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Treatment of water using Arc discharge plasma in Patan area

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Abstract

The quality of drinking water has been degraded and declining day by day and its impact is directly seen on human health and other organisms too. So, the way we want to solve this problem by using new technology which was not based on the Plasma Treatment. Plasma based technology which is one of the best and new technology it takes a short time for improvement of water quality. Water sample collected from various sources within Patan from different sources such as Jar water, Ground water, Tap water and Stone spout water.

The concentration of ammonia in the Jar and Tap water increased at 10 seconds after the sample was treated with Plasma. The hardness of groundwater increased significantly in all time periods as compared to without treatment. Overall, the hardness of Tap water decreased when treated with Plasma. But in case of Stone Spout water, hardness increased during 5 and 15 seconds whereas it decreased at 10 seconds. The concentration of Chloride only decreased in case of Jar water whereas there was a significant increase in its amount in all other remaining samples in each time factors i.e., 5,10,15 seconds. By using this technology water quality can be improved within short time.

Keywords: Bacteria, Plasma, Patan, Treatment & water quality.

1.Introduction

1.1 General Introduction

Plasma is considered the fourth state of matter. The three other states are solid, liquid, and gas. Plasma is a cloud of protons, neutrons and electrons where all the electrons have come loss from their respective molecules and atoms, giving the plasma the ability to act as a whole rather than as a branch of atoms. Just as a liquid will boil, changing into a gas when energy is added, heating a gas will form a plasma- a soup of positively charged particles(ions) and negatively charged particles(electrons). A plasma is more like a gas than any of the other state of matter because the atom is not in constant contact with each other, but it behaves differently from a gas. It has what scientists call collective behavior. This means that the plasma can flow like a liquid or it can contain areas that are like clumps of atoms sticking together [1].

High-voltage (HV) electric discharge in water is able to do various reaction such as degradation of organic compound, the destruction of bacteria and viruses, the oxidation of inorganic ions, and the synthesis of nanomaterial and polymers[2]. For the improvement of water quality based on the plasma treatment and to developed the way for the reactor design to maintain the quality, water has been treated with plasma for different time. The removal rate constant of impurities has been found directly proportional to the area of plasma liquid interface [3]. For the impact of strong electric field in water and organic liquid we have to inject plasma in water for removal of waste chemical, biological and environmental product in it [4]. The seasonal weather variation, climate change, increase in population are vital causes of water pollution. Water reuse is a direct process of wastewater for either indirectly or directly potable water reuse. For both case advance treatment technologies will be required to process the water to the point where it can be reuse in a meaningful way. Many micropollutants, such as pharmaceutical and personal care product are growing, which have been detected in drinking water. The impact of this micropollutants on the health is not well understood.

For the removal of these contaminants from water a new advance technology is required. One of new and emerging technology that could potentially address the removal of micropollutants in both drinking water as well as wastewater slated for reuse is plasma-based water purification. When plasma get contact with liquid water it generates a host of reactive species that attack and ultimately mineralized contaminants in solution. The development of plasma diagnostics used in this multiphase environment along with modeling efforts aimed at elucidating physical processes taking place [5]. Plasma generates highly reactive particles in the form of liquid or gas-liquid that attack the pollutant molecules in the water and reduce it [6]. The unused medicine gets dispose in the garbage of the home for a long time. Due to this our water resource get toxic effect and many aquatic animals, plants and microorganisms will be affected from it [7]. Plasma treatment with water is a chemical free and eco-friendly process. Plasma activate in water can change the redox potential, conductivity and formation of reactive oxygen and nitrogen species. It is an alternative process for microbial disinfection[8]. It is the advance oxidation process into water for purification. This technology can make a great revolution on the purification of drinking water[9]. Distributing fresh water in the world is a big challenge. Purification of the water through different process is a way to resolve it. So plasma based process is the emerging way of purification of drinking water[10]. The rapid population growth and industrialization induced the shortage of pure drinking water globally. Organic contaminant and pollution of existing water supply is the main cause of water pollution. One of the best and easiest way for purification of drinking water is non-thermal advance oxidation process (AOP). Plasma gets injected in the aqueous solution and high range of ultraviolent ray and other plasma species get contact with water and remove the contaminant presence in drinking water. For treating organic pollutant, it is one of the best alternative and advantage methods[11].

