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ORIGINAL ARTICLE

Estimation of Physico-Chemical, Trace Metals, Microbiological and Phthalate in PET Bottled Water

Laxmi Kant Bhardwaj[1] · **Archana Sharma**[2]

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Abstract
Polyethylene terephthalate (PET) is a usually used material in the industry of bottled water. Now days the consumption of bottled water has been steadily growing in the world from the last 30 years. A total of 24 PET bottled water, 4 of each brand with 2 different batch numbers were collected randomly from the local market of Noida city, India. Numerous water quality parameters such as physico-chemical, phthalate, trace metals, and total coliform were analyzed in these samples. These parameters may affect the safety of PET bottled water. The purpose of this study was to estimate the quality of PET bottled water of different brands available in Noida. The samples were analyzed as per the Indian Standard (IS)-14543 (2016). The results were compared with the standard of drinking water set by WHO, IS, USEPA and met the standard value of these agencies. pH was found in the range of 6.72–6.97 while turbidity and TSS were found < 1.0. Total hardness was found in the range of 5.0–131.0 mg/l and total alkalinity was found in the range of 3.33–115.0 mg/l. Sodium was present from 2.10–39.10 mg/l while potassium was present from 0.20–7.20 mg/l. The presence of fluoride was in the range of 0.18–0.67 mg/l. Heavy metals such as Pb, Hg, Cd and As were found in the range of 0.18–4.52 µg/l. Bis(2-ethylhexyl) phthalate was found below the detection limit while no growth was observed for total coliform in these samples. All six brands of PET bottled water were found to be safe and healthy for drinking.

Keywords Bottled water · Polyethylene terephthalate (PET) · Quality of water · Phthalate · Heavy metals · Coliform

1 Introduction

Water is essential for the life of animals as well as plants also and it is one of the most important natural resources [1]. The water consumed by human beings comes in various forms and from various sources. The quality of water and suitability for use is determined by its taste, odour, colour, the concentration of organic and inorganic matters [2]. Drinking water plays a significant role in maintaining human health and is recognized as a fundamental right of human beings. Pacheco-Vega [3] stated that the drinking water is packed generally in plastic bottles and regulated by local and national agencies. In recent years, the popularity of bottled water can be gauged by the number of brands (over 5000) produced worldwide [4].

According to Osei et al. [5], the bottled water industry is the fastest-growing beverage industry in the world over the last few years. Bottled water is a healthier alternative than municipal water or tap water and other beverages [6]. The bottled water acts as the dietary (mineral) supplement has become very popular for quenching thirst [7]. People are purchasing bottled water due to many reasons including convenience, fashion, and taste [8]. As per the study of Beverage Marketing Corporation [9], the usage of PET bottled water was increasing worldwide from 130,956 million liters in 2002 to 188,777 million liters in 2007. In spite of the high price, bottled water consumption has been increasing an average of 12% by people of all age groups each year [7, 10]. The maximum production and consumption of PET bottled water are in Italy [11].

The quality of PET bottled water may be affected by the treatment, source, storage conditions, and container type. Man-made pollution can also affect the sources, quality of water, and human health. The bottled water is defined as

✉ Laxmi Kant Bhardwaj
bhardwaj.laxmikant@gmail.com

1 Amity Institute of Environmental Sciences (AIES), Amity University, Block-J1, Sector 125, Noida, Uttar Pradesh 201303, India

2 M.K.U. (K.I), New Delhi, India

water that is intended for human consumption and sealed in bottles or other containers which could be PET [12]. PET is widely used as a container for commercially bottled water in many countries [13]. The usage of PET is also increasing rapidly in many developing countries due to its lower production costs in comparison with glass containers [14]. PET is an innocuous substance and is recyclable, but not biodegradable [15]. Due to its chemical and physical stability, PET is the most favorable packaging material for drinking water [16].

However, PET bottled water has been shown to contain some contaminants. These contaminants are categorized as inorganic, organics, radionuclides, disinfectants, and microorganisms [17]. Azrina et al. [18] observed that contamination in bottled water is mainly due to inorganic chemicals than organic chemicals. These inorganic chemicals are in the mineral form of trace metals which have the tendency to accumulate in human organs and are interfering with the normal functions of organs. The potential sources of contamination in bottled water are geological conditions, water treatment plants, industrial and agricultural activities.

Bacteria affect the quality of bottled water more than the chemical composition [19]. Several researchers have reported coliform bacteria in bottled water [20, 21]. Coliforms are a group of bacteria species. They are a gram-negative, lactose-fermenting, and non-spore-forming bacteria and could be a good indicator of water quality in terms of microbial contamination. They are non-pathogenic bacteria, but its presence indicates the possibility of finding other pathogens. *Escherichia coli* (*E. coli*) is the dominant faecal coliform bacteria and found in faeces. The presence of *E. coli* in water indicates faecal contamination. *E. coli* may be pathogenic itself; if it is found in water, there may be a good chance for the presence of other pathogens also.

