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SPATIAL DISTRIBUTION OF GROUND WATER QUALITY IN THE VICINITY OF VELLALORE LANDFILL SITE, COIMBATORE, TAMIL NADU, INDIA

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Abstract

The research work is proposed to compute the water quality index (WQI) of the ground water in the proximity around the vellalore landfill site in order to understand the quality of water for public utilization, other purposes. The manuscript handles with the evaluation of the impact of environmental characteristics on the water quality. Water quality index, specifies the water quality in terms of index numerals and provides a convenient portrayal of overall quality of water quality management. In this research water quality was set on various physico – chemical characteristics like pH, electrical conductivity (EC), total suspended solids (TSS), total dissolved solids (TDS), turbidity, total hardness (TH), total alkalinity (TA), calcium (Ca), magnesium (Mg), chloride (Cl), nitrate (No_3), sulphate (So_4), dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD) and fecal coli forms. The existance of contaminants in groundwater specifically near the landfill sites reminds its quality and thus provides the corresponding aquifer undependable for domestic water supply and other uses. Geographical Information System (GIS) sets out as substantial software that clears the way for multi – map integrations. In this investigation, ground water quality is assessed and presented in a GIS based water quality mapping.

Keywords: Ground water, Water quality index, GIS application, Vellalore landfill site

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Introduction

Water is the essential component in the biosphere. It is a natural asset and a vital resource. The origin of water sources are basically through precipitation which later forms into different features like stream, lakes, ground water and so on. Other than for consumption, the other necessity includes farming, rearing, power generation, etc. But due to the influence of industrialization, urbanization, the nature of the water has become diminished (Tyagi *et al*; 2013). The condition of water can be examined by means of assessing its various physical, chemical and microbiological elements, which are considered risky to human life if they are higher than the prescribed level (BIS 10500; 2012, WHO guidelines; 2012 and ICMR;1975). The significance of water quality for human utilization is represented through water quality index (WQI), which is considered as an ideal option to depict the condition of the water.

WQI presents the unique numerical figure that conveys the overall water quality criteria. The main goal of water quality index is to transform complex information into user friendly. All in all, water quality records are consolidated information from numerous water quality criteria statistically that rates the strength of water with a number (Yogendra and Puttaiah, 2008). In recent days Geographical Information System plays a major role in environmental monitoring and management. Ground water evaluation is based on laboratory study but the emergence of satellite technology and geographical information system (GIS) has made it very simple to consolidate various databases (Suryawanshi and Khan, 2014). This study elaborates about the implementation of GIS in depicting the ground water quality in the vicinity of Vellalore landfill site in Coimbatore.

MATERIAL AND METHODS

Study Area

Vellalore (10° 58’ 02” N 77° 01’ 40” E) is a panchayat township in Coimbatore area in the Indian territory of Tamil Nadu.

It is situated at 13 km east from the core of the city Coimbatore, on the southern bank of the river Noyyal. Vellalore is a western suburb of Coimbatore. As reported by Indian statistics in 2001, Vellalore had occupants of 17, 294 with equal representation of male and female. Vellalore is administered by a town panchayat comprising of 15 wards.

Since years, solid waste and sewage discharge of Coimbatore city is being dumped in Vellalore yard (Figure 1). It is accounted for huge amounts of trash getting accumulated each day from all nook and corner of the corporation limit of Coimbatore and arrives directly to Vellalore. Therefore around 5 lacs MT of waste has been collected in the yard throughout the year. Because of laborious task in isolation of waste and composting thereof each one of these wastes were shaping into greater and greater trash mountains on this huge land.

Figure 1: Aerial view of Vellalore Dump Yard cum Landfill Site

Sample Collection

The water specimens from the vicinity of the Vellalore dump yard were gathered and scrutinized for 16 physico chemical parameters by following the ideal methods. The sampling stations are represented in table 1 and illustrated in figure 2. The parameters like pH, electrical conductivity (EC) and dissolved oxygen (DO) were observed at the testing destinations and other parameters like total suspended solids (TSS), total dissolved solids (TDS), turbidity, total hardness (TH), total alkalinity (TA), calcium (Ca), magnesium (Mg), chloride (Cl), Nitrate (No_3), sulphate (So_4), biological oxygen demand (BOD), chemical oxygen demand (COD) and fecal coli form were investigated in the research facility according to the standard techniques of APHA (1995).

