Earth Science Research; Vol. 1, No. 2; 2012
ISSN 1927-0542 E-ISSN 1927-0550
Published by Canadian Center of Science and Education

Mathematical Model to Predict Conductive Properties of Contaminated Riverbed Sand in Ado-Odo Ota Local Government Area of Ogun State, Nigeria

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Received: February 1, 2012 Accepted: February 14, 2012 Online Published: June 5, 2012

doi:10.5539/esr.v1n2p43 URL: http://dx.doi.org/10.5539/esr.v1n2p43

Abstract

The possibility of contamination is especially rising due to the increase in the number of industries in the Local Government Area. In this study, riverbed sands were collected from five major rivers in Ado-Odo Ota Local Government Area, and conductivity properties were determined after the samples have been treated with varying concentration of petrol, engine oil, diesel, caustic soda and H_2SO_4. HANNAN Electrical Conductivity Meter, KD2 Thermal Conductivity Meter and Constant Head Method were used to determine the electrical, thermal and hydraulic conductivities respectively. A mathematical model was developed that describes the effect of contaminants on the electrical (σ), thermal (λ) and hydraulic (k) conductivities of riverbed sand from the major rivers in Ado-odo Ota Local Government Area. The model equation incorporates the bulk density of the riverbed sand samples, as well as the concentration and conductivity of the contaminants as follows: $\lambda = 0.107x_1 + 0.10x_2 - 0.017x_3 + 1.673$, $\sigma = 1.911x_1 + 18.229x_2 - 0.015x_3 + 47.173$ and $k = 0.056x_1 + 0.381x_2 - 0.031x_3 + 0.162$, where x_1, x_2 and x_3 are bulk density of samples, conductivity and concentration of contaminants respectively. From interpolation analysis, sample from Ilogbo river contained about 30 ml/kg of engine oil, Mosafejo river contained about 10 ml/kg of caustic soda, Ijako river contained about 20 ml/kg of caustic soda, Iju river contained about 10 ml/kg of diesel and Igbogbo river contained 10 ml/kg of H_2SO_4, thus showing clearly how waste products from industries end up as contaminants in nearby rivers.

Keywords: mathematical model, riverbed sand, thermal conductivity, electrical conductivity, hydraulic conductivity, contaminants concentration

1. Introduction

Pollution of the soil environment with petroleum and refinery products is one of the factors expressing anthropopression. Due to its toxicity, widespread presence and complex nature, this type of pollution is a serious problem, one reason being that as the modern civilisation, urbanisation and mechanisation develop, the use of petroleum and petroleum-based products grows. Contamination of soils with crude oil and refinery products is becoming an ever-increasing problem, especially in the light of several breakdowns of oil pipelines and wells reported recently. Nonetheless, major points of soil pollution with refinery products are petrol stations, garages servicing cars and tractors, seaport areas (Michalcewicz, 1995). Other areas of concern are mining and distribution of petroleum-based products (Song & Barhta, 1990, Amadi et al., 1996, Jørgensen et al., 2000). Besides, heavy use of machinery in agriculture leads to higher consumption of diesel oil. Certain negligence when transporting, collecting or storing refinery products together with unsatisfactory care while disposing of old or used petroleum products lead to considerable pollution of the natural environment (Leahy & Colwell, 1990). Petroleum and refinery products penetrating soil cause its degradation (Sztompka, 1999). Once they enter an ecosystem, petroleum-based products initiate a series of processes, affecting both its biotic and abiotic elements (Małachowska-Jutsz et al., 1997). Crude oil and products derived from this raw material are composed of aliphatic, oleic, naphthenic and aromatic hydrocarbons (Chi & Krishnamurthy, 1995), which modify physical and chemical properties of soil and its structure. These compounds are largely responsible for changed fertility of soil (Tyczkowski, 1993, Iwanow et al., 1994). Soil polluted by petroleum-based products loses its biological activity and may not be able to recover it over ten years (Sparrow & Sparrow, 1988, Racine 1993, Wyszkowska et al., 2001). Moreover, diesel oil has a negative effect on the biochemical and physicochemical characteristics of soils (Tyczkowski, 1993, Kucharski & Wyszkowska, 2001, Wyszkowska et al., 2002).

