WORLD JOURNAL OF PHARMACEUTICAL RESEARCH
SJIF Impact Factor 7.523
Volume 7, Issue 8, 10-21. Conference Article ISSN 2277–7105

# HEAVY METAL POLLUTION INDEX ON GROUNDWATER QUALITY BETWEEN TAMILNADU AND PONDICHERRY STATES, INDIA

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Article Received on
05 March 2018,
Revised on 25 March 2018,
Accepted on 15 April 2018
DOI: 10.20959/wjpr20188-10738

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## ABSTRACT

The objective of the study is to reveal the seasonal variations in the groundwater quality with respect to heavy metals contamination. Water samples were collected from 23 different locations in monsoon, winter and summer seasons. The concentrations of trace metals such as copper, iron, manganese, chromium and lead were determined using atomic absorption spectrophotometer. The analytical data was compared with the guidelines given by WHO. The Calculated value of HPI is 259. The results reveal that the concentration due to lead is higher than the permissible limit prescribed by the WHO. The result shows that the water quality of the study area is very poor and not suitable for drinking purpose. The heavy metal contamination may due to the discharge of industrial, municipal wastes, disposal of solid wastes, land filling and other anthropogenic influences in this region. It is a well known fact that the heavy metal ions are potentially toxic to human health and could be quite detrimental for human life. The results have been used to suggest models for predicting water quality. The analysis reveals that the groundwater of the area needs some degree of treatment before consumption, and it also needs to be protected from the perils of contamination.

**KEYWORDS:** Heavy metal pollution index, Industrial pollution, Seasonal variation, Groundwater.

## I. INTRODUCTION

Everything is originated from water and everything is sustained by water. The life on earth depends on water. The origin of water on the earth is not clear so far. However, the current presumption is that the primordial earth had no oceans and perhaps very little atmosphere. It is believed that the volatile constituents bound in the earth's crust being oozed to the surface through volcanoes, rock movements and hot springs condensed to form the ocean and the atmosphere. The remarkable combination of hydrogen and oxygen to form water molecule and thus water came into being and eventually became an indispensable component of the earth's crust. Increasing demand of water in domestic, agricultural and industrial sectors necessitates exploitation of groundwater directly for drinking as well as for other house-hold purposes. To safeguard the long-term sustainability of groundwater resources, the quality of the water needs to be periodically monitored. For this purpose, it is very important to determine the different physico-chemical parameters of groundwater and the corresponding water quality index.[1] Groundwater is a vital natural resource. Depending on its usage and consumption it can be a renewable or a non-renewable resource. It is estimated that approximately one third of the groundwater is being used for drinking.[2]

Groundwater is used for domestic and industrial water supply and irrigation all over the world. In the last few decades, there has been a tremendous increase in the demand for fresh water due to rapid growth of population and the accelerated pace of industrialization. Human health is threatened by most of the agricultural development activities particularly in relation to excessive application of fertilizers and unsanitary conditions. Rapid urbanization, especially in developing countries like India, has affected the availability and quality of groundwater due to its overexploitation and improper waste disposal, especially in urban areas.[3]

Groundwater contains various types of pollutants and several other substances which are dissolved in it. Concentration is useful for human body but in a specific limit. The study was conducted to know the physico-chemical and heavy metal properties of groundwater in different seasons and its impact on human life. The quality of water is of upper most importance compared to quantity in any water supply planning and especially for drinking purposes, purity is equally important. The chemical, physical, trace metal and bacterial characteristics of groundwater determine its usefulness for municipal, commercial, industrial, agricultural and domestic water supplies. The main objective of this work is to analyze

various physico-chemical and heavy metal parameters of the groundwater of Tamilnadu and Pondicherry states, India.