Drinking water is an important source for the daily intake of many trace elements which are present in the living organisms at very low levels. Some of these elements play a key role in many different biochemical reactions that occur in the human body. Iron (Fe) and fluorine (F) are the most widely known element for the protection against anemia and dental problems, respectively. Several elements like antimony (Sb), copper (Cu), lead (Pb), nickel (Ni), etc., and chemicals such as bisphenol A, dioxins, phthalate leach into the water through the PET bottle at a specific temperature.

These trace metals and chemicals are carcinogens therefore they may have a serious consequence to the health of humans. In recent years due to causing health problems, some heavy metals like nickel (Ni), arsenic (As), lead (Pb), zinc (Zn), magnesium (Mg), and copper (Cu) have received significant attention [22]. Pb is related to delay in the mental and physical growth of infants, while mercury (Hg) and arsenic (As) can cause skin cancer [22, 23]. DeZuane [24] studied cardiovascular, kidney, and neurocognitive diseases which are related to these trace metals. Metals such as arsenic, cadmium, lead, mercury are non-essential and are toxic to the human and water ecosystem [25, 26]. Dobaradaran et al. [27] stated that heavy metals persist in the environment for several years through the bioaccumulation-biomagnification process.

Phthalates are the esters of ortho-phthalic acid. They are a colourless, odourless liquid and do not evaporate easily. They are ubiquitous and toxic in nature [28]. They are manufactured chemicals and used to make plastics more flexible, transparent, durable, and soft [29, 30]. They are not chemically bound to polymers; hence they easily migrate into food, beverages, and drinking water from bottling materials or packaging or manufacturing processes [31–35]. Ingestion and dermal absorption are the major routes of exposure to phthalate via drinking water [29]. Many scientists studied the toxic effect of phthalates such as a decrease in fertility in females [36], fetal defect [37], reduced survival of offspring [38], and male reproductive abnormalities [39].

The aim of the present study was to evaluate the quality of PET bottled water of different brands available in Noida city, India. The parameters such as pH, turbidity, total suspended solids (TSS), total hardness, total alkalinity, sodium, potassium, phosphate, fluoride, phthalate, trace metals such as Pb, Hg, Cd, As, and total coliform were analyzed in each PET bottled water sample.

2 Materials and Methods

2.1 Sampling

We purchased a total of 24 PET bottled water of different 6 brands (Bisleri, Aquafina, Divyajal, Kinley, Railneer, and Catch) from the local market of Noida, India. We purchased four water bottles of each brand with two bottles having the same batch number and the other two bottles having the other same batch number. We selected these six brands because these brands are much popular with people and easily available in the local market. The sample's name, batch no., and year of packaging are shown in Table 1. All water bottles were stored in a dark place at room temperature (25 °C) until the analysis.

2.2 Equipment and Reagents

pH meter (LMPH-10, Labman), turbidity meter (2100P, HACH), rotary vacuum evaporator (R-300, BUCHI), weighing balance of 0.01–220 gm (MAB220, Wensar), UV–Vis spectrophotometer (Cary 60, Agilent), flame photometer (VSI-603/604, VSI Electronics Pvt. Ltd), GC–MS/MS (Gas chromatography-mass spectrometry) (7000C, Agilent), ICPMS (Inductively coupled plasma mass spectrometry)

Table 1 Identification of samples with batch no. and year of packaging

S. no.	Sample name	Batch no.	Packaging year
1	Bisleri	297	2018
		341	
2	Aquafina	7476D12J18	
		7476D18J18	
3	Divyajal	UP0330133	
		UP0330134	
4	Kinley	H30E8E11	
		H30E8E12	
5	Railneer	2310	
		2311	
6	Catch	100W008	
		100W154	

(ELAN 5000, Perkin–Elmer SCIEX), hot plate, and oven were used.

Bis (2-ethylhexyl) phthalate (CAS No. 117-81-7) was purchased from Sigma-Aldrich. Methylene chloride, ammonium hydroxide, ammonium molybdate, magnesium sulphate, potassium dihydrogen phosphate, stannous chloride, hydrochloric acid, potassium chloride, anhydrous sodium sulfate, and silica gel (100/200 mesh size) were purchased from Fisher Scientific. Hexane, sulfuric acid, and indicators like phenolphthalein, methyl red, erichrome black (EBT) were purchased from Merck. Bromocresol was purchased from CDH. EDTA (ethylenediaminetetraacetic acid) was purchased from Loba Chemie. Before use, anhydrous sodium sulfate was baked at 400 °C for 4 h and silica gel was activated at 130 °C for at least 16 h [40]. Double distilled water was used for standard and sample preparation.

2.3 Chemical/Instrumental Analysis

PET bottled water samples were analyzed by the method IS:14543 [41] with slight modification. Parameters such as total hardness and total alkalinity were analyzed by the titrimetric method while pH, turbidity, phosphate, sodium, potassium, phthalate, and trace metals were analyzed by their respective instrument. Total suspended solid (TSS) was analyzed by the filtration method.

