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Application of HPI (Heavy Metal Pollution Index) and Correlation Coefficient For The Assessment Of Ground Water Quality Near Ash Ponds Of Thermal Power Plants

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ABSTRACT:
The objective of the study is to divulge the yearly variation of underground water with the heavy metals like Pb,As,Cd,Se Cr contamination. Heavy metal pollution Index (HPI) is defined as a rating reflecting the composite influence of dissolved heavy metals.HPI is calculated from the point of view of the suitability of ground water for human consumption with respect to metals contamination. The present study is limited to analysis of heavy metals concentration in ground water and heavy metal pollution index and correlation between them is calculated.

KEY WORDS: Heavy metal pollution index (HPI) ,Correlation Coefficient, Heavy Metals ,Angul-Talcher industrial area, Ash ponds

INTRODUCTION:
Water is a most important source for the existence of mankind. Peoples around the world are using ground water as a source of drinking water and even today large population of the world depends on ground water i.e. wells ,tube wells for their survival [1].The ground water values not only depends on the availability but also on the good quality i.e. useable for drinking, domestic and irrigation purpose. The over exploitation of ground water resource and discharge of untreated effluent induces the degradation of water quality [2].Heavy metal contamination in ground water is documented as severe environmental pollution and therefore the study of this problem has become important. The heavy metals enter into the water system through cesspits and flowing water through steams. Heavy metals from industrial wastes are the major sources for pollution. Anthropogenic activities like industrial wastes, agricultural wastes, domestic wastes and the mining operation releases heavy metal s into environment [3, 4]. Heavy metals are serious pollutants because of their toxicity, persistence and non degradability in the environment [5-8] . Some of the metals are useful for metabolic activity of organism, but there is a narrow gap between their essentiality and their toxicity.

MATERIALS AND METHODS:

STUDY AREA:
Angul –Talcher is highly developed industrial belt in ODISHA. The study area (Angul-Talcher region) is bounded by latitudes 20° 37’ N to 21° 10’ N and longitudes 84°53’ E to 85° 28’ E and situated at an average height of 139 m above mean sea level. The river catchment is characterized by Precambrian granites, gneisses and schist’s of Eastern Ghats with local intrusive and volcanic lithologies; lime stone, sand stone and shales of the Gondwanas[9,10,11] .The area comes under sub tropic monsoon climate with an average annual rainfall of 1370 mm. The temperature varies from 20.9° C to 46° C. At present, it accommodates several large and medium scale industries such as NALCO Smelter and its Captive Power Plant (CPP-960MW), Talcher Super Thermal Power Station, NTPC (TSTPS-3000MW), Talcher Thermal Power Station, KANIHA (TTP-460MW), Ferro alloys industries and various coal mines. These industrial activities affect various components of ecology and the environment and impart heavy metal contamination in the ground water.

FIELD SAMPLING:
The common ground water structure near these ash pond area are mostly dug wells and tube wells which are used for drinking as well as domestic and irrigation .In order to achieve the research objective, samples were collected from wells and tube wells at twelve different locations around the ash ponds of TTPS, NALCO and NTPC to evaluate the heavy metal contamination during various seasons summer (MAY –JUNE) and winter (NOVEMBER –

DECEMBER) (FIG-1) from 2010-2015. Criteria for selection of sampling station were based on the locations of industrial units and land use pattern to quantify heavy metal concentration. Four sites were selected near the ash ponds of each industry i.e. NTPC, TTPS and NALCO.In the month of May the water level of the dug well is stood at about 15 meters and in November it stood at about 20 meters in almost all the wells under study. The samples taken from 10 to 15 cm below the water surface using acid washed polyethylene container to avoid unpredictable changes in characteristic as per standard procedures [12]. Samples were collected in May- June each year for summer season, and in November- December each year samples were collected for winter season. Care was taken to collect subsequent samples from same location in both the seasons.

