

FORTRAN ALGORITHM FOR MONITORING LEACHATES AND INTERPRETING PHYSICO-CHEMICAL DATA OF CONTAMINANTS IN GROUND WATER

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ABSTRACT

A FORTRAN 90 algorithm was developed to interpret leachate geochemical data of polluted ground water in Lagos, based on 19 selected physico-chemical parameters adopted by the United States Geological and Environmental Survey Agency in compliance with the World Health Organization (WHO) prescribed standards for safe water consumption. By applying the Fortran program, the portability of leachates contaminated water were ascertained in compliance with WHO requirements.

1. INTRODUCTION

Through percolation in landfills and sanitary sites, ground water becomes polluted. Various leachate parameters are recommended by International standard safety regulations for safe water assessment. In ascertaining the safety of water supply system for human consumption, elaborate analyses of water samples are conducted based on assessment of certain leachate parameters. In compliance with above demands, water samples from boreholes in Lagos State (on coastal aquifer of South Western Nigeria) were analysed.

Nineteen leachate parameters were examined as prescribed by the United States Geological and Environmental Survey Agency and in compliance with standard levels or optimum criteria set by the World Health Organization for ensuring safe water. Common methods of water quality analysis include Physical, Chemical and Gravimetric analyses. However, a Fortran 90 computer program was developed to monitor and interpret geochemical data of 19 leachate parameters of borehole water samples from Lagos.

Since ground water pollution is borne out of flow, the fundamental laws that govern fluid flow were also discussed. Variable density flow classifies flow pattern influenced by density difference in the fluid [1]. Variable flow analysis is associated not only with density alone, but with parameters that affect or change the fluid density, such as temperature, concentration (salinity) or both factors. Ground water is characterized by the prevailing geophysical and surface conditions, porosity, permeability, transmissivity and conductivity of the layered soil structure.

Lagos has annual population increase

of 3 % in recent times [2], accompanied by high demand for portable water, but shortage in portable water has created over dependence on borehole water by the inhabitants.

Over 10 million gallons of water are extracted per day from the multi-layer aquifers existing in the area [3]. However, most of the boreholes were abandoned due to salt water intrusion into the marine aquifer and portable water supply in the coastal belt of Lagos has become a major problem.

Saline intrusion into coastal aquifers constitutes the commonest pollutant in fresh water [4]. Salt water intrusion is the movement of ocean water into fresh ground water, causing contamination of ground water by salt. The phenomenon is a natural process occurring by density difference between salt and fresh water, which can be aggravated by human activities. The relationship between fresh water and sea water pressures is described by the Ghyben-Herzberg principle, based on density differences between the interfaces, such that for each metre above sea level, the fresh water head (depth to the sea water) is 40 times the amount below the sea level.

2. FIELD STUDIES

2.1. Layered Soil Structure in Lagos

The sub-surface geology of Lagos is constituted mainly by sandy-clay formation as shown in Table 1, which prevents saline water intrusion in the overlying fresh water zone, and therefore devoid of any significant contamination. Distinct zones of saline water contamination delineated consist of the near surface (0 - 30 m) and deeper sub-surface (60 - 100 m).

Table 1. Lithologies obtained from Lagos borehole sites.

Lithology from borehole	Depth (m)
Unconsolidated dry sand	0 – 2.7
Wet sand	2.7 – 5.1
Clayey-sand	5.1 – 12.0
Sandy-clay	12.0 – 36.7
Peat	> 36.7

2.2. Groundwater Data

The field work involved collection of water samples from selected boreholes for geochemical analysis. Samples were collected in plastic bottles, refrigerated and analyzed within 24 h. The plastic and glass wares utilized were pre-washed with detergent water solution, rinsed with tap water, soaked for 48 h in 50 % HNO₃, rinsed thoroughly with distilled de-ionized water, and finally, air-dried in dust free environment. The cations were analyzed by Atomic Absorption Spectrometer and the anions by Colorimetric method using Ultraviolet Spectrometer, while the Total dissolved solids (TDS) were analyzed by Gravimetric method [5, 6].

The physical parameters determined were temperature, TDS, conductivity, odour and colour. The geochemical parameters consisted of pH, cations of Ca²⁺, Mn²⁺, Fe²⁺, Mg²⁺, Al³⁺, Cu²⁺, Na⁺, Ag⁺, Zn²⁺, and anions of F⁻, Cl⁻, SO₄²⁻, NO₃⁻, PO₄²⁻. The presence and concentrations of Ca²⁺, Mn²⁺, Fe²⁺, Mg²⁺, Al³⁺ are responsible for varying degree of hardness of water samples.

3. CONTAMINANT TRANSPORT

3.1. Equations of Fluid Flow

The governing equations for variable density flow consist of continuity equation of flow, momentum and contaminant transport, which are linked to the equations of bulk fluid density and hydrodynamic dispersion.

The linearized equation of bulk fluid density under isothermal conditions in terms of hydraulic head is [7 - 11],

$$\rho = \rho_0(1 + \lambda_h(h - h_0)) + \lambda_c C \quad (1)$$

where h is hydraulic head, h_0 is reference hydraulic head, ρ is fluid density, ρ_0 is reference fluid density, λ_h represents coefficient of compressibility of the fluid associated with change of hydraulic head at constant mass fraction of the solute, λ_c is coefficient of expansivity resulting from change of mass concentration of the

solute at constant hydraulic head, and C is relative concentration.

Equation (1) has also been formulated as an exponential function to give an approximate relationship between density and concentration [10]. Another equation for describing a linear empirical relationship between the bulk fluid density and concentration or mass fraction was developed on assumption that when two liquids are well-mixed, the masses or volumes of respective components are additives [12 - 14].

3.2. Continuity Equation of Flow

The macroscopic mass balance equation of the fluid averaged over a representative elementary volume in a porous medium is [15],

$$\frac{\partial(S\rho)}{\partial t} + \Phi\rho\vec{v} = \rho Q \quad (2)$$

where S is saturation ratio, Φ is porosity, t is time, \vec{v} is fluid velocity, ρ is density and ρQ is source term of the fluid mass in an aquifer

If the flow is related to the driving forces, the flow equation can be written in terms of the equivalent fresh water hydraulic head, defined as [7, 16];

$$h = \frac{P}{\rho_0 g} + z \quad (3)$$

where P is pore pressure, ρ_0 is reference density of the fluid, z is positive directional coordinate defined in the negative gravitational acceleration (g) direction.

