Seasonable Variation of Trace Metals, Statistical Values of Groundwater in and around Tannery Areas of Vellore District

A. KISTAN1*, V. KANCHANA2 and N. K. GEETHA3

1Panimalar Institute of Technology, Chennai–123, India.
2Sree Sastha Institute of Engineering and Technology, Chennai–123, India.
3Dayananda Sagar College of Engineering, Bangalore-560098, India.
*Corresponding author E-mail: vishmikrish@gmail.com

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ABSTRACT

Authors investigates the determination of seasonable variation of trace metals named Copper, Zinc, Iron, Cadmium, Chromium and Lead set down in the groundwater in and around area of tannery areas of Vellore district. The tanneries discharge untreated tannery effluents, which get mixed with the soil, water of the Palar River, and underground in this area. The determination of metals was performed for the groundwater samples which are collected from adjacent to tannery localities, which bears untreated tannery effluents at pre-monsoon and post-monsoon seasons. The metals might be deposited into the plants and vegetables grown on that agricultural soil, which disturb human health. Somewhat risky amount of trace metals were found in some groundwater samples, especially in the case of in pre-monsoon. All these trace metals were analysed by the Atomic adsorption spectroscopy technique (AAS). These metals contamination in the groundwater is answerable for the support of harmfulness in farming crops and underground water.

INTRODUCTION

Over two third of earth’s surface is covered by water less than a third is taken up by land. On earth 96.5% of water is found in seas and oceans and the remaining is groundwater. Water plays an important role in the world economy because water is an excellent solvent for a wide variety of applications such as household, industries, and agriculture sectors. In earth, water moves continually through the water cycle of evaporation, transpiration, condensation and precipitation. Safe drinking water is essential to humans and other life form even though it does not provide calories or organic nutrients. The lakes, streams and rivers water level will be change with respect to weather but the level of groundwater will not be changed but it decreases due to use of irrigation, domestic and industrial purpose and recharge after several years or months due to rains subsequently.

The groundwater chemistry is mainly controlled by the reactions of geochemical along the direction of flow. It is important to identify these geochemical reactions in the water in order to assess the distribution of major ionic of the region.
In all living organism including human being to live in earth the basic need is water. In rural areas most of the people are using groundwater for drinking purpose but groundwater is unfit for drinking purpose because it carries total dissolved solids this is due to various factors such as industrial waste, disposal of sewage etc.

In many cities of India usage of groundwater is increased including vellore district due to over population, increased in industrial sector and agriculture, which decrease the groundwater level.

At present, pollution of groundwater is a global environmental problem, due to over exploration and demand of groundwater resources and their recharging is reduced. The trace metal contaminates in aquifers of groundwater as constitution of natural due to interaction of soil-water and chemical constituents movement. An ecosystem of aquatic and groundwater contaminations in trace metals. Many researchers have been studied by the contaminations of trace metal in groundwater. The natural process of leaching and precipitation is also susceptibly polluted in groundwater results erosion of soil and reduction of quality of water. At present study investigation of copper zinc iron lead chromium and cadmium content in groundwater in Vellore district.

MATERIALS AND METHODS

The groundwater samples were collected in 2L pre cleaned polythene bottles. Add 1mL of con. HNO₃ in each groundwater samples and filtered immediately using 0.45 µm membrane filter of millipore and stored at 4°C in laboratory. The hot plate used to digest the samples and volume reduces less than 50 mL. It is poured in volumetric flash and made up 50 mL used in double distilled water. These samples are kept in dark room and analyses the trace metal by atomic absorption spectrophotometer method.

RESULTS AND DISCUSSION

Heavy metals are one of the toxic pollutants in groundwater. It was extracted from earth's crust. Copper is one of the common trace metals, which enter into groundwater due to wastage of industries, copper pipes corrosion and pesticides used in agriculture. The human health need trace amount of copper but, but it concentration is high in drinking water cause damage of liver and kidney. The study area copper concentration varies from 0 to 2.25ppm with average of 0.71ppm, 0 to 1.33ppm with average of 0.477ppm and 0.04 to 1.94ppm with average of 0.767ppm and 0.19 to 2.82ppm with average of 1.104ppm in north, south, central and west parts of vellore district respectively. The maximum copper concentration recorded is (N1, W4, W6, W8, W10). According to World health organization 15 samples exceeds in permissible limit (1ppm). The zinc concentration varies between 0.36 to 2.84ppm with average 1.39ppm in north, 0.48 to 3.83ppm with average 1.841ppm in south, 0 to 3.28ppm with average 1.39ppm in central and 0.1 to 2.27ppm with average 1.224ppm in west part in Vellore district, which enters into groundwater from galvanic industries, productions of battery, zinc pipes and paints. The concentration of zinc is increased may cause stomach ache, fever, diarrhea and vomiting. In our study area all the samples were not exceed in BSI standards and worlds health organization. Iron is one of the essential trace metals in our body. It enters into water from ore, pipes corrosion, etc. The iron concentration ranges from 0 to 1.5ppm with average 0.481ppm in north, 0.04 to 2.17ppm with average 0.579ppm in south, 0 to 0.76ppm with average 0.205ppm in central and 0.02 to 2.17ppm with average 0.608ppm in west part of Vellore district. 44% of the samples are exceeds the permissible limit (0.3ppm) the maximum iron concentration was recorded in (S7). Lead is one of the toxic trace naturally occurring metals. The lead concentration may increase in environmental due to many human activities. Lead concentration varies between 0 to 0.38ppm with average of 0.008ppm, 0 to 0.0038ppm with average of 0.006ppm and 0. to 0.019ppm with average of 0.004ppm and 0.002 to 0.076ppm with average of 0.018ppm in north, south, central and west parts of Vellore district respectively. The drinking water contains small content of lead it cause blood pressure, damage of kidney etc. The present study areas most of samples within the desirable limit except W9 and W10 based on standards of ISI and WHO. The groundwater contains cadmium may naturally or contaminated from mining, sewage water, fertilizers and effluents of industries. It may be change in groundwater pH level. The cadmium concentration varies between 0-0.05ppm in north, 0-0.005ppm in south, 0-0.004ppm in central and 0-0.006ppm in west part of Vellore district. Based on WHO and BIS all the samples within the desirable limit (<0.01ppm). The presence of chromium in groundwater naturally but it exists in combined state. It causes cancer and respiration system damage. All the samples are within desirable limit based on WHO and BIS.
### Table 1: Trace metals statistical values of groundwater in north part of Vellore district