2.3.1 pH

The pH was measured in samples by using a pH meter. Before analysis, the instrument was calibrated with the standard solutions of pH 4, 7 and 9.2. The probe of the instrument was immersed in the sample and hold for some time to achieve a stabilized reading. The probe was cleaned with distilled water after each sample to avoid contamination between samples.

2.3.2 Turbidity (NTU)

Turbidity was measured in samples by using a turbidity meter. Before analysis, the instrument was calibrated with a standard solution of hydrazine-sulfate and hexamethylenetetramine. Each water sample was transferred to the sample vessel and kept inside the instrument for a few minutes to achieve a stable reading. After each sample, the sample holder was rinsed with distilled water to avoid cross-contamination between samples.

2.3.3 TSS (Total Suspended Solids) (mg/l)

TSS was analyzed in samples by the filtration method. First, the empty Whatman No. 41 filter paper was weighed (W1). 100 ml of each sample was filtered through the filter paper into a 250 ml conical flask. The filter paper was dried in a hot air oven at 105 °C for 2 h, then the filter paper was weighed (W2). TSS was calculated by the formula given below:

$$\text{TSS (mg/l)} = \frac{W_2 - W_1}{\text{Volume of the sample taken (ml)}}.$$

2.3.4 Total Hardness (mg/l)

Total hardness was analyzed in samples by the titrimetric method. 20 ml of each sample was taken into a 250 ml conical flask. Then 1–2 ml of ammonia buffer solution was added to produce a pH of 9–10. The flask was stirred and a pinch of EBT indicator was added then the sample was titrated with 0.01 M EDTA solution till the colour changes from red to blue colour. The consumed volume of EDTA solution was noted. A blank solution was prepared and analyzed in the same manner. Total hardness was calculated by the formula given below:

$$\text{Total Hardness } \left(\text{as } CaCO_3\right) \text{ (mg/l)} = \frac{\text{Volume of EDTA consumed (ml)} \times \text{Normality} \times 50 \times 1000}{\text{Volume of the sample taken (ml)}}.$$

2.3.5 Total Alkalinity (mg/l)

Total alkalinity was analyzed in samples by the titrimetric method. 100 ml of each sample was taken into a 250 ml conical flask. Then 2–3 drops of the mixed indicator were added to produce a blue colour. The sample was titrated with standard sulphuric acid (0.02 N) till the colour changes from blue to light pink colour. The

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consumed volume of standard sulphuric acid was noted. A blank solution was prepared and analyzed in the same manner. Total alkalinity was calculated by the formula given below:

$$\text{Total alkalinity}\left(\text{as } CaCO_3\right)(\text{mg/l}) = \frac{\text{Volume of sulphuric acid consumed (ml)} \times N \times 50{,}000}{\text{Volume of the sample taken (ml)}}.$$

2.3.6 Sodium and Potassium (mg/l)

Sodium and potassium were analyzed in samples by Flame Photometer. Before analysis, the instrument was calibrated with a mix. standard solutions (5.0, 10.0, 20.0 and 100.0 mg/l) of sodium and potassium chloride. Then the calibration curve was drawn. Each sample was aspirated through the nozzle and burned in the flame, then the instrument gave the reading against the calibration curve. A blank solution was analyzed in the same manner. Sodium and potassium were calculated by the formula given below:

$$\text{Sodium and potassium (mg/l)} = \text{Reading of the instrument (mg/l)} \times \text{dilution factor}.$$

2.3.7 Phosphate (mg/l)

Phosphate was analyzed in samples by UV–Vis spectrophotometer. Before analysis, the instrument was calibrated with a standard solution (2.5, 5.0, 10.0 and 50.0 mg/l) of potassium dihydrogen phosphate (KH_2PO_4). Then the calibration curve was drawn. 25 ml of each sample was taken into a 250 ml conical flask. 1 ml of ammonium molybdate solution was added and then the flask was swirl to mix the solution. 2–3 drops of stannous chloride solution were added and again the flask was swirl to mix the solution. The flask was kept for 5–10 min to develop a blue colour. The absorbance was taken at 650 nm and the instrument gave the reading against the calibration curve. A blank and standard solutions were prepared and analyzed in the same manner. Phosphate was calculated by the formula given below:

$$\text{Phosphate (as P) (mg/l)} = \text{Reading of the instrument (mg/l)} \times \text{dilution factor}.$$