2. Literature Review

In this field, a tremendous amount of work has been already done up to this date. In 14 April 2021 plasma treated water solution which generate reactive oxygen and nitrogen species (ROS and RNS) in liquid where the presence of ROS with strong power like hydrogen peroxide has been purposed as the main cause for cancer killing properties. RNS with nitric oxide are used in the activation of antioxidant responses and survival of cell [12].

Further, It has been observed that the change in physical parameter like pH, turbidity, conductivity and biological parameter when water has been treated with plasma using dielectric barrier discharge. In plasma treatment, the germination rate has been found higher. Shoot length, seeding length and germination rate has been found increase as compared to those germinated by normal water irrigation[13].The rate of growth and germination has been found significant when plasma activated water is used for the seed germination and seedling growth of radish, fenugreek and pea seed. This effect has been evaluated based at 7 and 12 days after treatment[14]. It has been found that perfluorooctanoic acid (PFOA) was reduced by 90% during the treatment of water up to 30 minutes. But in case of ground water, it has no significant role to reduce perfluorooctanoic acid (PFOA)[15].

Plasma has been used in industrials and agricultural sector. It has been investigated that the potential of plasma-activated water for seed performance enhancement in maize. It was carried out in two lots of maize seeds with a one-year difference in age. It has been found that the best protocol enhancing seed vigor and germination performance of maize[16]. It has been found that 98% of arsenic from ground water has been removed by non-thermal plasma treated for 30 min and after coagulation and membrane filtration[17].

Pharmaceutical compound was important class of water pollutants due to their increasing consumption over the last year. In 15 September 2015 it has been found that the oxidative degradation of pharmaceutical using non-thermal plasma in contact with water[18].

The removal of several water pollutants like methylene blue, phenol, paracetamol, caffeine and ceftriaxone by dielectric barrier discharge non-thermal plasma reactor was studied. After 5 minutes of treatment complete degradation and mineralization of methylene blue and ceftriaxone was found which took 15 minute for phenol and paracetamol and 25 minute for the caffeine[19].

Discharge plasma is a new advance oxidation technology for water treatment. It has been found that the degradation of phenolic pollutants, pharmaceuticals, dynes and personal care products when it gets treated with plasma. It explains well about plasma catalytic oxidation system and development of its application in the water treatment[20].

The presence of virus in water is a major risk for human and animal health due to their high resistance to disinfection. In 15 January 2022 it has been found that pulsed corona discharge plasma (PCDP) significantly inactive bacteria by causing damage to biological macromolecules. The inactivation efficiency was significantly improved by applying high

input energy density caused by voltage. This show that it has significantly implication for water borne virus removal and development of novel disinfection technologies[21].

3. Materials And Methods

3.1 Study Area

The area of study is located at Patan Lalitpur Sites. This is one of the place listed in world heritages site.

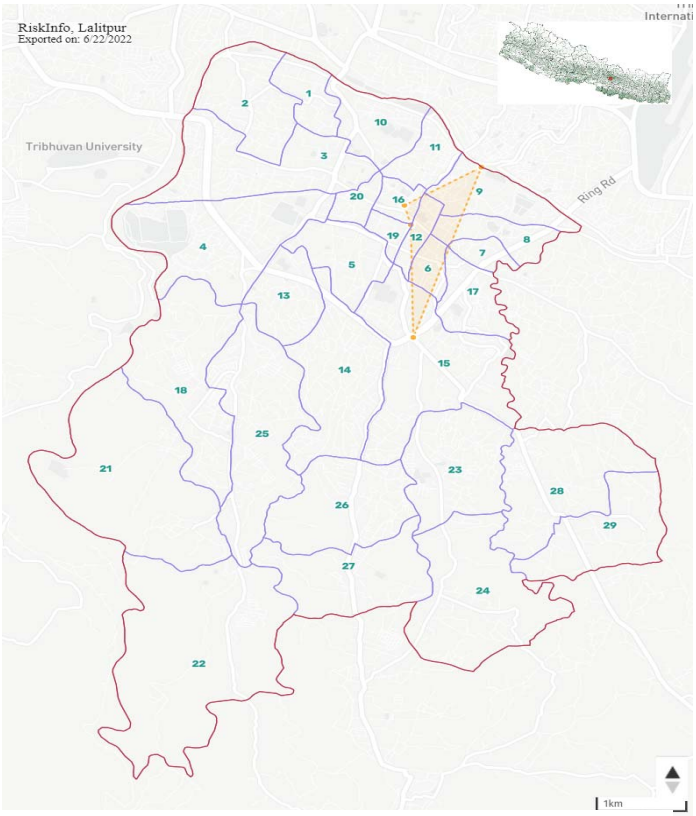

Figure 3.1: Patan Area (Study Area of project)

