The International Journal of Engineering and Science (IJES)
|| Volume || 6 || Issue || 5 || Pages || PP 52-58 || 2017 ||
ISSN (e): 2319 – 1813 ISSN (p): 2319 – 1805

Health Risk Assessment of Heavy Metal Contaminated Site: Case study of Rania Industrial Belt, Kanpur

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----------**ABSTRACT**----------
This paper emphasizes on the Health Risk Assessment of heavy metal contaminated soil at Rania Industrial belt, Kanpur Dehat, India. Study was conducted to determine the Hazard Index and Cancer risk for receptors (Child, Adult and Industrial worker) through different pathways (Ingestion, Inhalation and Dermal contact) based on the mean and maximum concentration of heavy metals in soils. Further this study also addresses Carcinogenic and Non-Carcinogenic health risks due to exposure to heavy metal to each of the receptors. Study shows that Ingestion is the dominant pathway of exposure to all the receptors for the health risk. The non-Carcinogenic risk to the children at Rania industrial belt has been obtained as HI=1.40 and 4.97 based on the mean and maximum concentration of heavy metals, respectively. The maximum Hazard Quotient was found for Pb (HQ = 0.55) followed by Fe (HQ = 0.52) in the Non-Carcinogenic Risk assessment. The exposure of the children to the site may cause various adverse health effects on them. Carcinogenic Risk due to Cr(VI) and Pb were found to be more than $1x10^{-6}$ for all the considered receptor. Exposure to the site by any of the receptors can cause the cancer risk. It was found that Non Carcinogenic and Carcinogenic risk for child is about 8.5 times more than that for adult.

Key Words: Carcinogenic Risk, Dermal Contact, Ingestion, Inhalation, Non-Carcinogenic Risk

Date of Submission: 23 February 2017 Date of Accepted: 20 May 2017

I. INTRODUCTION

Improper disposal of untreated industrial and municipal waste leads to the land contamination. Various types of contaminants such as heavy metals, organic and inorganic compounds etc. are responsible for the contamination of soil. Exposure to these contaminants may leads to carcinogenic and/or non carcinogenic health risks to human. On exposure, receptor (Child, Adult or Industrial Worker) may receive the contaminants by any one or more of the pathways (i.e., ingestion, inhalation and dermal contact). Since, health risk varies as per the age group (child and adult) and exposure time (residential and industrial worker) hence it is essential to perform health risk assessment for each receptor individually.

In India, around 537 mega sites with total area of about 175 million hectare has been identified as contaminated due to industrial and municipal waste effluents (MoEF, 2014). Remediation of contaminated land is a new research field in India. Hence only few researchers have reported their work in this field. Research on the concentration, evaluation and speciation of heavy metal has been done for various sites all over the India, such as Chhattisgarh (Patel et. al., 2006), Hyderabad (Govil et. al., 2008), Kanpur (Singh et. al., 2009; Rawat et. al., 2009; Gowd et. al., 2010; Sinha et. al., 2006), Mumbai (Krishna and Govil, 2005), Mysore (Shivakumar et. al., 2012), Patancheru (Govil et. al., 2001), Ranga Reddy (Dantu, 2007), Surat (Krishna and Govil, 2007), Tamil Nadu (Dheeba and Sampathkumar, 2012) and Thane (Bhagure and Mirgane, 2011). But no study has been reported regarding the aspects of health risk based site characterization.

The selected site, Rania, is one of the 537 identified contaminated sites located in Kanpur Dehat. Kanpur is well known for its large number of small scale industries. During the process of leather manufacturing, several chemicals are extensively used and therefore, the resultant effluent is rich in heavy metals such as chromium and sodium salts (Gowd et al., 2010). This paper presents the health risk assessment of a heavy metal contaminated site at Rania, Kanpur, India for three different receptors (i.e., child, adult and industrial worker) by three exposure pathways (Inhalation, Ingestion and Dermal contact). Non carcinogenic Hazardous Quotient (HQ) and carcinogenic risk was calculated for each heavy metal.

II. METHODOLOGY

Site Description and Sampling

Study site was Rania industrial belt (26N to 25 55'N latitude: 79" 30'E to 80"E Longitude) located in Kanpur Dehat, Uttar Pradesh, India. Source of the contamination at site was the disposal of effluent by nearby industries. A total of twenty eight samples were collected from different locations at the site and tested in the laboratory to find out the concentration of different heavy metals at each location. The samples were collected from a depth of 0 to 15 cm with the help of plastic shovel, kept in plastic bags and carried to the laboratory. For the collection of samples random approach was used. Figure 1 shows the location of site and sample collection points.

