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# SURVEILLANCE OF GROUND WATER QUALITY IN MADURAI, TAMIL NADU

**A. MURUGESAN, A. RAMU and N. KANNAN[a]**

School of Chemistry, Madurai Kamaraj University MADURAI – 625 021 (T N) INDIA
[a]Department of Chemistry, ANJA College, SIVAKASI–626 124 (T N) INDIA

## ABSTRACT

Madurai (Temple city) in south India, located on the banks of River Vaigai is the biggest developing corporation of southern part of Tamil Nadu. Anuppanadi is one of the main domestic and industrial waste drainage areas of this corporation. Present study deals with the assessment of borewell water quality around drainage places of human settlement Anuppanadi area in Madurai. Experiments were carried out to investigate the water quality parameters (WQPs) such as pH, EC, TDS, hardness, permanent hardness, $Ca^{2+}$, $Mg^{2+}$, $Hg^{2+}$, $Cr^{6+}$, $Pb^{2+}$ As (V), $Cl^{-}$, $F^{-}$, $PO_4^{3-}$, $SO_4^{2-}$, $SO_3^{2-}$, DO, COD and BOD. The Values of hardness, $Cl^{-}$, $Ca^{2+}$, $Mg^{2+}$, As(V) and $Pb^{2+}$ concentration were found to be above the permissible limits of water quality, prescribed by IS and WHO for drinking purpose. From the analysis of ground water quality, some of the borewell sites especially at Meenakshi Nagar and Bharadhi Nagar, Anuppanadi are not suitable for drinking purpose as well as domestic purposes.

**Key words :** Ground water quality (WQPs), Heavy metal, Anuppanadi, Madurai TN.

## INTRODUCTION

Water is one of the foremost essential components and it is essentially required by all living organisms[1]. Availability of good quality water for drinking purpose is very essential for healthy human society[2]. About 80% of the earth's surface is covered by water. Out of the estimated 1,011 million $km^3$ of the total water present on earth, only 33,400 $km^3$ of the total water is available for drinking, domestic and industrial consumption. The rest of the water is locked up in oceans as salt water, polar ice caps, glaciers and under ground[3]. Ground water pollution posses a serious problem in cities and industrial areas. It has been reported by Ramachandran *et al.*[4], that in the developing countries, pollution of ground water may cause 80% of human diseases and WHO has estimated that nearly 5 million deaths occur every year from polluted drinking water[5].

The source of water for drinking is the surface and ground water, which constitutes above 95% of water supply. Previous researchers estimated that there is 1,07,170 installation for tapping ground water in Tamil Nadu. Industries viz., tannery, textile, soil mining, coir retting, small–scale industries and household domestic waste products affect the aquatic systems and

jeopardize the entire ecosystem. The effect of industrial discharge depends upon the nature of raw material used and manufacturing process involved[6]. Even increasing population increases the water demand year by year soliciting major concern to combat the fast approaching drinking water crisis in the world in one side and industrialization surface sewage disposal and modern agricultural activities on the other side. Advent of hand pump schemes through bore wells caused the new trend in water supply. Most of the rural and urban water supply schemes functions with ground water as sources and new schemes are also formulated to tapping ground water in Tamil Nadu, because of less availability of surface water. It is imperative at this juncture to monitor the water quality of bore well water. The analysis of chemical nature of ground water is necessary as they are contaminated by pollutants due to discharge of industrial effluents causing harmful effects on human health as well as aquatic life[7,8]. Hence, an attempt is made to study the quality of bore well waters and to find out the pollution threat in Madurai, Tamil Nadu.

