TDS, low hardness and also low in certain nutrients that include Ca and Mg could lead to deficiencies of these minerals, especially in case of poor dietary habits [9].

2. Study area

The KMC area and its surrounding areas of West Bengal, India, were identified as study areas. Kolkata City lies on longitude 88˚ 24′ east of Greenwich meridian and latitude 22˚ 32′ north of the Equator and located on the east bank of river Hooghly. In addition to being the largest indigenous city in West Bengal, this is an important trade, educational and cultural centre of eastern India. Many industries are established in and around Kolkata city. The total area covered by the city and its metropolitan region are 185 and 1,886.67 sq km, respectively. According to the census conducted in 2011, the population of the city is about 4.5 million, making it the 7th most populated city in India [10]. The metropolitan region of the city houses a population of more than 14.1 million, making it the third most populated metropolitan region of the country. The density [10] of population of Kolkata is 24,250 per sq km. All the samples of PDW were collected from north metropolitan areas to south and east metropolitan areas to west.

3. Materials and methods

In the study, 27 types of bottled PDW and 10 types of bubble top can PDW of different brands were analysed. Plastic containers used for PDW were food grade quality. Physicochemical and bacteriological parameters of the collected samples were analysed at School of water Resources Engineering, Jadavpur University, as per procedure prescribed by APHA guidelines. Further, 18 samples of KMC supply water, collected randomly from different locations of Kolkata, were analysed and the results have been compared with that of PDW. At first, the samples were tested for bacteriological parameter such as total coliform with H_2S strip method. Thereafter, physicochemical analysis was carried out for eight different water quality parameters as per standard methods [11]. The parameters included pH, turbidity, TDS, total hardness (TH), calcium (Ca), magnesium (Mg), chloride (Cl^-) and fluoride (F^-). The pH and turbidity were measured using digital pH meter and nephelo-turbidity meter, respectively. TDS was measured with digital TDS meter, whereas F^- was determined with ion meter using Ion-Selective Electrode (ISE). TH was determined with EDTA titration method and Cl^- was determined with argentometric method using potassium chromate solution as indicator and Standard Silver Nitrate solution as titrant.

4. Results and discussion

Water quality is a function of bacteriological, different physical (pH, turbidity, etc.) and chemical (TH, Ca, Mg, Cl^-, etc.) parameters present in the water. After determination of all the nine parameters in PWD, the results have been compared with relevant Indian standards [2,6], International standards [1,7] and surface water supplied by KMC. Indian standards and some International standards for bottled water and tap water are given in Table 1. For comparison of quality between Indian PDW and bottled water of branded companies from some advanced countries, 15 bottled water brands from USA, Canada and Norway have been randomly taken to calculate the average water quality [8]. The detailed comparison has been described with the help of Tables 1, 2 and some plotting (Figs. 1–8).

It was found (Table 2) that all samples of PDW and KMC supply water under this study were free from coliform bacteria, which satisfy the requirement as per Indian [2,6] and International standards [1,7].

The pH values of different samples of Indian PDW and KMC supply water are plotted in Fig. 1. In the study, pH values were found to be less than 6.5 in case of 41% of bottled PDW and 90% of bubble top can PDW, which are beyond the acceptable range (6.5–8.5) as per Indian and International standards (Table 1). The pH of the balance portion of PDW and entire KMC supply water samples satisfied the above standards. However, the average pH values of Indian PDW (bottled) and those of the advanced countries have been found to be in the same range with small variation (Table 2).

The turbidity values are shown in Fig. 2. The turbidities of all Indian bottled PDW and bubble top can PDW under the study satisfied the requirement (Table 1) as per Indian and International (IBWA, FDA) standards [2,7]. Average turbidity of Indian PDW was found to be 0.11 NTU (bottled) and 0.20 NTU (bubble top can) which are slightly more than the average turbidity (0.04 NTU) of bottled water of branded companies from advanced countries (Table 2). On the other hand, it was found that the turbidity of KMC supply water samples varied from 0.34 to 1.27 NTU with an