Since contamination of soil with refinery products deteriorates its biochemical and physicochemical properties, it also limits the growth and development of plants, whose nutritive and technological value can be low and often questionable. In this connection, the present study has been undertaken to determine the effect of soil contamination with Diesel oil, Engine oil, Petrol, Caustic soda and H_2SO_4 on thermal, electrical and hydraulic conductivities, and to determine the predictive mathematical models for the physical properties.

2. Study Area

The study was carried out on five major rivers in Ado-Odo/Ota Local Government Area of Ogun State. Ado-odo/Ota Local Government is one of the 20 Local Government areas of Ogun State located in the West Senatorial District. Geographically, it is situated within the tropical zone lying between 60^0 and 47^0 N of equator and 20.33^0E and 30.18^0 E of the Greenwich's Meridian and covers a land area of 1,263 square kilometers with a Terrain of 1,010.4 sq kilometer plain land and about 252.6 square kilometers. Terrain comprises of 16% riverine and 4% hilly regions. The Local Government has an estimated population of 527,242 people (Male 262,523 & Female 265,719) (2006 Census) with about four hundred and fifty (450) towns, villages and settlements. The map shown in Figure 1, illustrate the location of the sampling sites and the potential source of pollutants, which include agricultural wastes, industrial wastes, sewage, animal wastes, market wastes, etc. Three of the rivers (Ilogbo, Mosafejo and Ijako rivers) are located in the southern district of the area. While the remaining two (Igbogbo and Iju rivers) are located in the northern part of area. The Ijako and Ilogbo Rivers are particularly unique for several reasons. The Ijako community has undergone great economic development in recent years and is notably one of the fastest growing economically important communities in Ado-odo/ota L.G.A. which accommodates a considerable number of micro- industries (Coca-Cola Nig. Ltd, Sona Breweries plc, Universal Gas Ltd, Nigeria Foundries Ltd, 3Ace lnd. Ltd and Fine chemicals ltd.).The very popular market (Ilogbo market) and the timber business coupled with agricultural practices have drawn people from several cultural background in the country to make the settlement inter- tribal. This increase in anthropogenic activities surrounding the area has lead to an increase in environmental degradation. These multiple sources make it especially difficult to identify and isolate the risks associated with this contaminated water.

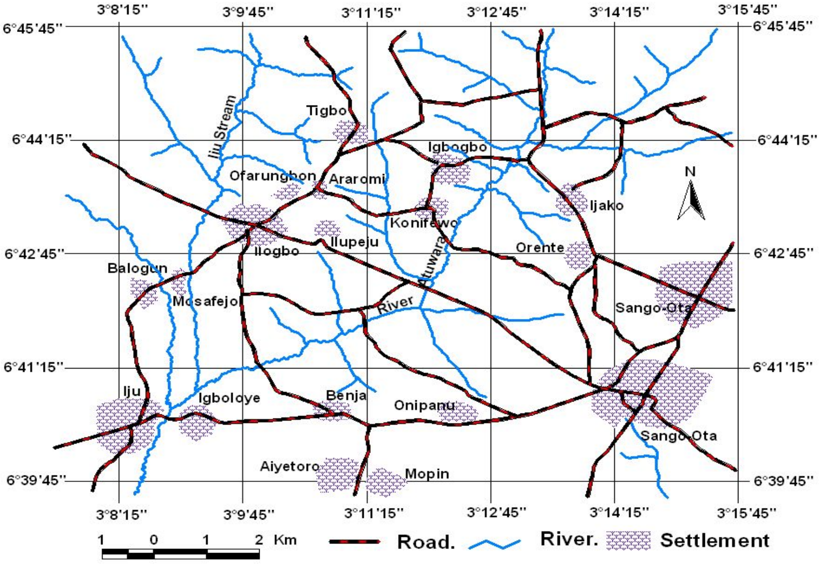


Figure 1. Map of study area

3. Materials and Methods

The equipments used in this work included Hannan electrical conductivity meter, KD2 thermal conductivity meter and Digital weight balance. Riverbed sands were collected from the five major rivers present in Ado-Odo

