A | R | J
Amrit Research Journal December 2022, Vol. 3, Issue 1, 46-55
ISSN: 2738-9553
RESEARCH ARTICLE

Physico-Chemical and Bacteriological Analyses for Evaluating the Quality of Municipal Water Supply in Kathmandu District

Parikshya Karki[1], Anup Subedee[1], Bhushan Shakya[1]*
[1]Department of Chemistry, Amrit Campus, Tribhuvan University, Kathmandu, Nepal
**E-mail: bhusansakya@gmail.com*

(Received: August 18, 2022, Received in revised form: November 15, Accepted: December 2, 2022, Available Online)

Highlights

- Samples of water from municipal water supplies in Kathmandu district were collected from 10 different sampling spots.
- Analyses of various physico-chemical parameters (pH, electrical conductivity, TDS, total alkalinity, total hardness, calcium, magnesium, chloride, iron, nitrate and ammonia) were conducted.
- The municipal supplies in Kathmandu district are not suitable for drinking without filtration and proper purification.

Abstract

Water samples from municipal water supplies in Kathmandu District were collected from 10 different sampling spots between April to May, 2018. Analyses of various physico-chemical parameters of water conducted. Physical parameters (pH, electrical conductivity, TDS) and Chemical Parameters like (total alkalinity, total Hardness, calcium, magnesium, chloride, iron, nitrate, and ammonia) were determined. This analysis was undertaken to determine whether water from municipal supply is suitable for drinking purpose or not. It indicates that in some places the municipal supplies in Kathmandu district are not suitable for drinking without filtration and proper purification.

Keywords: *municipal water supply, tap water, pH, total hardness, total coliform*

Introduction

Water is a matter containing elements hydrogen and oxygen and exists in gaseous, liquid, and solid states [1]. Water is a daily requirement of all living beings on earth. There are different purposes of water among them drinking is the most important. Having access to safe and clean water is a basic need [2]. Due to environmental pollution and rapid increase in population, drinking water is being more contaminated. Determination of water quality is the most important factor as it is directly linked with daily life of human beings. A country can develop only when the citizen is healthy, and safe water is the major health concern. Every effort should be made to maintain drinking water quality as safe as practicable.

Water contains organic compounds, radio-nuclides, calcium, magnesium iron, chloride, nitrate, ammonia, and other toxic heavy metals like arsenic, lead, copper, etc. as contaminants [3]. In the past, people used drinking water directly from the source. In Nepal, from the first Five Year Plan (1956-61) drinking water was supplied by making reservoirs and Drinking Water Corporation started supplying clean drinking water in various parts of the country. As a result, 87% of people in the country were able to enjoy basic water supply facility by the end of 2017 AD [4].

**Corresponding author*

During the 20th century, access to tap water became widespread in many areas and is now insufficient, especially in developing countries among those who are poor. Tap water is the major supply of water in Kathmandu valley. Since tap water is potable, if not also people can filter it before use, tap water becomes the best way for water supply. So, most of the people are dependent on tap water.

The majority of residents in Kathmandu district depend on the municipal water supplies of Kathmandu Upatyaka Khanepani Limited (KUKL) for drinking and other domestic purposes. However, it may get contaminated during storage and due to a lack of regulations and limited understanding and awareness among the population. When this water supply system encounters pathogenic microorganisms, it results in various waterborne diseases such as viral infections, parasitic worm infestations, diarrhea, dysentery, typhoid, salmonellosis, and listeriosis. This then contaminates groundwater and surface waterways, seriously polluting water supplies.

The physico-chemical and biological parameters have a significant influence on the quality of water. pH, electrical conductivity, total dissolved solids (TDS), alkalinity, total hardness, major and minor nutrients including calcium, magnesium, iron, chloride, and nitrate, as well as microbial components like total and faecal coliforms, are common metrics that indicate water quality. The quantitative value of these parameters within the permissible value or beyond the permissible value give information about the quality of water.

To determine water quality, many researches have been conducted, some of which are as listed below.