## II. STUDY AREA

Pondicherry is situated in the East Coast of India between two Major Ports of India namely, Chennai and Tuticorin. It is about 170 km south of Chennai and about 165 km North of Tiruchirappalli. Pondicherry is divided into two parts: the French quarters and the Indian quarters. For the same reason, French style colonial compounds and walls are a common tourist attraction here. The city offers excellent sites for soothing yoga and peaceful meditation. Karaikal is a very old temple town in Pondicherry. It is on the east coast, about 135 km from Pondicherry and 300 km from Chennai towards south. The town is small with a total of 161 sq Km with marine time climate and located on the Koramandel coast of the Bay of Bengal. The total population of the study area is approximately about two lakhs of which majority depends on groundwater for drinking, domestic and agricultural purposes. The soil nature of our selected study areas has been recorded possessing herbaceous organic deposits with underlying sandy textured sediments. Agriculture is one of the main occupations of the people of the Union territory of Pondicherry. About 45% of the total population of Pondicherry is engaged in agriculture. Paddy forms a major crop of Pondicherry agriculture. In the Union Territory, about 90% of the agricultural area is irrigated through modern technology. Pondicherry is mainly irrigated through water tanks and tube wells. The vegetation of Tamilnadu and Pondicherry comprises various types of plants including woody plant group, hedge plants, ornamental plants, hydrophytes and halophytes etc. The crops that are commonly grown in the region are paddy, pulses, coconuts, cotton, chillies, vegetables, sun flower and groundnuts etc (Fig. 1).

