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Impacts of Tanneries on Quality of Groundwater in Pallavaram, Chennai Metropolitan City

K.Ramesh*, V.Thirumangai
Centre for Water Resources, Department of Civil Engineering, Anna University, Chennai-600 025

ABSTRACT
The present study was carried out with the objective of determining the extent of groundwater pollution caused by tanning industries and solid waster dumpsite in Pallavaram area located south of Chennai (Madras), which is a town of number of small and large scale leather industries. About 22 groundwater samples were collected and analyzed for the concentration of physio-chemical parameters and trace ions during September 2011 and January 2012. Ca-Mg-Cl and Na-Cl are the major water types in this area. It is inferred that, total hardness falls in hard to very hard category. The water quality index rated as poor to very poor quality except few samples. The study reveals that the concentration of major ions and chromium are exceeding the permissible limit. Groundwater is unsuitable for human consumption as it contains higher concentration of major ions and chromium. Tannery uses a large number of chemicals during the process of discharging toxic wastes into open drains and municipality solid waste dumpsite to the nearby land is the major reasons deterioration of water quality in this area. Contamination of groundwater causes water scarcity for domestic purpose of this study is to highlight the impact of tannery effluent on groundwater.
Keywords – Groundwater Quality, Domestic, Tanneries, Solid Waste, Pallavaram.

I. INTRODUCTION

Groundwater is ultimate, most suitable fresh water resource with nearly balanced concentration of the salts for human consumption. Safe drinking water is primary need of every human being. Pollution of groundwater has been growing increasingly in several parts of India, particularly in areas of industrial development. Over burden of population pressure, unplanned urbanization, over exploitation of groundwater resources, dumping of polluted water at inappropriate place enhance the infiltration of harmful compounds to the groundwater. With the increasing demand for groundwater resources caused by an acute shortage of surface water, there is a noteworthy depletion of groundwater levels and quality due to geogenic as well as anthropogenic activities. The quality of world water resources is being increasingly degraded as a consequence of its intensified anthropogenic exploitation. The tanning industry is one of the oldest and fastest growing industries in south and south-east Asia. The states of Tamil Nadu, West Bengal and Uttar Pradesh together have 88% of the tannery units of the country. About 55% of total leather processed in the county is from Tamil Nadu and tannery units mainly spreads over Pallavaram and Chrompet in Chennai, Ranipet, Ambur, Vaniyambadi, Pernambut of Vellore district, Dindigul, parts of Erode district and Sembattu in Trichy district. Chennai (Madras) was one of the important trading centers during the British days in India. Tanneries use a large number of chemicals during the process, discharging toxic wastes (effluents) into the streams, which drain into ponds, thereby polluting the groundwater. Over the years the groundwater in the areas where tanneries are located, has become intolerably polluted. The industry is highly water-intensive; each tonne of hide/skin tanned requires over 40,000 liters of water. Hence even a small tannery with a capacity to process 3 to 4 tonnes a day uses over 1,00, 000 liters of water a day which is the daily household requirement of at least 2,500 people. It is established that a single tannery can cause the pollution of groundwater around radius of 7-8 km (1). The water pollution is not only devastating to people but also to animals, aquatic life and birds. The impact of tannery waste water disposal leads to environmental problem, even though this problem persists for a long time, it has attracted serious attention only in recent time. The chemical characteristics of tannery waste water are enriched in synthetic chemicals, some less degradable solids and salts, in addition to the toxic and carcinogenic pollutant metal. Release of ineffectively treated waste water into the surface leads to the contamination of groundwater and surface water sources. Contamination of the groundwater by domestic and industrial effluents is a serious problems faced by developing countries. Today there is numerous waste water treatment technologies available for tannery wastewater treatment, but these technological solutions appeared to be out of reach due to several economical factors. Already the pollutants from a large number of tanneries have caused a considerable