Table 1. Some of previously conducted studies on water quality

S.N.	Selected Area	Sample Size	Determined Parameters	Ref.
1.	Kathmandu, Lalitpur and Bhaktapur	Shallow well, deep well and tube wells	pH, coliform, hardness, arsenic, chloride, fluoride	[5]
2.	Kathmandu, Lalitpur and Bhaktapur	392 (Dug wells) 287 (Deep boring) 218 (Treated) 46 (Tap) and 26 (Other)	pH, conductivity, turbidity, hardness, chloride, iron, arsenic, ammonia, nitrate, coliform	[6]
3.	Rivers of Kathmandu	20 samples	pH, hardness, chloride, BOD, COD, heavy metals, coliform	[7]
4.	Bagmati river (Sundarijal to Balkhu)	10 Samples	Conductivity, Turbidity, Total dissolved solid, pH, DO, Iron, Arsenic	[8]
5.	Bagmati River	5 Samples	Alkalinity, conductivity, ammonia, pH, turbidity	[9]
6.	Kathmandu valley	50 (Boring) 50 (Well)	pH, turbidity, ammonia, nitrate, iron, chloride, arsenic	[10]
7.	Bagmati River	14 location (real time monitoring)	pH, conductivity, TDS, salinity, ORP*, DO#, turbidity,	[11]
8.	Kathmandu valley (Drinking Water)	35 tube wells, dug wells, stone spouts, tap water	Aluminium, antimony, arsenic, barium, beryllium, boron, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, molybdenum, nickel, selenium, thallium, uranium, vanadium, zinc, fluoride, fecal coliform	[12]

BOD : Biological oxygen demand; COD : Chemical oxygen demand; TDS : Total dissolved solids;
ORP : Oxidation reduction potential; DO : Dissolved oxygen

According to the cited literature, most researches on drinking water have been focused on river water. Regular analysis of water quality parameters is required for quality assurance. The policymakers will receive useful information from it so they can take action in the consumers' benefit. So, this study aims to ascertain the physico-chemical characteristics of drinking water samples collected from different sites of Kathmandu district.

Materials and Methods

The majority of people in Kathmandu valley rely on tap water, hence ten different locations in Kathmandu district (27.71° N, 85.31° E) were chosen as sample collection sites. Samples of water were taken from different locations in Kathmandu District (Fig. 1) in April and May of 2018. For physico-chemical parameter analysis, water samples were collected in sterilized PVC bottles, brought to the lab in icebox within 4 hours, and kept at about 4 °C in refrigerator until analyses were performed.

Fig 1. Location of sampling sites with sample code

Analysis of Physico-Chemical and Bacteriological Parameters

Physical parameters were analyzed by measuring pH, conductivity and total dissolved solids (TDS) using digital pH meter (model no.: HI-98107), conductometer (model no. HI-983003/304) and evaporation method respectively [13]. Chemical parameters were analyzed by determining total hardness (TH), total alkalinity (TA), calcium, magnesium, chloride by titrimetric method [13]. Nitrate and iron were determined spectrophotometrically, while ammonia was determined by Nesslerization method [14]. The chemicals and solvents of analytical grade used were procured from local suppliers in Kathmandu. Bacteriological analysis was carried out by enumerating total coliform using Multiple Tube Fermentation Technique [14].

10 mL each of single and double strength media in the culture tubes was pipetted and introduced Durham tube into it. It was stoppered well after removing air. The tubes containing broth and Durham tube were sterilized into an autoclave under 15 lb pressures at 110 °C for 15 minutes and cooled. The sample and media were kept near the burner. 10 mL well shaken sample was introduced to each of three culture tubes containing double strength culture media by well sterilized pipette. Next, six culture

tubes containing single strength culture media were taken. 1 mL of sample was introduced in remaining three tubes. All the samples were shaken and incubated for 48 hours at 44 °C. The number of positive tubes was noted and Most Probable Number (MPN) was calculated from the standard MPN table.

Results and Discussion

Physical Parameters of Sample Water

The values obtained for different physical parameters, Nepal Drinking Water Quality Standards (NDWQS) [15] and WHO Drinking Water Guidelines (WHO DWG)[16] are presented in table 2.