Sample Analysis

All the samples were oven dried by keeping in a hot-air oven at 70-80^{o}C for 24 hrs. This temperature was used to remove the moisture without thermal decomposition (Campbell and Plank, 1998). Dried samples were then sieved through the 2mm size sieve and XRF analysis was done to calculate the concentration of each heavy metal separately. It is increasingly acknowledged that chemical speciation of heavy metals plays an influential role in governing the fate and ecological toxicity of contaminants (Sauve et. al., 1997).

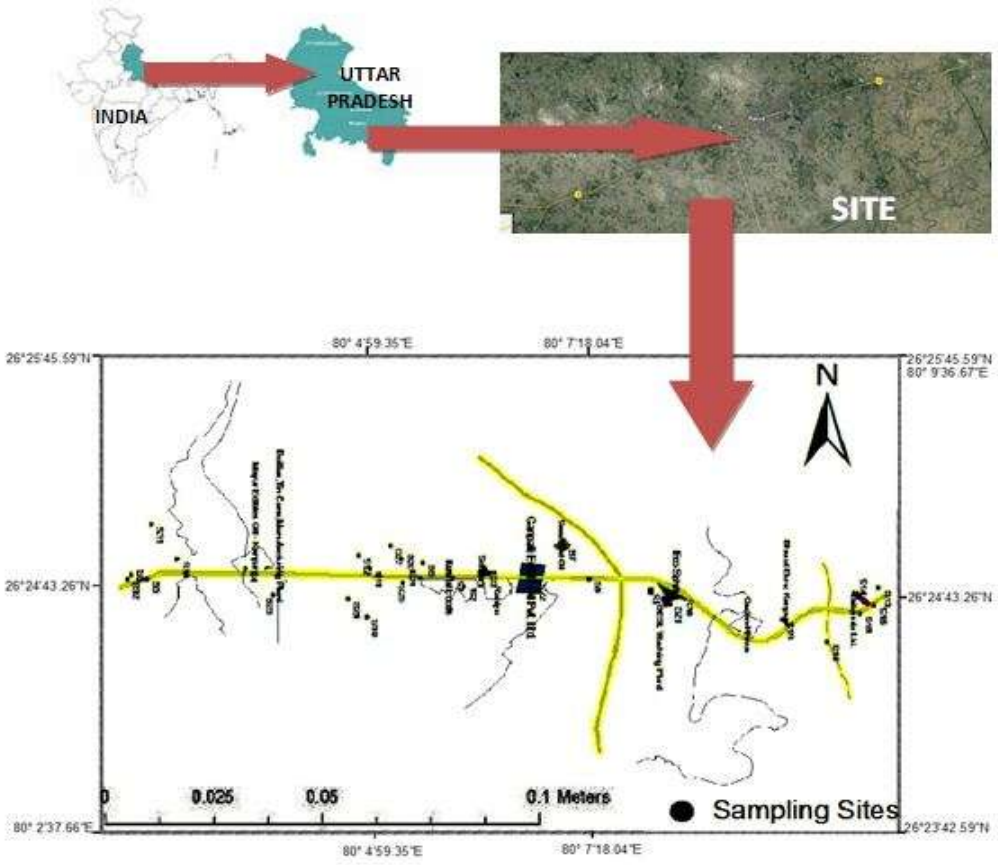

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Fig 1: Rania industrial belt site and sampling point's descriptions

HEALTH RISK ASSESSMENT

Chronic Average Daily Demand (CADD) has been calculated by using the equations shown in table 1 and factors used for obtaining the value of CADD are described in table 2. RfD values are shown in table 3. After calculating the CADD for the entire exposure pathway, non-carcinogenic Hazard Quotient (HQ) was calculated by dividing the CADD by reference dose (RfD).

$$HQ_{ij} = \frac{CADD_{ij}}{RfD_{ij}}$$

Where, i = heavy metal and j = exposure pathway. Reference dose (RfD) is an estimation of maximum permissible risk on human population through daily exposure taking into consideration sensitivity of group during a lifetime (Du et al. 2013). HQ ≤ 1 indicates no adverse effect and HQ > 1 indicates adverse health effects (USEPA 1986).
Minimum, mean and maximum concentrations of heavy metals present in soil samples (Cr(III), Cr(VI), Cu, Ni, Pb, Zn, Fe) in mg/Kg as obtained by XRF is presented in table 4. These heavy metals above a certain concentration may pose non-carcinogenic and carcinogenic health risks to human.

$$HI = \sum\sum HQ_{ij}$$

HI≤1 indicates no non-carcinogenic risk to the human health and HI>1 indicates non-carcinogenic risk to the human health (USEPA 2001 (b)).