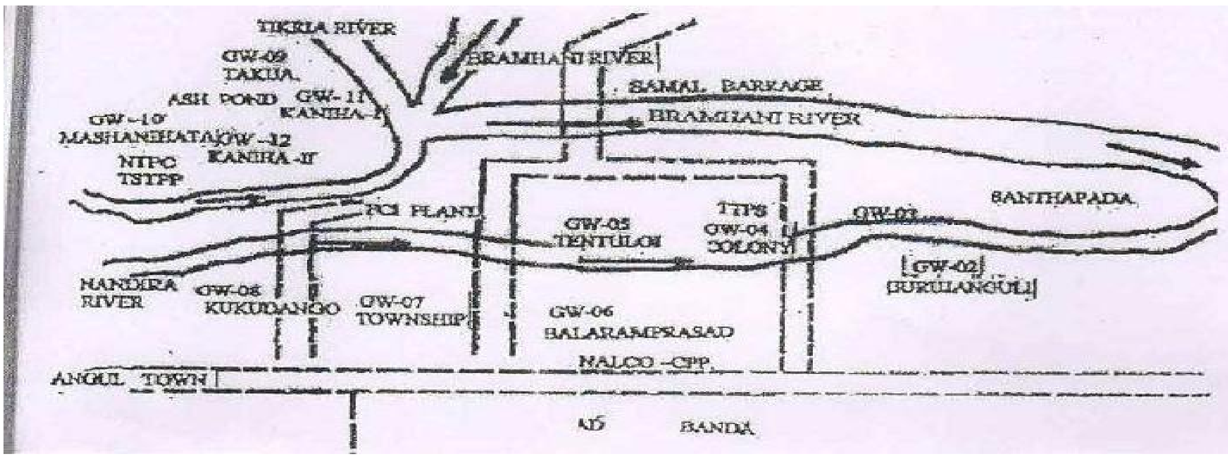

FIGURE-1 SKETCH OF THE STUDY AREA

Sl.No	Sampling Point	Sl.No	Sampling Point
1	Santhapada(NE of TTPS Ash Pond)	7	Township(SW of Nalco Ash Pond)
2	Gurujanguli(SW of TTPS Ash Pond)	8	Kubodanbar (W of Nalco Ash Pond)
3	Anandbazar(W of TTPS Ash Pond)	9	Takua (NE of NTPC Kaniha Ash Pond)
4	TTPS Colony(W of TTPS Ash Pond)	10	Mashannara(W of Nalco Ash Pond)
5	Tanjalal (NE of Nalco Ash Pond)	11	Kaniha I (SE of Nalco Ash Pond)
6	Balaramprasad(SE of Nalco Ash Pond)	12	Kaniha II (SE of Nalco Ash Pond)

LABORATORY METHODS

Water samples were collected from all the respective sampling stations around the ash ponds of the industries. The collected samples were filtered (Whatman no. 42) and preserved with 6N of HNO_3, HCl, and $HCLO_4$for further analysis [12]. Concentrations of heavy metals like Pb, As, Cr, Cd and Se in water samples after $HClO_4$,HNO_3 and HCl digestion were determined with an atomic absorption spectrometer (Model: Perkin ELMER: 303). Average values of three replicates were taken for each season determination. The average concentration value of both the seasons of each year was considered for analysis.

RESULT DISSUSSION:

The results regarding the average concentration values of the various metal concentration of ground water collected during the periods 2010 - 2015. The mean result of the heavy metal analysis of all the samples along with the mean, median, variance and standard deviations of three different areas are shown in Table 1, Table 2, Table 3 and Figures 2-4 given below.

TABLE -1 Average Heavy Metal Concentration near TTPS Ash Pond (all valves are in ppb)

Year	Pb	As	Cr	Cd	Se
2010	11.8	10.015	2.475	1.32	2.4
2011	12.1	10.45	4.57	1.34	2.6
2012	12.7	13	4.84	1.41	3.2
2013	17.92	15.15	5.45	1.7	3.6
2014	18.24	15.5	5.95	2.1	4.6
2015	19.25	17	7.8	2.2	4.9
Mean	15.335	13.51917	5.180833	1.678333	3.55
Median	15.31	14.075	5.145	1.555	3.4
variance of sample	12.07063	8.133604	3.066984	0.153057	1.055
std deviation of sample	3.474281	2.851947	1.751281	0.391225	1.027132

