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Assessment of drinking water quality of Kathmandu Municipality Area, Kathmandu, Nepal in pre-monsoon season

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Abstract

This study was conducted with a view to evaluate water quality status of Kathmandu Municipality area in pre-monsoon season. A total of 97 water samples from four different water sources viz., stone spouts, wells, boring and municipal public taps of the municipality area were examined for the purpose. Physico-chemical parameters such as turbidity, electrical conductivity (EC), pH, total hardness, sulphate, chloride, nitrate, ammonia, iron, manganese and arsenic, and total coloform as microbial parameter were determined and analyzed using standard protocols. Results revealed that the range and mean concentrations of the selected parameters were found to vary among the water sources. The results were also compared against the National Drinking Water Quality Standard (NDWQS) of Nepal and WHO guidelines. The pH, sulphate, chloride, nitrate, ammonia, manganese and iron levels of all tested samples were found within NDWQS as well as WHO standards. While 33 (34 %), 3 (3.1%), 16 (16.5%) and 47 (48.5%) of the total samples crossed NDWQS guideline for turbidity, electrical conductivity, ammonia and iron content respectively, 50 (51.6%), 8 (8.3%), 16 (16.5%) and 47 (48.5%) samples exceeded WHO standard respectively for the same parameters. Total hardness of all tested samples revealed their results within NDWQS guideline value but 50 (51.6%) samples crossed WHO standard as per its maximum permissible limit. The microbial analysis showed total coliforms in 82 (84.5%) of the total water samples exceeding both NDWQS and WHO standards. As for the microbial contamination range and risk level, only 15 (15.5%) of the total water samples were found risk free of which 15 (44.1%) samples were contributed from municipal tap water alone. Based on our findings, we conclude that the drinking water quality of Kathmandu Municipality area is not yet satisfactory which may be improved by effective planning and policies, strategies and management practices in terms of safe water supply and environmental sanitation.

Keywords: Water quality, physico-chemical parameters, total coliform, iron, arsenic, Kathmandu Municipality.

Introduction

The most vital resource for all living creatures on this planet is unconditionally water. Safe drinking water is univocally a major concern for all since health and well-being of the human race is closely connected with the quality of water used[1]. However, the increasing anthropogenic activities may adversely affect water in qualitative and quantitative manner. For instance, the agricultural and industrial wastes and disposal of unmanaged municipal wastes into water may not only affect their quality but also cause water borne transmissible diseases[2]. The presence of toxic heavy metals and radio-nuclides, high concentrations of nitrates, nitrites, sulphates, phosphates and organic matters in water may adversely affect on human health causing chronic illness, cancer and many other human body malfunctions[3]. It has been reported that the contaminated water is responsible for about 80% of all the diseases in human beings[4].

Kathmandu has become the most crowed and busiest city in Nepal because of its' haphazard urbanization and industrialization and rapid growth of population. This has brought adverse impacts on ground water system. The Kathmandu valley has its population growth rate of 4.7%. This growth rate exceeds the population growth rate of Nepal by more than double. The valley faces a daily demand of more than 360 million liters of water[5]. Kathmandu Upatyaka Khanepani Limited (KUKL), the government's authentic operator, is fulfilling the water demand of the valley people by only around 140 and 90 million liters per day in wet and dry seasons respectively. At present, more than 70% of households in the valley rely on municipal tap water as the primary source and the rest on ground water resources and others. Besides, more than 14% of households in the valley are receiving water supply from private drinking water tankers.

The drinking water supply system of Nepal has gone through multiple stages in history before coming to modern system today. The population of Kathmandu used to rely on groundwater, wells, stone spouts, natural streams and rivers for centuries before exposure to the western world[6].

Even today, groundwater is vital sources of water for people living in the Kathmandu Valley. Water supply from holy rivers, stone spouts and ancient wells also hold important cultural and spiritual meaning. Although many wells and stone spouts remain dried for several months in a year, many are still viable water sources, especially during the monsoon when water tables have risen. However, rapid urban development and an increasing reliance on groundwater are diminishing public water supplies like wells and spouts.

