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Analysis of physico-chemical Parameters and Heavy Metals in Ground Water Contaminated with Textile Dye Effluents

Chandra Mohan Nukala and Prof. A. Usha Rani*
(1).Dept. of Zoology, Govt. Degree College, Rajampeta, YSR Dt (2). Dept. of Zoology, Sri Venkateswara University, Titupati.
[1]nukalacm@gmail.com,[2]aur_svu@yahoo.co.in

Abstract : Water is a transparent fluid and occupies 71% of the Earth's surface. It is the major component of body fluids. Groundwater is most important sources of water for irrigation, drinking, bathing and industrial processes. Textile dye and printing units utilize major amount of ground water. Nagari town and it surrounds having about 120 small scale textile dye units. They release high amount of wastes in to the water. Due to this the ground water quality becomes degrade. To know the quality of ground water six ground water samples collected during March – June 2012 from six different cites around Nagari town (Ekambarakuppam(S1), Sathrawada(S2), Chintalapatteda(S3), Nagari Town-I(S4), Nagari Town-II(S5)and kothapet(S6) and analyzed for various physico-chemical parameters(by standard methods) and some heavy metals(by AAS). 13 physico-chemical parameters and 5 heavy metals have been analyzed. The results were compared with drinking water quality standards laid by World Health Organization and USEPA. The results shows water samples were odourless, some water samples were in yellow color and others in pale yellow color. Nagari Town – II showed the highest basic pH i.e., 7.6. Maximum amount of total solids(1673.33±41.311mg/L), total dissolved solids (1596.66±20.896mg/L), cadmium(0.029±0.009mg/), chromium(0.201±0.009mg/L)and iron(0.143±0.009mg/L) present in S1 sample. Low amount of DO (1.083±0.248mg/L) and high amount of BOD(99.666±7.118mg/L) present in S3 sample. It shows the S1 and S3 samples were highly polluted. Among all the heavy metals Cr range was high in all the samples. The present study may help to understanding the great threats to the ground water from the above said regions.

Keywords : Ground water, biological oxygen demand, total solids, cadmium, chromium.

INTRODUCTION:

Water is essential to people and the largest available source of fresh water is in the form of "Groundwater". The value of the ground water lies not only in its widespread occurrence and availability, but also in its consistent good quality, which makes it an ideal source of drinking water (Hanuman, 2012). The industrial and the municipal solid waste have emerged as the leading causes of pollution of surface and groundwater (Rajappa *et al.,* 2011).

The functioning of an aquatic ecosystem and its stability to support life forms depend to a great extent on the physico-chemical characteristics of its water. Oxygen is one of the most important factors in any living ecosystem. The main sources of DO are atmosphere and photosynthetic organisms. The amount of DO in water depends on surface area exposed, temperature etc. Monitoring oxygen concentration helps to know the health of a water body and its one convenient way of feeling the pulse of an aquatic ecosystem (Odum, 1971). Fresh water resource is under constant threat of deterioration of the water quality, which is now a global problem (Mahananda *et al.,* 2010; Rajappa *et al.,* 2011). In recent times, these resources were polluted due to anthrapogenic activities such as industrialization, indiscriminate usage of chemicals, dumping of wastes and discharging of the industrial effluents into the nearest water bodies. Among all the industries, Textile industry is the back-bone of our country's economy, since it contributes about $1/3^{rd}$ of the foreign exchange by export and provides jobs to about 25% labour force in the country (Chavan, 2001; Ravinder *et al.,* 2005; Subhasini *et al.,* 2006). In

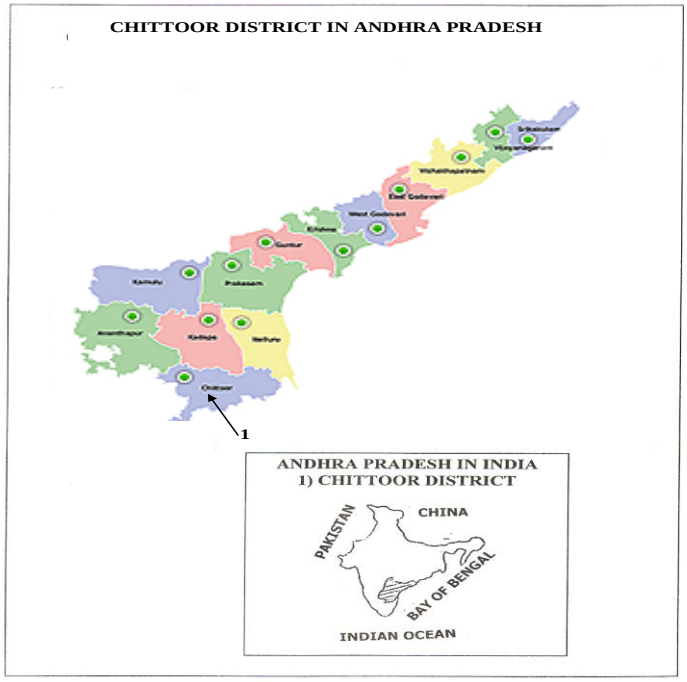
Andhra Pradesh state, Nagari Town of Chittoor District is well known for textile printing and dying industries. There are about 120 small and Large scale textile dye industries in and around Nagari Town, which discharge enormous quantity of waste leading to the degradation of water quality.

Textile dye effluents contain toxic heavy metals like Cd, Cr, Zn, Fe, Pb and Cu etc. Heavy metals such as cadmium (Cd), mercury (Hg) and Cr could cause hazardous effects on kidney, skin, muscle, lung and even cause hypertension. Continuous exposure of animals and humans to heavy metals causes hepatotoxicity and nephrotoxicity(Obaiah J. and Usha Rani, A. (2012). Mostly, these are the general effects that occur if someone has higher amounts of heavy metals like Cr in their body and such poisoning cases display nausea, vomiting and subsequently hair and nail changes and skin lesions (Cervantes *and* Campos-Garcia, 2007; Nordberg *et al.,* 2009). A Person ingesting large doses of copper may show symptoms like vomiting, nausea and diarrhea hematuria and jaundice (Nordberg *et al.,* 2007). Excessive intake of soluble salts of iron or copper by the body through different routes like oral or any other methods causes extensive and severe gastrointestinal manifestation, systemic toxicity, shock and lethal effect (Nordberg *et al.,* 2009), which are highly stable and not degradable easily and cannot be removed by conventional wastewater treatment methods. This property of non degradable nature and long time persistence in the environment the toxic waste often accumulates through tropic level causing a deleterious biological effects (Navarro *et al.,* 2001; Kannan *et al.,* .2005; Olayinka and Alo, 2004; Nardi *et al.,* 2009; UNESCO, 2011). As a result the local people are facing many problems such as poisoning, nausea, Gastrointestinal ulcers, nephritis, dysfunction of Central nervous system, vomiting (Eenadu daily, dt. 20-02-2006). Majority of the dyes are toxic, mutagenic, carcinogenic and stable to light and temperature (Cheng *et al.,* 1998; Carneiro *et al.,* 2010). Removal of such dyes is a matter of serious concern (Ong *et al.,* 2010; Barka *et al.,* 2011). The problem has attracted the attention of media and the Central and State Governments also. Hence the physico-chemical characteristics and heavy metals of groundwater samples collected from in and around Nagari Town, Chittoor Dist. A.P. India, have been assessed and enlightened the ill effects of ground water pollution.