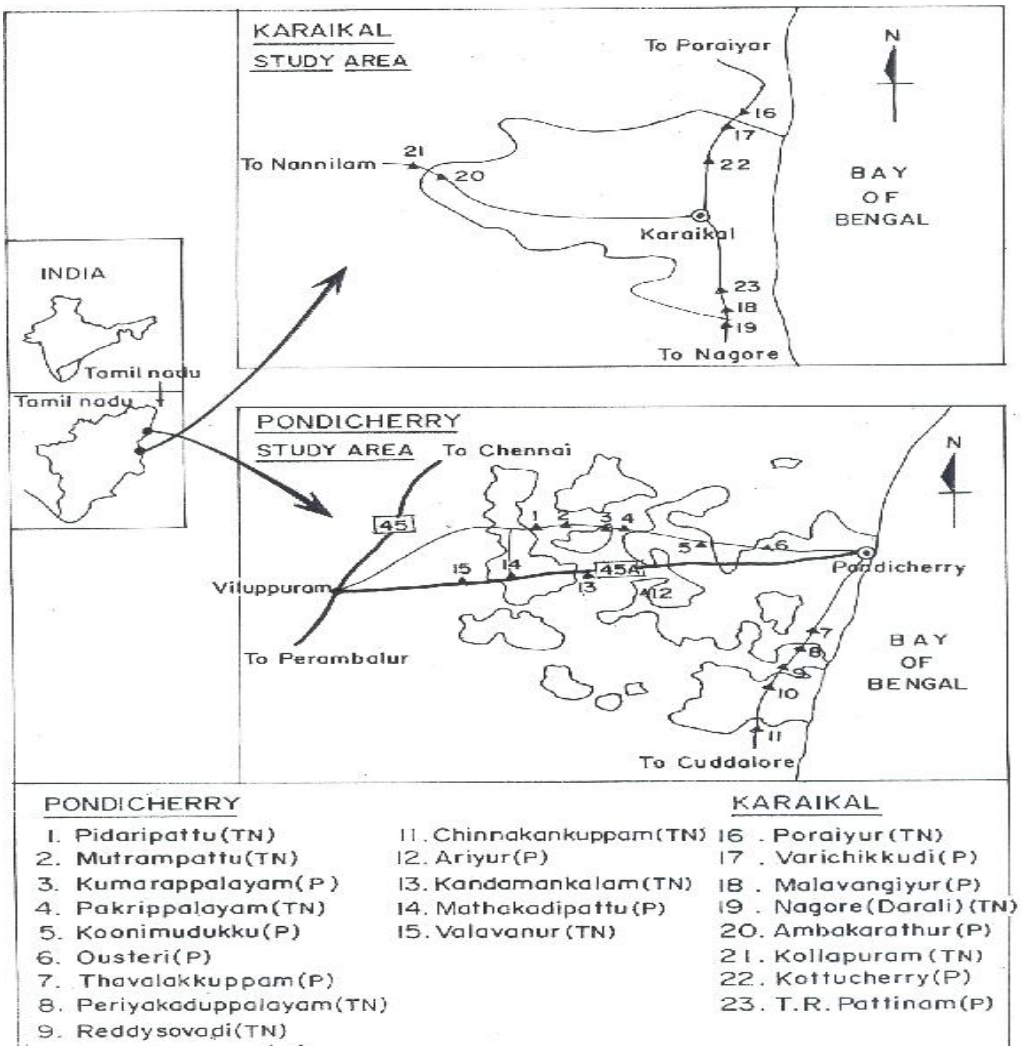


**Fig 1: Location map of the study area.**

## III. MATERIALS AND METHODS

Twenty three samples were collected in the study area spread over Pondicherry, Karaikal and three districts of Tamilnadu (Viluppuram, Cuddalore and Nagappattinam). The heavy metal analysis for the groundwater samples were performed during Monsoon, winter and summer seasons. The heavy metals such as copper, iron, manganese, chromium and lead were analyzed and tabulated (Table: 1). The samples were collected from bore wells as well as from deep hand pumps at different seasons. It was ensured that the concentrations of various water quality parameters do not change in time that elapses between drawing of samples and the analysis in the laboratory. 2.5 litres polythene bottles were used. The bottles were thoroughly cleaned with hydrochloric acid and then washed with tap water rendered free of acid and then washed with distilled water twice and again rinsed with the water sample to be collected and then filled up the bottle with the sample leaving only a small air gap at the top, stoppered and sealed the bottle with paraffin wax. Some samples which were turbid

or containing suspended matter were filtered at the time of collection. All the glassware and pipettes were first cleaned with tap water thoroughly and finally with deionised distilled water. The pipettes and burette were rinsed with solution before final use. The chemicals and reagent were used for analysis were of Analar grade. The atomic absorption spectrophotometer instrument was used to analyze these parameters. The groundwater samples were determined using standard methods[4] and the results were compared with the values of World Health Organization.[5]