Table 2. Water quality of different sampling points based on physical parameters

Parameters → / Sampling point ↓	pH	Conductivity (µS/cm)	Total Dissolved Solid (mg/L)
1	7.0	58	2381
2	6.9	66	2161
3	6.7	529	3335
4	7.4	391	1755
5	8.0	612	1587
6	6.7	175	3293
7	7.2	184	3088
8	7.9	471	3721
9	7.0	795	2615
10	7.6	132	2890
NDWQS	6.5- 8.5	1,500	1000
WHO DWG	6.5- 8.5	750	<600

pH

pH is the indicator of acidic or alkaline condition of water status. In the pH range of 6.5 to 8.5, no harmful health effects are anticipated, but a change in pH to an acidic or alkaline region can be harmful. Water that is extremely acidic or alkaline has a sour or bitter tastes. At lower pH levels, as the rate of corrosion of metal pipes in distribution systems tends to increase harmful corrosion products including lead, cadmium, and other metals that may be consumed with drinking water tend to be released [17, 18]. At higher pH levels, the disinfection process (germicidal potential of chlorine) is adversely affected, and mucous membrane irritation may occur [17]. The pH values of water samples were ranged from 6.7 – 8.0 (Fig.2) which lie within NDWQS and WHO permissible range 6.5 to 8.5.

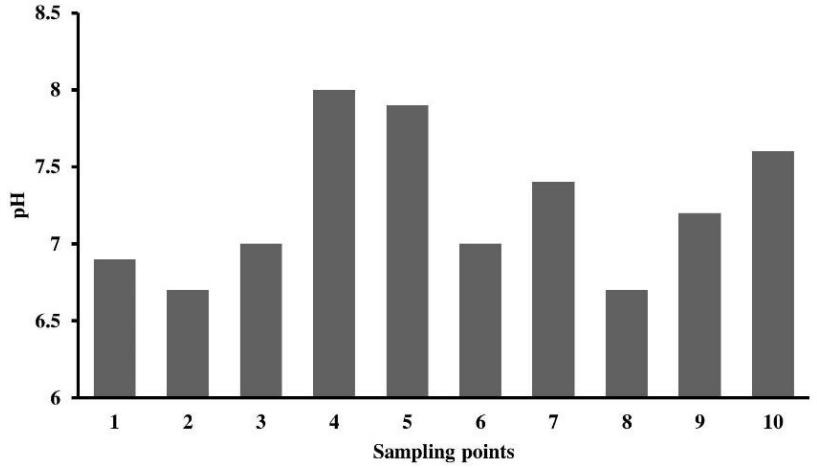

Fig 2. pH of water from municipal water supply in Kathmandu District

Electrical Conductivity

Electrical Conductivity (EC) is a measure of the ability of an aqueous solution to conduct electric current and is mainly influenced by the amount of dissolved inorganic particles in water, such as chloride, nitrate, calcium, magnesium, ammonium, and others. Since EC measurement is a rapid and excellent way to evaluate TDS, it serves as an indicator for the taste/salinity of drinking water. Electrical conductivity of water does not directly affect health; however high EC values are associated with unpleasant tastes. The results of electrical conductivity measurement are shown in Fig. 3. Electrical conductivity of all samples is within the NDWQS limit of 1500 µS/cm and WHO limit of 750 µS/cm, except for the sample from Swayambhu (EC 795 µS/cm) which is beyond the WHO permissible value. Greater concentrations of dissolved gases, ionic salts, and other compounds in water may be the cause of the higher electric conductance values.

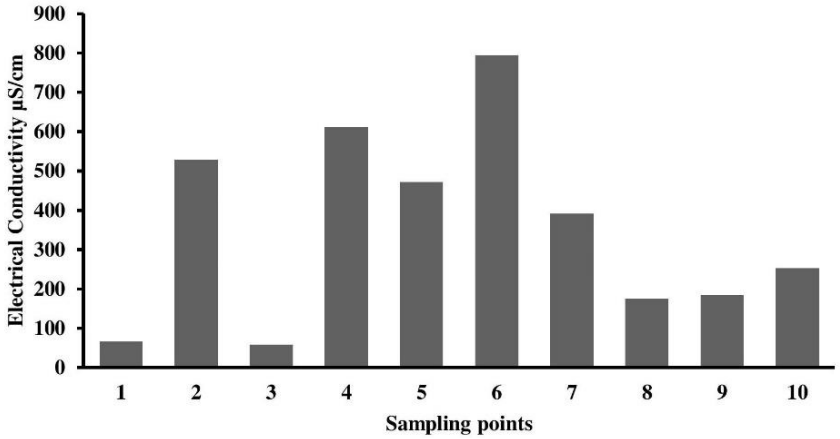

Fig 3. Electrical Conductivity of water samples from municipal water supplies in Kathmandu District

