Proceedings of the 5th International Conference on Civil Engineering for Sustainable Development (ICCESD 2020), 7~9 February 2020, KUET, Khulna, Bangladesh (ISBN-978-984-34-8764-3)

ANALYSIS OF SURFACE WATER QUALITY ADJACENT TO THE WASTE DISPOSAL SITE IN KHULNA

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ABSTRACT

Surface water near waste disposal sites are vulnerable due to the easy accessibility of the disposed contaminants. Heavy metal contamination in surface water is one of the major quality issues in regards of the sources of drinking water. This study was conducted mainly to assess the effect of the heavy metal concentrations in surface water during dry and rainy season in the year of 2019. Surface water samples were collected from 25 sampling points adjacent to a selected waste disposal site at Rajbandh, Khulna, Bangladesh. In the laboratory, the concentration of heavy metals like Fe, Mn, Cr, Cu, Pb, Zn, Ni, Cd and As in surface water were measured. The metal contaminations were evaluated using contamination factor (CF), contamination load index (CLI) and water quality index (WQI). The heavy metal contamination index (HPI),metal quality index (MQI),ecological risk index (ER) and potential ecological risk index (PERI) were also computed to evaluate the level of contamination of surface water of these heavy metals.The results of the index showed that almost all the sampling points of surface water were moderate to highly contaminated. The results of water quality index (WQI) were then compared withWQI from fuzzy synthetic analysis to get accurate distinction between utilization purpose.Even though the conventional WQI showed the results having the water samples lower quality; WQI from fuzzy synthetic analysis showed optimistic results in number of cases. The conventional WQI of station 7 in dry season was in class D; however, WQI from fuzzy showed the water quality was better in class C. Gradual improvement potential was seen in fuzzy analysis with the increasing distance from the waste disposal site as well.To treat the data sets Pearson correlation and cluster analysis has been done. Some heavy metals were positively correlated and the results of cluster analysis clearly states that the sources of heavy metal contamination are from two different sources of anthropogenic and geogenic.

Keywords: *Waste disposal site, Surface water, Heavy metal, Water quality indices, Fuzzy analysis, Water quality index, Pearson correlation, Cluster analysis.*

1. INTRODUCTION

The assessment of surface water quality is very important especially where it is considered to be used on drinking purpose. If the sources are under the threat of contamination it can lead to have various health issues including long term diseases(Satar, 2017). As the urbanization is growing fast; the disposed contaminants are also increasing in an alarming rate. Especially surface water sourcesin areas adjacent to waste disposal site are great concern due to the higher rate of possibility to get contaminated by the waste disposal site materials(Puri, 2015).These sources are more exposed to contamination. It is very important to know the rate of contamination and sources of contamination to manage the land and water resources. Identification and categorization of the contamination is a very important in management of ensuring potable water around the area. Seasonal variation also has a significant impact on the contamination rate. The variation in rainfall intensity, run off, agricultural method, atmospheric characteristics have strong effect on contamination(Rama Pal, 2017).Usually in clean water the concentration of heavy metal is very low and mostly subjected to other water quality parameter measures to ensure its drinking quality(World Health Organization, 1998). But the heavy metal concentration adjacent to waste disposal site gets additional concern along with other physiological water quality parameters as they are also relatively dependent on the heavy metal concentration. The sources of heavy metal in surface water can be geogenic or anthropogenic(APHA, 2012). The anthropogenic sources adjacent to disposal site is mainly for various waste, external disposal of waste, pesticide and chemicals from crop fields(Mohd Zahari Abdullah, 2016).