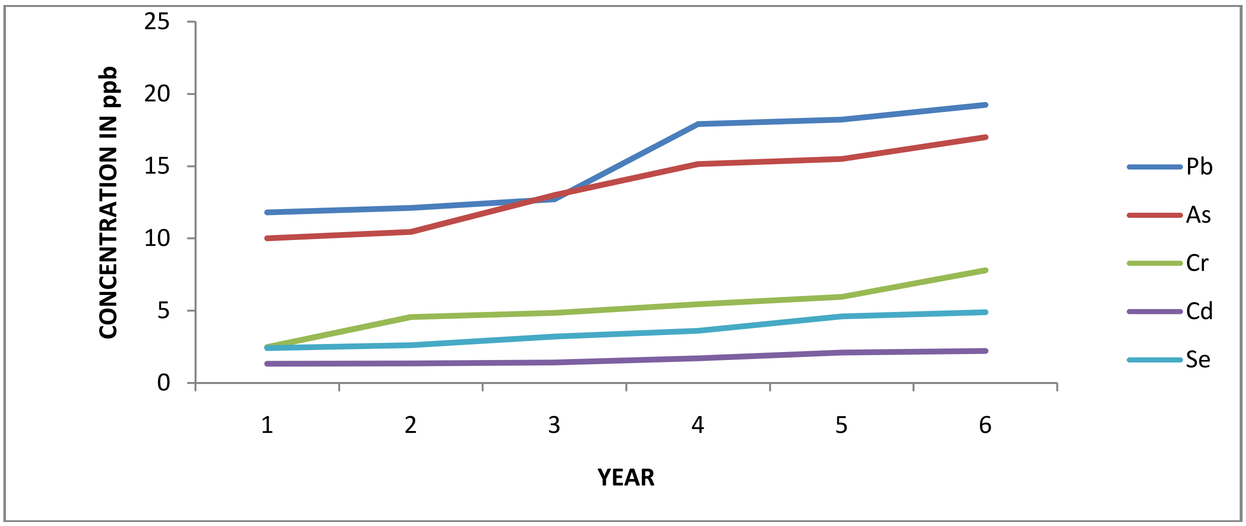

Figure-2 VARIATION OF HEAVY METALS NEAR TTPS ASH POND

TABLE -2 Average Heavy Metal Concentration near NALCO CPP Ash Pond (all valves are in ppb)

Year	Pb	As	Cr	Cd	Se
2010	12.07	9.65	3.775	0.962	3.4
2011	12.66	11.89	3.94	1.28	3.7
2012	14.27	13.71	4.24	1.47	4.1
2013	17.38	15.92	4.86	1.96	4.6
2014	18.68	16.09	6.78	3.12	5.2
2015	19.64	18.01	7.62	3.82	5.4
Mean	15.78333	14.21167	5.2025	2.102	4.4
Median	15.825	14.815	4.55	1.715	4.35
variance of sample	10.32963	9.464897	2.601637	1.276544	0.652
std deviation of sample	3.213974	3.076507	1.612959	1.129842	0.807465

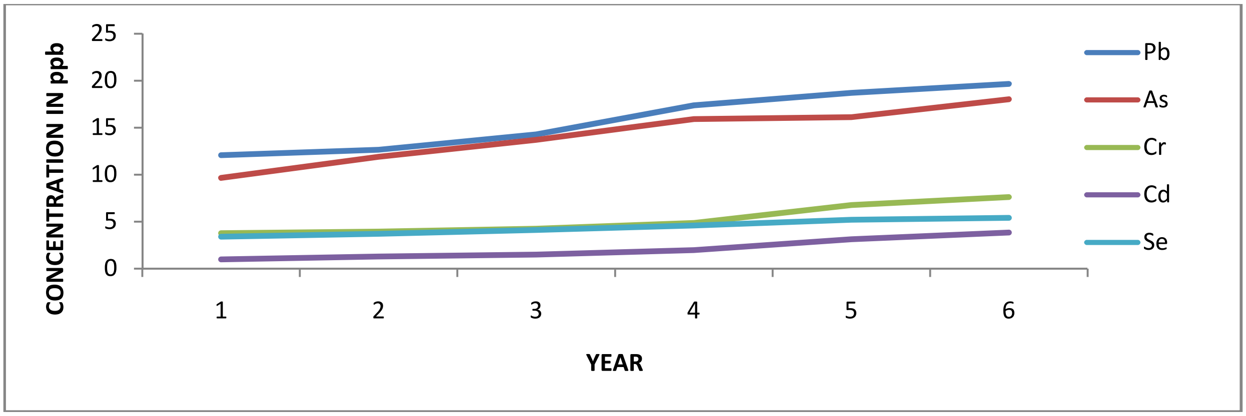

Figure-3 VARIATION OF HEAVY METALS NEAR NALCO CPP ASH POND

TABLE:3Average Heavy Metal Concentration near NTPC Kaniha Ash Pond (all valves are in ppb)

