iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 8 **Issue:** X **Month of publication:** October 2020

DOI: https://doi.org/10.22214/ijraset.2020.31975

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 8 Issue X Oct 2020- Available at www.ijraset.com

Performance Evaluation of Water Treatment Plant in the Vicinity of Gwalior (M.P.) and some suggestions to Improve Performance

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Abstract: Potable water is one of the basic need of humans and in today's era, due to pollution, wholesome water is not easily available in the cities. So, here comes the need of "Water treatment plant". The basic work of the water treatment plant is to remove the impurities from the water because when the rainwater flows on the surface of the earth, it picks up or it dissolves some impurities into it. The water treatment plant makes water feasible for drinking purpose for humans after removing such impurities. Gwalior is one of the city which is facing the problem of scarcity of drinkable water. The water treatment plant on which the study is being done is constructed in close proximity to the Sankh river. The main goal of the study of the water treatment plant is to check the performance of the plant on the basis of various parameters such as Alkalinity, pH, Total dissolved solids, Hardness, Turbidity, Chloride, Coliform test, Residual chlorine, Dissolved oxygen etc. After collecting the water samples, the values of various parameters were analysed after different stages of treatment to know whether water quality standards are under the permissible limit for drinking or not. The values of the range of various parameters are found to be as follows -TURBIDITY: Before treatment (6.0 – 8.4)NTU After treatment (0.63-0.92)NTU, pH: Before treatment (7.5 – 7.9) After treatment (7.0-7.5), ALKALINITY: Before treatment (37.8 – 48.6)mg/l After treatment (21.2-29.8) mg/l , HARDNESS: Before treatment (81.2– 98.6) mg/l as CaCO3 After treatment as CaCO3 (50.6-72.1) mg/l, CHLORIDE: Before treatment (24.7– 37.2) mg/l After treatment (21.2-32.4) mg/l, TOTAL DISSOLVED SOLID (TDS): Before treatment (222.9– 248.1) mg/l After treatment (156-182.4) mg/l, DISSOLVED OXYGEN: Before treatment (4.95-6.25) mg/l After treatment (7.2-7.90) mg/l. MPN/100 was totally removed and was observed zero in treated water. The maximum value of residual chlorine in treated water was observed 1.6 mg/l which was found more than the permissible limit(0.5mg/l) which needs to be reduced to decrease the cost as well as to ensure health aspects of users as high dose of residual chlorine is harmful to human beings. For remaining parameters, It is found that the water treatment plant is performing according to the BIS 10500-2012 for standard of drinking water.

***Keyword: water treatment plant, turbidity, aeration, flash mixer, Chlorination, Residual chlorine**.*

I. INTRODUCTION

One of the basic need of human beings is water and without water humans or other living organisms would not have any existence on this earth. Though our earth has 71% water (due to which earth is known as the blue planet) but only 2.5 % of this is fresh, which is useful for the consumption of humans and most of this water is not fit for drinking due to pollution /contamination. India stands on 120th rank in water quality index in the world. Seventy percent of the fresh water in India is contaminated and not fit for drinking. Water with several impurities may lead to diseases that may cause a pandemic. Therefore, there is a need to make use of the available water in the most appropriate way, and here comes the concept of the water treatment plant. Water treatment Plant is used to convert water with several impurities (garbage, chemical, basicity, biological) into drinkable form.

In the traditional water treatment plant, water enters from the nearest source and passes through various stages of treatments, such as screening (which removes the large floating particles), then it is followed by aeration. After the treatment of water in aeration, coagulation is done in a flash mixer after which water enters into a tube settling tank/sedimentation tank for removal of suspended impurities. After the tube settling tank water enters in filtration unit where fine particles are removed. After filtration, chlorination is done using liquid chlorine for the killing of pathogenic bacteria and other harmful microorganisms. Finally, water is stored in a sump well and then sent for distribution. The water treatment plants with time may show decreased performance which may lead to reduction in the water standards laid down for drinking. So, there is a need to assess the performance of the water treatment plant periodically and check whether the performance of the plant is up to mark or not. According to a survey conducted by CPCB, many of the water treatment plants are not working satisfactorily to produce water fit for drinking.

