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STATISTICAL AND GIS BASED ANALYSIS OF PHYSICOCHEMICAL PARAMETERS OF GROUND WATER SAMPLES AROUND RAJBANDH DUMPING SITE

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ABSTRACT

Khulna is the 3rd largest metropolitan industrial and port city in Bangladesh. The enhancement of business and financial activities resulted in a sharp increase in city population. Therefore, the amount of municipal solid waste (MSW) generation has increased with population. A pilot scale sanitary landfill and an open dumped site are situated at Rajbandh, Khulna. Groundwater samples were collected from tube-wells from Rajbandh, Khulna dumping site as well as its adjoining area to find out the concentration of different water quality parameters. In the laboratory, nine different water quality parameters such as pH, E.C, TDS, Cl^-, NO_3^-, turbidity, alkalinity, Mn and Fe were measured through standard test methods. In order to establish the relationship between physicochemical parameters to predict the intensity of one parameter with respect to another for a particular location, statistical analysis has been done by Microsoft Excel. It includes correlation coefficient, t-test, and regression analysis. Methodical calculation of correlation co-efficient between water quality parameters has been done. Regression equations also established. This is because of to find out the strength and the linear relationship between different pairs of parameters as well as to predict the level of pollution of groundwater. The significance level further verified by t-test. The water samples were collected and analyzed from four distinct locations. In this study an appreciable strong positive correlation was found for E.C with turbidity, alkalinity; turbidity with alkalinity also for chloride with TDS. A strong negative correlation was found for pH with turbidity, alkalinity, E.C. All the physicochemical parameters of respective groundwater were within limit set by ECR (1997). The water quality index (WQI) was used to analyze the groundwater quality of study site. The water quality parameters such as pH, E.C, TDS, C^{l-}, NO_3^-, turbidity, alkalinity, Mn, and Fe were used which were collected from four different locations since a period of 2018. The test result reveals that 50% water samples were found poor quality and 50% samples were found unsuitable for drinking purposes. The WQI ranges from 72.998 to 164.332. Further, the WQI at different locations were analyzed with respect to variation in space using spline curve technique using ArcGIS 10.5 software. Therefore, there is a need of some treatment before usage of water and also require to protect the area from landfill contamination.

Keywords: *Statistical analysis, Groundwater, ArcGIS, Physicochemical parameters, WQI.*

1. INTRODUCTION

Municipal solid waste (MSW) disposal in the surrounding environment has increased a large amount due to rapid urbanization and industrialization. Disposal of solid waste and sewage, urban runoff, agricultural activities and polluted surface water are major contributors to deteriorate urban groundwater resources (Jain et al., 1995). Groundwater are used for domestic and agricultural purposes. According to WHO organization, about 80% of all the diseases in human beings are caused by water. The water quality may be described by its physicochemical and micro-biological parameters. The quality is a function of the physical, chemical and biological parameters, and could be subjective, since it depends on a particular intended use (Tatawat et.al, 2008). Once the groundwater is contaminated, its quality cannot be restored by stopping the pollutants from (Ramakrishnaiah et.al, 2009) the source. So, continuously water quality monitoring is very much necessary. The modeling, arrangement and explanation of checking data are the most important steps in the appreciation of water quality. Generally, water quality parameters are interacting with each other. Although laboratory facilities and sufficient manpower, regularly checking all the parameters is very much challenging tasks. Generally, the laboratory methods are time consuming and very much costly so, some methods can develop which will provide easy, reliable and cost effective methods to collect data and provide information of the level of pollution by different parameters(Agarwal et.al, 2011). For this reason, in recent years a very simple method track based on statistical correlation has been developed using mathematical relationship for comparison of physicochemical parameters (Kaur et.al, 2011). Uncertainty range reduces by the study of correlation. Further, correlation coefficients have been tested by using t-test to determine the significance.

Khulna, Rajbandh zone was selected because city corporation solid waste is dumped in that area. So, it can be said that groundwater can normally be polluted in that area and people get affected by ingestion though people drink water from deep tube-well. For this study, four locations namely Hogladanga landfill (location 1), Joykhali landfill (location 2), Progoti Secondary School, Hogladanga (location 3), R.S.O Hasari and Culture station (location 4) were selected.