| Sample Code | Copper | Zinc | Iron | Lead | Cadmium | Chromium |
|-------------|--------|------|------|------|---------|----------|
| N1          | 2.25   | 2.84 | 0.99 | 0.003| 0.002   | 0.038    |
| N2          | 0.67   | 1.03 | 0.48 | 0.01 | 0.003   | 0.004    |
| N3          | 0.573  | 1.35 | 0.08 | 0.004| 0.003   | 0.002    |
| N4          | 0.48   | 0.99 | 0.38 | 0.019| 0.005   | 0.004    |
| N5          | 0.04   | 0.99 | 0.57 | 0.003| 0.002   | 0.003    |
| N6          | 0.97   | 1.12 | 0.09 | 0.003| 0.002   | 0.003    |
| N7          | 1.52   | 1.79 | 0.05 | 0.009| 0.001   | 0.001    |
| N8          | 0.48   | 0.88 | 0.29 | 0.004| 0.002   | 0.002    |
| N9          | 1.18   | 0.88 | 1.26 | 0.004| 0.002   | 0.001    |
| N10         | 0.06   | 1.94 | 0.57 | 0    | 0.001   | 0.001    |
| N11         | 0      | 0.36 | 0.02 | 0.002| 0       | 0.002    |
| N12         | 0.57   | 2.50 | 1.50 | 0.004| 0.001   | 0.010    |
| N13         | 1.33   | 1.94 | 0    | 0.005| 0.002   | 0.002    |
| N14         | 0.19   | 0.99 | 0.38 | 0    | 0.004   | 0.002    |
| N15         | 0.04   | 1.39 | 0.48 | 0.001| 0       | 0.001    |
| N16         | 0.08   | 0.87 | 0.02 | 0.004| 0.002   | 0.001    |
| Minimum     | 0      | 0.36 | 0    | 0    | 0       | 0.001    |
| Maximum     | 2.25   | 2.84 | 1.5  | 0.038| 0.005   | 0.038    |
| Mean        | 0.704  | 1.39 | 0.481| 0.008| 0.002   | 0.006    |

Units = mgL⁻¹ (ppm)

### Table 2: Trace metals statistical values of groundwater in south part of Vellore district

| Sample Code | Copper | Zinc | Iron | Lead | Cadmium | Chromium |
|-------------|--------|------|------|------|---------|----------|
| S1          | 1.33   | 2.02 | 0.57 | 0.005| 0.005   | 0.019    |
| S2          | 1.33   | 1.89 | 0.04 | 0.038| 0.003   | 0        |
| S3          | 0.76   | 2.17 | 0.38 | 0.001| 0.001   | 0.001    |
| S4          | 0.47   | 1.12 | 0.19 | 0    | 0.004   | 0.002    |
| S5          | 0.04   | 1.45 | 0.09 | 0.002| 0.004   | 0.001    |
| S6          | 0.38   | 2.34 | 1.2  | 0.002| 0       | 0.010    |
| S7          | 0.38   | 2.55 | 2.17 | 0.003| 0       | 0.010    |
| S8          | 0.02   | 0.48 | 0.08 | 0    | 0.001   | 0.001    |
| S9          | 0      | 0.97 | 0.08 | 0.001| 0.001   | 0.001    |
| S10         | 0.97   | 1.73 | 0.76 | 0.004| 0.001   | 0.002    |
| S11         | 0.04   | 1.89 | 0.57 | 0.002| 0.004   | 0.004    |
| S12         | 0.76   | 3.83 | 0.51 | 0.004| 0.002   | 0.002    |
| S13         | 0.29   | 1.50 | 0.19 | 0.002| 0.001   | 0.002    |
| S14         | 0.19   | 1.39 | 0.06 | 0.001| 0.002   | 0.002    |
| S15         | 0.01   | 1.89 | 0.76 | 0.001| 0.002   | 0.002    |
| S16         | 0.29   | 1.6  | 0.57 | 0.002| 0.004   | 0.002    |
| Minimum     | 0      | 0.48 | 0.04 | 0    | 0       | 0        |
| Maximum     | 1.33   | 3.83 | 2.17 | 0.038| 0.005   | 0.019    |
| Mean        | 0.477  | 1.841| 0.579| 0.0059| 0.002   | 0.004    |

Units = mgL⁻¹ (ppm)