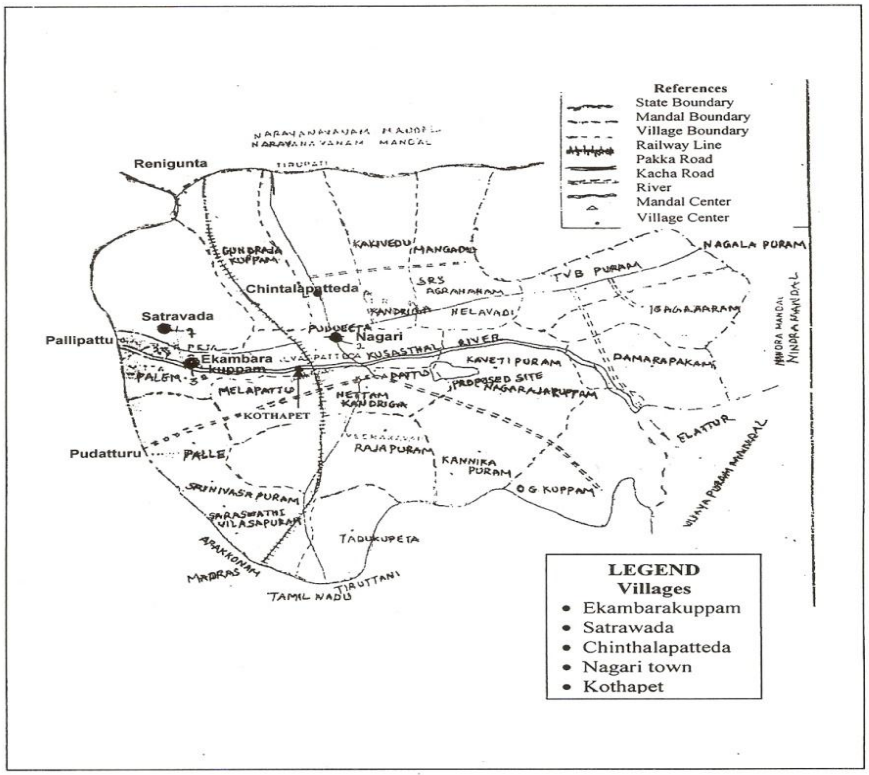
COLLECTION OF WATER SAMPLES:

To measure the quality of groundwater polluted by textile dying industries in and around Nagari Town, Chitooor Dist., Andhra Pradesh State - six different areas were selected i.e. Ekambarakuppam (S1), Sathrawada (S2), Chintalapatteda (S3), Nagari Town – I (S4), Nagari Town – II (S5) and Kothapet (S6) (Pic. 1&2). The groundwater samples were collected from six different bore-wells of the above said regions during March – June, 2012 (summer season). The groundwater samples were collected in prewashed (with detergent, diluted HNO_3 and doubly de-ionized distilled water respectively) polyethylene bottles (1-2 L). Before collecting the samples, the sample bottles and their caps were rinsed three times with the selected bore-well water. The collected water sample bottles were brought to the laboratory for the analysis of physico-chemical characteristics like color, temperature, pH, odour, total solids, total dissolved solids, total suspended solids, chlorides, dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), inorganic phosphates and organic matter. The collected water samples were directly taken into reagent bottles and fixed immediately for the estimation of DO. Water samples were fixed with a few drops of ether / toluene as described by Stewart *et al.,* (1975). Then the collected samples were transported to the analytical laboratory and stored in freeze. After reaching the lab, the remaining physico-chemical characteristics were carried out within 72 hrs as per the procedures adopted by APHA (2005), AWWA, WPCF (1991).

By using the Atomic Absorption Spectrophotometer (Schimadzu AA- 6300) different heavy metals were measured in the groundwater samples contaminated by textile dye effluents in and around Nagari Town.



Picture 1: Locations of Study Area



Picture 2: Locations of Study Area

MATERIALS:

Chemicals:

The chemicals which were used in the present study were obtained from the standard chemical companies like Sigma Chemical Co. Merck, SD Fine Chemicals.

METHODS:

Collection of groundwater samples:

Six different bore-well water samples from six sampling sites were collected from Nagari Town and its surrounding textile industrial areas. The sampling areas selected eventually and were reported in Table- I.

Table-I: List of the Sampling sites in and around Nagari Town and source of groundwater samples.

S. No.	Name of the Area	Source of groundwater
1.	Ekambarakuppam (S1)	Bore-well
2.	Sathrawada (S2)	Bore-well
3.	Chintalapatteda (S3)	Bore-well
4.	Nagari Town – I (S4)	Bore-well
5.	Nagari Town – II (S5)	Bore-well
6.	Kothapet (S6)	Bore-well

Analysis of physico-chemical characteristics of groundwater samples:

Colour:

By visible observation.

Temperature:

The temperature of the collected groundwater samples was measured with the help of a laboratory Centigrade thermometer (1°C -100°C) graduated to 0.1°C.

pH:

The pH measurements were made using Elico digital pH meter (PL170).

Odour :

By manual mechanism.

Total Solids:

The total solids were estimated by adopting the method of Trees, (1978). The results expressed in mg/l.

Total Dissolved Solids:

The total dissolved solids were estimated by adopting the method of APHA, 2005.

Total Dissolved Solids: Weight of the residue(mg)/volume of the sample (ml).

Total Suspended Solids:

The total soluble solids were estimated by adopting the method of APHA, 2005.

Total Suspended Solids = weight of the residue (mg)/volume of the sample (ml).

Chlorides:

Estimation of chlorides from the groundwater samples was done by Mohr Argentometric method (Hermanowicz *et al.*, 1999).

Dissolved Oxygen (DO):

The dissolved oxygen content was estimated by Winklers iodometric method (1989) and expressed in ppm.

Biological Oxygen Demand (BOD):

BOD was estimated by the method of Ruchnoft and Moore (1940). Water samples were collected in 300 ml BOD bottles from the source. The dissolved oxygen present in the water samples was determined by Winkler's method. This is the value of dissolved oxygen when t = 0(DO_0). The other BOD bottle was kept in incubation at 20°C for 5 days (DO_5). And the dissolved oxygen after 5 days was also determined. The BOD values were expressed in ppm.

Chemical Oxygen Demand (COD):

Estimation of COD by the method of APHA(2005).

Inorganic Phosphates (IP):

The inorganic phosphate content in the water sample was measured by following the Stannous chloride method (APHA (2005), AWWA, WPCF, 1981). The inorganic phosphate content is expressed in mg of phosphate/L.

Organic Matter:

The organic matter was estimated by adopting the method of APHA, 2005.

Estimation of heavy metals:

Heavy metal concentrations in the groundwater samples were measured by using Schimadzu (AA-6300), double beam Atomic Absorption Spectrophotometer.

RESULTS:

Physico-chemical characteristics:

The average physical and chemical properties of the groundwater samples which were mentioned above were given in table - II.

Colour:

The water samples collected from Ekambarakuppam and Sathrawada were in yellow. The water samples collected from other remaining sites were pale yellow in colour.

Temperature:

The temperature of the selected ground water samples was varied from 28.1°C to 29.9°C(Table – II). The maximum temperature (29.9°C) was recorded in groundwater collected from Kothapet whereas groundwater collected from both Ekambarakuppam and Nagari Town – I showed low temperature (28.1°C) (Fig – 1).

pH:

The Ph of all the groundwater sampl es were ranged from 6.9 to 7.6 with slight acidic to base. The slight acidic pH was noticed in Ekambarakuppam (6.9) (Fig. 2). Remaining all the samples were base in nature. Among all the remaining samples, Nagari Town – II showed the highest basic pH i.e., 7.6

Odour :

The groundwater samples collected from all the six selected areas were odourless.

Total Solids:

The total solids present in the water samples collected from the selected areas in and around Nagari Town varied from 1182.5±40.218 mg/L to 1673.33±41.311mg/L.

The total solids of Ekambarakuppam, Sathrawada, Chintalapatteda, Nagari Town–I, Nagari Town-II and Kothapet water samples showed 1673.33±41.311mg/L, 1377.667±40.207mg/L, 1489.167±28.708mg/L, 1382±24.443mg/L, 1495±24.289mg/L and 1182.5±40.218mg/L respectively (Fig. 3). High amount of total solids were observed in sample collected from Ekambarakuppam (1673±41.311mg/L) and low amount of total solids were found in the ground water collected from Kothapet (1182±40.218 mg/L) (Table – II).