It has become a matter of concern for people when the disposal of untreated industrial effluents and municipal sewage, leakage of domestic septic tanks, agricultural runoff containing chemical fertilizers and pesticides are polluting the ground water system in the valley. Several studies have revealed both chemical and bacterial contaminations in groundwater of the valley[1,7]. Particularly, the level of contamination in water increases during monsoon season. Under the given situation, standards and safety of drinking water have always become major concerns. This study therefore assesses the municipal tap water as well as groundwater quality in Kathmandu Municipality area during pre-monsoon season and evaluates its suitability for drinking by comparison against Nepal standard (NDWQS)[8] and WHO guidelines[4].

Materials and methods

Study area: Nepal, a landlocked country in South Asia, has internationally bordered with China at the north and India at the south, east and west. The country has a geographical location between latitudes 26^{o}22′N to 30^{o}27′N and longitude 80^{o}04′E to 88^{o}12′E. Covered with a total area of 147,181km^2, Nepal is predominantly a mountainous country elevating from 64m above sea level to 8,848m at the peak of Sagarmatha, the Mt. Everest. The country may be differentiated by a cold climate, diverse topography and geology.

Kathmandu, the eldest metropolitan city of the country, forms the urban core of the valley bordering with Lalitpur and Bhaktapur districts. Four major hills *viz.*, Shivapuri, Phulchowki, Nagarjun and Chandragiri surround the city all-around. Centrally located in the bowl-shaped valley, it is elevated approximately at 1,400m above the sea level. The population density of the valley is only 97 per square kilometer whereas Kathmandu metropolitan city (KMC) is densely populated by 13,225 per square kilometer.

The region is characterized by semi tropics, warm and temperate climate. During monsoon period, about 80% of total rainfall is recorded with 2,000 mm as an average precipitation per annum in the valley. Because of gentle slope towards the centre of the closed basin of the valley, groundwater has become a reliable source of drinking water in Kathmandu. It has been reported that about 50% of the total water consumption is derived from groundwater in the area[9]. According to a KMC report, there are only 96 stone water spouts out of the total of 165 in the city which are still in operational status[10].

A total of 33 stone spouts does not exist presently and 34 no longer in working condition. As for the public wells and borings, the Kathmandu Municipality has no official records. The KUKL data reveal that it has a total of 199416 tap connections and 1196 public taps in Kathmandu alone.

Sample collection and analysis: The present study was carried out in Kathmandu Municipality area during pre-monsoon period (March to May 2018). Altogether 97 water samples were collected from four major water sources *viz.*, stone spouts (n_1=15), wells (n_2=21), borings (n_3=27), and municipal taps (n_4=34). For physico-chemical characterizations, water samples from stone spouts, wells and borings were collected during early morning hours to avoid any kind of human disturbance while municipal tap water samples were collected during the KUKL scheduled water supply hours. Precautions, preservation of water samples and standard methods for analyses of physico-chemical parameters were adopted as described in APHA[11] and Trivedy & Goel[12].

Table-1 shows a brief summary on material and methods adopted for physico-chemical and microbial analyses. The pH and EC values of water samples were recorded at the sampling sites using digital pH meter (Hanna HI 8314) and conductivity meter (DiST3 Tester-HI98303) respectively. While total hardness, sulphate, chloride and total coliforms (membrane filtration technique adopted) were analyzed in Environment Laboratory of Padmakanya Multiple Campus, Bagbazar; turbidity, ammonical-nitrogen, nitrate-nitrogen, iron, manganese and arsenic were analyzed in Aaastha Scientific Services, Dillibazar, Kathmandu. All the collected water samples were well labeled and delivered immediate to the laboratory where the analyses were carried out the same day. The samples were preserved at 4^{0}C in a refrigerator unless immediate analyses were possible. All the collected samples were analyzed in triplicate.

Results and discussion

Physico-chemical and microbial characterizations of the collected water samples from different sources are discussed in this section. The groundwater as well as municipal tap water is used by the inhabitants of Kathmandu Municipality area for multiple purposes.

Table-2 shows the mean and range of all tested water quality parameters and the values (Table-3 and 4) compared against NDWQS and WHO guidelines for assessing drinking water quality.

Table-1: Materials/ Methods used for analyzing water quality parameters.

