International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 11 Issue: 05 | May 2024 www.irjet.net p-ISSN: 2395-0072

Water Quality Assessment of Drinking Water in Government Hospitals in Patna District of Bihar, India

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Abstract- *Monitoring of drinking water quality is an important component of water management, while data analysis is necessary for the identification and characterization of water quality problems. Assessment is the process by which water quality data is transformed into information. Monitoring can also verify water pollution following corrective action. It is therefore vital to regularly monitor the quality of groundwater. Drinking water contamination with different chemicals and heavy metals, released from different anthropogenic sources has become a global concern.The city of Patna is a large city and the capital of Bihar, which is located in the northeastern part of India. It is a historic city built on the southern banks of the Ganges River, lies on 25.5941° N latitude, 85.1376°E at an altitude of 53 m (174 ft) above mean sea level. The city is spread over an area of about 3,202 square km. According to census 2011 population of Patna is 1,684,222 million and the current estimated population of Patna city in 2024 is 2,633,000. This paper presents a study on drinking water quality of samples collected from ten different* Government Hospitals situated in Patna town and analyzed from August 2023 to October 2023. *Physico-chemical studies such as temperature, pH, total dissolved solids, electrical conductivity, chlorides, alkalinity, total hardness, ionic concentration: calcium, magnesium, sodium, potassium, iron, arsenic, fluoride, sulphate and nitrate of drinking water were carried out and compared with the standard values prescribed by WHO and BIS standards. Correlation matrix was prepared to find out the relation between different parameters.*

Keywords: Drinking water quality, physico-chemical analysis, government hospitals, water pollution

1. INTRODUCTION:

Clean drinking water is one of the United Nations Sustainable Development Goals. Despite significant progress in the water purification technology, many regions still lack access to clean water. Water quality has been linked to health outcomes across the world. Availability and easy access to safe and quality water is a fundamental human right **(1)**.

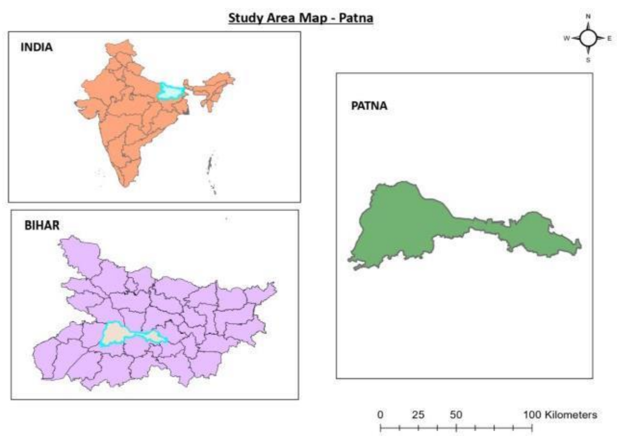
In addition, the water supply sector is facing enormous challenges due to climate change, global warming and urbanization. Insufficient quantity and poor quality of water have serious impact on sustainable development, especially in developing countries **(2)**. According to World Health Organization safe water should also not contribute to any sensitivity that may occur during different stages of life **(3)**. Drinking water is considered safe if its physical, chemical and biological characteristics meet WHO guidelines or any other national standards.

Efforts to understand the implications for health, particularly outcomes with long latency or critical exposure windows, have been hampered by lack of historical exposure data for unregulated pollutants. Adequate characterization of water quality heterogeneity within water supplies is an important component of exposure assessment methodologies in health studies investigating impacted drinking water **(4)**.

Tap water supplies are considered to be among the safest in the world, water contamination can still occur. There are many possible sources of contamination. In addition, drinking water, that is not properly treated or that travels through an improperly maintained distribution system (pipes) may also create conditions that increase risk of contamination. The presence of certain contaminants in our water can lead to health issues, including gastrointestinal illness, reproductive problems, and neurological disorders. Infants, young children, pregnant women, the elderly, and the people with weakened immune systems may be especially at risks of illness.