Ota Local Government Area of Ogun state. Surface sediment sample were collected manually from the rivers' bank, transferred into plastic containers, and transported to the laboratory (UNAAB). Samples collected were thoroughly washed to remove any hidden contaminant, air dried and sieved to ensure uniform grain size. 1.3g/cm^3 bulk density of each treated sample were moistened with uniform grain size of 0.2mm. Five readings of thermal conductivity and electrical conductivity were taken at different points in the cylinder in order to obtain the average values, after which the hydraulic conductivity was measured using constant head method. 5ml of each contaminant was added and mixed thoroughly.

4. Results and Discussion

Table 1. ANOVA Table for conductivity properties of Riverbed sands

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	Thermal Conductivity	85.302[a]	60	1.422	32.359	.000
	Electrical Conductivity	291562.322[b]	60	4859.372	230.467	.000
	Hydraulic Conductivity	74.213[c]	60	1.237	29.020	.000
Intercept	Thermal Conductivity	518.814	1	518.814	11808.518	.000
	Electrical Conductivity	1440968.749	1	1440968.749	68341.241	.000
	Hydraulic Conductivity	125.521	1	125.521	2944.959	.000
Sample	Thermal Conductivity	7.236	4	1.809	41.175	.000
	Electrical Conductivity	1308.401	4	327.100	15.513	.000
	Hydraulic Conductivity	3.184	4	.796	18.678	.000
Contaminant	Thermal Conductivity	31.157	4	7.789	177.288	.000
	Electrical Conductivity	237296.004	4	59324.001	2813.577	.000
	Hydraulic Conductivity	55.921	4	13.980	328.004	.000
Concentration	Thermal Conductivity	1.881	4	.470	10.704	.000
	Electrical Conductivity	57.719	4	14.430	.684	.605
	Hydraulic Conductivity	6.144	4	1.536	36.039	.000
Sample * Contaminant	Thermal Conductivity	13.759	16	.860	19.573	.000
	Electrical Conductivity	6563.030	16	410.189	19.454	.000
	Hydraulic Conductivity	6.126	16	.383	8.982	.000
Sample * Concentration	Thermal Conductivity	1.068	16	.067	1.519	.121
	Electrical Conductivity	185.115	16	11.570	.549	.909
	Hydraulic Conductivity	1.320	16	.083	1.936	.033
Contaminant * Concentration	Thermal Conductivity	30.201	16	1.888	42.962	.000
	Electrical Conductivity	46152.053	16	2884.503	136.804	.000
	Hydraulic Conductivity	1.518	16	.095	2.226	.013
Error	Thermal Conductivity	2.812	64	.044		
	Electrical Conductivity	1349.434	64	21.085		
	Hydraulic Conductivity	2.728	64	.043		
Total	Thermal Conductivity	606.927	125			
	Electrical Conductivity	1733880.505	125			
	Hydraulic Conductivity	202.462	125			
Corrected Total	Thermal Conductivity	88.113	124			
	Electrical Conductivity	292911.756	124			
	Hydraulic Conductivity	76.941	124			

a. R Squared = .968 (Adjusted R Squared = .938)

b. R Squared = .995 (Adjusted R Squared = .991)

c. R Squared = .965 (Adjusted R Squared = .931)

From Table 1, thermal conductivity, electrical conductivity and hydraulic conductivity of different sand samples differ significantly at 5% ($p< 0.05$) level of significance. It is also observed from the table that these three properties differ significantly for the different contaminants used on the sand samples, but this is not the case for the different concentration of the contaminants. Rather it is seen that while the thermal and hydraulic conductivities differ significantly at 5% level for the different concentration of contaminants used, electrical conductivity is not significantly different at 5% level.

