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Article

Total Organic Carbon Analyzer: Emerging Technique for Quality Assessment of Potability of Drinking Water

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ABSTRACT

Water is an essential vital element among the natural resources and is important for the endurance of all living creatures including human, animals, microorganism, and plants. Water quality is affected due to the human activity such as urbanization, road construction, and industrial production. India has 75.8 million people living without access to clean water. Indian busiest railway stations are always in demand for drinking water; hence, packaged drinking water concept has started to provide the safe and clean drinking water to the travelers. Bureau of Indian Standards has given quality assessment standard for drinking water. However, parameter like total organic carbon (TOC) is not mentioned in that standard. Various researchers have proved that TOC can help to determine the degree of pollution and organic matters present in the water. In the present study, packaged drinking water and tap drinking water were collected from the railway station and analyzed for total organic content using TOC analyzer. TOC was found in the range of 0.71–98.57 ppm. This system would be implanted in the drinking water and sewage water filtration plant to effectively identify the organic carbon and there is a serious need to incorporate this parameter in the water quality standard to keep track on the organic matters present in the drinking water.

Key words: Potable water, Total organic carbon, Bottled water, Non-purgeable organic carbon.

1. INTRODUCTION

Water is considered as a source of life and most essential vital element among the natural resources and is an important for the endurance of all living creatures including human, animals, microorganism, and plants[1]. Approximately 0.036% of the earth's water is available for the drinking purpose, approximately 98% of the earth's total water is seawater and is not appropriate for human consumption due to high salt content, and approximately 2% of the earths' water is fresh, but 1.6% is locked up in polar ice caps and glaciers. Another 0.36% is found underground in aquifers and wells [2]. Rainfall, groundwater, and surface water these are some most important drinking water sources found in India [3]. India recorded 5400 m^3 of water per person in 1950 and today (2000), per capita water availability has decreased to 1900 m^3/person [4]. The quality of water is affected due to the human activity and increase in inhabitants, urbanization process, industrial production, and climate change these led to a substantial growth in water requirement [1,5], and because of these factors, main water pollutant present in the environment are pharmaceuticals, pesticides, fluoride, phenols, insecticides, pesticides and dyes, heavy metal, detergents, discharge of raw sewage, garbage, as well as oil spills [1,2,5]. According to the NCIWRD, that is, National Commission on Integrated Water Resources Development, the projected water demand for India is recorded approximate 697–710 billion cubic meter in 2010, 784–843 billion cubic meters in 2025, and 973–1180 billion cubic meters in 2050 mainly for irrigation, industry, drinking water, energy, and other [6].

According to UNICEF and the World Health Organization One in eight people worldwide, lack access to safe, clean potable drinking water, and even most of the people have to drink water contaminated with potentially life-threatening bacteria and chemicals [7]. Coagulation, chlorination, membrane process, adsorption, dialysis, foam flotation, reverse osmosis, photocatalytic degradation, and biological methods have been used for the removal of toxic pollutants from water and wastewater [2,7]. Bamboo charcoal (activated carbon) solar sterilization, distillation, chlorine filters, scorching creature bones char, everything but the sink portable filter, slow sand filtration, and emergency homemade filter, natural sunlight, and ultraviolet (UV) light treatment are some low-cost water purification techniques used in rural area for water purification [7]. In Zambia, filtration (sand filter), chemical disinfection (chlorine), sedimentation, flocculation, stabilization, reverse osmosis, Lifestraw, nanofilter, ceramic water filter, biosand filter, and Kanchan Arsenic Filter techniques are used for the wastewater treatment procedures [8].

India is very colonized country hence packed drinking water is much in demand at the railway station, bus station, road side stores, and even at the airports. It is a fairly common practice among people to buy bottled drinking water while traveling in India with the hope that it will minimize the risk of getting ill due to contaminated water. Packed drinking water is manufactured by treating and disinfecting normal drinking water with the process of filtration, ozone treatment, or reverse osmosis and then packed into the good quality plastic bottle, pouches for consumption. Bottled water must be free of sweeteners, additives, and must be calorie free and sugar free. Indian market for packed bottle expected to reach reached Rs. 160 billion in 2018. There are around 150

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domestic Indian Bottled Water Brands in the market today [9]. In the 19th century, earliest bottled water company was founded in the United States. In India, three types of bottled water business are reported which include premium nature mineral water, natural mineral water, and packaged drinking water. Evian, San Pelligrino, and Perrier are imported in India and these are the few examples of premium natural mineral water. Himalaya and Catch comes under natural mineral water and Parle, Bisleri, Coca-Cola's Kinley, and PepsiCo's Aquafina are few examples of international packaged drinking water, whereas Mount Everest, Manikchand, Kingfisher, Mohan Meakin, SKN Breweries, Indian Railways Rail Neer, these are some examples of local packaged drinking water. Ahmedabad-based Consumer Education and Research Society indicates that there is an urgent need to revise standards for bottled water [10,11]. It is observed that bottled water market is increasing against carbonates or soda with respect to liter volume, that is, approximately 5.6 billion liters observed in 2015 and 6.8 billion liters in 2016. In one of the newspaper articles, it was reported that the used packed bottle which was thrown by the passengers on the railway tracks, dustbins, platform, etc., was collected by the packed bottle vendors. They washed it and refilled with ordinary water then they wrapped plastic tape around the neck of bottles to give them a clean finished look. Vendors sell these bottles to the passengers [12].