The study was assessed on the surface water of 25 different sampling site around the waste disposal site in Rajbandh, Khulna in both dry and rainy season. The study also evaluated the drinking quality of the water samples along with the possible adverse health impact on the habitants of the area. In the laboratory, the concentration of heavy metals like Fe, Mn, Cr, Cu, Pb, Zn, Ni, Cd and As in surface water were measured. The metals contaminations were evaluated using contamination factor (CF), contamination load index (CLI) and water quality index (WQI). The heavy metal contamination index (HPI),metal quality index (MQI), ecological risk index (ER) and potential ecological risk index (PERI) were also computed to evaluate the level of contamination of surface water of these heavy metals. The fuzzy synthetic evaluation technique was also done among ten of the water quality parameters to compare the conventional WQI with WQI from Fuzzy analysis. The results came out to be optimistic than conventional WQI and more distinct in classification to be (Chanapathi, 2019) useful for various purpose. The conventional WQI showed results of the water samples poor but WQI from fuzzy synthetic analysis showed improved results in number of cases. For example, the conventional WQI of station 7 in dry season was in class D; fuzzy showed the water quality was better in class C. Gradual improvement potential was seen in fuzzy analysis with the increasing distance from the waste disposal site as well. In addition, the data sets were analyzed by cluster analysis (CA) and Pearson correlation analysis. From the CA the sources of heavy metal in surface water has been found to be anthropogenic and geogenic.The results of multivariate indices of all the sampling points seemed to be contaminated in terms of standard drinking limits (BIS, 1998).

2. METHODOLOGY ADOPTED

2.1 Description of Study area

The waste disposal site at Rajbandh, Khulnawas selected as case study. The geological coordinate of the radial center of the sampling points are 22.794722 (Latitude) & 89.499722 (Longitude).A location map of the study area with sampling details formulated by the software ArcGIS is shown in Figure 1.

2.2 Collection of Surface Water Samples

Before collecting surface water samples, the bottles were washed with distilled water and the bottles were air-dried. A solution prepared by concentrated nitric acid and distilled water was used as preservatives by adding to an amount of 2-3 mL to the bottles. The concertation of water and nitric acid was to the ratio of 1:1. The bottles were kept for about a day in order to prevent any precipitation of metal substance or biological contaminate activities and prepared for the sample collection. Total 25 location of surface water sources adjacent to the waste disposal site were selected for the sample collection. The sampling points included the nearby pond, pothole and confined water in the crop field. The locations were tracked by their GPS coordinates. Sample collection was done from the same location both in dry and rainy season.

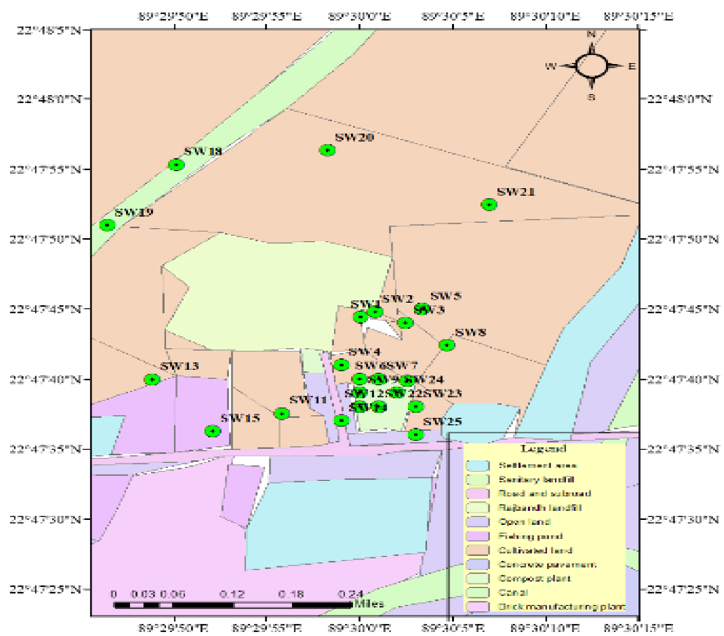

Figure 1: Location map showing sampling details of selected waste disposal site at old Rajbandh, Khulna.

2.3 Laboratory Investigations

The surface water samples in two different seasons were collected as well as the concentrations of heavy metal other physiochemical tests were measured according to the standard test methods.

2.4 Indices

To evaluate the various indices of the collected surface water samples this study was focused in physiochemical parameters and heavy metal contamination parameters. All the indices were determined to come to the point of decision of the sample water is contaminated or not. If contaminated, then to determine the severity of contamination with the reference of drinking water parameter. The indices were determined based on the research proposed by various researchers and hence discussed in the following articles.