3.3. Momentum Balance Equation

In terms of hydraulic head, the variable density fluid flow in a porous medium is expressed as [17, 18];

$$Q = \Phi v = - \frac{k\rho_0 g \vec{e}}{\mu(h/((\rho - \rho_0)/\rho_0))} \quad (4)$$

where k is the permeability of porous medium, Φ is porosity of the medium, v is fluid velocity and \vec{e} is unit vector in the gravitational direction. The dispersion tensor is written as [19];

$$D = \gamma D_m \delta + \alpha_T \sigma + (\alpha_L - \alpha_T)(v_i v_j) v \quad (5)$$

where γ is tortuosity, D_m is coefficient of molecular diffusion, δ is kroenecker delta, σ is characteristic value of macroscopic velocity, α_T is transverse dispersivity, α_L is longitudinal dispersivity, and v_i and v_j are the respective velocities in the i and j directions.

3.4. Solute Transport Equation

The solute transport with a source is

governed by the advection-dispersion equation [20, 21];

$$\frac{\partial(\Phi C)}{\partial t} + (\Phi v C) - (\Phi \bar{D} C) = Q_c \quad (6)$$

where Q_c is source term of the solute in terms of mass concentration, Φ is porosity and \bar{D} is the hydraulic dispersion tensor.

3.5. Advection-Reaction-Dispersion Equation

Conservation of mass for a chemical entity transported yields the advection-reaction-dispersion equation [22 - 25]

$$\partial C / \partial t = -v \partial C / \partial x + D_L \partial^2 C / \partial x^2 - \partial q / \partial t \quad (7)$$

where C is concentration in water (mol/kg), t is time (s), v is pore water flow velocity (m/s), x is distance (m) and ∂q is concentration in the solid space (mol/kg). D_L is hydrodynamic dispersion coefficient (m²/s), expressed as

$$D_L = D_e + \alpha_L v \quad (8)$$

where D_e is effective diffusion coefficient, α_L is dispersivity (m). In eqn. (7), $-v \partial C / \partial x$ represents advective transport, $D_L \partial^2 C / \partial x^2$ represents dispersive transport and $\partial q / \partial t$ is change in concentration in the solid phase due to reactions (q has same unit as C). With the assumption that v and D_L are equal for all solute species, C can be the total dissolved concentration for any element, including all redox species.

3.6. Ghyben-Herzberg Approximation

The approximate location of a stationary sharp interface between fresh and sea water is determined by the Ghyben-Herzberg equation [18, 26],

$$h_g = \delta h = \rho_f / (\rho_s - \rho_f) h_s \quad (9)$$

where $\delta = \rho_f / (\rho_s - \rho_f) = 40$. Using standard values of density of fresh water ($\rho_f = 1000$ kg/m³) and sea water ($\rho_s = 1025$ kg/m³), $h_s = 40 h_f$, where h_s is depth of the stationary interface below sea level and h_f is fresh water table above sea level.

By Dupuit's assumption for a shallow phreatic coastal aquifer, the ground water flow is essentially in the horizontal direction. If the aquifer is uniformly recharged from above by an amount N [L/s] and discharged laterally by the amount Q_o , the application of continuity equation gives [19],

$$Q_o + N_x = -k(h + h_f) \partial h_f / \partial x = k(1 + \delta) h_f \partial h_f / \partial x \quad (10)$$

where $h(x) = \delta h_f(x)$ and $\delta = \rho_f / (\rho_s - \rho_f)$.

4. DEVELOPMENT OF ALGORITHM

4.1. Mathematical Formulation

Darcy law $Q = q / A_t = -K \Delta h$ relates Q (specific discharge or volume of fluid per unit cross-sectional area per unit time, m³/m²/s, or Darcy velocity), h (dimensionless driving force of ground water flow per unit weight of ground water) and constant K , neglecting hydraulic conductivity, directional dependence or anisotropy of K .

Darcy equation is a simplified form of the general law of fluid flow in a porous medium, which also applies to variable-density fluids [27],

$$q / A_t = -k / \mu (P - \rho g) \quad (11)$$

where k is intrinsic permeability of porous medium (m²), μ is dynamic viscosity of ground water (kg/m/s), P is fluid pressure (kg/m/s²), ρ (kg/m³) is fluid density, and g is gravitational acceleration (m/s²). Equation (11) illustrates the two basic driving forces for ground water flow, namely, the force per unit volume of ground water due to spatial difference in pure water pressure (P) and the gravity force per unit volume experienced by the ground water (ρg).

The solute transport with a source is governed by advection-dispersion eqn. (6), and neglecting expansivity resulting from change of mass concentration λ_c , eqn. (6) was rewritten as,

$$\partial C / \partial t + (1 - \Phi) \lambda_h C \partial h / \partial t + \Phi v \cdot \text{div} C - \text{div}(\Phi \bar{D} \text{grad} C) + C Q_p = Q_c \quad (12)$$

4.2. Flow Chart

The flow chart for developing the algorithm is illustrated in Fig. 1.

4.3. Structured Program

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REAL:: Physical and Chemical Parameters
REAL:: TMP,CLR,CDTY,ODR,TDS,PH,NA,CA,MG,FE,MN,AL,
L,CU,ZN,AG,CHL,SUL,PHS,FL,NTR
NA:=0 : CA:=0 : MG:=0 : FE:=0 : MN:=0 : AL:=0 : CU:=0 :
ZN:=0 : AG:=0 : CHL:=0 : SUL:=0 :
PHS:=0 : FL:=0 : NTR:=0 : Z:=0 : A:=0 : C:=0
READ DATA OF THE PHYSICAL PARAMETERS:
TMP,CLR,CDTY,ODR,TDS
PRINT*
WRITE' INTERPRETATION & TEST RESULT
WRITE'PHYSICAL PARAMETERS
IF PHYSICAL <=PRESCRIBED MAXIMUM THEN
PHYSICAL PARAMETER IS WITHIN STANDARD
IF PHYSICAL PARAMETER >=PRESCRIBED MAXIMUM
THEN
PHYSICAL PARAMETER EXCEEDS STANDARD
WRITE'
    