Table 1: Geographic Coordinates of different Sampling Spots (in decimal degrees)

Sample	Latitude	Longitude
1	10.96811	77.00645
2	10.95276	76.99218
3	10.94919	77.00206
4	10.95409	76.99336
5	10.95900	76.99725
6	10.97703	77.02163
7	10.97688	76.98606
8	10.94018	76.98338
9	10.93789	77.01962
10	10.95458	77.02214

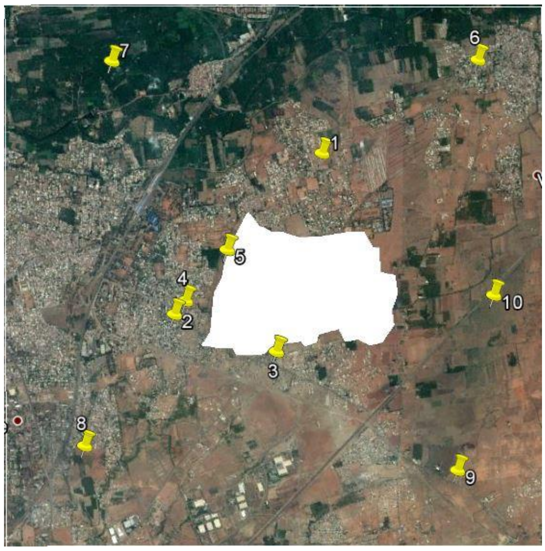

Figure 2: Ground water sampling placements in the vicinity of landfill site

In this examination for figuring of water quality, sixteen vital parameters were picked. The WQI has been computed by utilizing the benchmark of drinking water quality prescribed by the World Health Organization (WHO), Bureau of Indian Standards (BIS), and Indian Council for Medical Research (ICMR). The weighted arithmetic index technique (Brown *et al*; 1972) has been utilized in the estimation of WQI of the water body.

Weighted arithmetic water quality index technique characterized the water quality as per the level of clarity by utilizing the most frequently measured water quality variables. The strategy has been generally utilized by different researches (Chauhan and Singh, 2010; Chowdhury *et al*., 2012; Rao *et al*., 2010; Balan *et al*., 2012) and the count of WQI was made by utilizing the calculation mentioned underneath (Brown *et al*; 1972)

$$WQI = \sum QiWi / \sum Wi$$

The quality rating scale (Q_i) for each variable is computed by using this expression:

$$Qi = 100[(Vi - Vo / Si - Vo)]$$

Where, V_i is estimated concentration of i^{th} parameter in the analysed water

V_0 is the absolute value of the variable in pure water = 0 (excluding pH = 7.0 and DO = 14.6 mg/l)

S_i is approved standard value of i^{th} parameter

The unit weight (W_i) for each water quality variable is calculated using the formula stated below

$$Wi = K/Si$$

Where K = proportionality constant and can also be computed by using the expression

$$K = \frac{1}{\sum(1/Si)}$$

Water quality index (WQI) and stature of water quality and drinking water standards approved by different organization are depicted in table 2 and 3 respectively.

Table 2: Water Quality Status as per Weighted Arithmetic Water Quality Index Method

WQI Value	Status of Water Quality	Grading
0 - 25	Excellent	A
26 - 50	Good	B
51 -75	Poor	C
75 - 100	Very Poor	D
Above 100	Unsuitable	E

Table 3: Drinking Water Standards recommending Agencies

S.No	Parameter	Unit	Standard	Recommended Agency
1	pH	-	6.5 – 8.5	ICMR/BIS
2	EC	µS/cm	300	ICMR
3	TSS	mg/L	500	WHO
4	TDS	mg/L	500	ICMR/BIS
5	Turbidity	NTU	5	WHO
6	Total Hardness	mg/L	300	ICMR/BIS
7	Total Alkalinity	mg/L	120	ICMR
8	Calcium	mg/L	75	ICMR/BIS
9	Magnesium	mg/L	30	ICMR/BIS
10	Chloride	mg/L	250	ICMR
11	Nitrate	mg/L	45	ICMR/BIS
12	Sulphate	mg/L	150	ICMR/BIS
13	DO	mg/L	5	ICMR/BIS
14	BOD	mg/L	5	ICMR
15	COD	mg/L	10	WHO
16	Fecal Coliform	CFU/100 ml	0	ICMR/BIS/WHO

GIS process system turned out to be very convenient for intensifying the precision. The position of the sample sites were collected by using GPS and later imported into Arc GIS software. Arc GIS 10.1 is the software used in this study.

Spatial interpolation is a technique by using points with investigated values to approximate values at other points. Spatial interpolation is a method of transforming point data to surface data. The IDW (Inverse Distance Weightage) was implemented to observe the spatial dispersal of ground water quality (Subramani *et al*., 2012). Steps are represented in figure 3.