Statistical studies have been done on different pairs of parameters to find out the correlation coefficient and then regression equations were established to understand the limit of pollution level by parameters. Further t-test was applied for checking significance. Now a day's software- based analysis for the assessment of groundwater quality is increasing. Different types of software are used for groundwater modelling as well as groundwater quality assessment for examples Modflow, Phreeqe, MT3D, GIS etc. To determine the water quality, these software -based study is followed to compare the numerical or analytical based study. So, there are several techniques used to determine groundwater contamination or water quality assessment which is caused by landfill.

2. MATERIALS AND METHODS

2.1 Study area

Khulna Rajbandh location was selected for this study. It is 8 km far from the city center. Groundwaters were collected from tube-wells from 4 locations around landfill site.

Location:
Latitude: 22º47'43.17''
Longitude: 89º29'58.35"

Figure 1: Selected study area at Rajbandh from google earth

2.2 Analytical method

The groundwater samples were immediately transferred to the laboratory and stored in Refrigerator. The analysis was started without any delay in the lab based on APHA (1999) methods. In case of physicochemical parameters includes pH was measured by pH meter, Electrical Conductivity (EC) was measured by EC meter, turbidity was measured by Turbidimeter. On the other hand, Chloride, alkalinity was tested by titration. TDS was tested by gravimetric method.NO_3^-, Fe, Mn were tested by Spectrophotometer.

2.3 Statistical analysis

The correlation between various physicochemical parameters of water samples were analyzed statically conducting Pearson correlation through Microsoft Excel by equation (1).

Coefficient of correlation (r):

$$r = \frac{n(\sum xy) - \sum x * \sum y}{\sqrt{[n\sum x^2 - (\sum x)^2] * [n\sum y^2 - (\sum y)^2]}} \quad (1)$$

where,

x = Individual reading of 1st parameter
y = Individual reading of 2nd parameter
n = number of values of single parameter

The correlation among the different parameters will be true when the value of correlation coefficient (r) is high and approaching to one (Joshi et.al, 2009). Correlation, the relationship between two variables, is closely related to prediction. The greater the association between variables, more accurately can predict the outcome of events (Kaur et.al, 2011).

2.4 t-test

For checking the significance t-test was conducted and the formula is given below by equation (2):

$$t = \frac{|\overline{x1} - \overline{x2}|}{\sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}}} \quad (2)$$

where,

$\bar{x}1$ = average value of 1st parameter
$\bar{x}_2$ = average value of 2nd parameter
n_1 = number of reading of 1st parameter
n_2 = number of reading of 2nd parameter
s_1 = standard deviation of 1st parameter

s_2 = standard deviation of 2nd parameter

In case of standard deviation, the formula is given below by equation (3):

$$S = \sqrt{\frac{\sum (x-\bar{x})^2}{n-1}} \quad (3)$$

After finding the t value it was checked by the critical value from t-table provided by (Pearson et.al, 1966). The table 1 is shown below.

Table 1: Critical values of the t distribution

df	One-Tail = .4 Two-Tail = .8	0.25 0.5	0.1 0.2	0.05 0.1	0.025 0.05	0.01 0.02	0.005 0.01	0.0025 0.005	0.001 0.002
1	0.325	1.000	3.078	6.314	12.706	31.821	63.657	127.32	318.31
2	0.289	0.816	1.886	2.920	4.303	6.965	9.925	14.089	22.327
3	0.277	0.765	1.638	2.353	3.182	4.541	5.841	7.453	10.214
4	0.271	0.741	1.5333	2.132	2.776	3.747	4.604	5.598	7.173
5	0.267	0.727	1.476	2.015	2.571	3.365	4.032	4.773	5.893
6	0.265	0.718	1.440	1.943	2.447	3.143	3.707	4.317	5.208
7	0.263	0.711	1.415	1.895	2.365	2.998	3.499	4.029	4.785
8	0.262	0.706	1.397	1.860	2.306	2.896	3.355	3.833	4.501
9	0.261	0.703	1.383	1.833	22.262	2.821	3.250	3.690	4.297

I Considered p level at p = 0.05 (5%), which means 95% confident. Also considered two tailed tests.