## DESCRIPTION OF STUDY AREA

Madurai is one of the developing and oldest corporation in the southern part of Tamil Nadu. The exact location of the study area lies between latitudes 09°10" and 9°50"N and longitudes 78°10" and 78°20"E. Arid to semi–arid is the prevailing climate. Rainfall is occasional. This city receives rainfall by southwest monsoon during the period of June to September followed by northeast monsoon in the month of October and November, being major portion in the later case. A few torrential showers are also experienced during summer season that is April and May. Annual average rainfall is 850–900 mm. Mixed geological formations are found. Hard rock with overburden soil is present. Static ground water level is generally in the depth range of 25 to 35 m below surface level. In the city the two main industrial drainage areas have been constructed namely Avaniyapuram and Anuppanadi in 1957 by Nathanan (Madras Agricultural Minister). Nowadays, where increasing population of the city people is moving on to these two drainage areas for their residential purpose, where Anuppanadi is a major industrial and domestic drainage area of this corporation. Few houses in this area were surrounded by drainage wastewater, which create bad environmental atmosphere to the human beings and animals. Hence, the title of study has been taken up for investigation.

### Sampling sites of the study area

(i) Pagalavan Nagar (front to Meenakshi street)

(ii) Bharathi Nagar (Ganesan street Via)

(iii) Bharathi Nagar (Backium street)

(iv) Meenakshi Nagar (Rajiv Gandhi street)

(v) Meenakshi Nagar (Sakthi Vinayagar temple opp.)

(vi) Uppukaramettu theru

(vii) Athimoolam pillai street

(viii) Vengalamoorthi Vinayagar temple opp.

(ix) Ayyanar temple street (center)

(x) Ayyanar temple street (chai naidu lane)

## MATERIALS AND METHOD

Considering the present stock of the situation in ground water quality and possible degradation of it by environmental pollution, ten borewells in this area viz., Anuppanadi have been chosen as observation sites for water quality surveillance. They are presented in Figure 1. As the quality variation is true dependent in addition to space, ground water samples are collected four times in the year 2002. It is well known fact that ground water level will rise as a result of recharge through rainfall and will reach the maximum depth of storage and the end of monsoon season leading to possible dilution with a possibility to a pollutant entry nearer is the ground water level to the earth's crust, more will be the pollutant entry. Contrarily at the end of summer season, the phreatic level will be at it's lowest due to crawl from the storage for various purposes during non–rainy season. So the samples were collected during the months of January, April, July, and October 2002 considering the monsoon, and summer seasons prevalent in Tamil Nadu. Standard methods with precise instruments are used to test the samples as per the literature method[9] (APHA and AWWA).

The location of sampling stations and their surrounding are given in Figure 1. The samples were collected in clean polyethene bottle (2 liter). The physico–chemical parameters such as temperature, pH, EC, TDS, hardness, permanent hardness, chloride, sulphate. fluoride, phosphate, acidity, $Ca^{2+}$, $Mg^{2+}$, alkalinity, $Hg^{2+}$, As (V), $Pb^{2+}$, DO, BOD and COD were analyzed by standard methods[9] (APHA, 1985). The samples were also collected for heavy metal analysis in pre–treated–polyethene bottle (1 liter). 1 mL concentrated $HNO_3$ was added to samples to avoid bacterial degradation, and preserved in a refrigerator at $4^oC$ before analysis.

The heavy metals were extracted by solvent extraction APDC method (using Ammonium Pyrrolidine Dithio Carbomate as complexing agent). The extracted samples were then analyzed using AAS. A calibration curve was plotted with known solution concentrations . The average values of water quality data for each sampling site is shown in Table 1.

The analytical results of ground water samples from Anuppanadi area in Madurai are shown in Table 1. Physico–chemical parameters and heavy metal analysis viz., temperature, pH, EC, TDS, hardness, permanent hardness, chloride, sulphate, fluoride, phosphate, acidity, $Ca^{2+}$, $Mg^{2+}$, alkalinity, $Hg^{2+}$, $Cr^{6+}$, As (V), $Pb^{2+}$, DO, BOD and COD values indicate that the quality of water considerably varies from location to location, which may be due to sewage (domestic