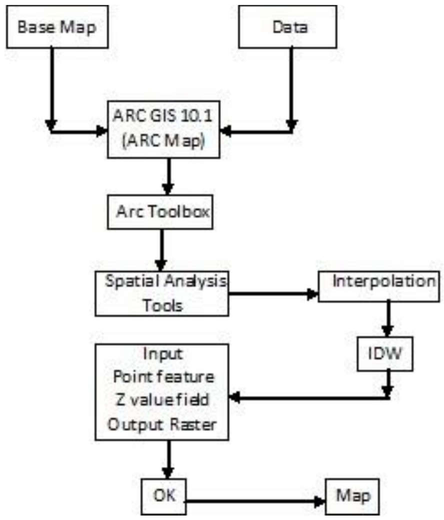

Figure 3: Systematic Illustration For Generating Spatial Distribution Map

With the help of Arc GIS 10.1, the spatial interpolation was carried out on the basis of attribute values like pH, EC, TSS, TDS, Turbidity, TH, TA, Ca, Mg, Cl, No_3, So_4, DO, BOD, COD and Fecal Coli Form. Spatial analysis was performed and map was generated (excluding nitrate and dissolved oxygen as there is less deviations). Spatial variation of ground water quality parameter was consolidated and the combined ground water quality map were produced.

RESULTS AND DISCUSSION

In order to evaluate the ground water quality 10 specimen sites were identified in the vicinity of Vellalore landfill site and water samples have been collected. The crucial water quality parameters such as pH, EC, TSS, TDS, Turbidity, TH, TA, Ca, Mg, Cl, No_3, So_4, DO, BOD, COD and Fecal Coli form have been calculated. The pilot data of 10 locations for each parameter have been transformed into spatial variation using GIS.

pH

Typically, pH is the estimate of acidity or alkalinity of water. It is one of the most significant water quality parameter with the ideal pH required often being in the range of 6.5 – 8.5. The pH values of ground water samples collected ranged between 6.90 to 7.80 which showcases that all the water samples are marginally basic in nature and capable for methanogenic bacteria.. Corresponding outcomes were acquired by Tränkler *et al*.(2005) who revealed that leachate samples had a marginally high pH and maintained in the range of 7.0–8.0 during the process which denotes the brief acidic period and rapid methanogenic period.Spatial distribution of pH concentration is shown in Figure 4. The values of pH displayed that all of the samples showed pH value within the maximum acceptable limit.

Table 4:Physico chemical parameters of ground water samples during the year 2016 - 2017
(All values except pH, Electrical Conductivity, Turbidity and Fecal Coliform are in mg/L)

Parameter/Samples	1	2	3	4	5	6	7	8	9	10
pH	6.96	7.52	7.44	7.55	7.54	6.94	7.35	7.57	7.02	7.78
EC	2801.25	1450.00	2257.50	1607.50	3430.00	2193.25	1519.25	1811.25	1743.25	2470.00
TSS	0.00	5.00	4.00	4.00	9.00	1.50	0.00	0.00	0.00	2.00
TDS	1657.00	885.00	1338.50	992.00	207.25	1310.56	908.14	1082.26	1041.49	1101.83
Turbidity	0.05	0.20	0.18	0.20	1.75	0.20	0.00	0.00	0.00	0.33
Total Hardness	1017.50	437.50	605.00	597.50	1277.50	660.00	452.50	500.00	555.00	675.00
Total Alkalinity	307.50	250.00	335.00	332.50	550.00	412.50	255.00	225.00	342.50	465.00
Calcium	243.39	111.17	125.21	131.20	288.48	143.29	100.20	117.23	119.24	149.30
Magnesium	99.63	38.88	71.08	65.61	135.47	73.51	49.21	53.46	62.57	73.51
Chloride	725.00	282.50	412.50	272.50	750.00	507.50	280.00	317.50	375.00	505.00
Nitrate	0.52	0.65	0.58	0.82	1.10	0.78	0.38	0.47	0.24	0.90
Sulphate	166.19	158.58	164.06	113.40	257.16	211.33	147.67	178.63	186.67	241.19
DO	0.75	0.63	0.50	0.80	0.78	0.58	0.05	0.28	0.00	0.20
BOD	24.25	15.75	14.00	13.50	30.25	5.75	0.00	5.00	0.00	6.00
COD	94.00	60.00	45.00	49.00	110.00	15.00	0.00	5.00	0.00	15.00
Fecal Coliform	4	2	2	2	4	2	2	2	2	2
WQI	260.25	175.48	158.58	157.89	318.51	93.16	46.42	73.73	49.40	96.56