Total Dissolved Solids:

The total dissolved solids present in the water samples, which were collected from the selected areas in and around Nagari Town varied from 999.166±14.288mg/L to 1596.66±20.896mg/L (Fig. 4).

The total dissolved solids in Ekambarakuppam, Sathrawada, Chintalapatteda, Nagari Town–I, Nagari Town-II and Kothapet samples were to be 1596.66±20.896 mg/L, 1273.33±39.832 mg/L, 1293.333±13.291 mg/L, 1290±22.894mg/L, 1400±14.142 mg/L and 999.166±14.288 mg/L respectively.

Maximum amount of total dissolved solids were observed in groundwater sample collected from Ekambarakuppam (1596.66±20.896mg/L) and low amount of total solids were found in the ground water collected from Kothapet (999.166±14.288mg/L) (Table - II).

Total Suspended Solids:

The total suspended solids in the groundwater samples collected from the test areas in and around Nagari Town varied from 98.666±8.710 mg/L to 198±8.602 mg/L (Fig. 5).

The total suspended solids of Ekambarakuppam, Sathrawada, Chintalapatteda, Nagari Town–I, Nagari Town-II and Kothapet samples showed 98.666±8.710 mg/L, 99.166±7.359 mg/L, 192.833±14.905 mg/L, 99.5±3.937 mg/L, 101.166±5.419 mg/L and 198±8.602 mg/L respectively.

Maximum amount of total suspended solids were noticed in the sample collected from Kothapet (198±8.602mg/L) whereas the sample collected from Ekambarakuppam showed low amount of total suspended solids (98.666±8.710 mg/L) (Table - II).

Chlorides:

The amount of chlorides in the selected ground water samples were ranged from 277.55±7.007mg/L to 478.833±7.626mg/L. The amount of chlorides in the samples collected from Ekambarakuppam, Sathrawada, Chintalapatteda, Nagari Town–I, Nagari Town-II and Kothapet were found to be 357±5.099mg/L, 478.833±7.626mg/L, 277.55±7.007mg/L, 359.166±4.355mg/L, 370.333±3.502mg/L and 288.5±5.468mg/L respectively (Fig. 6).

High amount of chlorides were observed in the sample collected from Sathrawada (478.833±7.626mg/L) and Low amount of chlorides were present in Chintalapatteda sample (277.55±7.007mg/L).

Dissolved Oxygen (DO):

The amount of DO in all the groundwater samples ranged from 1.083±0.160 mg/L to 4.091±0.185mg/L. The groundwater samples collected from Ekambarakuppam, Sathrawada, Chintalapatteda, Nagari Town–I and Nagari Town-II and Kothapet showed 1.383 ±0.160mg/L, 3.333±0.294mg/L, 1.083±0.248mg/L, 3.108±0.220mg/L, 4.091±0.185mg/L and 2.071±0.220mg/L respectively. The high amount of DO was recorded in the sample collected from Nagari Town – II (4.091±0.185mg/L), while the sample collected from Chintalapatteda showed low amount of DO (1.083±0.248mg/L) (Fig. 7).

Biological Oxygen Demand:

BOD values of the samples collected from the selected areas were ranged from 41±2.607mg/L to 99.666±7.118 mg/L. The BOD value of groundwater samples collected from Ekambarakuppam, Sathrawada, Chintalapatteda, Nagari Town–I, Nagari Town-II and Kothapet were found to be 80.333±3.559 mg/L, 49.666±6.153mg/L, 99.666±7.118mg/L, 43.166±3.816mg/L, 41±2.607mg/L and 50.166±3.430mg/L respectively (Fig. 8).

Maximum amount of BOD was found in the sample collected from Chintalapatteda (99.666±7.118mg/L) and the minimum amount of BOD was noticed the sample collected from Nagari Town – II (41±2.607mg/L).

Chemical Oxygen Demand (COD):

The COD values of the collected ground water samples were ranged from 51.5± 3.937mg/L to 159.66± 10.132 mg/L. The COD values of groundwater samples from Ekambarakuppam, Sathrawada, Chintalapatteda, Nagari Town–I, Nagari Town-II and Kothapet were found to be 93±3.898mg/L, 63.5±3.082mg/L, 159.666±10.132mg/L, 63.557±3.557mg/L, 51.5±3.937mg/L and 63.166±3.816mg/L respectively (Fig. 9).

Maximum COD was observed in the sample collected from Chintalapatteda (159.666±10.132mg/L) and low level of COD was found in the sample collected from Nagari Town – II (51.5±3.937mg/L) (Table- II).

Inorganic Phosphates:

The amount of inorganic phosphates found in the groundwater samples varied from 0.061±0.021mg/L to 0.616±0.248mg/L. The amount of inorganic phosphates in the test samples collected from Ekambarakuppam, Sathrawada, Chintalapatteda, Nagari Town–I Nagari Town-II and Kothapet were found to be 0.111±0.030mg/L, 0.061±0.021mg/L, 0.616±0.248mg/L, 0.085±0.044mg/L,

0.101±0.024mg/L and 0.616±0.213mg/L respectively (Fig. 10).

Samples collected from both Chintalapatteda and Kothapet showed more amount of inorganic phosphates i.e. 0.616±0.248mg/L. However low amount of inorganic phosphates were found in the Sathrawada sample (0.061±0.021mg/L).

Organic Matter:

The amount of organic matter in the tested ground water samples was ranged from 99.666±7.118mg/L to 150.333±7.118mg/L. The amount of organic matter present in the samples collected from Ekambarakuppam, Sathrawada, Chintalapatteda, Nagari Town–I, Nagari Town-II and Kothapet were found to be 150.333±7.118mg/L, 99.666±7.118mg/L, 197.05±9.354mg/L, 121.666±8.164mg/L, 147.5±9.354mg/L and 122.5±9.354mg/L respectively (Fig. 11).

High amount of organic matter was observed in the sample collected from Chintalapatteda (150.333±7.118mg/L) and Low amount of organic matter was present in Sathrawada sample (99.666±7.118mg/L).

Estimation of metal concentrations:

Cadmium (Cd):

The mean Cd levels in the groundwater samples were ranged from 0.017±0.008mg/L to 0.029±0.009mg/L. Maximum Cd concentration levels were found in the sample collected from Ekambarakuppam (0.029±0.009mg/L) and low amount of Cd concentration was noticed in Kothapet sample (0.017±0.008mg/L) (Table - III).

The mean levels of Cd in the groundwater samples collected from Ekambarakuppam, Sathrawada, Chintalapatteda, Nagari Town–I, Nagari Town-II and Kothapet were found to be 0.029±0.009mg/L, 0.025±0.008mg/L, 0.026±0.009mg/L, 0.019±0.008mg/L, 0.028±0.008mg/L and 0.017±0.008mg/L respectively (Fig. 12). Cd concentration levels in the test sample areas were in the following order:

Ekambarakuppam > Nagari Town-II > Chintalapatteda > Sathrawada > Nagari Town–I > Kothapet

Chromium (Cr):

The mean Cr concentration levels in the selected groundwater samples were ranged from 0.176±0.007mg/L to 0.201±0.009mg/L. Maximum Cr levels were noticed in the sample collected from Ekambarakuppam (0.201±0.009mg/L) and low amount of Cr was found in Nagari Town – I sample (0.176±0.007mg/L).