Table 2. Mean values of the different conductivity properties for the different sand samples

2. Sample

				95% Confidence Interval	
Dependent Variable	Sample	Mean	Std. Error	Lower Bound	Upper Bound
Thermal Conductivity	Sample A	1.923	.042	1.839	2.007
	Sample B	2.024	.042	1.940	2.108
	Sample C	1.665	.042	1.581	1.749
	Sample D	2.207	.042	2.123	2.291
	Sample E	2.367	.042	2.283	2.451
Electrical Conductivity	Sample A	103.543	.918	101.708	105.377
	Sample B	107.550	.918	105.715	109.385
	Sample C	104.128	.918	102.293	105.963
	Sample D	109.484	.918	107.649	111.319
	Sample E	112.132	.918	110.297	113.967
Hydraulic Conductivity	Sample A	.765	.041	.682	.847
	Sample B	.968	.041	.885	1.050
	Sample C	1.262	.041	1.180	1.344
	Sample D	.974	.041	.892	1.057
	Sample E	1.042	.041	.959	1.124

Mean values of the different conductivities for the different sand samples used are shown in Table 2. It is seen that sample E has the highest thermal conductivity value (2.367), while sample C has the lowest thermal conductivity value (1.665).

Table 3. Mean values of the different conductivities properties for the different contaminants

3. Contaminant

				95% Confidence Interval	
Dependent Variable	Contaminant	Mean	Std. Error	Lower Bound	Upper Bound
Thermal Conductivity	Petrol	1.674	.042	1.591	1.758
	Diesel	2.297	.042	2.213	2.381
	Engine Oil	1.458	.042	1.375	1.542
	H2SO4	2.868	.042	2.784	2.952
	Caustic Soda	1.889	.042	1.805	1.973
Electrical Conductivity	Petrol	114.650	.918	112.815	116.485
	Diesel	54.580	.918	52.745	56.414
	Engine Oil	59.685	.918	57.850	61.519
	H2SO4	149.680	.918	147.845	151.515
	Caustic Soda	158.242	.918	156.408	160.077
Hydraulic Conductivity	Petrol	.708	.041	.626	.790
	Diesel	.420	.041	.338	.503
	Engine Oil	.446	.041	.363	.528
	H2SO4	1.230	.041	1.148	1.312
	Caustic Soda	2.206	.041	2.124	2.289

Table 3 shows the mean values of the different conductivities for the different contaminants used. It is seen that H2SO4 has the highest thermal conductivity value, (2.868) while Engine oil has the lowest thermal conductivity value (1.458).

Table 4. Mean values of the different conductivities properties for the different concentration of contaminants

4. Concentration of Contaminant

Dependent Variable	Concentration of Contaminant	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
Thermal Conductivity	5 ml	2.222	.042	2.138	2.306
	10 ml	2.093	.042	2.009	2.177
	15 ml	2.056	.042	1.972	2.140
	20 ml	1.952	.042	1.869	2.036
	25 ml	1.863	.042	1.779	1.947
Electrical Conductivity	5 ml	107.320	.918	105.485	109.155
	10 ml	106.869	.918	105.034	108.703
	15 ml	108.324	.918	106.489	110.158
	20 ml	107.890	.918	106.055	109.725
	25 ml	106.434	.918	104.600	108.269
Hydraulic Conductivity	5 ml	1.312	.041	1.230	1.395
	10 ml	1.168	.041	1.086	1.250
	15 ml	.997	.041	.914	1.079
	20 ml	.841	.041	.758	.923
	25 ml	.692	.041	.610	.775

It is observed from Table 4 that the thermal conductivity value is highest at 5ml concentration of the contaminants used while it is lowest at 25ml concentration of the contaminants used.

Table 5. Mean separation for thermal conductivity of different sand samples

Thermal Conductivity

Duncan[a,b,c]

Sample	N	Subset			
		1	2	3	4
Sample C	25	1.6652			
Sample A	25		1.9228		
Sample B	25		2.0240		
Sample D	25			2.2072	
Sample E	25				2.3672
Sig.		1.000	.093	1.000	1.000

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares
The error term is Mean Square(Error) = .044.