Physico-chemical/ microbial parameters	Material/ Methods
Turbidity	Nephelometric method
EC	Digital conductivity meter
pH	pH meter
Total hardness	EDTA volumetric method
Sulphate	Turbidimetric method
Chloride	Argentrometric method
Nitrate	Stannous chloride reduction method/Colorometric
Ammonia	Nesslerization method
Iron	1,10 phenanthroline method/ Colorimetric
Manganese	Atomic Absorption Spectrophotometer
Arsenic	Atomic Absorption Spectrophotometer (Hydride generation)
Total coliforms	Membrane filtration technique

Table-2: Physico-chemical characteristics of different water sources (Mean ± SD; n =3).

Parameters		Stone spouts (n_1=15)	Wells (n_2=21)	Borings (n_3=27)	Municipal tap water (n_4=34)	NDWQS	WHO
Turbidity (NTU)	Range	0 - 5	5 - 144	5 - 60	5 - 80	5 (10)	5
	Mean	3 ± 1	31 ± 22	28 ± 16	24 ± 12	-	-
EC (µS)	Range	122 - 944	524 - 1816	140 -1143	218 - 918	1500	800-1000
	Mean	400 ± 115	890 ± 240	695 ± 190	563 ± 165	-	-
pH	Range	7.2 - 8.2	6.9 - 8.2	6.7 - 7.3	6.5 - 7.1	6.5 - 8.5	6.5 - 8.5
	Mean	7.8 ± 1.3	7.5 ± 1.2	7.1 ± 1.0	6.7 ± 0.9	-	-
T. Hardness (mg/L)	Range	50 - 370	110 - 400	44 - 320	12 - 430	500	80 - 120
	Mean	259 ± 67	254 ± 72	181 ± 58	148 ± 86	-	-
Sulphate (mg/L)	Range	16 - 82	26 - 105	10 - 20	14 - 110	250	250
	Mean	31 ± 15	47 ± 18	16 ± 8	55 ± 26	-	-
Chloride (mg/L)	Range	4.4 – 6.6	85.2 - 177.5	5.7 - 7.7	5.3 – 92.0	250	250
	Mean	4.9 ± 1.0	120.7 ± 28.5	6.9 ± 1.6	28.7 ± 16.2	-	-
Nitrate (mg/L)	Range	12.85 - 49.24	15.17 - 25.87	33.85 – 46.56	0.44 - 0.53	50	50
	Mean	43.40 ± 10.8	22.55 ± 8.5	40.24 ± 16.4	0.48 ± 0.12	-	-
Ammonia (mg/L)	Range	0.08 - 1.02	0.4 - 29.1	0.02 - 65.0	0.02 – 12.0	1.5	1.5
	Mean	0.41 ± 0.14	5.84 ± 3.8	33.9 ± 18.6	3.36 ± 2.65	-	-
Iron (mg/L)	Range	0.1 - 0.5	0.1 - 12.4	1.5 - 6.0	0.1 - 0.3	0.3	0.3
	Mean	0.2 ± 0.1	4.2 ± 2.5	2.5 ± 1.0	0.2 ± 0.1	-	-
Manganese (mg/L)	Range	0.08 – 0.17	0.04 – 0.12	0.05 – 0.2	0.05 – 0.19	0.2	0.2
	Mean	0.11 ± 0.07	0.09 ± 0.04	0.14 ± 0.08	0.12 ± 0.08	-	-
Arsenic (mg/L)	Range	*ND	ND	ND	ND	0.05	0.01
	Mean	-	-	-	-	-	-

*ND: Not detected.

Table-3: Number of water samples above NDWQS guideline value (%).

*Parameters	Stone spouts (n_1=15)	Wells (n_2=21)	Borings (n_3=27)	Municipal tap water (n_4=34)	Total (n_t=97)
Turbidity	0	13 (61.9)	8 (29.6)	12 (35.3)	33 (34.0)
EC	0	3 (14.3)	0	0	3 (3.1)
pH	0	0	0	0	0
T. Hardness	0	0	0	0	0
Sulphate	0	0	0	0	0
Chloride	0	0	0	0	0
Nitrate	0	0	0	0	0
Ammonia	0	4 (19.1)	9 (33.3)	3 (8.8)	16 (16.5)
Iron	6 (40.0)	14 (66.7)	27 (100.0)	0	47 (48.5)
Manganese	0	0	0	0	0
Arsenic	0	0	0	0	0

*Figures in parentheses indicate percentage.