3.2 Water sample collected from various place of Patan from different sources.

Water sample have been collected from various place of Patan from different sources. Water has been collected in the liter bottle provided by NAST. Sample have been collected only after rinsing the bottle with the sample up to 2 times. Stone spout water sample has been collected from Chysal of Patan. Tap water sample has been collected from Loule, Patan. It has been stored one day before sample was collected. Underground water has been collected from Mangal bazar of Patan area.

3.3 Water sample treated with plasma.

Water sample collected from different sources has been treated with plasma for various time period. Each of water sample were treated for 5sec,10 sec and 15 sec of time period. The bottle used for sample has been distilled. Stop watch has been used for the time calculation. After finishing plasma treatment, sample has been taken for lab test in NAST.


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3.4: Lab test of Ammonia, Nitrate and Arsenic.

3.4.1 Test of Ammoniain water

S. N	Sample of water	Without treatment of Plasma (mg/lit)	5 sec	10 sec	15 sec
1	Jar water	0	0	0.2	0
2	Ground water	10	10	10	10
3	Tap water	0.2	0.2	0.5	0
4	Stone spout water	0	0.2	0.2	0

Table1 Test of Ammonia in water

3.4.2 Test of Nitrate in water

S. N	Sample	Without treatment of plasma (mg/lit)	5 sec	10 sec	15sec
1	Jar water	0	2	2	0
2	Ground water	15	15	15	15
3	Tap water	2	2	8	2
4	Stone spout water	10	15	8	10

Table 2 Test of Nitrate in water

3.4.3 Test of Arsenic in water

S. N	Sample	Without treatment of plasma (mg/lit)	5 sec	10 sec	15 sec
1	Jar water	0	0	0	0
2	Ground water	0	0	0	0
3	Tap water	0	0	0	0
4	Stone spout water	0	0	0	0

Table 3 Test of Arsenic in water

3.5 Lab test of pH and Conductivity

3.5.1 Test ofpH in water

S. N	Sample	Without treatment (mg/lit)	5 Sec	10 Sec	15 Sec
1	Jar water	8.08	8.05	8.12	8.14
2	Ground water	6.76	7.67	7.62	6.73
3	Tap water	7.08	8.33	8.22	7.09
4	Stone spout water	6.89	8.21	8.11	7.02

Table 4 Test of pH in water

3.5.2 Test of Conductivity in water

S. N	Sample	Without treatment (mg/lit)	5 Sec	10 Sec	15 Sec
1	Jar water	14.17	6.89	6.6	16.4
2	Ground water	680.5	311.3	314.8	689.4
3	Tap water	237.1	104.4	105.5	238.4
4	Stone spout water	663.4	293.1	307.5	666.9

Table 5 Test of Conductivity in water

3.6 Lab test of Turbidity

3.6.1 Test of Turbidity in water

S. N	Sample	Without treatment (mg/lit)	5 Sec	10 Sec	15 Sec
1	Jar water	1.01	8.05	8.12	1.27
2	Ground water	8.95	7.67	7.62	9.93
3	Tap water	1.34	8.3	8.22	1.49
4	Stone spout water	0.94	8.21	8.11	1.24

***T*able 6** Test of Turbidity in water

3.7 Lab test of hardness.

50 mL of water sample was taken in a conical flask. 1 mL of ammonium buffer solution was added to it. Then, 100-200 mg of Eriochrome black T indicator was added to the mixture. The mixture was titrated against EDTA solution until the color change from wine red to blue.

$$Total\ hardness\ \left(\frac{mg}{L}\right) = \frac{Volume\ of\ EDTA\ used * 100}{Volume\ of\ sample\ taken}$$

3.7.1 Test of Hardness in water

S. N	Sample	Without treatment (mg/lit)	5 sec	10 sec	15 sec
1	Jar water	0	0	0	0
2	Ground water	120	168	156	160
3	Tap water	12	108	112	108
4	Stone spout water	112	128	108	114

Table 7 Test of hardness in water

3. 8 Lab test of Chloride

50 mL of water sample was taken in a conical flask. Added 1.0 mL indicator solution, (Potassium chromate). The initial color of the mixture is slightly yellow. Titrate with standard silver nitrate solution to brick red end point and note down volume of titrant used.