If calculated t value < critical t value, then accept null hypothesis (H_0)
If calculated t value > critical t value, then reject null hypothesis (H_0)

Where null hypothesis means there is no significant difference and $t > t_c$ this would mean there is a significant difference.

2.5 Regression analysis

Regression analysis is a set of statistical methods for estimating the relationships among variables. It measures the nature and extent of correlation and predicts the unknown values of one variable from known values of another variable (Agarwal et.al, 2011). The regression equation (4) is shown below

$$y = a + bx \quad (4)$$

where a is called y axis intercept and b is the slope of regression line. Now a and b can be expressed by the following equations (5) & (6).

$$b = \frac{\sum xy - n\bar{x}\bar{y}}{\sum x^2 - n\bar{x}^2} \quad (5)$$

and $a = \bar{y} - b\bar{x}$ (6)

2.6 Drinking water quality index (DWQI)

Water quality assessment was carried out using WQI, which is widely used for evaluating drinking water quality. The WQI was initially invented by Brown et.al (1970) and then modified by Backman et.al (1998). According to the reports by the "World Health Organization (WHO)" in 2004, using

WQI would help to clarify combinatorial effect of each parameters as well as all qualitative parameters on drinking water quality (Abbasnia et.al, 2018). Each of the parameters has been assigned according to its relative importance in the overall quality of water for drinking purposes. The relative weight was computed using the following equation (7):

$$Wi = \sum \frac{wi}{\sum_{i=1}^{n} wi} \tag{7}$$

Where,

Wi = relative weight of each parameter
wi = weight of each parameter
n = number of parameters

For each parameter, the quality rating scale was calculated by dividing its concentration in each water sample to its respective standards (released by World Health Organization 2011) (Edition 2011) and finally multiplied the results by 100 through equation (8).

$$qi = \left(\frac{Ci}{Si}\right) x\ 100 \tag{8}$$

Where,

qi = the quality rating
Ci = concentration of each parameter (mg/L)
Si = standard limit (mg/L) according to WHO released in 2011

The quality of water is calagorized into five types which is shown in table 2

For computing of sub index of each parameter, weight (Wi) of each parameter is needed which is shown in table 3.

Table 2: Rating of water quality index (Tyagis et.al, 2013)

WQI value	**Rating of water quality**	**Grating**
0-25	Excellent water quality	A
26-50	Good water quality	B
51-75	Poor water quality	C
76-100	Very poor water quality	D
Above 100	Unsuitable for drinking purposes	E

Table 3: The weight (wi) and WHO standard values for drinking water

Parameters	**Concentration (mg/L) (Ci)**	**WHO (mg/L) (Si)**	**weight (wi)**
pH	7.64	6.5-8.5	4
E.C	1102	750	4
TDS	1280	500	4
Cl-	600	250	3
NO3-	0.15	10	5
turbidity	3.01	4	3
alkalinity	260	300	3
Mn	0.1	0.1	4
Fe	0.32	0.3	4
		Sum =	34

In the final stage of WQI computing the SIi was first determined for each parameter and then the sum of SIi values gave the WQI for each sample shown in equations (9) &(10)

$$SIi = Wi \times qi \tag{9}$$

Where, SIi is the sub-index of each parameter

$$WQI = \sum_{i=1}^{n} SIi \tag{10}$$

Where, WQI is the water quality index

3. RESULTS AND DISCUSSION

At first the concentration of water quality parameters was determined in the laboratory and compared with allowable limit referred by ECR (1997) for groundwater sample. The data are shown in Table 4.

Table 4: Values of physicochemical parameters with Bangladesh standard

Items	pH	Chloride (mg/L)	E.C (µs/cm)	Turbidity (NTU)	TDS (mg/L)	alkalinity (mg/L)
Location 1	7.2	420	1400	4.44	860	295
Location 2	7.6	230	538	2.11	486	255
Location 3	7.64	600	1102	3.01	1280	260
Location 4	7.82	500	800	1.95	980	225
Sum	30.26	1750	3840	11.51	3606	1035
average (X)	7.565	437.5	960	2.8775	901.5	258.75
Standard deviation (S)	0.261	156.710	373.0273	1.1413	328.5254	28.686
Variance	0.068	24558.333	139149.3	1.3027	107929	822.916
n	4	4	4	4	4	4
BD standard	6.5-8.5	150-600(mg/L)	-µs/cm	10 NTU	1000 (mg/L)	200 (mg/L)