2.3.8 Fluoride (mg/l)

Fluoride was analyzed in samples by UV–Vis spectrophotometer. Before analysis, the instrument was calibrated with a standard solution (0.1, 0.5, 1.0 and 1.5 mg/l) of sodium fluoride. Then the calibration curve was drawn. 50 ml of each water sample was taken into a Nesseler's tube. 10 ml of a mixed acid Zirconyl-SPADNS reagent was added into the tube. Then the tube was swirl to mix the solution and kept for 5–10 min to develop a blue colour. The absorbance was taken at 570 nm and the instrument gave the reading against the calibration curve. A blank and standard solutions were prepared and analyzed in the same manner. Fluoride was calculated by the formula given below:

$$\text{Fluoride (mg/l)} = \frac{\text{Absorbance of the blank} - \text{absorbance of the sample}}{\text{Absorbance of the blank} - \text{absorbance of the standard}}.$$

2.3.9 Phthalate (µg/l)

Bis(2-ethylhexyl) phthalate was analyzed in samples by GC–MS/MS. Before analysis, the instrument was calibrated with standard solutions (2.5, 5.0, 10.0 and 25 µg/l) of Bis(2-ethylhexyl) phthalate. Then the calibration curve was drawn. 500 ml of each sample was extracted by the method USEPA-3510B [42] with slight modification. After extraction, the cleanup was done by the method USEPA-3630C [43]. The final residue solution of each sample (1 µl) was introduced into the GC–MS/MS system. The details of the instrument parameters are given in Table S_1. Then the instrument gave the reading against the calibration curve. A blank solution was extracted and analyzed in the same manner. It was calculated by the formula given below:

$$\text{Bis(2-ethylhexyl) Phthalate } (\mu g/l) = \text{Reading of the instrument } (\mu g/l) \times \text{dilution factor}.$$

2.3.10 Trace Metals (µg/l)

Trace metals Pb, Hg, Cd and As were analyzed in samples by ICPMS. Before analysis, the instrument was calibrated with a mix. standard solution (1.0, 5.0, 10.0 and 50.0 µg/l) of these metals. Then the calibration curve was drawn. 100 ml of each sample was taken into a 250 ml beaker. 2 ml nitric acid was added into the same beaker. Then the sample was kept on the hot plate and digested at 70 °C. When the volume of the sample was left up to 5–10 ml. Then the sample was transferred into a 100 ml volumetric flask and make up the volume with distilled water. A blank solution was prepared in the same manner. Each sample solution was aspirated through the nozzle and burned into the plasma, then the instrument gave the reading against the calibration curve. The details of the instrument parameters are given in Table S_2. Metals were calculated by the formula given below:

$$\text{Trace Metals } (\mu g/l) = \text{Reading of the instrument } (\mu g/l) \times \text{dilution factor.}$$

2.4 Microbiological Analysis

For total coliform, the samples were analyzed by the method IS:1622 [44]. This method included the three phases presumptive, confirmative, and completed. On the basis of the number of positive tubes in the confirmed test, the probable no. of coliform/100 ml of sample was calculated by using the MPN table. The result was recorded as the number of MPN coliform/100 ml.

2.5 Quantitative Analysis

Each sample was analyzed in three replicates and the mean value was taken. For every set of samples; one blank and one standard for quality control were processed. The sample recovery for the target compounds was found in the range of 40–100%, which achieved the recovery limit of the method USEPA-1699 [45]. *E. coli* was used as a positive control in microbiological evaluation. The limit of detection (LOD) and limit of quantification (LOQ) were defined as the level of analyte giving a signal (S) to noise (N) ratio equivalent to 3 and 10, respectively. LOD and LOQ values of the measured variables are given in Table S_3.

3 Result and Discussion

The analytical results for pH, turbidity, TSS, total hardness, total alkalinity, sodium, potassium, phosphate, fluoride, phthalate, trace metals, and total coliform are presented in Table 2. These results have found under the limits which are set by WHO [22], IS:14543 [41], and USEPA [46]. The differences in the mineral content directly affect the odour and taste of PET bottled water. Saad et al. [47] have stated that in spite of having some impurities the PET bottled water has a higher social impact on the consumer than tap water. In these samples, the colour was found < 1.0 Hazen, while odour and taste were agreeable. The graphical representation of the different parameters is shown in Figs. 1, 2, 3, 4, 5, 6 and 7.

pH is one of the most important and basic parameter of water quality. The acidity or alkalinity of the water depends on its pH. If the pH is below 7.0 then the water is considered to be acidic, while higher than 7.0 then the water is considered to be alkaline. The corrosion of metal pipes is due to acidic water while due to alkalinity water shows disinfection. According to WHO [22], IS:14543 [41], and USEPA [46] the pH of the drinking water is mentioned between 6.5–9.5. It was found in the range of 6.72–6.97 in all PET bottled water samples.

Turbidity is a principal physical characteristic of water. It is due to the cloudiness and diversity of suspended particles such as clay, slit, finely divided inorganic and organic matter. It is related to the disease-causing organism which may arise in the water from soil runoff. According to WHO [22], the maximum recommended limit for turbidity in drinking water is 1.5 nephelometric turbidity units (NTU) while as per the IS:14543 [41] and USEPA [46] the limit is 2 NTU and 5 NTU. The results indicated that the turbidity in all PET bottled water samples was < 1.0 NTU.