The mean levels of Cr in the groundwater samples collected from Ekambarakuppam, Sathrawada, Chintalapatteda, Nagari Town–I, Nagari Town-II and Kothapet were found to be 0.201±0.009mg/L, 0.199±0.008mg/L, 0.187±0.009mg/L, 0.176±0.007mg/L, 0.0192±0.011mg/L and 0.193±0.010 mg/L respectively (Fig. 12). Cr concentration levels in the test sample areas were in the following order:

Ekambarakuppam > Sathrawada > Kothapet > Nagari Town-II > Chintalapatteda > Nagari Town–I

Copper (Cu):

Mean levels of Cu found in the groundwater samples collected from in and around Nagari Town was ranged between 0.027±0.010mg/L to 0.038±0.010mg/L.

Mean levels of Cu in the test samples collected from Ekambarakuppam, Sathrawada, Chintalapatteda, Nagari Town–I, Nagari Town-II and Kothapet were observed to be 0.033±0.009mg/L, 0.027±0.008mg/L, 0.038±0.009mg/L, 0.031±0.006mg/L, 0.038±0.007mg/L and 0.025±0.005 mg/L respectively. The mean levels of Cu in the test areas were in the following order:

Chintalapatteda > Nagari Town-II > Ekambarakuppam > Nagari Town–I > Sathrawada > Kothapet.

Zinc (Zn):

The Mean concentration of Zn found in the groundwater samples collected from in and around Nagari Town was ranged from 0.014±0.004mg/L to 0.05±0.010mg/L.

Zn levels in the test samples collected from Ekambarakuppam, Sathrawada, Chintalapatteda, Nagari Town–I, Nagari Town-II and Kothapet were noticed to be 0.014±0.004mg/L, 0.023±0.005mg/L, 0.05±0.010mg/L, 0.022±0.008mg/L, 0.029±0.008mg/L and 0.043±0.009mg/L respectively (Fig. 12). The mean concentration levels of Zn were observed in the following order:

Chintalapatteda > Kothapet > Nagari Town-II > Sathrawada > Nagari Town–I > Ekambarakuppam.

Iron (Fe):

Mean levels of Fe found in the selected groundwater samples collected from different areas in and around Nagari Town was ranged from 0.091±0.007mg/L to 0.143±0.009mg/L.

The mean values of Fe levels in test samples collected from Ekambarakuppam, Sathrawada, Chintalapatteda, Nagari Town–I, Nagari Town-II and Kothapet were found to be 0.143±0.009mg/L, 0.101±0.009mg/L, 0.091±0.007mg/L, 0.099±0.006mg/L, 0.128±0.011mg/L and 0.116±0.008mg/L respectively (Table - III). The mean concentration levels of Fe were observed in the following order:

Ekambarakuppam > Nagari Town-II > Kothapet > Sathrawada > Nagari Town–I > Chintalapatteda.

DISCUSSION:

The quality of ground water (borehole) is generally neglected based on the general belief that it is pure through the natural purification process. But this natural resource i.e. groundwater was contaminated with various effluents which were discharged in to the environment by various industries like textile dye industry (Nassef, 2006, Mohan and Pittman, 2006; Hanuman *et al.*, 2012).

The physico-chemical analysis of the textile dye effluent contaminated groundwater reflects the impact of the textile dye wastes on groundwater pollution. Nagari Mandal has been identified as one of the polluted areas in Chittoor Dist, Andhra Pradesh state, India and attracted the government, media(Eenadu Telugu Daily (20-02-2006); Vartha Telugu Dina Patrika (25-09-2006) and researchers (Chandramohan *et al.,* 2009). The grave pollution situation that exists in six different places in and around Nagari Town due to the textile dye based industries. The adverse effects of dyeing unit effluents on the quality of ground water had been reported by several workers (Gupta, 1999; Sharma *et al.,* 2005).

The physico-chemical parameters and heavy metal contamination was associated with the anticipated generation of waste water from textile dye industries and dyeing intermediate products. The dye wastes thus produced might contain toxic heavy metals and hazardous substances interfering with the physico-chemical parameters, which are not acceptable to the recipient environment, if released uncontrolled (Jain *et al.,* 2003; Chandramohan *et al.,* 2009). Many of the dyes used in the textile industry are responsible for carcinogenicity (Anonym, 1982) and teratogenicity (Beck, 1983). Dyes are introduced into the environment through the waste discharges of these industries. There are ample evidences of their harmful effects (Pal and Brijmohen, 1980; Subhasini *et al.,* 2006; Ali *et al.,* 2009; Carneiro *et al.,* 2010; Joshi *et al.,* 2010).

During the present study of the test areas, there was no significant difference in the temperature of the groundwater samples in the selected areas. The temperature that was noticed in this study was in the optimum level for the survival of microorganisms (Guha *et al.,* 2001). Regarding the pH findings in the present study demonstrated that all the samples were alkaline except the sample collected from Ekambarakuppam (Fig. 2). This might be due to temperature that reduces the solubility of CO_2 (Mahananda *et al.,* 2010). The Alkalinity nature of all the samples might be due to low water table and lower temperature bringing down the rate of decomposition of salts to a minimum thereby increasing the alkalinity.

The low amount of DO was recorded in sample collected from Chintalapatteda (Table III – Fig. 7) was might be due to the high rate of oxygen consumption by oxidisable matter. The maximum value of DO was observed in Nagari Town – II water sample might be on the basis of the capacity of water to hold the oxygen. The higher level of nutrient load and other factors caused lower level of DO in all the samples (Mahananda *et al.,* 2010).

Total dissolved solids were commonly found as carbonates, bicarbonates, chlorides, sulphates and nitrates of various metals like iron, manganese and mineral containing rocks. The high content of dissolved solids increases the density of water (Rajappa, 2011). The water samples collected from all the selected areas in the present study were found to possess high amount of total dissolved solids with normal level of 500mg/L (ISI:10500). Further, total dissolved solids are an indication of the degree of dissolved substances such as metal ions in the water. This might be evidenced with the presence of various metal ions like Cd, Cr, Cu, Zn and Fe in the ground water collected from the selected sites (Table - II and Fig. 4).

Total suspended solids were also high in all the samples with compared to the

limitations described by ISI: 10500 (2009) (Table II). Water contain high amount of suspended solids may be aesthetically unsatisfactory for bathing (APHA, 2005). The total suspended solids are composed of carbonates, bicarbonates, chlorides, phosphates and nitrates of calcium, magnesium, sodium, potassium, manganese, organic matter, salts and other particles. The groundwater samples collected from all the selected sites contained maximum amount of total suspended solids. This might indicate the textile dye effluents containing the various pollutants such as carbonates, bicarbonates and organic matter etc., It was evidenced with the presence of high amounts of chlorides in all the groundwater samples (Mahananda *et al.,* 2010).

Table – II shows the variation of chloride content in the groundwater samples collected from the selected sites in and around Nagari Town. The chloride content of the test samples were ranged from 277.5mg/L to 478.833mg/L. Chloride content can increase with the increasing degree of eutrophication. It might suggest that all the test samples were rich in organic matter.

The inorganic phosphate levels were also varied among the test samples. Phosphates occur in natural water at low quantity. As many plants absorb and stores phosphorous more than their actual needs. Maximum concentration was observed in the samples collected from both Chintalapatteda and Kothapet, which interferes with chemical coagulation of turbid water (Figure - 10). The maximum concentration value of phosphates might be due to the solar radiation in the form of increasing temperature, which might have encouraged the biological degradation of the organic matter.

From the obtained results, it is clear that the metal concentrations in all the six areas were different. Cd concentrations in the groundwater samples were relatively high with compared to permissible limits described by ISI: 10500 (2009).

The levels of Cu, Fe and Zn in the groundwater samples from all the selected sites were very low and were within the limits described by WHO (1971) and ISI: 10500 (2009).

Cr levels in the groundwater samples were higher than the other elements in the studied areas. Cr content varied between 0.176 mg/L to 0.201mg/L. It might be due to the usage of Cr in the manufacture of the dyes, which were used in textile dye industry. Due to untreated discharge of textile dye effluents may cause the appearance of various metals in the ground water.