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This situation may lead to many water hygiene-related problems. Every unit in the water treatment plant has an important role in purifying water, therefore, it is important to study the working performance of each unit. With the time treatment plants may need to upgrade their units used in the treatment of water for which the latest technologies can be used. Performance evaluation of these plants plays a vital role in monitoring and evaluating efficiency of plant for better understanding of the design and operating difficulties in water treatment plants. Gwalior is one of the main cities of the central part of India, which is situated in the north of the state of Madhya Pradesh. Since it is situated near Delhi, it has a number of industrial areas, Government offices, and Corporate offices. Gwalior is also considered as the tourism capital of Madhya Pradesh and every year huge numbers of tourists comes from the entire part of the country and foreign tourists also visit the city. Tourism is expanding day by day and with increasing population, the need for water is also increasing. To fulfil the need of the people, raw water from the Tighra dam is used for water supply. The population of Gwalior Municipal Corporation has increased tremendously during the last few decades. In 1991 GMC had a population of 6,90,765 souls. This population further increased to 8,27,026 souls as per 2001, and finally 1159032 souls as per 2011 census records of Gwalior Municipal Corporation. Recently 6 more Wards were added to the Gwalior Municipal Corporation. The existing Water supply system is not sufficient for catering the future demand. Water treatment plant under study is covered in Gwalior Augmentation Water Supply Scheme for the year 2035, supplying potable water @ 135 lpcd in the Municipal area at a residual head of 10-12 m. The city has a municipal area of approx. 289 Sq. km. and is administered by dividing the city. into 60 municipal wards, the city of Gwalior is located at 26° 12 12.50" N 78° 18 58.76" E, and the average elevation of Gwalior is 212 meters above Mean sea level. The city consists of three distinct settlements namely urban Old Gwalior in the north, Lashkar about 3 km to the southwest, and Morar towards the east of Gwalior city. Tighra dam (source of water supply) is built on the sankh river and is situated towards 23Km east of the city whereas the water treatment plant is situated 18 Km from the city. Tighra dam is considered the lifeline of the Gwalior people. The treatment plant on which study is being done has the capacity of 45 MLD, which was commissioned during year 2012.

Following is the flow diagram of the water treatment plant

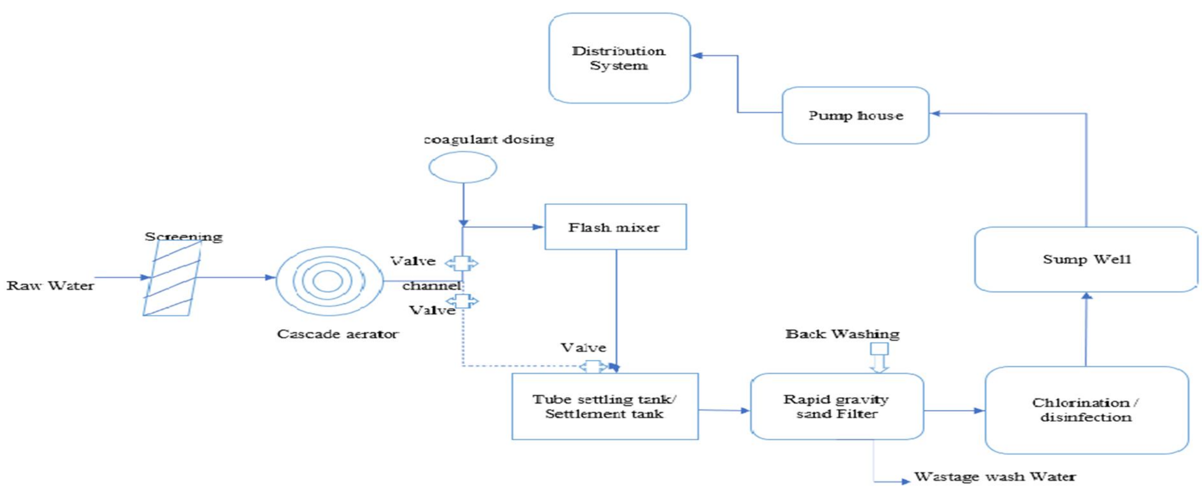


Fig1.1 Layout of water treatment plant

II. OBJECTIVES OF STUDY

Following are the main objectives of the study

A. To evaluate the performance of each unit and to check their working efficiencies.
B. To access the quality of water, analysing various physico-chemical parameters.
C. To ensure the water is safe for drinking purpose.
D. Check whether the water treatment process is cost efficient or not.
E. Give some suggestions to improve efficiency of water treatment plant and to make it more cost efficient.