Table 1
WHO, IBWA, US FDA, US EPA and Indian Standards of Drinking Water

S. no.	Test	Water quality standard					
		IS-10500: 2012	IS-14543: 2004	WHO: 2011	IBWA: 2012	FDA: 2015	EPA: 2010
1	Total coliform	Shall not be detectable in any 100 mm sample	Shall be absent in any 250 mm sample	Shall be absent in any 100 mm sample	No validated detectable in a 100 ml sample	MPN: <2.2 organisms per 100 ml sample	Not more than 5% of monthly samples valid
2	pH	6.5–8.5	6.5–8.5	6.5–8.5	6.5–8.5	NA	6.5−8.5
3	Turbidity (NTU)	1	2	1	0.5	5	0.5
4	Total Dissolved Solids (mg/l)	500	500	600	500	500	500
5	Total Hardness as $CaCO_3$ (mg/l)	200	–	300	–	–	–
6	Calcium as Ca (mg/l)	75	75	75	–	–	–
7	Magnesium as Ca (mg/l)	30	30	50	–	–	–
8	Chloride as Cl (mg/l)	250	200	250	250	250	250
9	Fluoride (mg/l)	1	1	1.5	1.4–2.4 (variable based on air temperature	1.4–2.4 (variable based on air temperature	4

average value of 0.64 NTU (Table 2). This satisfies Indian standards (<1 NTU) [6] but does not conform to a relevant International (US EPA) standard (<0.5 NTU).

All PDW samples and KMC supply water samples under the study showed their TDS concentration (Fig. 3) within the acceptable limit (Table 1) satisfying Indian and International standards [1,2,6,7]. But the obtained TDS results of PDW were found to have very low values with a maximum of 117 mg/l. Average TDS of Indian PDW were found to be 38.26 mg/l (bottled) and 24.68 mg/l (bubble top) which are substantially lower than the average TDS (144 mg/l) of bottled water of some branded companies of advanced countries (Table 2). Further, it was found from the study that 78% of bottled PDW and 100% of bubble top can PDW contained TDS below 50 mg/l. Subsequently, KMC supply water showed the results of higher TDS values ranging between 135 and 253 mg/l which satisfy both International and Indian standards [6,7]. The average TDS of KMC supply water was found to be 186 mg/l that can be better compared with that of average TDS (144 mg/l) of bottled water of said branded companies (Table 2), which are more or less in the same range.

All bottled PDW and bubble top can PDW under the study were found to have TH (Fig. 4) much below the stipulated values as per Indian and International (WHO) standards (Table 1) [1,6]. The maximum value of TH was found to be 76 mg/l. In this case, 78% bottled PDW and 70% bubble top can PDW showed its TH below 25 mg/l. The average TH of PDW obtained was-17.58 mg/l (bottled) and 21.2 mg/l (bubble top can). For KMC supply water, all TH results were found to have higher concentration with an average of 162 mg/l, which is within the standard values [1,6].

Similarly, all PDW samples of both kinds showed low concentration of calcium (Ca) ranging from "not detected (ND)" to 13.41 mg/l (Fig. 5), which is much below standard concentration as per Indian standards [2,6] and International (WHO) standards [1]. In this case, 85% bottled PDW and 60% bubble top can PDW showed Ca concentration below 5 mg/l. Average Ca concentration of Indian PDW was calculated to 3.09 mg/l (bottled) and 4.61 mg/l (bubble top can), which is also significantly lower than the average Ca

Table 2
Comparison of Indian PDW with bottled water of branded companies from advanced country

S. no.	Test	Average water quality of Indian drinking water (PDW and municipal corporation (KMC) supply water)						Average quality of bottled water of branded companies from advanced country	
		Indian PWD: Bottled		Indian PWD: Bubble top can		KMC supply water			
		Range	Average	Range	Average	Range	Average	Range	Average
1	Total coliform	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent
2	pH	5.68–7.54	6.57	5.13–6.64	5.76	7.3–7.82	7.6	5.5–7.7	6.6
3	Turbidity (NTU)	0.06–0.19	0.11	0.06–0.31	0.20	0.34–1.27	0.64	ND-0.09	0.04
4	Total Dissolved Solids (mg/l)	4.9–117.3	38.26	6.4–49.9	24.68	135.7–253	186	3–384	144
5	Total Hardness as $CaCo_3$ (mg/l)	ND-76	17.58	8–32	21.2	132−196	162	–	–
6	Calcium as Ca (mg/l)	ND-13.41	3.09	1.32–7.79	4.61	25.86–49.67	36	5–104	36
7	Magnesium as Ca (mg/l)	ND-10.19	1.03	1.06–3.19	2.22	10.88–25.25	19	1–22	9.8
8	Chloride as Cl (mg/l)	3–36	10.56	ND-36	15.22	13–101	41	ND-0.09	9.15
9	Fluoride (mg/l)	ND-0.021	0.001	ND-0.012	0.0	0.098–0.254	0.16	ND-0.17	0.17

Note: ND = Not detected.