### Table 3: Trace metals statistical values of groundwater in central part of Vellore district

| Sample Code | Copper | Zinc | Iron | Lead | Cadmium | Chromium |
|-------------|--------|------|------|------|---------|----------|
| C1          | 0.67   | 0.48 | 0.38 | 0.002| 0.002   | 0.004    |
| C2          | 1.07   | 1.33 | 0.01 | 0.001| 0.002   | 0.001    |
| C3          | 1.94   | 0.76 | 0.01 | 0.002| 0.004   | 0.004    |
| C4          | 0.76   | 1.07 | 0.76 | 0.004| 0.001   | 0.001    |
| C5          | 0.48   | 0.97 | 0.19 | 0.019| 0.001   | 0.003    |
| C6          | 0.38   | 0    | 0.01 | 0    | 0.002   | 0        |
| C7          | 0.19   | 0.88 | 0.01 | 0.001| 0       | 0.001    |
| C8          | 0.19   | 0.02 | 0    | 0    | 0.001   | 0.001    |
| C9          | 0.38   | 1.38 | 0.57 | 0.001| 0.001   | 0.002    |
| C10         | 1.18   | 0.34 | 0.04 | 0.002| 0.002   | 0.001    |
| C11         | 1.28   | 2.78 | 0    | 0.005| 0.003   | 0.002    |
| C12         | 1.14   | 2.23 | 0.76 | 0.004| 0.002   | 0.002    |
| C13         | 0.97   | 1.73 | 0    | 0.002| 0.002   | 0.001    |
| C14         | 0.04   | 2.55 | 0    | 0.004| 0       | 0.002    |
| C15         | 0.67   | 1.89 | 0.19 | 0.004| 0.003   | 0.004    |
| C16         | 0.48   | 3.28 | 0    | 0.006| 0.004   | 0.006    |
| Minimum     | 0.04   | 0    | 0    | 0    | 0       | 0        |
| Maximum     | 1.94   | 3.28 | 0.76 | 0.019| 0.004   | 0.006    |
| Mean        | 0.7667 | 1.387| 0.205| 0.004| 0.018   | 0.002    |

Units = mgL⁻¹ (ppm)
Table 5,6,7: Trace metals statistical values of groundwater in west part of Vellore district

| Sample Code | Copper | Zinc | Iron | Lead | Cadmium | Chromium |
|-------------|--------|------|------|------|---------|----------|
| W1          | 0.19   | 1.01 | 0.38 | 0.004| 0.001   | 0.002    |
| W2          | 0.38   | 0.57 | 1.07 | 0.002| 0.001   | 0.01     |
| W3          | 0.48   | 1.18 | 0.06 | 0.004| 0.002   | 0.002    |
| W4          | 2.82   | 1.83 | 2.17 | 0.002| 0.001   | 0.01     |
| W5          | 0.38   | 0.97 | 0.1  | 0.002| 0.002   | 0.01     |
| W6          | 2.13   | 1.89 | 0.97 | 0.019| 0.004   | 0.002    |
| W7          | 0.93   | 1.18 | 0.76 | 0.019| 0.006   | 0.001    |
| W8          | 2.36   | 1.41 | 0.06 | 0.01 | 0.004   | 0.002    |
| W9          | 0.69   | 1.18 | 1.09 | 0.076| 0.004   | 0.004    |
| W10         | 2.3    | 2.27 | 0.57 | 0.057| 0.002   | 0.005    |
| W11         | 0.57   | 1.6  | 0.06 | 0.002| 0.002   | 0.002    |
| W12         | 0.48   | 0.72 | 0.02 | 0.002| 0.004   | 0        |
| W13         | 0.57   | 1.3  | 0.04 | 0.002| 0       | 0        |
| W14         | 0.38   | 0.1  | 0.19 | 0.002| 0.001   | 0.019    |
| Minimum     | 0.19   | 0.1  | 0.02 | 0.002| 0       | 0        |
| Maximum     | 2.82   | 2.27 | 2.17 | 0.076| 0.006   | 0.019    |
| Mean        | 1.104  | 1.224| 0.608| 0.0176|0.002   |0.006     |

Units = mgL⁻¹ (ppm)

Seasonal Analysis

The Table 5,6,7 shows physico-chemical characteristic of groundwater in various seasons. The copper concentration increases from pre-monsoon to monsoon and further increase post monsoon. The maximum copper value were recorded in VEL47 (2.48ppm) in pre-monsoon, VEL46 (2.72ppm) in monsoon and post monsoon (2.84ppm). According to World health organization 31% of the samples exceeds in permissible limit in pre-monsoon and monsoon, 21% of the samples exceeds in post monsoon (>1ppm).

The concentration of zinc ranging from 0.1-4.02ppm with average 1.58ppm in pre-monsoon, 0.2 to 3.62ppm with average 1.65ppm in monsoon and 0.24-3.12ppm with average 1.41ppm in post monsoon. The zinc values decreases from pre-monsoon to monsoon and further decrease in post-monsoon. According to WHO all the groundwater samples are within the desirable limit (5ppm). The maximum values recorded in (VEL24) in pre-monsoon, the minimum values recorded in VEL52 in pre-monsoon, VEL9 in monsoon and post-monsoon.

The observer values of iron ranging from 0.001-2.28ppm with average 0.42 in pre-monsoon, 0.002-3.62ppm with average 0.435ppm in monsoon and 0.001-2.18ppm with average 0.352ppm in post-monsoon. The iron concentration gradually increases from pre-monsoon to monsoon and decreases in post-monsoon. The iron permissible limit in drinking water is 0.1ppm prescribed by IS, but 8 samples exceed the permissible limit in pre monsoon, monsoon and post post-monsoon period. Hence this type of groundwater drawn from bore well is clean but after sometimes the cloudy and brown colour, due to Fe(OH)₂ is precipitated¹⁸. The sampling site of VEL19 is recorded with maximum concentration in pre monsoon and monsoon periods.