Heavy metals have great ecological significance due to their toxicity and tendency to accumulate in organisms (Obaiah *et al.,* 2012; Siraj Basha and Usha Rani, 2003). The findings of the present study indicating the enrichment rate of pollutants in ground water reflects the contamination sources i.e., textile dye effluents.

Metals play an integral role in the life processes of microorganisms. Some metals, such as calcium, cobalt, Cr, Cu, iron, potassium, magnesium, manganese, sodium, nickel and Zn are essential, serves as micronutrients and are used for redox-processes; to stabilize molecules through electrostatic interactions; as components of various enzymes; and for regulation of osmotic pressure (Bruins *et al.,* 2000). Many other metals have no biological role (e.g. silver, Cr, Cd, gold, lead and mercury), non-essential (Bruins *et al.,* 2000) and potentially toxic to microorganisms.

Toxicity of nonessential metals occurs through the displacement of essential metals from their native binding sites or through ligand interactions occurs in the biological system (Nies, 1999; Bruins *et al.,* 2000). For example, Hg, Cd, Cr and Ag tend to bind to SH groups, and thus inhibit the activity of sensitive enzymes (Nies, 1999). In addition, at high levels, both essential and non-essential metals can damage cell membranes; alter enzyme specificity; disrupt cellular functions and damage the structure of DNA (Bruins *et al.,* 2000).

Even though microorganisms have specific uptake systems, high concentrations of non-essential metals may be transported into the cell by a constitutively expressed unspecific system. This "open gate" is the one reason in which metal ions are toxic to microorganisms (Nies, 1999). As a consequence, microorganisms have been forced to develop metal-ion homeostasis factors and metal-resistance determinants (Nies and Silver, 1995; Nies, 1999; Bruins *et al.,* 2000).

As metal ions cannot be degraded or modified like toxic organic compounds, there are six possible mechanisms for a metal resistance system. They are exclusion 1) by-permeability barrier; 2) intra- cellular sequestration 3) extra-cellular sequestration; 4) active efflux pumps; 5) enzymatic reduction and 6) reduction in the sensitivity of cellular targets to metal ions (Ji and Silver, 1992; Nies and Silver, 1995; Nies, 1999; Rensing *et al.,* 1999; Bruins

et al., 2000). One or more of these resistance mechanisms allows microorganisms to survive in metal contaminated environments.

Hence, the heavy metal concentrations were found to be influenced by the interaction of textile dye waste materials and chemicals near the test areas of the present study i.e., particularly borewells of all the six places in contrast to many such other places in and around Nagari Town.

In the present study, the heavy metal analysis clearly demonstrated that the concentration of Cr was high in all the groundwater samples collected from in and around Nagari Town. When the groundwater was subjected to the treatment of *Pseudomonas fluorescens*, it significantly reduced the Cr levels from the groundwater contaminated with textile dye effluents.

Table-II: Physico-Chemical Characteristics of Ground Water Samples Collected from Different Places in and Around Nagari Town During the Summer Season (March - June 2012).

S. No.	Name of the Phycico-chemical parameter	S1	S2	S3	S4	S5	S6	WHO	USEPA
1.	Colour	Yellow	Yellow	Pale Yellow	Pale Yellow	Pale Yellow	Pale Yellow	Colourless	Colourless
2	Temperature (°C)	28.1 ±0.664	28.2 ± 0.495	29.7 ±0.484	28.1 ± 0.308	29 ± 0.374	29.9 ±0.355	12	12
3	pH	6.9 ± 0.047	7.4 ±0.043	7.5 ±0.037	7.1 ±0.216	7.6 ±0.048	7.2 ±0.273	7	7
4	Odour	odourless	odourless	odourless	odourless	odourless	odourless	Odourless	Odourless
5	Total Solids	1673.33 ±41.311	1377.667 ±40.207	1489.167 ±28.708	1382.5 ±24.443	1495 ±24.289	1182.5 ±40.218	500 - 550	500
6	Total Dissolved Solids	1596.66 ±20.896	1273.33 ±39.832	1293.333 ±13.291	1290 ±22.894	1400 ±14.142	999.166 ±14.288	500	500
7	Total Suspended Solids	98.666 ±8.710	99.166 ±7.359	192.833 ±14.905	99.5 ±3.937	101.166 ±5.419	198 ±8.602	5	0 - 5
8	Chlorides	357 ±5.099	478.833 ±7.626	277.55 ±7.007	359.166 ±4.355	370.333 ±3.502	288.5 ±5.468	200-500	250
9	Dissolved Oxygen	1.383 ±0.160	3.333 ±0.294	1.083 ±0.248	3.108 ±0.220	4.091 ±0.185	2.071 ±0.220	3(MIN)	4.6
10	Biological Oxygen Demand	80.333 ±3.559	49.666 ±6.153	99.666 ±7.118	43.166 ±3.816	41 ±2.607	50.166 ±3.430	--	4
11	Chemical Oxygen Demand	93 ±3.898	63.5 ±3.082	159.666 ±10.132	63 ±3.557	51.5 ±3.937	63.166 ±3.816	10	4

12	Inorganic Phosphates	0.111 ±0.030	0.061 ±0.021	0.616 ±0.248	0.085 ±0.044	0.101 ±0.024	0.616 ±0.213	0.1	--
13	Organic matter	150.333 ±7.118	99.666 ±7.118	197.05 ±9.354	121.666 ±8.164	147.5 ±9.354	122.5 ±9.354	3-4	4

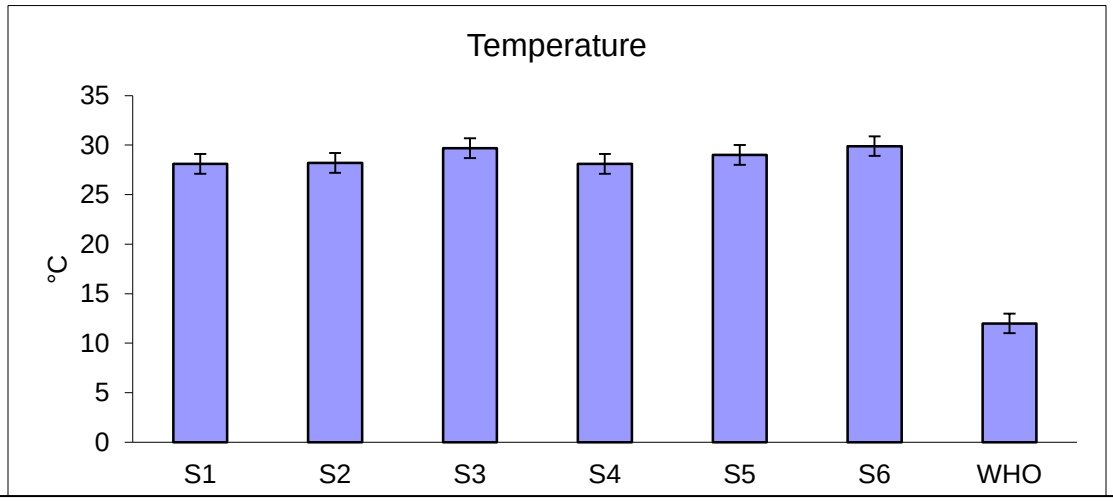
All values are expressed as Mean ± SD of 6 individual samples.
All values are significant @ $p<0.05$

Table -III: Various metal concentrations (mg/L) in the ground water samples contaminated with textile dye effluents in and around Nagari Town collected during the summer season (March– June 2012).