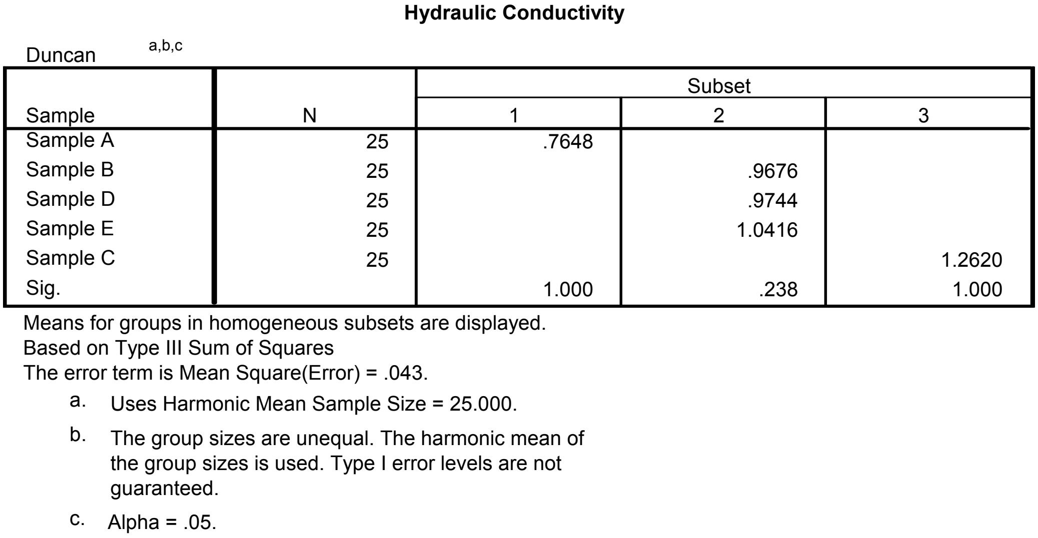
[a] Uses Harmonic Mean Sample Size = 25.000.

[b] The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

[c] Alpha = .05.

From Table 5, mean separation for thermal conductivity of the different sand samples. It was observed from the table that thermal conductivity of sample A is not significantly different from that of sample B, while thermal conductivity of all other samples are significantly different at 5% ($p< 0.05$) level.

Table 6. Mean separation for hydraulic conductivity of different sand samples



Hydraulic Conductivity

Duncan [a,b,c]

Sample	N	Subset		
		1	2	3
Sample A	25	.7648		
Sample B	25		.9676	
Sample D	25		.9744	
Sample E	25		1.0416	
Sample C	25			1.2620
Sig.		1.000	.238	1.000

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares
The error term is Mean Square(Error) = .043.

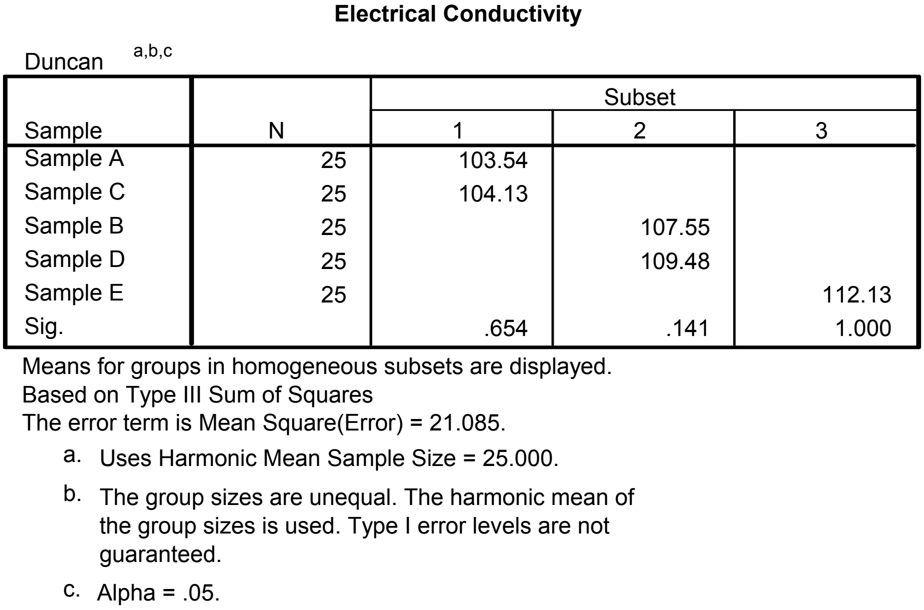
[a] Uses Harmonic Mean Sample Size = 25.000.