III. METHODOLOGY

To access performance of water treatment plant, water samples(raw/treated) are collected using standard sampling procedure as monitored below

A. Sampling Strategy And Procedure

1) During the 4 months study duration, a total 15 set of water samples were collected.
2) All the samples were collected with adequate precautions and care to avoid errors.
3) The samples were collected in the month of December (2019), January (2020), February (2020), and March (2020).
4) In each set of sample, initially the raw water sample was collected simultaneously one sample each after aeration unit, sedimentation unit, filtration unit and disinfection is also collected forming a set of 5 water samples including raw water.
5) All the samples were collected in sterile bottle which had a capacity of 2 litres.
6) Water samples that were collected from the units analysed for various parameters such as pH, TDS, Chloride, Hardness, Residual chlorine, Alkalinity, Turbidity, Dissolved oxygen, MPN.
7) The analysis was done by performing analysis in the laboratory as per the standard norms and thereafter results were concluded from the analysis of the experiments.

The Following methods and reagents were used to analyse the various parameters:

TABLE 1.1 Methods & Reagents used for analysis water sample in laboratory

Parameters	Method	Reagents/Instruments
Alkalinity (mg/l as CaCO3)	Titrimetric method	N/50 Standard Sulphuric acid, Phenolphthalein, Methyl orange indicator
pH	pH meter (Potentiometer method)	Buffer solution
Total dissolved solid(mg/l)	Volumetric method	Beaker, Ovens, Filter paper (No.44)
Hardness (mg/l as CaCO3)	EDTA Titrimetric Method	EBT indicator, Ammonia buffer (pH10), Standard EDTA solution (0.01M)
Turbidity (NTU)	Nephelometer	Standard solution 40 NTU ,100 NTU and zero NTU.
Chloride(mg/l)	Titrimetric method	Silver Nitrate, Sodium Chloride, Potassium Chromate
Coliform Test (No/100ml)	Multiple tube serial dilution	MacConkey's broth, Sulphuric acid, Sodium hydroxide, Bromo cresol purple
Residual Chlorine (mg/l)	Titrimetric method (Iodometric Method)	.01N Sodium thiosulphate, Potassium iodide, Starch solution, Glacial acetic acid
Dissolved oxygen (mg/l)	Titrimetric method (Winkler Method)	Standard Manganese sulphate, Alkali iodide azide reagent, standard Sodium Thiosulphate solution (0.025), Starch indicator, conc. Sulphuric acid

IV. OBSERVARIONS & RESULTS

Results and observations obtained after analysis are tabulated as below:

TABLE 1: Turbidity (in NTU) during treatment after various unit

Date	Raw water	Aerated water	Sedimented water	Filtrated water	Chlorinated water
		After aeration unit	After clarifier unit	After rapid Sand gravity filter unit	After Disinfection unit
02-12-19	8.4	8.2	3.0	0.68	0.63
09-12-19	8.4	8.0	4.1	0.9	0.90
16-12-19	8.3	7.9	4.0	0.8	0.84
23-12-19	7.3	6.8	3.9	0.93	0.91
30-12-19	6.0	6.0	1.7	0.85	0.85
06-01-20	6.9	6.1	2.1	0.96	0.92
13-01-20	7.0	6.7	3.4	0.75	0.72
20-01-20	6.9	6.8	3.5	0.85	0.81
27-01-20	7.4	7.1	4.2	0.95	0.90
03-02-20	7.8	7.5	3.9	0.89	0.85
10-02-20	7.5	7.2	3.7	0.75	0.71
17-02-20	7.1	6.8	4.2	0.82	0.79
24-02-20	7.2	6.9	3.4	0.93	0.89
02-03-20	7.7	7.1	4.1	0.79	0.75
12-03-20	8.1	7.8	3.6	0.84	0.81