2.4.1Contamination Factor

The contamination factor (CF) is determined by the following Equation[1], where C_{metal}= metal element concentration and $C_{background}$= background value of same metal element(S. Gupta, 2019). CF < 1 indicates low contamination, 3<CF<6 is considerable contamination and CF>6 refers very high contamination.

$$CF = \frac{C_{metal}}{C_{background}} \ldots\ldots [1]$$

2.4.2 Heavy Metal Contamination Index

Heavy metal contamination index shows the composite influence of the heavy metal individually and rates the contamination rate(Singh, 2013). w_i= the weight associated with the heavy metal of concern and Q_i= sub index of i^{th} heavy metal. Here n is the number of heavy metal measured in the following Equation [2].

$$HPI = \frac{\sum_{i=1}^{n} W_i Q_i}{\sum_{i=1}^{n} W_i} \ldots\ldots [2]$$

The critical value of HPI is 100. If HPI value crosses100 indicates that the water sample is critically polluted with the heavy metal content(Rama Pal, 2017).

2.4.3 Metal Quality Index

The higher the concentration of a metal substance in the water to the respective permissible limit the worse the quality of the water(Pal, 2017). The metal quality index MQI can be calculated by the following Equation [3]:

$$MQI = \sum_{i=1}^{n} \frac{M_i}{S_i} \ldots\ldots [3]$$

Where M_i= observed heavy metal concentration and $S_{i=}$ permissible standard value of the respective heavy metal. MQI> 1 is a threshold of concern.

2.4.4 Potential Ecological Risk Index

Potential ecological risk index (PERI) is based on the summation of ER of heavy metals (Santos-Francés, 2017)by Equation [4]:

$$PERI = \sum ER \ldots\ldots [4]$$

The Ecological Risk Degree for PERI proposed by as PERI<40 refers slight, 40<PERI<80 refers medium, 80< PERI< 160 refers strong,160< PERI < 320 refers very strong,PERI > 320 refers extremely Strong.

2.5Water Quality Index &Fuzzy Synthetic Evaluation of Water Quality Index

The water quality index (WQI) has been the most efficient method to determine the water quality of a certain water body approach consists of variousparameters. In this study, pH, DO, SS, Turbidity, COD, EC, Cl, SO_4, NO_3, Na has been used. 100 being the finest quality and 0 being the lowest of WQI value. The values of WQI was computed using Equation [5].

$$WQI = \frac{\sum_{i=1}^{n} w_i q_i}{\sum_{i=1}^{n} w_i} x\ 100 \ldots\ldots [5]$$

Here, w_i= the weight of the parameter of concern [Table 3] and q_i= water quality parameter (Puri, 2015). Here n is the number of constituents (Bhatri N, 2011). In this study, the values of w_i and q_i were considered in accordance with BIS (1998). The class indicating by the WQI value is shown in Table 1.

Lately the increasing use of water the unclear distinction among the classification leaves major impact in critical area with possible source of high contamination. Using fuzzy synthetic evaluation, the uncertainties can be solved and the classification can be more focused so that the water that is not suitable for drinking purpose can be used for other purpose for the best utilization.(Ni-Bin Chang, 2001). The fuzzy membership functions were used for various parameter using MATLAB. The results of the individual functions merged to the ultimate result which differs from the conventional cases. Out of all the water parameters ten parameters like pH, DO, SS, Turbidity, COD, EC, Cl, SO_4, NO_3, Na were selected for this evaluation. The membership function of the parameters has been shown from Figure 2 to Figure 11. How the membership function in fuzzy evaluation works that may be understood by the rules shown inTable 2 with some parameters as example.In this study a comparison between traditional WQI and the results of WQI from fuzzy evaluation was done.

Table 1: Class with WQI values

Class	**WQI**
A	90-100
B	80-90
C	60-80
D	30-60
E	0-30

Table 2: Rules with membership functions in fuzzy logic

Parameter	**Rule 1**	**Rule 2**	**Rule 3**
pH	Excellent	Good	Good
DO	Excellent	Good	Poor
SS	Excellent	Poor	Good
Turbidity	Good	Very good	Very Good
class	Excellent	Good	Good

Table 3: Parameters with weightage and weightage limit

Parameter	unit	BIS limit	Weight(w_i)
pH	-	7.5	4
DO	mg/L	5	3
TSS	mg/L	200	2
Turbidity	NTU	5	2.4
COD	mg/L	300	3
EC	µS/cm	2000	2.5
Cl	mg/L	250	3
SO4	mg/L	200	3
NO3	mg/L	45	4
Na	mg/L	100	3