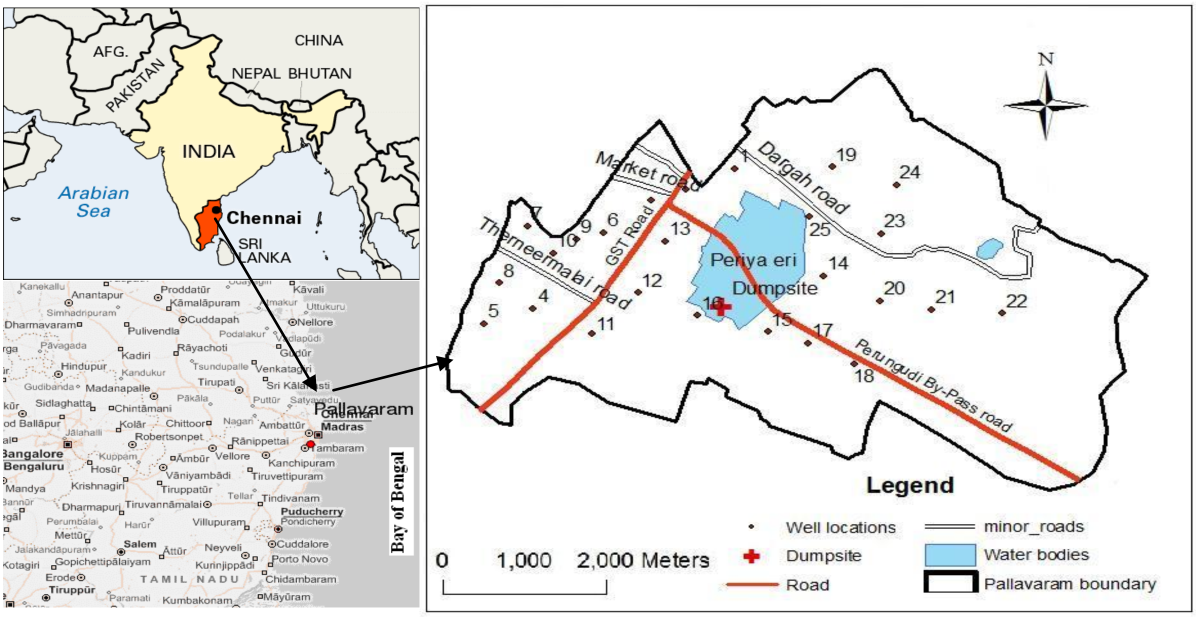

Fig. 1 - Location map of study area

amount of damage of water in river courses by affecting water supply and agricultural productivity. In the present works attempts to identify the extent of groundwater pollution in and around Pallavaram region.

II. STUDY AREA

The study was carried out in Pallavaram (Pallavapuram) region is a town and located in the suburbs of Chennai (Madras) city (Fig.1) which is well known for tanneries. The geographic location of the area is between 80^{0}07'30" to 80^{0}10'56" East longitude and 12^{0}57'13" to 12^{0}58'56" North latitude. The area serves as a home town for lots of small scale and large scale tanning industries. Chrome tanning is the popular method practiced in this area. The area has periya eri (big tank), once a sprawling water body covering about 189 acres, now shrunken into to small patch and used as storage for effluents from leather industry, sewage and dumping of garbage which has adversely affected the quality of the groundwater. The study area is 13 km away from the Bay of Bengal. The general topography falls from south to north and west to east. The climate of the area is with low humidity and high temperature, and the temperature is around 18ºC - 25ºC during winter and during summer has a maximum of 35ºC - 42ºC is generally hot. Temperature starts rising towards the end of February. The area receives maximum rainfall from North-West monsoon and annual rainfall is 1,124 mm. The flow of groundwater is from west to east. Most of the study area consists of barren land and the land use pattern of this area is mainly of buildings, roads, industries, schools and college. Pallavaram a satellite town for Chennai City is well connected by good network of roads and railway line, located on South Chennai Grand Southern Trunk Road (National Highway 45) and along the Chennai-Tambaram Railway line

III. MATERIAL AND METHODS

Based on a well investigation survey 25 representative wells were chosen for collection of groundwater samples in around Pallavaram area. The well locations were fixed using hand-held GPS. The groundwater samples were collected from bore wells and dug wells during the month of Aug 2011 (Premonsoon) and January 2012 (postmonsoon). The samples were collected in a clean polyethylene bottles. The bottles
were cleaned thoroughly with 1% Nitric acid before sample collections. Before the samples were collected the bottles were thoroughly rinsed with the samples. Electrical conductivity and pH were measured insitu using Electrical Conductivity and pH meter. The physio-chemical parameters were analyzed as per (2). The location of the wells where the groundwater has been collected is represented in the following map processed by ArcGIS 9.3.