Table-4: Number of water samples above WHO guideline value (%).

*Parameters	Stone spouts (n_1=15)	Wells (n_2=21)	Borings (n_3=27)	Municipal tap water (n_4 =34)	Total (n_t=97)
Turbidity	0	15 (71.4)	16 (59.3)	19 (55.9)	50 (51.6)
EC	0	6 (28.6)	2 (7.4)	0	8 (8.3)
pH	0	0	0	0	0
T. Hardness	7 (46.7)	15 (71.4)	12 (44.4)	16 (47.1)	50 (51.6)
Sulphate	0	0	0	0	0
Chloride	0	0	0	0	0
Nitrate	0	0	0	0	0
Ammonia	0	4 (19.1)	9 (33.3)	3 (8.8)	16 (16.5)
Iron	6 (40.0)	14 (66.7)	27 (100.0)	0	47 (48.5)
Manganese	0	0	0	0	0
Arsenic	0	0	0	0	0

*Figures in parentheses indicate percentage.

Turbidity: In the present study, well water samples showed the highest turbidity both in terms of its mean value (31.3NTU) and range (5.0 – 144.0NTU) while water samples from stone spouts showed lowest turbidity of all (Table-2). The NDWQS and WHO standard (Table-3, 4) for turbidity were found to be violated by 33 (34%) and 50 (51.6%) samples respectively. Among the water sources, 13 (61.9%) samples of well water exceeded the NDWQS permissible limit while the water samples from the same source exceeding the WHO standard reached to 15 (71.4%). None of the samples from stone spouts exceeded both the guideline values. High turbidity was also reported in the previous studies conducted in drinking water quality of Kathmandu metropolitan city[13-15]. Turbidity in water is an important indication of particulate matters present either in suspended or dissolved form. The particles may include sediments particularly algae, microorganisms, slit and clay, and other inorganic as well as organic matter[12]. They scatter light making the water appear cloudy and can reduce photosynthetic activity. Although health impact due to turbidity has not been reported, it may enhance the growth of microorganisms. Several disease-causing agents such as parasites, bacteria and viruses may provide indication for turbidity in water. Turbidity can also be a cause for headaches, diarrhea, nausea, cramps, and associated health disorder.

Electrical conductance (EC): It was found that well water showed the highest mean and range of EC value compared to other water sources. Of the total samples under investigation, 3(3.1%) water samples were found above NDWQS standard while 8 (8.3 %) samples exceeded WHO guideline value alone. Among them, 6(28.6%) well and 2 (7.4%) samples of bore well water crossed the maximum permissible limits of WHO standard while only 3(14.3%) well water exceeded NDWQS guideline. The higher values of EC were also reported in related works conducted by Bajracharya *et al.*[13], Tamrakar and Shakya[14] and ENPHO[16]. The EC value measures ionic mobility in water. Inorganic materials and other salts in dissolved state are responsible for electrical conductivity of water. Carbonate, phosphate, nitrate, chloride and sulphate as anions or iron, calcium, magnesium, iron, sodium, calcium, aluminum and potassium as cations show conductance in water[17]. Although there are very few reports on health impact due to EC in water, highly saline water and soil can be unfavorable for survival of plants and animals.

pH: Results revealed that the mean pH values of well and stone spout waters were found to be slightly alkaline; however the pH ranges of all water sources were found to be within the NDWQS as well as WHO guideline values. This means that the water samples from different sources showed the acceptable level of pH. Tamrakar and Shakya[14] and Tamrakar[15] also reported similar findings in groundwater and municipal tap water of Kathmandu Metropolitan city. pH value indicates free H^+ and OH^- ions in relative amount in water. The physico-chemical parameters that determine water quality may be altered with change in pH value[18]. The fluctuation in pH levels may be attributed to respiration and photosynthetic activities in water body. The acidity of water is more commonly due to CO_2. This increases carbonic acid and decreases water pH. Besides, a large variety of industrial discharges that contain considerable amount of acids, alkalies, bleaching materials, heavy metals, detergents etc., also alter the pH of receiving water[12].