The area for the present investigation was selected in Patna town. The city of Patna is a large city and the capital of Bihar, which is located in the northeastern part of India. It is a historic city built on the southern banks of the Ganges River, lies on 25.5941° N latitude, 85.1376° E at an altitude of 53 m (174 ft) above mean sea level. The city is spread over an area of about 3,202 Square km. According to census 2011 population of Patna is 1,684,222 million and the current estimate population of Patna city in 2024 is 2,633,000 **(5).**

It is therefore vital to regularly monitor the quality of groundwater. Human Health Risk Assessment due to Heavy Metals in Ground and Surface Water and Association of diseases with drinking water sources were reported by several workers **(6, 7)**. Quality assessment of drinking water of different Government Hospitals was carried out and reported **(8-10)**. This paper presents a study on drinking water quality of samples collected from ten different Government Hospitals (marked in GIS map) situated in Patna town and analyzed from August 2023 to October 2023. Seventeen physicochemical parameters were analyzed and the results were compared with water quality standards prescribed by World Health Organization (**2)** and BIS: IS 10500:2012 **(11).**



2. METHODOLOGY:

This paper presents a study on drinking water quality of samples collected from ten different Government Hospitals (marked in GIS map) situated in Patna town and analyzed from August 2023 to October 2023. Seventeen physicochemical parameters were analyzed and the results were compared with water quality standards prescribed by World Health Organization **(2)** and BIS: IS 10500:2012 **(11).**

The physico–chemical properties electrical conductivity, pH and temperature of water were measured in the field using portable meters at the time of sampling. The instruments were calibrated in accordance with the manufacturer's guideline before taking the measurements. The value of each sample was taken after submerging the probe in the water and held for a couple of minutes to achieve a reliable reading. After measurement of each sample, the probe was rinsed with de-ionized water to avoid cross contamination among different samples. Water samples were placed in clean containers provided by the analytical laboratory (glass and acid-washed polyethylene for heavy metals). Nitric acid was used to preserve samples for metal analysis. All physicochemical parameters were analyzed as per the standard method prescribed by American Public Health Association (APHA) **(12, 13**).

2.1. Analysis of Physical Parameters:

2.1.1. pH:
A calibrated pH meter (Eco Tester pH 1) was used for on-site measurements followed by testing in the laboratory by using Systronics, pH System 361 and the average of the two readings was recorded. It was standardized with a buffer solution of pH range between 4 and 9.

2.1.2. Temperature:
This was carried out at the site of sample collection using a mobile thermometer. This was done by dipping the thermometer into the sample and recording the stable reading.

2.1.3. Turbidity:
Turbidity was determined by using Systronics Digital Nephlo-Turbidity Meter 132.

2.1.4. Conductivity and TDS:
Systronics Conductivity-TDS meter 307 was used to determine conductivity. The probe was dipped into the container of the samples until a stable reading was obtained and recorded.

2.2. Analysis of Chemical Parameters:

2.2.1. Total Hardness: Total hardness in water samples was done by titrating samples with standard solution of ethylene diamine tetraacetic acid (EDTA), a chelating agent by using complexometric titration.

2.2.2. Alkalinity:
The alkalinity of water was determined by titrating the water samples with standard acid solution of known pH and Stoichiometry of the reaction and number of moles of acid needed to reach the end point, the concentration of alkalinity in water was calculated by volumetric methods. Alkalinity of water is attributed to the presence of OH^-, HCO_3^- and CO_3^{2-} ions (12).

2.2.3. Mineral Concentration:
The chloride content was determined by argentometric method. The samples were titrated with standard silver nitrate using potassium chromate indicator. Calcium and Magnesium ions concentrations (hardness) were determined using EDTA titrimetric method. Sulphate ions concentration was determined using colorimetric method.
Mineral concentrations, including calcium, magnesium, sodium, and potassium were analyzed by Flame Photometer 128 of Systronics.
Concentration of nitrates was analyzed by APHA 23rd Edition –NO_3-Method D by UV screening method **(13)**.
Sulphate ions concentration was determined by APHA 23rd Edition 4500-SO4 Method by using UV screening method **(14).**
Iron concentration in water samples was analyzed by APHA 23rd Edition 3500-Fe Method B using Phenanthroline Method.
Arsenic concentration was determined by IS3025 (PART37)1987 **(14)**; silver diethyl dithiocarbamate method (AAS)
Ion selective electrode was used to measure fluoride concentrations in water samples.

3. RESULTS AND DISCUSSION:

Water quality parameters were analyzed and incorporated in Table-1. Graphical representation of all the parameters tested for all sampling sites and their correlations are shown in Graphs –1 to 9.