[b] The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

[c] Alpha = .05.

Table 6 shows the mean separation for hydraulic conductivity of the different sand samples. It was observed from the table that hydraulic conductivity of sample B and D are not significantly different from that of sample E, while the hydraulic conductivity of sample A is significantly different from that of sample C at 5% level.

Table 7. Mean separation for electrical conductivity of different sand samples



Electrical Conductivity

Duncan [a,b,c]

Sample	N	Subset		
		1	2	3
Sample A	25	103.54		
Sample C	25	104.13		
Sample B	25		107.55	
Sample D	25		109.48	
Sample E	25			112.13
Sig.		.654	.141	1.000

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares
The error term is Mean Square(Error) = 21.085.

[a] Uses Harmonic Mean Sample Size = 25.000.

[b] The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

[c] Alpha = .05.

Table 7 shows the mean separation for electrical conductivity of the different sand samples. It was observed from the table that electrical conductivity of sample A is not significantly different from that sample C, while the electrical conductivity of sample B is not significantly different from that of sample D, while electrical conductivity of sample E is significantly different from all other samples at 5% ($p<0.05$) level.

Table 8. Mean seperation for thermal conductivitiy of the sand samples for different contaminants used

Thermal Conductivity

Duncan[a,b,c]

		Subset				
Contaminant	N	1	2	3	4	5
Engine Oil	25	1.4584				
Petrol	25		1.6744			
Caustic Soda	25			1.8888		
Diesel	25				2.2968	
H2SO4	25					2.8680
Sig.		1.000	1.000	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares
The error term is Mean Square(Error) = .044.

[a] Uses Harmonic Mean Sample Size = 25.000.

[b] The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

[c] Alpha = .05.

Mean separation for thermal conductivities of the sand samples for different contaminants used as shown in Table 8. It is seen from the table that thermal conductivities of the sand samples differ significantly at 5% ($p<0.05$) level for the different contaminants used.

Table 9. Mean seperation for electrical conductivitiy of the sand samples for different contaminants used

Electrical Conductivity

Duncan[a,b,c]

		Subset				
Contaminant	N	1	2	3	4	5
Diesel	25	54.58				
Engine Oil	25		59.68			
Petrol	25			114.65		
H2SO4	25				149.68	
Caustic Soda	25					158.24
Sig.		1.000	1.000	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares
The error term is Mean Square(Error) = 21.085.

[a] Uses Harmonic Mean Sample Size = 25.000.

[b] The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

[c] Alpha = .05.

Electrical conductivities of the sand samples differ significantly at 5% ($p<0.05$) level for the different contaminants used as shown in Table 9.

Table 10. Mean seperation for hydraulic conductivitiy of the sand samples for different contaminants used

Hydraulic Conductivity

Duncan[a,b,c]

Contaminant	N	Subset			
		1	2	3	4
Diesel	25	.4204			
Engine Oil	25	.4456			
Petrol	25		.7080		
H2SO4	25			1.2300	
Caustic Soda	25				2.2064
Sig.		.668	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares
The error term is Mean Square(Error) = .043.

a. Uses Harmonic Mean Sample Size = 25.000.

b. The group sizes are unequal. The harmonic mean of the group sizes used. Type I error levels are not guaranteed.

c. Alpha = .05.