TSS is the dry weight of suspended particles which do not dissolve in water and can be trapped by a filter. It is used to assess the quality of any type of water or water body. TSS was found < 1.0 in all PET bottled water samples.

Total hardness is defined as the concentration of calcium and magnesium ions in water and expressed as an equivalent amount of calcium carbonate. Hardness refers to the tendency of water to precipitate an insoluble residue when soap is used. Hard water reduces the ability of soap and detergents to clean clothes. Calcium and magnesium ions are largely responsible for the behavior of hard water. According to WHO [22], the maximum recommended limit for hardness is 500 mg/l in drinking water. Its value was found to be in the range of 5.0–131.0 mg/l in all PET bottled water samples. The maximum hardness was found in Catch, followed by Divyajal, Kinley, Railneer, Bisleri, and Aquafina.

Total alkalinity is the amount of base required to change in pH that would make the water more acidic. It is the strength of a buffer solution which forms the weak acids and their conjugate bases. According to IS:14543 [41], the maximum recommended limit for total alkalinity in drinking water is 200 mg/l. Its value was found to be in the range from 3.33 to 115.0 mg/l in all PET bottled water samples. The maximum alkalinity was found in Catch, followed by Divyajal, Bisleri, Railneer, Kinley and Aquafina.

Sodium is an essential mineral for human beings. It is found in the form of sodium chloride. Sodium salts are generally highly soluble in water and are leached from the terrestrial environment to groundwater. Sodium salts are used in water treatment, including softening, disinfection, corrosion control, pH adjustment, and coagulation. According to WHO [22], the maximum recommended limit for sodium in drinking water is 40 mg/l while as per IS:14543 [41] and USEPA [46] the limit is 200 and 20 mg/l. Its value was found to be in the range from 2.10 to 39.10 mg/l in all PET bottled water samples. The maximum sodium was found in Railneer, followed by Bisleri, Divyajal, Aquafina, Catch and Kinley.

Table 2 Physico-chemical, phthalate, trace metals and microbiological analysis in the PET bottled water of different brands

S. no.	Parameters	Limit			Brands name			
					Bisleri		Aquafina	
		USEPA (2012)	WHO (2017)	IS:14543 (2016)	297	341	7476D12J18	7476D18J18
1	Colour (Hazen)	5	5	2	< 1.0	< 1.0	< 1.0	< 1.0
2	Odour			Agree*	Agree*	Agree*	Agree*	Agree*
3	Taste			Agree*	Agree*	Agree*	Agree*	Agree*
4	pH	6.5–8.5	6.5–9.5	6.5–8.5	6.76	6.72	6.95	6.97
5	Turbidity (NTU)	5	1.5	2	< 1.0	< 1.0	< 1.0	< 1.0
6	Total suspended solids (TSS) (mg/l)				Absent	Absent	Absent	Absent
7	Total hardness as $CaCO_3$ (mg/l)		500		10.00	12.50	5.00	5.80
8	Total alkalinity (mg/l)			200	22.10	20.00	3.33	3.45
9	Sodium as Na (mg/l)	20	40	200	23.60	20.00	8.80	9.20
10	Potassium as K (mg/l)				1.80	1.50	0.20	0.25
11	Phosphate (mg/l)				< BDL	< BDL	< BDL	< BDL
12	Fluoride (mg/l)	4	1.5	1	0.57	0.52	0.18	0.21
13	Bis(2-ethylhexyl) phthalate (μg/l)				< BDL	< BDL	< BDL	< BDL
14	Pb (μg/l)		10	10	0.32	0.47	0.86	0.97
15	Hg (μg/l)	2		1	0.36	0.49	0.31	0.48
16	Cd (μg/l)	5	3	10	3.62	2.65	1.02	1.63
17	As (μg/l)	10	10	50	2.32	1.46	2.31	1.42
18	Total coliform/100 ml	Absent	Absent	Absent	Absent	Absent	Absent	Absent

