HEALTH RISK ASSESSMENT OF SOME HEAVY METALS IN GROUNDWATER OF TANGAIL SADAR UPZILLA, TANGAIL, BANGLADESH

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Outline of the Presentation

- Objective of the Study
- Material and Methods
- Results and Discussion
- Health Risk Assessment
- Conclusion

Concern about Groundwater

- Increased Anthropogenic activities, both agricultural and industrial

- Heavy metal pollution in GroundWater

- Risk posed from GW with potentials to cause diseases like anorexia, immune dysfunction, hypertension, liver and kidney disorders, cancers etc.

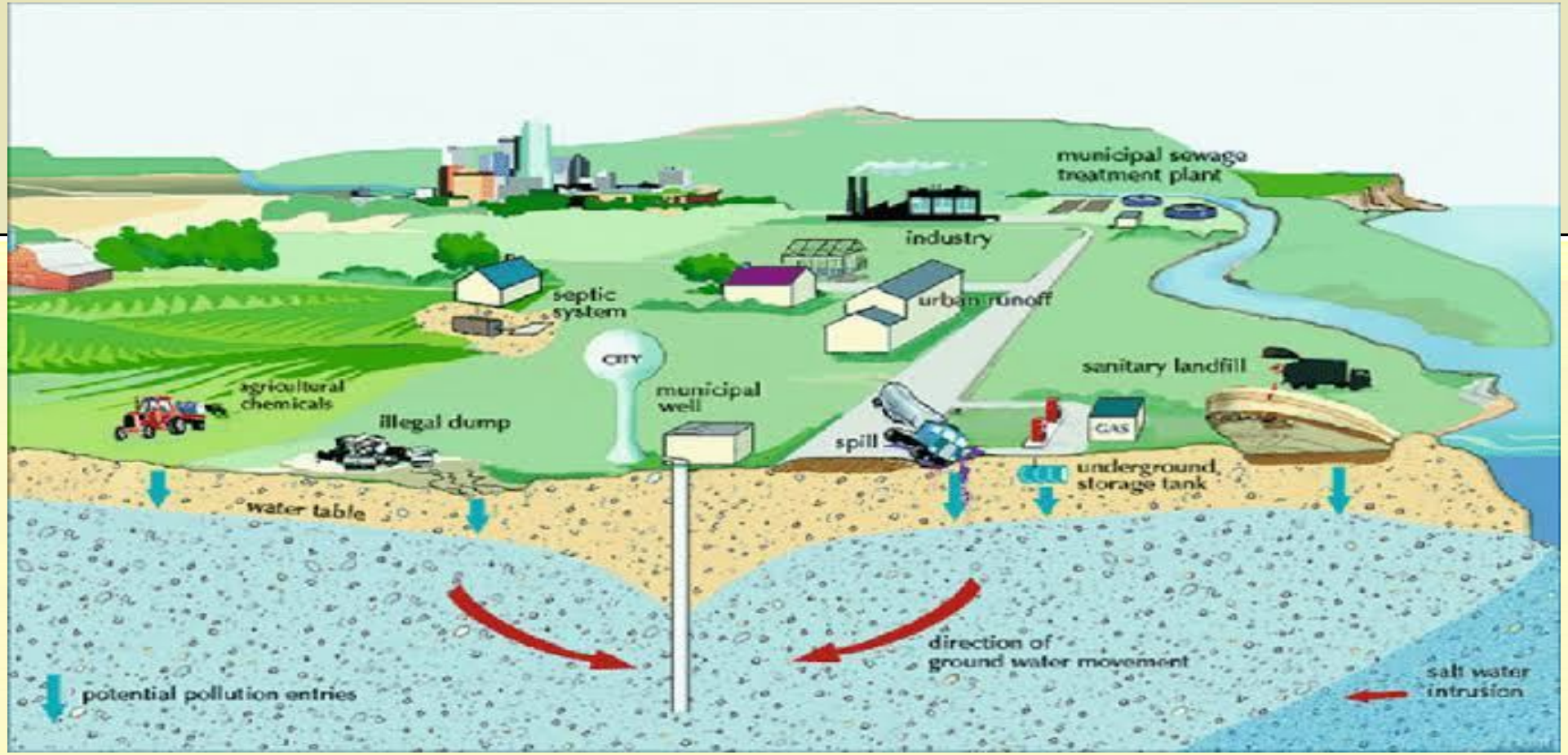


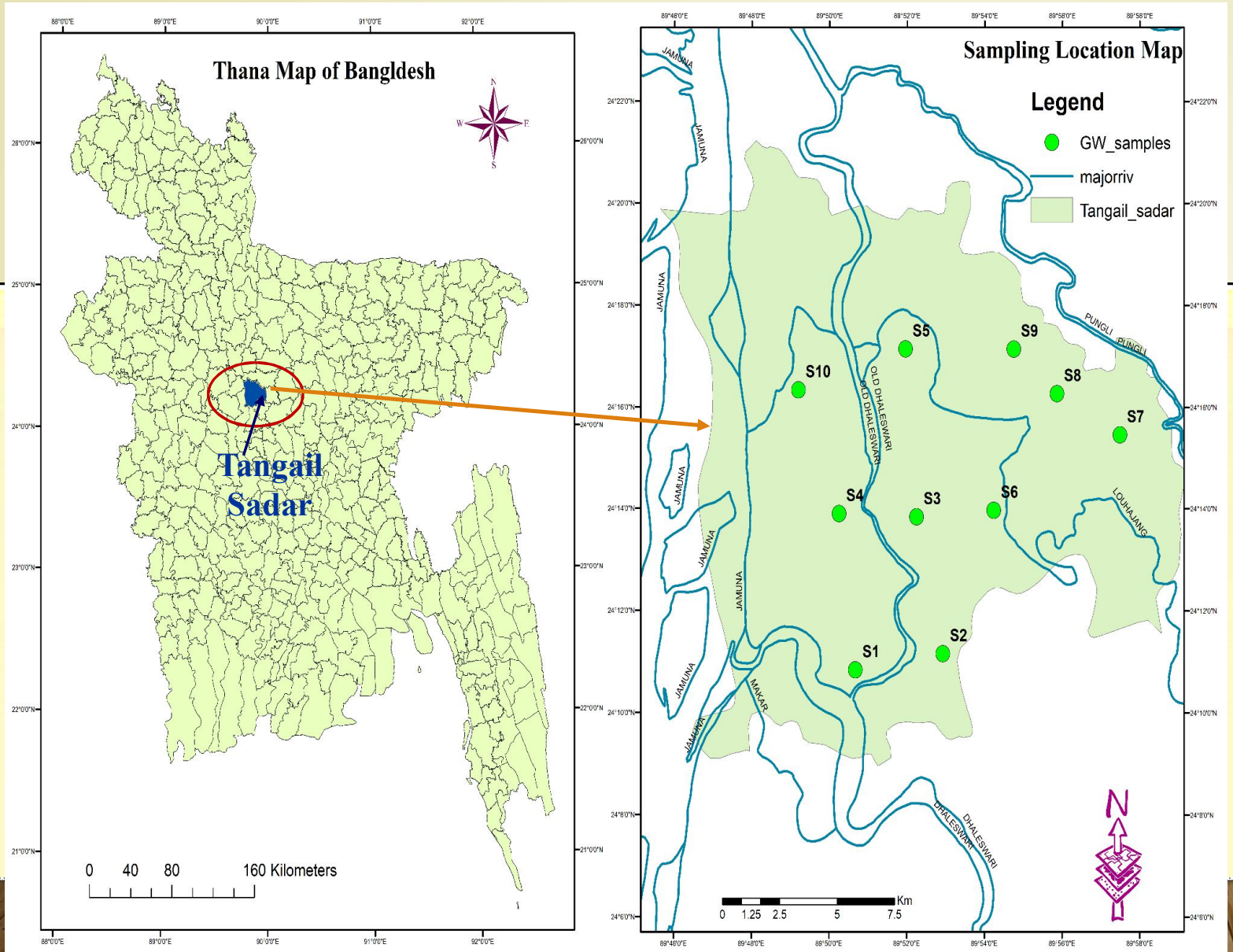
Fig 1: **Groundwater pollution**

Objective of the Study

- Determine the concentrations of trace elements like; Fe, Mn, Zn, Cr, Cd, Pb, Ni and As in ground water of the different locations of Tangail Sadar Upzilla.

- Identify the suitability of GW for drinking purposes in comparison with several national and international standards.

- **HEALTH RISK ASSESSMENT** as posed from GW with exposure to these trace metals via oral ingestion and absorption through skin.



Study Area

Tangail Sadar Upazilla is located in between 24'10' and 24'22' north latitudes and in between 88'46' and 89'59' east longitudes. The upazilla is situated on the bank of Jamuna River. Sampling has done from April 2017 to August 2017.

Fig 2: Sampling sites

Material and Methods

- **Ten (10)** GW samples (1000 mL each) were collected from different depths (varying from 60 to 180ft) of selected tubewells from different region of Tangail Sadar Upzilla.

- Plastic bottles were rinsed with 0.02M HNO_3 before sampling.

- pH, Electrical conductivity (EC) and Dissolved Oxygen (DO) were measured on field

- For heavy metals and trace element analysis, acid digestion method was used. Atomic Absorption Spectrophotometer (Shimadzu AA6800) was used for heavy metals detection.