It is seen from the Table 10 that, hydraulic conductivity of diesel is not significantly different from that engine oil at 5% ($p<0.05$) level for the different contaminants used. While hydraulic conductivities of other contaminants (petrol, H2SO4 and caustic soda) are significantly different at 5% level.

Table 11. Mean seperation for thermal conductivitiy of the sand samples at different concentration of contaminants used

Thermal Conductivity

Duncan[a,b,c]

Concentration of Contaminant	N	Subset			
		1	2	3	4
25 ml	25	1.8628			
20 ml	25	1.9524	1.9524		
15 ml	25		2.0560	2.0560	
10 ml	25			2.0932	
5 ml	25				2.2220
Sig.		.136	.085	.533	1.000

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares
The error term is Mean Square(Error) = .044.

a. Uses Harmonic Mean Sample Size = 25.000.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

c. Alpha = .05.

It was observed that thermal conductivity of the sand samples when 25ml concentration of the contaminants used is not significantly different at 5% level from when 20ml concentration of the contaminant is used as shown in Table 11. Also the thermal conductivity does not differ at 5% level when 15ml concentration of the contaminant is used and when 20ml concentration of the contaminant is used, but that of 15ml differ significantly at 5% level from that of 25ml. also thermal conductivity at 10ml concentration does not differ significantly at 5% ($p<0.05$) level from that at 15ml, but it differs significantly from those at other concentrations. Thermal conductivity at 5ml concentration is observed to be significantly different at 5 % ($p<0.05$) from those at other concentrations.

Table 12. Mean seperation for electrical conductivitiy of the sand samples at different concentrations of contaminants used

Electrical Conductivity

Duncan[a,b,c]

Concentration of Contaminant	N	Subset
		1
25 ml	25	106.43
10 ml	25	106.87
5 ml	25	107.32
20 ml	25	107.89
15 ml	25	108.32
Sig.		.202

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares
The error term is Mean Square(Error) = 21.085.

a. Uses Harmonic Mean Sample Size = 25.000.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

c. Alpha = .05.

Table 12 shows the mean separation for the electrical conductivity of the sand samples at different concentrations of the contaminants used. It was observed that electrical conductivity of the sand samples are not significantly different at 5% ($p< 0.05$) level for the different concentration of contaminants used.

Table 13. Mean seperation for hydraulic conductivitiy of the sand samples at different concentration of contaminants used

Hydraulic Conductivity

Duncan[a,b,c]

Concentratior of Contamina	N	Subset				
		1	2	3	4	5
25 ml	25	.6924				
20 ml	25		.8408			
15 ml	25			.9968		
10 ml	25				1.1680	
5 ml	25					1.3124
Sig.		1.000	1.000	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares
The error term is Mean Square(Error) = .043.

a. Uses Harmonic Mean Sample Size = 25.000.

b. The group sizes are unequal. The harmonic mean of the group sizes error levels are not guaranteed.

c. Alpha = .05.

From Table 13, mean separation for the hydraulic conductivity of the sand samples at different concentrations of the contaminants used shown. It was seen from this table that the hydraulic conductivities of the sand samples differ significantly at 5% ($p< 0.05$) level for the different concentration of contaminants used.

Table 14. Regression analysis tables for thermal conductity of the sand sample

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	7.219	3	2.406	3.599	.016[a]
	Residual	80.895	121	.669		
	Total	88.113	124			

a. Predictors: (Constant), Concentration of Contaminant, Contaminant, Sample

b. Dependent Variable: Thermal Conductivity

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.673	.278		6.009	.000
	Sample	.107	.052	.181	2.073	.040
	Contaminant	.100	.052	.168	1.934	.055
	Concentration of Contaminant	-.017	.010	-.145	-1.661	.099

a. Dependent Variable: Thermal Conductivity

From the regression analysis results for thermal conductivity as shown in Table 14, it was observed that the thermal conductivity of the sand samples is significantly dependents at 5% level on the explanatory factors (concentration of contaminant, types of contaminant and sand sample) under consideration. These factors are responsible for 8.2% in the variation of the thermal conductivity of the sand sample. From the tables the regression equation as found to be $y = 0.107x1 + 0.10x2 – 0.017x3 + 1.673$ as shown in Table 14