```

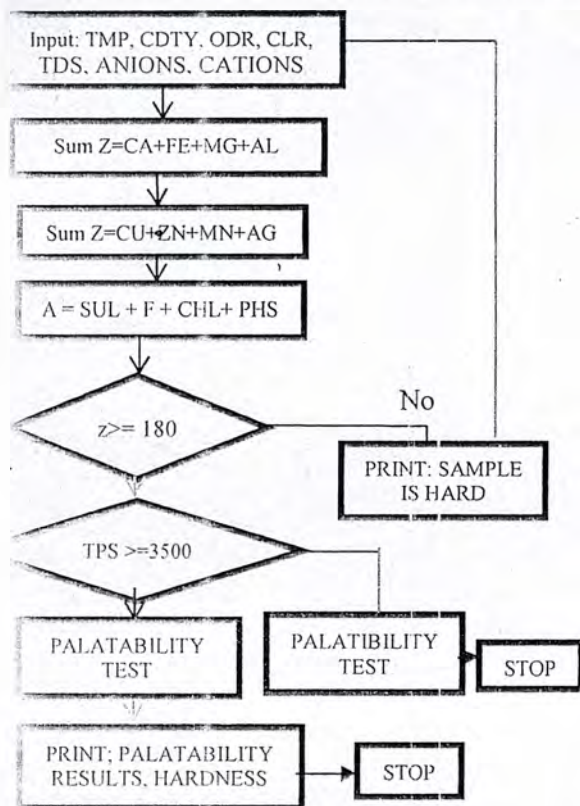



Fig. 1. Algorithm Flow Chart

```

    IF
    D DATA OF THE CHEMICAL PARAMETERS:THE
    'ATIONS & ANIONS
    FE
    FE 'CHEMICAL PARAMETERS'
    IT*,
    D :PH
    FE'PH
    I>=6.5.AND,PH<=8.5 THEN
    FE'PH WITHIN STANDARD'
    IF PH>=8.5 THEN
    FE'PH WITHIN STANDARD"
    FE 'PH EXCEEDS STANDARD-ALKALINE'
    FE
    FE 'PH BELOW STANDARD-VERY ACIDIC'
    IF
    IT*
    FE
    FE
    IT*, 'INPUT THE
    IONS:NA,CA,MG,FE,MN,AL,CU,ZN,AG'
    D:NA,CA,MG,FE,MN,AL,CU,ZN,AG
    IT*
    IT*, 'INPUT THE ANIONS: CHL,SUL,PHS,FL,NTR'
    D:CHL,SUL,PHS,FL,NTR
    IT*
    FE ANION CONTENT
    ION<=PRESCRIBED MAXIMUM THEN
    N IS WITHIN STANDARD
    IF ANION>=PRESCRIBED STANDARD
    FE ANION CONTENT EXCEEDS STANDARD