Table 4: Water quality classification with utility

Class	**A**	**B**	**C**	**D**	**E**
	1. Public water supply without treatment 2.Swimming	1.Public water supply (Conventional treatment needed) 2. Fishery 3. Can be used for sensitive aquatic species	1.Public water supply (Extensive treatment needed) 2.Fishery (Secondary level) 3. Industry water supply (Primary level)	1. Irrigation 2. Industrial water supply (Secondary level) 3. Can be used for tolerant aquatic species	Environment protection
pH	6.5-8.5	6.0-9.0	6.0-9.0	6.0-9.0	6.0-9.0
DO	>6.5	>5.5	>4.5	>2.0	>2.0
SS	<25	<25	<40	<100	-
Turbidity	<5	5-10	10-20	20-250	>250
COD	<10	25	50	100	>100
EC	<100	1000	1750-2250	2250-4000	>4000
Chloride	0-50	50-100	100-300	300-500	>500
SO_4	<50	50-150	250	350	450
NO_3	<2.5	7.5	15	25	>25
Na	31.25	93.75	156	218	281.25

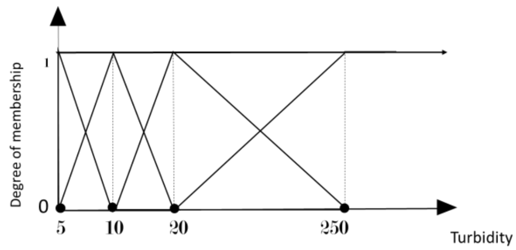

Figure 2: Membership function for turbidity

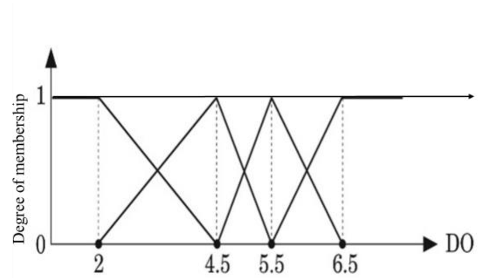

Figure 3: Membership function for DO

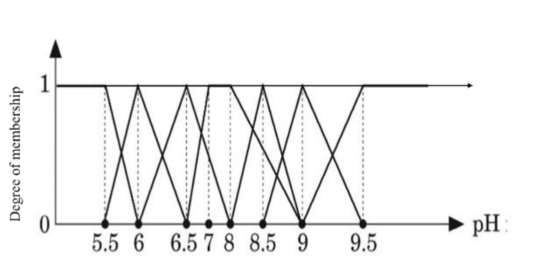

Figure 4: Membership function for pH

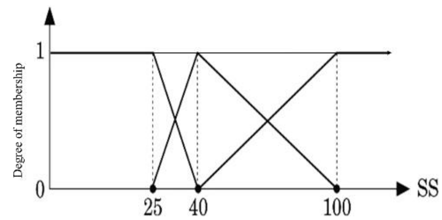

Figure 5: Membership function for SS

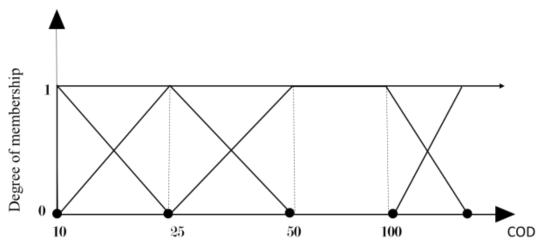

Figure 6: Membership function for COD

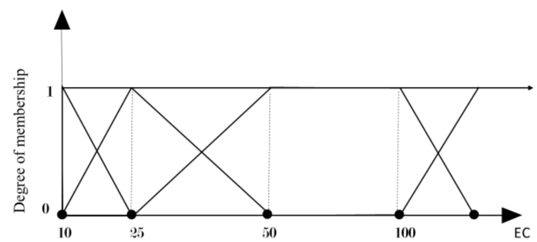

Figure 7: Membership function for EC

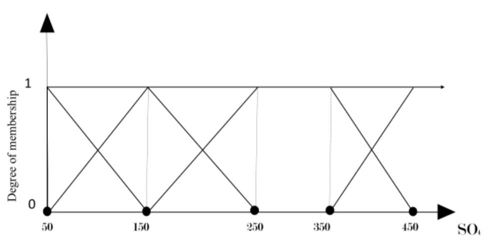

Figure 8: Membership function forSO_4

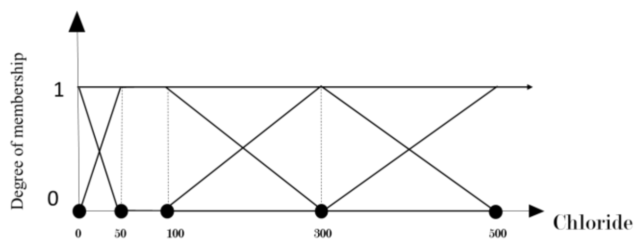

Figure 9: Membership function for Chloride

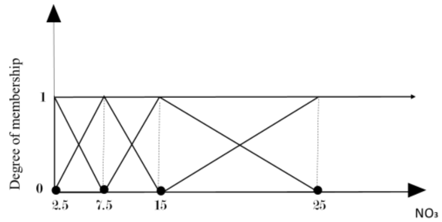

Figure 10: Membership function for NO_3

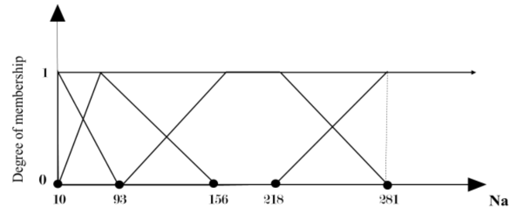

Figure 11: Membership function for Na

3. RESULTS AND DISCUSSION

The basis statistical analysis, results of various indices and the level of contamination, results from Fuzzy synthetic analysis as well as Pearson's correlations are analyzed and hence discussed in the following articles.

3.1 Basic Statistical Analysis