4.1 Groundwater Chemistry

Groundwater quality assessment was carried to determine its suitability in terms of drinking purposes. The groundwater samples were collected in and around the Pallavaram suburbs town, Chennai. The concentration with the limits recommended by BIS is discussed.

GIS is used to understand the spatial distribution and variation of the ions with respect to the location. pH is a term to express the intensity of acidic or alkaline conditions. pH is an important parameter in assessing the water quality. The pH of the groundwater samples ranges from 6.1 to 8.0 in premonsoon and 5.8 to 7.8 in postmonsoon. The groundwater samples are faintly alkaline in nature. High pH causes a bitter taste; water pipes and water-using appliances becomes encruste; depresses the effectiveness of the disinfection of chlorine. The factors like air temperature also bring about changes the pH of water. If the pH is found beyond the permissible limit, it affects the mucous membrane of cells (3).

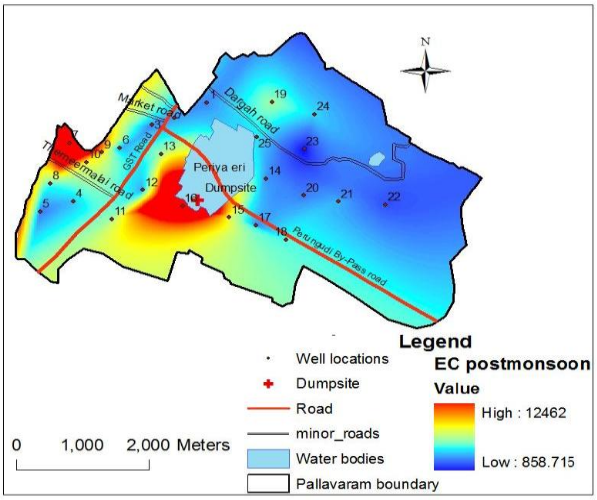

Fig.2 -Spatial Variation of EC

Electrical Conductivity (EC) or salinity value is a manifestation to signify the total concentration of soluble salts in water. This property is called electrical conductivity. It is a useful tool to assess the purity of water. A sudden rise in EC in the water indicates addition of some pollutants to it (4). The depth of dug wells range from 10 m to 26 m bgl while that of tube wells extend beyond 40 m. The EC of tube well and dug well samples did not show much variation. The spatial distribution of EC in well samples as shown in the fig. 2, reveals that groundwater salinity increases toward the southern part of the study area. However, some heterogeneity in salinity distribution is observed. The EC recorded disturbances in the groundwater quality of the study area which as per field observation is due to industries and dumping site. The increase in conductivity indicates that there must be an increase in number of ions which is supported by salinity values. Salinity of samples in the study area ranges from 809 to 15119 μScm^{-1} during premonsoon and 800 to 12000 μScm^{-1} during post monsoon period. Few samples show very high concentration >12,000 μScm−1during pre and post monsoon period in the Southeastern and Southwestern part of the study area due to the influence of industrial effluent and solid waste dumping site on groundwater quality.