    FE ANION CONTENT EQUALS STANDARD
    IF
    FE
    A+MG+FE+MN+AL
    N+CU+NA+AG
    IL,+NTR+SUL+PHS+FL
  
```

```

    WRITE ' SUM OF ANIONS',A
    WRITE
    WRITE ' SUM OF CATIONS',C
    WRITE
    WRITE
    WRITE HARDNESS TEST RESULT
    IF Z>PERCENTAGE HARDNESS LEVEL THEN
    WRITE ' SAMPLE IS HARD'
    ELSE IF Z<HARDNESS LEVEL THEN
    WRITE SAMPLE IS SOFT
    END IF
    WRITE 'SALINITY & PALATABILITY TEST RESULT'
    IF TDS>MAXIMUM PRESCRIBED LEVEL THEN
    WRITE SAMPLE IS BRINY AND UNPALATABLE
    ELSE IF TDS>=MINIMUM DESIRABLE LEVEL &
    TDS<=MAXIMUM PRESCRIBED LEVEL THEN SAMPLE
    IS VERY SALINE AND UNPALATABLE
    ELSE IF TDS<=MINIMUM DESIRABLE LEVEL
    WRITE SAMPLE IS NON-SALINE AND EXCELLENTLY
    PALATABLE
    END IF
    STOP
    END program
  
```

4.4. Program Implementation

Appendix 1 shows the program designed based on Fortran 90 Microsoft Developer compiler for the interpretation of geochemical data from leachate polluted groundwater focused on 19 physico-chemical key parameters (mainly inorganic) in accordance with WHO standard [28, 29] and the United State Geological Survey and Environmental Protection Agency Standard [30] on secondary drinking water regulations.

The input parameters consisted of geochemical and physical parameters which were substituted in the program. The geochemical parameters were the cations and anions, while the physical parameters were pH, TDS, conductivity, temperature and colour. The hardness, salinity levels were determined and the portability deduced following compliance or non compliance with the standard values.

5. RESULTS

5.1. Field Data

The sampling data of physical and geochemical parameters is shown in Table 2. WHO standard reference range of drinking water quality values are shown in Table 3, while the values of percentage hardness of water samples are indicated in Table 4.

The hydro-chemical analysis showed that the temperature ranged from 25.8 - 29.5 °C with a mean value of 27.3 °C, and the pH ranged from 6.0 - 8.4 with a mean value of 7.24. The mean value of electrical conductivity was 320.6 µS/cm in a range of 17.9 -1511.

Table 2. Hydro-chemical analysis of bore-hole water samples from Lagos State.

S/N	Temp (°C)	pH	Ca ²⁺ (mg/L)	Mg ²⁺ (mg/L)	Fe ²⁺ (mg/L)	EC (µS/cm)	TDS (mg/L)	Cl ⁻ (mg/L)	SO ₄ ²⁻ (mg/L)	PO ₄ ³⁻ (mg/L)	Zn ²⁺ (mg/L)	Cu ²⁺ (mg/L)	Mn ²⁺ (mg/L)	Al ³⁺ (mg/L)	Na ⁺ (mg/L)	Ag ⁺ (mg/L)	F ⁻ (mg/L)	NO ₃ ⁻ (mg/L)
1	26.70	6.30	32.60	17.90	0.01	31.90	14.70	32.10	0.00	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.05	1.00
2	26.60	6.40	46.10	15.30	0.09	63.20	29.70	33.40	2.00	0.00	0.02	0.01	0.01	0.00	0.00	0.00	0.01	1.20
3	29.50	6.50	8.80	9.70	0.00	198.80	95.10	62.20	1.00	0.00	0.01	0.01	0.01	0.00	0.10	0.00	0.08	1.00
4	26.80	6.00	32.10	19.00	0.20	437.00	211.00	107.00	13.00	0.40	0.05	0.03	0.03	0.00	0.20	0.00	0.17	1.50
5	26.90	7.10	45.90	37.60	0.20	410.00	198.00	117.00	8.00	0.42	0.04	0.03	0.03	0.00	0.30	0.00	0.19	1.30
6	27.80	7.00	109.00	97.00	0.30	617.00	300.00	156.00	44.00	0.48	0.07	0.04	0.04	0.00	0.30	0.00	0.12	1.40
7	27.50	7.50	189.00	108.00	0.30	1511.00	751.00	493.00	72.00	0.67	0.08	0.06	0.06	0.00	0.80	0.00	0.18	1.10
8	28.20	8.00	117.00	104.00	0.30	779.00	380.00	265.00	60.00	0.54	0.06	0.04	0.04	0.00	0.40	0.00	0.13	1.90
9	27.00	7.70	10.30	12.10	0.00	117.10	53.30	45.90	11.00	0.01	0.02	0.01	0.01	0.00	0.00	0.00	0.05	1.20
10	26.90	7.50	15.70	21.20	0.10	213.40	102.00	73.40	1.00	0.03	0.02	0.00	0.00	0.00	0.10	0.00	0.03	1.20
11	27.20	6.80	43.70	33.50	0.20	101.10	56.10	43.10	0.60	0.01	0.01	0.00	0.00	0.00	0.10	0.00	0.01	1.10
12	28.10	7.40	67.00	81.30	0.30	210.10	89.40	67.80	1.00	0.02	0.02	0.01	0.01	0.00	0.20	0.00	0.01	1.20
13	26.20	6.90	23.00	36.30	0.20	72.90	32.80	21.50	0.20	0.00	0.01	0.02	0.00	0.00	0.00	0.00	0.01	1.00
14	25.90	7.00	16.10	24.00	0.10	34.20	16.90	19.80	1.20	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00
15	28.10	7.60	3.90	2.70	0.00	22.20	11.30	16.80	1.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	26.40	8.20	39.30	32.10	0.10	17.90	8.70	11.70	1.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	27.70	8.10	11.50	23.10	0.00	21.00	11.20	12.80	1.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10
18	28.20	6.70	10.00	91.20	0.30	397.30	316.00	259.00	22.00	0.40	0.06	0.08	0.00	0.00	0.05	0.00	0.05	1.50
19	29.00	7.20	87.40	72.10	0.30	762.10	380.00	245.00	1.50	0.50	0.07	0.07	0.00	0.00	0.05	0.00	0.02	1.40
20	25.80	7.80	23.20	20.00	0.10	23.60	11.10	23.10	2.00	0.10	0.00	0.01	0.00	0.00	0.00	0.00	0.02	0.40
21	27.30	8.40	12.20	9.90	0.00	19.90	8.10	10.30	1.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.10
Mean	27.32	7.24	49.25	41.33	0.15	302.70	146.49	100.76	11.71	0.17	0.03	0.05	0.02	0.00	0.02	0.00	0.01	0.17
Std dev.	0.94	0.63	44.06	24.84	0.12	1717.70	213.96	145.99	21.19	0.20	0.03	0.07	0.02	0.00	0.01	0.00	0.06	0.64

Table 2. Physical-chemical parameters & standards for drinking water [28, 29].

Physical/Chemical Parameter	Highest desirable level	Maximum permissible level
pH	7-8.5	6.5-9.2
Colour (°H)	5	50
Total dissolved solids (TDS)	500	1500
Total hardness (mg/L)	100	500
Na ⁺ (mg/L)	-	-
K ⁺ (mg/L)	-	-
Ca ²⁺ (mg/L)	75	200
Mg ²⁺ (mg/L)	50	150
Fe ²⁺ (mg/L)	0.1	1.0
PO ₄ ³⁻ (mg/L)	-	-
NO ₃ ⁻ (mg/L)	45	50
SO ₄ ²⁻ (mg/L)	200	400
Cl ⁻ (mg/L)	250	600
CO ₃ ²⁻ (mg/L)	-	120
HCO ₃ ⁻ (mg/L)	-	-

Table 3. Percentage hardness of water samples [31]

Hardness (Ca ²⁺ , Mg ²⁺ , CO ₃ ²⁻)	Water classification
0-75	Soft
75-150	Moderately hard
150-300	Hard
>300	Very hard

$\mu\text{S/cm}$. The TDS had a mean value of 146.5 mg/L in a range from 10.3 – 493 mg/L, while WHO recommended value of 500 mg/L is desirable, and 1,500 mg/L as maximum permissible level for drinking water.

For chloride, WHO desirable level is 250 mg/L. About 4 out of a total of 21 water samples collected from Lagos, Cl^- concentration level exceeded WHO value. The samples from locations 7, 8, 18 and 19 gave Cl^- values of 493, 265, 259 and 245 mg/L respectively, high values of electrical conductivity (implying low resistivity), and high values for TDS. The high values of Cl^- concentration, TDS and electrical conductivity indicated dissolved substances in the ground water.

Sample 21 had the lowest electrical conductivity, chloride concentration, and TDS values, indicating low conductivity and high resistivity values. Based on the field data and WHO prescribed values, the saline content of sample 21 was minimal.

The analysis indicated that nearly 20 % of the boreholes were very saline, but about 80 % of the borehole water samples were in congruity with the prescribed international standards, making the waters portable.

The palatability assessment of the water samples was based on physico-chemical analysis and reference to prescribed standards and regulation. Using the Fortran-90 software, the hardness level of the water samples and palatability were also ascertained.

5.2. Computer Program Output

The programs gave the hardness level, and palatability of groundwater samples with leachates. The program ran well and turned out the output in a run time of less than 1 minute (Appendix II).

6. DISCUSSION