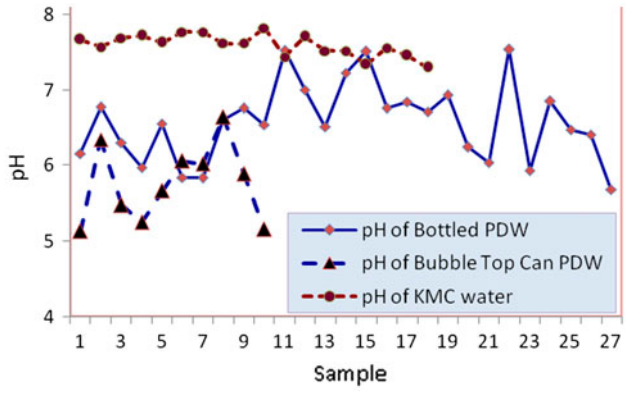

Fig. 1. pH values of PDW and municipal corporation supply water.

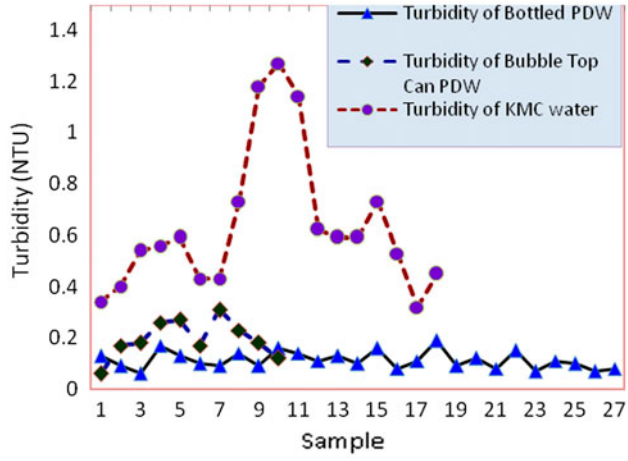

Fig. 2. Turbidity of PDW and municipal corporation supply water.

(36 mg/l) of bottled water of branded companies of advanced countries (Table 2). In case of KMC supply water, all results of Ca concentration were found to be of higher values but within the standard value (75 mg/l) (Table 2) having an average value of 36 mg/l, which can be better compared with that of the aforesaid bottled water of branded companies (36 mg/l) of advanced countries (Table 2).

The same tendency followed for magnesium (Mg) concentrations. In this case, all PDW samples of both kinds, showed low concentration of Mg, ranging from ND to 10.19 mg/l (Fig. 6), which was much below the standard concentration (Table 1) as per Indian standards [2,6] and International (WHO) standards [1]. Here, 93% bottled PDW and 100% bubble top can PDW showed its Mg concentration below 5 mg/l. Also, the average Mg concentration of Indian PDW was 1.03 mg/l (bottled) and 2.22 mg/l (bubble top can), which is substantially lower than that of bottled water of branded companies (9.8 mg/l) of advanced countries (Table 2). For KMC supply water, all results of Mg concentration were found to be of higher values (10.88–25.25 mg/l) with an average of 19 mg/l, which satisfy the standard requirement (Table 1).

All samples of both kind of PDW were found with very low chloride (Cl^-) concentration having a

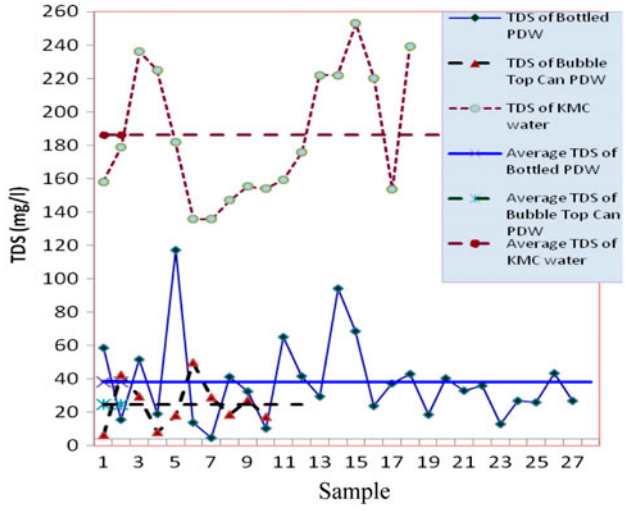

Fig. 3. TDS of PDW and municipal corporation supply water.