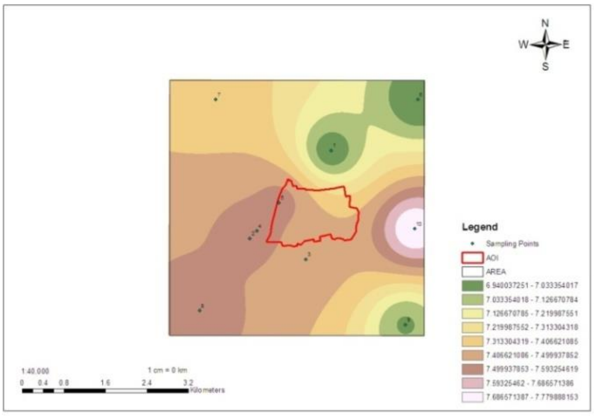

Figure 4: Spatial Distribution of pH

Electrical Conductivity

The significance of EC is its estimate of salinity, which affects the taste. Thus EC has a notable influence on determining the potability of water. Conductivity is used as a sign of the plenty of dissolved inorganic species or total concentration of ions (Banar *et al.*, 2006). The calculation of electrical conductivity is exactly associated with the concentration of ionized substances in water and may also be associated with complication due to excessive hardness and/or other mineral contamination. The conductivity values in the ground water samples varied between 1400 to 3450 µS/cm, as depicted in Figure 5. These high conductivity values achived in the underground water specimens near the landfill is an evidence of its effect on the water quality (Mor S. *et al.*, 2006).

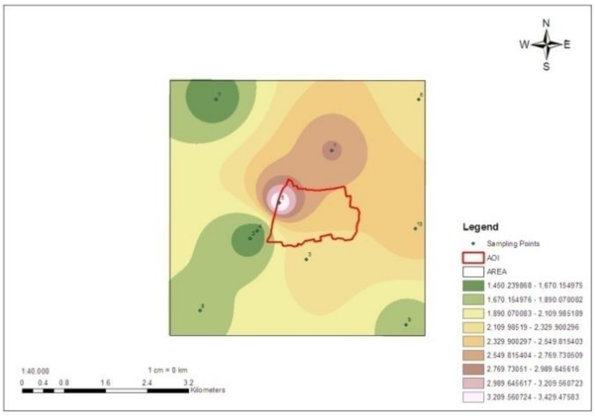

Figure 5: Spatial Distribution of Electrical Conductivity

Total Suspended Solids

In collected water specimens total suspended solids ranged between 0 to 9 mg/l may be due to fewer amounts of suspended particles. The total suspended solids are made up of carbonates, bicarbonates, chlorides, phosphates, nitrates of Ca, Mg, Na, K, Mn, organic matter, salt and other particles. The impression due to the presence of total suspended solids is the turbidity due to silt and organic matter (Bundela *et al*., 2012). Spatial distribution is depicted in figure 6.

Total Dissolved Solids

To determine the suitability of ground water for any purposes, it is important to grade the ground water depending upon their hydro chemical characteristics based on their TDS value. TDS comprises mainly of inorganic salts and dissolved organics. TDS is one of the parameters taken into consideration for licensing discharge of landfill leachate in many countries such as the U.K. (Koshy *et al.*, 2008). The amount of TDS reflects the extent of mineralization and a higher TDS concentration can change the physical and chemical characteristics of the receiving water (Al-Yaqout and Hamoda, 2003). The increase in salinity due to increase in TDS concentration also increases toxicity by changing the ionic composition of water.The TDS value ranges from 200 to 1660 mg/l. From the spatial distribution map it is shown that maximum area of the TDS values were above 500 mg/l as in Figure 7.

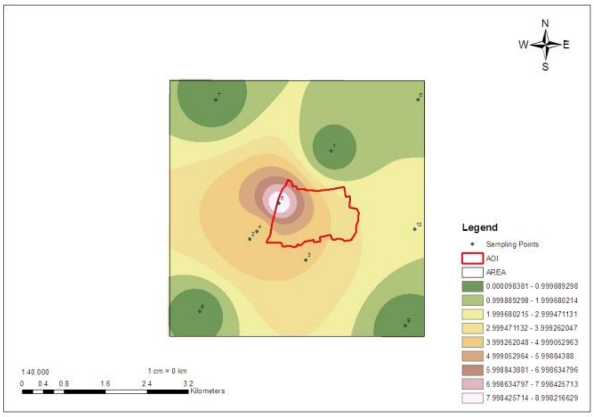

Figure 6: Spatial Distribution of Total Suspended Solids

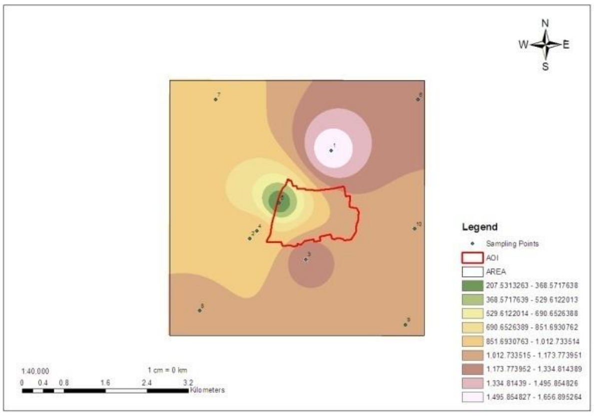

Figure 7: Spatial Distribution of Total Dissolved Solids

Turbidity

Turbidity indicates the mixture of fine scattering of suspended solids. Even microorganisms provide turbid nature for the water samples. The turbidity of all samples (0 – 2 NTU) was within the bench mark prescribed by the standard recommended agency (5 NTU). The spatial distribution is depicted in Figure 8. Hypothetically, turbidity must be less than 1 NTU because higher values denotes health risks owing to bacterial contamination Adams, 2001). Hence the water in the study area is potable as specified by WHO.