Total Dissolved Solids

Total dissolved solids (TDS) refer to any minerals, salts, metals, cations or anions smaller than 2 microns. TDS value indicates the salinity behaviour of water. The TDS measurement reveals how water behaves in terms of salinity. High levels of TDS in water have no adverse health effects, but they can have a harmful impact on people who have kidney and heart diseases. High dissolved solids in water may have laxative or constipating effects [19]. Due to its salinity, water with a TDS concentration of more than 500 mg/L is not recommended for drinking purposes, but in unavoidable cases 1500 mg/L is permitted. Total dissolved solids present in all samples (Fig. 4) exceeded NDWQS and WHO permissible limit of 1000 mg/L and 600 mg/L, respectively. Therefore, it can be inferred that municipal tap water is too salty to be used for drinking purposes without proper treatment.

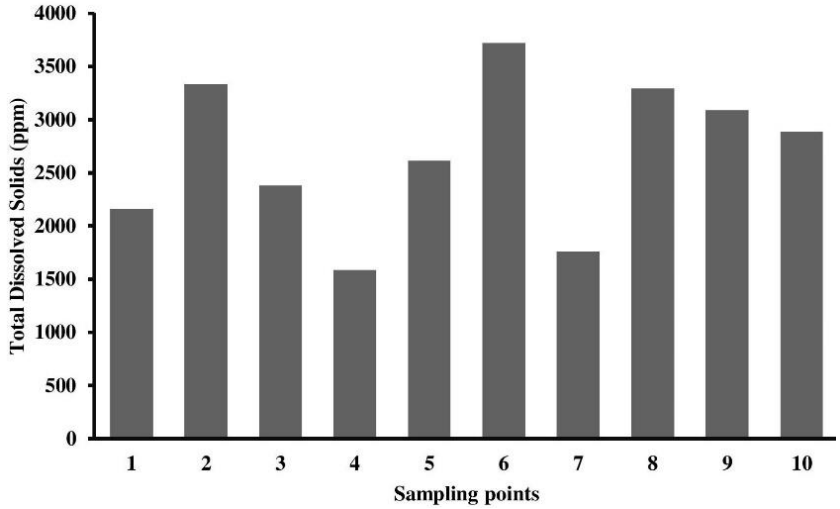

Fig 4. Total Dissolved Solids in water from municipal supplies in Kathmandu District

The results of determination of different chemical parameters, Nepal Drinking Water Quality Standards (NDWQS) [15] and WHO Drinking Water Guidelines (WHO DWG) [16] are presented in table 3 and Fig. 5.

Table 3. Water quality of different sampling points based on chemical parameters

Parameters→ Sampling point↓	Total Alkalinity (mg/L)	Total Hardness (mg/L) as $CaCO_3$	Calcium (mg/L)	Magnesium (mg/L)	Chloride (mg/L)	Nitrate (mg/L)	Ammonia (mg/L)	Iron (mg/L)
1	57.50	37.33	32.06	10.57	133.48	1.67	0.17	2.53
2	20.00	15.33	10.42	6.89	60.35	0.95	0.38	0.18
3	25.00	23.33	8.02	9.32	78.81	1.21	0.09	0.18
4	102.50	170.00	66.53	3.04	69.58	19.59	0.22	<0.05
5	100.00	140.00	24.44	29.78	95.14	0.84	0.15	0.09
6	92.50	55.00	18.44	11.55	53.25	1.23	0.61	0.64
7	75.00	53.00	19.24	13.78	71.71	<0.10	1.75	1.43
8	99.00	108.70	44.48	2.43	62.48	0.66	0.49	0.39
9	72.50	144.67	34.86	5.47	69.22	0.32	0.84	0.28
10	85.00	99.00	32.06	7.09	115.02	4.06	0.16	0.44
NDWQS	500	500	200	NA	250	50	1.5	0.3
WHO DWG	NA	200	150-300	<150	250	50	1.5	0.3

Total Alkalinity

Alkalinity is the ability of water to neutralize a strong acid. It measures how much ions are involved in the reaction that neutralizes hydrogen ions. The health of people is not adversely affected by alkalinity. Scale formation and a distinct flat and unpleasant taste are the results of excessive alkalinity. The alkalinity values range from 20 to 103 mg/L which is within the NDWQS and WHO permissible values.