Total hardness: It was found that water samples from stone spouts recorded the highest mean concentration (259mg/L) of total hardness followed by well water (254mg/L). While all water samples under the present investigation revealed total hardness as per NDWQS guideline, 50 (51.6%) samples of them simply crossed the WHO limit. Among the sources, well water showed the highest percentage (71.4%) exceeding the WHO guideline value for total hardness. Hardness of water is caused due to calcium and magnesium ions. Human diets also need the same elements which may be fulfilled to extent by drinking hard water but no health effect has been reported so far due to hardness of water.

Sulphate: Tests revealed that all four categories of water sources contained variable range and levels of sulphate. Municipal tap water showed the highest mean concentration of sulphate (55mg/L) under the present investigation whereas water from bore tubewell recorded the lowest mean concentration (15.5mg/L). None of the samples tested contained sulphate content above NDWQS and WHO guideline values. Sulphate ions are present in significant quantities in natural water. The anions are more stable in aqueous form and present in completely oxidized form of sulfur[19]. Sulfate is ubiquitous in groundwater system due to natural as well as anthropogenic activities. Sulphate mineral dissolution, sulphide mineral oxidation and atmospheric deposition are some of the primary sources of sulphate[20] whereas anthropogenic sources include metallurgical and phosphate refineries, power plants and coal mines[21]. Infants usually suffer from diarrhea by consumption of water with high sulphate concentration while adults generally digest it after a few days[22].

Chloride: Results revealed that the mean concentrations of well, tap water, boring water and stone spout water were found to be 120.7, 28.7, 6.9 and 4.9mg/L respectively. However, none of the tested samples in the present study violated the guideline values for chloride prescribed by NDWQS and WHO. Chlorides occur in all natural water system as NaCl, KCl and $CaCl_2$ in varying concentrations. They can be an indicator of pollution and are important in detecting the contamination of groundwater by sewage[23]. Agricultural runoff containing inorganic fertilizers, leachates from landfill sites, runoff containing road deicing salts, animal feeds, septic tank effluents, industrial effluents etc., are some of the notable sources of chloride contamination in ground water[24]. Human excreta, particularly the urine, contain chloride in an average amount of about 6g per person per day and increase the amount of chloride in municipal waste water[12] and the receiving groundwater.

Nitrate: Water samples from stone spouts showed the highest mean concentration of nitrate (43.40 mg/L) while municipal tap water showed the lowest nitrate contamination (0.48mg/L) in the present study. Similarly, well and boring water showed 22.55 and 40.24 mg/L as their mean nitrate levels respectively. However, none of the water sources crossed the NDWQS and WHO standard. Diwarkar *et al*[25] also reported nitrate concentration within the WHO and Nepal standards for all the water samples in their studies. Lake, river and groundwater may contain nitrate in varying amount. Sources of nitrate may include sewage disposal system, septic tanks, industrial and municipal wastewater, refuse dumps, animal feeds, decaying plant debris and urban drainage. They can also be contaminated into surface or groundwater directly from agriculture runoff containing nitrate in fertilizer[26]. Nitrate is often considered as a contaminant in drinking water (primarily from groundwater and wells) since it brings about harmful biological effects. Small children, infants, and fetuses suffer from nitrate in drinking water. When ingested into the body through drinking and other dietary sources, N-nitroso compounds (NOC) are formed by reacting nitrite and nitrate with amines and amides. They are carcinogenic for animals and human beings. The oxygen carrying capacity of blood in human may be reduced by high nitrate concentration in water, causing methemoglobinemia. Gastric and intestinal cancer has been reported due to nitrate[27].

Ammonia: In the present study, the highest mean value (33.9 mg/L) of ammonia was recorded in boring water and the lowest (0.41mg/L) in stone spouts. Of the total water samples under investigation, 16 (16.5%) samples crossed both the NDWQS and WHO guideline values for ammonia. Among the water sources, boring water showed the highest percentage (33.3%) of samples exceeding both NDWQS and WHO standards while the tested samples of water from stone spouts did not exceed the limit. High concentration of ammonia was also reported in the previous studies conducted in drinking water quality of Kathmandu Valley[13,28,29]. Ammonia (both from natural and artificial sources) may be contaminated with groundwater in varying concentrations. Nitrogen fixation processes, human and animal excreta, and forest fires are some of the natural sources of ammonia[30]. Artificial source of ammonia may include runoff of fertilized agriculture lands rich in ammonium compounds. Ammonia is one of the toxic pollutants that can cause reduction in growth, lower reproduction or even death. Ammonia at high pH is more toxic since they remain in the gaseous form. This gaseous form is detrimental to aquatic animals including fish. Water contaminated with ammonia only indicates the recent pollution due to sewage. While the nitrite with ammonia indicates the lapse of sometime for the occurrence of pollution, only nitrate form indicates that all nitrogenous matter has been oxidized. Bacteria can oxidize ammonia to nitrite (NO_2^-) and nitrate (NO_3^-), and finally used by plants. This gaseous compound in nitrite (NO_2^-) form is more toxic than nitrate (NO_3^-). Drinking water with high ammonia content may reveal severe symptoms such as shaking of hands or arms, agitation, drowsiness, personality changes and sluggish movement[31].