Total Hardness

The hardness of water is due to the existence of salts such as carbonates and bicarbonates, chloride and sulphates of calcium, magnesium incorporated in it. The categorization of ground water based on total hardness illustrates that all specimens are more than 300 mg/l as per ICMR and BIS, lying between the range of 430 to 1280 mg/l. The hardness of water samples may be due to discharge of Ca and Mg ions into the groundwater (Srinivasamoorthy *et al.*, 2009). Boiling of water at boiling temperature will naturally eliminate temporary hardness while addition of carbonates and sulphates will eradicate permanent hardness. Spatial variation map of total hardness is shown below in figure 9.

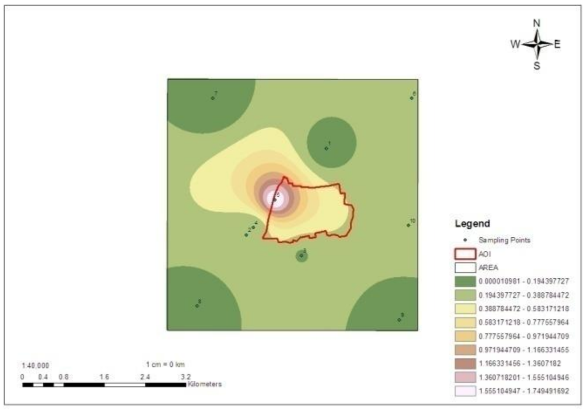

Figure 8: Spatial Distribution of Turbidity

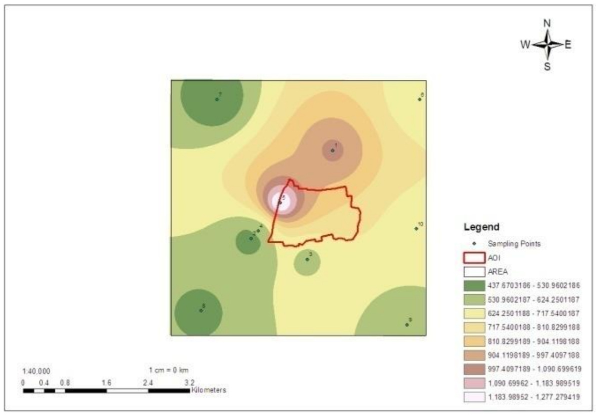

Figure 9: Spatial Distribution of Total Hardness

Total Alkalinity

The existence of carbonates, bicarbonates and hydroxides are the primary motive of alkalinity in natural water. The total alkalinity values of landfill leachate are often found to be obviously higher than natural waters. This is because of the biochemical disintegration and dissolution process which happens within a landfill and disposal site. The biodegradation activity of organic matter within the waste mass produce a notable amount of bicarbonate, which indicates dissolved carbon dioxide and is also the vital element of alkalinity (Naveen *et al.,* 2014). The total alkalinity value in ground water lies between 220 to 550 mg/l. The high alkalinity observed in this study reveals the level of biodegradation process taking place within the disposal site. Ground water samples with higher concentration of total alkalinity could have consequnces on human well-being due to the reduced solubility of many heavy metals. It might generate awful stench in the water sample that is objectionable for many users. The taste turns out to be unpalatable beyond the fixed limit (Raju, 2012). The illustrated image (figure 10) shows the distribution of total alkalinity.