In the laboratory, the water quality parameters like pH, turbidity, electrical conductivity, sulphate, phosphate, nitrate, BOD, COD, DO, SS, TDS, Fe, Mn, Cr, Cu, Pb, Zn, Ni, Cd and As were measured for both dry and rainy seasons. The results of heavy metal are provided in Table 4. The heavy metal Zn showed maximum concentration of 1.06 mg/L and 1.7 mg/L in both and dry season respectively, while Cd minimum concentration of .00093 and 0.00095 in dry and rainy season, respectively. The standard deviation of Zn was highest in both dry and rainy season having the value of 0.2226 and 0.3267 respectively. Cd showed the lowest standard deviation of value 0.0023 and 0.0017 in dry and rainy season respectively.

Table 4: Basic statistical data of observed heavy metal in dry and rainy season

	Rainy season					Dry Season				
Metal	**Min**	**Max**	**Mean**	**SD**	**Variance**	**Min**	**Max**	**Mean**	**SD**	**Variance**
Fe	0.1200	0.6400	0.3296	0.1565	0.0245	0.1200	0.5000	0.3441	0.0864	0.0075
Mn	0.1060	0.8930	0.3474	0.1706	0.0291	0.1500	0.7600	0.3496	0.1442	0.0208
Cr	0.0020	0.0140	0.0062	0.0032	0.0000	0.0020	0.0140	0.0056	0.0031	0.0000
Cu	0.2000	0.8300	0.4717	0.1758	0.0309	0.2000	0.7200	0.4667	0.1310	0.0172
Pb	0.0100	0.0600	0.0299	0.0116	0.0001	0.0100	0.0400	0.0225	0.0075	0.0001
Zn	0.1793	1.0670	0.7093	0.2226	0.0496	0.4375	1.7000	0.8491	0.3267	0.1067
Ni	0.0200	0.1000	0.0479	0.0185	0.0003	0.0230	0.0690	0.0451	0.0124	0.0002
Cd	0.0009	0.0090	0.0041	0.0023	0.0000	0.0009	0.0065	0.0032	0.0017	0.0000
As	0.0148	0.0238	0.0188	0.0024	0.0000	0.0090	0.0300	0.0184	0.0051	0.0000

3.2 Multivariate Indices

The indices indicating the quality of sampled surface water in respect of contamination and drinkable parameter are determined for both the dry and rainy seasons with the increasing distance from the waste disposal site. The comparison between the results of dry and rainy seasons and the variation of the results in sampling location with the increasing distance from the waste disposal site are discussed in followings.