Quality standards for packed bottles are given by Bureau of Indian Standards, which includes the parameters such as color, odor, turbidity, pH, total hardness, phenolic compounds, alkalinity, and pesticides [13]. Total organic carbon (TOC) monitoring is one of the most important parameters that drinking water and wastewater facilities can use to make decisions about treatment. TOC helps to determine the degree of pollution present in the drinking water. Carbohydrates, amino acids, hydrocarbons, fatty acids and phenolics, natural macromolecules and colloids (e.g., humics), sewage and industrial particulates, soil organic matter, living phytoplankton, and other plant material are certain examples of organic matter present in the aquatic system and these organic matters present in water are measured in terms of total organic content. According to the Environment and Resource Management Department, the concentration of TOC in surface waters is generally <10 mg/L and in ground water <2 mg/L [14]. British Columbia has reported 4 mg/L TOC in source water for drinking water supply with chlorination [15] and South Africa has reported 10 mg/L TOC in drinking water [16]. Knowing and understanding TOC levels used to measure treatment efficacy and as good indicator of contamination [17]. During purification process, TOC presents in drinking water react with disinfectant like chlorine and produces DBP, that is, disinfectant by-product which causes bladder cancer [18]. Two types of carbon are present in water: TOC and inorganic carbon (IC). Collectively, the two forms of carbon are referred to as total carbon (TC) and the relationship between them is expressed as: TOC = TC – IC.

TOC stands for non-purgeable organic carbon (NPOC) and refers to organic carbon that is present in a sample in a non-volatile form. Measuring TOC can be critical to a water treatment facility's water quality in helping to optimize treatment processes [19]. Two oxidation techniques are now commonly used in TOC analysis: Catalytic combustion, where carbon compounds are converted into CO_2 using a catalyst under high temperatures with subsequent detection of the resulting CO_2 using a non-dispersive infrared (NDIR) detector. Wet chemical oxidation applies a combination of UV irradiation and persulfate for oxidation. The resulting CO_2 is either detected through an NDIR detector or using a conductivity detector [20]. Depending on the sample treatment, results should be reported as follows: TC: Sample analyzed without filtration or acidification, TOC: Sample analyzed without filtration, but acidified and purged with inert gas to remove IC, dissolved carbon: Sample analyzed after filtration, but without acidification, and dissolved organic carbon: Sample analyzed after filtration and acidification and purging to remove IC [21].

In Shimadzu TC analyzer, TOC can be measured using three methods, that is, TC-IC method, NPOC method, and POC-NPOC method. In the TC-IC method, TOC is measured as the difference between the TC and IC analysis. NPOC method is recommended for samples in which IC content is more than the TC content. In this method sample acidified to evolve carbon dioxide to remove inorganic content and then same oxidised to measure NPOC. The POC+NPOC method is used when the amount of POC present in the sample cannot be disregarded. This method is used to measure the volatilized component of TOC, which is produced during the NPOC sample sparging process. According to European Standardization EN 1484 (instructions for the determination of TOC and dissolved organic carbon), the difference method can only be applied when the TIC value (total IC) is smaller than the TOC value. For drinking water analysis, the NPOC method is used because of high content of IC [22]. In the present study, packed and tap drinking water samples are collected from different railway stations in Ahmedabad and Gandhinagar and further tested for TOC with TOC analyzer using NPOC method.

2. MATERIALS AND METHODS

2.1. Sampling

Ahmedabad junction railway station is the main railway station of Ahmedabad, Gujarat, India. It is also the biggest and busiest railway station within Gujarat. Gandhinagar railway station is just an hour away from Ahmedabad and they are referred to as twin cities. Including all the railway stations within the area, the twin cities hold around 10 railway stations with trains coming from cities within Gujarat and from almost all over India including major cities such as Mumbai, Delhi, Bangalore, Kolkata, Chennai, Hyderabad, Vishakhapatnam, Trivandrum, Ajmer, Dhanbad, Daltonganj, Jaipur, Indore, and Howrah.