S. no.	Parameters	Brands name							
		Divyajal		Kinley		Railneer		Catch	
		UP0330133	UP0330134	H30E8E11	H30E8E12	2310	2311	100W008	100W154
1	Colour (Hazen)	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
2	Odour	Agree*	Agree*	Agree*	Agree*	Agree*	Agree*	Agree*	Agree*
3	Taste	Agree*	Agree*	Agree*	Agree*	Agree*	Agree*	Agree*	Agree*
4	pH	6.92	6.95	6.93	6.91	6.89	6.85	6.85	6.87
5	Turbidity (NTU)	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
6	Total suspended solids (TSS) (mg/l)	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent
7	Total Hardness as $CaCO_3$ (mg/l)	45.00	46.80	20.00	18.60	16.30	15.00	128.50	131.00
8	Total alkalinity (mg/l)	52.67	46.27	10.00	9.50	16.67	14.43	115.00	112.00
9	Sodium as Na (mg/l)	11.30	10.50	2.10	2.40	36.00	39.10	7.60	7.10
10	Potassium as K (mg/l)	0.70	0.80	0.22	0.20	0.24	0.20	6.90	7.20
11	Phosphate (mg/l)	< BDL	< BDL	< BDL	< BDL	< BDL	< BDL	< BDL	< BDL
12	Fluoride (mg/l)	0.67	0.63	0.26	0.29	0.66	0.61	0.55	0.50
13	Bis(2-ethylhexyl) phthalate (μg/l)	< BDL	< BDL	< BDL	< BDL	< BDL	< BDL	< BDL	< BDL
14	Pb (μg/l)	0.30	0.31	0.79	0.86	0.37	0.34	0.29	0.32
15	Hg (μg/l)	0.65	0.46	0.41	0.45	0.18	0.22	0.42	0.51
16	Cd (μg/l)	4.21	4.52	0.64	0.59	1.36	1.21	4.02	3.98
17	As (μg/l)	1.25	2.20	1.89	1.65	1.15	1.53	3.20	2.80
18	Total coliform/100 ml	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent

*Agree** agreeable

Potassium is an essential element for the growth of animals and plants. The primary source of potassium is diet and it is found in all food particularly vegetables and fruits. However, increased exposure to potassium causes several diseases such as kidney failure, heart attack, hypertension, diabetes, adrenal insufficiency, and pre-existing hyperkalemia. Its value was found to be in the range from 0.2 to 7.20 mg/l in all PET bottled water samples. The maximum

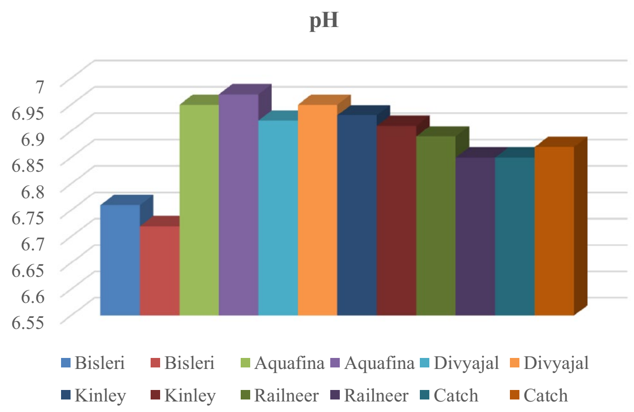

Fig. 1 The graphical representation of the pH in PET bottled water of different brands

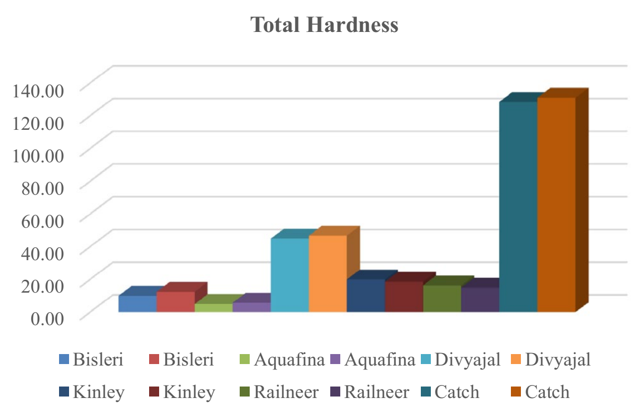

Fig. 2 The graphical representation of the total hardness in PET bottled water of different brands

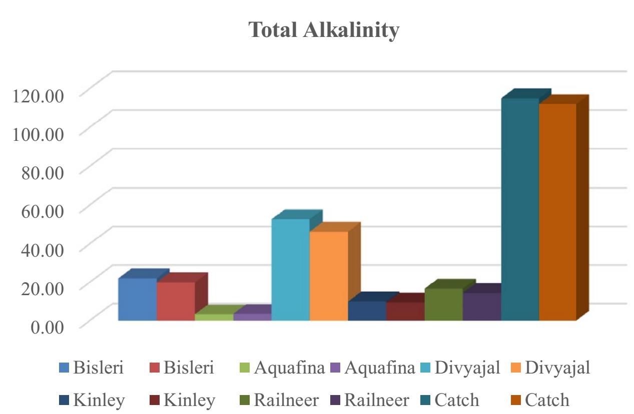

Fig. 3 The graphical representation of the total alkalinity in PET bottled water of different brands