$$Chloride\ ion\ (mg/L) = \frac{Volume\ of\ AgNO3 * Normality\ of\ AgNO3 * 1000 * 35.5}{Volume\ of\ sample}$$

3.8.1 Test of Chloride in water

S. N	Sample	Without treatment (mg/lit)	5 sec	10 sec	15 sec
1	Jar water	17.04	8.52	11.36	14.2
2	Ground water	65.32	62.48	65.32	82.36
3	Tap water	11.36	8.52	11.36	19.88
4	Stone spout water	36.92	36.92	39.76	39.76

Table 8 Test of Chloride in water

3.9 Microbial analysis.

All the samples were filtered prior to analysis through 0.45 µm pore size membrane filter for isolation of total coliforms. The filter was then placed on M-Endo agar media. These plates were incubated at 37 degrees Celsius for 24 hours. The values of physio-chemical parameters were compared with NDWQS, 2005 and WHO guideline, 2017.

3.9.1 Heterotrophic plate count (HPC) of sample

Then, 0.1 mL sample was spread on plate count agar and incubate at 37 degrees Celsius for 24 hours. After incubation then bacterial colonies were counted by using colony counter.

Figure 3.9.1 Jar water without treatment and after 15 sec

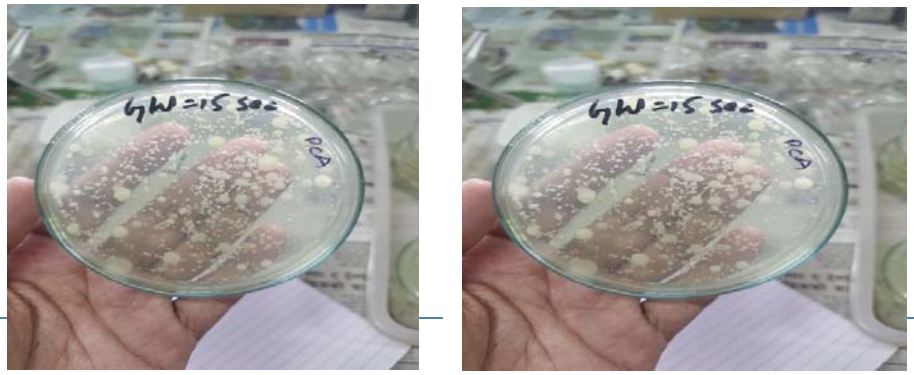

Figure 3.9.2 Ground water without treatment and after 15 sec

Figure 3.9.3 Tap water without treatment and after 15 second

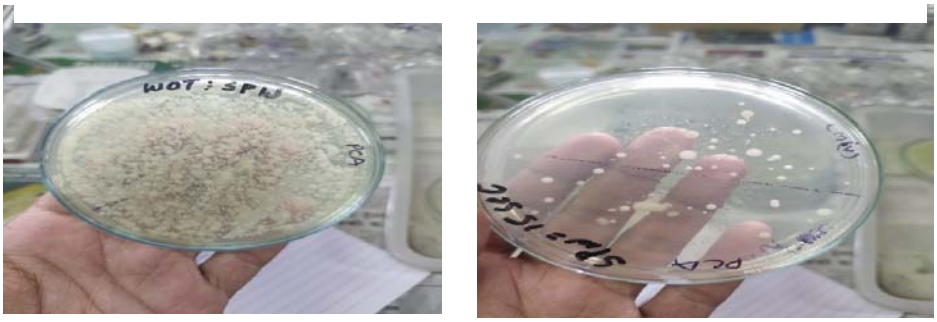

Figure 3.9.4 Stone spout water without treatment and after 15 sec

Heterotrophic plate count (HPC)

S. N	Sample	Without treatment	5 sec	10 sec	15 sec
1	Jar water	500	483	467	320
2	Ground water	760	703	678	500
3	Tap water	490	503	496	600
4	Stone spout water	800	123	88	60

Table 9 Data of Heterotrophic plate count

4.Results And Discussion

The result of this research are presented in table below. The major significant outcomes and resultants are described briefly.