3.1. TDS: According to the WHO, the acceptable TDS range for drinking water is less than 600 ppm. TDS in the present study was observed in the range of 229 to 641 mg/L. High values of TDS in ground water is generally not harmful to human beings **(15)**, but high concentration of these (S-3 & S-4) may affect persons who are suffering from kidney and heart diseases and may be objectionable to consumers owing to the resulting taste and to excessive scaling in water pipes, heaters, boilers, and household appliances. Water containing high solid may cause laxative or constipation effects.

3.2. EC: Pure water is not a good conductor of electric current rather is a good insulator. Increase in ions concentration enhances the electrical conductivity of water. Generally, the amount of dissolved solids in water determines the electrical conductivity. Electrical conductivity (EC) actually measures the ionic process of a solution that enables it to transmit current. According to WHO standards, EC value should not exceeded 400µS/cm and the current investigations showed that EC value was 361 –1069 µS/cm. These results clearly indicate that water in the study area is considerably ionized and has high the level of ionic concentration activity due to dissolve solids. Highest EC was observed in water samples S-3 and S-4. EC and TDS are water quality parameters which indicate level of salinity **(16).**

3.3. Total Hardness: Total hardness is one of the most important properties of drinking water. It is a measure of the quantity of divalent ions (salts with two positive charges) such as calcium (Ca), magnesium (Mg) and/or iron (Fe) in water. Calcium contributes to the hardness of water within the bicarbonate (HCO_3^-) forming temporal carbonate hardness while sulphate (SO_4^{2-}), chloride (Cl^-) and nitrate (NO_3^-) forming permanent or non carbonate hardness. According to BIS acceptable limit of total hardness i.e. 200 mg/L and permissible limit in the absence of alternate source is 600 mg/L.

3.4. Magnesium Ion Concentration: Mg is the 8th most abundant element on earth crust and natural constituent of water. It is essential for proper functioning of living organisms and found in minerals like dolomite, magnetite etc. Human body contains about 25g of Magnesium (60% in bones and 40% in muscles and tissues). According to WHO standards, the permissible range of magnesium ions (Mg^{2+}) in water should be 50 mg/L. Magnesium ion concentration in the study areas range from 5.9 to 34.5 mg/L, which is within permissible limit.

3.5. Calcium Ion Concentration: Ca is the 5th most abundant element on earth crust and is very important for human cell physiology and bones. About 95% of calcium in human body is stored in bones and teeth. The high deficiency of calcium in humans may cause rickets, poor blood clotting, bones fracture etc., and the exceeding limit of calcium produced cardiovascular diseases. According to WHO (2011) standards, the permissible range of calcium ions (Ca^{2+}) in drinking water is 75 mg/L. In the study areas, results show that the concentration of calcium ranges from 23.6 to 56.2 mg/L which was lower than the standard limit.

3.6. Mg to Ca Ratio: The ratio of calcium and magnesium in water is also a crucial factor to cause several hard water related health problems (**17).** It was recommended that the Mg to Ca total intake ratio should be 1 to 2 as required for the best Mg absorption (**18)**. Magnesium and calcium ratio was calculated and from the finding (Table-1), it is evident that in the samples S-3, S-5, S-6, S-7 & S-8, this ratio is within the limit as per requirements. However, in the samples S-1, S-2 and S-4, the ratio is much higher i.e. 1:6, 1:5 and 1:4, respectively. The reduction in Mg to Ca ratio is associated with increasing risk for mortality from ischemic heart disease and acute myocardial infarction **(19)**, while the increase in Mg: Ca ratio is associated with increasing risk for gastric cancer.

The acceptable limit of alkalinity is 200mg/l and in the absence of alternate water source, alkalinity up to 600 mg/l is acceptable for drinking. Total alkalinity of analyzed water samples varied from 108 to 428 mg/l as given in Table1. Total alkalinity of all samples was below the permissible limit. Water quality with respect to hardness and alkalinity is important for the assessment (**20).**

3.7. Chloride Ion Concentration: Chloride (Cl^-) is mainly obtained from the dissolution of salts of hydrochloric acid as table salt (NaCl), and added through industrial waste, sewage, sea water etc. Surface water bodies often have low concentration of chlorides as compared to ground water. It has key importance for metabolism activity in human body and other main physiological processes. High chloride concentration damages metallic pipes and structure, as well as harms growing plants. According to WHO standards, concentration of chloride should not exceed 250 mg/l. In the study areas, the chloride value ranges from 20-114.2 mg/l in study areas.