Year	Pb	As	Cr	Cd	Se
2010	40.65	12.25	3.675	1.627	5
2011	42.86	13.65	3.98	1.78	5.7
2012	45.98	14.95	4.41	1.84	7.28
2013	58.14	16.49	5.56	2.28	7.64
2014	60.12	17.57	5.88	2.42	8.2
2015	61.83	18.2	6.32	2.95	9.1
Mean	51.59667	15.51833	4.970833	2.1495	7.153333
Median	52.06	15.72	4.985	2.06	7.46
variance of sample	89.57787	5.368097	1.193884	0.247266	2.377387
std deviation of sample	9.464558	2.316915	1.09265	0.497258	1.541878

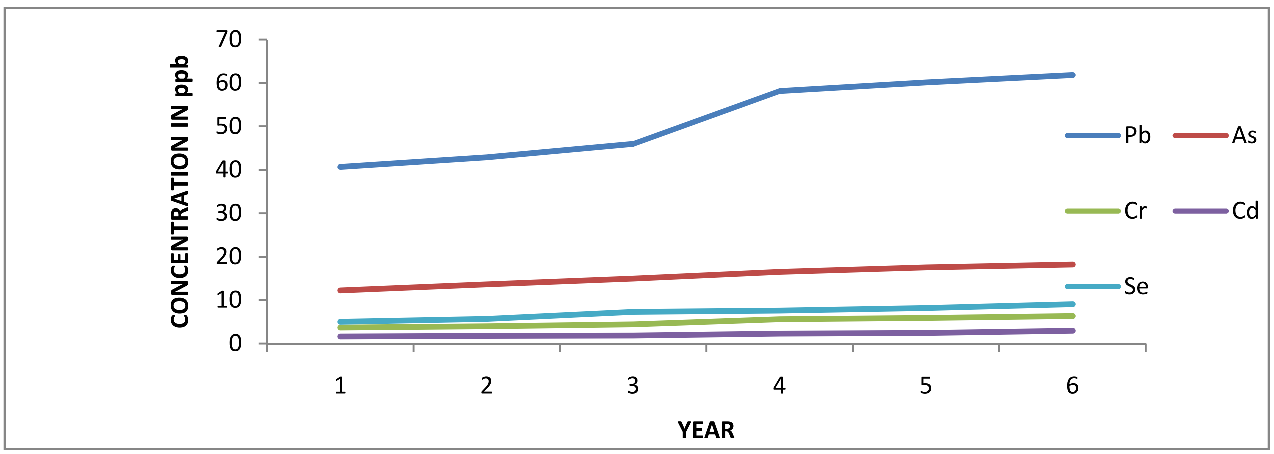

FIGURE-4 VARIATION OF HEAVY METALS NEAR NTPC KANIHA ASH POND

It is observed that in the trend of six years of constant study it was found that there is an increasing trend in the concentration of the different heavy metals i.e. Pb ,As, Cr, Cd , Se but is within the permissible limit as prescribed by ISI. In area 1 i.e. at area around that ash pond near TTPS Thermal Pb , As, Cr , Cd and Se has a mean concentration of 15.34 ppb ,13.52 ppb ,5.18 ppb ,1.68 ppb , and 3.55 ppb respectively. In area 2 i.e. at area around the ash pond near NALCO CPP Pb , As, Cr , Cd and Se has a mean concentration of 15.78 ppb ,14.21 ppb ,5.20ppb ,2.10 ppb , and 4.35 ppb respectively. In area 2 i.e at area around the ash pond near NTPC Kaniha Pb , As, Cr , Cd and Se has a mean concentration of 51.60 ppb 15.52 ppb ,4.97 ppb ,2.15ppb , and &7.15ppb respectively. The increasing trend may be attributed mainly due to increase in industrial activities in these power plants. Further the contamination of underground water is due to the seepage of the industrial waste, mining activities, organic, domestic waste and agricultural waste through soil. The increasing lead concentration may also be due to industrial waste as well as due to the less soluble minerals in natural water [17, 18]. The accumulation of chromium may be due high evaporation of surface water followed by elevated temperature [19].The concentration of cadmium may be due to the coal combustion in the power plants ,metal industry ,waste incineration[20] and also due to the domestic uses .