Cancer Risk
Cancer risk was determined by multiplying Lifetime Average Daily Dose (LADD) with Cancer Slope Factor (CSF). It indicates the probability of cancer to the exposed receptor during lifetime.

Cancer Risk = LADD x CSF

Cancer slope factor is shown in table 3. LADD was calculated using equations given in table 1 by replacing Average Time (AT) by Lifetime (LT).
Total carcinogenic risk was calculated by the summation of risk induced by all the exposure pathways.

Total risk = $Risk_{ing}$ + $Riski_{nh}$ + $Risk_{der}$

Risk ≥ 1 x 10^{-6} indicates carcinogenic risk to the receptor (USEPA 2005)

III. RESULTS AND DISCUSSION

Non-Carcinogenic Analysis:
As per mean concentration of heavy metals
Hazard index for adult and child is shown in table 4 and for industrial worker it is shown in table 5. Mean concentration of heavy metals was found to be in the order: Fe > Cr(III) > Zn > Ni > Cu > Pb > Cr(VI). The values of HQ and HI are shown in table 4 and 5. Hazard index considering three exposure pathways (Ingestion, Inhalation, Dermal) of intake in the decreasing order is for (a) adults: Pb > Fe > Ni > Cr(VI) > Cu > Zn > Cr, (b) Child: Pb > Fe > Ni > Cr(VI) > Cu > Zn >Cr, (c) Industrial Worker: Pb > Fe > Ni > Cr(VI) > Zn > Cr(III) > Cu. For adult, non-carcinogenic Hazard Index for each present heavy metal was negligible as the maximum HI of Pb was 0.0651, Hence it can be stated that no non- carcinogenic risk is associated with these heavy metal (Pb, Fe, Ni, Cr(VI), Cu, Zn and Cr) to the adults. For Child HI for Pb and Fe was 0.575 and 0.55 respectively. Children are more susceptible to non carcinogenic risk by Pb and Fe. Lead has serious consequences for the health of children. At high levels of exposure, lead attacks the brain and central nervous system to cause coma, convulsions and may even lead to death (WHO). Considerable Measures should be taken care to avoid the contact with Pb for child. For the industrial worker, non-carcinogenic HI for individual heavy metal was also insignificant.

Table 1: Equations for exposure of contaminant to human via ingestion, inhalation and dermal contact pathways

Chronic Average Daily Dose (CADD)			Reference
Ingestion	Inhalation	Dermal Contact	
$\frac{C \times IingR \times EF \times ED \times CF}{BW \times AT}$	$\frac{C \times InhR \times EF \times ED}{PEF \times BW \times AT}$	$\frac{C \times SA \times ABS \times AF \times EF \times ED \times CF}{BW \times AT}$	USEPA 1989

Table 2: Factors used for estimation of CADD for cancer and non-cancer risk

Factors	Symbol	Unit	Value				Reference
			Adult	Children	Worker		
					Outdoor	Indoor	
Soil Ingestion rate	IngR	mg/day	100	200	100	50	USEPA(2002)
Exposure Duration	ED	Year	24	6	25	25	USEPA(2002)
Exposure Frequency	EF	day/year	350	350	305	305	USEPA(2002)
Average body weight	BW	Kg	63	14	63	63	ICMR(2000), Shome (2014)
Average time for non-cancer risk	AT*	days	8760	2190	25550	25550	USEPA(2002)
Average time for cancer risk	AT*	days	24258	24258	24258	24258	USEPA(2002)
Conversion Factor	CF	Kg/mg	$1x10^{-6}$	$1x10^{-6}$	$1x10^{-6}$	$1x10^{-6}$	USEPA(2002)
Surface area of the skin that contact the soil	SA	cm^2/event	5700	2800	3300	3300	USEPA(2002)
Skin adherence factor	AF_{soil}	mg/cm^2	0.07	0.2	0.2	NA	USEPA(2002)
Dermal absorption factor for NCR	ABS	mg/cm^2	0.001	0.001	0.001	0.001	USEPA(2011)
Dermal absorption factor for CR	ABS	mg/cm^2	0.03	0.03	0.03	0.03	USEPA(2011)
Inhalation factor	InhR	m^3/day	20	20	20	20	USEPA(2002)
Particle emission factor	PEF	m^3/day	$1.36x10^9$	$1.36x10^9$	$1.36x10^9$	$1.36x10^9$	USEPA(2002)
Life Time (ED for cancer risk)	LT	Year	66.46				World Bank