Calcium (Ca^{2+}) is the next dominant cation found in groundwater. The calcium and magnesium are the most abundant elements in the groundwater. In groundwater the cacium content generally exceeds the magnesium content (5). Ca^{2+}may dissolve readily from carbonate rocks and limestone's or is leached from soils. However, dissolved magnesium concentration is lower than Ca^{2+} in the groundwater. Other sources are primarily industrial and municipal discharges. Ca^{2+} is an essential nutritional element for human being, plant cells and soils. It is found in alkaline in nature. The concentration of Ca^{2+} ranges from 42 to 680 mg/l in premonsoon and in postmonsoon ranges from 16 to 498 mg/l. The permissible limit of calcium in drinking water is 75 mg/l, so all the samples exceeded the permissible limit. The rapid industrialization and urbanization in the area contributed to the high concentration of Ca^{2+} in the groundwater of the area. Magnesium usually occurs in lesser concentration than calcium due to the fact that the dissolution of magnesium rich minerals is slow process and that of calcium is more abundant in the earth's crust. If the concentration of magnesium in drinking water is more than the permissible limit (30 mg/l), it causes unpleasant taste to the water. Magnesium concentration is found between in pemonsoon is 19 to 792 mg/l and in postmonson is 11 to 302 mg/l. Most of the locations exceeded the permissible limit.

In groundwater total hardness (TH) is mainly contributed by Ca^{2+}, magnesium, carbonate, bicarbonate, sulphate, and chloride of calcium and magnesium salts. Hardness of water is caused by certain salts held in solution. Total Hardness (TH) ranges between 181 to 4706 mg/l in premonsoon and 50 to 3160 mg/l in postmonsoon (Fig.3). In the present study most of the samples collected have high amount of hardness and crossed the permissible limit with sample number 7 having highest TH and low has lowest hardness sample 20. Presence of too much hardness in the water makes the people using the water prone to disease like kidney stones and other aliments (6). Hardness is an important criterion for determine the usability of water for domestic, drinking and many industrial uses (7). The increasing of hardness in drinking water has bad health effects.

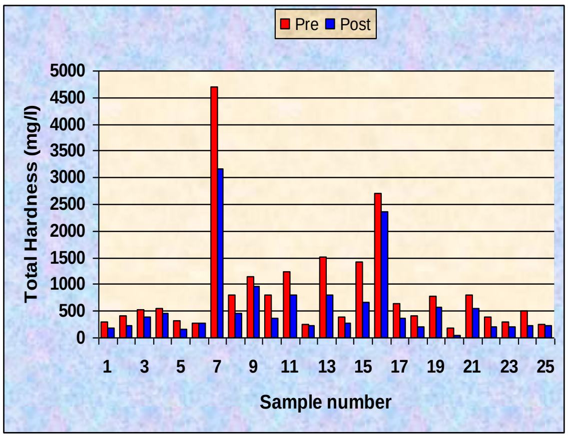

Fig.3 -Total Hardness

The total hardness is relatively high in all samples due to the presence of calcium, magnesium, chloride and sulphate ions. Based on TH, groundwater exceeding the limit of 300 mg/l is considered very hard (8) and this may be due to industrial effluent discharge and solid waste leachate. Very hard groundwater is dominant in the aquifers of the study area. Water hardness has no known adverse effects; however, some evidence indicates its role in heart diseases and hardness of 150-300 mg/l and above may cause kidney problems, kidney stone formation, stomach disorders and urinary concretions as it causes unpleasant taste (9). Hard water is unsuitable for