4.1 Test for Ammonia and its concentration

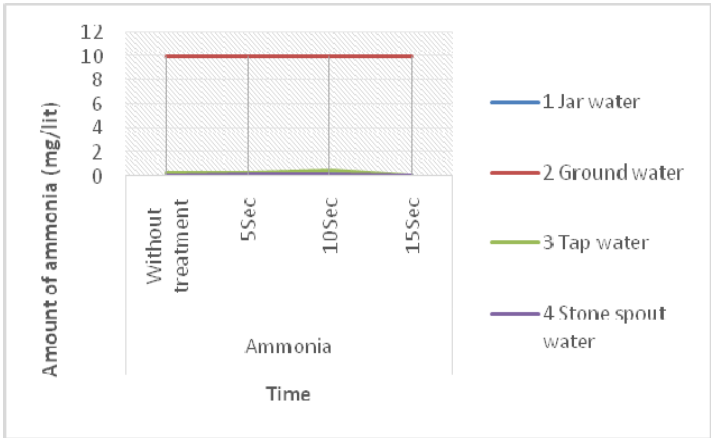

Figure 4.1.1 Graph of Ammonia and its concentration with time

An ammonia test of water samples from different sources at various times was studied. In jar water, ammonia increases for 10 seconds but then remains unchanged, whereas no change was observed in ground water. In tap water, there was no change at 5 seconds but increased at 10 seconds and became zero at 15 seconds. In a stone spout, it was found there was no change at 15 seconds but there was equal change at 5 seconds and 10 seconds.

4.2 Test for Nitrate and its concentration

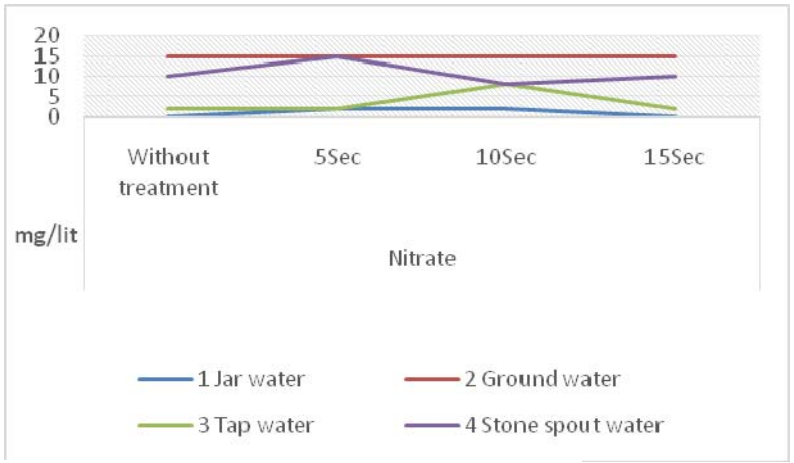

Figure 4.2.1 Graph of Nitrate and its concentration with time

In a study of nitrate tests at different times from various sources of water samples, we found nitrate was equally increased at 5 seconds and 10 seconds in Jar water but remained unchanged at 15 seconds. There was no change we found in the ground water either. However, in tap water, nitrate increased after 10 seconds and remained constant at other times. In stone spout water, nitrate increased at 5 seconds, decreased at 10 seconds, and remained unchanged at 15 seconds.

4.3 Test for Arsenic and its concentration

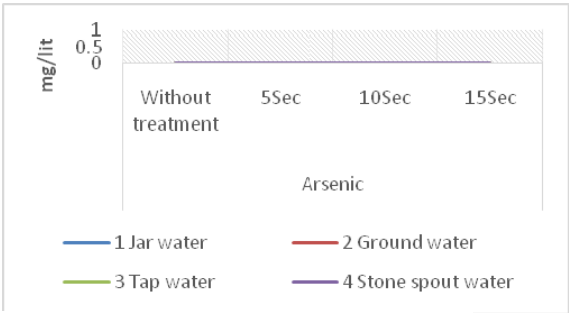

Figure 4.3.1 Graph of arsenic and its concentration with time

At plasma treatment for different times from various sources of water samples, there was no change.

