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Comparative Study of Untreated and Ozonated Well Water from Bhaktapur Municipality, Nepal

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Abstract: *This study is based on comparison of the quality of well water before and after ozonation. The study was conducted in eight different sites of Bhaktapur Municipality in November 2016 to February 2017. Different water quality parameters such as Temperature, pH, Electric Conductivity, Dissolved Oxygen, BOD, Total hardness, Ca-hardness, Mg-hardness, Iron, Total coliform, Fecal coliform and Non-coliform were analyzed. The study determined physico-chemical and microbial quality of well water sources before and after treatment. There were no significant changes in conductivity of water from eight different sources before and after treatment. Conductivity values remained stable before and after treatment. pH of water after treatment varied slightly with respect to pH of untreated water. DO of all samples increased significantly after ozonation. BOD of samples decreased after ozonation. There was overall decrease in Total hardness, Magnesium hardness and Calcium hardness after treatment. Iron in its ferrous state had charge of 2+. When ozone was passed through the solution containing ferrous salts, it contributed oxygen atom that reacted with Fe^{2+} resulted to ferric salt and hence concentration of Fe^{2+} decreased. There was overall decrease in microbial parameters (Total coliform, Fecal coliform and Non-coliform).*

Keywords: *Ozonation, water, ozone.*

1. INTRODUCTION

Availability of water for human consumption is decreasing everyday, eventually growing pollution and discharge of more than 80% of sewage without treatment results water pollution despite the effort to improve its quality in developing countries (WWAP, 2009). Dielectric Barrier Discharge (DBD) is one of the emerging technologies suitable for wastewater treatment (Eliasson et al., 1978). Water purification by conventional methods are either costly or have limited efficiency, similarly researches have revealed that many years of chlorine use for water disinfection has been concluded to be harmful for human health. This has raised concern for an effective method of water treatment (Subedi et al., 2012). Water purification by ozone synthesis is an industrially accepted application of electrical discharges (Bubnov et al., 2004; Chang & Wu 1997; Eliasson et al. 1987). Conventional chlorination process is being replaced by ozonation process due to its strong oxidising and effective disinfectant nature without any side effect (Kurica et al., 2004, Malik et al., 2001). This technology avoids chemical storage and handling; its by-products have no adverse effects to human health and environment, it safely destroys broader range of organic contaminants and removes colour, odour and suspended solid materials (Rajeshwari et al., 2001). Moreover, ozone is highly efficient in killing bacteria, viruses, spores and cysts (Malik et al., 2001).

2. Experimental Set Up of DBD

This study used DBD technique to produce ozone out of the various methods of ozone production. High voltage auto cut power supply was used to generate discharge from coaxial DBD operated at 26 kHz. Central rod made up of brass was placed inside the tube and connected to anode while cathode was connected to sheet of aluminium shielded outside the tube. The gap between the anode and the glass that passes the gas inside the tube was 1.85 mm. The concentration of ozone passed was 0.2mg/l. Diameter of brass rod was 3.18 mm; length of outer electrode and central electrode was 4.73 cm and 12.54 cm respectively. Thickness of dielectric (glass) was 1.88 mm, internal diameter of glass was 8.05mm, and thickness of aluminium sheet was 0.14mm. The experimental setup used for ozone generation in this study is shown in figure 1.

In DBD reactor the electrical discharge takes place between electrodes where at least one of the electrodes is covered with a thin layer of dielectric material. This dielectric material is a type of insulator made of ceramic, glass, PVC, and so forth. AC voltage is applied across the electrode and discharge generated with the production of UV. The discharge is organized through many filamentary channels of streamers, 100–200μm in diameter. Air is passed through the DBD under high energy electrons within the inter electrode space and the dissociation of oxygen molecules occurs. Ozone is produced by the combination of atomic oxygen and another oxygen molecule ($O_2 \rightarrow O^* + O^*$; $O^* + O_2 \rightarrow O_3$). Ozone is released into water where it oxidizes various organic and inorganic chemicals present in water and converts them into simpler form, which is decomposed in the nature (Malik et al., 2001).