- For method validation we used the “Spike System” and the heavy metals recovery were 88% to 93%.

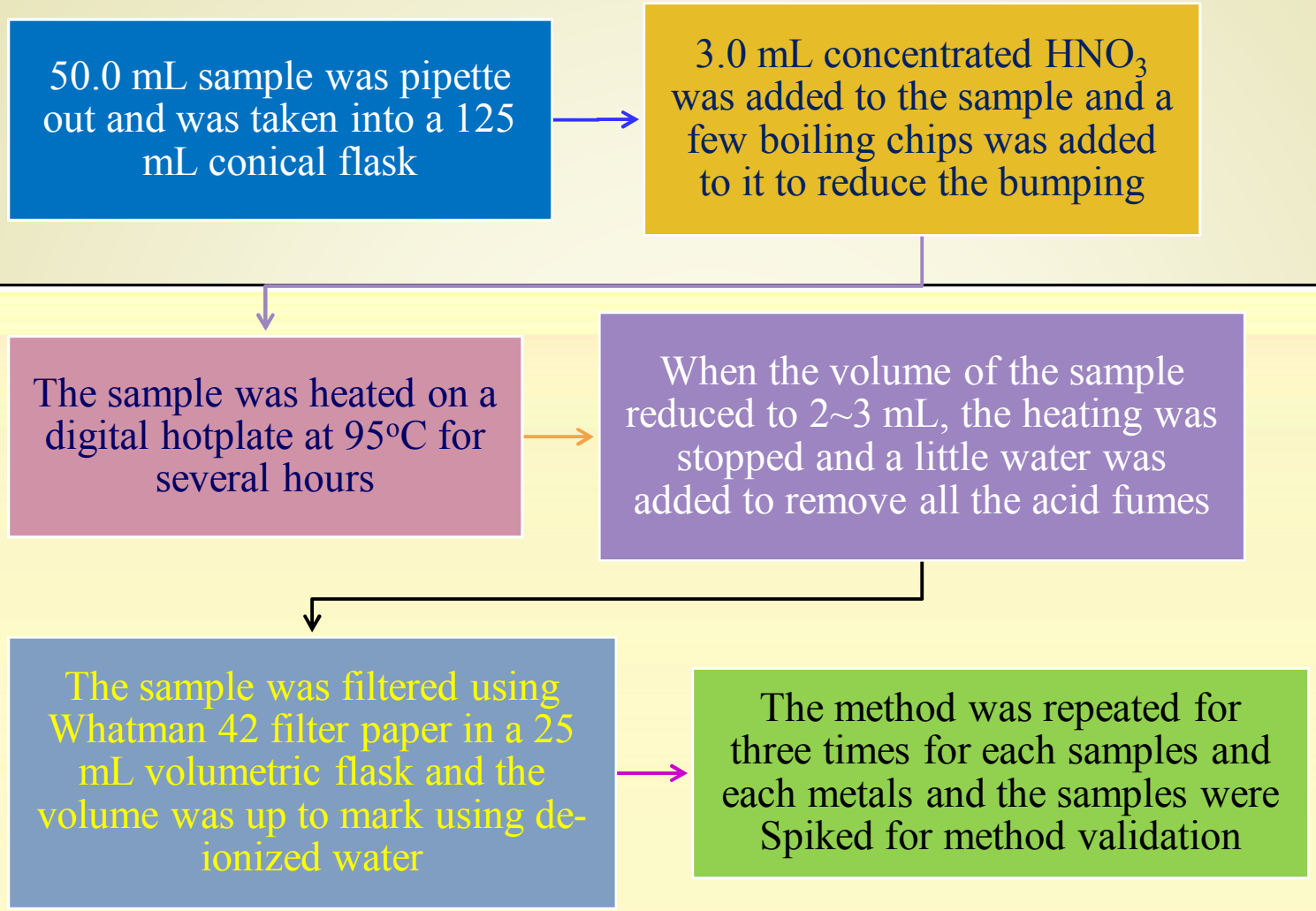


Figure 3: Digestion method of ground water samples

Material and Methods

Table-1: Working condition of AAS for heavy metal detection

Parameter	Fe	Mn	Cd	Pb	Cr	Ni	Zn	As
Wavelength (nm)	248.5	279.5	228.8	283.3	357.9	232.0	213.9	193.7
HCL current (mA)	12.0	10.0	8.0	10.0	10.0	12.0	8.0	12.0
Acetylene flow rate (L/min)	2.2	2.0	1.8	1.6	2.2	1.6	2.0	2.0
Slit (nm)	0.2	0.2	1.0	1.0	0.5	0.2	0.5	1.0

Results and Discussion

Table 2: Descriptive statistics of heavy metals in collected samples.