'*' AT=365xED

Table 3: Reference dose and cancer slope factor for the heavy metals for the different exposure pathway

Metal	CSF	RfD_{ing}	RfD_{inh}	RfD_{dev}	Reference
Cd	6.3	0.001	0.001	0.00001	USEPA(2002) USEPA (1993)
Co	-	0.02	-	-	
Cr(VI)	0.5	0.003	0.0001	.00006	
Cr(III)	-	1.5			
Cu	-	0.0371	0.0402	0.0019	
Fe	-	0.7	-	-	
Pb	0.0085	0.0035	0.00352	0.000525	
Zn	-	0.3	0.3	0.06	
Ni		0.02	0.0206	o.oo1	

HI order for the exposure pathways is as follows (a) Adults: Ingestion (0.1638) >Dermal (0.005818845)> Inhalation (0.000048) (b) Child: Ingestion (1.4752)>Dermal (0.012845555)> Inhalation (0.000320572) (c) Industrial Worker: Ingestion (0.163) > Inhalation (0.0029) > Dermal (0.000053281). Ingestion was found dominant exposure pathway of exposure leading to health risk.

HI of this study was high for child (i.e., 1.4188). HI for Adult and Industrial worker was found to be nearly same as 0.1638 and 0.163 respectively. HI value was more than 1 for child through Ingestion pathway. It shows the non-carcinogenic health risk associated with the exposure of combination of present metals with the concentration as specified in table 4 to child near to the site.

It is observed that non carcinogenic health risk to child is about 8.6 times more than adult and industrial worker.

As per maximum value of concentration

Maximum concentration of heavy metals was found in the order of Fe > Cr > Zn > Pb > Ni > Cu > Cr. Hazard Index for child, adult and industrial worker was 5.2144, 0.5948 and 0.5941 respectively. It shows the severe non-carcinogenic risk to child health as the value of HI for child exceeds 1. Pb has the highest HI among all the heavy metals (i.e. 3.75 for child, 0.405 for adult and 0.417 for industrial worker). Non-Carcinogenic risk associated to child, adult, and industrial worker as per the maximum concentration is 3.5034, 3.5038 and 3.5792 times higher than non-carcinogenic risk associated as per the mean concentration, respectively.

Table 4: Non-carcinogenic Hazard Index (HI) for adult and child for different exposure pathways