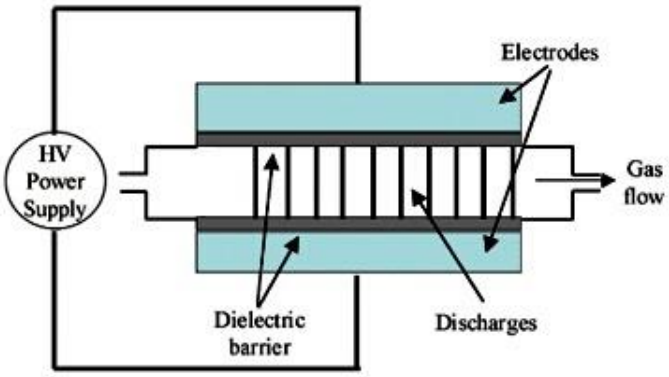

Figure 1. *Experimental set up of DBD*

3. Materials and Methods

This study was carried out in Bhaktapur Municipality using random sampling. Eight samples of well water were collected from Nagancha (NA), Nasley (NS), Gauchhen (GA), Taullachen (TA), Chochhen (CH), Tuchimala (TU), Khhichey (KH) and Balakhu (BA). Sample water was treated in the Physical laboratory of Khwopa Engineering College while water quality was tested in Environmental laboratory of Khwopa College. The treatment was carried out by bubbling ozone to bottom of the beaker containing the sample of water. Each 100 ml of sample were treated for two minutes. Temperature was measured by Thermometer, pH and Conductivity were measured by digital pH meter and conductivity meter respectively. DO was determined by Wrinkle Iodometric method. Water sample was filled in BOD bottle; 2 ml of $MnSO_4$ and KI was added, and precipitate appeared. Contents were shaken in figure 8 repeatedly. Then 2ml of concentrated H_2SO_4 was added. 50 ml of content was taken in conical flask and titrated against $Na_2S_2O_3$.

$$\text{Dissolved Oxygen (mg/L)} = \frac{\text{Vol X Normality of Na2S2O3 X 8 X 1000}}{\frac{\text{V2 (V1-V)}}{\text{V1}}}$$

BOD was also determined by Wrinkle Iodometric method.

BOD (mg/l) = $(D_0\text{-}D_5) \times$ dilution factor

Total hardness and Calcium hardness was determined by titrating 50 ml of sample against EDTA solution using Erichrome Black T indicator and Murexide indicator respectively.

$$\text{Total Hardness (mg/1 CaC03)} = \frac{\text{Vol of EDTA used X 1000}}{\text{Vol of sample taken}}$$

$$\text{Calcium Hardness (mg/1)} = \frac{\text{Vol of EDTA used X 400.8}}{\text{Vol of sample taken}}$$

Magnesium Hardness (mg/l) = Total Hardness (as mg/l $CaCO_3$) – Calcium Hardness (as mg/l $CaCO_3$)

Iron was determined by using Spectro-photometry at 510 nm.

Total coliform, Fecal coliform and Non-coliform were determined by using Membrane filter. 100 ml of sample was poured into membrane filter funnel. Member filter was transferred on EMB. The agar plate was incubated at 37ºC for 24 hrs and thus colonies developed on filter were enumerated.

Table 1. *Parameters and its test methods*

Parameters	Units	Test methods
Temperature	ºC	Thermometer
pH	-	pH meter
Conductivity	µs/cm	Conductivity meter
DO	mg/ml	wrinkles Iodometric method
BOD	mg/l	wrinkles Iodometric method
Total hardness	mg/l	EDTA titrimetric
Calcium hardness	mg/l	EDTA titrimetric
Magnesium hardness	mg/l	EDTA titrimetric
Iron	mg/l	spectrophotometer
Total coliform, Fecal coliform, Non-coliform	CFU/100ml	Membrane filter Method

4. Result and Discussion

A. Physico-Chemical Parameters

1. Temperature Analysis

Temperature of sample water varied between 12°c to 15°c while temperature of treated water varied between 13°c to 14°c. The temperature variation might be due to difference in timing of sample collection.