Parameters	Fe(mg/L)	Mn(mg/L)	Zn (mg/L)	Ni (mg/L)	Cr (mg/L)	Cd (mg/L)	Pb (mg/L)	As(ppm)
Maximum	**7.390**	**0.910**	1.520	**0.152**	**0.077**	**0.034**	**0.107**	**0.170**
Minimum	**0.440**	0.020	0.220	**0.014**	0.020	BDL*	0.009	**0.040**
Mean	3.572	0.415	1.091	0.075	0.039	0.014	0.040	0.119
SD	0.8723	0.0962	0.1196	0.0163	0.0051	0.0032	0.0106	0.0115
WHO Std (2004)	**0.3**	**0.4**	**3.0**	**0.02**	**0.05**	**0.003**	**0.01**	**0.01**
BD Std (2009)	**1.0**	**0.1**	**5.0**	**0.1**	**0.05**	**0.005**	**0.05**	**0.05**
USEPA (2014)	**0.3**	**0.05**	**5.0**	**0.1**	**0.1**	**0.005**	**0.015**	**0.01**

*BDL= Below Detection limit, BDL for Cd is <0.005 mg/L

Results and Discussion

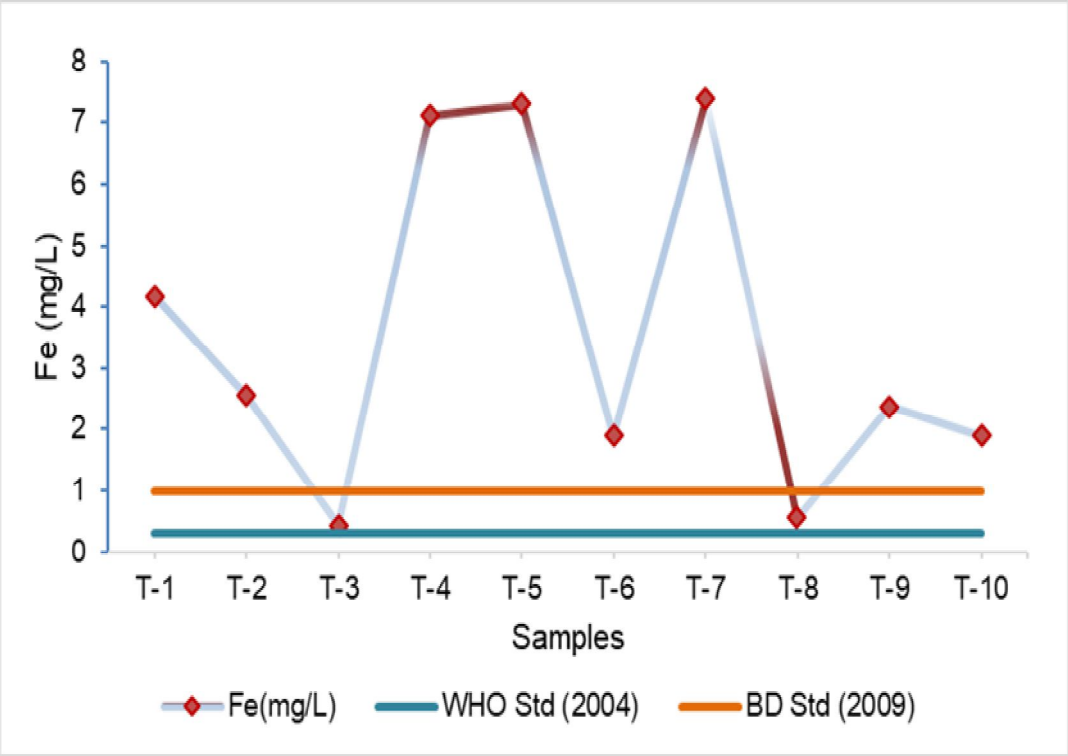


Fig 4: Comparison of Fe concentration with WHO and Bangladesh standards for drinking water in different samples