3.8. Sulphur Concentration: Sulphur in groundwater is normally present in sulphate form. Sulphate may enter into ground water through weathering of sulphide bearing deposits. The highest desirable limit of sulfate in drinking water as established by WHO, is 200 mg/l. Sulphate ions (SO_4^{2-}) content in analyzed water samples varied from 10.14 to 88.04 mg/l as shown in Table1. All the samples found to be well within permissible limit. The results exhibit that concentration of sulfate are found to be lower than the standard limit and it may not be harmful for human health.

3.9. Sodium Ion Concentration: Sodium (Na) is a silvery white metallic element and found in less quantity in water. Proper quantity of sodium in human body prevents many fatal diseases like kidney damages, hypertension, headache etc.

No health base guideline values have been derived (WHO, 2006). On comparison with BIS standards, sodium ion (Na^+) concentration of all samples was found to be within the permissible limit. In the study areas, the finding shows that sodium concentration ranges from 13.8 to 72.1 mg/1.

3.10. Potassium Ion Concentration: Potassium (K) is silver white alkali which is highly reactive with water. Potassium is necessary for living organism functioning hence found in all human and animal tissues particularly in plants cells. The total potassium amount in human body lies between 110 and 140 g. It is vital for human body functions like heart protection, regulation of blood pressure, protein dissolution, muscle contraction, nerve stimulus etc. Potassium is deficient in rare but may led to depression, muscle weakness, heart rhythm disorder etc. According to WHO standards the permissible limit of potassium is 12 mg/1. K^+ concentration of analyzed water samples varied from 0.3 to 0.8mg/l.

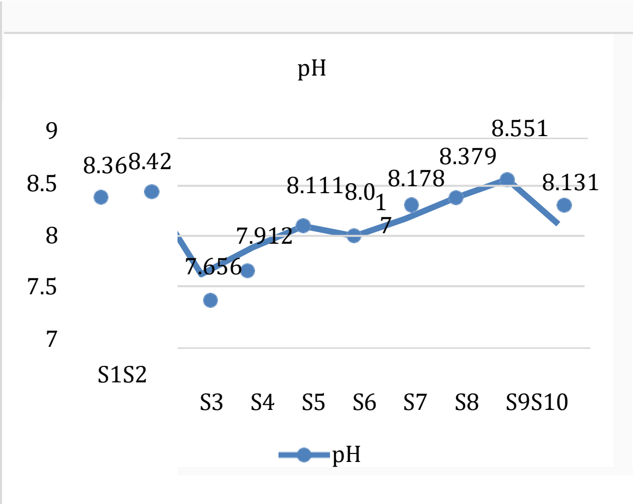
3.11. Nitrate Ion Concentration: Nitrate (NO_3^-) is one of the most important diseases causing parameters of water quality particularly b$_3$lue baby syndrome in infants. The sources of nitrate are nitrogen cycle, industrial waste, nitrogenous fertilizers etc. WHO allows maximum permissible limit of nitrate 50mg/l in drinking water. In study areas, results more clear that the concentration of nitrate ranges from 43.8 to 0.42 mg/l. These results indicate that the quantity of nitrate in the study sites is acceptable.

3.12. Iron Ion Concentration: Iron is higher (Graph-9) than the permissible limit in three water samples (S-2, S-4 & S-8). It is responsible for the bad taste associated with the water. High concentration of iron in water stains laundry, sanitary ware, gives an undesirable taste and develops turbidity as well. Iron also promotes the growth of "iron bacteria" which derives their energy from the oxidation of ferrous iron to ferric iron and in the process deposits a slimy coating on the piping.