The lead concentration is varies from 0.001 to 0.08ppm with average 0.08ppm, 0.01 to 0.08ppm with average 0.008 and 0.001 to 0.04ppm with average 0.005ppm in pre monsoon, monsoon and post monsoon respectively. The lead concentration may constant in pre monsoon and monsoon but it decrease in post monsoon. All samples in three seasons within the desirable limit (<0.05ppm). Cadmium is one of the hazardous metal in environment, because greater accumulation and high toxicity. The range of cadmium is 0.001-0.005ppm with average 0.002ppm in pre monsoon and monsoon, 0.001- 0.004ppm with average 0.002ppm in post monsoon. Almost all the groundwater samples within the desirable limit (<0.005ppm) based on World health organization. The chromium concentration varies from 0.001 to 0.04ppm with average 0.004ppm in pre monsoon, 0.001-0.002ppm with average 0.005ppm in monsoon and 0.001 to 0.01ppm with average 0.004ppm in post monsoon, the chromium concentration gradually decrease from pre-monsoon to post-monsoon.
Table 5: Trace metals statistical values of groundwater in Vellore district at pre-monsoon

| Sample Code | Copper | Zinc | Iron | Lead | Cadmium | Chromium |
|-------------|--------|------|------|------|---------|----------|
| VEL1        | 2.36   | 2.98 | 1.04 | 0.004| 0.002   | 0.04     |
| VEL2        | 0.7    | 1.08 | 0.5  | 0.01 | 0.003   | 0.004    |
| VEL3        | 0.6    | 1.42 | 0.08 | 0.04 | 0.004   | 0.003    |
| VEL4        | 0.5    | 1.04 | 0.4  | 0.02 | 0.005   | 0.004    |
| VEL5        | 1.02   | 1.18 | 0.1  | 0.003| 0.002   | 0.003    |
| VEL6        | 0.5    | 0.92 | 0.3  | 0.004| 0.002   | 0.002    |
| VEL7        | 1.24   | 0.92 | 1.32 | 0.004| 0.002   | 0.001    |
| VEL8        | 0.06   | 2.04 | 0.6  | Nil  | 0.001   | 0.001    |
| VEL9        | 0      | 0.38 | 0.02 | 0.002| Nil     | 0.002    |
| VEL10       | 0.6    | 2.62 | 1.58 | 0.004| 0.001   | 0.01     |
| VEL11       | 1.4    | 2.04 | 0.005| 0.005| 0.002   | 0.002    |
| VEL12       | 0.2    | 1.04 | 0.4  | Nil  | 0.004   | 0.002    |
| VEL13       | 0.08   | 0.92 | 0.02 | 0.004| 0.002   | 0.001    |
| VEL14       | 1.4    | 2.12 | 0.6  | 0.005| 0.005   | 0.02     |
| VEL15       | 1.4    | 1.98 | 0.04 | 0.04 | 0.003   | Nil      |
| VEL16       | 0.8    | 2.28 | 0.4  | 0.001| 0.001   | 0.001    |
| VEL17       | 0.04   | 1.52 | 0.09 | 0.007| 0.004   | 0.001    |
| VEL18       | 0.4    | 2.46 | 1.26 | 0.002| Nil     | 0.01     |
| VEL19       | 0.4    | 2.68 | 2.28 | 0.004| Nil     | 0.01     |
| VEL20       | 0.02   | 0.5  | 0.08 | Nil  | 0.001   | 0.001    |
| VEL21       | 0      | 1.02 | 0.08 | 0.001| 0.001   | 0.001    |
| VEL22       | 1.02   | 1.82 | 0.8  | 0.004| 0.001   | 0.002    |
| VEL23       | 0.04   | 1.98 | 0.6  | 0.002| 0.004   | 0.004    |
| VEL24       | 0.8    | 4.02 | 0.54 | 0.004| 0.002   | 0.002    |
| VEL25       | 0.3    | 1.58 | 0.2  | 0.002| 0.001   | 0.002    |
| VEL26       | 0.2    | 1.46 | 0.06 | 0.001| 0.002   | 0.002    |
| VEL27       | 0.3    | 1.68 | 0.6  | 0.002| 0.004   | 0.002    |
| VEL28       | 0.7    | 0.5  | 0.4  | 0.002| 0.002   | 0.004    |
| VEL29       | 1.12   | 1.4  | 0.01 | 0.001| 0.002   | 0.001    |
| VEL30       | 2.04   | 0.8  | 0.01 | 0.002| 0.002   | 0.001    |
| VEL31       | 0.8    | 1.12 | 0.8  | 0.004| 0.001   | 0.001    |
| VEL32       | 0.5    | 1.02 | 0.2  | 0.02 | 0.001   | 0.003    |
| VEL33       | 0.2    | 0.92 | 0.01 | 0.001| Nil     | 0.001    |
| VEL34       | 0.4    | 1.45 | 0.6  | 0.001| 0.001   | 0.002    |
| VEL35       | 1.24   | 0.36 | 0.04 | 0.002| 0.002   | 0.001    |
| VEL36       | 1.34   | 2.92 | 0.003| 0.005| 0.003   | 0.002    |
| VEL37       | 1.2    | 2.34 | 0.8  | 0.004| 0.002   | 0.002    |
| VEL38       | 1.02   | 1.82 | 0.002| 0.002| 0.002   | 0.001    |
| VEL39       | 0.04   | 2.68 | 0.004| 0.004| Nil     | 0.002    |
| VEL40       | 0.7    | 1.98 | 0.2  | 0.004| 0.003   | 0.004    |
| VEL41       | 0.5    | 3.44 | 0.001| 0.006| 0.004   | 0.006    |
| VEL42       | 0.2    | 1.06 | 0.4  | 0.004| 0.001   | 0.002    |
| VEL43       | 0.4    | 0.6  | 1.12 | 0.002| Nil     | 0.01     |
| VEL44       | 0.5    | 1.24 | 0.05 | 0.004| 0.002   | 0.002    |
| VEL45       | 0.4    | 1.02 | 0.1  | 0.002| 0.002   | 0.009    |
| VEL46       | 2.24   | 1.98 | 1.02 | 0.02 | 0.004   | 0.002    |
| VEL47       | 2.48   | 1.48 | 0.06 | 0.01 | 0.004   | 0.002    |
| VEL48       | 0.72   | 1.24 | 1.14 | 0.08 | 0.004   | 0.004    |
| VEL49       | 2.42   | 2.38 | 0.6  | 0.06 | 0.002   | 0.005    |
| VEL50       | 0.6    | 1.68 | 0.06 | 0.002| Nil     | 0.002    |
| VEL51       | 0.5    | 0.76 | 0.02 | 0.002| 0.004   | Nil      |
| VEL52       | 0.4    | 0.1  | 0.2  | 0.002| 0.001   | 0.02     |
| Minimum     | 0.001  | 0.1  | 0.001| 0.001| 0.001   | 0.01     |
| Maximum     | 2.48   | 4.02 | 2.28 | 0.08 | 0.005   | 0.04     |
| Mean        | 0.7509 | 1.5763| 0.42 | 0.0084| 0.0024 | 0.0044   |