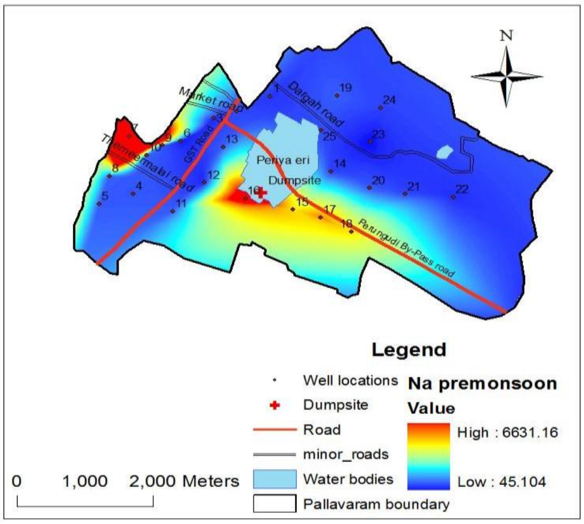

Fig.4 - Spatial Variation of Na

domestic use. The high value of TH in water supply pipes causes corrosion. Among the cations, sodium (Na^+) is the most dominant in water. Na^+ concentrations of more than 50 mg/l make the water unsuitable for domestic purpose. High concentrations of Na^+ and Ca^{2+} in the groundwater are attributed to cation exchange among minerals and pollutants from effluent. Sodium chloride and sodium sulphide is one of the major chemical used in the tanning industry used during liming process. The concentration of sodium in the study area is ranges between 89 to 6292 mg/l in premonsoon and 89 to 4410mg/l in postmonsoon. The iso-concentration map as shown in sodium is shown in Fig.4. The groundwater in lake and industrial area has a high concentration of sodium (>200 mg/l). Higher concentration of sodium ion in drinking water may cause heart problems. Excess amount of sodium ion in groundwater normally affects the palability of water. As sodium chloride is the major chemicals used by the tanneries, the concentration of chloride is high in the groundwater. The dominant anion in the groundwater of the study area is the chloride ion.

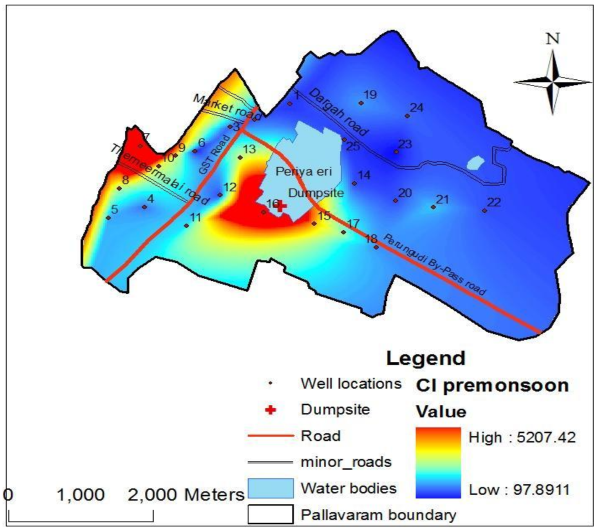

Fig.5 - Spatial Variation of Cl

The Cl ion was never preponderant in these waters with very high mineral contents and the high concentrations were always combined with high Na and Ca levels giving the water of mixed calcium-sodium-chloride type. Chloride is an anion found in variable amount in groundwater. The high chloride in groundwater may probably be come from the raw material used for the processing of the leather. The spatial variation map shown in fig. 5. The value of chloride (Cl^-) for the groundwater samples is ranged from 127 to 6747 mg/l for premonsoon and in postmonsoon is 62 to 3970 mg/l. The values are high in and around the periyari residential area and also in those where tanneries are located. Most of the groundwater samples show above the acceptable limit (250 mg/l) as per (10). Because of improper drainage systems the industrial wastes enters into the groundwater systems and contaminate the fresh groundwater. It produces salty taste at 250 to 500 mg/l also, chloride remains in the wastewater resulting from deliming, pickling and tanning processes (11). Chloride imparts a salty taste and some times higher consumption causes for the development of essential hypertension, risk for stroke, osteroporosis, renal stones and asthma in human beings. Increase of chloride kevel in water is injurious to people suffering due to heart and kidney diseases (12). Mostly, the chlorides are found in the form of sodium chloride in the groundwater.

The possible source of sulphate (SO_4^{2-}) from the tanneries is from ammonium sulphate, sodium sulphate, chrome sulphates which are among the chief chemicals used in the tanning process and leaching of the effluents into the groundwater could have led to contamination of groundwater. The factories let out effluents into the open drain and this made suffocating smell also emitted from it sporadically. The sulphate concentration ranges from 36.5 to 611 mg/l in premonsoon and 16.9 to 456 mg/l in postmonsoon. The sulphate ion is one of the important anions present in natural water which produces catharsis, dehydration and gastrointestinal irritation effect upon human beings when it is present in excess of 150 mg/l. In the study area the SO_4^{2-} concentration are exceed the permissible limit of 200 mg/l (10).