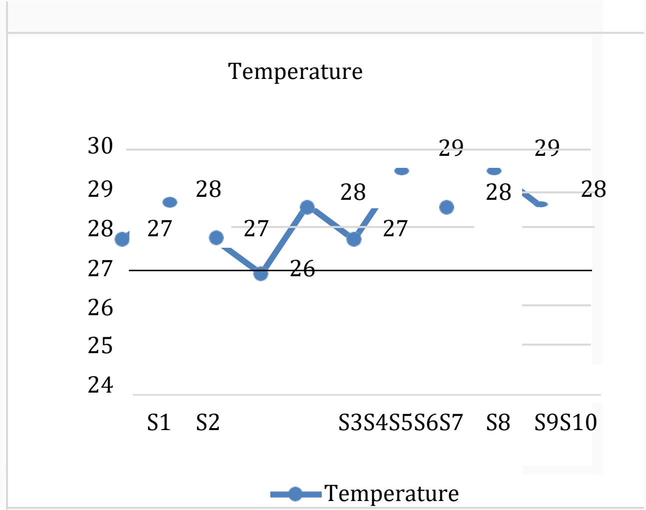
Table-1

Parameters	IS 10500 : 2012 Acceptable limit	IS 10500: 2012 Permissible limit	Samples									
			S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
			N 25°34'40.48356" E 85°4'49.33848"	N 25°33'34.97436" E 85°2'38.8248"	N 25°38'5.28972" E 85°2'44.25864"	N 25°36'5.052" E 85°11'54.456"	N 25°36'23.96592" E 85°6'4.47336"	N 25°36'17.32572" E 85°5'14.67564"	N 25°36'34.434" E 85°7'51.5244"	N 25°35'4.81524" E 85°2'25.72476"	N 25°37'58.0872" E 85°6'57.96"	N 25°37'16.2192" E 85°9'26.09928"
pH	6.5 - 8.5	No Relaxation	8.36	8.42	7.656	7.912	8.111	8.017	8.178	8.379	8.551	8.131
Temperature			27	28	27	26	28	27	29	28	29	28
Turbidity (NTU)	1	5	0.2	0.3	0.3	0.2	0.3	0.2	0.2	0.3	0.2	0.3
Total dissolved solid (ppm)	500	2000	229	233	641	638	426	462	336	355	337	345
Conductivity (µmhos/cm)			361	379	1069	1063	691	765	595	624	542	570

Total Hardness (mg/l)	200	600	181	96	204	170	118	136	119	114	112	88
Calcium(mg/l)	75	200	52.6	28.2	44.3	47.4	51.3	56.2	53.6	40.1	32.2	23.6
Magnesium (mg/l)	30	100	8.5	5.9	22.2	11.6	25.9	26.5	25.2	22.8	10.4	8.2
Mg^{2+} : Ca^{2+}			1:6	1:5	1:2	1:4	1:2	1:2	1:2	1:2	1:3	1:3
Alkalinity (mg/l)	200	600	212	106	420	428	212	180	144	184	168	108
Chlorides (mg/l)	250	1000	114.2	112.6	64.2	56.6	24.2	32.2	34.3	26.1	34.2	20
Fluorides (mg/l)	1	1.5	0.09	0.02	0.03	0.09	0.01	0.02	0.08	0.04	0.02	0.12
Sodium(Na^{+})			25.1	39.8	25.9	13.3	72.1	13.8	66.6	20.2	20.7	31.5
Potassium(K^{+})			0.3	0.4	0.6	0.5	0.6	0.4	0.3	0.4	0.5	0.8
Iron (mg/l)	1	No Relaxation	0.62	1.36	0.56	1.12	0.57	0.58	0.62	2.26	0.99	0.94
Arsenic (mg/l)	0.01	No Relaxation	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Sulphates (mg/l)	200	400	12.28	13.22	36.33	88.04	26.54	30.37	17.06	19.54	11.14	10.14
Nitrates (mg/l)	45	No Relaxation	11.42	27.72	43.8	14.42	0.42	4.65	9.22	17.56	10.12	12.44



Graph:1



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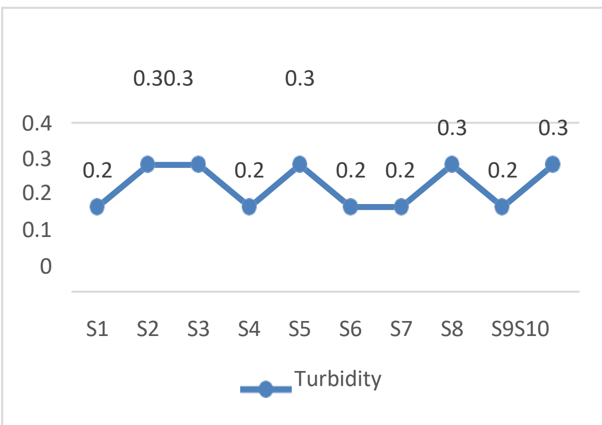