Iron: Among the water sources under the present investigation, well water was found to be heavily contaminated with iron showing 4.21mg/L as its' mean concentration. This was followed by water from bore tubewell having mean value of 2.5 mg/L. Of the total samples from four different water sources, altogether 47 (48.5%) samples crossed both the NDWQS and WHO guideline values. While all 27 (100%) boring water samples were found to exceed both the NDWQS and WHO standards, none of tap water samples from municipal supply crossed these limits. This means that all tap water samples under the present study followed the NDWQS as well as WHO guidelines. High iron content was also found in public tap water and different groundwater sources of Kathmandu Valley as reported in different studies[13,14,25,28,32]. Iron is present in nature such as in rivers, lakes and groundwater, soil, sediments and rocks. Drinking water may also be contaminated with iron from natural sources. Municipal and industrial wastes, refining of iron ores, and corrosion of pipes and pumps also contain iron[33]. Iron is essentially required in trace amount for human health. It acts as an oxygen carrier in the blood of mammals and fish as hemoglobin, and stores oxygen in muscle tissues as myoglobin. Although iron draws little concern as a health hazard, its' ingestion in large amount can damage blood vessels, kidneys and liver, and even cause death[34]. Iron can promote undesirable bacterial growth in water containing dissolved CO_2. It can develop slimy coating on pipes and screen and clog them. In addition, it can leave water with an unpleasant taste and odor and can even leave brownish stains on laundry, and fixtures with reddish-brown particles.

Manganese: Manganese was detected in all four sources of water to almost same levels in the present investigation. Municipal tap water, well, boring water and stone spout water contained 0.12, 0.09, 0.14 and 0.11mg/L respectively as their mean concentrations. However, none of the water samples was found to exceed both NDWQS and WHO guideline values. Manganese exists naturally in soils, surface and groundwater sources. Besides, manganese contamination in water is also from anthropogenic activities. The element in trace amount is also essential for proper metabolism in human body but is toxic when ingested in high concentration. It is an important factor for bone formation, blood-clotting and also in connective tissues. Besides, the element has a key role in calcium absorption, fat and carbohydrate metabolism and regulation of blood sugar[33].

Arsenic: Results revealed that all four sources of water from Kathmandu Municipality area were found to be free from any arsenic contamination. In other words, all the water samples from the area were found to be arsenic free as per the NDWQS and WHO guideline values. A study conducted by Dewakar *et al*[25] also found their water samples free of arsenic contamination. Arsenic is a ubiquitous element that occurs naturally in the earth's crust. It ranks 12^{th} in human body and 20th in natural abundance[35]. Pesticide application, mining operation, burning of fossil fuels and natural geography are some of the ultimate sources of arsenic. Arsenic shows four different oxidation states (-3, 0, +3 and +5) in the environment but the element in natural water may exist both in organic and inorganic forms. Inorganic forms of arsenic in +3 and +5 oxidation states are more detrimental to human health. As (III) is significantly more toxic and mobile than As (V). In natural waters with pH from 5 to 9, arsenic occurs predominantly as $H_2AsO_4^-$ (lower pH) and $HAsO_4^{-2}$ (higher pH) in +5 (arsenate) state and H_3AsO_3 in +3 (arsenite) state[36]. Arsenic contamination in water is of special concern for human because of its toxicity and persistent nature. Health risk due to arsenic includes skin cancer, gangrene, hematological poisoning, cardiovascular and nervous disorders[36].