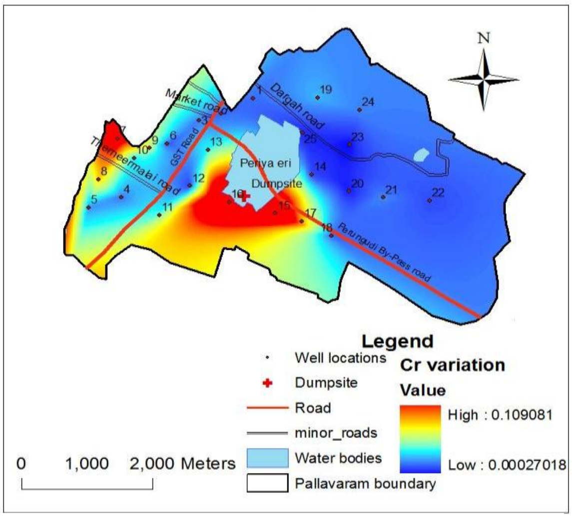

Fig.6 - Spatial Variation of Cr^{6+}

Tannery effluents are mostly characterized by high organic loading, salinity, chromium (13). Chromium (Cr^{6+}) is used to convert the skin to leather, being in excess for improve the quality of the tanning process (14). Chromium which is present in effluents is usually in the toxic trivalent form. But, when this effluent is discharged into the soil, due to varying environmental conditions, Cr (III) is oxidized to toxic hexavalent form which seldom remains as Cr (15). The Cr is toxic and even in small concentrations cause disease in humans and animals. The Cr^{6+} is highly toxic to human even in low concentration. The concentration of $Cr6^{+}$ in the area is ranges between 0 to 0.109 mg/l as shown in fig. 6. The permissible limit of Cr^{6+} in groundwater is 0.05 mg/l. Cr^{6+} is an essential nutrient in man because it helps the body in the use of sugar, protein and fats but at low concentrations. However, intake excess cause various health effects such as skin rashes, stomach upset, ulcer, respiratory problems, alteration of genetic material, weakness of immune system, kidney damage, liver damage and can lead to death (16). The distribution of EC, Na^{+}, Cl^{-} and Cr^{6+} values are shown in the Figure 2, 4, 5 and 6 respectively. It is seen that samples of low ionic concentration are observed in the northern part of the study area and very high concentration observed in the southern part of the study area. Hence Na^{+}, Cl, Cr^{6+}, Ca^{2+}, Mg^{2+} and SO_4^{2-} contaminated the groundwater of Pallavaram is attributed to industrial effluent and solid waste dumping. This clearly shows the interference of human activities on geochemical process of groundwater quality.

4.2 Durov Plot

The use of interpretive diagrams for an understanding the nature and origin of different water qualities is well established. In this case, the Durov diagram (17) can be used to indicate the relationship between different points in the systems and potential drivers

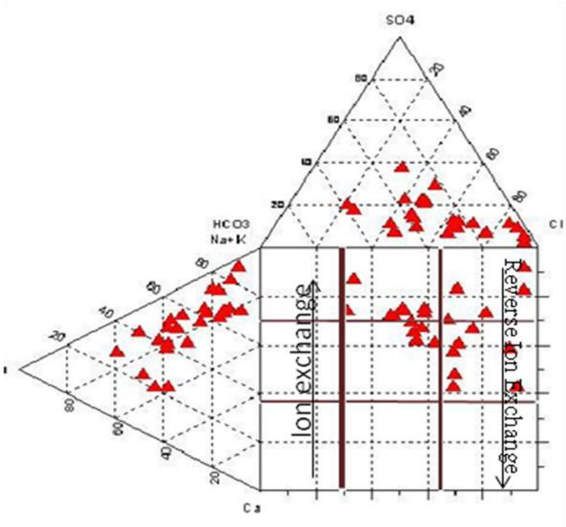

Fig. 7 - Durov plot

on the quality. From this plot, certain relationships can be inferred. The Durov diagram shows in fig.7 that the quality of groundwater found from the groundwater samples in the study area. It is also important that the water in the latter boreholes have a stronger Na-Cl nature than the Calcium or magnesium or Sulphate domination of waters elsewhere, which may indicate that some acidity is neutralized by Sodium and Chloride in the subsurface both during premonsoon and postmonsoon season.