3.2.1 Contamination Factor

The contamination factor (CF) from heavy metals in surface water is shown in Figure 12. Cu being the highest in contribution of contamination factor and Fe was the least in regards of contamination. The variation in dry and winter season was very low. The CF of Zn was slightly higher in dry season than rainy season. Almost every metal showed their CF values in moderately contaminated.

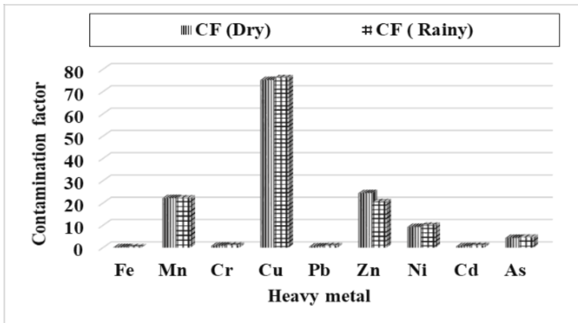

Figure 12: Contamination factor ofheavy metals in surface water for dry and rainy

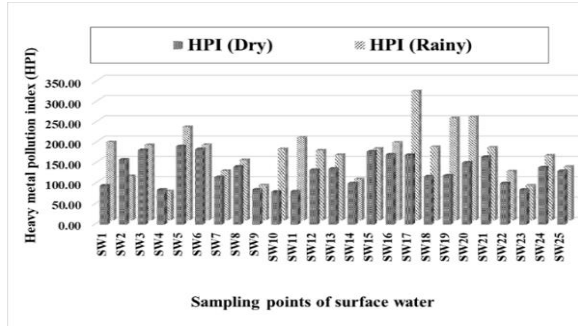

Figure 13: Heavy metal pollution index of surface water for dry and rainy seasons

3.2.2 Heavy Metal Contamination Index

Heavy metal contamination index of the sampling points is shown in Figure 13. HPI crossing 100 indicates critical contamination. In both seasons the HPI indicates critical contamination of heavy metals having higher values in rainy season than dry season.

3.2.3 Metal Quality Index

Metal quality index is shown in Figure 14. MQI of all the points in both rainy and dry season crossed 1. For MQI that is threshold concern. The MQI decreases with increasing distance from disposal site in both cases.

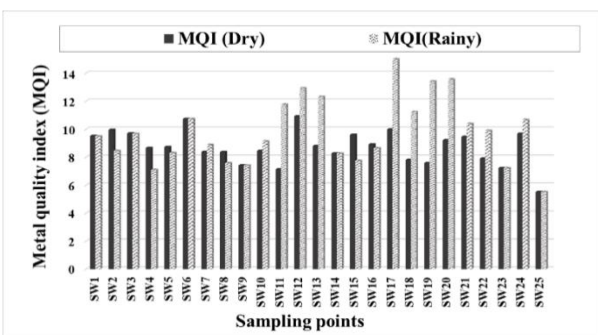

Figure 14: Metal quality index of surface water for dry and rainy seasons

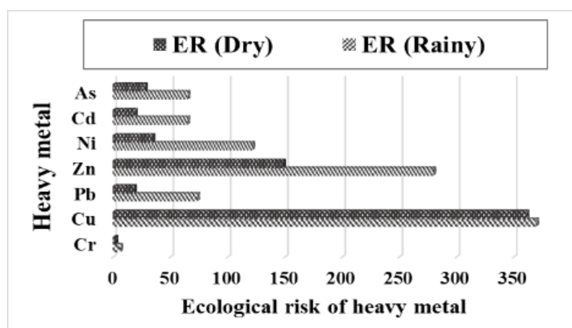

Figure 15: Ecological risk index of surface water for dry and rainy seasons

3.2.4 Ecological Risk Index&Potential Ecological Risk Index

Ecological risk index (ER)is shown in Figure 15 in respect of heavy metal. To calculate the ER one metal is to be taken as reference metal. In this study Fe was taken as reference metal. The ER of As, Cd, Pb and Cr was lower than Cu, Zn and Ni. The ER was lower in dry season and higher in rainy season. The ER range was ER< 30=Slight, 30< ER < 60=Medium, 60< ER < 120=Strong, 120< ER < 240=Very Strong,ER > 240=Extremely Strong.PERI was the summation of ER of all the sampling points shown in Figure 16. The PERI was seen to be lower in dry season and higher in rainy season and decreased thoroughly with the increasing distance of the points from the waste disposal site.