Site Name	Metal concentrations in the ground water sample (mg/L)				
	Cd	Cr	Cu	Zn	Fe
EkambaraKuppam (S1)	0.029	0.201	0.033	0.014	0.143
Sathrawada (S2)	0.025	0.199	0.027	0.023	0.101
Chintalapatteda (S3)	0.026	0.187	0.038	0.05	0.091
Nagari town – I(S4)	0.019	0.176	0.031	0.022	0.099
Nagari town - II (S5)	0.028	0.192	0.038	0.029	0.128
Kothapet (S6)	0.017	0.193	0.025	0.043	0.116
WHO	0.01	0.05	0.3	0.5	0.03
USEPA	0.01	0.1	0.3	0.5	0.04

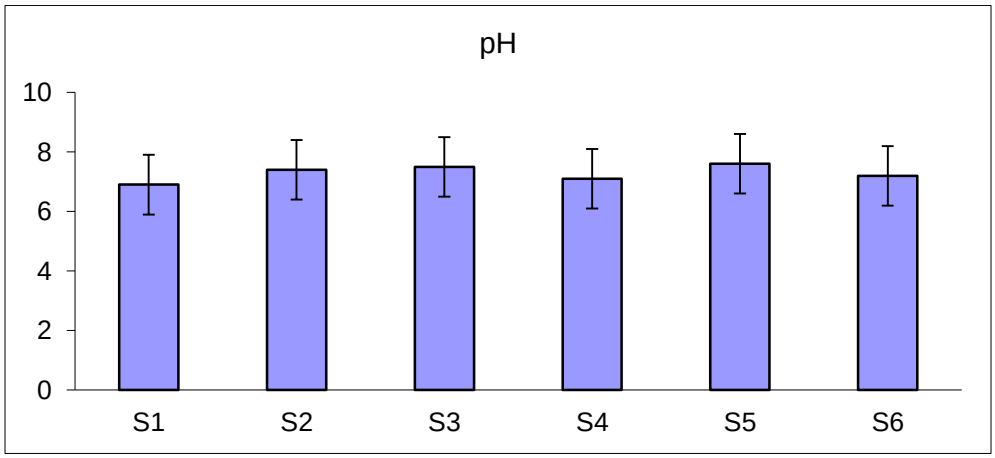
All values are expressed as Mean ± SD of 6 individual samples.
All values are significant @ $p<0.05$

Fig.-1: Temperatures (°C) in the ground water samples contaminated with textile dye effluents collected from in and around Nagari Town.



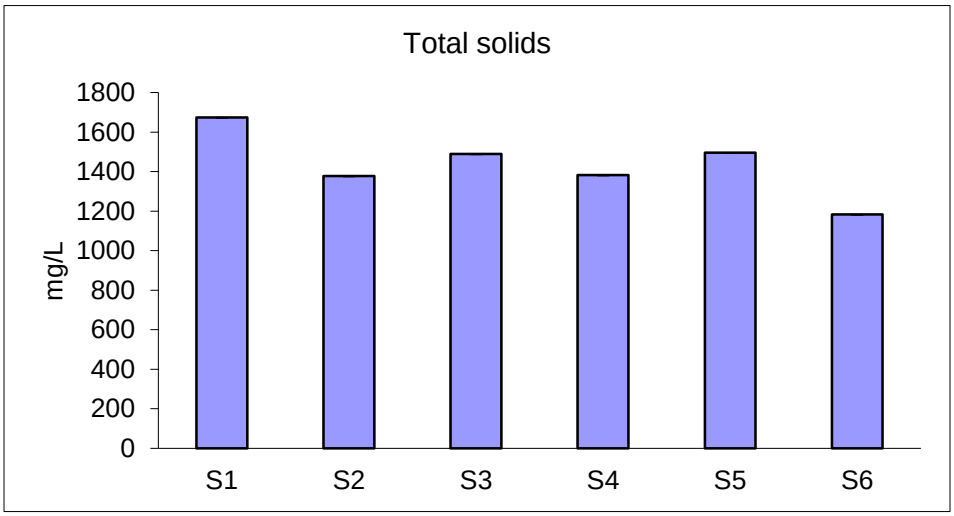
S1- Ekambarakuppam	S3- Chintalapatteda	S5- Nagari Town - II
S2- Sathrawada	S4- Nagari Town – I	S6 - Kothapet

Fig. 2: The pH values in the ground water samples contaminated with textile dye effluents collected from in and around Nagari Town.



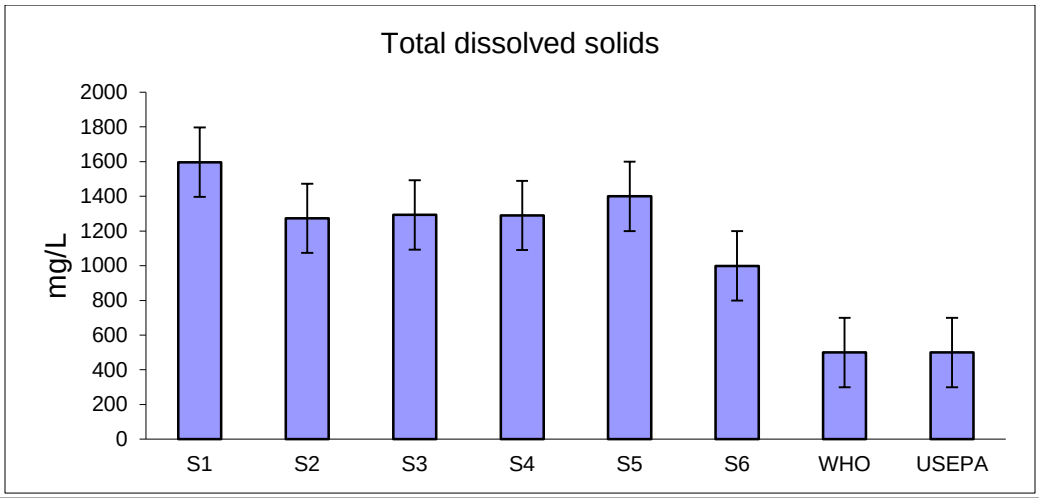
S1- Ekambarakuppam	S3- Chintalapatteda	S5- Nagari Town - II
S2- Sathrawada	S4- Nagari Town – I	S6 - Kothapet

Fig. 3:Total solids (mg/L) present in the ground water samples contaminated with textile dye effluents collected from in and around Nagari Town.



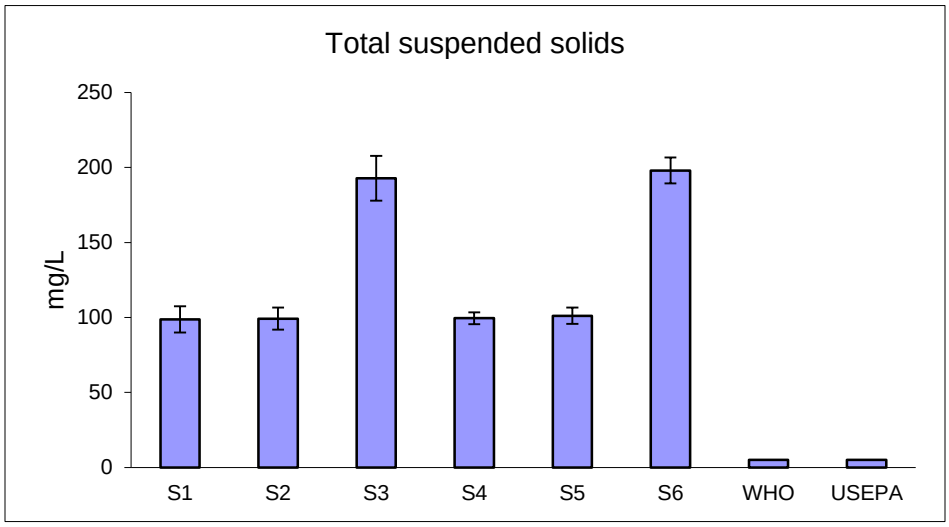
S1- Ekambarakuppam	S3- Chintalapatteda	S5- Nagari Town - II
S2- Sathrawada	S4- Nagari Town – I	S6 - Kothapet

Fig. 4: Total dissolved solids (mg/L) present in the ground water samples contaminated with textile dye effluents collected from in and around Nagari Town.