TABLE 2: pH value during treatment after various unit

Date	Raw water	Aerated water	Sedimented water	Filtrated water	Chlorinated water
		After aeration unit	After clarifier unit	After rapid Sand gravity filter unit	After Disinfection unit
02-12-19	7.9	7.8	7.7	7.6	7.5
09-12-19	7.5	7.4	7.2	7.1	7.0
16-12-19	7.9	7.7	7.5	7.5	7.4
23-12-19	7.8	7.6	7.6	7.5	7.5
30-12-19	7.8	7.7	7.7	7.6	7.5
06-01-20	7.7	7.6	7.6	7.5	7.4
13-01-20	7.9	7.8	7.7	7.5	7.3
20-01-20	7.2	7.1	7.1	7.1	7.1
27-01-20	7.5	7.4	7.2	7.1	7
03-02-20	7.8	7.6	7.5	7.4	7.2
10-02-20	7.8	7.6	7.6	7.4	7.2
17-02-20	7.7	7.5	7.4	7.2	7
24-02-20	7.9	7.6	7.4	7.4	7.2
02-03-20	7.9	7.8	7.7	7.5	7.3
12-03-20	7.5	7.3	7.3	7.1	7

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 8 Issue X Oct 2020- Available at www.ijraset.com

TABLE 3: Alkalinity (In mg/l **as** $CaCO_3$) during treatment after various unit

Date	Raw water	Aerated water	Sedimented water	Filtrated water	Chlorinated water
		After aeration unit	After clarifier unit	After rapid Sand gravity filter unit	After Disinfection unit
02-12-19	42.6	41.9	34.6	26.2	26.1
09-12-19	43.1	42.6	35.2	23.8	23.5
16-12-19	44.8	43.8	35.6	22.9	22.6
23-12-19	43.2	42.9	33.8	24.3	24.1
30-12-19	37.8	37.4	32.9	25.6	25.1
06-01-20	45.2	44.1	34.8	21.3	21.2
13-01-20	39.8	39.4	38.2	26.5	26.1
20-01-20	45.4	44.9	37.1	29.2	29.0
27-01-20	48.6	47.2	40.5	30.1	29.8
03-02-20	46.2	46.1	39.4	29.9	29.4
10-02-20	42.3	41.2	34.6	27.8	27.2
17-02-20	40.5	40.1	32.5	26.3	25.1
24-02-20	38.7	38.2	33.1	28.2	27.9
02-03-20	41.2	39.9	34.2	25.1	24.8
12-03-20	39.3	39.1	34.3	24.5	24.1

TABLE 4: TDS (In mg/l) during treatment after various unit

Date	Raw water	Aerated water	Sedimented water	Filtrated water	Chlorinated water
		After aeration unit	After clarifier unit	After rapid Sand gravity filter unit	After Disinfection unit
02-12-19	225	222.1	189.6	169.2	168.1
09-12-19	236	235.2	188	161.7	160
16-12-19	241.6	239.8	191.1	160.2	156
23-12-19	222.9	220	189.2	162	159.2
30-12-19	246.1	244.8	187.3	163.1	161.3
06-01-20	241.6	239	162.1	159.8	156.2
13-01-20	224.4	221.3	201	178.2	175.6
20-01-20	236.2	235.4	198.2	187.9	182.4
27-01-20	248.1	246.5	195.4	182.3	179.2
03-02-20	239.2	237.8	192.4	178.5	174.2
10-02-20	227.9	221.1	188.4	174.4	172.1
17-02-20	229	228.9	179.4	168.9	164.2
24-02-20	239.2	237.8	181.2	162.2	160.1
02-03-20	231.5	229.2	192.1	162.1	160.9
12-03-20	226.1	224.8	188.4	169.7	168.1

TABLE 5: Hardness (In mg/l equivalent as CaCO3)during treatment after various unit