## IV. RESULTS AND DISCUSSION

**Table 1: The heavy metal concentrations of groundwater samples collected during October 2013 to April 2014.**

| Parameters | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Seasons** | **Rainy** | | | | | **Winter** | | | | | **Summer** | | | | |
| **Stations** | **Cu** | **Fe** | **Mn** | **Cr** | **Pb** | **Cu** | **Fe** | **Mn** | **Cr** | **Pb** | **Cu** | **Fe** | **Mn** | **Cr** | **Pb** |
| **01** | 1.38 | 0.96 | 0.34 | 0.05 | 0.06 | 1.48 | 0.76 | 0.34 | 0.04 | 0.08 | 1.57 | 1.07 | 0.42 | 0.05 | 0.10 |
| **02** | 1.18 | 0.95 | 0.24 | 0.03 | 0.06 | 1.32 | 0.89 | 0.29 | 0.03 | 0.06 | 1.40 | 1.47 | 0.41 | 0.05 | 0.09 |
| **03** | 0.03 | 0.17 | 0.02 | 0.01 | 0.03 | 0.01 | 0.04 | 0.05 | 0.01 | 0.04 | 0.02 | 0.13 | 0.05 | 0.01 | 0.05 |
| **04** | 0.47 | 0.49 | 0.18 | 0.02 | 0.04 | 0.54 | 0.54 | 0.15 | 0.02 | 0.05 | 1.09 | 0.70 | 0.24 | 0.03 | 0.06 |
| **05** | 0.06 | 0.47 | 0.16 | 0.02 | 0.04 | 0.8 | 0.49 | 0.14 | 0.02 | 0.05 | 0.78 | 0.64 | 0.19 | 0.03 | 0.06 |
| **06** | 1.44 | 0.89 | 0.29 | 0.03 | 0.05 | 1.16 | 0.84 | 0.31 | 0.04 | 0.06 | 1.45 | 0.98 | 0.39 | 0.06 | 0.11 |
| **07** | 0.03 | 0.12 | 0.05 | 0.01 | 0.02 | 0.03 | 0.04 | 0.03 | 0.01 | 0.03 | 0.03 | 0.06 | 0.02 | 0.01 | 0.04 |
| **08** | 0.48 | 0.50 | 0.19 | 0.03 | 0.03 | 1.22 | 0.59 | 0.19 | 0.03 | 0.04 | 1.02 | 0.83 | 0.28 | 0.07 | 0.08 |
| **09** | 0.02 | 0.40 | 0.04 | 0.01 | 0.02 | 0.02 | 0.04 | 0.03 | 0.02 | 0.03 | 0.03 | 0.06 | 0.04 | 0.02 | 0.04 |
| **10** | 0.2 | 0.1 | 0.02 | 0.01 | 0.01 | 0.03 | 0.04 | 0.02 | 0.02 | 0.03 | 0.03 | 0.05 | 0.06 | 0.02 | 0.04 |
| **11** | 1.48 | 1.03 | 0.35 | 0.04 | 0.07 | 1.37 | 0.88 | 0.35 | 0.04 | 0.07 | 1.59 | 1.13 | 0.46 | 0.05 | 0.11 |
| **12** | 0.73 | 0.68 | 0.22 | 0.02 | 0.03 | 0.81 | 0.50 | 0.17 | 0.02 | 0.04 | 1.14 | 0.64 | 0.21 | 0.03 | 0.05 |
| **13** | 0.6 | 0.81 | 0.2 | 0.02 | 0.04 | 1.06 | 0.67 | 0.23 | 0.03 | 0.05 | 1.21 | 0.85 | 0.34 | 0.04 | 0.07 |
| **14** | 0.07 | 0.25 | 0.05 | 0.01 | 0.02 | 0.12 | 0.07 | 0.07 | 0.01 | 0.03 | 0.04 | 0.16 | 0.05 | 0.02 | 0.04 |
| **15** | 0.09 | 0.23 | 0.05 | 0.01 | 0.02 | 0.01 | 0.04 | 0.04 | 0.01 | 0.03 | 0.02 | 0.14 | 0.06 | 0.02 | 0.04 |
| **16** | 0.37 | 0.23 | 0.05 | 0.01 | 0.02 | 0.04 | 0.07 | 0.04 | 0.01 | 0.04 | 0.03 | 0.14 | 0.05 | 0.02 | 0.04 |
| **17** | 0.78 | 0.54 | 0.17 | 0.02 | 0.03 | 0.73 | 0.60 | 0.10 | 0.02 | 0.04 | 0.80 | 0.66 | 0.2 | 0.03 | 0.06 |
| **18** | 1.47 | 0.90 | 0.31 | 0.04 | 0.05 | 1.67 | 0.89 | 0.35 | 0.06 | 0.06 | 1.83 | 1.12 | 0.44 | 0.09 | 0.11 |
| **19** | 0.35 | 0.13 | 0.05 | 0.01 | 0.01 | 0.04 | 0.06 | 0.04 | 0.02 | 0.03 | 0.04 | 0.11 | 0.04 | 0.02 | 0.04 |
| **20** | 1.32 | 0.73 | 0.18 | 0.03 | 0.03 | 1.42 | 0.63 | 0.22 | 0.05 | 0.06 | 1.67 | 1.04 | 0.4 | 0.08 | 0.09 |
| **21** | 0.13 | 0.27 | 0.05 | 0.02 | 0.03 | 0.02 | 0.09 | 0.02 | 0.02 | 0.04 | 0.05 | 0.15 | 0.28 | 0.02 | 0.05 |
| **22** | 0.07 | 0.19 | 0.04 | 0.02 | 0.02 | 0.03 | 0.07 | 0.05 | 0.02 | 0.04 | 0.06 | 0.15 | 0.05 | 0.02 | 0.05 |
| **23** | 1.29 | 0.63 | 0.17 | 0.03 | 0.03 | 1.37 | 0.71 | 0.25 | 0.03 | 0.05 | 1.43 | 0.89 | 0.27 | 0.05 | 0.08 |