The above value shows pH are within allowable limit, chlorides are also within allowable limit, but in case of Bangladesh some region above 250mg/L amount of chloride creates salty tastes in drinking water. Due to moderate amount of chloride present in water EC shows high values and there is no Bangladesh standard limit in this case. Turbidity values are within limit. Drinking natural alkaline water is generally considered safe, since it contains natural minerals. Alkalinity acts as a buffer.

For the calculation of correlation coefficient and t-test, some calculation has already shown above table. Different pairs of water quality parameters with significant correlation coefficients are given in Table 5.

Table 5: correlation between different pairs of parameters and t-test results

SL No	Pairs of Parameters	correlation	t test	Significant or not significant ($p<0.05$)
1	pH & Cl-	0.2216	5.4869	Significant
2	pH & E.C-	-0.7024	5.1065	Significant
3	pH & Turbidity	-0.9201	8.0063	Significant
4	pH & Alkalinity	-0.9721	17.5117	Significant
5	pH & TDS	0.1901	5.4421	Significant
6	Cl- &E.C	0.5299	2.5827	Significant
7	Cl- &Turbidity	0.1779	5.5467	Significant
8	Cl- & Alkalinity	-0.1306	2.2439	Not Significant
9	Cl- & TDS	0.9929	2.5495	Significant
10	E.C & Turbidity	0.9227	5.1316	Significant
11	E.C & Alkalinity	0.7198	3.7487	Significant
12	E.C & TDS	0.5392	0.2354	Not significant
13	Turbidity & Alkalinity	0.9263	17.8251	Significant
14	turbidity & TDS	0.2056	5.4706	Significant
15	alkalinity & TDS	-0.0750	3.8981	Significant

In the present study, pH has strong significant negative correlation with E.C (r = -0.7024, t = 5.1065), turbidity (r = -0.9201, t = 8.0063). The chloride has weak negative correlation with alkalinity (r = -0.1306, t = 2.2439); weak correlation for alkalinity with TDS (r = -0.0750, t = 3.8981) also pH has strong negative correlation with alkalinity (r = -0.9721, t = 17.5117). This shows that with any increase or decrease in the values of pH; electrical conductivity (E.C), turbidity, alkalinity exhibit decreases or increase in their values.

EC shows significant strong positive correlation with turbidity (r = 0.9227, t = 5.1316), alkalinity (r = 0.7198, t = 3.7487) also for chloride with TDS (r = 0.9929, t = 2.5494). Turbidity shows significant strong positive correlation with alkalinity (r = 0.9263, t = 17.8251). Chloride has moderate positive correlation with E.C (r = 0.5299, t = 2.5827) also has weak positive correlation with turbidity (r = 0.1779, t = 5.5467).E.C has moderate positive correlation with TDS (r = 0.5393, t = 0.2354). pH shows weak positive correlation with chloride (r = 0.2216, t = 5.4869) also for pH with TDS (r = 0.1901, t = 5.4421); for turbidity with TDS (r = 0.2056, t = 5.4706). The result of calculated correlation coefficient using equation further checked by MS Excel using CORREL function. Figure 2 represent strong positive correlation between alkalinity and turbidity. Regression equation also shows in the graph. R^2 (coefficient of determination) reveals that 86% in the variation of turbidity is due to variation of alkalinity.

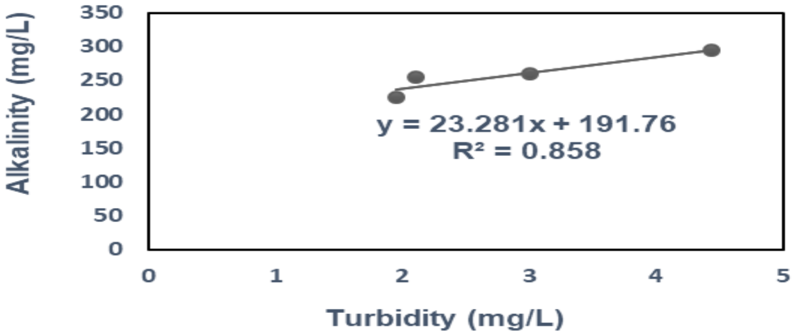

Figure 2: Correlation between alkalinity and turbidity

Figure 3 represents strong negative correlation between alkalinity and pH. Regression equation of pH also shows in this graph. The intercept (expected mean) value is 1065.6 and slope is -106.66. For any value of pH the value of alkalinity can forecast.