HEAVY METAL	HEAVY METAL CONC. (mg/kg)		ORAL				DERMAL				INHALATION				HI	
			ADULT		CHILD		ADULT		CHILD		ADULT		CHILD			
			CADD	HQ	CADD	HQ	CADD	HQ	CADD	HQ	CADD	HQ	CADD	HQ	ADULT	CHILD
Cr(III)	Min	68	1.03E-04	6.90E-05	9.32E-04	6.21E-04	4.13E-07	-	9.11E-07	-	1.52E-08	-	6.87E-08	-	6.90E-05	6.21E-04
	Max	2000	3.04E-03	2.03E-03	2.74E-02	1.83E-02	1.21E-05	-	2.68E-05	-	4.48E-07	-	2.02E-06	-	2.03E-03	1.83E-02
	Mean	560	8.52E-04	5.68E-04	7.67E-03	5.11E-03	3.40E-06	-	7.50E-06	-	1.25E-07	-	5.66E-07	-	5.68E-04	5.11E-03
Cr(VI)	Min	12	1.83E-05	6.09E-03	1.64E-04	5.48E-02	7.28E-08	1.21E-03	1.61E-07	2.68E-03	2.69E-09	2.69E-05	1.21E-08	1.21E-04	7.33E-03	5.76E-02
	Max	28	4.26E-05	1.42E-02	3.84E-04	1.28E-01	1.70E-07	2.83E-03	3.75E-07	6.25E-03	6.27E-09	6.27E-05	2.83E-08	2.83E-04	1.71E-02	1.34E-01
	Mean	15	2.28E-05	7.61E-03	2.06E-04	6.85E-02	9.11E-08	1.52E-03	2.01E-07	3.35E-03	3.36E-09	3.36E-05	1.52E-08	1.52E-04	9.16E-03	7.20E-02
Cu	Min	83	1.26E-04	3.41E-03	1.14E-03	3.06E-02	5.04E-07	2.65E-04	1.11E-06	5.85E-04	1.86E-08	4.62E-07	8.38E-08	4.41E-05	3.67E-03	3.13E-02
	Max	405	6.16E-04	1.66E-02	5.55E-03	1.50E-01	2.46E-06	1.29E-03	5.43E-06	2.86E-03	9.07E-08	2.26E-06	4.09E-07	2.15E-04	1.79E-02	1.53E-01
	Mean	203	3.09E-04	8.33E-03	2.78E-03	7.50E-02	1.23E-06	6.49E-04	2.72E-06	1.43E-03	4.55E-08	1.13E-06	2.05E-07	1.08E-04	8.98E-03	7.65E-02
Ni	Min	139	2.12E-04	1.06E-02	1.90E-03	9.52E-02	8.44E-07	8.44E-04	1.86E-06	1.86E-03	3.11E-08	1.51E-06	1.40E-07	6.82E-06	1.14E-02	9.71E-02
	Max	895	1.36E-03	6.81E-02	1.23E-02	6.13E-01	5.43E-06	5.43E-03	1.20E-05	1.20E-02	2.00E-07	9.73E-06	9.04E-07	4.39E-05	7.36E-02	6.25E-01
	Mean	278	4.23E-04	2.12E-02	3.81E-03	1.90E-01	1.69E-06	1.69E-03	3.73E-06	3.73E-03	6.23E-08	3.02E-06	2.81E-07	1.36E-05	2.28E-02	1.94E-01
Pb	Min	50	7.61E-05	2.17E-02	6.85E-04	1.96E-01	3.04E-07	5.78E-04	6.70E-07	1.28E-03	1.12E-08	3.18E-06	5.05E-08	1.43E-05	2.23E-02	1.97E-01
	Max	906	1.38E-03	3.94E-01	1.24E-02	3.55E+00	5.50E-06	1.05E-02	1.21E-05	2.31E-02	2.03E-07	5.77E-05	9.15E-07	2.60E-04	4.05E-01	3.57E+00
	Mean	146	2.22E-04	6.35E-02	2.00E-03	5.71E-01	8.86E-07	1.69E-03	1.96E-06	3.73E-03	3.27E-08	9.29E-06	1.47E-07	4.19E-05	6.52E-02	5.75E-01
Zn	Min	111	1.69E-04	5.63E-04	1.52E-03	5.07E-03	6.74E-07	1.12E-05	1.49E-06	2.48E-05	2.49E-08	4.14E-07	1.12E-07	1.87E-06	5.75E-04	5.10E-03
	Max	1520	2.31E-03	7.71E-03	2.08E-02	6.94E-02	9.23E-06	1.54E-04	2.04E-05	3.39E-04	3.40E-07	5.67E-06	1.54E-06	2.56E-05	7.87E-03	6.98E-02
	Mean	335	5.10E-04	1.70E-03	4.59E-03	1.53E-02	2.03E-06	3.39E-05	4.49E-06	7.48E-05	7.50E-08	1.25E-06	3.38E-07	5.64E-06	1.73E-03	1.54E-02
Fe	Min	11000	1.67E-02	2.39E-02	1.51E-01	2.15E-01	6.68E-05	9.54E-05	1.47E-04	2.11E-04	2.46E-06	-	1.11E-05	-	2.40E-02	2.15E-01
	Max	32900	5.01E-02	7.15E-02	4.51E-01	6.44E-01	2.00E-04	2.85E-04	4.41E-04	6.30E-04	7.37E-06	-	3.32E-05	-	7.18E-02	6.45E-01
	Mean	28072	4.27E-02	6.10E-02	3.85E-01	5.49E-01	1.70E-04	2.43E-04	3.76E-04	5.37E-04	6.29E-06	-	2.84E-05	-	6.13E-02	5.50E-01