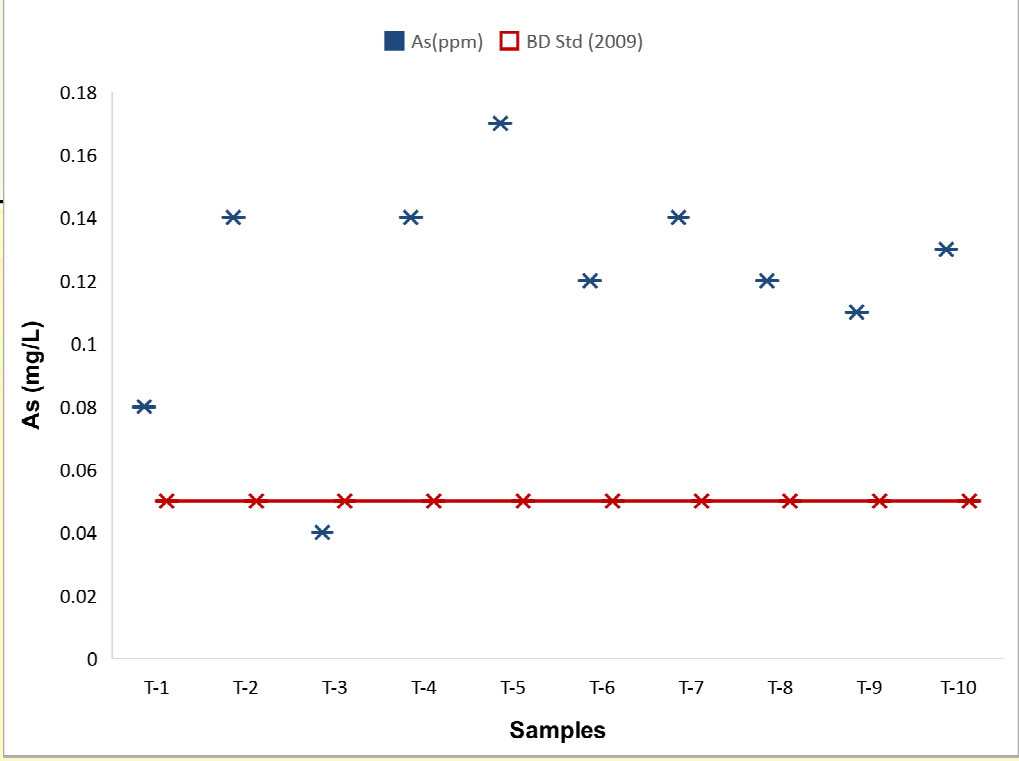


Fig 5: Concentration of As in different samples and the comparison with drinking water standard of Bangladesh