Water picks up and mixes with diverse range of contaminants or pollutants while flowing through the layered soil. Since the flow of water and contaminant pollution are connected, transport equations for fluid flow were discussed for leachate transport. Saline intrusion to fresh water aquifers affects water resources. The water leachates were identified as contaminants of broad ranges.

The drive for safe water has been the main justification for the research. Nineteen

leachate water contaminants of parameters prescribed by the United States Geological and Environmental Survey Agencies [18] were analysed in line with WHO recommended standard of acceptable parameters for leachate polluted water. Comparison of the water quality values with WHO recommended values indicated the water samples from the boreholes complied with the prescribed desirable standard level. The Fortran Program indicated that the samples were relatively portable.

7. CONCLUSIONS

Nineteen leachate water contaminants complying with World Health Organization standards were analyzed from samples of borehole water collected in Lagos. The geochemical analysis revealed the presence and amount of chemical parameters present in the samples. The physical parameters were also determined. The portability of the borehole water samples was determined based on data of the physico-chemical analysis and comparison with WHO standard values. The Fortran software developed aided in determining the saline and hardness level of the borehole water samples, as salt water intrusion has been a challenging problem in Lagos. With the aid of the Fortran Software, the portability of the water samples was also ascertained.

8. REFERENCES

1. Holzbecher E.O., *Modelling density driven-flow in porous media: Principles numerics software*, Springer-Berlin, 1998.
2. UNDP., *Country evaluation: Assessment of developmental results of Nigeria*, 2006.
3. Longe E.O., Malomo S. and Olorunniwo M.A., Hydrogeology of Lagos Metropolis, *Afri J. Earth Sci.*, Vol 6, No.2, 1987, pp. 163 - 170.
4. Batayneh A.T., Saline water and delineating their interface configuration: a case study of the eastern dead sea coastal aquifers, *Jordan Hydrogeol. J.*, Vol. 14, 2006, pp. 1277 - 1283.
5. Offodile M.E., *An Approach to Ground Water Study and Development in Nigeria*, Mecon Services Ltd., Jos, Nigeria, 1991.
6. Ofoma A.E., Onwuka O.S. and Egbu O.C., Groundwater quality in Lekwesi Umuchieze area, South-Western Nigeria, *The Pacific J. Sci. Technol.*, Vol 6, 2005, pp. 170 - 176.
7. Frind E.O., Simulation of long-term transient density-dependent transport in ground water, *Advances in Water Resources.*, Vol. 5, 1982, pp. 73 - 78.

8. Huyakorn P.S., Andersen P.F., Mercer J.W. and Whitw H.O., Salt water intrusion in aquifers, Development and Testing of a 3-Dimensional Finite Element Model, *Water Resources Research*, Vol. 23, 1987, pp. 293 - 312.
9. Oteri A.U., Electric log interpretation for the evaluation of salt water intrusion in the eastern Niger-Delta, *Hydrol. Sciences J.*, Vol. 33, Nos 1 - 2, 1988, pp. 19 - 30.
10. Kolditz O., Benchmarks for numerical simulations, in *Diersch H.J. FEFLOW User Manual Release*, Vol 5, Nos.1-5, 1994.
11. Kolditz O., Ratke R., Diersch H.J.G. and Zielke W., Coupled ground water flow and transport: Verification of variable density flow and transport models, *Advances in Water Resources*, Vol. 21, 1998, pp. 27 - 46.
12. Herbert A.W. and Jackson C.P., Lever coupled ground water-flow and solute transport with fluid density strongly dependent upon concentration, *Water Resources Research*, Vol.24, 1988, pp. 1781 - 1795.
13. Oldenburg C.M. and Pruess K., Dispersive transport dynamics in a strongly coupled ground water-brine flow system: Reply; *Water Resources Research*, Vol. 31, 1995, pp. 289 - 302.
14. Oldenburg C.M and Pruess K., 1996. Dispersive transport dynamics in a strongly coupled ground water-brine flow system: Reply; *Water Resources Research*, Vol. 32, 1996, pp. 3411 - 3412.
15. Bredehoeft J.D. and Pinder G.F., Mass transport in flowing groundwater, *Water Resources*, Vol.9, 1973, pp. 194-210.
16. Frind E.O., Solution of the advection-dispersion equation with free exit boundary, *Numerical Methods for Partial Differential Equations*, Vol. 4, 1988, pp. 301 – 313.
17. Strack O.D.L., Some cases of interface flow towards drains, *J. Enginerg. Maths.*, Vol.6, 1972.
18. Strack O.D.L., Single-Potential solution for regional interface problems in coastal aquifers, *Water Resources*, Vol.12, 1976, pp.1165-1174
19. Bear J., *Hydraulics of Ground Water*, McGraw Hill International Book, New York, 1979.
20. Herbert A.W. and Jackson C.P., Lever coupled ground water-flow and solute transport with fluid density strongly dependent upon concentration, *Water Resources*, Vol.24, 1988, pp.1781-1795.
21. Konikow L.F. and Bredehoeft J.D., Computer Model of Two-Dimensional solute transport and dispersion in groundwater, *USGS Techniques Water Resources Investigations*, Book 7, US Geological Survey, Washington DC, 1978.
22. Scotting R.J., Moser H. and Hassanizadeh S.M., High concentration-gradient dispersion in porous media: Experiments, analysis and approximations, *Advances in Water Resources*, Vol. 22,1999, pp. 665-680.
23. Hassanizadch S.M. and Leijnse A, A non-linear theory of high-concentration gradient dispersion in porous-media, *Advances in water Resources*, Vol.18, 1995, pp. 203-215.
24. Hassanizadeh S.M. and Gay W.G., General conservation equations for multi-phase systems: 2; Mass, momenta, energy, and entropy equations, *Advances in Water Resources*2, Vol. 2,1979b, pp.191-203.
25. Frind E.O., Solution of the advection-dispersion equation with free exit boundary, *Numerical methods for partial differential equations*, Vol. 4,1988, pp. 301-313.
26. Cheng A.H.D, Halhi, Najji A. and Ouazar D., Pumping optimization in salt water intruded coastal aquifers, *Water Resources Research*, Vol. 36, pp. 2155-2165.
27. Bear J., *Dynamics of Fluids in Porous Media*, American Elsevier, New York, 1972.
28. WHO., *Guidelines for drinking water quality*, Report of the First Review, Group Meeting on Inorganics, Geneva,WHO/PEP/91.18, 1991.
29. Office of Technology Assessment, *Protecting the Nation's Groundwater from Contamination*, Washington D.C. OTA-O-233, 1984.
30. United States Geological and Environmental Survey Agencies, *Techniques of water Resources Investigations*, Book 1, US Geological Survey, Washington D.C, 2000.
31. Freeze and Cherry, *Groundwater* Prentice-Hall, 1979.

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APPENDIX I: Fortran 90 Software for interpreting leachate and contaminant levels

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program
!THIS PROGRAM IS DESIGNED IN THE SYNTAX OF THE
FORTRAN 90 MICROSOFT DEVELOPER !COMPILER FOR
THE INTERPRETATION OF GEOCHEMICAL DATA FROM
LEACHATES-POLLUTED !GROUNDWATER WITH MAIN
FOCUS ON NINETEEN !PHYSIO-CHEMICAL PRIORITY
PARAMETERS !(MAINLY INORGANIC) IN ACCORD-
ANCE WITH WHO (1984) STANDARD AND !THE UNITED
STATE GEOLOGICAL SURVEY AND !THE UNITED
STATE ENVIRONMENTAL PROTECTION AGENCY STAN-
DARD (2002) !ION SECONDARY !DRINKING WATER
REGULATION.
!TMP: TEMPERATURE
!CLR: COLOUR
!CDTY: CONDUCTIVITY
!ODR: ODOUR
!TDS: TOTAL DISSOLVED SOLIDS
!PH: HYDROGEN ION CONCENTRATION
    
```