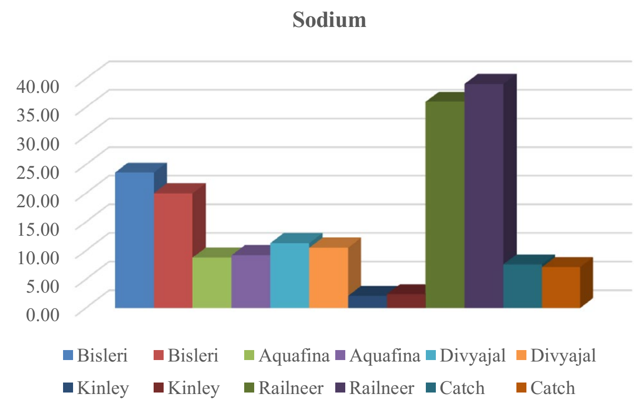

Fig. 4 The graphical representation of the sodium in PET bottled water of different brands

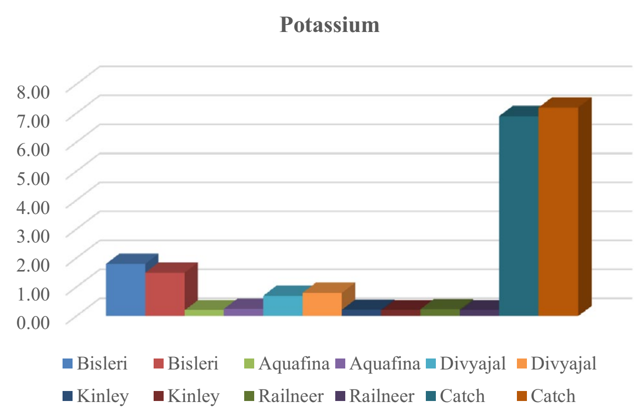

Fig. 5 The graphical representation of the potassium in PET bottled water of different brands

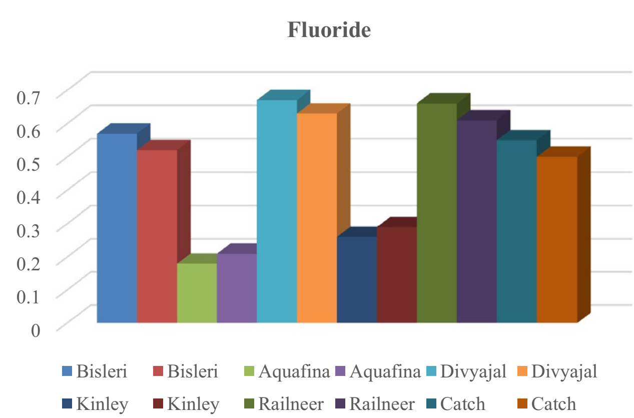

Fig. 6 The graphical representation of the fluoride in PET bottled water of different brands

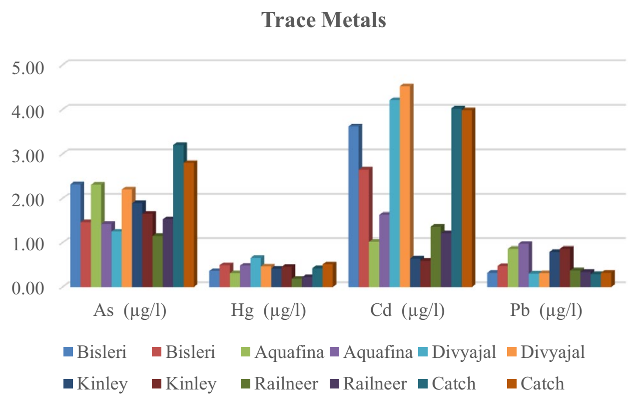

Fig. 7 The graphical representation of the concentration of trace metals in PET bottled water of different brands

potassium was found in Catch, followed by Bisleri, Divyajal, Aquafina, Railneer, and Kinley.

Phosphate is a plant nutrient. It stimulates the growth of aquatic plants or plankton, which provide food for fishes. It is not toxic to animals or plants. Most phosphorous in the surface water is in the form of phosphates and is one of the key elements necessary for the growth of plants and animals. Human waste, animal waste, agricultural waste, and industrial waste are the major source of phosphate. A large amount of organophosphate insecticides used on grapes, pomegranates, and vegetables in the field may get washed by rainwater then reach the river through agricultural runoff. High levels of phosphates are resulting in eutrophication, increased algal blooms, increased biochemical oxygen demand (BOD), and decreased dissolved oxygen (DO). Phosphate was found below the detection limit in all PET bottled water samples.

Fluoride causes fluorosis in people. Fluorosis may occur when the fluoride level exceeded the recommended limits and it is a very serious problem in India and China [48]. The presence of a low or high concentration of fluoride in water is due to natural sources or anthropogenic activity. It is widely distributed in the environment and has adverse effects on human health [49, 50]. Several researchers have reported the fluoride content in PET bottled water from 0.07 to 0.76 mg/l [51–57]. According to WHO [22], the recommended limit for fluoride in drinking water is 1.5 mg/l while as per IS:14543 [41] and USEPA [46] the limit is 1.0 and 4.0 mg/l. Its value was found to be in the range from 0.18 to 0.67 mg/l in all PET bottled water samples. The maximum fluoride was found in Divyajal, followed by Railneer, Bisleri, Catch, Kinley, and Aquafina.