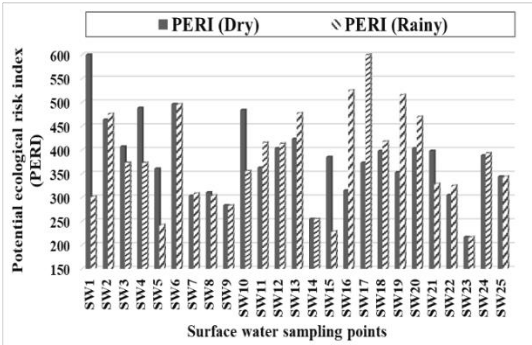

Figure 16: Potential Ecological Risk Index

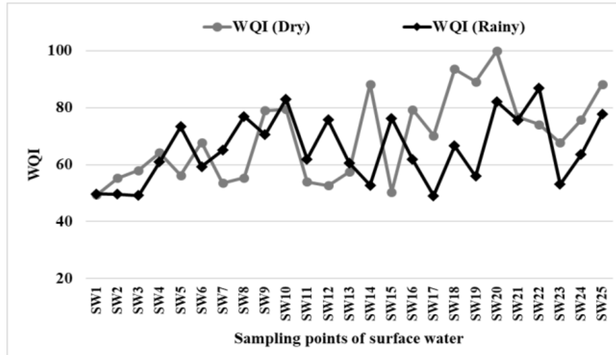

Figure 17: WQI of the surface water sampling stations

3.3 Water Quality Index &Fuzzy synthetic evaluation of Water Quality Index

The area near waste disposal site is critical location for decent water quality for drinking. The results of WQI in class are shown in Figure 17. The WQI values happen to be higher with the increasing distance from waste disposal site. The quality classes were mostly within C and D. Some of them were B and A generally having a distant from the waste disposal site. The requirement is mostly C and B based on the geological condition of the adjacent area. The WQI was found to be lower mostly in terms of requirement. But in fuzzy synthetic evaluation of simple fuzzy classification method and fuzzy information intensity the results are a bit upgraded in some cases which is shown in Table 5. This indicates that the water quality might not be drinkable without treatment in some conditions but can be used in other utility purposes. At station 12 the conventional WQI(Dry) was classified as D but the fuzzy analysis classification wasC indicating a higher quality. The plus (+) and minus (-) indicates the increasing tendency towards better or poor water quality condition. Comparing the outputs, fuzzy analysis indicates that the improvement potentiality was gradual with the increasing water sampling points with respect to the central point of the disposal site. At station 19 the WQI(Rainy) indicates the worst water quality condition D whereas the Fuzzy Synthetic Evaluation indicates relative optimistic condition C+. Similar result variation occurred in other cases.

Table 5: Comparison of WQI with Fuzzy evaluation

SL. No.	Require-ment	WQI (Dry)	Fuzzy method	WQI (Rainy)	Fuzzy method	SL. No	Require-ment	WQI (Dry)	Fuzzy method	WQI (Rainy)	Fuzzy method
SW1	C	D	D	D	D	SW14	C	B	C+	D	C+
SW2	C	D	C	D	C	SW15	C	D	C-	C	C-
SW3	C	D	C	D	C	SW16	C	C	C+	C	C+
SW4	C	C	C	C	C	SW17	C	C	C-	D	C-
SW5	C	D	C	C	C	SW18	B	A	B-	C	B-
SW6	C	C	C	D	C-	SW19	B	B	B	D	C+
SW7	C	D	C	C	B-	SW20	B	A	C	B	B
SW8	C	D	C+	C	C+	SW21	B	C	C-	C	C+
SW9	C	C	C+	C	B-	SW22	B	C	B	B	B+
SW10	C	C	C	B	C	SW23	B	C	C+	D	C+
SW11	C	D	C-	C	C-	SW24	B	C	B	C	B
SW12	C	D	C	C	C	SW25	B	B	B	C	B+
SW13	C	D	C+	C	C+						

4. PEARSON'S CORRELATION

Intermetallic relationships for surface water adjacent to the waste disposal site were significantly correlated by Pearson correlationfor both seasons using XLSTAT. The results for dry season are provided in Table 6. The correlation coefficient *r* indicates if there is a positive correlation and $r^2 > 0.5$ then the correlation among two metals is positive. In dry season the correlated metals are Fe-Cr, Zn-Ni, Cr-Pb. In rainy season Mn-Pb and Mn-Cu are positively correlated.