**All the values are expressed in ppm**

The presence of excess potent of heavy metal ions in potable groundwater is likely the reasons for chronic diseases such as kidney damage, carcinogenic, bone damage, nervous disorder and cancerous diseases.[6] Heavy metals may also adversely affect mental and neurological functions as well as altering metabolic processes in human body systems. It could also induce impairment and dysfunction in blood, cardiovascular, endocrine, immune,

reproductive and urinary functions.[7] The contamination of groundwater with slight excess of Pb, Cr, Hg and Cd shall lead unfit for drinking and other purposes.

**1) Copper**

Copper is an essential micronutrient, but in high concentration causes physiological effects in human. Water containing 3ppm was associated with gastrointestinal disturbance in adults, whereas water containing 1mg/l was not.[8] The copper values are recorded in the range of 0.02-1.48, 0.01-1.48 and 0.02-1.83ppm for the groundwater samples collected in monsoon, winter and summer seasons respectively (Table: 1). In the present study, the values of copper are within the permissible limit of WHO (2.0ppm) in all the samples (Fig. 2). Copper is an essential element and good for health in very small quantities but quantities by excessive is toxic. The sources of copper are the industrial and domestic wastes.[9] On the other hand, lack of copper intake causes anemia, growth inhibition and blood circulation problems.

**2) Iron**

Iron is one of the most important micronutrients for plants and it is present as complexes in plant tissues.[10] The soil containing 7% of $CaCO_3$ is generally poor in iron content.[11] Iron is easily found in an iron-bearing mineral of igneous, metamorphic and sedimentary rocks. It could therefore be derived from the lateritic soils zone of Benin formation. The iron values are recorded in the range of 0.1-1.03, 0.04-0.89 and 0.05-1.47ppm for the groundwater samples collected in monsoon, winter and summer seasons respectively (Table: 1). In the present study, the values of iron most of the samples are within the permissible limit of WHO (1.0ppm) in all the samples except few stations (Fig. 3). The deficiency of iron causes a disease called anaemia and prolonged consumption of drinking water with high concentration of iron may lead to liver disease called as haermosiderosis.

**3) Manganese**

Manganese is a vital micronutrient for both plant and animals. It is found in various salts and minerals, frequently in association with iron compounds.[12] Manganese is essential to all organisms. Its deficiency leads to infertility. It is responsible for the production of molecular oxygen in plants during photosynthesis. Manganese is an essential nutrient that is important for normal processes in the human body. In the present investigation, the concentration of manganese ranged from 0.02-0.35, 0.02-0.35 and 0.02-0.46ppm for the groundwater samples collected in monsoon, winter and summer seasons respectively (Table: 1). In the present study, the values of manganese are within the permissible limit of WHO (0.4ppm) in all the

samples except summer season at four stations (Fig. 4). This shows that the groundwater is not very much polluted by manganese. However, slight rise in its level may be accumulated for by the influence of domestic waste, natural geological rocks and industries effluent especially that of sugar mill. The value of Manganese is within the permissible limit of WHO (0.5ppm), but according to ISI for drinking water, permissible limit of Manganese is 0.3and it is said that the water is affected above the value of 0.1ppm. In this study, values less than 0.3ppm. This shows that the groundwater not polluted by Manganese.