DATA EVALUATION:

INDEXING APPROACH

Heavy Metal Pollution Index:

Heavy metal pollution index (HPI) is a technique of rating that provides the composite influence of individual heavy metal on the overall quality of water. The rating is a value between zero and one, reflecting the relative importance of individual quality considerations and inversely proportional to the recommended standard (Si) for each parameter. Water quality and its suitability for drinking purpose can be examined by determining its quality index [13, 14, 15, 16]. The calculation of HPI involves the following steps -

1) The calculation of weight age of i^{th} parameter,W_i

2) The quality rating for each of the heavy metal,Qi.

3) The summation of these sub-indices in the overall index

The weight age of i^{th} parameter $Wi = K/Si$ **(1)**

Where Wi is the unit weight age and Si the recommended standard for i^{th} parameter, while k is the constant of proportionality.

Individual quality rating is given by the expression $Qi = 100\ Vi/Si$ **(2)**

Where Qi is the sub index of ith parameter, Vi is the monitored value of the ith parameter in μg/l and Si the standard or permissible limit for the ith parameter.

The Heavy Metal Index (HPI) is then calculated as follows -

$$HPI = \frac{\sum_{i=0}^{n} (Qi*Wi)}{\sum_{i=0}^{n} Wi} \quad \textbf{(3)}$$

Where Qi is the sub index of ith parameter. Wi is the unit weight age for ith parameter, n is the number of parameters considered. The critical pollution index value is 75, above this value is not suitable for drinking purposes

In order to calculate the HPI of the water, the mean concentration value of the selected metals (Pb, Cd,As,Cr,Se) have been taken into account details the calculations of HPI with unit weightage (Wi) and standard permissible value (Si) as obtained in the presented study in Table 4,5,6.The HPI was calculated using Indian standard and the following data was observed for the three area of study for each year.

Table -4 HPI at the area near TTPS Ash Pond

YEAR	METAL	Wi	Wi *Qi	HPI
2010	Pb	0.3794	4.47692	
	As	0.7588	15.19876	
	Cr	0.7588	3.75606	
	Cd	3.794	50.0808	
	Se	3.794	91.056	17.3504
2011	Pb	0.3794	4.59074	
	As	0.7588	15.85892	
	Cr	0.7588	6.935432	
	Cd	3.794	50.8396	
	Se	3.794	98.644	18.6472
2012	Pb	0.3794	4.81838	21.8024
	As	0.7588	19.7288	
	Cr	0.7588	7.345184	
	Cd	3.794	53.4954	
	Se	3.794	121.408	

2013	Pb	0.3794	6.798848	25.2128
	As	0.7588	22.99164	
	Cr	0.7588	8.27092	
	Cd	3.794	64.498	
	Se	3.794	136.584	
2014	Pb	0.3794	6.920256	30.9616
	As	0.7588	23.5228	
	Cr	0.7588	9.02972	
	Cd	3.794	79.674	
	Se	3.794	174.524	
2015	Pb	0.3794	7.30345	33.138
	As	0.7588	25.7992	
	Cr	0.7588	11.83728	
	Cd	3.794	83.468	
	Se	3.794	185.906	

In this area it was found that each year the concentration of the heavy metal is increasing and it is observed that the water quality for drinking is getting degraded each year but yet it's safe to use.