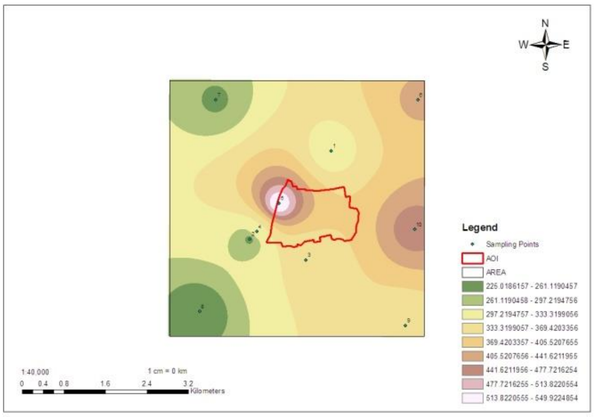

Figure 10: Spatial Distribution of Total Alkalinity

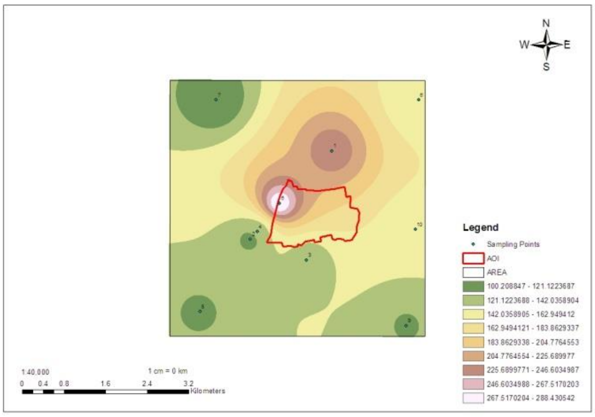

Figure 11: Spatial Distribution of Calcium

Calcium

The excessive concentration of calcium were estimated in all the specimens when compared with approved benchmarks (75 mg/l), starting from 100 to 290 mg/l signifies danger of hardness in water. The indication is that forming lather with soap will be a major challenge for domestic users (Akinbile, 2006). Figure 11 represents the spatial distribution of calcium content. Calcium is ranked third in metal composition of Earth's crust. Excess of calcium ions get accumulated in kidneys resulting in uneasiness during excretion (Senthamil Selvan Kuppusamy et al., 2015).

Magnesium

The benchmark setup by the science agencies like ICMR and BIS for magnesium is 30 mg/l. But the collected water specimens from the vicinity of Vellalore landfill site crossed the limit ranging from 38 to 136 mg/l as in Figure 12. According to Panno et al. (2006); Uma (2004); dumpsite, landfill leachate, and sewage are indeed known sources of chloride, bicarbonate, calcium, and magnesium loading into native groundwater. The surplus concentration of magnesium may be due to the seepage of leachate into ground water. High concentration of Mg leads to clearing of the bowel system of human being (Senthamil Selvan Kuppusamy et al., 2015)..

Chloride

The chloride ion concentration differs from 270 to 750 mg/l exceeding the benchmark of 250 mg/l as per ICMR. The maximum chloride content was found to in sample 5 as it was collected from the landfill area.. Department of National Health and Welfare, Canada [1978] reported that chloride in ground water may result from both natural and anthropogenic sources such as run-off containing salts, the use of inorganic fertilizers, landfill leachates, septic tank effluents, animal feeds, industrial effluents, irrigation drainage and seawater intrusion in coastal areas. Chloride is not harmful to human at low concentration but could alter the taste of water at concentration above 250 mg/l (Hauser., 2001).Figure 13 depicts the spatial distribution of chloride in the vicinity of Vellalore dump yard.

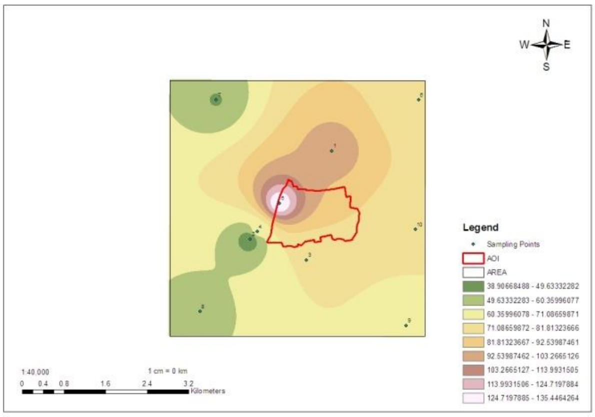

Figure 12: Spatial Distribution of Magnesium

Nitrate

Nitrates may seep into the drinking water by means of runoff from compost, discharge from septic tanks, sewage and weathering of natural sediments. As derived from the table, all the water samples accept to ICMR and BIS guidelines. Above this limit, infants below the age of six months who drink water containing nitrate in excess of the MCL could become seriously ill, and if untreated, may die (EPA, 2015). The water specimens measured in terms of nitrate gave nominal values which showcases the presence of nitrate in trace quantity (Mendoza *et al.*, 2017). The nitrate value showed less variation ranging from 0.20 to 1.10 mg/l which is well within the permissible limit. As such the ground water does not constitute any danger to human health.

Sulphate

Sulphate was considered unsafe as the ground water sample exceeded the saturation point of sulphate (150 mg/l) as per ICMR and BIS. The specimen ranged from 110 to 260 mg/l, which may have originated from oxidation of iron sulphide present in the dump (Asuma and Aweto, 2013). The distribution pattern is clearly illustrated in Figure 14. High quantity of sulphate in water is hazarous as it causes dehydration and diarrhea in children than adults (Longe and Balogun, 2010).