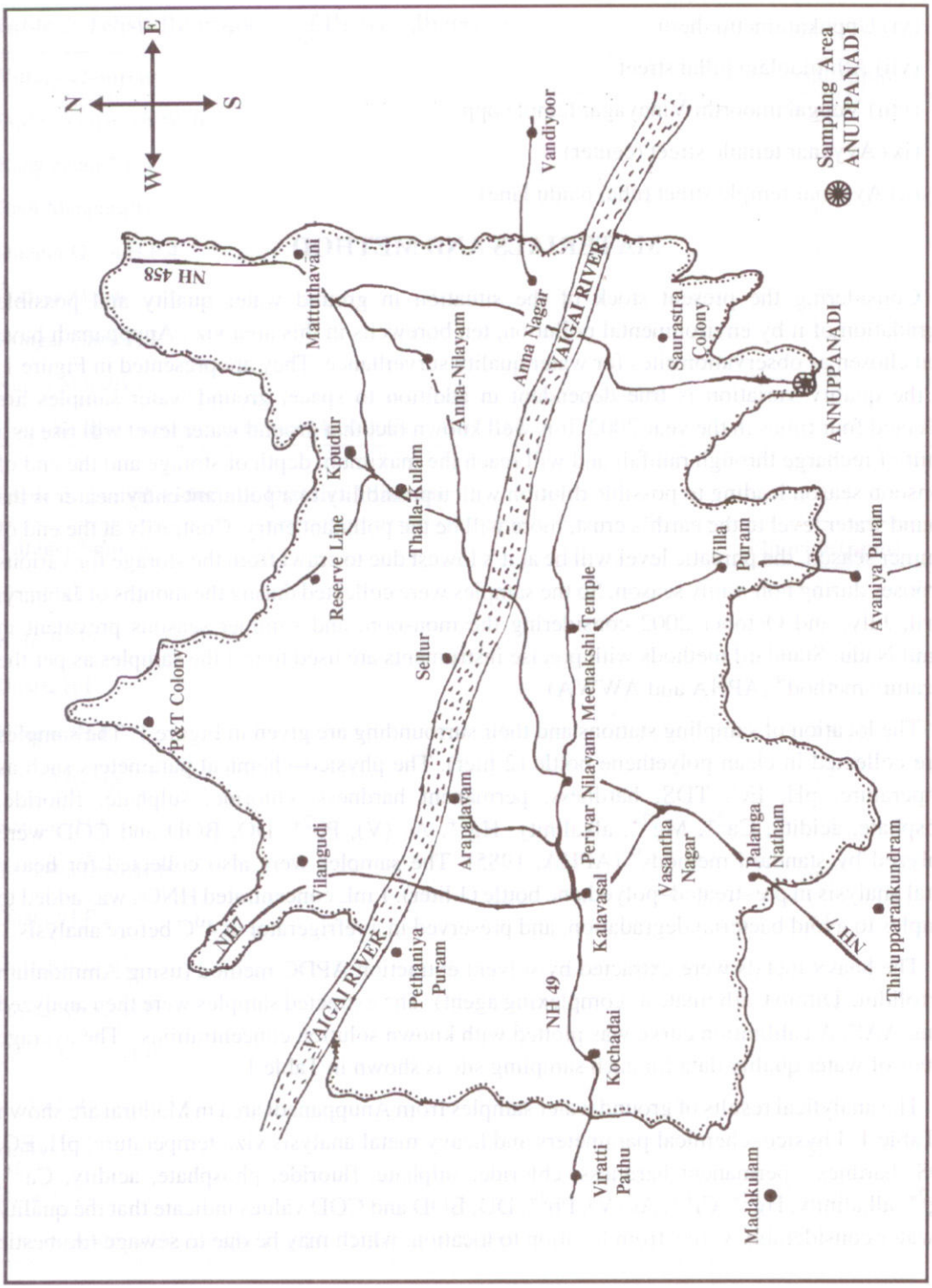


Fig. 1 Description of Study Area (Madurai City)

and industrial) water contamination by percolation through soil into the ground water system. The pH values are varying from 6.20 to 6.60. The samples were slightly acidic due to mineral salts ($SO_4^{2-}$, $Cl^-$) and also heavy metals. pH values of these samples were slightly less as compared with WHO (1984) water quality standards[14] by domestic and industrial wastes water. It affects soil quality, many microorganisms and their activities.