Total Hardness

Total hardness, a measure of water quality, describes the impact of dissolved minerals (mostly Ca and Mg) and assesses whether water is suitable for use in domestic, industrial, and drinking purposes. It is mostly caused by the presence of dissolved bicarbonates, sulphates, chloride of calcium and magnesium. The level of hardness in water may have an impact on how palatable it is. Water with a hardness level above 200 mg/L can interfere with filtration and cause encrustation in tanks, piping, and distribution system [20]. There is some evidence that hard water may lead to a lower risk of cardio-vascular diseases, but there is no evidence that hardness itself causes any health-related issues [21]. The permissible values for total hardness of water are 200 mg/L and 500 mg/L, respectively, according to WHO and NDWQS. The hardness of the water is below the WHO and NDWQS range with the values ranging from 15 to 145 mg/L.

Calcium and Magnesium

Magnesium and calcium are both essential for maintaining human health. However, consuming too little of either nutrient may increase the likelihood of disease. Excessive calcium intake may have adverse health effects on those who are prone to milk alkali syndrome and hypercalcaemia. Drinking water with a high magnesium content may have a laxative effect [22]. The calcium concentration ranged from 8.02 mg/L at the lowest point to 66.53 mg/L at its highest point, which is still within the 200 mg/L NDWQS acceptable threshold. In contrast, the magnesium concentrations ranged from 2.43 to 29.78 mg/L.

Chloride

The concentration of chloride in water serves as an indicator of pollution by sewage. Chloride concentrations in unpolluted water are typically modest (<10 mg/L). Chloride in drinking water may result from the leakage of subterranean water supply line and sewage discharge. Chloride has no harmful effects on health when present in amounts lower than 200 mg/L. When the chloride concentration in water exceeds 600 mg/L, it will taste distinctly salty and will not quench thirst [17]. For chloride, WHO and NDWQS permitted maximum of 250 mg/L. The value of chloride in tap water samples ranges from 53.25 to 133.48 mg/L which is within the permissible range.