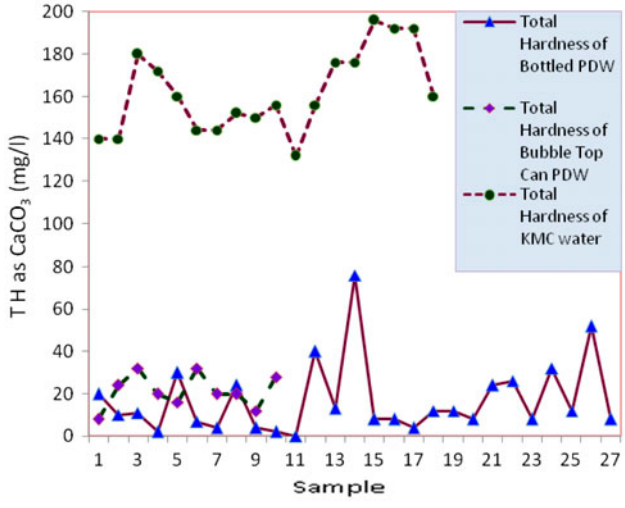

Fig. 4. TH of PDW and municipal corporation supply water.

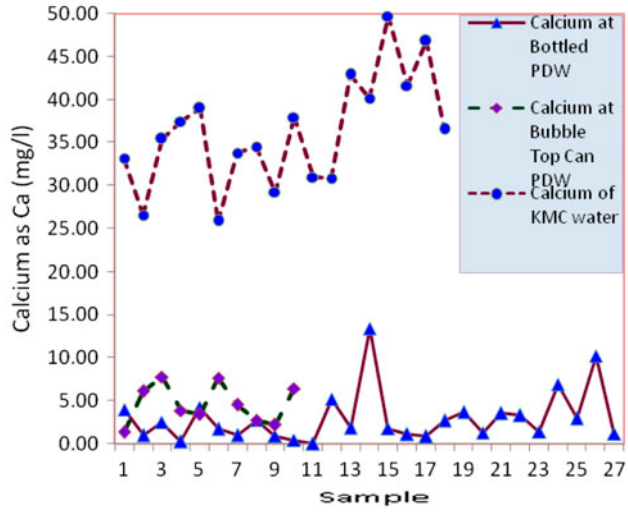

Fig. 5. Calcium concentration of PDW and municipal corporation supply water.

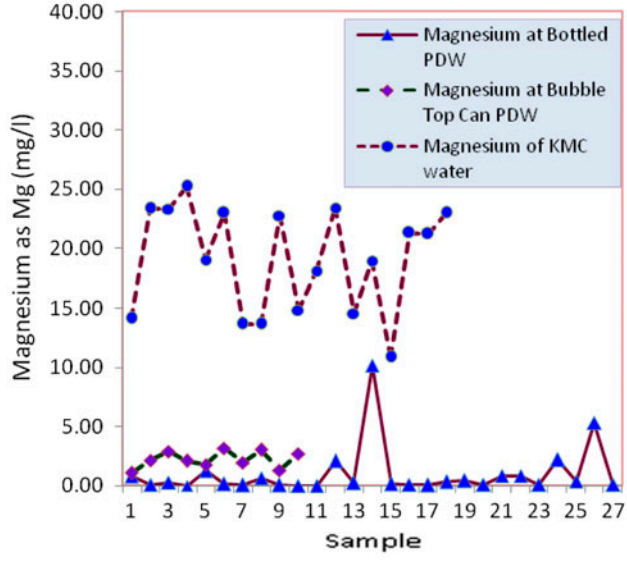

Fig. 6. Magnesium concentration of PDW and municipal corporation supply water.