4.3 Groundwater Types

The groundwater is further evaluated to determine its facies by plotting the percentages of select chemical constituents in Piper diagram (18). The plots for premonsoon and post monsoon season indicated scattered distribution with minor or negligible variations in their chemical characteristics between two seasons (Fig.8).

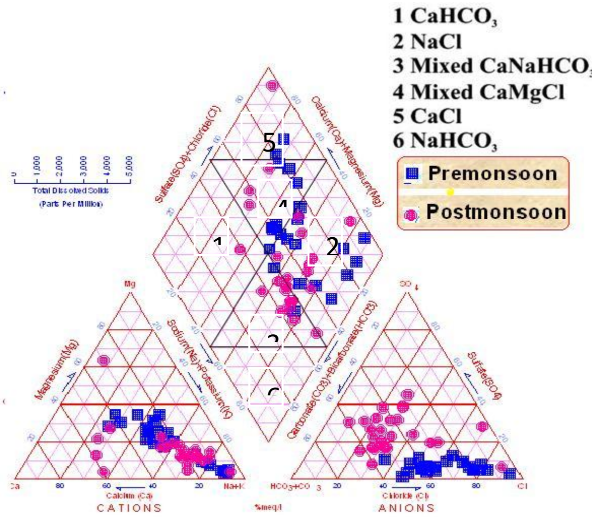

Fig. 8 - Piper Plot

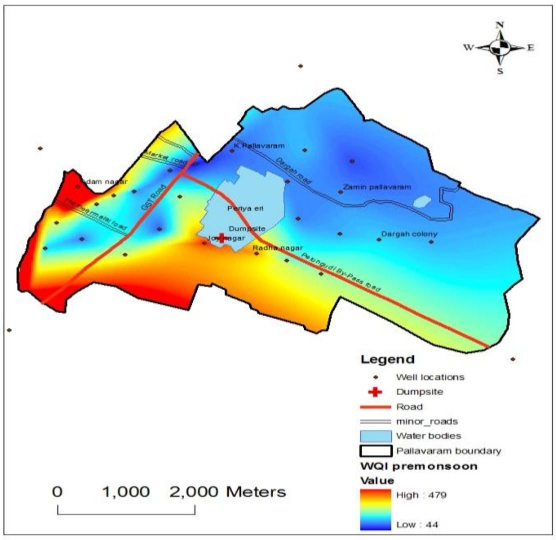

Fig. 9- Water Quality Index

The groundwater samples of Pallavaram show significant changes in percentage of samples belonging to different water types, but for the variations in the number of samples, the groundwater in general was of Na–Cl, Ca-Na–HCO_3 and Ca–Mg-Cl types. Few samples (one in each) fall in two or three sub-blocks of the diagram i.e., Ca-HCO_3 and Ca-Cl types. It can be inferred from plots that the groundwater was of mixed type with multiple processes involved in its evolution. The piper plots further strengthen that the fact that the anthropogenic factors predominate the mineralogy process taking place in the study area in determining the water chemistry. The plots also suggest that among cations Na followed by Ca and Mg and in anions Cl dominate the ionic concentration in groundwater. Aquifer parameters seem to play minimum role in the determination of the water facies as no seasonal changes were evident. Change in storage of aquifer between seasons did not influence the major geochemical makeup of groundwater quality of the area due to continuous dumping of waste. The major source of all these ions is sodium chloride and sodium sulphate, which are used in large amounts in the tanneries during different stages of the process for bringing out fine quality leather from skins and hides. The groundwater type of the study area was distinguished and grouped by their position on a Piper diagram. In most of the sample Na-Cl dominated facies was clearly observed.