Units = mgL⁻¹ (ppm)
| Sample Code | Copper | Zinc | Iron  | Lead  | Cadmium | Chromium |
|-------------|--------|------|-------|-------|---------|----------|
| VEL1        | 2.48   | 3.32 | 1.12  | 0.005 | 0.001   | 0.02     |
| VEL2        | 0.8    | 1.84 | 0.6   | 0.01  | 0.005   | 0.008    |
| VEL3        | 0.7    | 1.62 | 0.08  | 0.02  | 0.003   | 0.006    |
| VEL4        | 0.8    | 1.28 | 0.2   | 0.02  | 0.005   | 0.009    |
| VEL5        | 1.04   | 1.26 | 0.1   | 0.008 | 0.003   | 0.004    |
| VEL6        | 0.6    | 1.12 | 0.9   | 0.002 | Nil     | 0.001    |
| VEL7        | 1.18   | 0.88 | 1.24  | 0.004 | 0.001   | 0.002    |
| VEL8        | 0.04   | 1.88 | 0.4   | 0.001 | Nil     | 0.001    |
| VEL9        | 0.01   | 0.2  | 0.02  | Nil   | Nil     | Nil      |
| VEL10       | 0.5    | 2.38 | 1.56  | 0.003 | 0.001   | 0.01     |
| VEL11       | 1.4    | 2.68 | 0.008 | 0.008 | 0.004   | 0.002    |
| VEL12       | 0.3    | 1.44 | 0.5   | 0.001 | 0.002   | 0.004    |
| VEL13       | 0.05   | 1.02 | 0.04  | 0.002 | 0.002   | 0.001    |
| VEL14       | 1.8    | 2.2  | 0.7   | 0.006 | 0.005   | 0.01     |
| VEL15       | 1.2    | 1.86 | 0.08  | Nil   | 0.002   | Nil      |
| VEL16       | 0.8    | 2.14 | 0.4   | 0.002 | 0.002   | 0.001    |
| VEL17       | 0.04   | 1.82 | 0.09  | Nil   | 0.001   | 0.001    |
| VEL18       | 0.5    | 2.28 | 1.26  | 0.004 | 0.001   | 0.01     |
| VEL19       | 0.5    | 2.32 | 1.88  | 0.004 | 0.001   | 0.02     |
| VEL20       | 0.01   | 0.9  | 0.08  | Nil   | Nil     | Nil      |
| VEL21       | 0.09   | 1.02 | 0.09  | 0.001 | 0.001   | 0.001    |
| VEL22       | 1.08   | 1.24 | 0.4   | 0.002 | 0.001   | 0.001    |
| VEL23       | 0.09   | 1.88 | 0.6   | 0.001 | 0.001   | 0.001    |
| VEL24       | 0.8    | 2.16 | 0.4   | 0.002 | 0.003   | 0.003    |
| VEL25       | 0.6    | 1.48 | 0.2   | 0.001 | 0.002   | 0.001    |
| VEL26       | 0.2    | 1.12 | 0.09  | Nil   | 0.001   | Nil      |
| VEL27       | 0.4    | 1.54 | 0.6   | 0.001 | 0.001   | 0.001    |
| VEL28       | 0.8    | 0.62 | 0.9   | 0.001 | 0.004   | 0.004    |
| VEL29       | 1.18   | 1.2  | 0.01  | Nil   | 0.002   | Nil      |
| VEL30       | 1.4    | 0.86 | 0.07  | Nil   | 0.004   | Nil      |
| VEL31       | 0.8    | 1.24 | 0.4   | Nil   | 0.002   | Nil      |
| VEL32       | 0.6    | 1.14 | 0.5   | 0.001 | 0.001   | 0.005    |
| VEL33       | 0.2    | 1.02 | 0.04  | Nil   | Nil     | Nil      |
| VEL34       | 0.6    | 1.44 | 0.8   | 0.001 | 0.001   | 0.001    |
| VEL35       | 0.8    | 0.8  | 0.06  | Nil   | 0.004   | Nil      |
| VEL36       | 1.6    | 2.86 | 0.005 | 0.005 | 0.002   | 0.002    |
| VEL37       | 1.08   | 2.88 | 0.8   | 0.005 | 0.001   | 0.002    |
| VEL38       | 1.2    | 1.98 | 0.002 | 0.002 | 0.002   | 0.001    |
| VEL39       | 0.04   | 2.24 | 0.004 | 0.004 | 0.001   | Nil      |
| VEL40       | 0.8    | 2.26 | 0.2   | 0.002 | 0.005   | 0.004    |
| VEL41       | 0.2    | 3.62 | 0.008 | 0.002 | 0.004   | 0.002    |
| VEL42       | 0.3    | 1.04 | 0.4   | 0.001 | 0.002   | 0.001    |
| VEL43       | 0.4    | 1.12 | 1.18  | 0.002 | 0.002   | 0.01     |
| VEL44       | 0.6    | 1.42 | 0.06  | 0.004 | 0.002   | 0.004    |
| VEL45       | 0.4    | 1.28 | 0.1   | 0.01  | 0.002   | 0.01     |
| VEL46       | 2.72   | 2.46 | 1.26  | 0.03  | 0.002   | 0.02     |
| VEL47       | 2.4    | 1.72 | 0.06  | 0.01  | 0.003   | 0.002    |
| VEL48       | 1.8    | 1.42 | 1.04  | 0.06  | 0.005   | 0.004    |
| VEL49       | 2.24   | 2.68 | 0.6   | 0.08  | 0.003   | 0.006    |
| VEL50       | 0.7    | 1.62 | 0.08  | 0.004 | Nil     | 0.002    |
| VEL51       | 0.92   | 0.92 | 0.02  | 0.02  | 0.004   | Nil      |
| VEL52       | 0.2    | 1.24 | 0.4   | 0.001 | 0.001   | Nil      |
| Minimum     | 0.01   | 0.2  | 0.002 | 0.001 | 0.001   | 0.001    |
| Maximum     | 2.72   | 3.62 | 1.88  | 0.08  | 0.005   | 0.02     |
| Mean        | 0.8076 | 0.2  | 0.4353| 0.0082| 0.0023  | 0.005    |