Date	Raw water	Aerated water	Sedimented water	Filtrated water	Chlorinated water
		After aeration unit	After clarifier unit	After rapid Sand gravity filter unit	After Disinfection unit
02-12-19	98.6	96.2	88.1	72	71
09-12-19	95.2	93.1	83.2	73.4	71.2
16-12-19	93.8	90.9	84.6	71.2	70
23-12-19	81.2	79.2	70.8	51.3	50.6
30-12-19	91.1	88.3	76.6	59.6	58.9
06-01-20	86.5	84.1	70.9	52.1	51.6
13-01-20	94.2	80.4	79.6	69.4	68.2
20-01-20	89.3	87.6	84.1	72.5	72.1
27-01-20	96.4	94.8	86.2	62.8	60.2
03-02-20	88.5	85.9	75.2	61.5	59.9
10-02-20	92.4	91.2	81.5	59.1	58.9
17-02-20	90.8	89.8	78.2	69.9	68.5
24-02-20	87.6	84.2	72.1	64.5	62.7
02-03-20	82.4	81.7	74.2	67.1	65.4
12-03-20	91.2	89.4	73.5	63.8	61.5

TABLE 6: Chloride (In mg/l) during treatment after various unit

Date	Raw water	Aerated water	Sedimented water	Filtrated water	Chlorinated water
		After aeration unit	After clarifier unit	After rapid Sand gravity filter unit	After Disinfection unit
02-12-19	31.1	28.2	24.1	22.8	23.1
09-12-19	28.6	26.9	23.8	21.2	22.8
16-12-19	26.2	25.1	22.9	21	23.4
23-12-19	27.1	25.9	23.1	22	22.8
30-12-19	25.9	24.3	21.9	20.8	21.2
06-01-20	24.7	23.5	21.1	20.2	22.1
13-01-20	32.5	30.2	28.6	27.8	28.4
20-01-20	36.4	34.1	30.2	29.7	30.1
27-01-20	37.2	36.4	32.1	31.8	32.4
03-02-20	35.8	34.8	31.2	30.4	31.2
10-02-20	29.2	26.4	23.2	22.5	23.1
17-02-20	31.5	29.1	26.8	25.8	26.4
24-02-20	28.4	26.7	23.5	22.9	23.1
02-03-20	29.7	25.9	23.7	22.5	23.4
12-03-20	33.4	30.1	27.8	26.4	27.1

TABLE 7: Dissolved oxygen (In mg/l) during treatment after various unit

Date	Raw water	Aerated water	Sedimented water	Filtrated water	Chlorinated water
		After aeration unit	After clarifier unit	After rapid sand gravity filter unit	After Disinfection unit
02-12-19	6.15	7.2	7.25	7.63	7.90
09-12-19	5.90	6.83	7	7.45	7.56
16-12-19	6.0	7.2	6.9	7.21	7.65
23-12-19	6.25	7.0	6.85	7.10	7.31
30-12-19	5.95	6.87	6.9	7.4	7.9
06-01-20	4.95	6.1	6.5	6.93	7.2
13-01-20	5.70	6.6	7.1	7.40	7.56
20-01-20	5.89	6.89	7.4	7.56	7.83
27-01-20	6.23	7.10	6.9	7.20	7.4
03-02-20	5.89	6.45	7.1	7.5	7.64
10-02-20	6.18	7.20	7.3	7.8	7.9
17-02-20	5.85	6.80	7.1	7.4	7.6
24-02-20	6.22	7.1	7.20	7.55	7.88
02-03-20	4.98	6.87	6.97	7.21	7.45
12-03-20	5.14	6.74	6.98	7.54	7.76

TABLE 8: Residual chlorine (In mg/l) during treatment after various unit

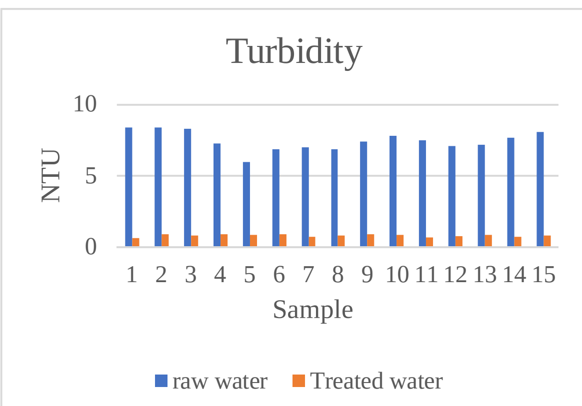
S. No	Clear water
02-12-19	1.50
09-12-19	1.31
16-12-19	1.28
23-12-19	1.12
30-12-19	1.32
06-01-20	1.36
13-01-20	1.18
20-01-20	1.50
27-01-20	1.32
03-02-20	1.40
10-02-20	0.95
17-02-20	1.60
24-02-20	1.12
02-03-20	1.32
12-03-20	1.14