**Table 1. Water analysis results**

| WQPs | Sampling stations in Anuppanadi Area | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** |
| Temperature | 26.3 | 26.3 | 26.6 | 26.4 | 26.4 | 27.2 | 24.8 | 25.1 | 26.12 | 6.3 |
| pH | 6.44 | 6.44 | 6.20 | 6.39 | 6.41 | 6.32 | 6.60 | 6.52 | 6.48 | 6.44 |
| EC | 7658 | 6956 | 7472 | 6386 | 5725 | 4237 | 3269 | 2987 | 2183 | 2083 |
| TDS | 5336 | 3000 | 7296 | 6424 | 4816 | 2160 | 2320 | 2504 | 2176 | 2134 |
| Hardness | 1492 | 1008 | 1900 | 1332 | 1168 | 424 | 708 | 684 | 604 | 548 |
| Per. hardness | 996 | 604 | 1172 | 864 | 660 | 208 | 380 | 324 | 296 | 268 |
| Chloride | 1763 | 723 | 1623 | 1063 | 959 | 491 | 719 | 715 | 771 | 731 |
| Sulphate | 332 | 160 | 240 | 316 | 76 | 166 | 276 | 132 | 124 | 132 |
| Fluoride | 1.73 | 0.87 | 1.64 | 0.92 | 0.53 | 0.86 | 0.78 | 0.64 | 0.59 | 0.48 |
| Phosphate | – | – | – | – | – | – | – | – | – | – |
| Acidity | 10.0 | 38.0 | 18.0 | 10.0 | 12.0 | 16.0 | 8.0 | 8.0 | 12.0 | 8.0 |
| $Ca^{2+}$ | 1340 | 440 | 1640 | 1184 | 868 | 440 | 276 | 268 | 292 | 264 |
| $Mg^{2+}$ | 704 | 440 | 912 | 624 | 616 | 248 | 384 | 364 | 300 | 244 |
| Alkalinity | 224 | 208 | 244 | 192 | 148 | 136 | 104 | 92 | 80 | 60 |
| $Hg^{2+}$ | – | – | – | – | – | – | – | – | – | – |
| $Cr^{6+}$ | 0.030 | 0.036 | 0.080 | 0.020 | 0.033 | – | – | – | – | – |
| As (V) | 2.149 | 1.413 | 3.275 | 0.638 | 0.403 | – | – | – | – | – |
| $Pb^{2+}$ | 0.271 | 0.195 | 0.352 | 0.100 | 0.2062 | – | – | – | – | – |
| DO | 2.9 | 2.8 | 3.3 | 2.7 | 2.4 | 3.3 | 3.0 | 2.3 | 2.5 | 2.5 |
| BOD | 13.2 | 12.6 | 12.7 | 11.1 | 10.2 | 10.3 | 7.4 | 6.8 | 6.3 | 6.0 |
| COD | 160 | 128 | 105 | 105 | 102 | 124 | 102 | 102 | 108 | 105 |

**Table 2.**[14]

| Water Quality Parameters | Tolerance Limit | Rejection Limit |
|---|---|---|
| pH | 7.0–8.5 | <6.5 or >9.2 |
| TDS | 500 | >1500 |
| Total hardness | 200 | >600 |
| $Ca^{2+}$ | 75 | >200 |
| $Mg^{2+}$ | 30 | >150 |
| $SO_4^{2-}$ | 200 | >400 |
| $Cl^-$ | 200 | >1000 |
| $F^-$ | 1.0 | >1.5 |
| Fe | 0.1 | >1.0 |
| As (V) | 0.05 | >0.05 |
| $Cr^{6+}$ | 0.05 | >0.05 |
| $Pb^{2+}$ | 0.1 | >0.1 |
| $Hg^{2+}$ | 0.001 | >0.001 |