Table 5: Non-carcinogenic Hazard Index (HI) for Industrial worker for different exposure pathways

HEAVY METAL	HEAVY METAL CONC.		INDUSTRIAL WORKER						HI
			ORAL		DERMAL		INHALATION		
			ADD	HQ	ADD	HQ	ADD	HQ	
Cr(III)	Min	68	1.08E-04	7.21E-05	2.08E-07	-	1.33E-08	-	7.21E-05
	Max	2000	3.18E-03	2.12E-03	6.12E-06	-	3.90E-07	-	2.12E-03
	Mean	560	8.90E-04	5.94E-04	1.71E-06	-	1.09E-07	-	5.94E-04
Cr(VI)	Min	12	1.91E-05	6.36E-03	3.67E-08	6.12E-04	2.34E-09	2.34E-05	7.00E-03
	Max	28	4.45E-05	1.48E-02	8.57E-08	1.43E-03	5.46E-09	5.46E-05	1.63E-02
	Mean	15	2.39E-05	7.95E-03	4.59E-08	7.65E-04	2.93E-09	2.93E-05	8.74E-03
Cu	Min	83	1.32E-04	1.89E-04	2.54E-07	1.34E-04	1.62E-08	4.03E-07	3.23E-04
	Max	405	6.44E-04	9.20E-04	1.24E-06	6.52E-04	7.90E-08	1.96E-06	1.57E-03
	Mean	203	3.23E-04	4.61E-04	6.21E-07	3.27E-04	3.96E-08	9.85E-07	7.89E-04
Ni	Min	139	2.21E-04	1.11E-02	4.25E-07	4.25E-04	2.71E-08	1.32E-06	1.15E-02
	Max	895	1.42E-03	7.12E-02	2.74E-06	2.74E-03	1.75E-07	8.47E-06	7.39E-02
	Mean	278	4.42E-04	2.21E-02	8.51E-07	8.51E-04	5.42E-08	2.63E-06	2.30E-02
Pb	Min	50	7.95E-05	2.27E-02	1.53E-07	2.91E-04	9.75E-09	1.86E-05	2.30E-02
	Max	906	1.44E-03	4.12E-01	2.77E-06	5.28E-03	1.77E-07	3.37E-04	4.17E-01
	Mean	146	2.32E-04	6.63E-02	4.47E-07	8.51E-04	2.85E-08	5.42E-05	6.72E-02
Zn	Min	111	1.76E-04	5.88E-04	3.40E-07	5.66E-06	2.16E-08	7.22E-08	5.94E-04
	Max	1520	2.42E-03	8.06E-03	4.65E-06	7.75E-05	2.96E-07	9.88E-07	8.13E-03
	Mean	335	5.33E-04	1.78E-03	1.03E-06	1.71E-05	6.53E-08	2.18E-07	1.79E-03
Fe	Min	11000	1.75E-02	2.50E-02	3.37E-05	4.81E-05	2.15E-06	-	2.50E-02
	Max	32900	5.23E-02	7.47E-02	1.01E-04	1.44E-04	6.42E-06	-	7.49E-02
	Mean	28072	4.46E-02	6.38E-02	8.59E-05	1.23E-04	5.47E-06	-	6.39E-02

Table 6: Carcinogenic risk for adult and child for different exposure pathways

Heavy Metal	Heavy Metal Conc.		Adult						Child						Risk	
			Ingestion		Dermal		Inhalation		Ingestion		Dermal		Inhalation			
			LADD	Risk	LADD	Risk	LADD	Risk	LADD	Risk	LADD	Risk	LADD	Risk	Adult	Child
Cr(VI)	Min	12	1.83E-05	9.13E-06	7.28E-08	3.64E-08	2.69E-09	1.34E-09	1.64E-04	8.22E-05	1.61E-07	8.04E-08	1.21E-08	6.06E-09	9.17E-06	8.23E-05
	Max	28	4.26E-05	2.13E-05	1.70E-07	8.50E-08	6.27E-09	3.14E-09	3.84E-04	1.92E-04	3.75E-07	1.88E-07	2.83E-08	1.41E-08	2.14E-05	1.92E-04
	Mean	15	2.28E-05	1.14E-05	9.11E-08	4.55E-08	3.36E-09	1.68E-09	2.06E-04	1.03E-04	2.01E-07	1.01E-07	1.52E-08	7.58E-09	1.15E-05	1.03E-04
Pb	Min	50	7.61E-05	6.47E-07	3.04E-07	2.58E-09	1.12E-08	9.52E-11	6.85E-04	5.82E-06	6.70E-07	5.70E-09	5.05E-08	4.29E-10	6.50E-07	5.83E-06
	Max	906	1.38E-03	1.17E-05	5.50E-06	4.67E-08	2.03E-07	1.73E-09	1.24E-02	1.06E-04	1.21E-05	1.03E-07	9.15E-07	7.78E-09	1.18E-05	1.06E-04
	Mean	146	2.22E-04	1.89E-06	8.86E-07	7.53E-09	3.27E-08	2.78E-10	2.00E-03	1.70E-05	1.96E-06	1.66E-08	1.47E-07	1.25E-09	1.90E-06	1.70E-05