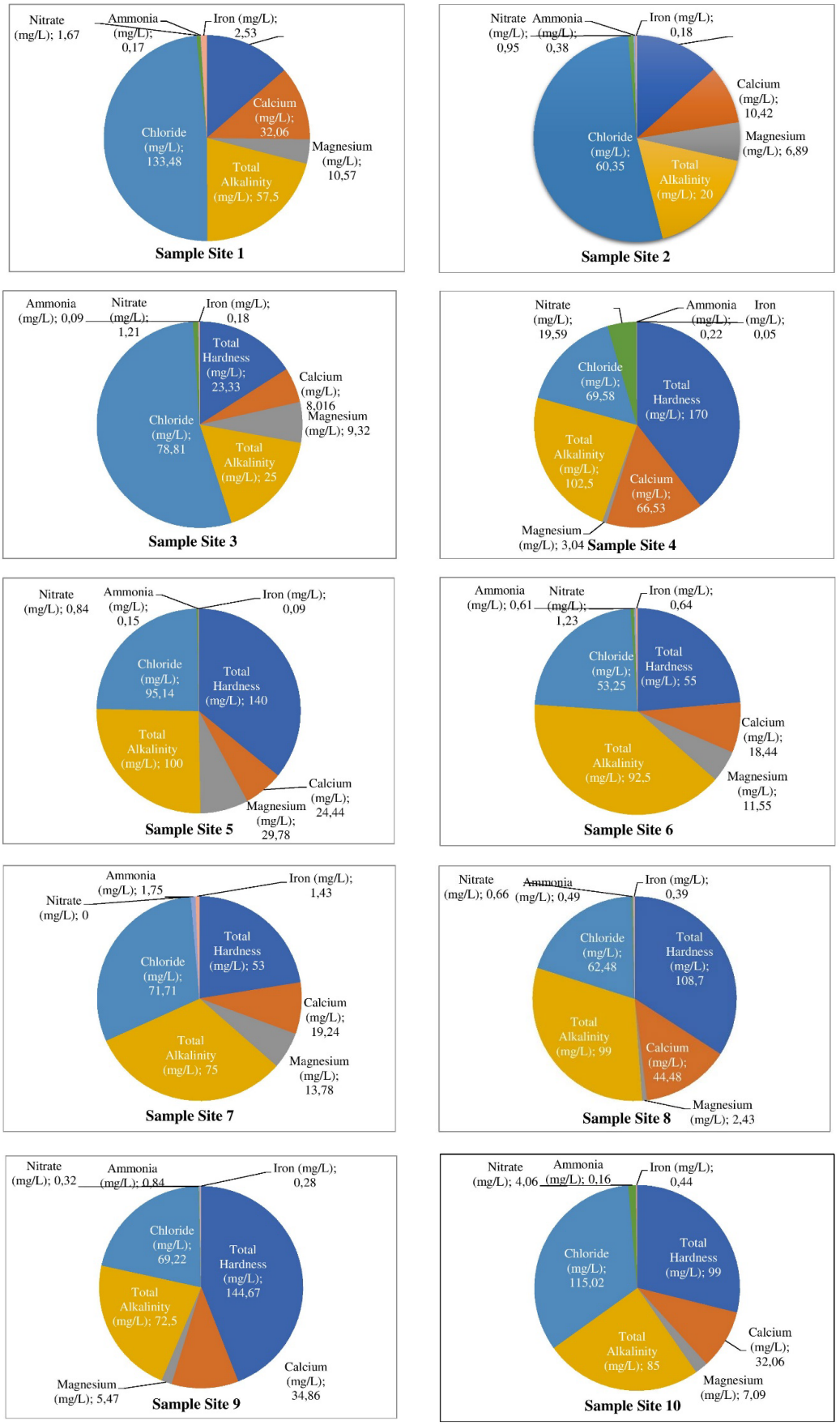

Fig 5. Chemical parameters in water from municipal supplies in Kathmandu District

Nitrate

One of the most pervasive chemical pollutants of water bodies worldwide is nitrate [21]. High amounts of nitrate in drinking water may cause serious illness methemoglobinemia or "blue baby syndrome," cancer risks [23], an increase in starchy deposits, and splenic hemorrhaging [23, 24]**.** In drinking water, nitrate concentration should be less than 50 mg/L according to WHO DWG and NDWQS. The nitrate concentration in all samples is under permissible values of both WHO and NDWQS.

Ammonia

Ammonia in water indicates the presence of organic contamination [25]. The presence of elevated ammonia levels in drinking water has aesthetic effects (taste threshold of 35 mg/L and odour threshold concentration of 1.5 mg/L at alkaline pH), which may cause consumers to reject the water in favor of an alternative, less safe source. However, the ammonia content of drinking water is typically minimal and has no direct impact on health [20]. Guidelines from WHO and NDWQS state that ammonia concentrations should not exceed 1.5 mg/L. With the exception of water from Bohoratar, the ammonia concentration in water samples is within WHO and NDWQS acceptable limits.

Iron

Iron in drinking water is objectionable because of the unpleasant taste and other aesthetic effects such as brown staining of laundry, sanitary ware, and development of turbidity. Though no health consequences are anticipated, excessive quantities are nonetheless considered as a nuisance [18]. Iron concentration should not exceed 0.3 mg/L according to WHO DWG and NDWQS. The iron concentration in water samples is between 0.05 to 2.53 mg/L. Samples from Lainchaur, Nepaltar, Bohoratar, and Bijeshwori have iron concentrations over the WHO permissible limit. This could have been caused by corrosion of pipes, pumps, etc. in the distribution system.

Total Coliform

The total coliform count provides a general indication of hygienic status of a water supply. There is an increasing risk of disease transmission at total coliform counts of above 10 count/100 mL [17]. The use of old pipelines that have not been repaired, parallel alignment of the drinking water pipeline with the drainage system, and irregular supply in the pipeline are the main causes of bacteriological contamination of drinking water supplies.

Table 4. Water quality of different sampling points based on microbial parameters

Sampling point → Parameter↓	1	2	3	4	5	6	7	8	9	10	NDWQS	WHO DWG
Total Coliform (MPN/100 mL)	48	21	Nil	7	Nil	Nil	Nil	15	Nil	23	Nil in 95% samples	Nil

Total coliform in water samples from different sampling points are summarized in table 4 and Fig. 6. According to WHO DWG and NDWQS, there should be no coliform bacteria. But water samples from Thamel, Lainchaur, Sorahkhutte, Gongabu, and Bijeshwori contained coliform. The contamination may have resulted from either improper disinfection at treatment plant or from polluted water (sewage) seeping in through cross-connection and leakage sites.