It was observed that the electrical conductivity values were ranging from 20.83 to 7658 μ mohs/cm. All the samples were above the permissible limits. If the conductivity and TDS values, exceeds it may lead to scaling in boilers, corrosion and quality degradation of the product. Total dissolved solids are varying from 2134 to 7296 ppm (Figure 2). It is maximum in all bore well samples. This may be due to the contamination of inorganic salts like carbonates, chlorides, sulphates, nitrates etc., and also organic substances (ketones, esters and carboxylic acids ie, aromatic or aliphatic) which are generally found in polluted water. Dissolved solids are important parameters in water quality management.

The total hardness ($Ca^{2+}$, $Mg^{2+}$, $Cl^-$, $SO_4^{2-}$) of all water samples were found to be above the permissible limits, varying from 424 to 1900 ppm (Fig. 3). This is mainly attributed to the natural action i.e. rock weathering rather than

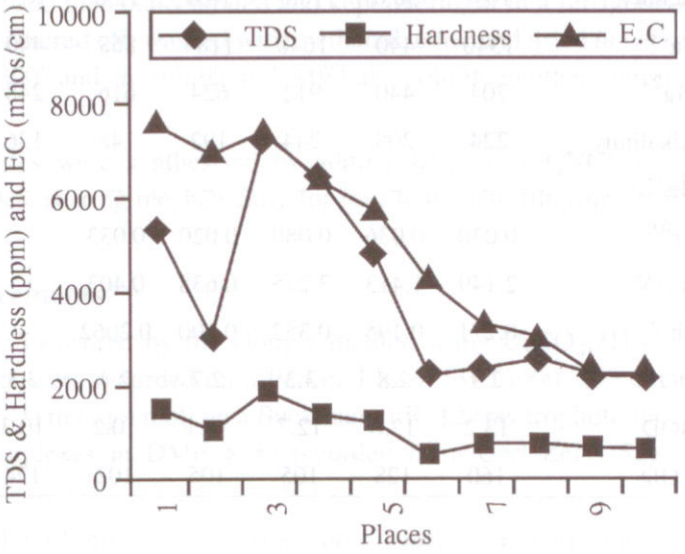


**Fig. 2 Dissolved salts**

man–made pollution, which were affecting the soil nature like, aeration and permissibility of earth surface. Spent liquors from tanneries undergo putrefaction very rapidly; thus offering a good amount of nutrients and favourable environment for bacterial growth[4].

The chloride contents of water samples were observed between 491.85 to 1763.45 ppm and these values of all samples were above the permissible limits (250 ppm). Excess chloride content in water imparts a salty taste. Peoples those who are not accustomed to high chlorides can be subjected to laxative effects as suggested[10]. The chloride content in the ground water may be contributed from minerals like apatite, mica and hornblendes and also from the liquid inclusions in the igneous rocks. It is harmless up to 1500 ppm. The sulphate values of water samples are ranging from 76 to 566 ppm. Most of the samples were above the standard permissible limits. These levels produce bitter taste and also purgative effect, if exceeds the liunt.

It is observed that phosphate contents are not available in ground water, but it was available in surface water namely pond water, lake water, river water, cannel water, etc. The fluoride content in water samples are obtained in the range (from 0.48 to 1.73 ppm). Except few samples, these are within the permissible limits. If fluoride content in water exceeds 1 ppm then it may produce dental and skeletal fluorosis.

Dissolved oxygen is the ability of the surface and ground water to purify itself through biochemical process. From the observed values, dissolved oxygen was observed ranging from 2.3 to 3.3 ppm. In all water samples it was within the acceptable limits. The higher value of DO content in water is an indication of organic pollution particularly when pollution is contributed by sewage out fall. High depletion in oxygen content produces foul odour due to the anaerobic decomposition of organic waste leading to the evaluation of $H_2S$[11], which is evinced in this area.