**4) Chromium**

Chromium occurs naturally in the Earth's crust and can be detected in all environmental media. The continental dust flux is the main natural source of Chromium in the atmosphere, but much larger amounts are released by human activities. Chromium is an important mineral the body must have to function properly. It's responsible for stimulating the activities of insulin in the body and also help controls blood cholesterol levels. The chromium values are recorded in the range of 0.01-0.05, 0.01-0.06 and 0.01-0.09ppm for the groundwater samples collected in monsoon, winter and summer seasons respectively (Table: 1). In the present study, the values of chromium in few samples exceeded the permissible limit of WHO (0.05ppm) in all the three seasons (Fig. 5). Chromium contamination, as main cause of various illnesses, is related with contaminated water. Diseases related to digestive, excretory, respiratory and reproductive system have been reported due to excessive intake of Cr. Heavy doses of Chromium salt even though are rapidly eliminated from human body could corrode the intestinal tract.[5]

**5) Lead**

The lead values are recorded in the range of 0.01-0.07, 0.03-0.08 and 0.04-0.11ppm for the groundwater samples collected in monsoon, winter and summer seasons respectively (Table: 1). In the present study, the values of lead exceeded the permissible limit of WHO (0.01ppm) in all the sampling stations in all seasons (Fig. 6). Lead is a serious cumulative body poison that can cause chronic health effects such as brain and nerve damage, kidney damage, digestive disturbance, blood disorders and hypertension. Lead is a highly toxic metal and they should normally be present only in traces. Lead is used principally in the manufacturing of lead acid battery and alloys. Lead is generally toxic and it accumulates in kidney and skeleton. In fact, children up to the age of six years and pregnant women are most susceptible to it is adverse effect.[13]

### *A.* Heavy Metal Pollution Index

Heavy metal pollution index (HPI) is a technique of rating that provides the composite influence of individual heavy metal on the overall quality of water. The rating is a value between zero and one, reflecting the relative importance of individual quality considerations and inversely proportional to the recommended standard (Si) for each parameter. The calculation of HPI involves the following steps-First, the calculation of weight age of $i^{th}$ parameter second, the calculation of the quality rating for each of the heavy metal.

The weight age of $i^{th}$ parameter

$W_i = k/S_i$ (1)

Where $W_i$ is the unit weight age and $S_i$ the recommended standard for $i^{th}$ parameter, (i=5), While k is the constant of proportionality.

Individual quality rating is given by the expression

$Q_i = 100v_i / S_i$ (2)

Where $Q_i$ is the sub index of $i^{th}$ parameter, $v_i$ is the monitored value of the $i^{th}$ parameter in µg/l and $S_i$ the standard or permissible limit for the $i^{th}$ parameter.

The Heavy Metal Index (HPI) is then calculated as follows

$HPI = \sum_{i=1}^{n}(QiWi) / \sum_{i=1}^{n} Wi$ (3)

Where $Q_i$ is the sub index of $i^{th}$ parameter. $W_i$ is the unit weight age for $i^{th}$ parameter, n is the number of parameters considered. The critical pollution index value is 75, above this value is not suitable for drinking purposes (Table: 2).

**Table 2: Status Categories of HPI.**

| HPI | Quality of Water |
|---|---|
| 0-25 | Very Good |
| 26-50 | Good |
| 51-75 | Poor |
| Above 75 | Very Poor (Unsuitable for Drinking) |

### *B.* Calculation of HPI values for the heavy metal concentration of groundwater around study area.

**Table 3: Mean values heavy metal concentrations of groundwater samples in and around between Tamilnadu and Pondicherry states.**

| Heavy metals | Mean value in ppm ( $v_i$ ) | Highest permitted value (WHO) ($S_i$) | Unit weightage ($W_i$) | $W_i \times Q_i$ |
|---|---|---|---|---|
| **Cu** | 0.67 | 2.0 | 0.004 | 0.13 |
| **Fe** | 0.49 | 1.0 | 0.008 | 0.39 |
| **Mn** | 0.17 | 0.4 | 0.02 | 0.85 |
| **Cr** | 0.02 | 0.05 | 0.016 | 0.80 |
| **Pb** | 0.04 | 0.01 | 0.8 | 220 |