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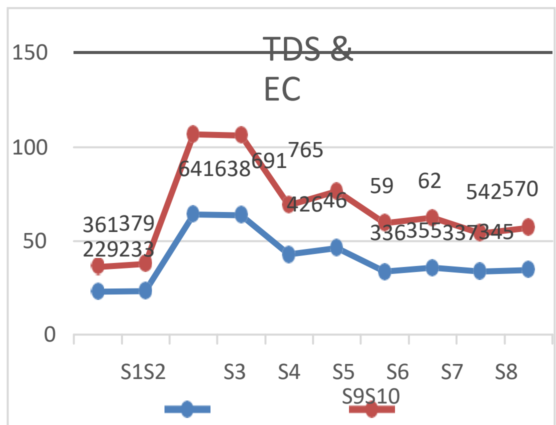
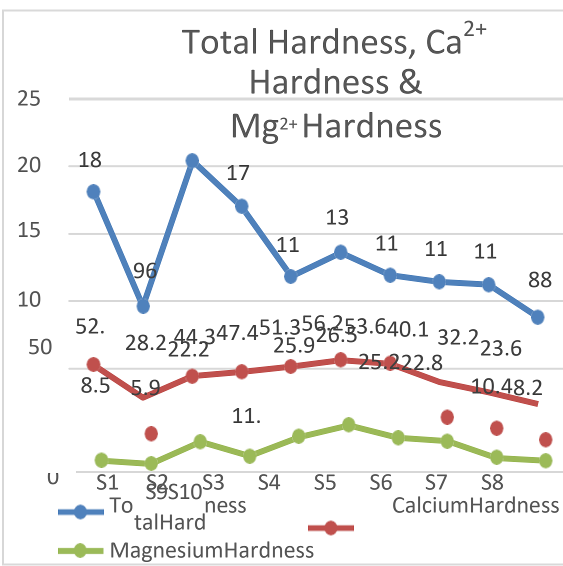


Graph-4



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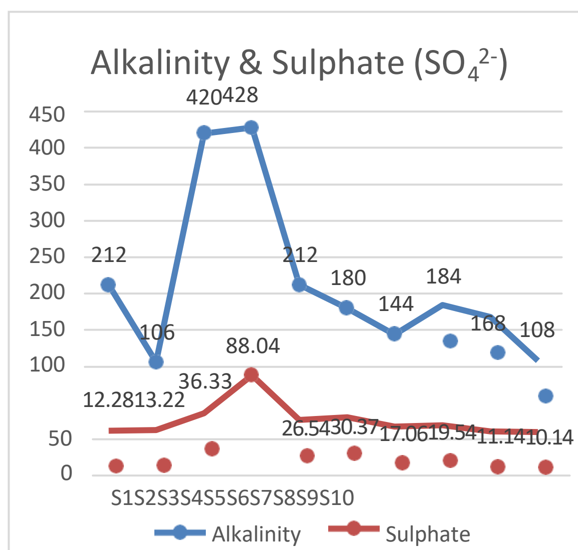

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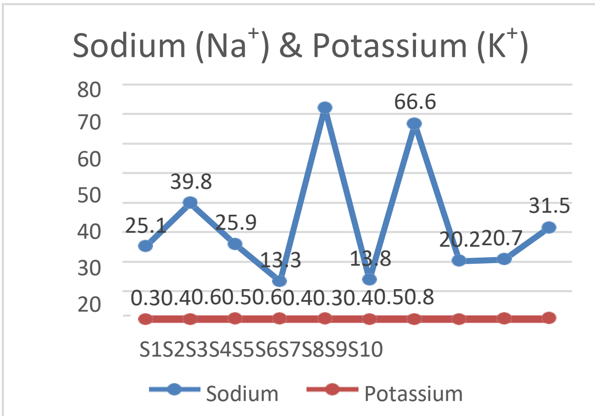
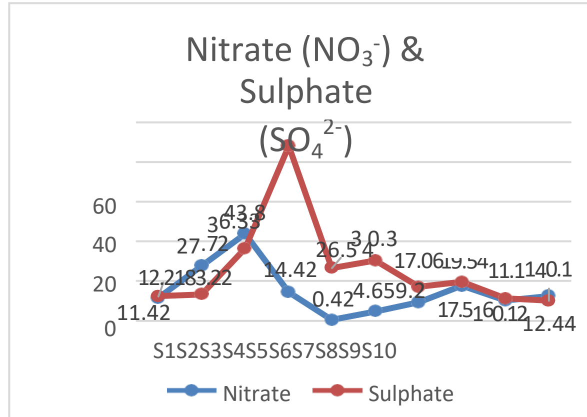
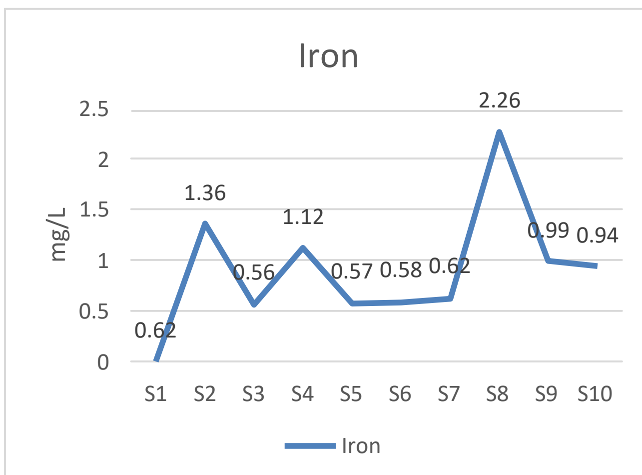