Total coliforms: The microbial analyses showed total coliforms in 82 (84.5%) water samples (Figure-1). The result indicated positive test for total coliforms in water samples in majority. As for the microbial contamination range and risk level, only 15 (15.5%) of the total samples were found to be risk free as per the NDWQS and WHO guidelines of which 15 (44.1%) samples were contributed from municipal tap water alone (Table-5). None of the stone spouts, wells and boring water was found to be free from microbial contamination. Likewise, a very high risk was found in 15 (15.5%) samples and so for high risk category. Twenty one (21.7%) water samples were found to be of low risk. It was found that all the water sources revealed intermediate levels of risk to the maximum. Accordingly, a total of 31 (32%) samples fall to this risk category of which stone spout, well, boring water and municipal tap water contributed a maximum of 7 (46.7%), 7 (33.3%), 9 (33.3%) and 8 (23.5%) samples respectively. Considering the NDWQS and WHO guidelines for microbiological contamination, only 15 (15.5%) of the total water samples was found to obey them while the rest 82 (84.5%) exceeded both the limits. This means that only 15 (15.5%) of the total water samples was total coliform count negative. Among the sources, only 15 (44.1%) municipal tap water was found within both the guideline values (0 cfu/100ml) while 19 (55.9) samples crossed the limits. Results from source wise distribution of coliform count clearly revealed that stone spouts 15 (100 %), wells 21 (100%) and bore water 27 (100%) exceeded both the NDWQS and WHO standards. The results are in agreement with Diwakar *et al*[25], Pant[32], Prasai *et al*[37] and Koju *et al*[38] who also reported microbial contamination in water from different sources such as tap water, stone spout, well, tube well water exceeding both Nepal standard and WHO guideline value.

Table-5: Number and percentage showing microbial contamination and risk levels in different water sources based on total coliform count.

Microbial contamination ranges /Risk level	Stone spouts (n_1=15)	Wells (n_2=21)	Borings (n_3=27)	Municipal tap water (n_4=34)	Total (n_t=97)
0/ risk free	0	0	0	15 (44.1)	15 (15.5)
1-10/Low risk	3 (20)	5 (23.8)	6 (22.2)	7 (20.6)	21 (21.7)
10-100/Intermediate risk	7 (46.7)	7 (33.3)	9 (33.3)	8 (23.5)	31 (32)
100-1000/High risk	3 (20)	3 (14.3)	7 (25.9)	2 (5.9)	15 (15.5)
> 1000/ Very high risk	2 (13.3)	6 (28.6)	5 (18.5)	2 (5.9)	15 (15.5)
Total	15 (100%)	21 (100%)	27 (100%)	34 (100%)	97 (100%)