maximum value of 36 mg/l (Fig. 7) and average values of 10.56 mg/l (bottled) and 15.22 mg/l (bubble top can), which is significantly below the stipulated values (250 mg/l) as per Indian and International standards [1,2,6,7] as stated in Table 1. In this case, about 89% bottled PDW and 80% bubble top can PDW showed its Cl^- concentration below 20 mg/l. However, the ionic concentration of Cl^- at PDW is nicely compared with the average Cl^- concentration (9.15 mg/l) of bottled water of branded companies of advanced countries (Table 2), which are nearly in the same range. Compared to these results, the Cl^- concentration of KMC supply water was found to be quite high, varying from 13 to 101 mg/l with an average of 41 mg/l.

Subsequently, fluoride (F^-) concentration of all study samples of bottled as well as bubble top can PDW was found to be very low and almost negligible (Fig. 8), which is much below the stipulated values specified in Indian and International standards [1,2,6,7] as referred in Table 1. About 85% bottled PDW and 90% bubble top can PDW showed its F^- ion concentration as "not detected". Compared to these results, the average F^- concentrations of bottled water

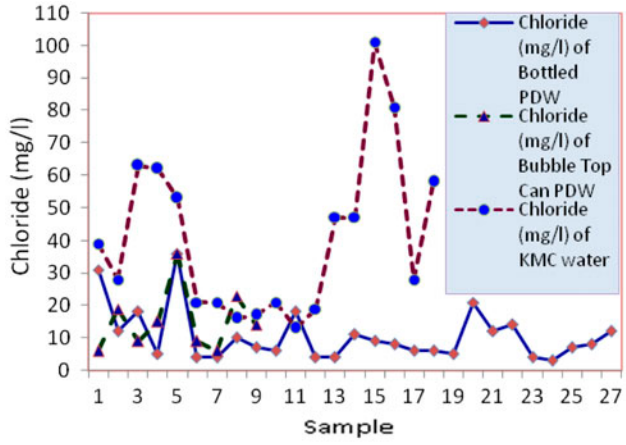

Fig. 7. Chloride concentration of PDW and municipal corporation supply water.

of branded companies of advanced countries have been found to be quite high (0.17 mg/l) as shown in Table 2. On the other hand, the F^- concentrations of KMC supply water having average value of 0.16 mg/l, may be compared well with that of branded companies from advanced countries (Fig. 2).

From the above results, it is found that all brands of Indian PDW of both kinds were free from coliform bacteria and hence, safe for drinking. KMC supply water was also observed to be safe as no bacteria were found in its samples. While considering pH values, it was observed that maximum proportions of PDW was of low pH and was acidic in nature. The pH results of PDW, more or less, matched with that of bottled water of branded companies of some advanced countries; for long-term exposure of the low pH water may result in irritation to mucous membranes, eyes and skin [12]. Further, it is found from the result that pH of all samples of KMC supply water satisfied the acceptable range as per Indian and International standards. However, the study revealed that both the PDW appeared to be crystal clear with respect to turbidity parameter, which almost match that of bottled water of branded companies of some advanced countries. At the same time, KMC supply water quality may be categorised as good quality considering turbidity results, as it is within the standard value.

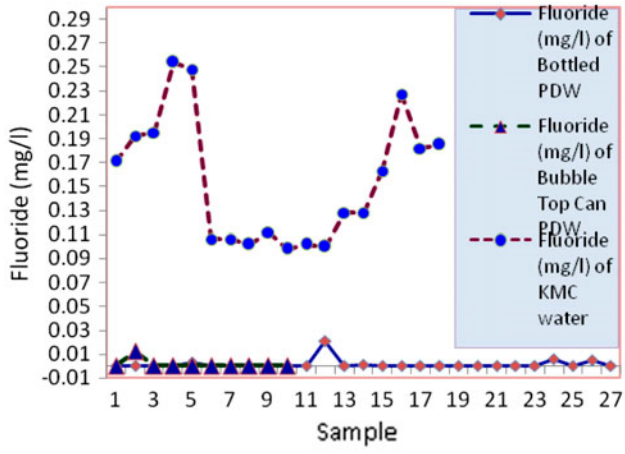

Fig. 8. Fluoride concentration of PDW and municipal corporation supply water.