Table 6: Pearson correlation for dry season

	Fe	*Mn*	*Cr*	*Cu*	*Pb*	*Zn*	*Ni*	*Cd*	*As*
Fe	1								
Mn	-0.213	1							
Cr	0.505	-0.004	1						
Cu	0.170	0.465	0.434	1					
Pb	0.536	-0.272	0.689	0.011	1				
Zn	0.400	-0.340	0.050	0.288	0.076	1			
Ni	0.379	-0.232	0.073	0.097	0.100	0.514	1		
Cd	-0.219	-0.241	-0.486	-0.131	-0.202	0.140	0.078	1	
As	0.318	-0.652	0.085	0.046	0.023	0.573	0.453	0.073	1

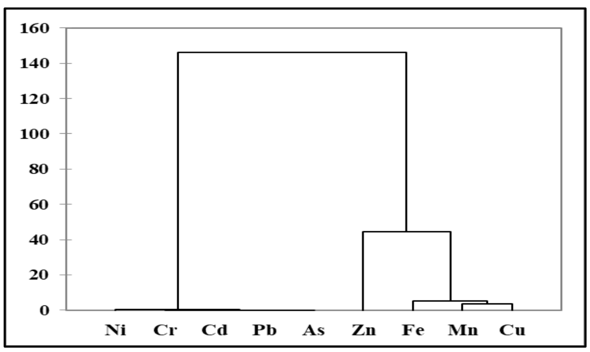

Figure 18: Dendrogram of the selected metals in surface water using ward's method in dry

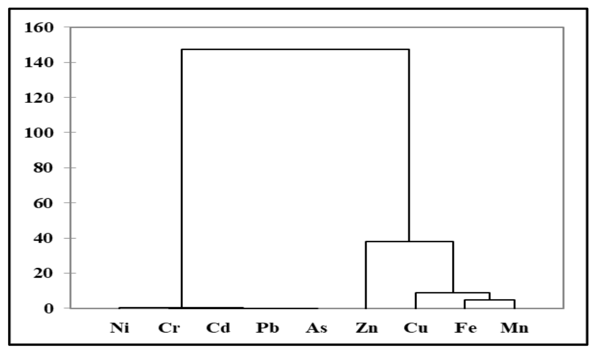

Figure 19: Dendrogram of the selected metals in surface water using ward's method in rainy

5. CLUSTER ANALYSIS

To treat data set of the heavy metal concentration cluster analysis has been performed in XLSTAT software. The metal classification was determined inputting z- transformation, squared the Euclidean distance as dissimilarity measure and ward's method of linkage(Mohd Zahari Abdullah, 2016). With regard to dendrogram for dry season and rainy season is shown in Figure 18 and Figure 19 respectively. In both season the sampling sites were grouped in two clusters. Cluster I includes the Ni, Cr, Cd, Pb and Aswhich indicates these metals are generated from anthropogenic sources and cluster II includes Zn, Mn, Fe, Cu which states that these metals are from geogenic sources.

6. CONCLUSION

In this study multivariate water quality indices were used to determine the overall water quality and the level of contamination. Regarding with heavy metal, the contamination level was also determined and the results were approached with Pearson correlation and cluster analysis (CA).Result reveals the contamination level of surface water categorizing into the severity level and also presented the variation in contamination level during dry and rainy seasons.Surface water in rainy season was generally more contaminated than dry season. Surface water closer to the waste disposal site was more contaminated than the farthest points. The level of contamination gradually decreases in relation to the increasing of sampling points.the conventional WQI of station 7 in dry season was in class D; WQI from fuzzy analysis showed the water quality was better in class C. Gradual improvement potential was seen in fuzzy analysis with the increasing distance from the waste disposal site as well.The fuzzy synthetic evaluation showed optimistic distinction in some of the cases which can be very useful indication for various utilization purpose. Nevertheless, all the points showed that the surface water was moderate to severe contaminated. The metal contaminants are contributed by two possible sources like anthropogenic and geogenic. The local city corporation necessitates proper water treatment policies and management planning of waste disposal site to control the quality of water and spread prohibition drinking this water without treatment.

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