Graph-7



Graph-8



Graph:9

3.13. Arsenic Concentration: Arsenic may be introduced into drinking water via natural sources primarily by dissolution of naturally occurring minerals, ores, and industrial effluents. Study on ground water contamination and associated diseases in Bihar were reported earlier **(21).** The present study revealed that the value of Arsenic in water samples lies within WHO and BIS guidelines.

3.14. Fluoride Concentration: Fluoride is found in trace amounts in water, plants, soil, and animals in the natural environment. Fluoride concentration in drinking water must be controlled to avoid skeletal, non-skeletal and dental fluorosis. The Public Health Engineering Department, Bihar found that the groundwater in 4,157 habitats of 98 blocks of 11 districts of Bihar have dangerously high level of fluoride. Ever since the work under fluorosis mitigation programme **(22, 23),** focusing on consumption of fluoride safe potable water together with Moringa leaf powder on fluorosis patients of some habitation of Rajauli block, Nawada, Bihar, reported positive impacts to fluorosis patients.

However, fluoride content in all samples in present study has been found to be within the permissible limit prescribed by World Health Organization.

Maximum correlation has been observed between total dissolved solids and electrical conductivity. (Graph-4). Among all the water samples analyzed, lowest values of temperature and turbidity but highest values of sulphate and alkalinity are recorded in sample S4 however values of TDS and EC are lower than S-3. Sample S-2 shows lowest value of total hardness, alkalinity, TDS, EC and highest value of iron. Iron is higher than the permissible limit in three water samples (S2, S4 & S8). All the observed parameters in the samples S-2 and S-10 show maximum correlation among each other.

4. CONCLUSION:

On the basis of findings, it was concluded that all Physico-chemical parameters of drinking water in the Government Hospitals located in Patna were consistent with WHO and BIS standard for drinking water. The samples were analyzed for intended water quality parameters following internationally recognized and well-established analytical techniques. It is evident that physico-chemical parameters, temperature, pH, total dissolved solids, electrical conductivity, chlorides, alkalinity, total hardness, calcium, magnesium, sodium, potassium, arsenic, fluoride, sulphate and nitrate fall under the permissible limit and there was no toxicity problem. It was recommended that the Mg to Ca total intake ratio should be 1 to 2 as required for the best magnesium absorption. In the samples S-3, S-5, S-6, S-7 & S-8, this ratio is within the limit as per requirements. However, in the samples S-1, S-2 and S-4, the ratio is much higher i.e. 1:6, 1:5 and 1:4, respectively. Correlation matrix was prepared, maximum correlation has been observed between total dissolved solids and electrical conductivity. Iron is higher than the permissible limit in three water samples (S2, S4 & S8). It is responsible for the bad taste associated with water. Strategies like protection of natural sources, treatment and distribution management should be applied in order to maintain and improve drinking water supply system. Among all the samples of drinking water, the observed parameters of S2 and S10 show maximum correlation among each other.

Author's Acknowledgement: The authors are thankful to Centre for Fluorosis Research (CFR) Laboratory, A.N. College, Patna, India for providing facilities for analysis.

Author's Contribution: A. Kumar (First Author): On-site monitoring, laboratory analysis of water samples and manuscript preparation. J. Kumar: execution of work on-site and laboratory analysis. A. Anand: acquisition of data, analysis and reviewing the article, T. Gangwar (corresponding Author): conception of work, study design, interpretation of data and framework of the manuscript.

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