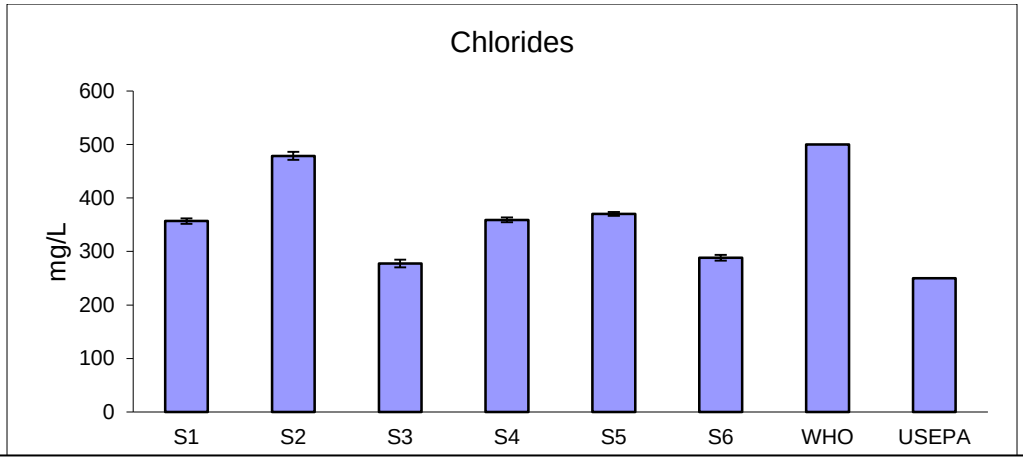
S1- Ekambarakuppam	S3- Chintalapatteda	S5- Nagari Town - II
S2- Sathrawada	S4- Nagari Town – I	S6 - Kothapet

Fig. 5: Total suspended solids (mg/L) present in the ground water samples contaminated with textile dye effluents collected from in and around Nagari Town.



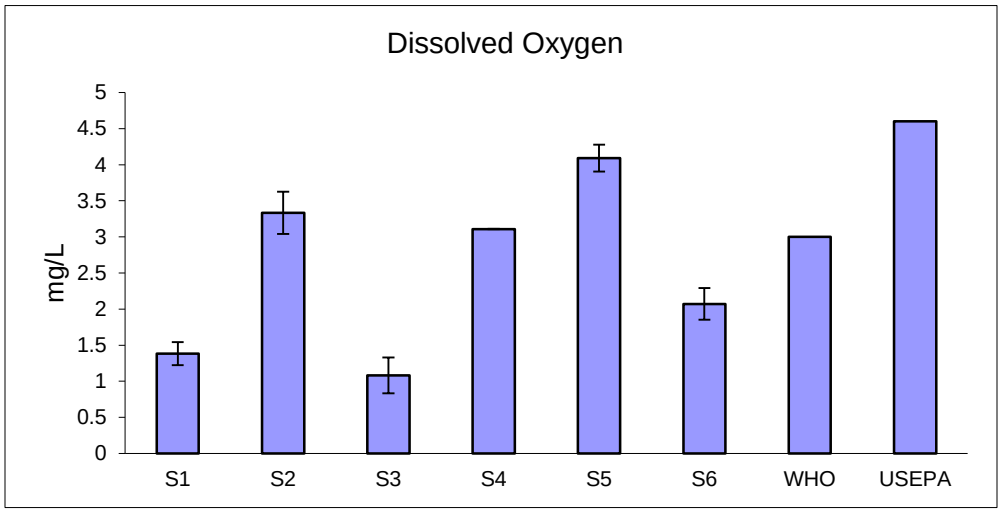
S1- Ekambarakuppam	S3- Chintalapatteda	S5- Nagari Town - II
S2- Sathrawada	S4- Nagari Town – I	S6 - Kothapet

Fig. 6: Chloride levels (mg/L) present in the ground water samples contaminated with textile dye effluents collected from in and around Nagari Town.



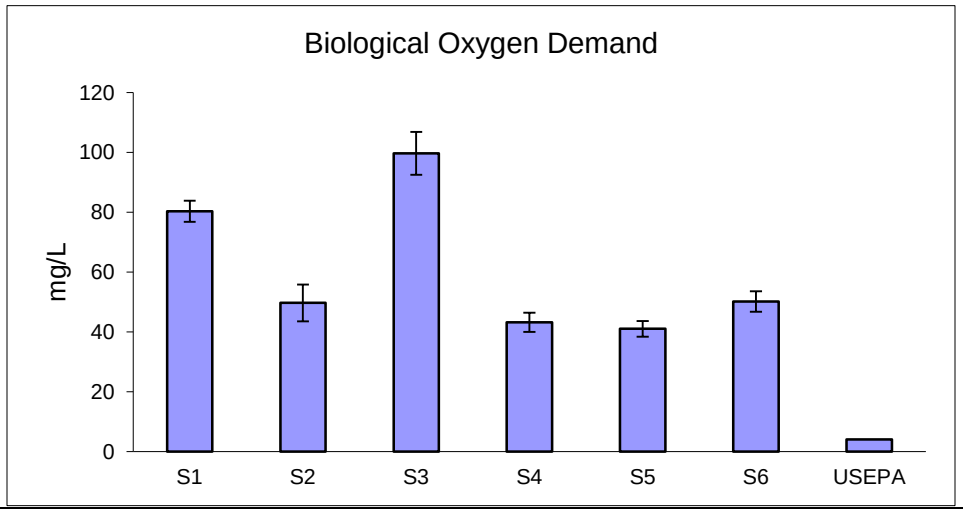
S1- Ekambarakuppam	S3- Chintalapatteda	S5- Nagari Town - II
S2- Sathrawada	S4- Nagari Town – I	S6 - Kothapet

Fig 7: Dissolved Oxygen levels (mg/L) in the ground water samples contaminated with textile dye effluents collected from in and around Nagari Town**.**



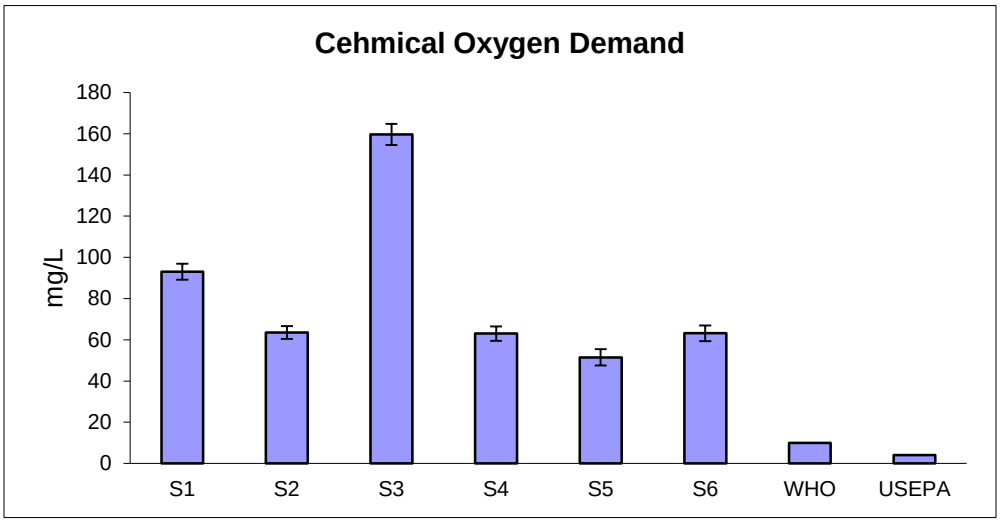
S1- Ekambarakuppam	S3- Chintalapatteda	S5- Nagari Town - II
S2- Sathrawada	S4- Nagari Town – I	S6 - Kothapet

Fig.8: Biological Oxygen Demand values (mg/L) in the ground water samples contaminated with textile dye effluents collected from in and around Nagari Town.