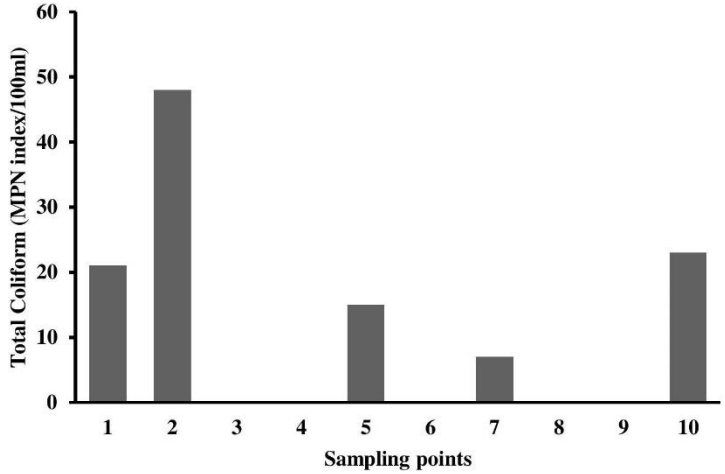

Fig 6. Total coliform in water from municipal supplies in Kathmandu District

Conclusions

Various physical parameters like pH, Conductivity and TDS were measured by digital pH meter, Conductometer and Evaporation methods and others chemical parameters were analyzed by using standards methods of APHA (2012).

pH of water was under WHO and NDWQS permissible limits. Electrical Conductivity of most samples of water is within the range 58-795 µS/cm which is under NDWQS. The total dissolved solids of all the samples are out of WHO and NDWQS range. The total dissolved solids of water varied from 1587 mg/L to 3721 mg/L exceeding both WHO and NDWQS permissible values. Total hardness, total alkalinity as well as calcium, magnesium, chloride and nitrate contents of all samples are within both WHO and NDWQS guidelines. Ammonia content of samples should vary from 0 mg/L to 1.5 mg/L but some of the samples were out of WHO and NDWQS range. The sample from Bohoratar had found more ammonia than the WHO range. All of the samples lie within the WHO and NDWQS acceptable ranges for alkalinity, which should be around 350 mg/L. The total hardness of water is within the NDWQS range as well. Calcium content in water is also within the NDWQS range. Iron content of water samples from Lainchaur, Nepaltar, Bohoratar Gongabu, and Bijeshwori are out of WHO range while other samples are within WHO and NDWQS range i.e., above 10 mg/L and 50 mg/L respectively. The coliform bacteria should be Nil in the samples according to WHO and NDWQS but the samples from Lainchaur, Thamel, Gongabu, Sorahkhutte, and Bijeshwori contain the coliform bacteria.

Acknowledgements

Authors gratefully acknowledge the Department of Chemistry, Amrit Campus and Aastha Scientific Research Pvt. Ltd. for laboratory support.

References

1. S. S. Zumdahl, S. S. 2022. *Water*. In *Encyclopedia Britannica*. Retrieved August 30, 2022, from https://www.britannica.com/science/water.
2. L. Vanny, G. Jiwen and H. Seingheng, Phnom Penh's municipal drinking water supply: Water quality assessment, *Sustainable Water Resources Management*, (2015), *1*, 27-39.
3. T. R. Sahoo, and B. Prelot, Adsorption processes for the removal of contaminants from wastewater: the perspective role of nanomaterials and nanotechnology. In *Nanomaterials for the detection and removal of wastewater pollutants,* Elsevier, 2020. pp. 161-222.
4. C. B. Budhathoki, Water supply, sanitation and hygiene situation in Nepal: A review. *Journal of Health Promotion,* **(**2019), *7*, 65-76.
5. B. R. Pant, Ground water quality in the Kathmandu valley of Nepal, *Environmental Monitoring and Assessment*, (2011), *178*(1), 477-485.
6. N. K. Koju, T. Prasai, S. M. Shrestha, and P. Raut, Drinking water quality of Kathmandu valley, *Nepal Journal of Science and Technology*, (2015), *15*(1), 115–120.
7. R. K. Regmi, B. K. Mishra, Y. Masago, P. Luo, A. Toyozumi-Kojima, and S. M. Jalilov, Applying a water quality index model to assess the water quality of the major rivers in the Kathmandu valley, Nepal, *Environmental Monitoring and Assessment,* (2017), *189*(8), 1-16.
8. K. B. Pal, R. R. Pant, B. Rimal, and A. D. Mishra, Comparative assessment of water quality in the Bagmati river basin, Nepal, *ZOO-Journal*, (2019), *5*, 68-78.
9. M. P. Adhikari, M. R. Neupane, and M. Kafle, Physico-chemical parameterization and determination of effect of tributaries on enhancement of pollutants in Bagmati river, *Journal of Nepal Chemical Society*, (2019), *40*, 36-43.
10. S. Ghartimagar, P. Khatri, S. Neupane, D. R. Joshi, and T. P. Joshi, Evaluation of ground water quality of Kathmandu valley and antibiotic susceptibility test against Klebsiella pneumoniae, *Tribhuvan University Journal of Microbiology*, (2020), *7*, 83–90.