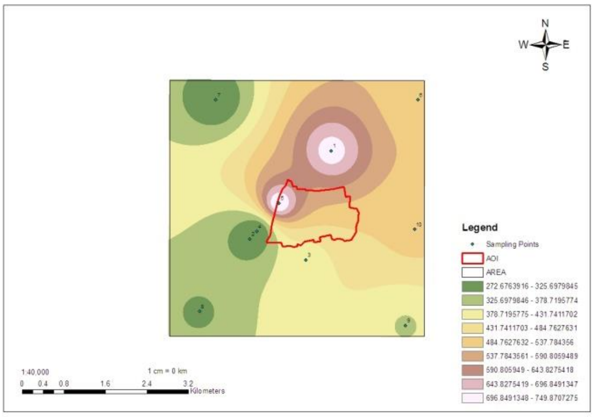

Figure 13: Spatial Distribution of Chloride

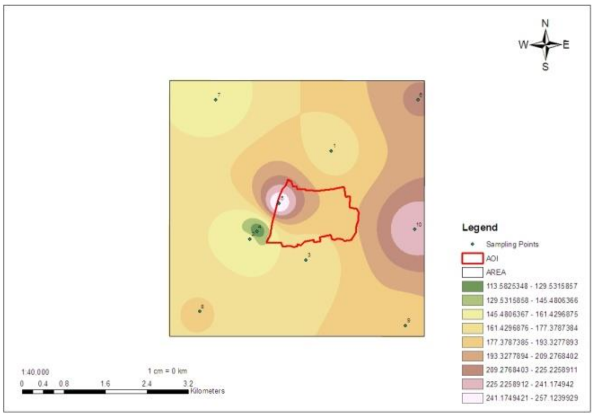

Figure 14: Spatial Distribution of Sulphate

Dissolved Oxygen

Dissolved oxygen is one of the salient characteristics of ground water quality. Dissolved oxygen present in drinking water adds taste and it is highly fluctuating factor in water. It is of great importance to all living organisms and is considered to be the lone factor which to a greater extent reveals the nature of aquatic system even when information on other physical, chemical and biological parameter is not available (Adoni *et al.,* 1985). The DO values showed less variation ranging from 0 to 1 which are well within the acceptable limit by ICMR and BIS (5 mg/l). Insufficiency of dissolved oxygen comes as consequence of anaerobic decomposition of organic waste (Council Directive, 1975).

Biological Oxygen Demand

The BOD level in the ground water specimens ranged from 0 to 30.50 mg/l with maximum samples crossing the prescribed level (5 mg/l as per ICMR). The BOD value points out the organic content in the sewage. From the above BOD values, it is distinct that the ground water is polluted by the land fill leachates. Normally no BOD or BOD less than 1.0 mg/l is considered for consumption (Raju, 2012). The leachate originated from the landfill site transfers abundant amount of organic matters, perculating though the soil and entering into the ground water showing the BOD value. Figure 15 shows the spatial distribution of demand of oxygen by biological organisms.

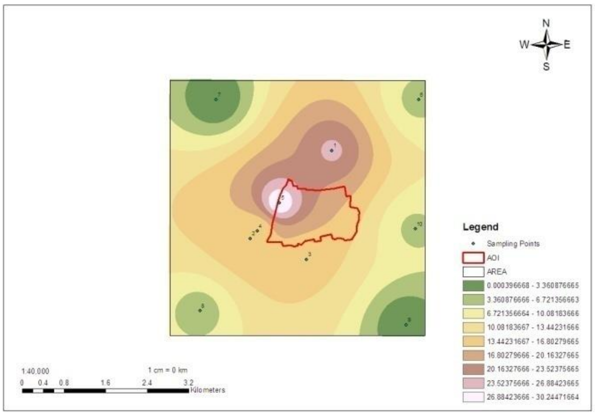

Figure 15: Spatial Distribution of Biological Oxygen Demand

Chemical Oxygen Demand

The concentration level of oxygen for deterioration of organic matter and oxidation of inorganic chemicals ranged from 0 to 110 mg/l. Out of 10 samples 7 samples showed higher concentration (> 10 mg/l) as per WHO indicating the presence of oxidizable organic materials that had leached from domestic refuse in landfill site. Figure 16 depicts the spatial distribution of chemical oxygen demand. In the cuurent research the COD values are very high compared to BOD values. It clearly represents that the ground water is contaminated with more of non biodegradable chemical contaminants (Raju, 2012).

Fecal Coli forms

Fecal coliform is a sub-group of coliform bacteria, which live and multiply in the abdomen of humans and other warm-blooded animals. Most fecal coliform bacteria are gentle, but a few can cause moderate to critical diseases. Most waterborne pathogens are fed into drinking-water supplies through human or animal faeces, which do not reproduce in water and begin infection in the digestive tract following ingestion (WHO (b), 2006). Populace of bacteria (fecal coli form) in ground water has become a crucial issue in India, owing to infestation of pure drinking water. The values are represented in CFU/100 ml and are found to differ from 2 – 4 per 100 ml and distributed as in Figure 17. In all the locations, faecal coliform exceeds the standards for drinking water (BIS, 2012; WHO (a), 2006; WHO (b), 2006) which put the groundwater unsuitable for drinking but due to lack of other drinking water sources people are forced to drink the water.