Adetoyinbo & Adewole, Journal of Applied Science and Technology, Vol. 17, Nos. 1 & 2, 2012, pp. 36 – 45

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ICLR: COLOUR
ICDTY: CONDUCTIVITY
IODR: ODOUR
ITDS: TOTAL DISSOLVED SOLIDS
IPH: HYDROGEN ION CONCENTRATION
INA: SODIUM
ICA: CALCIUM
IMG: MAGNESIUM
IFE: IRON
IMN: MANGANESE
IAL: ALUMINIUM
ICU: COPPER
IZN: ZINC
IAG: SILVER
ICHL: CHLORIDE
ISUL: SULPHATE
IPHS: PHOSPHATE
IFL: FLUORIDE
INTR: NITRATE
IZ: SUMMATION OF THE DATA OF THE FIVE
MAJOR CATIONS:CA,MG,FE, MN& AL FOR THE I
HARDNESS TEST
IA: SUMMATION OF ANIONS
IC: SUMMATION OF CATIONS

7 FORMAT(T1,A25,',F9.3,',A20)
10 FORMAT(T1,A160)
17 FORMAT(T1,A35,T1/T1,32('='),1X)

REAL::
TMP,CLR,CDTY,ODR,TDS,PH,NA,CA,MG,FE,MN,AL,CU,Z
N,AG,CHL,PHS,FL,NTR,Z
OPEN (UNIT=1, FILE='RESULTS')

PRINT*, THE INTERPRETATION OF
&GEOCHEMICAL DATA OF NINETEEN INORGANIC
PRIORITY LEACHATES PARAMETERS &IN
GROUNDWATER POLLUTION IN ACCORDANCE WITH
THE UNITED STATE &GEOLOGICAL SURVEY AND THE
ENVIRONMENTAL PROTECTION &AGENCY
STANDARD (2002) AND STRICT COMPLIANCE WITH
WHO STANDARD(1984)ON SECONDARY DRINKING
WATER REGULATION TO &DETERMINE THE LEVEL
OF THE PARAMETERS, HARDNESS, SALINITY AND
PALABILITY &OF UNDERGROUND WATER TEST
SAMPLE.'
PRINT*,'
WRITE(1,7)'DATE:'
WRITE(1,10)
WRITE(1,7)'SAMPLE ID:'

WRITE(1,10)
WRITE(1,7)'SITE/LOCATION:'

WRITE(1,10)
WRITE(1,10)
PRINT*,INSERT THE DATA OF THE PHYSICAL
PARAMETERS:TMP,CLR,CDTY,ODR,TDS'
READ(*,*) TMP,CLR,CDTY,ODR,TDS
PRINT*,'

WRITE(1,17)'INTERPRETATION & TEST RESULT'
WRITE(1,10)
WRITE(1,17)'PHYSICAL PARAMETERS'
WRITE(1,10)

WRITE(1,7)'TEMPERATURE = ',TMP,'°C'
IF(TMP.GE.12.AND.TMP.LE.25.)THEN
WRITE(1,10)'TEMPERATURE WITHIN STANDARD'
ELSEIF (TMP.LT.12)THEN
WRITE(1,10)'TEMPERATURE BELOW
STANDARD.VISCOSITY & IONIZATION MAY INCREASE'
ELSE
WRITE(1,10)'TEMPERATURE EXCEEDS
STANDARD.POSSIBILITIES OF INCREASE IN VAPOUR
& PRESSURE & SOLUBILITY.'
ENDIF
WRITE(1,10)

WRITE(1,7)'COLOUR = ',CLR,'UNIT'
IF(CLR.GT.15.)THEN
WRITE(1,10)'COLOUR EXCEEDS STANDARD'
ELSEIF(CLR.LT.15.)THEN
WRITE(1,10)'COLOUR WITHIN STANDARD'
ELSE
WRITE(1,10)'COLOUR EQUALS STANDARD'
ENDIF
WRITE(1,10)
WRITE(1,7)'CONDUCTIVITY = ',CDTY,'mS/cm'
IF(CDTY.GT.1000)THEN
WRITE(1,10)'CONDUCTIVITY EXCEEDS STANDARD'
ELSEIF(CDTY.LT.1000)THEN
WRITE(1,10)'CONDUCTIVITY WITHIN STANDARD'
ELSE
WRITE(1,10)'CONDUCTIVITY EQUALS STANDARD'
ENDIF
WRITE(1,10)

WRITE(1,7)'ODOUR = ',ODR,'Threshold Number'
IF(ODR.GT.3.)THEN
WRITE(1,10)'ODOUR EXCEEDS STANDARD'
ELSEIF(ODR.LT.3.)THEN
WRITE(1,10)'ODOUR WITHIN STANDARD'
ELSE
WRITE(1,10)'ODOUR EQUALS STANDARD'
ENDIF
WRITE(1,10)

WRITE(1,7)'TOTAL DISSOLVED SOLIDS = ',TDS,'mg/L'
IF(TDS.GT.500.)THEN
WRITE(1,10)'TDS EXCEEDS STANDARD'
ELSEIF(TDS.LT.500.) THEN
WRITE(1,10)'TDS WITHIN STANDARD'
ELSE
WRITE(1,10)'TDS EQUALS STANDARD'
ENDIF
WRITE(1,10)
WRITE(1,10)PRINT*,INSERT THE DATA OF THE
CHEMICAL PARAMETERS:THE PH,CATIONS & ANIONS'
WRITE(1,10)
WRITE(1,17)'CHEMICAL PARAMETERS'
PRINT*,"

PRINT*,INPUT THE PH'
READ(*,*)PH
WRITE(1,10)
WRITE(1,7)'PH= ',PH
IF(PH.GE.6.5.AND.PH.LE.8.5)THEN
WRITE(1,10)'PH WITHIN STANDARD'
ELSEIF(PH.GT.8.5)THEN
WRITE(1,10)'PH EXCEEDS STANDARD-ALKALINE'
ELSE
WRITE(1,10)'PH BELOW STANDARD-VERY ACIDIC'
ENDIF
PRINT*,'
WRITE(1,10)
WRITE(1,10)

PRINT*,INPUT THE CATIONS: NA, CA, MG, FE ,MN, AL,
CU, ZN, AG'
READ(*,*)NA,CA ,MG,FE,MN,AL,CU,ZN,AG
PRINT*,'
WRITE(1,10)

WRITE(1,7)'SODIUM ION CONTENT= ',NA,'mg/L'
IF(NA.GE.30.AND.NA.LE.60.)THEN

```



```
WRITE(1,10)'SODIUM ION CONTENT WITHIN
STANDARD'
ELSEIF(NA.LT.30.)THEN
WRITE(1,10)'SODIUM ION CONTENT BELOW
STANDARD'
ELSE
WRITE(1,10)'SODIUM ION CONTENT EXCEEDS
STANDARD'
ENDIF
WRITE(1,10)
```