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 8 Issue X Oct 2020- Available at www.ijraset.com

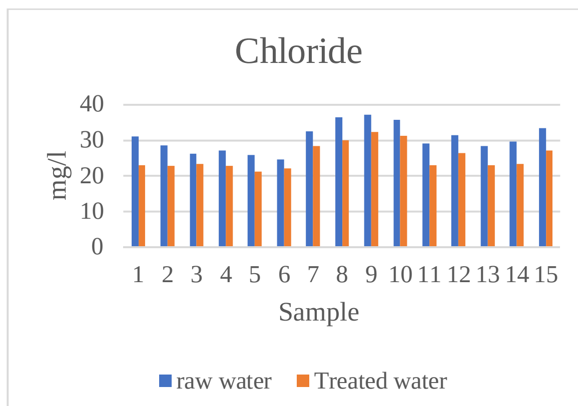
TABLE 9: MPN (Number/100 ML) during treatment after various unit

Date	Raw water	Aerated water After aeration unit	Sedimented water After clarifier unit	Filtrated water After rapid sand gravity filter unit	Chlorinated water After disinfection unit
02-12-19	8	6	4	0	0
09-12-19	6	4	2	0	0
16-12-19	12	9	9	2	0
23-12-19	10	9	7	0	0
30-12-19	14	12	8	2	0
06-01-20	14	10	6	0	0
13-01-20	8	6	5	3	0
20-01-20	12	10	9	7	0
27-01-20	10	9	7	4	0
03-02-20	14	13	10	6	0
10-02-20	12	10	9	5	0
17-02-20	10	6	2	0	0
24-02-20	6	5	4	2	0
02-03-20	10	8	6	5	0
12-03-20	12	10	8	4	0

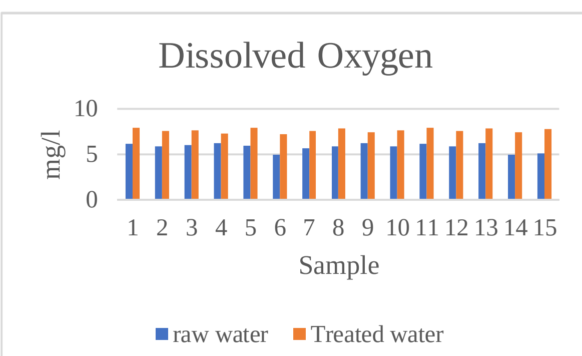
Above tabulated results are shown in graphical form as below



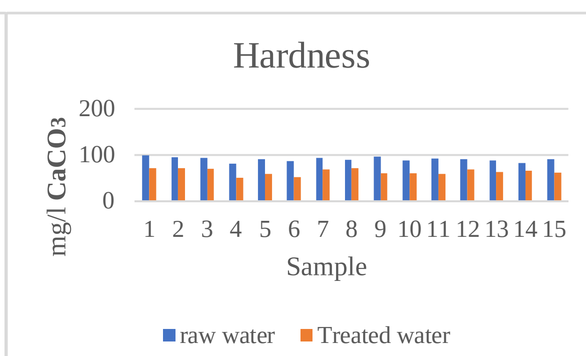
Graph 1- Graph represent change in turbidity