2. Conductivity Analysis

The conductivity of water sample was within World Health Organization (WHO) standard i.e. 1500 µS/cm. The conductivity of untreated water sample ranged between 146 µS/cm and 410 µS/cm. While conductivity of treated water sample ranged between 147 µS/cm and 384 µS/cm. The conductivity of five samples increased after ozonation (NAU<NAT, GAU<GAT, TAU<TAT, KHU<KHT, BAU<BAT) while conductivity of other three samples decreased after treatment (NSU>NST, CHU>CHT, TUU>TUT). There was no significant change in conductivity of water from the eight sources before and after treatment. Since the electrical conductivity is a measure to the capacity of water to conduct electrical current, it is directly related to the concentration of salts dissolved in water (Radtke et al., 2005) and ozonation does not contribute to addition of extra ions (Subedi et al., 2012). According to Patrick et al. (2007), the value of conductivity remains stable before and after the treatment. Another study done by Tyata (2009), reported that conductivity varied slightly before and after treatment, i.e. conductivity of untreated water was in range 37−903 µScm−1 and conductivity of

treated water was in range 40−900 μScm^{-1}. Conductivity was found to increase or decrease slightly in treated water than untreated water that resembles our result.

3. pH Analysis

Out of the eight samples, pH of six samples increased after ozonation (NAU<NAT, GAU<GAT, TAU<TAT, TUU<TUT, KHU<KHT, BAU<BAT) and pH of two samples decreased after ozonation (NSU>NST, CHU>CHT). pH of untreated water ranged between 7.27 to 8.99 while that of treated ranged between 7.53 to 9.13 which shows that pH of treated water varied slightly compared to pH of untreated water. WHO acceptable concentration of pH in drinking water is 6.5 to 8.5 and allowable concentration is 9.2, and thus the pH of treated sample lied within WHO standard. According to Patrick et al. (2007), the value of pH remains stable before and after the treatment. Khadgi et al. (2012) reported that there was no statistical significant difference in the value of pH before and after the treatment like this study.

4. Dissolved Oxygen (DO) Analysis

DO of water sample were between 1.21 mg/l and 6.89 mg/l. DO increased significantly after ozonation for all samples which were between 6.48 mg/l and 8.10 mg/l. DO levels depend on ambient temperature, atmospheric pressure, ion activity, atmospheric aeration, production through photosynthesis, many chemical and biological reactions in ground and surface water (Lewis 2006). Bhatta et al. (2015), found that the value of DO increased significantly after treatment which resembles our findings in this study.

5. Biological Oxygen Demand (BOD) Analysis

BOD is the measure of the degradable organic material present in a water sample and can be defined as the amount of oxygen required by the bacteria and microorganism in stabilizing the biologically degradable organic matter under aerobic conditions at a specified temperature (Delzer et al., 2003). BOD must be zero in drinking water. BOD of sample water ranged between 4.05 mg/l to 22.30 mg/l while that of treated ranged between 0 mg/l to 22.30 mg/l. Out of eight samples, BOD of four samples remained constant before and after treatment (NAT=NAU, NST=NSU, GAT=GAU, CHT=CHU). It might be due to delay in laboratory analysis while in four samples there was significant decrease in BOD after the treatment.