```
WRITE(1,7)'CALCIUM ION CONTENT='CA,'mg/L'
IF(CA.GE.30.AND.CA.LE.100)THEN
WRITE(1,10)'CALCIUM ION CONTENT WITHIN
STANDARD'
ELSEIF(CA.LT.30)THEN
WRITE(1,10)'CALCIUM ION CONTENT BELOW
STANDARD'
ELSE
WRITE(1,10)'CALCIUM ION CONTENT EXCEEDS
STANDARD'
ENDIF
WRITE(1,10)
```

```
WRITE(1,7)'MAGNESIUM ION CONTENT='MG,'mg/L'
IF(MG.LT.0.005)THEN
WRITE(1,10)'MAGNESIUM ION CONTENT WITHIN
STANDARD'
ELSEIF(MG.GT.0.005)THEN
WRITE(1,10)'MAGNESIUM ION CONTENT EXCEEDS
STANDARD'
ELSE
WRITE(1,10)'MAGNESIUM ION CONTENT EQUALS
STANDARD'
ENDIF
WRITE(1,10)
```

```
WRITE(1,7)'IRON ION CONTENT='FE,'mg/L'
IF(Fe.LT.0.3)THEN
WRITE(1,7)'IRON ION CONTENT WITHIN STANDARD'
ELSEIF(Fe.GT.0.3)THEN
WRITE(1,10)'IRON ION CONTENT EXCEEDS STANDARD'
ELSE
WRITE(1,10)'IRON ION CONTENT EQUALS STANDARD'
ENDIF
WRITE(1,10)
```

```
WRITE(1,7)'MANGANESE ION CONTENT='MN,'mg/L'
IF(MN.LT.0.05)THEN
WRITE(1,10)'MANGANESE ION CONTENT WITHIN
STANDARD'
ELSEIF(MN.GT.0.05)THEN
WRITE(1,10)'MANGANESE ION CONTENT EXCEEDS
STANDARD'
ELSE
WRITE(1,10)'MANGANESE ION CONTENT EQUALS
STANDARD'
ENDIFWRITE(1,10)
```

```
WRITE(1,7)'ALUMINIUM ION CONTENT='AL,'mg/L'
IF(AL.GE.0.05.AND.AL.LE.0.2)THEN
WRITE(1,10)'ALUMINIUM ION CONTENT WITHIN
STANDARD'
ELSEIF(AL.LT.0.05)THEN
WRITE(1,10)'ALUMINIUM ION CONTENT BELOW
STANDARD'
ELSE
WRITE(1,10)'ALUMINIUM ION CONTENT EXCEEDS
STANDARD'
ENDIF
WRITE(1,10)
```

```
WRITE(1,7)'COPPER ION CONTENT='CU,'mg/L'
IF(CU.LT.1.0)THEN
```

```
WRITE(1,10)'COPPER ION CONTENT WITHIN
STANDARD'
ELSEIF(CU.GT.1.0)THEN
WRITE(1,10)'COPPER ION CONTENT EXCEEDS
STANDARD'
ELSE
WRITE(1,10)'COPPER ION CONTENT EQUALS
STANDARD'
ENDIF
WRITE(1,10)
```

```
WRITE(1,7)'ZINC ION CONTENT='ZN,'mg/L'
IF(ZN.LT.5.)THEN
WRITE(1,10)'ZINC ION CONTENT WITHIN STANDARD'
ELSEIF(ZN.GT.5.)THEN
WRITE(1,10)'ZINC ION CONTENT EXCEEDS STANDARD'
ELSE
WRITE(1,10)'ZINC ION CONTENT EQUALS STANDARD'
ENDIF
WRITE(1,10)
```

```
WRITE(1,7)'SILVER ION CONTENT='AG,'mg/L'
IF(AG.LT.0.1)THEN
WRITE(1,10)'SILVER ION CONTENT WITHIN
STANDARD'
ELSEIF(AG.GT.0.1)THEN
WRITE(1,10)'SILVER ION CONTENT EXCEEDS
STANDARD'
ELSE
WRITE(1,10)'SILVER ION CONTENT EQUALS
STANDARD'
ENDIF
PRINT*,'
WRITE(1,10)
WRITE(1,10)
```

```
PRINT*,'INPUT THE ANION:CHL,SUL,PHS,FL,NTR'
READ(*,*)CHL,SUL,PHS,FL,NTR
PRINT*,'
```

```
WRITE(1,7)'CHLORIDE ION CONTENT='CHL,'mg/L'
IF(CHL.LT.250.)THEN
WRITE(1,10)'CHLORIDE ION CONTENT
WITHIN STANDARD'
ELSEIF(CHL.GT.250.)THEN
WRITE(1,10)'CHLORIDE ION CONTENT EXCEEDS
STANDARD'
ELSE
WRITE(1,10)'CHLORIDE ION CONTENT EQUALS
STANDARD'
ENDIF
WRITE(1,10)
```

```
WRITE(1,7)'SULPHATE ION CONTENT='SUL,'mg/L'
IF(SUL.LT.250.)THEN
WRITE(1,10)'SULPHATE ION CONTENT WITHIN
STANDARDS'
ELSEIF(SUL.GT.250.)THEN
WRITE(1,10)'SULPHATE ION CONTENT EXCEEDS
STANDARD'
ELSE
WRITE(1,10)'SULPHATE ION CONTENT EQUALS
STANDARD'
ENDIF
WRITE(1,10)
```

```
WRITE(1,7)'PHOSPHATE ION CONTENT='PHS,'mg/L'
IF(PHS.LT.0.01)THEN
WRITE(1,10)'PHOSPHATE ION CONTENT WITHIN
STANDARD'
ELSEIF(PHS.GT.0.01)THEN
WRITE(1,10)'PHOSPHATE ION CONTENT EXCEEDS
STANDARD'
```