Phthalate is the main compound which is leached out into the water from the PET bottle. Several scientists have reported the leaching behavior of phthalate from PET bottles at a particular temperature and a particular time period [58–60]. Luo et al. [61] studied more than three hundred brands of PET bottled water from 21 different countries and reported the presence of phthalate. Xu et al. [62] reported the presence of phthalate in PET bottled water ranging from 0.18 to 0.98 µg/l under outdoor and indoor storage conditions. Abtahi et al. [29] have reported the highest levels of phthalate from 0.18–0.52 $\pm$ 0.06 µg/l in PET bottled water. Phthalate is regulated in the USA at a maximum level of 6.0 µg/l [63]. We found the Bis(2-ethylhexyl) phthalate below the detection limit in all PET bottled water samples. We also observed that there is no correlation between phthalate and other quality parameters of water.

Trace metals in high concentrations can cause a harmful effect on the health of humans. Therefore, the estimation of trace metals in drinking water is an essential parameter. These metals can be introduced into the water through plastic stabilizers, paints, pigments, fertilizers, fossil fuel, sewage sludge disposal, mining, and smelting operations. These metals can also enter into the drinking water through the treatment process. Several researchers have reported the leaching of metals into the water from plastic bottles and glass bottles [64, 65]. Cd enters into the water when rocks and soil contact groundwater or surface water [66]. Cd is the well-known element that it poses risks to human so it is recommended to control its concentrations in water and food. Several diseases have been reported in humans by different researchers such as chronic renal failure due to Pb [67], damage of membrane and DNA due to Cd [68], cytogenic damage due to As [67].

According to WHO [22], the recommended limit for Pb, Cd and As in drinking water is 10.0, 3.0 and 10.0 µg/l while as per the IS:14543 [41] the limit for Pb, Hg, Cd and As is 10.0, 1.0, 10.0 and 50.0 µg/l and as per the USEPA [46] the limit for Hg, Cd and As is 2, 5 and 10 µg/l. In the present study, Pb was found in the range of 0.3–0.97 µg/l and maximum concentration was found in Aquafina, followed by Kinley, Bisleri, Railneer, Catch, Divyajal. Hg was found in the range of 0.18–0.65 µg/l, and maximum concentration was found in Divyajal, followed by Catch, Bisleri, Aquafina, Kinley, Railneer. Cd was found in the range of 0.59–4.52 µg/l and maximum concentration was found in Divyajal, followed by Catch, Bisleri, Aquafina, Railneer, Kinley. As was found in the range of 1.15–3.2 µg/l and maximum concentration was found in Catch, followed by Bisleri, Aquafina, Divyajal, Kinley, Railneer.

The estimation of total coliform is useful for the monitoring of the microbial quality of water. *E. coli* is considered a specific and reliable indicator of fecal contamination of water [69]. Fecal coliform bacteria are harmless microorganisms which are present in the intestine of human and animals. The presence of fecal coliform bacteria in the aquatic environment indicates that the water has been polluted with the fecal material of humans and other animals. As per the study of WHO [70], coliform bacteria may not always be directly related to the occurrence of fecal contamination in drinking water. Tamburini et al. [71] have reported microbial contamination from 5.0×10^3 CFU/ml to 1.5×10^5 CFU/ml in PET bottled water. Some diseases such as typhoid fever, hepatitis A, viral, and bacterial gastroenteritis are related to these pathogens. No growth of coliform bacteria was observed in all PET bottled water samples.

4 Conclusions

In this study, the evaluation of different parameters within the two different batches of the same brand had been made. The levels of different quality parameters of water in all PET bottled water samples were found within the recommended limits of WHO, Indian Standard and USEPA. Due to the taste, smell, colour, and health issues, many people of different age groups recommend bottled water as a healthy alternative to tap water. So the demand for bottled water is increasing all around the globe. GC–MS/MS was used for the analysis of Bis(2-ethylhexyl) phthalate and it was found below the detection limit while ICPMS was used for the analysis of trace metals. Trace metals (Pb, Hg, Cd and As) were found within the limits of standards set by national and international agencies. The maximum hardness and alkalinity were found in the Catch brand while the minimum was found in Aquafina. The maximum concentration of sodium was found in the Railneer brand and the minimum was found in Kinley. The maximum concentration of potassium was found in the Catch brand and the minimum was found in Kinley. Fluoride was found below the limits of standards set by different agencies. Phosphate was found below the detection limit while total coliform bacteria was found absent in all samples. All PET bottled water distributed in Noida city was found to be harmless and fit for drinking purposes. The monitoring and licensing agencies for the bottled water should be established in the countries including African countries where bottled water markets are growing [72]. It is suggested that all PET bottled water should be checked regularly for its quality.

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Declarations

Conflict of Interest The authors declare that they have no competing interests.

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