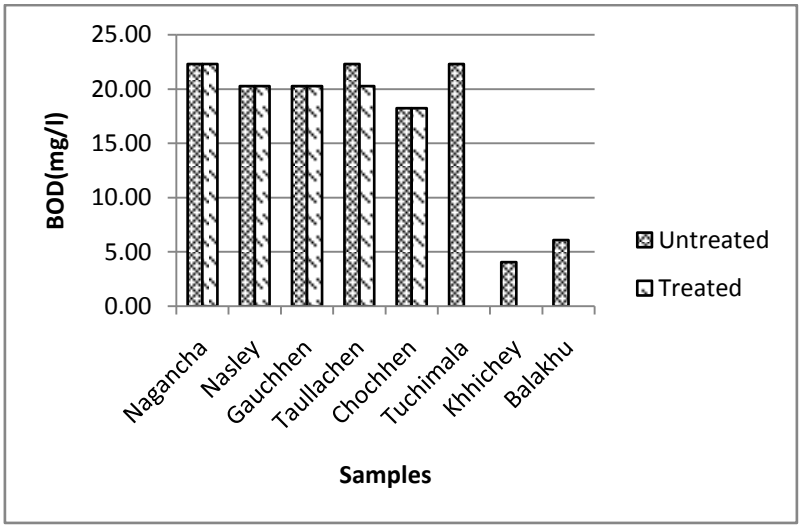

Figure 2. *BOD of samples*

6. Total Hardness Analysis

Among eight samples, Total hardness of all samples decreased after treatment. Total hardness of sample water was within WHO standard i.e. 500 mg/l. Total hardness of untreated sample ranged between 144 and 434 while that of treated water ranged between 128 to 426. There was overall decrease in Total hardness after treatment. Hardness is not regarded as pollution parameter because it does not harm health in a major way. However, very hard water affects human health as it creates favorable condition for existence of harmful organisms. According to Subedi et al., (2012), the Total hardness of tap water and stone spout was found to decrease after the treatment as like in this study.

7. Calcium Hardness Analysis

Calcium hardness of untreated sample ranged between 32.06 and 125.85, which decreased after treatment ranging between 24.85 and 124.25. According to Subedi et al. (2012), the Calcium hardness of tap water, stone spout and tube well decreased after treatment.

8. Magnesium Hardness Analysis

Magnesium hardness of six water samples decreased while two samples increased after treatment. Water samples before and after treatment were recorded 105.91mg/l to 345.82mg/l and 103.15mg/l to 345.04mg/l respectively.

9. Iron Analysis

After ozonation, concentration of iron decreased in three samples (NAU>NAT, CHU>CHT, KHU>KHT. Iron was not detected from two samples before and after treatment. In remaining three samples there was increase in iron concentration after treatment. According to Subedi et al, (2012) concentration of iron in well water, was 18.91 mg/l before treatment and 16.37 mg/l after treatment. The Fe^{2+} concentration was found to decrease in tap water, stone spout and tube well samples after treatment. Ferrous state iron has charge of 2+. When ozone is passed through the solution containing ferrous salts, the oxygen atom generated from ozonation reacts with the Fe^{2+} to give ferric salt and hence concentration of Fe^{2+} decreases.

Table 2. *Physico-chemical parameters before and after treatment*

S.N.	Location	Temperature (°C)		Conductivity (µS/cm)		pH		DO(mg/l)		Iron(mg/l)	
		UT	T	UT	T	UT	T	UT	T	UT	T
1.	Nagancha (NA)	12	13	146	147	8.54	8.7	3.65	7.30	1.45	1.1
2.	Nasley (NS)	15	13	168	167	8.06	7.9	3.65	7.30	0.05	0.2
3.	Gauchhen (GA)	12	13	199	216	7.52	7.7	1.22	7.70	1.25	1.65
4.	Taullachen (TA)	13	13.5	154	163	7.27	7.53	4.46	7.30	0	0.1
5.	Chochhen (CH)	14	14	363	362	8.91	8.05	5.27	6.49	0.1	0.05
6.	Tuchimala (TU)	13	13	410	384	8.47	9.07	6.89	8.11	0	0
7.	Khhichey (KH)	13	13.5	312	314	8.86	8.93	4.87	8.11	0.2	0.05
8.	Balakhu (BA)	14	14	172	173	8.99	9.13	6.89	7.30	0	0

Table 3. *Chemical parameters before and after treatment*

S.N.	Location	Total hardness (mg/l)		Calcium hardness (mg/l)		Magnesium hardness(mg/l)	
		UT	T	UT	T	UT	T
1.	Nagancha (NA)	268	240	64.128	59.3184	203.872	180.6816
2.	Nasley (NS)	150	144	44.088	32.064	105.912	111.936
3.	Gauchhen (GA)	328	314	125.8512	124.248	202.1488	189.752
4.	Taullachen (TA)	144	128	32.064	24.8496	111.936	103.1504
5.	Chochhen (CH)	368	348	71.3424	66.5328	296.6576	281.4672
6.	Tuchimala (TU)	434	426	88.176	80.9616	345.824	345.0384
7.	Khhichey (KH)	384	370	72.9456	68.9376	311.0544	301.0624
8.	Balakhu (BA)	176	172	45.6912	40.08	130.3088	131.92