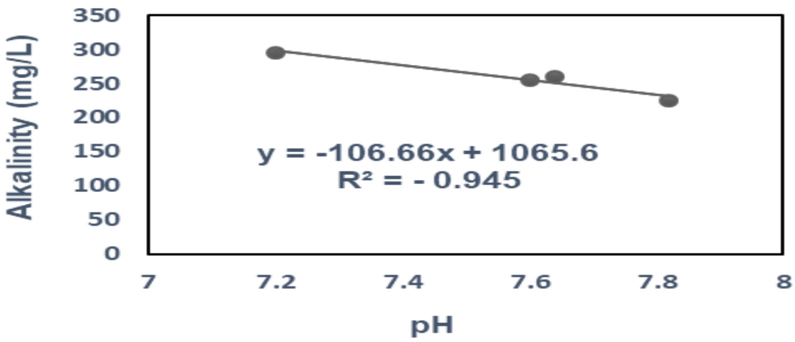

Figure 3: Correlation between alkalinity and pH

Figure 4 represents strong positive correlation between TDS and chloride. Regression equation of chloride also shows in this graph. The intercept value is -9.1591 and slope is 2.081. For any value of chloride, the value of TDS can forecast without laboratory test. If the independent variables can't all equal zero, or one get an impossible negative y-intercept, don't interpret the value of the y-intercept! The developed equations can further apply to predict the approximate value of one variable with respect to another which is a time saving process.

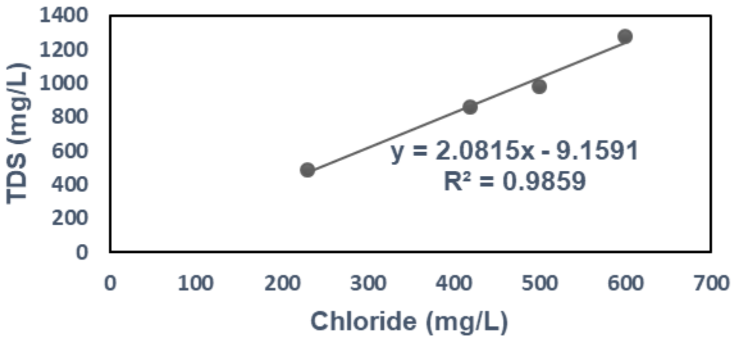

Figure 4: Correlation between TDS and Chloride

Now it is necessary to calculate the degrees of freedom and go to the t-table 1 to determine if the t-test is significant at $p < 0.05$. The degree of freedom in this study was (4+4-2) = 6 and for 5% p value and for two tailed test the critical t value was 2.447.

So, the t-test result indicating a 95% probability of a significant difference between pH with chloride, electrical conductivity (E.C), turbidity, alkalinity. Also, a 95% probability of a significant difference between electrical conductivity with turbidity, alkalinity; turbidity with alkalinity; chloride with E.C, turbidity. But in case of chloride and alkalinity null hypothesis means there is no significant difference shows.

Table 6: Results of WQI for location 1

Parameters	Concentration (mg/L) (Ci)	WHO (mg/L) (Si)	weight (wi)	relative weight(Wi)	qi = (Ci/Si)*100	SIi = Wi*qi
pH	7.2	6.5-8.5	4	0.117647	96	11.29412
E.C	1400	750	4	0.117647	186.66	21.96
TDS	860	500	4	0.117647	172	20.23529
Cl-	420	250	3	0.088235	168	14.82353
NO3-	0.2	10	5	0.147059	2	0.294118
turbidity	4.44	4	3	0.088235	111	9.794118
alkalinity	295	300	3	0.088235	98.33	8.676176
Mn	0.5	0.1	4	0.117647	500	58.82353
Fe	0.47	0.3	4	0.117647	156.66	18.43059
		Sum =	34		WQI =	164.3315

As the required WQI exceeds value of 100, so it is said that the water quality in this location is not suitable for drinking purposes and grating as E (Table 2).