Graph 2- graph represent change in Chloride



Graph 3 graph represent change in Hardness



Graph 4 graph represent change in Dissolved oxygen

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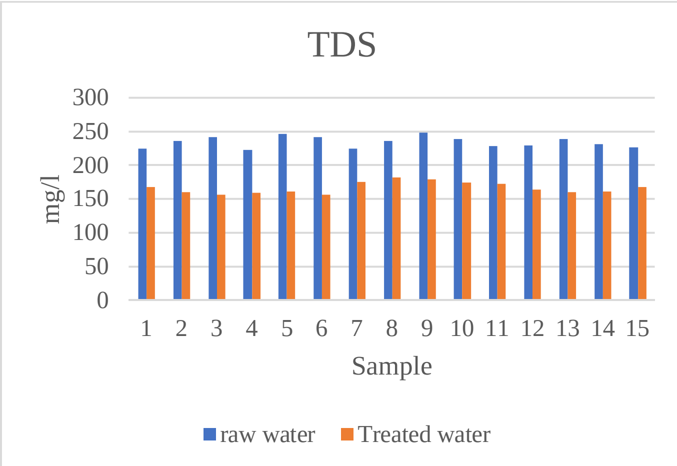
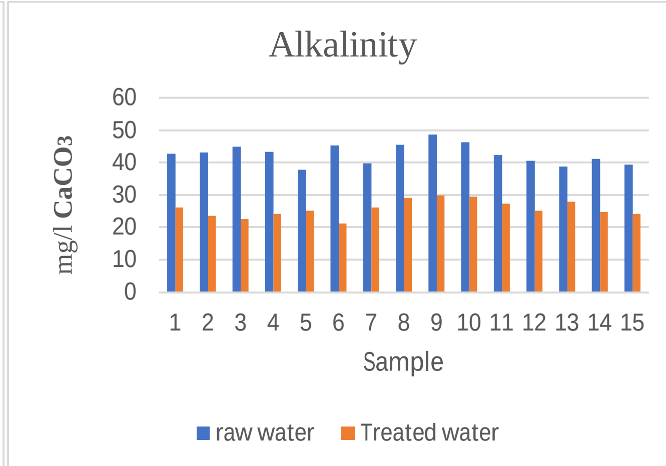
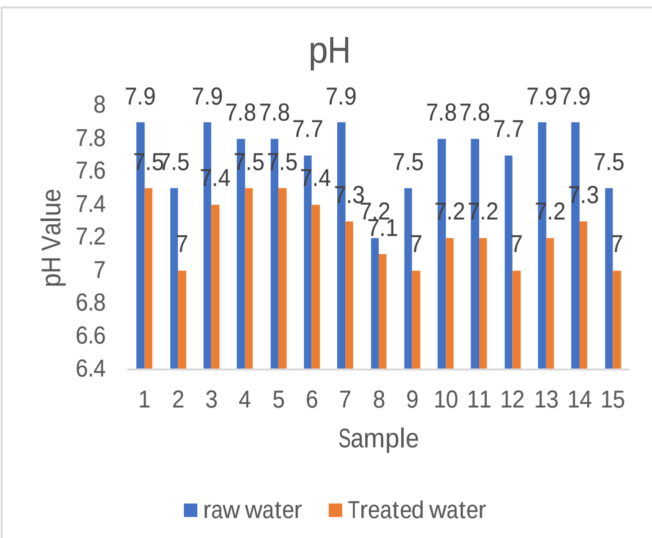
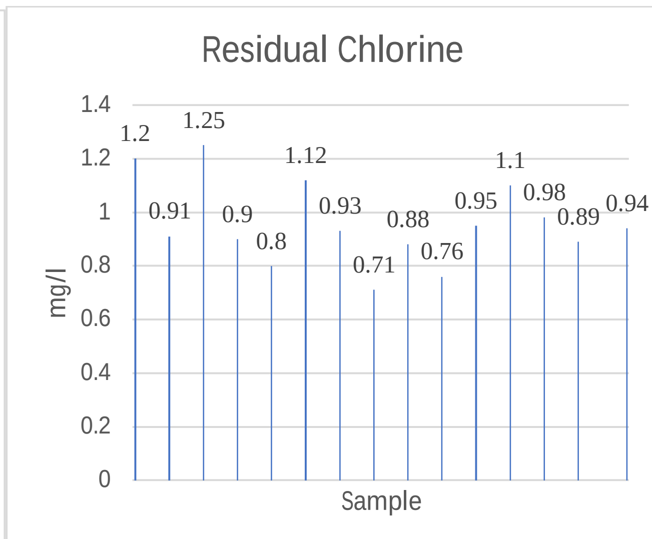




Graph 5- Graph represent change in Alkalinity Graph 6- Graph represent change in total dissolved





Graph 7- Graph represent change in pH Graph 8- Graph represent change in Residual Chlorine