4.4 Water Quality Index

The WQI has been calculated to evaluate the suitability of groundwater quality for drinking purposes (19). WQI is defined as a technique of rating that provides the composite influence of individual water quality parameters on the overall quality of water for human consumption (20).

The water quality index (WQI) gives overall quality of water on the basis of large number of physio-chemical characteristics of water. Fig.9 shows spatial distribution of WQI in the study area both during Premonsoon and Postmonsoon season. It varies from 44 to 479 mg/l during premonsoon season and from 35 to 345 mg/l during postmonsoon season. High value of WQI has been observed in the industrial zones of Adam Nagar and near the dumpsite regions both during premonsoon and postmonsoon period. Low values of WQI were observed in the northern part of the study area including Zamin Pallavaram and old Pallavaram. Almost all the water samples in the southern part show either bad quality or unfit for drinking purpose while in the northern part during postmonsoon some samples were of excellent quality due to dilution but most of the samples comes in the range of good quality both during premonsoon and postmonsoon period. The monsoonal dilution does not serve much towards the quality improvement in the industrially contaminated or solid waste dumping site contaminated area and so the WQI of these regions does not change much with season.

4.5 Problems Identified in the Area

Pallavaram, now a part of Chennai Metropolitan Development Authority (CMDA) and less than 3 kilometers from south of Chennai Airport, has cluster of 152 tanneries predominantly processing raw to wet blue. Though it was away from residential areas when the tanneries came up nearly a century ago, now it has become a part of the city with a substantial population residing there. This industrialization combined with urbanization had resulted in the contamination of groundwater. This was further worsened with the

Fig. 10- A view of dumpsite in Periya eri lake.

bifurcation and conversion of 'Periya eri' lake into landfill site threatens the ground water resource in that area (Fig.10). The Pallavaram 'periya eri' (big lake) was once a sprawling water body, spread over nearly 200 acres. Today, all that remains of it is a small patch on the lines of a pond on one side and a hillock of garbage on the other side. The portion of the lake to southern side of the road has completely been covered by garbage. On the northern side of the road, the discharge of sewage from commercial establishments and homes and also effluents from some of the leather manufacturing units in Nagalkeni has affected the water. The quality of the water has deteriorated considerably and ground water in several thousand homes around the lake has gone from bad to worse over the years. Due to the contamination of groundwater with heavy metals and ions from the industrial and dumping site affect the health and socio-economic conditions of the people residing in the area. Tanneries used high percentage of ammonium sulphate, sodium chloride, sodium sulphate. Chromium sulphate and leaching of the effluents into the ground could have led to contamination of groundwater is the reason for the high concentration of major ions and chromium in groundwater. The groundwater is unfit for drinking and domestic purpose. In fact, the solid waste that is decomposes more easily, attracts insects and causes diseases. Organic waste can be decomposed and then used as fertilizer. Due to contaminated groundwater the dependency on other sources was increased which again is burdening the people particularly those of the low income people with respect to inadequacy and interrupted supply. The residents in this area are fully dependents on Palar water supplied by municipality for drinking and other purpose.

IV. Conclusion

The groundwater in most of the area is highly polluted and in few sites it was moderately polluted in comparison with drinking water standards. Groundwater types of Ca-Mg-Cl type along with Na-Cl domination both the seasons occurring in the region. TH falls under hard to very hard categories and is not suitable for drinking purposes. Further, the water quality index found for the region suggest that the WQI consists of mixed value and less variation with respect to pre and post monsoon season showing profound human interference. It was found that the quality of groundwater in this area has deteriorated mainly due to extensive use of chemical in the tannery industries and solid waste dumpsite seriously affected due to the combined effect of industrialization and urbanization. As there is no natural or other possible reason for high concentration of these pollutants, it can be concluded that tannery effluent and landfill site has significant impact on groundwater quality in the area. It is high time that the suffering of the people had to be relieved by taking proper policy action. Further, the effluent from industries is let out lethargically and hence, the stagnating water percolating into the groundwater medium and thereby polluting the groundwater resources.

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