11. M. P. Adhikari, N. B. Rawal, and N. B. Adhikari, Real-time fine-scale measurement of water quality parameters along the Bagmati river in the Kathmandu valley, *Nature Environment & Pollution Technology*, (2021), *20*(3), 1047-1057.
12. B. Sarkar, E. Mitchell, S. Frisbie, L. Grigg, S. Adhikari and R. Maskey Byanju, Drinking water quality and public health in the Kathmandu valley, Nepal: coliform bacteria, chemical contaminants, and health status of consumers, *Journal of Environmental and Public Health,* (2022), 1-21. https://doi.org/10.1155/2022/3895859.
13. R. K. Trivedi and P. K. Goel, *Chemical and biological methods for water pollution studies*. Environmental Publications. Aligarh, India, 1986.
14. E. W. Rice, R. B. Baird, A. D. Eaton and L. S. Clesceri, L.S., (eds). *Standard methods for the examination of Water and Wastewater*. 22nded, American Public Health Association. 2012.
15. *National Drinking Water Quality Standards (NDWQS)*. 2062, Government of Nepal, Ministry of Physical Planning and Works, Kathmandu, 2006.
16. *Guidelines for Drinking Water Quality.* 4th ed. Incorporating the first addendum, Geneva, Switzerland: World Health Organization, 2017, Licence: CC BY-NC-SA 3.0 IGO.
17. P. L. Kempster, H. R. van Vliet and A. Kuhn, The need for guidelines to bridge the gap between ideal drinking-water quality and that quality which is practically achievable and acceptable, *Water SA,* (1997), *23*(2), 163-167.
18. J. Diwakar K. D. Yami and T. Prasai, Assessment of drinking water of Bhaktapur municipality area in pre-monsoon season, *Scientific World*, (2008), *6*(6), 94-98
19. A. A. Werkneh, B. Z. Medhanit, A. K. Abay and J. Y. Damte, Physico-chemical analysis of drinking water quality at Jigjiga city, Ethiopia, *American Journal of Environmental Protection,* (2015), *4*(1), 29-32.
20. A global overview of national regulations and standards for drinking water quality, second edition. Geneva: World Health Organization; 2021. License: CC BY-NC-SA 3.0 IGO
21. G. Howard, M. E. Ince and M. D. Smith, Rapid assessment of drinking water quality: a handbook for implementation, Loughborough: WEDC, Loughborough University, 2003.
22. J. Cotruvo and J. Bartram (eds)., Calcium and magnesium in drinking-water: public health significance, Geneva, World Health Organization, 2009.
23. Y. S. Yang and L. Wang, Catchment-scale vulnerability assessment of groundwater pollution from diffuse sources using the DRASTIC method: a case study. *Hydrological Sciences Journal,* (2010), *55*(7), 1206-1216.
24. A. Aydin, The microbiological and physico-chemical quality of groundwater in West Thrace, Turkey, *Polish Journal of Environment Studies,* (2007), *16*(3), 377-383.
25. M. Wiatkowski and L. Paul, Surface water quality assessment in the river catchment in the context of Wlodzienin reservoir construction, *Polish Journal of Environment Studies*, (2009), *18*(5), 923-929.