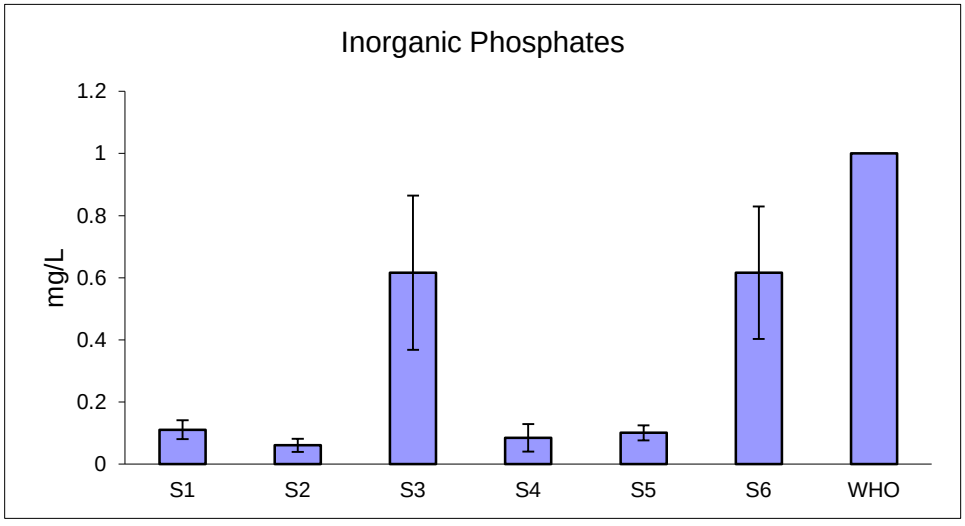
S1- Ekambarakuppam	S3- Chintalapatteda	S5- Nagari Town - II
S2- Sathrawada	S4- Nagari Town – I	S6 - Kothapet

Fig. 9: Chemical Oxygen Demand values (mg/L) in the ground water samples contaminated with textile dye effluents collected from in and around Nagari Town.



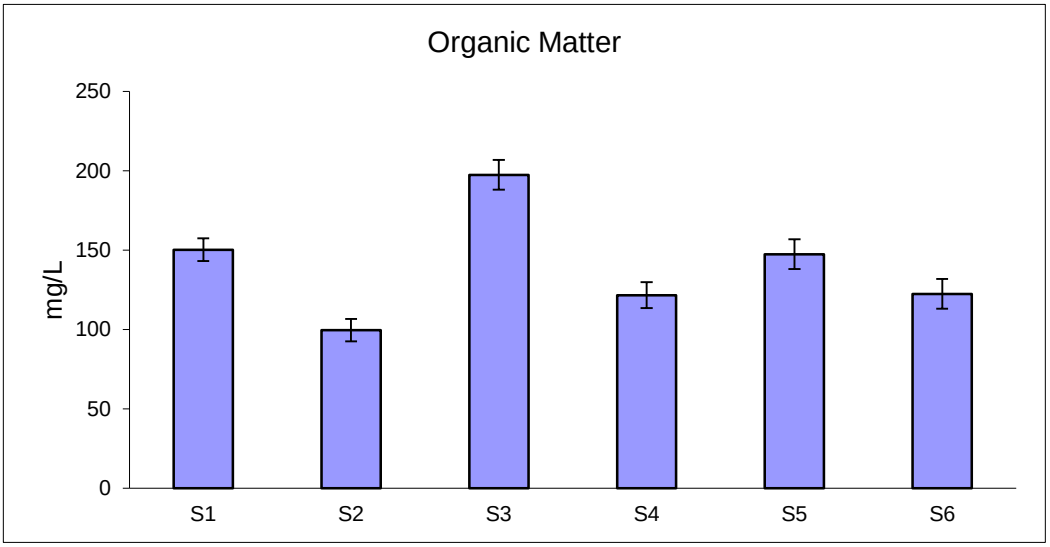
S1- Ekambarakuppam	S3- Chintalapatteda	S5- Nagari Town - II
S2- Sathrawada	S4- Nagari Town – I	S6 - Kothapet

Fig. 10: Inorganic Phosphates levels (mg/L) in the ground water samples contaminated with textile dye effluents collected from in and around Nagari Town



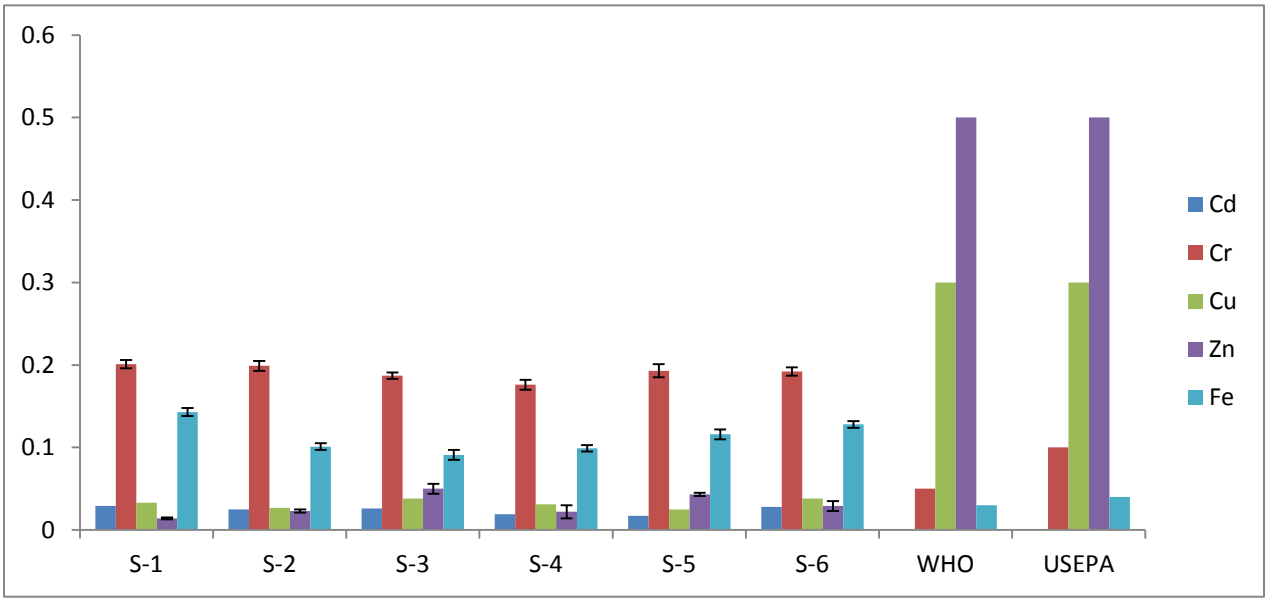
S1- Ekambarakuppam	S3- Chintalapatteda	S5- Nagari Town - II
S2- Sathrawada	S4- Nagari Town – I	S6 - Kothapet

Fig. 11:Organic Matter concentration levels (mg/L) in the ground water samples contaminated with textile dye effluents collected from in and around Nagari Town



S1- Ekambarakuppam	S3- Chintalapatteda	S5- Nagari Town - II
S2- Sathrawada	S4- Nagari Town – I	S6 - Kothapet

Fig. 12: Different metal concentrations (mg/L) in the ground water contaminated with textile dye effluents in and around Nagari Town.



S1- Ekambarakuppam	S3- Chintalapatteda	S5- Nagari Town - II
S2- Sathrawada	S4- Nagari Town – I	S6 - Kothapet

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