Units = mg/L⁻¹ (ppm)
Table 7: Trace metals statistical values of groundwater in Vellore district at post-monsoon

| Sample Code | Copper  | Zinc   | Iron   | Lead   | Cadmium | Chromium |
|-------------|---------|--------|--------|--------|---------|----------|
| VEL1        | 2.28    | 2.82   | 1.02   | 0.002  | 0.001   | 0.01     |
| VEL2        | 0.6     | 1.05   | 0.4    | 0.009  | 0.002   | 0.002    |
| VEL3        | 0.5     | 1.12   | 0.05   | 0.01   | 0.002   | 0.002    |
| VEL4        | 0.5     | 1.02   | 0.1    | 0.01   | 0.002   | 0.003    |
| VEL5        | 0.9     | 1.16   | 0.09   | 0.002  | 0.001   | 0.002    |
| VEL6        | 0.4     | 0.82   | 0.2    | 0.002  | Nil     | 0.001    |
| VEL7        | 1.08    | 0.82   | 1.02   | 0.002  | Nil     | 0.001    |
| VEL8        | 0.042   | 1.82   | 0.5    | Nil    | Nil     | Nil      |
| VEL9        | 0.001   | 0.24   | 0.01   | 0.001  | Nil     | Nil      |
| VEL10       | 0.4     | 2.14   | 1.55   | 0.003  | Nil     | 0.009    |
| VEL11       | 1.2     | 1.88   | 0.004  | 0.001  | 0.001   | 0.001    |
| VEL12       | 0.1     | 1.02   | 0.2    | Nil    | 0.001   | 0.001    |
| VEL13       | 0.04    | 0.86   | 0.01   | 0.002  | 0.002   | Nil      |
| VEL14       | 1.2     | 2.04   | 0.5    | 0.004  | 0.004   | 0.01     |
| VEL15       | 0.9     | 1.76   | 0.02   | Nil    | 0.001   | Nil      |
| VEL16       | 0.8     | 2.04   | 0.2    | Nil    | 0.002   | Nil      |
| VEL17       | 0.03    | 1.22   | 0.08   | 0.001  | Nil     | 0.001    |
| VEL18       | 0.3     | 2.18   | 1.06   | 0.001  | Nil     | 0.008    |
| VEL19       | 0.2     | 2.04   | 1.68   | 0.002  | Nil     | 0.009    |
| VEL20       | Nil     | 0.4    | 0.03   | Nil    | Nil     | Nil      |
| VEL21       | Nil     | 0.98   | 0.07   | Nil    | Nil     | Nil      |
| VEL22       | 0.09    | 1.22   | 0.3    | 0.001  | Nil     | Nil      |
| VEL23       | 0.03    | 1.86   | 0.4    | Nil    | 0.001   | 0.001    |
| VEL24       | 0.5     | 2.06   | 0.3    | 0.002  | 0.001   | 0.001    |
| VEL25       | 0.2     | 1.38   | 0.1    | Nil    | 0.002   | Nil      |
| VEL26       | 0.1     | 1.02   | 0.04   | Nil    | Nil     | Nil      |
| VEL27       | 0.2     | 1.52   | 0.5    | Nil    | Nil     | Nil      |
| VEL28       | 0.6     | 0.4    | 0.2    | Nil    | 0.001   | 0.003    |
| VEL29       | 1.02    | 0.9    | 0.009  | Nil    | 0.001   | Nil      |
| VEL30       | 1.28    | 0.6    | 0.009  | Nil    | 0.001   | Nil      |
| VEL31       | 0.6     | 0.98   | 0.1    | Nil    | Nil     | Nil      |
| VEL32       | 0.4     | 0.82   | 0.1    | Nil    | Nil     | 0.002    |
| VEL33       | 0.1     | 0.82   | 0.02   | Nil    | Nil     | Nil      |
| VEL34       | 0.4     | 1.34   | 0.6    | Nil    | Nil     | Nil      |
| VEL35       | Nil     | 0.3    | 0.03   | Nil    | Nil     | Nil      |
| VEL36       | 1.24    | 2.82   | 0.002  | 0.004  | 0.002   | 0.001    |
| VEL37       | 0.9     | 1.92   | 0.6    | 0.002  | 0.001   | 0.001    |
| VEL38       | 0.98    | 1.78   | 0.001  | 0.001  | 0.001   | Nil      |
| VEL39       | 0.02    | 2.04   | 0.002  | 0.002  | Nil     | Nil      |
| VEL40       | 0.7     | 1.98   | 0.1    | 0.001  | 0.002   | 0.002    |
| VEL41       | 0.1     | 3.12   | 0.002  | 0.001  | 0.001   | 0.001    |
| VEL42       | 0.1     | 1.04   | 0.2    | 0.001  | Nil     | 0.001    |
| VEL43       | 0.3     | 0.92   | 1.08   | 0.001  | Nil     | 0.009    |
| VEL44       | 0.4     | 1.22   | 0.04   | 0.002  | 0.001   | 0.001    |
| VEL45       | 2.84    | 1.84   | 2.18   | 0.001  | Nil     | 0.009    |
| VEL46       | 2.02    | 1.98   | 0.98   | 0.01   | 0.002   | 0.009    |
| VEL47       | 2.2     | 1.42   | 0.04   | 0.009  | 0.001   | 0.001    |
| VEL48       | 0.68    | 1.12   | 1.02   | 0.04   | 0.002   | 0.002    |
| VEL49       | 1.98    | 2.24   | 0.4    | 0.04   | 0.001   | 0.004    |
| VEL50       | 0.5     | 1.62   | 0.05   | 0.002  | Nil     | 0.001    |
| VEL51       | 0.5     | 0.72   | 0.01   | 0.001  | 0.002   | Nil      |
| VEL52       | 0.1     | 0.98   | 0.1    | Nil    | Nil     | Nil      |
| Minimum     | 1.412   | 0.001  | 0.352  | 0.001  | 0.001   | 0.001    |
| Maximum     | 3.12    | 2.18   | 2.18   | 0.04   | 0.004   | 0.01     |
| Mean        | 0.24    | 0.001  | 0.001  | 0.0052 | 0.0015  | 0.0036   |