Note: UT-Untreated; T-Treated

B. Microbial Parameters

1. Total Coliform Analysis

The coliform group are defined as "all of the aerobic and facultative anaerobic, gram-negative, non-spore forming rod-shaped bacteria which ferment lactose with gas formation within 48 hours at 35 °C." (Amer. Public Health Assoc. et al., 1965). Total coliform of seven samples decreased

significantly i.e. NSU>NST, GAU>GAT, TAU>TAT, CHU>CHT, TUT>TUT, KHU>KHT, BAU>BAT. The maximum value of Total coliform in untreated sample ranged between 8 and 102 while that of treated ranged between 0 and 154. The total coliform of Chochhen (CHT) and Khichhen (KHT) decreased to zero that means this well water is drinkable after ozonation. The increase in Total coliform after treatment i.e. NAU<NAT might be due to contamination during laboratory analysis or during storage. Total coliform is none detectable per 100 ml (WHO 1996). According to Patrick et al. (2007), the use of Daguaflo-UMF process followed by a final disinfection decreased the Total coliform despite high levels of Total coliform was detected in raw water. After disinfection, Total coliforms should be absent immediately, and their presence indicates inadequate treatment if Total coliform is present in distribution systems and stored water supplies can reveal regrowth and possible biofilm formation or contamination through ingress of foreign material, including soil or plants (WHO 2006).

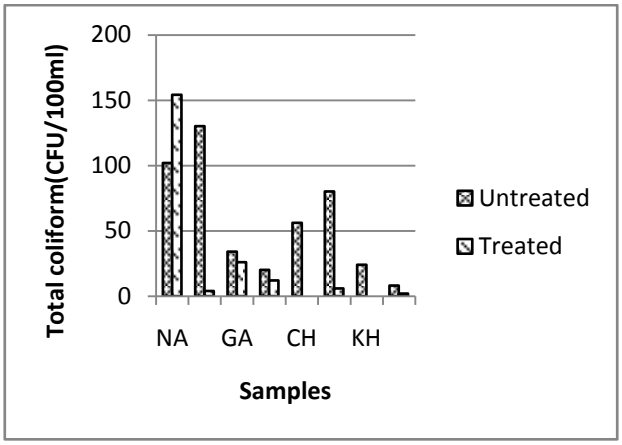

Figure 3. *Total coliform of samples*

2. Fecal Coliform Analysis

Fecal Coliforms are bacteria and are a normal part of feces of warm-blooded animals. Fecal coliform decreased significantly after treatment. Maximum fecal coliform was found in sample of BAU (66 CFU/100ml) while minimum in sample of CHU (4 CFU/100ml). After treatment maximum, fecal coliform was found in TAT (16 CFU/100ml) while minimum in KHT and BAT (0 CFU/100ml). According to WHO standard, Fecal coliform should be zero CFU/100ml in drinking water. Fecal coliform of Khichhen (KHT) and Balakhu (BAU) was completely removed, after the ozonation. Study done by Subedi et al. (2012) on the analysis of water subject to ozone also indicated a remarkable decrease in fecal coliform. In the case of tap water, stone spout and tube well the mean value of fecal coliform was 84 CFU per 100 mL, 5 CFU per 100 ml, 250 CFU per 100 mL before the treatment, which was reduced to 8 CFU per 100 ml, completely removed, 4 CFU per 100 ml after treatment respectively. The presence of fecal coliform in well water may indicate recent contamination of the groundwater by human sewage or animal droppings, which could contain other bacteria, viruses, or disease-causing organisms. Their presence warns of the potential presence of disease causing organisms