Where:

y = Sample Thermal conductivity, x1 = Sample density,

x2 = Contaminant thermal conductivity, x3 = Concentration of contaminant

Table 15. Regression analysis tables for electrical conductity of the sand sample

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	47.173	14.153		3.333	.001
	Sample	1.911	2.628	.056	.727	.468
	Contaminant	18.229	2.628	.533	6.936	.000
	Concentration of Contaminant	-.015	.526	-.002	-.029	.977

a. Dependent Variable: Electrical Conductivity

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	83984.351	3	27994.784	16.213	.000[a]
	Residual	208927.4	121	1726.673		
	Total	292911.8	124			

a. Predictors: (Constant), Concentration of Contaminant, Contaminant, Sample

b. Dependent Variable: Electrical Conductivity

From the regression analysis results for electrical conductivity, it was observed that the electrical conductivity of the sand samples is significantly dependents at 5% level on the explanatory factors (concentration of contaminant, types of contaminant and sand sample) under consideration. These factors are responsible for 28.7% in the variation of the electrical conductivity of the sand sample. From the tables the regression equation y = 1.911x1 + 18.229x2 – 0.015x3 + 47.173 as shown in Table 15

Where:

y = Sample Electrical conductivity, x1 = Sample density,

x2 = Contaminant electrical conductivity, x3 = Concentration of contaminant

Table 16. Regression analysis tables for hydraulic conductity of the sand sample

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	43.147	3	14.382	51.496	.000[a]
	Residual	33.794	121	.279		
	Total	76.941	124			

a. Predictors: (Constant), Concentration of Contaminant, Contaminant, Sample

b. Dependent Variable: Hydraulic Conductivity

Coefficients[a]

		Unstandardized Coefficients		Standardized Coefficients		
Model		B	Std. Error	Beta	t	Sig.
1	(Constant)	.162	.180		.901	.369
	Sample	.056	.033	.101	1.677	.096
	Contaminant	.381	.033	.686	11.388	.000
	Concentration of Contaminant	-.031	.007	-.282	-4.689	.000

a. Dependent Variable: Hydraulic Conductivity

From the regression analysis results for hydraulic conductivity, it was observed that the hydraulic conductivity of the sand samples is significantly dependents at 5% level on the explanatory factors (concentration of contaminant, types of contaminant and sand sample) under consideration. These factors are responsible for 56.1% in the variation of the hydraulic conductivity of the sand sample. From the tables the regression equation y = 0.056x1 + 0.381x2 – 0.031x3 + 0.162 as shown in Table 16

Where:

y = Sample Hydraulic conductivity, x1 = Sample density,

x2 = Contaminant hydraulic conductivity, x3 = Concentration of contaminant

5. Conclusion

In this work, results of electrical conductivity, thermal conductivity and hydraulic conductivity have been modeled to determine effects of contaminants (petrol, diesel, engine oil, caustic soda and H_2SO_4) on conductive properties of riverbed sands. Duncan results showed that, thermal conductivity of sample A is not significantly different from that of sample B, while thermal conductivity of all other samples are significantly different at 5% ($p< 0.05$) level. Electrical conductivity is not significantly different from that of sample C at 5% ($p< 0.05$) level, while hydraulic conductivity of samples B and D are not significantly different from that of sample E, but hydraulic conductivity of sample A is significantly different from that of sample C at 5% ($p< 0.05$) level.

Results from the coefficients of determination showed that concentration of contaminants, types of contaminants and sand samples are responsible for 8.2% in the variation of thermal conductivity, while these factors are also responsible for 28.7% and 56.1% in variation of electrical and hydraulic conductivities respectively.

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