Results and Discussion

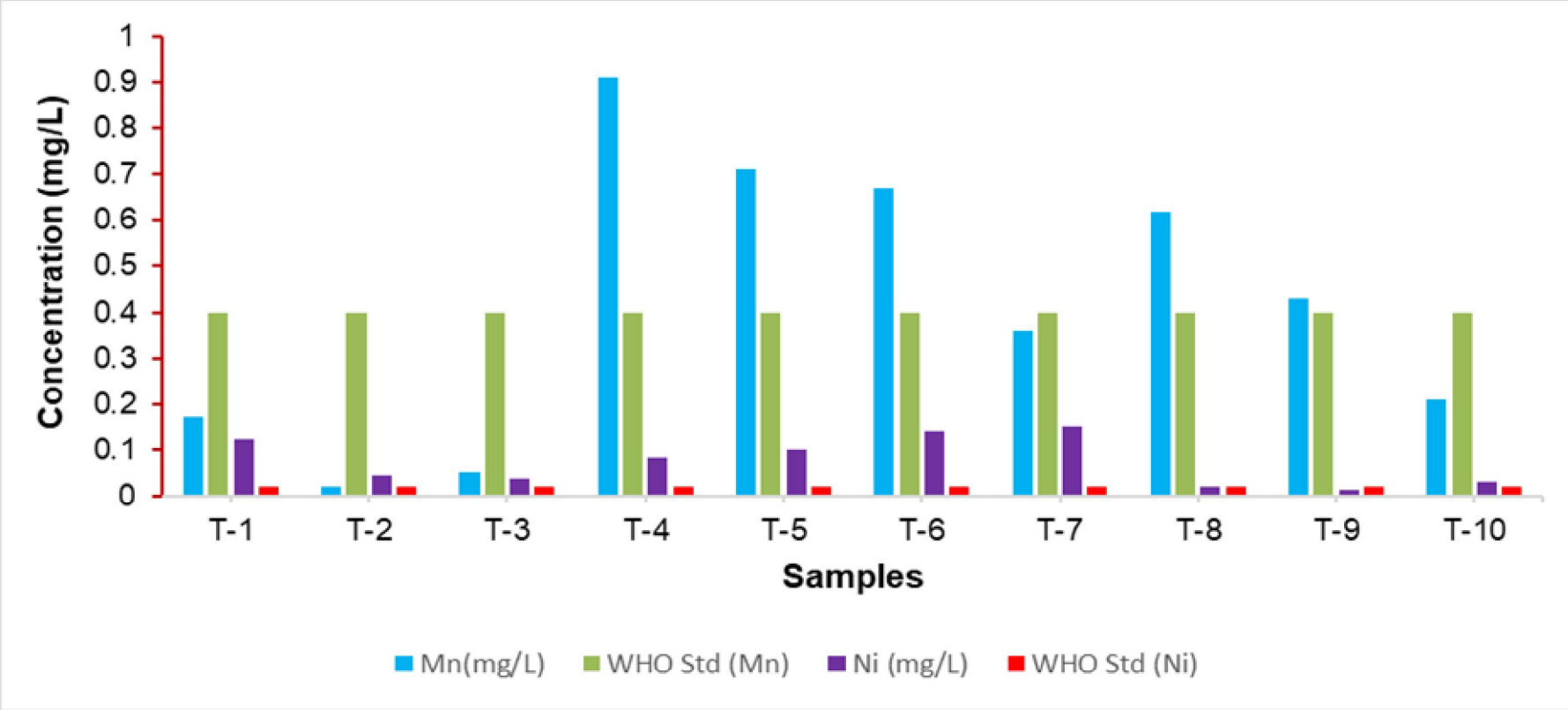


Fig 6: Comparison of Mn and Ni concentration in different samples with WHO standards for drinking water

Results and Discussion

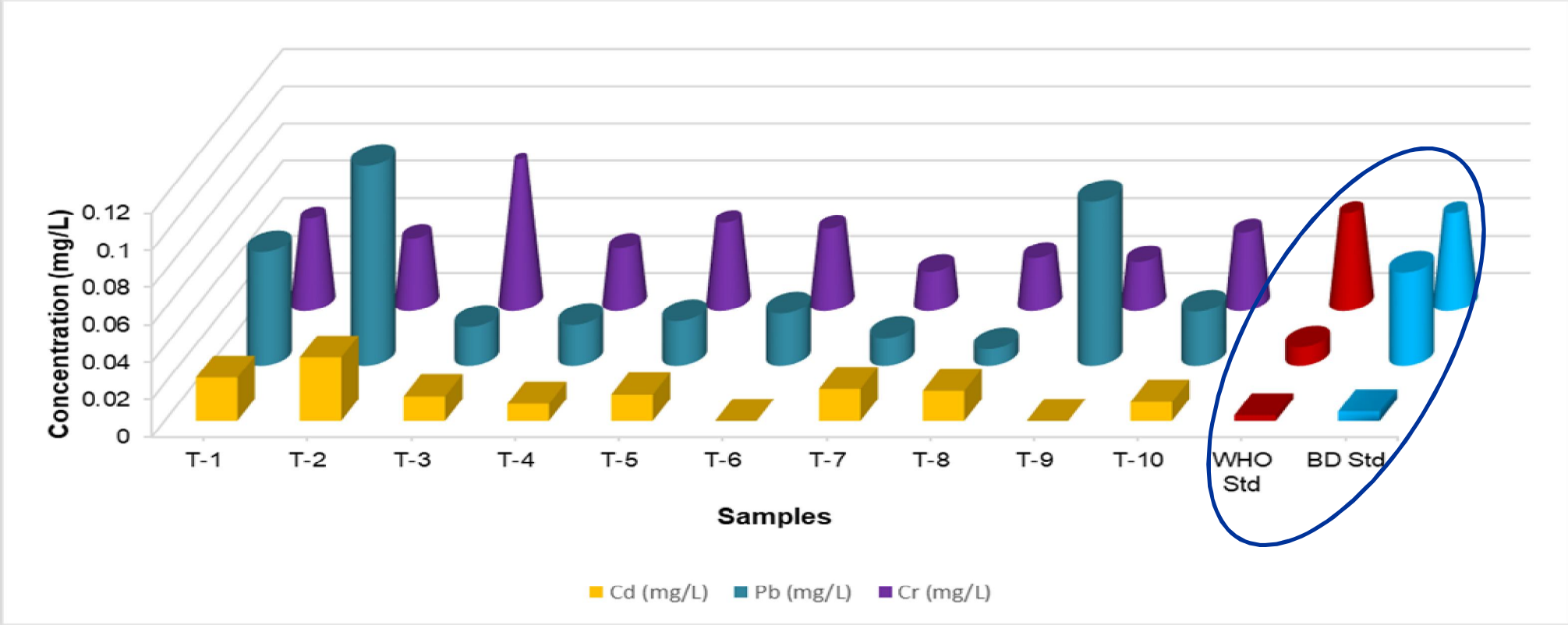


Fig 7: Comparison of Cd, Pb and Cr concentration in different samples with WHO and BD standards for drinking purpose

Results and Discussion

Table-3: Correlation analysis of heavy metals in the collected samples.