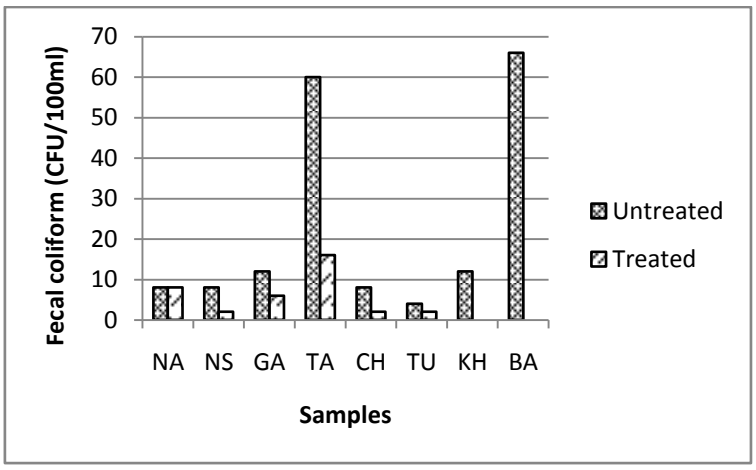

Figure 4. *Fecal coliform of samples*

3. Non-Coliform Analysis

Non-coliform bacteria are mainly environmental organisms and in large numbers can compete with total coliform and make it difficult for coliform(s) to be detected. High levels of non-coliform bacteria indicate a reduction in water quality (Flint, 2011). Non-coliform does not ferment lactose and are pathogenic (true pathogens). Non-coliform samples are Salmonella typhi, Shigella dysenteries. Non-coliform of six samples decreased significantly i.e. NAU>NAT, NSU>NST, GAU>GAT, TAU>TAT, CHU>CHT, KHU>KHT. The non-coliform of untreated sample ranged between Too Numerous to Count (TNC) and zero while that of treated ranged between 168 and 0. The increase in non-coliform after treatment might be due to contamination while doing laboratory analysis or during storage.

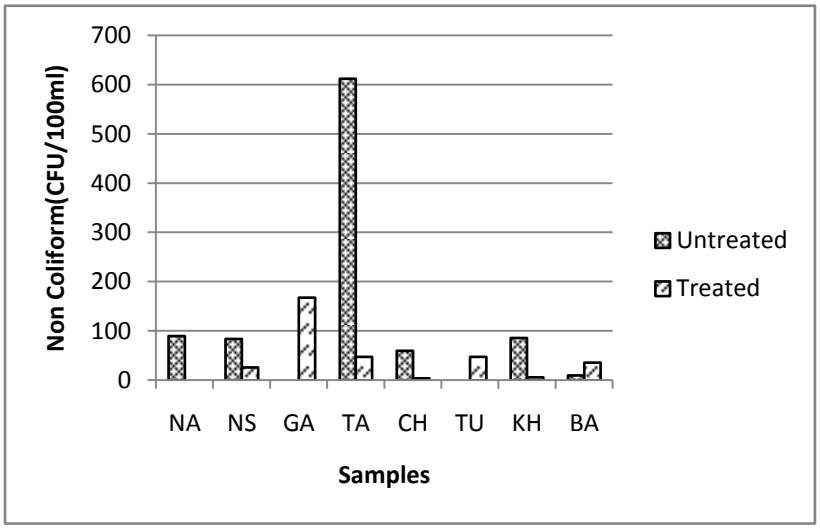

Figure 5. *Non-coliform of samples*

Non-coliform of GAU was TNC.

5. CONCLUSION

Conductivity is directly related to amount of dissolved water and ozonation does not contribute to addition of extra ions. Our finding also shows no significant change in conductivity of water before and after treatment. pH of water after treatment varied slightly with respect to pH of untreated water. DO of all samples increased significantly after ozonation. DO levels depend on the water and atmosphere interface, production through photosynthesis, consumption by plants, animals and decomposer organism in respiration. BOD of samples decreased after ozonation. There was overall decrease in Total hardness, Magnesium hardness and Calcium hardness after treatment. Iron in its ferrous state has charge of 2+. When ozone is passed through the solution containing ferrous salts, it contributes the oxygen atom that reacts with the Fe^{2+} to give ferric salt and hence concentration of Fe^{2+} decreases. There was overall decrease in microbial parameters (Total coliform, Fecal coliform and Non-coliform). Our study showed that ozonation do not have significant role in physical parameters of water but microbial parameters such as Total coliform, Fecal coliform and Non-coliform of water are significantly reduced to the level that are harmless for human consumption.

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