Units = mg L⁻¹ (ppm)
**Table 8: Heavy metal Pollution Index (HPI) and Metal Index (MI) estimation for groundwater samples from Vellore district**

| Sample Code | Pre-monsoon HPI | MI | Monsoon HPI | MI | Post-monsoon HPI | MI |
|-------------|-----------------|----|-------------|----|-----------------|----|
| VEL1        | 104.0           | 0.780 | 108.19      | 0.737 | 108.71         | 0.607 |
| VEL2        | 99.43           | 0.309 | 90.30       | 0.397 | 101.25         | 0.248 |
| VEL3        | 91.59           | 0.339 | 98.96       | 0.285 | 104.87         | 0.177 |
| VEL4        | 89.22           | 0.325 | 89.75       | 0.361 | 104.73         | 0.188 |
| VEL5        | 105.88          | 0.253 | 100.70      | 0.294 | 110.49         | 0.208 |
| VEL6        | 105.16          | 0.197 | 113.09      | 0.272 | 114.60         | 0.119 |
| VEL7        | 103.06          | 0.487 | 107.70      | 0.450 | 112.90         | 0.369 |
| VEL8        | 109.40          | 0.153 | 114.23      | 0.101 | 114.15         | 0.111 |
| VEL9        | 114.89          | 0.021 | 115.18      | 0.007 | 115.06         | 0.008 |
| VEL10       | 106.84          | 0.456 | 107.00      | 0.430 | 111.47         | 0.389 |
| VEL11       | 105.92          | 0.314 | 96.55       | 0.364 | 110.92         | 0.245 |
| VEL12       | 96.49           | 0.185 | 105.11      | 0.199 | 110.34         | 0.081 |
| VEL13       | 105.69          | 0.077 | 105.92      | 0.070 | 105.98         | 0.058 |
| VEL14       | 91.16           | 0.524 | 90.89       | 0.578 | 95.96          | 0.190 |
| VEL15       | 96.37           | 0.445 | 106.41      | 0.267 | 110.95         | 0.190 |
| VEL16       | 109.95          | 0.249 | 105.33      | 0.267 | 106.01         | 0.189 |
| VEL17       | 96.87           | 0.115 | 114.93      | 0.049 | 144.93         | 0.035 |
| VEL18       | 112.27          | 0.344 | 107.53      | 0.382 | 112.83         | 0.281 |
| VEL19       | 109.71          | 0.523 | 106.14      | 0.519 | 111.27         | 0.373 |
| VEL20       | 110.58          | 0.042 | 115.06      | 0.025 | 115.16         | 0.009 |
| VEL21       | 110.44          | 0.048 | 110.44      | 0.065 | 115.08         | 0.023 |
| VEL22       | 168.60          | 0.360 | 109.85      | 0.287 | 114.45         | 0.082 |
| VEL23       | 95.74           | 0.215 | 109.32      | 0.159 | 109.90         | 0.112 |
| VEL24       | 104.77          | 0.321 | 100.85      | 0.291 | 109.95         | 0.183 |
| VEL25       | 110.11          | 0.131 | 105.85      | 0.190 | 106.12         | 0.099 |
| VEL26       | 106.07          | 0.103 | 110.61      | 0.077 | 115.17         | 0.035 |
| VEL27       | 95.79           | 0.249 | 109.39      | 0.204 | 114.18         | 0.134 |
| VEL28       | 105.26          | 0.242 | 95.36       | 0.374 | 110.44         | 0.164 |
| VEL29       | 106.40          | 0.244 | 106.55      | 0.245 | 110.98         | 0.198 |
| VEL30       | 106.46          | 0.394 | 97.51       | 0.321 | 111.04         | 0.238 |
| VEL31       | 108.60          | 0.312 | 105.59      | 0.247 | 115.16         | 0.128 |
| VEL32       | 107.58          | 0.221 | 109.65      | 0.233 | 115.11         | 0.099 |
| VEL33       | 115.12          | 0.052 | 115.20      | 0.051 | 115.21         | 0.029 |
| VEL34       | 109.38          | 0.209 | 108.99      | 0.273 | 114.00         | 0.182 |
| VEL35       | 106.19          | 0.261 | 115.10      | 0.019 | 115.15         | 0.008 |
| VEL36       | 101.46          | 0.330 | 105.99      | 0.356 | 106.05         | 0.288 |
| VEL37       | 104.25          | 0.413 | 108.56      | 0.385 | 109.37         | 0.298 |
| VEL38       | 106.26          | 0.234 | 106.31      | 0.266 | 110.87         | 0.203 |
| VEL39       | 114.71          | 0.057 | 110.2       | 0.062 | 114.98         | 0.033 |
| VEL40       | 100.98          | 0.249 | 92.35       | 0.295 | 106.11         | 0.199 |
| VEL41       | 96.65           | 0.228 | 97.4        | 0.155 | 110.69         | 0.075 |
| VEL42       | 109.35          | 0.148 | 105.32      | 0.168 | 114.67         | 0.068 |
| VEL43       | 112.54          | 0.300 | 103.46      | 0.349 | 112.75         | 0.274 |
| VEL44       | 105.73          | 0.159 | 105.73      | 0.186 | 110.49         | 0.114 |
| VEL45       | 105.87          | 0.165 | 104.74      | 0.198 | 110.92         | 0.090 |
| VEL46       | 92.75           | 0.705 | 99.87       | 0.691 | 103.17         | 0.617 |
| VEL47       | 96.37           | 0.546 | 100.84      | 0.519 | 109.92         | 0.439 |
| VEL48       | 83.54           | 0.670 | 82.41       | 0.786 | 98.46          | 0.469 |
| VEL49       | 96.99           | 0.780 | 89.63       | 0.840 | 104.66         | 0.585 |
| VEL50       | 114.98          | 0.142 | 114.67      | 0.168 | 114.98         | 0.120 |
| VEL51       | 97.115          | 0.168 | 94.65       | 0.300 | 106.23         | 0.130 |
| VEL52       | 110.10          | 0.1911 | 109.78     | 0.138 | 115.04         | 0.044 |
Correlation Studies