The constituents of alkalinity in natural water system mainly include carbonates, bicarbonates and hydroxides. These constituents result from dissolution of mineral substances in the soil and atmosphere. Carbonate and bicarbonate may originate from microbial decomposition of organic matter. The WHO acceptable limit is 200 mg/L; beyond this limit, the taste may become unpleasant, whereas in the absence of alternate source of water, alkalinity up to 600 ppm is acceptable (Ministry of Rural Development, Govt. of India).

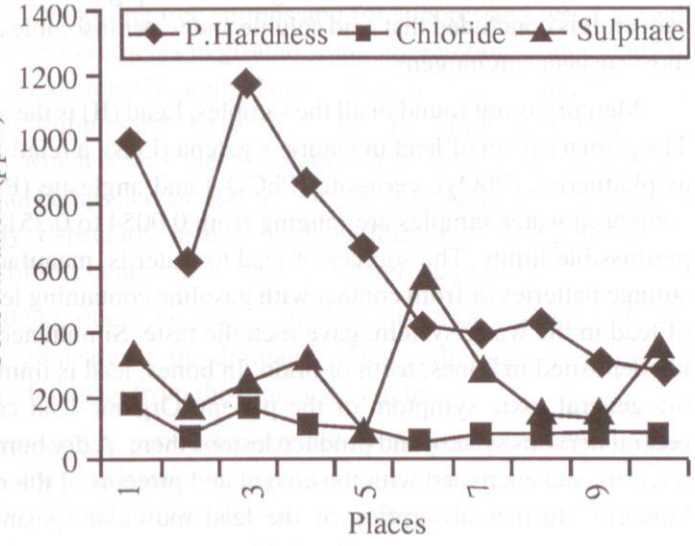


**Fig. 3 Permanent hardness**

The total alkalinity values are varying from 60 to 244 ppm. From these data in most of water samples, the alkalinity values are within the acceptable limits except three stations viz., Pagalavan Nagar, Bharathi Nagar (Ganesan street) and Meenakshi Nagar (Rajeev Gandhi Nagar). Alkalinity in natural waters is due to dissociation of $CO_2$.

The presence of calcium and magnesium in ground water is mainly due to its passage through or over deposits of limestone, dolomite, gypsum and other gypsiferous materials. Calcium and magnesium are the too major scale forming constituents in most raw water supplies. From the results it has been observed that calcium and magnesium are ranging from 264 to 1640 and 224 to 912 ppm, respectively. All of the samples were above the permissible limits. Acidity varies from 8 to 38 ppm. Ground water contains considerable amount of carbon dioxide acidity. This concentration results from bacteriological oxidation of organic matter with which the water has been in contact, and under that condition, carbon dioxide is not free to escape into the atmosphere[12]. Drinking water usually has a BOD of less than 1 ppm and water is considered fairly pure with a BOD level of 5 ppm. These were ranging from 11 to 18.2 mg/L, i.e. the water is of doubtful purity. COD values were ranging from 102.4 to 160 ppm.

The concentration of different dissolved heavy metals namely Cr, Hg, Pb and As are shown in Table 1 (Fig. 4). These metals have a history as occupational hazards and some of them have been linked to cancer and heart disease. From the results during the course of present investigation, the chromium concentration of water samples are ranging from 0.020 to 0.080 ppm. All the samples were below the permissible limits except Meenakshi Nagar (Rajeev Gandhi street) bore well. Chromium is an essential nutrient; it is bioaccumulated by a variety of aquatic organisms. Zimdahl and Hassett[13] found three cases of bronchial carcinoma in the study of 24 workers with more than 3–year exposure to chromate pigments including zinc chromate. A mortality study in manufacturing chromate pigments showed a significant increase in lung cancer. It is concluded that acid soluble and water insoluble derivatives of chromite ore were the most suspect carcinogens.