Exactly, 15 water samples were collected from Kalupur Junction, Maninagar station, Sabarmati station A, and Sabarmati station Band Gandhinagar railway station. Tap water meant for drinking purpose available at the platforms at all the above railway stations were collected in a pre-washed rinsed bottle. Packaged bottled and pouched water sold at the platforms were also bought and stored at room temperature. One liter of water sample was also collected from water point – a water dispenser machine which is set up on the platform of Kalupur junction. AZ water, X-Lliant, Rail Neer, Gallons, Kalupur tap drinking water, Kalupur waiting room tap water, Sabarmati tap drinking water-A, Sabarmati tap drinking water-B, water point Kalupur, Gandhinagar tap drinking water, Maninagar tap drinking water, Stream, Once more, Kinley, and Kens are name sample no-1 to sample no-15, respectively.

2.2. Materials

Potassium hydrogen phthalate (KHP), hydrochloric acid, Milli-Q water, etc., were used.

2.3. Methods

One thousand ppm standards solutions for TC were prepared by potassium hydrogen phthalate which was prepared in Milli-Q water. Using this standard solution as a stock solution, further dilution of 500 ppm, 250 ppm, 100 ppm, and 10 ppm of TC solution was prepared. HCL solution was prepared by dissolving HCL in 1:1 ratio. The sample is acidified to pH 3 or lower in the syringe, using hydrochloric acid. After this, sparge gas is bubbled through the sample to eliminate the IC component. The remaining TC is measured to determine TOC, and the result is generally referred to as TOC.

Table 1: Total organic carbon in ppm for all samples.

Sample no.	Total organic carbon (ppm)
Sample 1	6.71
Sample 2	1.10
Sample 3	0.71
Sample 4	0.90
Sample 5	33.41
Sample 6	72.02
Sample 7	15.87
Sample 8	37.53
Sample 9	26.36
Sample 10	98.57
Sample 11	15.89
Sample 12	1.47
Sample 13	1.53
Sample 14	1.42
Sample 15	2.10

3. RESULTS AND DISCUSSION

TOC is the amount of organic carbon present in the water. Presence of any concentration of TOC in water is hazardous to the body and makes the water unsuitable for consumption. Hence, the WHO has made this a mandatory parameter what water quality assessment. Groundwater may contain up to 50 mg/L (50 ppm) of TOC due to the presence of organic matter which gets into the water bodies naturally. As per Table 1, the concentration of TOC was found in all samples in the range of 0.71–98.57 ppm. Lowest concentration of TOC was found in the sample no 3 (Rail Neer), that is, 0.7, second lowest concentration of TOC was also observed in sample no-4 (Gallons), that is, 0.90 both are packed drinking water hence making it the best among the other drinking water samples for consumption. Highest concentration of TOC was observed in the sample no-10 (Gandhinagar tap drinking water), that is, 98.57 ppm. In Bureau of Indian Standards, maximum permissible value has given for total dissolved solids and not for TOC. However, the tap water samples show an exceedingly high concentration of TOC, especially samples no 6 and 10 (Kalupur waiting room tap drinking water and Gandhinagar tap drinking water, respectively), hence making it the most unsuitable water for consumption. A study by Kortelainen [23] on Finnish Lakes found that the TOC concentration varied in all the lakes but the highest concentration was found in small lakes with large catchment area and a high proportion of peatlands in the catchment and located in central or southern parts of the country where the topography is flat. Wallace *et al*., 2002, conducted similar study on potable water samples which were collected from five different locations across the USA. He had compared two techniques, that is, UV persulfate and high-temperature combustion, found that both the techniques yielded good recoveries for potable water samples. Wu (2017) also conducted similar study in which TOC for tap water was reported in the range of 1.6–151.6 mg/L and for surface it was reported in the range of 0.6–47.3 mg/L.

4. CONCLUSION

Water is an essential element of everyone's life. No one can live or survive in the world without water. Quality of drinking water is affected mainly due to the water pollution which includes mixing of industrial waste into the river water, urbanization, road building and construction, gravel pit operations, and mixing of sewage water into the drinking water. These factors affect the water quality and hence for that Bureau of Indian Standards have developed water quality standards and guideline for the drinking water. As per that guideline, they have mentioned few parameters for water quality assessment. However, it was observed that total organic content also affects human life. Various researchers considered it as a one of the parameters which determine degree of pollution in the water. Total organic content analyzer helped in concentration determination of total organic content. This system could be implanted in the drinking water and sewage water filtration plant to effectively treat water and positively impact the costs of treatment, to meet current and future regulatory requirements.

5. DECLARATIONS

5.1. Ethics Approval and Consent to Participate

Not applicable.

5.2. Consent for Publication

Not applicable.

5.3. Availability of Data and Material

Data generated or analyzed during this study are included in this published article.

5.4. Competing Interest

The authors declare that they have no competing interest.

5.5. Funding

Not applicable.

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****Bibliographical Sketch***

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