Table -5 HPI at the area near NALCO CPP Ash Pond

YEAR	METAL	Wi	Wi *Qi	HPI
2010	Pb	0.3794	4.579358	
	As	0.7588	14.64484	
	Cr	0.7588	5.72894	
	Cd	3.794	36.49828	
	Se	3.794	128.996	20.0788
2011	Pb	0.3794	5.414038	
	As	0.7588	18.04426	
	Cr	0.7588	5.979344	
	Cd	3.794	48.5632	22.9592
	Se	3.794	140.378	
2012	Pb	0.3794	5.414038	
	As	0.7588	20.8063	
	Cr	0.7588	6.434624	
	Cd	3.794	55.7718	25.7228
	Se	3.794	155.554	
2013	Pb	0.3794	6.593972	
	As	0.7588	24.16019	
	Cr	0.7588	7.375536	
	Cd	3.794	74.3624	30.26
	Se	3.794	174.524	
2014	Pb	0.3794	7.087192	37.6864
	As	0.7588	24.41818	
	Cr	0.7588	118.3728	
	Cd	3.794	118.3728	
	Se	3.794	197.288	
2015	Pb	0.3794	7.451416	41.7664
	As	0.7588	27.3319	
	Cr	0.7588	11.56411	
	Cd	3.794	144.9308	
	Se	3.794	204.876	

In this area it was found that the water quality is good but if the pollution continues in this rate then the water quality will become poor

Table -6 HPI at the area near NTPC Kaniha Ash Pond

YEAR	METAL	Wi	Wi *Qi	HPI
2010	Pb	0.3794	15.42261	30.682
	As	0.7588	18.5906	
	Cr	0.7588	5.57718	
	Cd	3.794	61.72838	
	Se	3.794	189.7	
2011	Pb	0.3794	16.26108	34.4552
	As	0.7588	20.71524	
	Cr	0.7588	6.040048	
	Cd	3.794	67.5332	
	Se	3.794	216.258	
2012	Pb	0.3794	17.44481	41.4168
	As	0.7588	22.68812	
	Cr	0.7588	6.692616	
	Cd	3.794	69.8096	
	Se	3.794	276.2032	
2013	Pb	0.3794	22.05832	45.5336
	As	0.7588	25.02522	
	Cr	0.7588	8.437856	
	Cd	3.794	86.5032	
	Se	3.794	289.8616	
2014	Pb	0.3794	22.80953	48.6368
	As	0.7588	26.66423	
	Cr	0.7588	8.923488	
	Cd	3.794	91.8148	
	Se	3.794	311.108	
2015	Pb	0.3794	23.4583	54.5964
	As	0.7588	27.62032	
	Cr	0.7588	9.591232	
	Cd	3.794	111.923	
	Se	3.794	345.254	

In this area the water quality has already become poor as per the ISI standard. **Table 7: Status categories of HPI**

HPI	QUALITY OF WATER
0-25	Very good
26-50	Good
51-75	Poor
Above 75	Very poor (unsuitable for drinking)

PEARSON CORRELATION COEFFICIENT

Pearson's correlation coefficient when applied to a sample is commonly represented by the letter *r* and may be referred to as the sample correlation coefficient or the sample Pearson correlation coefficient. We can obtain a formula for *r* by substituting estimates of the covariance's and variances based on a sample into the formula below.

$$r = \frac{\sum(X-\overline{X})(Y-\overline{Y})}{\sqrt{\sum(X-\overline{X})^2}\sqrt{\sum(Y-\overline{Y})^2}}$$

Where X,Y are the values whose correlation coefficient is to be calculated. X and $\overline{Y}$ are the mean value of X and Y. The correlation coefficient is a measure of linear association between two variables. Values of the correlation coefficient are always between -1 and +1.

A correlation coefficient is a statistical measure of the degree to which changes to the of one change to the value of another. In positively correlated variables, the value increases or decreases in tandem. Correlation coefficients are expressed as values between +1 and -1. A coefficient of +1 indicates a perfect positive correlation: A change in the value of one variable will predict a change in the same direction in the second variable. A positive correlation is a relationship between two variables such that their values increase or decrease together.

The correlation between the different metals of each area was calculated using Pearson coefficient.

Table -8 Correlation Coefficient at the area near TTPS Ash Pond

	Pb	As	Cr	Cd	Se
Pb	1				
As	0.954365	1			
Cr	0.842264	0.905498	1		
Cd	0.94047	0.917729	0.86528	1	
Se	0.926176	0.955015	0.908191	0.983229	1

Table -9 Correlation Coefficient at the area near NALCO CPP Ash Pond

	Pb	As	Cr	Cd	Se
Pb	1				
As	0.966179	1			
Cr	0.927726	0.86598	1		
Cd	0.942082	0.898792	0.996628	1	
Se	0.990069	0.964506	0.953771	0.966559	1

Table -10 Correlation Coefficient at the area near NTPC Kaniha Ash Pond

	Pb	As	Cr	Cd	Se
Pb	1				
As	0.972064	1			
Cr	0.994104	0.984442	1		
Cd	0.936503	0.937832	0.964273	1	
Se	0.926241	0.98095	0.952559	0.920258	1

It is observed in the three different areas that there is positive correlation between the heavy metals Pb , As, Cr, Cd and Se nearly equal to one i.e. if there is increase in one metal concentration than the other metals concentration also increases may be due to the industrial wastes seepage into the ground water .The positive correlation between the different metals in the three different areas have been plotted in the graphs using weka software.