Water Quality Index

From the Figure 18 produced, the higher and lower WQI has been found to be 318.5 and 46.42 which fall under "unsuitable" and "good" status respectively. In the current research it is discovered that ground water (sample 5) adjacent to the landfill site qualify in the "unsuitable" grade with highest value recorded from the samples collected. The optimal limit of contamination level of groundwater quality due to leachate percolation depends upon a number of factors like chemical composition of leachate, precipitation, depth and distance of the well from the pollution source (the landfill site in the present case) From the evaluation, it is obvious that the concentrations of contaminants were found to be high in the sampling locations which are closer to the landfills. Interestingly, the groundwater contamination declines rapidly with increase in the distance of sampling points from the landfill site. The seepage of leachate was further found to become gradual. However, the concentrations of few contaminants did not exceed drinking water standard even then the groundwater quality potray a notable risk to public health. (Nagarajan et al.,2012). With the administration of GIS in portraying the water quality in the surrounding area of Vellalore landfill site the distribution improvising the quality of water from landfill site as moving from the centre.

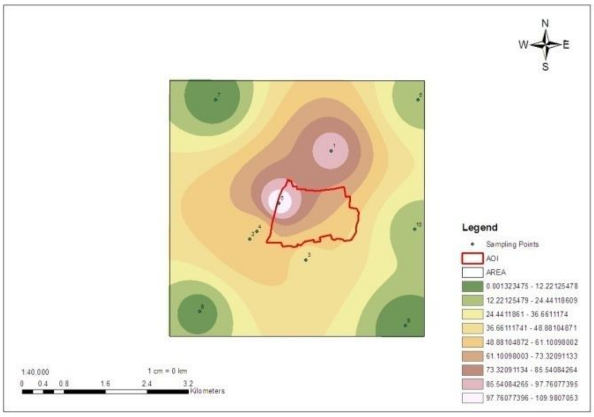

Figure 16: Spatial Distribution of Chemical Oxygen Demand

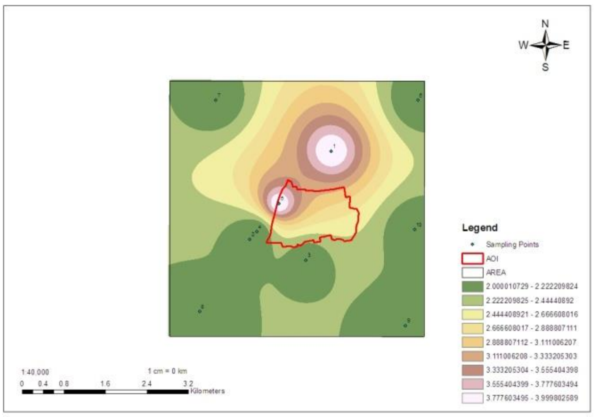

Figure 17: Spatial Distribution of Fecal Coli forms

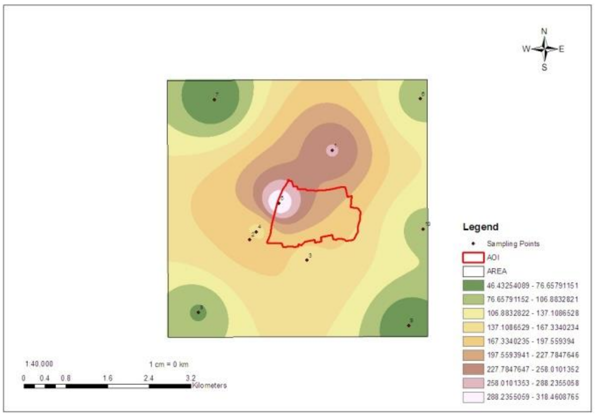

Figure 18: Overall Water Quality Condition

Conclusions

Spatial distribution in ground water quality in the area on interest was evaluated successfully by using Geographical Information System (GIS). It is summarized from the investigation of ground water from nearby area of landfill site because of discarding solid waste and other anthropogenic activities, leachate seepage in past, and also by the expanding environmental pollution. Because of city development, the ground water quality in Vellalore area has been worsened near the landfill site. As there is no natural or other viable cause for high concentration of these pollutants, it can be finalised that the leachate has remarkable influence on groundwater quality in the area near to the landfill site. Strictly speaking one should ignore the groundwater situated in proximity of the waste disposing site. If this is inevitable, deeper drilling and periodic investigation of water samples are beneficial. According to weighted arithmetic water quality index drinking water from the research territory is suitable for drinking water after treatment. The results achieved in this research and the spatial database displayed in GIS, shows that the same approach can be applied for deciding, observing and controlling ground water quality and its populace for wider areas.

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