V. RESULTS AND DISCUSSION

After collecting samples and performing analysis on them it was concluded that the water treatment plant was producing water satisfying the standards of studied Parameters laid down by BIS:10500-2012 for drinking purpose (Except for residual chlorine). Observed value/concentrations of all physico - chemical parameter lies within the specified range as laid down by BIS: 10500-2012. After analysis the range of various phsico- chemical parameters of treated water noted are. Turbidity (0.63-0.92 NTU), Alkalinity (21.2-29.8 mg/l as CaCO3), pH (7.0-7.5), Total Dissolved Solid (158-168.1 mg/l), Chloride (21.2-32.4 mg/l), Hardness (50.6-71.2 mg/l as CaCO3), Dissolved Oxygen (7.2-7.9 mg/l) respectively. However, the maximum concentration of Residual chlorine was found to be (1.6 mg/l) which is more than the Maximum permissible limit 0.5 mg/l.

Values of all parameters lie in the range set by BIS, hence it can be stated that water treatment plant is working satisfactory and all units giving satisfactory outputs and the treated water was drinkable after the complete treatment process. However it is observed that value of residual chlorine is found to be considerably high upto 1.6 mg/l against desirable limit of 0.2-0.5 mg/l. it is also observed that dose of coagulant is not being added according to raw water turbidity .It is observed that a block of alum is placed in water channel around which water is flowing thus dosing is being done arbitrarily .Since the turbidity observed in treated water is less than the permissible limit of (1-5 NTU),therefore the coagulant dose may be more than the optimum dose causing extra consumption of alum effecting economics of the treatment plant adversely.

VI. CONCLUSION

Based on the evaluation of treatment plant, the following things can be concluded

1) It is Observed that both lime and alum are being added in the coagulation process however, alkalinity of raw water is found within the range of 45 to 50 mg/l as $CaCO_3$. A minimum value of alkalinity equal to half of the dose of alum is required to be present in water for effective coagulation. Thus, the available alkalinity can facilitate alum dose up to 90 mg/l. Since the maximum dose (40 mg/l in monsoon season) of alum is much less than 90 mg/l (maximum allowable dose), hence it is not required to add lime along with alum.
2) Charts and tables are not used for deciding optimum dose of coagulant and lime.
3) In the disinfection process amount of chlorine added is 2 mg/l and out of which only 0.3 to 0.5 mg/l is being used in the disinfection process while around 1.5 mg/l of chlorine amount is observed as a residual chlorine which is quite more than the recommended limit i.e. 0.5mg/l as per BIS10500:2012. Higher amount of residual chlorine causes the irritating effect to eyes and nasal passage and stomach discomfort. Other health effect that comes from drinking high concentration of chlorinated water is that it may cause bladder cancer. By reducing dose of chlorine, considerable saving can be achieved which is calculated as follows.:
4) Chlorine demand 0.5 mg/l and residual chlorine maximum value = 0.5 mg/l
   Hence chlorine dose required = chlorine demand + residual chlorine = 0.5+0.5 = 1.0 mg/l
   Extra dose of chlorine 2.0 -1.0 = 1.0 mg/l
   Total chlorine dosage = 45kg/day, Daily chlorine extra dose = 45kg/day
   Extra chlorine dose in kg in a year is provided =45* 365= 16425kg/year
   Cost of liquid chlorine Rs 40/kg (including transportation)
   Total yearly cost is 40*16425=Rs 6,57,000 (Rs six lac, fifty-seven thousand)
5) MPN in raw water rages from (8-14) and after disinfection treatment it is completely removed hence treated water is safe from bacteriological point of view.
6) Flash mixer was not working.

VII. SUGGESTIONS

A. Chlorine demand of water shall be continuously evaluated and according to residual chlorine requirement. The optimum dose of liquid chlorine shall be decided, as per study. It is revealed that an amount of rupees 6,57,000 can be saved per annum, if chlorine dose is reduced from 2 mg/l to 1 mg/l

B. Charts/ Tables / Curves for deciding optimum dose of coagulants be prepared and accordingly dosing of alum shall be done using dosing devices. This will ensure saving in consumption of alum and will produce less sludge in clarifier. Thus sludge handling cost will also get reduced considerably.

C. Justification of addition of lime in raw water shall be reviewed. During monsoon season when turbidity is quit high and alkalinity of water is considerably less lime addition may be done as per the requirement. This will also save some amount towards addition of lime when it is not required to be added.

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