HPI = $\sum_{i=1}^{n}(QiWi)/\sum_{i=1}^{n}Wi$ **HPI** = 259

The computed value of HPI is 259 (Table: 3). This value is found to be above 75 as per HPI (Table: 2) which shows the nature of the water quality of the areas during three seasons seems to be very poor. It is clearly understood that the groundwater of our study area is not recommended for civic purposes as per the HPI standard values.[14]

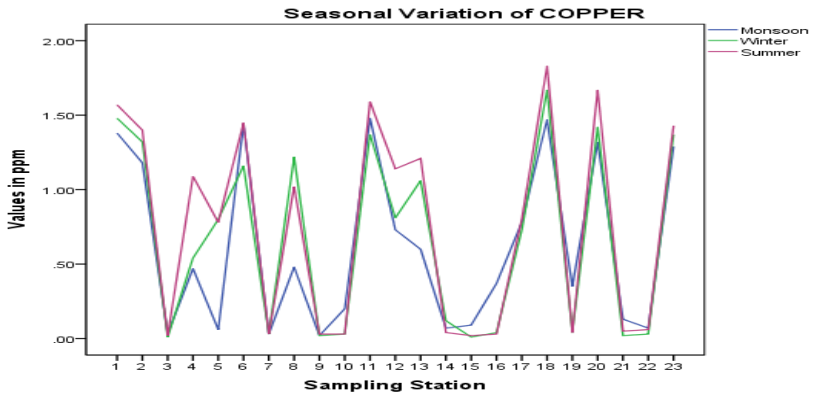


**Fig. 2: Variation of copper values of groundwater samples collected at different seasons.**

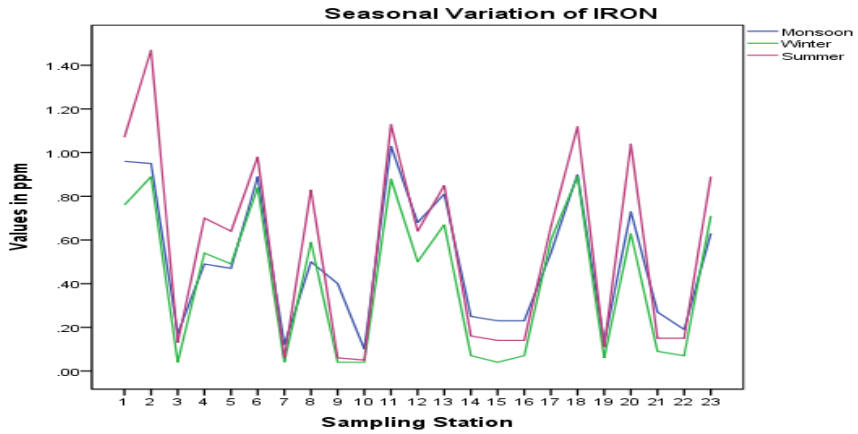


**Fig. 3: Variation of iron values of groundwater samples collected at different seasons**

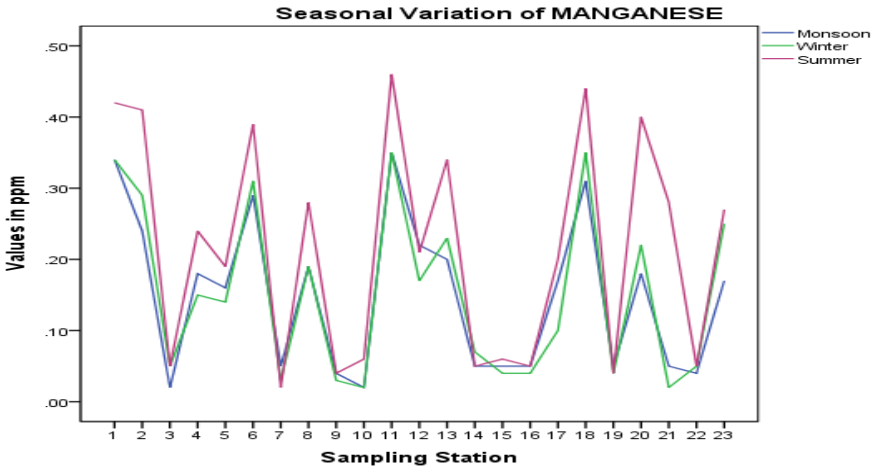


**Fig 4: Variation of manganese values of groundwater samples collected at different seasons.**

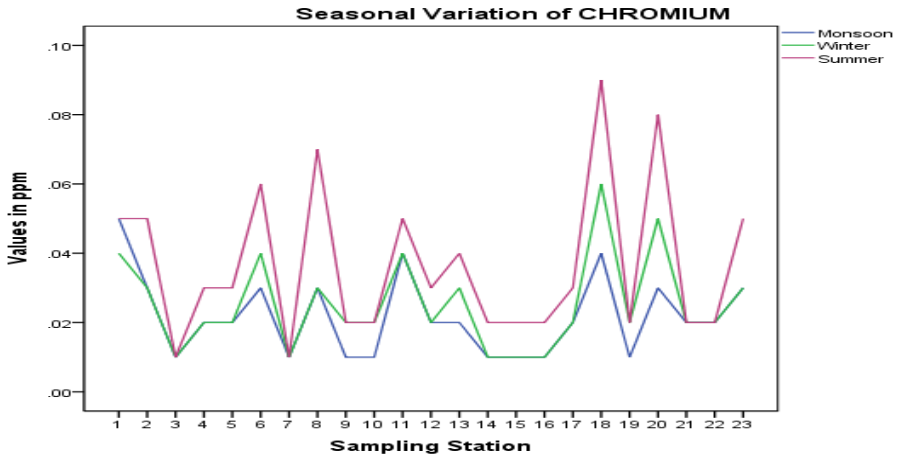