4.4 Test for pH and its concentration

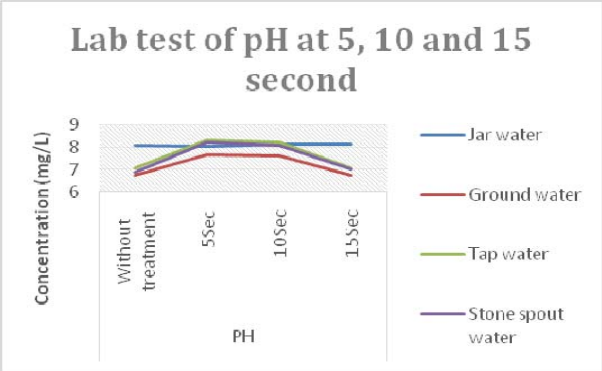

Figure 4.4.1 Graph of PH and its concentration with time

The pH of the jar water was reduced after 5 seconds but increased after 10 and 15 seconds. In ground water, pH was decreased but increased in tap and stone spout water.

4.5 Test for Conductivity and its concentration

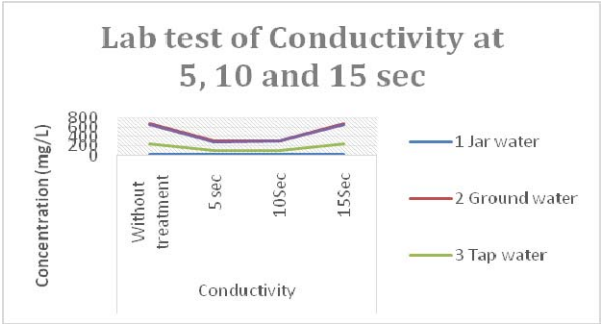

Figure 4.5.1 Graph of conductivity and its concentration with time

The conductivity of jar, ground, tap, and stone spout water was found to be highly decreased at 5 seconds, and found to be slightly decreased at 10 seconds, but increased at 15 seconds.

4.6 Test for Turbidity and its concentration.

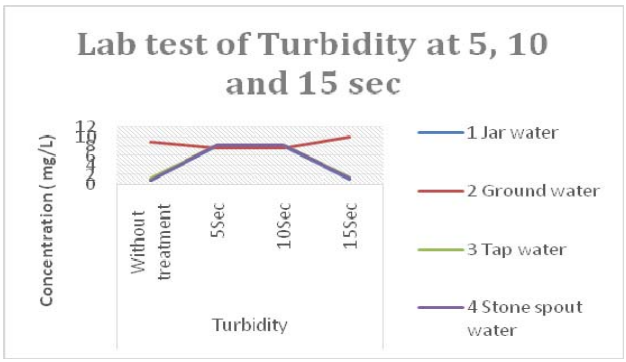

Figure 4.6.1 Graph of Turbidity and its concentration with time

The turbidity of Jar, Tap, and Stone spout water was found to be highly increased at 5 and 10 seconds but slightly increased at 15 seconds. Turbidity in groundwater was found to be decreased at 5 and 10 seconds but increased at 15.

4.7 Test of Hardness and its concentration

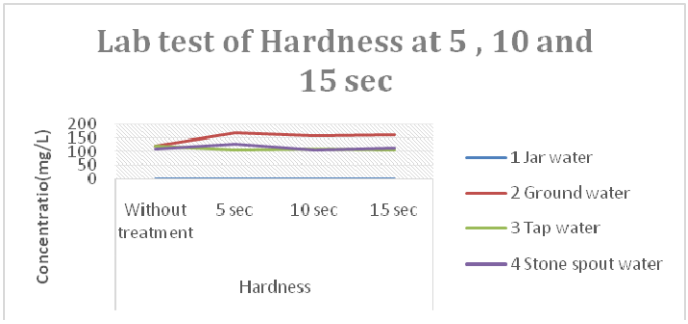

Figure 4.7.1 Graph of Hardness and its concentration with time

The hardness of water has not changed in jar water. In groundwater, hardness has been found to have increased. The hardness of tap water seemed to be decreasing, but in stone spout it increased at 5 seconds and 15 seconds, but was found to decrease at 10 seconds.

4.8 Test of Chloride and its concentration

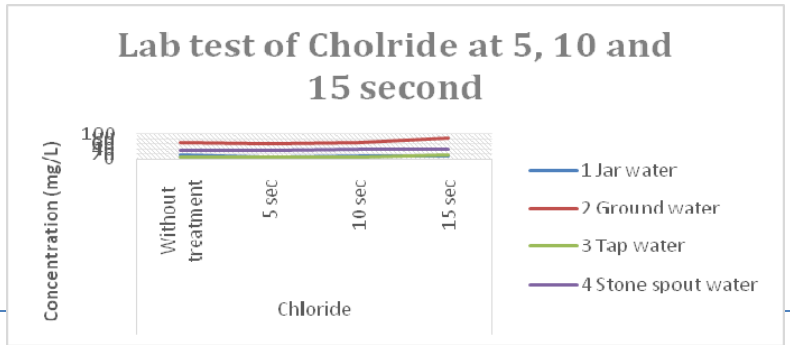

Figure 4.8.1 Graph of chloride and its concentration with time

Chloride is found to have decreased in jar water. It is discovered to be reduced after 5 seconds in both ground and tap water, but constant after 10 seconds and increased after 15 seconds. Chloride is constant at 5 seconds on stone spout water but is found to increase at 10 seconds and 15 seconds.