The value of WQI was found 72.99 reveals in the ranges of 76 to 100, so the water quality is very poor for location 2 and grating as D. In addition, the value of WQI exceeding 100 (119.38) for location 3 and the water quality is not suitable for drinking purposes and the grating is as E. And finally, for location IV the value is 80.08 which is between the range of 76 to 100 that means water quality is very poor of this location and grating as D.

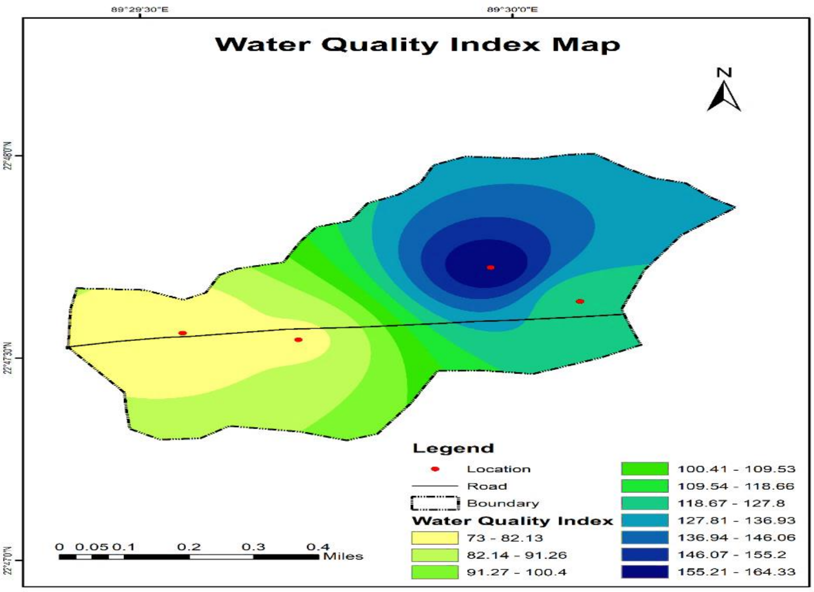

Figure 5: Spatial variation of water quality index by ArcGIS

The graph represents the spatial variation of WQI around Rajbandh dumping site. Low WQI value less than 50, represent good quality water. The yellow to green sign indicates the location of poor to very poor water quality, on the other hand, the blue to deep blue sign indicates lager WQI values unsuitable water quality for drinking purposes because it is location of landfill. So, graph mainly represents WQI reduces from landfill to surrounding locations because at landfill location groundwater quality somehow affect by solid waste.

4. CONCLUSIONS

Generally, groundwater is an important source for drinking purposes. Usually use of correlation coefficient (a value between -1 and 1) to display how strongly two variables are related to each other. A comprehensible negative correlation was found for pH with electrical conductivity (E.C), turbidity, alkalinity. A significant positive correlation was found for E.C with turbidity, alkalinity and for turbidity with alkalinity. The obtained values of correlation coefficients and their significance levels which was tested by t-test will help in selecting the precise treatments to reduce the contamination of groundwater around Rajbandh dumping site. Regression analysis also determined. The developed equations further can be used to findout the value of one parameter with respect to another if time is limited or budget is shorted. The above analysis is also cost effective and time saving because statistical equations used for calculating the value of physicochemical parameters and to measure the limit of pollution in groundwater around Rajbandh so that some preventive measure can take before the detailed observation. The average data of at least two years as well as by considering seasonal variation could bring more accurate analysis.WQI was used to analyze the underground water quality of study site.The test result reveals that 50% water samples were found poor quality and 50% water samples were found unsuitable for drinking purposes. Also, GIS based Graph showed WQI reduced from landfill to surrounding locations.So, it can be said that overall the groundwater quality of most of the locations were not suitable for drinking purposes or need to be treated. The results support the need for continuous monitoring of the groundwater.

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