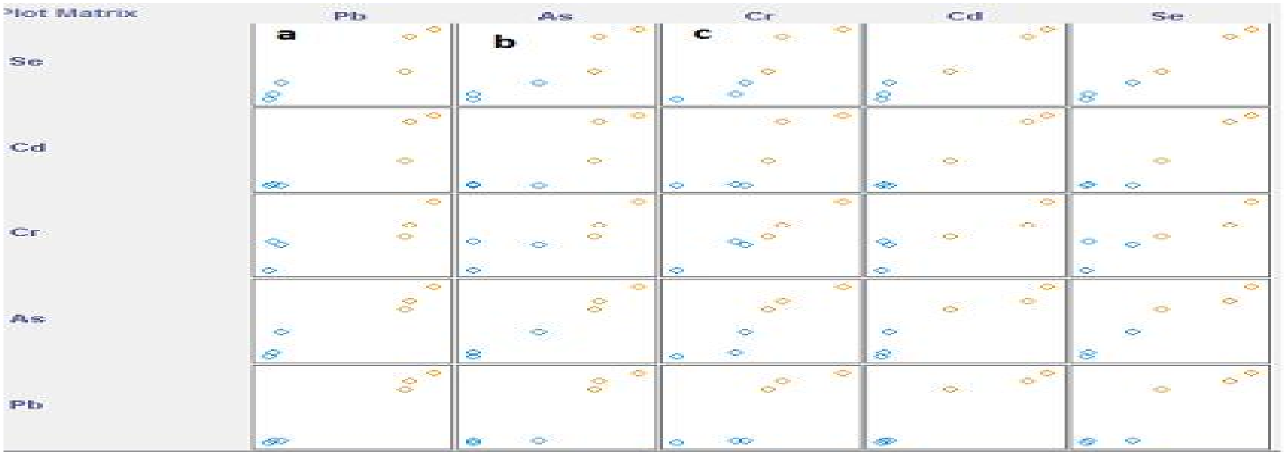

FIGURE 5- CORRELATION OF HEAVY METALS NEAR TTPS ASH POND

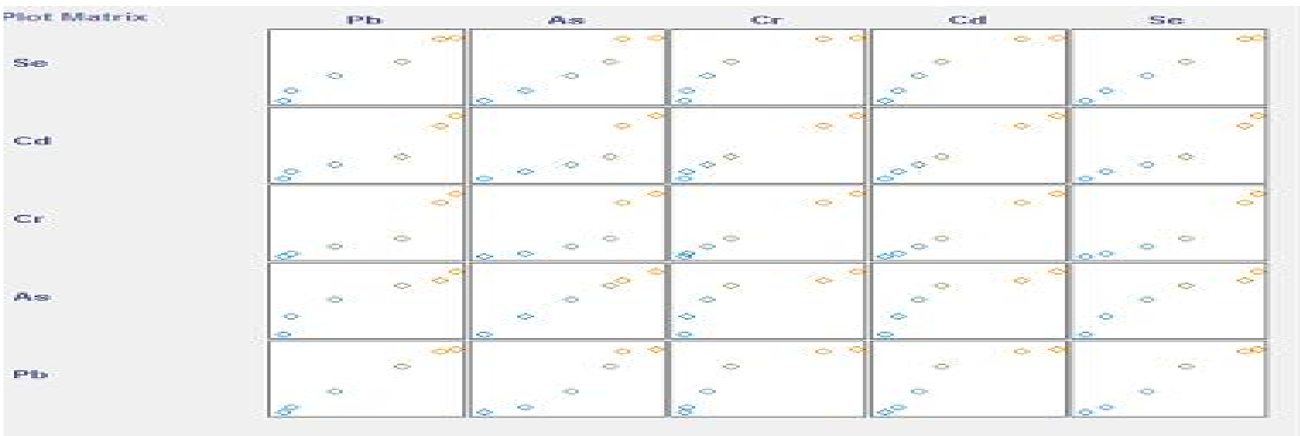

FIGURE 6- CORRELATION OF HEAVY METALS NEAR NALCO CPP ASH POND

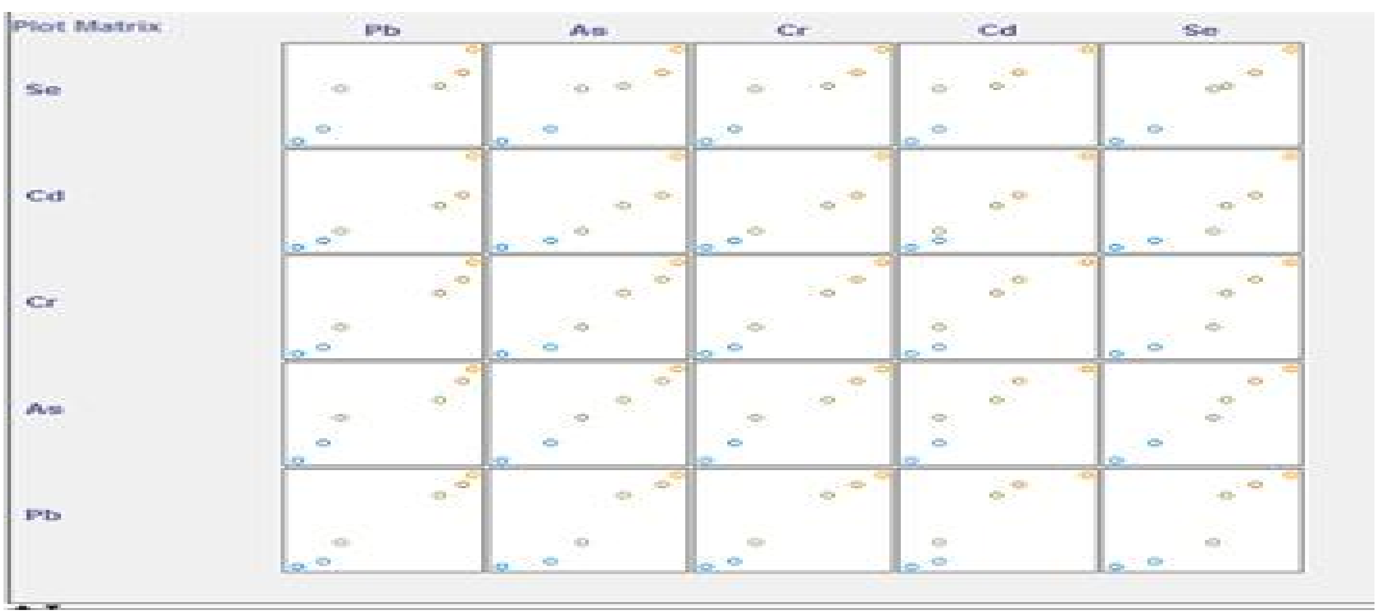

FIGURE 7- CORRELATION OF HEAVY METALS NEAR NTPC KANIHA ASH POND

CONCLUSION:

The present study reveals that most of the water samples of ground water system at Angul –Talcher industrial area were found less polluted in heavy metal contamination profile. Samples collected from NTPC Kaniha evidence the slightly significant metal concentration in water samples .It is attributed to the concentration of various mines and associated power plants industries. The HPI is very useful tool in evaluating over all pollution of water bodies with respect to heavy metals .The HPI values of the present study indicate that the water samples from the wells and tube wells are not critically contaminated with respect to heavy metals. But the correlation is showing that increases in concentration of heavy metals are to be inter related. It is proposed that if a good correlation can be discovered then determination of few important water quality parameters along with toxic heavy metals which are highly correlated to other would provide an overall idea of water quality. Though correlation among water quality parameters have been studied by different group of worker[21,22,23] .It is still required to have similar regular investigation to provide up to date possible information from the different sources of pollution. More over metal pollution by mining and associated industrial activities is somewhat moderate because of strict implementation of clean technology and environmental measures by industries.

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