4.9 Test of Heterotrophic plate count (HPC) and its concentration

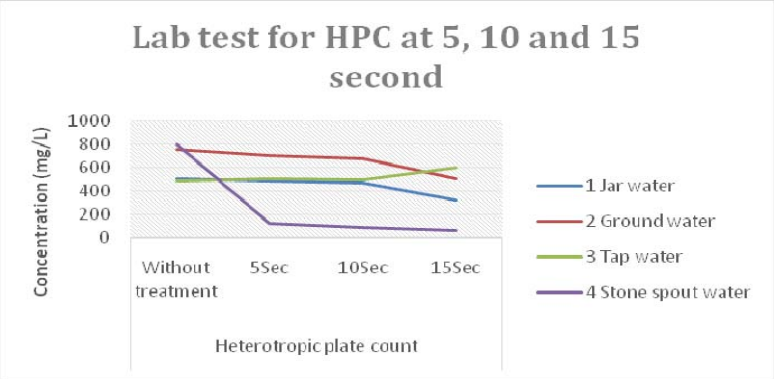

Figure 4.9.1 Graph of heterotrophic plate count with time

Heterotopic plate count was found to be decreased slightly in jar and ground water. In Tap water it increased but in Stone spout it was found that it drastically decreased.

5. Conclusion

The main aim of the research paper was to find out the impact of treatment of Plasma with water at different time frames and observing the effect on various water quality parameterssuch as Ammonia, Chloride, Nitrate, Arsenic, pH, Conductivity, Turbidity, Hardness and Heterotrophic Plate Count (HPC). The subject material was different forms of water taken from various sources such as Jar Water, Ground Water, Tap Water and Stone Spout Water.

The concentration of Ammonia in the Jar and Tap water increased at 10 seconds after the sample was treated with Plasma. After treatment of the water sample, it was found that amount of Nitrate was increased only at 5 second in Jar and Stone Spout water. There was no change in concentration of Arsenic in different sources of water at different time periods. The pH of ground water was found to be decreased but it increased in Tap and Stone Spot water at respective time periods. The turbidity of Jar, Tap and Stone spout water highly increased at 5 and 10 seconds whereas it increased slightly during 15 seconds.

In case of Jar water, after its treatment with Plasma in different time factors, no change was recorded. The hardness of groundwater increased significantly in all time periods as compared to without treatment. Overall, the hardness of Tap water decreased when treated with Plasma. But in case of Stone Spout water, hardness increased during 5 and 15 seconds whereas it decreased at 10 seconds.

The concentration of Chloride only decreased in case of Jar water whereas there was a significant increase in its amount in all other remaining samples in each time factors i.e., 5,10,15 seconds.

Finally, in HPC the overall concentration of Bacteria decreased in all the cases but in case of Stone Spout water, it had the major significant effect where the bacteria count was depleted by huge margin.

Acknowledgement

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Reference

[1] D. A. Frank-Kamenetskii, *Plasma: the fourth state of matter*. Macmillan International Higher Education, 1972.

[2] Y. Yang, A. Fridman, and Y. I. Cho, "Plasma Discharge in Water," in *Advances in Heat Transfer*, vol. 42, Y. I. Cho and G. A. Greene, Eds. Elsevier, 2010, pp. 179–292. doi: 10.1016/S0065-2717(10)42003-1.

[3] G. R. Stratton, C. L. Bellona, F. Dai, T. M. Holsen, and S. M. Thagard, "Plasma-based water treatment: Conception and application of a new general principle for reactor design," *Chem. Eng. J.*, vol. 273, pp. 543–550, 2015.

[4] B. R. Locke, M. Sato, P. Sunka, M. R. Hoffmann, and J.-S. Chang, "Electrohydraulic discharge and nonthermal plasma for water treatment," *Ind. Eng. Chem. Res.*, vol. 45, no. 3, pp. 882–905, 2006.