Variables	*Fe(mg/L)*	*Mn(mg/L)*	*Zn (mg/L)*	*Ni (mg/L)*	*Cr (mg/L)*	*Cd (mg/L)*	*Pb (mg/L)*	*As(mg/L)*
Fe(mg/L)	1.0000							
Mn(mg/L)	0.4401	1.0000						
Zn (mg/L)	0.1797	0.4888	1.0000					
Ni (mg/L)	**0.6080**	0.2418	0.1423	1.0000				
Cr (mg/L)	-0.3546	-0.4058	-0.4435	-0.0865	1.0000			
Cd (mg/L)	0.0904	**-0.5372**	-0.3641	0.0024	0.0676	1.0000		
Pb (mg/L)	-0.1697	-0.4744	-0.2705	-0.2876	-0.1104	0.3421	1.0000	
As (mg/L)	**0.5931**	**0.5268**	**0.6304**	0.1981	**-0.6621**	0.0530	-0.0207	1.0000

Health Risk Assessments

To identify the potential health risks several parameters has been measured.

- Acceptable Daily Intake (ADI)
- Hazard Quotient (HQ)
- Hazard Index (HI)
- Carcinogenic Risk (CR)

Acceptable Daily Intake (ADI)

Acceptable daily intake or ADI is a measure of the amount of a specific substance in food or drinking water that can be ingested (orally) on a daily basis over a lifetime without an appreciable health risk. It can be calculated by the equation below and the unit is mgkg/day.

$$\mathbf{ADI = (C \times IR)/ BW}$$

Here, C is the heavy metal concentration (mg/L), IR is daily ingestion rate of drinking water (L/d), BW is the average body weight (kg).

Table-4: Acceptable Daily Intake (ADI) of Trace Elements

Sample ID	Unit	Fe	Mn	Zn	Pb	Cr	Cd	Ni	As
T-1	mg/kg/day	**0.1314**	**0.0053**	0.0069	0.0019	0.0015	0.0007	0.0039	0.0025
T-2	mg/kg/day	**0.0801**	**0.0006**	**0.0343**	0.0034	0.0012	0.0011	0.0013	0.0047
T-3	mg/kg/day	**0.0138**	**0.0015**	**0.0251**	0.0007	0.0024	0.0004	0.0012	0.0013
T-4	mg/kg/day	**0.2237**	**0.0286**	**0.0324**	0.0008	0.0011	0.0003	0.0026	0.0044
T-5	mg/kg/day	**0.2297**	**0.0223**	**0.0437**	0.0007	0.00142	0.0004	0.0031	0.0053
T-6	mg/kg/day	**0.0594**	**0.0211**	**0.0478**	0.0009	0.0013	---	0.0044	0.0038
T-7	mg/kg/day	**0.2323**	**0.0113**	**0.0462**	0.0005	0.0007	0.0005	0.0048	0.0044
T-8	mg/kg/day	0.0145	**0.0195**	**0.0380**	0.0003	0.0008	0.0005	0.0007	0.0050
T-9	mg/kg/day	**0.0748**	**0.0135**	**0.0365**	0.0025	0.0008	---	0.0004	0.0035
T-10	mg/kg/day	**0.0597**	**0.0066**	**0.0321**	0.0009	0.0013	0.0003	0.0010	0.0041
Maximum ADI	mg/kg/day	**0.018**	**0.002**	**0.011**	**0.010**	**0.035**	**0.006**	**0.070**	---

Hazard quotient (HQ):

The ratio of the potential exposure to a substance and the level at which no adverse effects are expected (calculated as the exposure divided by the appropriate chronic or acute value). A hazard quotient of 1 or lower means adverse non cancer effects are unlikely, and thus can be considered to have negligible hazard.

Hazard index (HI):

The sum of hazard quotients for toxics that affect the same target organ or organ system.

$$HI_{ing} = \sum HQ_{ing} \quad \text{or} \quad HI_{dermal} = \sum HQ_{dermal}$$

Calculation of Hazard Quotient (HQ)

According to USEPA (2011), Hazard quotient for **oral ingestion** can be calculated by the following equation:

$$HQ_{ing} = \frac{C_{water} \times IR \times EF \times ED}{AT \times BW \times R_fD_{oral}}$$

**Oral reference Dose R_fD of Zn: 0.30, Pb: 0.0014, Cd: 0.0005, Cr: 0.003, Ni: 0.02, Fe: 0.7, Mn: 0.024 and As: 0.0003 mg/kg/d .

Exposure Factors	Unit	Values
C_{water} (Metal concentration in water)	mg/L	-----
IR (Ingestion Rate)	L/day	2.2
EF (Exposure Frequency)	Day/year	365
ED (Exposure Duration)	Year	30
AT (Average Time)	Days	10,950
BW (Average Body Weight)	Kg	70
R_fD (Oral Reference Dose)	mg/kg/d	**

Calculation of Hazard Quotient (HQ)

Hazard Quotient via dermal exposure can be calculated by the following equation:

$$HQ_{dermal} = \frac{C_{water} \times IR \times EF \times ED \times S_A \times E_T \times K_p \times CF}{AT \times BW \times R_fD_{dermal}}$$

**Dermal reference Dose R_fD of

Zn: 0.06, Pb: 1.40E-04, Cd: 2.50E-05,

Cr: 7.50E-05, Ni: 8.00E-04, Fe: 0.14,

Mn: 9.60E-04 and As: 1.90E-04 mg/kg/d.