```

ELSE
WRITE(1,10)'PHOSPHATE ION CONTENT EQUALS
STANDARD'
ENDIF
WRITE(1,10)
WRITE(1,7)'FLUORIDE ION CONTENT= ',FL,'mg/L'
IF(FL.LT.2.0)THEN
WRITE(1,10)'FLUORIDE ION CONTENT WITHIN
STANDARD'
ELSEIF(FL.GT.2.0)THEN
WRITE(1,10)'FLUORIDE ION CONTENT EXCEEDS
STANDARD'
ELSE
WRITE(1,10)'FLUORIDE ION CONTENT EQUALS
STANDARD'
ENDIF
WRITE(1,10)
WRITE(1,7)'NITRATE ION CONTENT= ',NTR,'mg/L'
IF(NTR.LT.10)THEN
WRITE(1,10)'NITRATE ION CONTENT WITHIN
STANDARD'
ELSEIF(NTR.GT.10)THEN
WRITE(1,10)'NITRATE ION CONTENT EXCEEDS
STANDARD'
ELSE
WRITE(1,10)'NITRATE ION CONTENT EQUALS
STANDARD'
ENDIF
WRITE(1,10)
WRITE(1,10)
WRITE(1,10)
Z=CA+MG+FE+MN+AL
C=ZN+CU+NA+AG
A=CHL+NTR+SUL+PHS+FL
WRITE(1,7)'**** SUM OF CATIONS:',A,'mg/L'
WRITE(1,10)
WRITE(1,7)'**** SUM OF ANIONS:',C,'mg/L'
WRITE(1,10)
WRITE(1,10)
WRITE(1,17)'HARDNESS TEST RESULT: '
IF(Z.GT.180)THEN
WRITE(1,10)'SAMPLE IS VERY HARD'
ELSEIF(Z.GT.120.AND.Z.LE.180)THEN
WRITE(1,10)'SAMPLE IS HARD'
ELSEIF(Z.GT.60.AND.Z.LE.120)THEN
WRITE(1,10)'SAMPLE IS MODERATELY HARD'
ELSEIF(Z.GT.30.AND.Z.LE.60)THEN
WRITE(1,10)'SAMPLE IS SOFT'
ELSE
WRITE(1,10)'SAMPLE IS VERY SOFT'ENDIF
WRITE(1,10)
WRITE(1,10)
WRITE(1,17)'SALINITY & PALABILITY TEST RESULT: '
IF(TDS.GT.35000)THEN
WRITE(1,10)'SAMPLE IS BRINY & VERY UNPALATABLE'
ELSEIF(TDS.GE.10000.AND.TDS.LE.35000)THEN
WRITE(1,10)'SAMPLE IS VERY SALINY &
UNPALATABLE'
ELSEIF(TDS.GE.3000.AND.TDS.LT.10000)THEN
WRITE(1,10)'SAMPLE IS MODERATELY SALINE &
UNPALATABLE'
ELSEIF(TDS.GE.1000.AND.TDS.LT.3000)THEN
WRITE(1,10)'SAMPLE IS SLIGHTLY SALINE &
UNPALATABLE'
ELSEIF(TDS.GE.900.AND.TDS.LT.1000)THEN
WRITE(1,10)'SAMPLE IS SLIGHTLY SALINE &
UNPALATABLE'
ELSEIF(TDS.GE.600.AND.TDS.LT.900)THEN
WRITE(1,10)'SAMPLE IS FRESH (NON-SALINE) BUT
FAIRLY PALATABLE'
ELSEIF(TDS.GE.300.AND.TDS.LT.600)THEN

```

```

WRITE(1,10)'SAMPLE IS FRESH (NON-SALINE) WITH
GOOD PALATABILITY'
ELSE
WRITE(1,10)'SAMPLE IS FRESH (NON-SALINE), AND
EXCELLENTLY PALATABLE'
ENDIF
STOP
END program

```

APPENDIX II: Program Output

```

DATE: SAMPLE ID: SITE/LOCATION:
INSERT THE DATA OF THE PHYSICAL PARAMETERS
:TMP,CLR,CDTY,ODR,TDS
27.3:7.1:70.78:79.22:146.5
INTERPRETATION & TEST RESULT
PHYSICAL PARAMETERS
TEMPERATURE = 27.300 C : TEMPERATURE EXCEEDS
STANDARD. POSSIBILITIES OF INCREASE IN VAPOUR
& PRESSURE & SOLUBILITY
COLOUR = 7.100 UNIT COLOUR WITHIN STANDARD
CONDUCTIVITY = 70.780 mS/cm: CONDUCTIVITY
WITHIN STANDARD
ODOUR = 79.220 Threshold Number: ODOUR EXCEEDS
STANDARD
TOTAL DISSOLVED SOLIDS = 146.500 mg/L: TDS WITHIN
STANDARD
INSERT THE DATA OF THE CHEMICAL PARAMETERS:
THE PH,CATIONS & ANIONS
CHEMICAL PARAMETERS
INPUT THE PH: 7.0
PH= 7.000: PH WITHIN STANDARD
INPUT THE CATIONS: NA, CA, MG, FE,MN, AL, CU, ZN,
AG
0.1:32.6:17.9:0.01:0.01:0.0:0.03:0.02:0.0
SODIUM ION CONTENT= 0.100 mg/L: SODIUM ION
CONTENT BELOW STANDARD
CALCIUM ION CONTENT= 32.600 mg/L: CALCIUM ION
CONTENT WITHIN STANDARD
MAGNESIUM ION CONTENT= 17.900 mg/L: MAGNESIUM
ION CONTENT EXCEEDS STANDARD
IRON ION CONTENT= 0.010 mg/L: IRON ION CONTENT
WITHIN Standard
MANGANESE ION CONTENT = 0.010 mg/L: MANGANESE
ION CONTENT WITHIN STANDARD
ALUNMINIUM ION CONTENT= 0.000 mg/L: ALUMINIUM
ION CONTENT BELOW STANDARD
COPPER ION CONTENT= 0.030 mg/L: COPPER ION
CONTENT WITHIN STANDARD
ZINC ION CONTENT= 0.020 mg/L: ZINC ION CONTENT
WITHIN STANDARD
SILVER ION CONTENT= 0.000 mg/L: SILVER ION
CONTENT WITHIN STANDARD
INPUT THE ANION:CHL,SUL,PHS,FL,NTR
17.6:2.0:0.02:0.01:1.5
CHLORIDE ION CONTENT= 17.600 mg/L: CHLORIDE ION
CONTENT WITHIN STANDARD
SULPHATE ION CONTENT= 2.000 mg/L: SULPHATE ION
CONTENT WITHIN STANDARDS
PHOSPHATE ION CONTENT= 0.020 mg/L: PHOSPHATE
ION CONTENT EXCEEDS STANDARD
FLUORIDE ION CONTENT= 0.010 mg/L: FLUORIDE ION
CONTENT WITHIN STANDARD
NITRATE ION CONTENT= 1.500 mg/L: NITRATE ION
CONTENT WITHIN STANDARD
*SUM OF CATIONS: 21.130 mg/L
*SUM OF ANIONS: 0.150 mg/L
HARDNESS TEST RESULT: SAMPLE IS SOFT
SALINITY & PALABILITY TEST RESULT: SAMPLE IS
FRESH (NON-SALINE) AND EXCELLENTLY PALATABLE
Press RETURN to close window

```