**Fig 5: Variation of chromium values of groundwater samples collected at different seasons.**

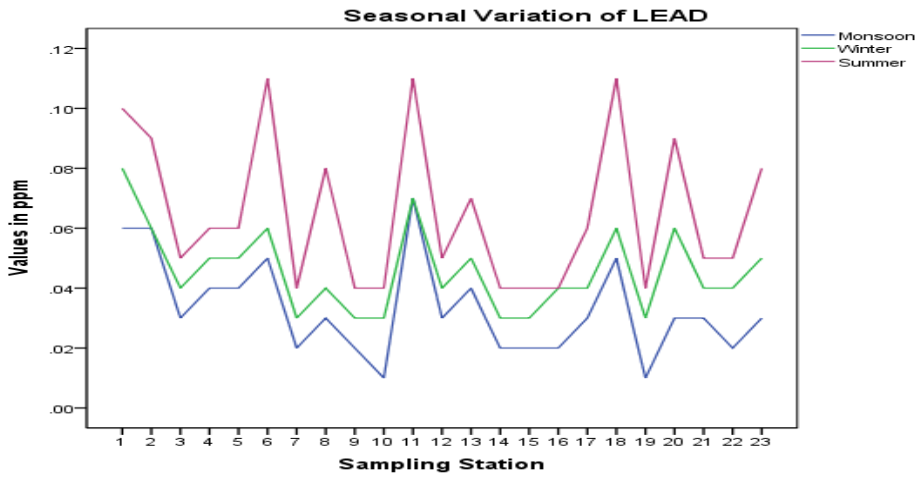


**Fig 6: Variation of lead values of groundwater samples collected at different seasons.**

## V.CONCLUSION

Present investigation involves the assessment of quality of groundwater samples with respect to the impact of industrial effluents, domestic sewages, agricultural activities and seawater intrusion in different seasons monsoon, winter and summer for the three successive years (October 2010-April 2013). From the analytical data the concentrations of some heavy metal ions such as Fe, Mn, Cr and Pb are high in most of the stations. The results of Heavy Metal Pollution Index (HPI) indicate the very poor status of groundwater for drinking. On the basis of above discussion it may conclude that the underground drinking water at almost all sites in this study area is highly contaminated.

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