[5] J. E. Foster, "Plasma-based water purification: Challenges and prospects for the future," *Phys. Plasmas*, vol. 24, no. 5, p. 055501, 2017.

[6] M. Magureanu, C. Bradu, and V. I. Parvulescu, "Plasma processes for the treatment of water contaminated with harmful organic compounds," *J. Phys. Appl. Phys.*, vol. 51, no. 31, p. 313002, 2018.

[7] N. Jha, P. R. Shankar, and S. Palaian, "Knowledge and practice on ecopharmacovigilance and medicine storage amongst medical and dental students in Lalitpur, Nepal," *Risk Manag. Healthc. Policy*, vol. 14, p. 793, 2021.

[8] R. Thirumdas*et al.*, "Plasma activated water (PAW): Chemistry, physico-chemical properties, applications in food and agriculture," *Trends Food Sci. Technol.*, vol. 77, pp. 21–31, 2018.

[9] J. Foster, B. S. Sommers, S. N. Gucker, I. M. Blankson, and G. Adamovsky, "Perspectives on the interaction of plasmas with liquid water for water purification," *IEEE Trans. Plasma Sci.*, vol. 40, no. 5, pp. 1311–1323, 2012.

[10] U. M. Ekanayake *et al.*, "Utilization of plasma in water desalination and purification," *Desalination*, vol. 500, p. 114903, 2021.

[11] S. Ma, S. Lee, K. Kim, J. Im, and H. Jeon, "Purification of organic pollutants in cationic thiazine and azo dye solutions using plasma-based advanced oxidation process via submerged multi-hole dielectric barrier discharge," *Sep. Purif. Technol.*, vol. 255, p. 117715, 2021.

[12] E. Sardella*et al.*, "Plasma treated water solutions in cancer treatments: The contrasting role of RNS," *Antioxidants*, vol. 10, no. 4, p. 605, 2021.

[13] R. P. Guragain*et al.*, "Impact of Plasma-Activated Water (PAW) on Seed Germination of Soybean," *J. Chem.*, vol. 2021, 2021.

[14] R. P. Guragain, H. B. Baniya, S. P. Pradhan, B. P. Pandey, and D. P. Subedi, "Influence of plasma-activated water (PAW) on the germination of radish, fenugreek, and pea seeds," *AIP Adv.*, vol. 11, no. 12, p. 125304, 2021.

[15] G. R. Stratton, F. Dai, C. L. Bellona, T. M. Holsen, E. R. Dickenson, and S. MededovicThagard, "Plasma-based water treatment: efficient transformation of perfluoroalkyl substances in prepared solutions and contaminated groundwater," *Environ. Sci. Technol.*, vol. 51, no. 3, pp. 1643–1648, 2017.

[16] W. Thongmak, K. Ruangwong, A. Wongkaew, S. Srisonphan, and D. Onwimol, "Responses of seed vigour and germination of maize to plasma-activated water priming, silver-nanopriming and green silver-nanopriming," *Seed Sci. Technol.*, vol. 50, no. 1–2, pp. 117–131, 2022.

[17] J. O. Back, W. Stadlmayr, S. Jabornig, F. Winkler, K. Winkler, and M. Rupprich, "Removal of arsenic from water with non-thermal plasma (NTP), coagulation and membrane filtration," *Water*, vol. 10, no. 10, p. 1385, 2018.

[18] M. Magureanu, N. B. Mandache, and V. I. Parvulescu, "Degradation of pharmaceutical compounds in water by non-thermal plasma treatment," *Water Res.*, vol. 81, pp. 124–136, 2015.

[19] G. Iervolino, V. Vaiano, and V. Palma, "Enhanced removal of water pollutants by dielectric barrier discharge non-thermal plasma reactor," *Sep. Purif. Technol.*, vol. 215, pp. 155–162, 2019.

[20] J. Fan, H. Wu, R. Liu, L. Meng, and Y. Sun, "Review on the treatment of organic wastewater by discharge plasma combined with oxidants and catalysts," *Environ. Sci. Pollut. Res.*, vol. 28, no. 3, pp. 2522–2548, 2021.

[21] K. Song *et al.*, "Inactivation efficacy and mechanism of pulsed corona discharge plasma on virus in water," *J. Hazard. Mater.*, vol. 422, p. 126906, 2022.