Further, the above results revealed that all brands of PDW of both kinds contained substantially lower concentration of total dissolved solids (TDS), TH and other minerals like Cl^- and F^- compared to the TDS values of bottled water of some advanced countries as per Indian and International standards. In addition to low TDS and low TH, the Indian PDW under this study also had deficiencies in calcium and magnesium. On the other side, the municipal corporation (KMC) supply water showed higher concentration of the same chemical parameters (TDS, TH, Ca, Mg, etc.), which satisfy the Indian and International standards and also nicely matched with the bottled water of some branded companies of advanced countries.

Thus, considering bacteriological and physico-chemical quality parameters, all Indian PDW samples under the study appeared to be of good quality and met the relevant drinking water specifications of Indian and International standards [1,2,6,7]. In this context, it was stated that Mg and Ca deficiency along with other mineral deficiencies have the potential of causing higher incidence rates of goitre, hypertension, ischaemic heart disease, chronic gastritis, cholecystitis, etc. [9]. Substantial lack of essential minerals in drinking water did not permit the characteristics of safe drinking water for regular and long-term consumption for human beings, which might lead to health risks as referred by Kozisek [13,14]. A number of studies [13–15] concluded that higher Mg content in water is related to decreased risks for cardiovascular disease (CVD), and especially from sudden death by CVD. This relationship was independently described in epidemiological studies with different study designs, performed in different areas, different populations, and at different times. Besides intake of water, low magnesium content might be associated with a higher risk of motor neuronal disease, pregnancy disorders, sudden death in infants and some types of cancer [13].

Calderon and Craun [15] concluded that lower cardiovascular death rates were found in populations where the water supply contained relatively high levels of water hardness or calcium and magnesium, compared to populations in areas with low levels.

It was also referred that the population who lived in soft water areas might have, at best, a 25% percent excess CVD mortality risk than populations in hard water areas. Mg deficiency was reported to cause an increase in inflammatory cytokines, endothelial damage and atherosclerosis, the thickening and hardening of arterial walls [16], and as such PDW and beverages could be fortified to provide required supplemental minerals. Monarca et al. [17] found a correlation of a high mortality for CVD and stroke in populations with low Mg concentration in DW, and vice versa.

In fact, addition of minerals in drinking water is necessary, considering the benefit of public health. According to the Indian code for packaged natural mineral water specifications [18], the TDS requirement is also specified as 150–700 mg/l, which are almost maintained in bottled water by branded companies of advanced countries. Recent studies [13] revealed additional information about minimum and optimum levels of minerals that should be contained in demineralised water. It was suggested that the minimum magnesium content of DW should be 10 mg/L and the minimum calcium content should be 20 mg/L rather than 30 mg/L as recommended in the 1980 WHO report. Meanwhile, four Central European countries such as Czech Republic, Hungary, Poland and Slovakia have specified the minimum and optimum required concentration of some minerals in demineralised water in their respective regulations [13]. Concerned authorities at the national and International levels should consider guidelines for desalination water treatment, specifying the minimum content of the elements such as calcium, magnesium, TDS, etc. and encourage for additional and targeted research in this field to establish guidelines in view of elaborate health benefits.

5. Conclusions

This study has given an inner view of overall quality status of Indian PDW available in and around Kolkata city and the quality of municipal supply water for drinking. The quality of said PDW and KMC supply water was compared in this study. Also, the quality of PDW has been compared with that of bottled water of some branded companies of a few advanced countries with respect to relevant Indian and International standards. The study revealed that maximum proportion of PDW was acidic in nature. Further, it was found that all PDW under the study contained very low concentration of TDS, TH, Ca, Mg and other minerals. It has been stated in the previous sections that regular consumption of very low-mineralised water may not be considered safe as it has a potential health risk for human beings. On the other hand, the quality of KMC supply water has been found to be good and contained all minerals with sufficient concentrations as per requirements specified in relevant Indian and International standards.

Under this situation of low-mineralised PDW, municipal supply water can be a good alternative for drinking. For this purpose, municipal authority should carry on regular and proper monitoring of supply water to ensure desired quality. In India, the PDW is presently consumed by higher economic class people at limited places like social gatherings, occasions, office programmes, restaurants and hotels. In such circumstances, concerned authorities should encourage people to use corporation supply water. At the same time, regulatory authorities should consider guidelines specifying the minimum content of essential minerals.

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