Table 7: Carcinogenic risk for adult and for different exposure pathways

Heavy Metal	Heavy Metal Conc.		INDUSTRIAL WORKER						Risk
			INGESTION		DERMAL		INHALATION		
			LADD	Risk	LADD	Risk	LADD	Risk	
Cr(VI)	Min	12	1.91E-05	9.54E-06	3.67E-08	1.84E-08	2.34E-09	1.17E-09	9.56E-06
	Max	28	4.45E-05	2.23E-05	8.57E-08	4.28E-08	5.46E-09	2.73E-09	2.23E-05
	Mean	15	2.39E-05	1.19E-05	4.59E-08	2.30E-08	2.93E-09	1.46E-09	1.19E-05
Pb	Min	50	7.95E-05	6.76E-07	1.53E-07	1.30E-09	9.75E-09	8.29E-11	6.77E-07
	Max	906	1.44E-03	1.22E-05	2.77E-06	2.36E-08	1.77E-07	1.50E-09	1.23E-05
	Mean	146	2.32E-04	1.97E-06	4.47E-07	3.80E-09	2.85E-08	2.42E-10	1.98E-06

Carcinogenic Risk Analysis

As per mean concentration of heavy metals

Heavy metals (Cr (VI), Pb) are liable to induce carcinogenic risk to human health. The carcinogenic risk study for adult, child and industrial worker is shown in table 6 and 7. Carcinogenic risk from the exposure to Cr (VI) and Pb, for child, adult and industrial worker was obtained 119 x 10^{-6}, 13.3 x 10^{-6}, and 13.9 x 10^{-6} respectively. It shows the high cancer risk to the child. Carcinogenic risk to child was about 8.97 times more than that for adult. For all the receptors risk through pathways is in the order of $Risk_{ing} > Risk_{der} > Risk_{inh}$

Carcinogenic Risk for all the considered receptors exceeds the value of 1 x 10^{-6}. Hence the concentration shown in table 6 can cause carcinogenic risk to all the receptors.

As per maximum concentration of heavy metals

For the maximum concentration, carcinogenic risk from the exposure to Cr(VI) and Pb, for child, adult and industrial worker was calculated as 297.616 x 10^{-6}, 33.16 x 10^{-6} and 34.5 x 10^{-6} respectively. It shows the very high carcinogenic risk to each receptor as it is a most conservative approach. Sustainable metals extraction techniques should be employed to reduce the effect of exposure at the site.

IV. CONCLUSION

Heavy metal concentrations for the soil collected from Rania Industrial belt were analyzed in order to assess the health risks to human. Non-carcinogenic and carcinogenic health risk assessment for the heavy metals through each of the exposure pathways (Ingestion, Inhalation, Dermal Absorption) for the receptors (Child, Adult, Industrial worker) is presented in this study. It was observed that ingestion is the dominant pathway of exposure to every receptor. Highest value of HQ=0.575 for Pb in child was obtained. More emphasis should be given to the remediation of Pb as it may cause various health issues to child. Study shows non-carcinogenic risk (HI=1.49, 5.21) was associated to child as per mean and maximum concentrations respectively. Based on high concentration, severe non-carcinogenic risk was evaluated for the child at Rania industrial belt. Study shows that carcinogenic risk existed for all receptors as the cancer risk exceeds the safe value of 1 x 10^{-6}. It was found that non-carcinogenic health risk and carcinogenic risk for child was about 8.6 and 8.9 times more than adult and industrial worker, respectively.

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