Table 9, shows correlation analysis of heavy metals in pre-monsoon, monsoon and post-monsoon seasons. During pre-monsoon the correlation between heavy metals didn’t considerable because the value is very low but in monsoon season a moderately correlated between the metals Cu-Pb (r=0.528) and strongly correlated between the metals Fe-Cr (r=0.667) and also strongly correlated in post-monsoon season Fe-Cr (r=0.711). This is due to heavy metals may be dissolved.

Heavy Metal Pollution Index and Metal Index

The total water quality of groundwater is represented by heavy metal pollution index (HPI). The metal index value used to determine suitable for drinking purpose in groundwater. Table 5,6,7 shows HPI and MI values in all urban areas of Vellore district. In the study area 71%, 75% and 90% of groundwater samples exceeds the critical index values 100 in pre-monsoon, monsoon and post-monsoon respectively. This is due to trace metals leaching from pigments, fertilizers, etc. Based on MI classification 40% of samples are pure and 60% of samples are very pure in pre-monsoon, 35% of samples are pure and 65% of the samples are very pure in monsoon and 17% of samples are pure and 83% of the samples are very pure in post-monsoon.

Table 10: Correlation between variables and factor in Vellore district

| Heavy Metals | Pre-monsoon | Monsoon | Post-monsoon |
|--------------|------------|---------|--------------|
|              | F1         | F2      | F1           | F2           | F1           | F2           |
| Cu           | 0.362      | 0.154   | 0.07         | 0.363        | 0.018        | 0.406        |
| Zn           | 0.033      | 0.54    | 0.221        | 0.118        | 0.207        | 0.163        |
| Fe           | -0.228     | 0.538   | 0.509        | -0.2         | 0.526        | -0.179       |
| Pb           | 0.45       | -0.076  | -0.031       | 0.386        | -0.016       | 0.344        |
| VEL          | 0.458      | -0.076  | -0.202       | 0.473        | -0.185       | 0.493        |
| Cr           | -0.134     | -0.276  | 0.451        | -0.033       | 0.45         | -0.025       |
| Eigen value  | 1.775      | 1.351   | 2.584        | 1.368        | 2.44         | 1.365        |
| Variability (%) | 29.589 | 22.52   | 43.073       | 22.807       | 40.673       | 22.742       |
| Cumulative % | 29.589     | 52.109  | 43.073       | 65.88        | 40.673       | 63.415       |
Eigen values and two principal components values were extracted greater than 1 in all seasons. During pre-monsoon season, factor 2 moderately loaded with Zn and Fe. In monsoon season, factor 1 moderately loaded with Fe and post monsoon season also moderately loaded with Fe in factor 1 (Table 5,6,7), which explain 30%, 52% and 40% of the variability in pre-monsoon, monsoon and post-monsoon seasons respectively of the data set.

During pre-monsoon season factor 2 moderately loaded with Fe and Zn. In monsoon and post monsoon seasons factor 1 moderately loaded with Fe. The groundwater contains trace amount of lead, cadmium and chromium this is due to metal dissolution during recharge of aquifer by rainfall.

CONCLUSION

The overall analysis of trace heavy metals in groundwater in and around Vellore district, they suggest following conclusions. The copper concentration of study areas, 33% of the samples exceed in permissible limits. Iron concentration, 8 samples exceed permissible limits based on BIS. Lead concentration within the desirable limit in all three seasons.

In correlation analysis, monsoon and post-monsoon periods were moderately correlated between Cu-Pb and Fe-Cr. The study of principle component analysis shows moderately loaded in pre-monsoon, monsoon and post-monsoon seasons. This is due to dissolution of heavy metals, the effect of recharge in rain water and degradation of microbial by organic matter presence from wastewater.

Heavy Metal Pollution Index (HPI) and Metal Index (MI) values in most of the samples were pure and very pure.

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