Mercury is not found in all the samples. Lead (II) is the abundant of the natural heavy metal. The primary form of lead in nature is galena (PbS), a relatively insoluble ore. Lead also occurs as plattnerine ($PbO_2$), cerussite ($PbCO_3$) and anglesite ($PbSO_4$). From the observation, lead content in water samples are ranging from 0.0054 to 0.3519 ppm. Four samples are below the permissible limits. The sources of lead to water is, manufacture of pesticides, insecticides and storage batteries or from contact with gasoline containing lead activities. Higher level exposure of lead in the water system, gave metallic taste. Simultaneously, the lead may be redistributed i.e. deposited in bones, teeth or brain. In bones, lead is immobilized and dose not contribute to the general toxic symptom of the patient. Organic lead compounds have an affinity for the central nervous system and produce lesions there. A dry burning sensation in the throat, cramps, retching and encrusted with the coagulated proteins of the nectoic mucosa, will occur; thereby hindering further absorption of the lead muscular spasms, numbness and local palsy may appear.

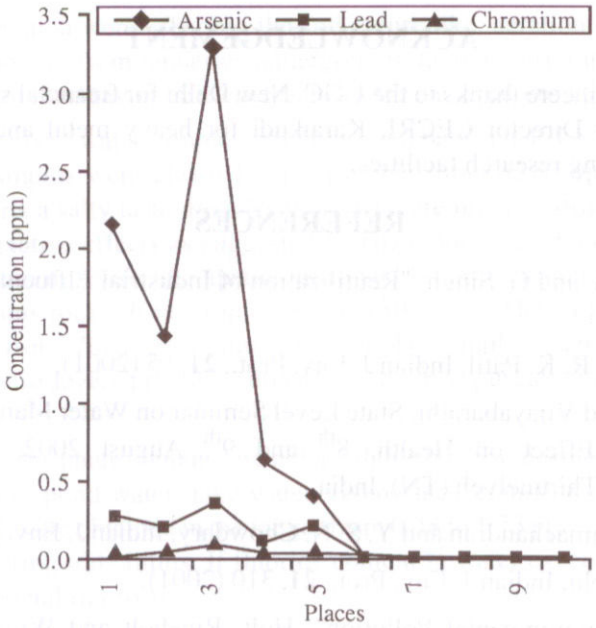


**Fig. 4 Heavy metals**

Arsenic (V) occurs naturally in a wide range of minerals, which together with a once widespread use of arsenic in pigments, insecticides, and herbicides represent the major sources of arsenic to the natural water system (about 70% of all arsenic used in pesticides). The other uses of arsenic and arsenic compounds are in wood preservatives, glass manufacture, alloys, electronics, catalysts, food additives and veternary chemicals[14]. Sodium arsenite has been used to kill vegetation, for removing bark and killing tree stumps and for suppressing weed growth in reservoirs. From the results, the arsenic contents in ground water are ranging from 0.0092 to 3.2753 ppm. Except two sampling location (Bharathi Nagar Backium street and Ayyanar temple street Chinaidu Lane) all other samples are above the permissible limits. If ground water has higher values of arsenic content, which is only the percolation of sewage water through the soil, it leads to some disease to human beings and animals ie, mouth, skin, and nails are effected by slow intake of arsenic in our body. Especially, arsenic has been found to enter the hair roots of human beings within 30 minutes of this contaminated water through bathing.

Based on the TDS, hardness and chloride values, and sampling sites 1–5, water quality are awful because these sampling sites are nearer to the drainage system. Alternatively sampling sites 6–10 are usual as these sites are far away from the drainage system.

At sampling sites 6–10, the water quality parameters are below the permissible limits and hence, it is more or less suitable for drinking purposes. Whereas water samples from sites 1–5 could not be used for drinking purpose without any treatment, since, the level of TDS, hardness, chloride and heavy metal contents are above the permissible limits.

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