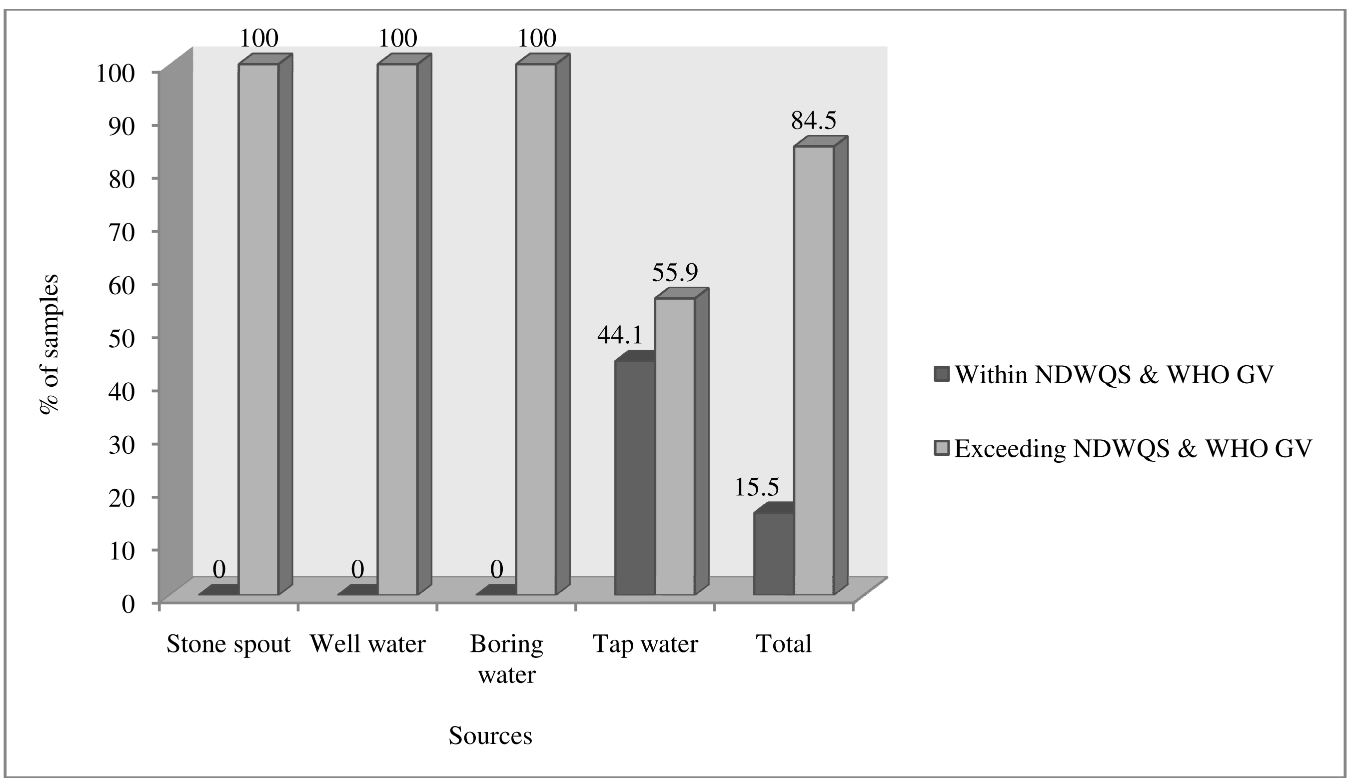

Figure-1: Percentage of water samples against NDWQS and WHO guideline values based on total coliform count with respect to different water sources.

Fecal matter is the potential source of bacteriological contamination in surface and groundwater. Bacteria belonging to coliform group are often treated as the indicator of fecal contamination. Therefore, they are often used in water quality assessment. Coliform bacteria may get contaminated with river or groundwater through surface runoff, especially after a heavy rainfall[39]. Fecal matter in water can seep into water sources like spring, dug well, tube well, stone spout etc. The bacterial population may pollute not only the environment but also affect human health by water borne diseases like cholera, hepatitis, typhoid fever, dysentery, gastroenteritis etc[39]. It is often difficult to detect specific disease-causing organisms in water that we drink every day. Therefore, indicator organisms of faecal origin are often detected in drinking water. Besides, unrepaired old pipeline systems, irregular supply of drinking water in the pipeline, improper drainage system, pipeline leakage and untreated water sources are some of the principal reason of microbiological contamination in water sources affecting drinking water quality[12].

Conclusion

In this study, four different water sources *viz.*, stone spouts, wells, borings and municipal tap water in Kathmandu Municipality area were evaluated for drinking water quality by their physico-chemical properties and microbial contamination levels in pre-monsoon season. Results revealed variable ranges and mean concentrations of the parameters among the water sources. The results were also compared against NDWQS and WHO standards. pH, sulphate, chloride, nitrate, ammonia, manganese and iron levels in water samples from all sources followed both NDWQS and WHO guidelines. Of the total water samples under the present investigation, 33 (34%), 3 (3.1%), 16 (16.5%) and 47 (48.5%) samples of water exceeded NDWQS limits for turbidity, electrical conductivity, ammonia and iron content respectively whereas 50 (51.6%), 8 (8.3%), 16 (16.5%) and 47 (48.5%) samples crossed WHO standard respectively for the same parameters. As for the microbial contamination levels, results showed total coliforms in 82 (84.5%) of the total water samples exceeding both NDWQS and WHO standards. Only 15 (15.5%) of the total samples were found to be risk free of which 15 (44.1%) samples were contributed from municipal tap water alone. From the present study, it can be concluded that the drinking water status in Kathmandu Municipality area is not yet satisfactory for safe and healthy consumption by the people. We, therefore recommend for launch of effective planning and policies, and management practices for safe water supply and environmental sanitation by the concerned authorities.

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