Exposure Factors	Unit	Values
S_A (Exposed skin area)	cm^2	28000
E_T (Exposure Time)	h/day	0.52
K_p (Dermal permeability coefficient in water)	cm/h	Fe, Mn, Cd: 0.001 Cr: 0.002 Zn: 0.0006 Ni: 0.0001 As: 0.0011 Pb: 0.004
CF (Conversion factor)	L/cm^3	0.001
R_fD (Dermal Reference Dose)	mg/kg/d	**
C_{water}, IR, EF, ED, AT, BW means same meaning as previous		

Table-5: Calculated Hazard Quotient (HQ) and Hazard Index (HI) of Heavy metals for Groundwater ingestion

Sample ID	$Fe(HQ_{ing})$	$Mn(HQ_{ing})$	$Zn(HQ_{ing})$	$Ni(HQ_{ing})$	$Cr(HQ_{ing})$	$Cd(HQ_{ing})$	$Pb(HQ_{ing})$	$As(HQ_{ing})$	HI_{ing}
T-1	0.1877	0.2226	0.0230	0.1933	0.4924	**1.4457**	**1.3694**	**8.3810**	**12.3151**
T-2	0.1145	0.0262	0.1142	0.0676	0.3876	**2.1371**	**2.4020**	**15.7143**	**20.9635**
T-3	0.0198	0.0655	0.0838	0.0613	0.8067	0.8171	0.4714	**4.1905**	**6.5160**
T-4	0.3197	**1.1917**	0.1079	0.1304	0.3352	0.5657	0.4939	**14.6667**	**17.8112**
T-5	0.3282	0.9298	0.1456	0.1540	0.4714	0.8800	0.5388	**17.8095**	**21.2573**
T-6	0.0849	0.8774	0.1592	0.2216	0.4400	---	0.6286	**12.5714**	**14.9830**
T-7	0.3318	0.4714	0.1540	0.2389	0.2095	**1.0686**	0.3367	**14.6667**	**17.4776**
T-8	0.0207	0.8119	0.1268	0.0330	0.2829	**1.0057**	0.2020	**16.7619**	**19.2448**
T-9	0.1069	0.5631	0.1215	0.0220	0.2619	---	**1.9755**	**11.5238**	**14.5747**
T-10	0.0853	0.2750	0.1069	0.0503	0.4190	0.6286	0.6510	**13.6190**	**15.8351**
HI_{ing}	**1.5993**	**5.4345**	**1.1430**	**1.1723**	**4.1067**	**8.5486**	**9.0694**	**129.9048**	**160.9784**

Sample ID	$Fe(HQ_{derm})$	$Mn(HQ_{derm})$	$Zn(HQ_{derm})$	$Ni(HQ_{derm})$	$Cr(HQ_{derm})$	$Cd(HQ_{derm})$	$Pb(HQ_{derm})$	$As(HQ_{derm})$	HI_{derm}
T-1	0.0137	0.0810	0.0010	0.0070	0.5735	0.4210	0.7975	0.2119	**2.1067**
T-2	0.0083	0.0095	0.0050	0.0025	0.4515	0.6223	**1.3989**	0.3974	**2.8955**
T-3	0.0014	0.0238	0.0037	0.0022	0.9396	0.2380	0.2746	0.1060	**1.5893**
T-4	0.0233	0.4338	0.0047	0.0047	0.3905	0.1647	0.2876	0.3709	**1.6803**
T-5	0.0239	0.3384	0.0064	0.0056	0.5491	0.2563	0.3138	0.4504	**1.9438**
T-6	0.0062	0.3194	0.0070	0.0081	0.5125	---	0.3661	0.3179	**1.5371**
T-7	0.0242	0.1716	0.0067	0.0087	0.2441	0.3112	0.1961	0.3709	**1.3334**
T-8	0.0015	0.2955	0.0055	0.0012	0.3295	0.2929	0.1177	0.4239	**1.4677**
T-9	0.0078	0.2050	0.0053	0.0008	0.3051	---	**1.1505**	0.2914	**1.9659**
T-10	0.0062	0.1001	0.0047	0.0018	0.4881	0.1830	0.3792	0.3444	**1.5075**
HI_{derm}	0.1164	**1.9782**	0.0499	0.0427	**4.7834**	**2.4893**	**5.2820**	**3.2851**	**18.0271**

Table-6: Calculated Hazard Quotient (HQ) and Hazard Index (HI) of Heavy metals for dermal exposure by Groundwater

Hazard Index (HI)

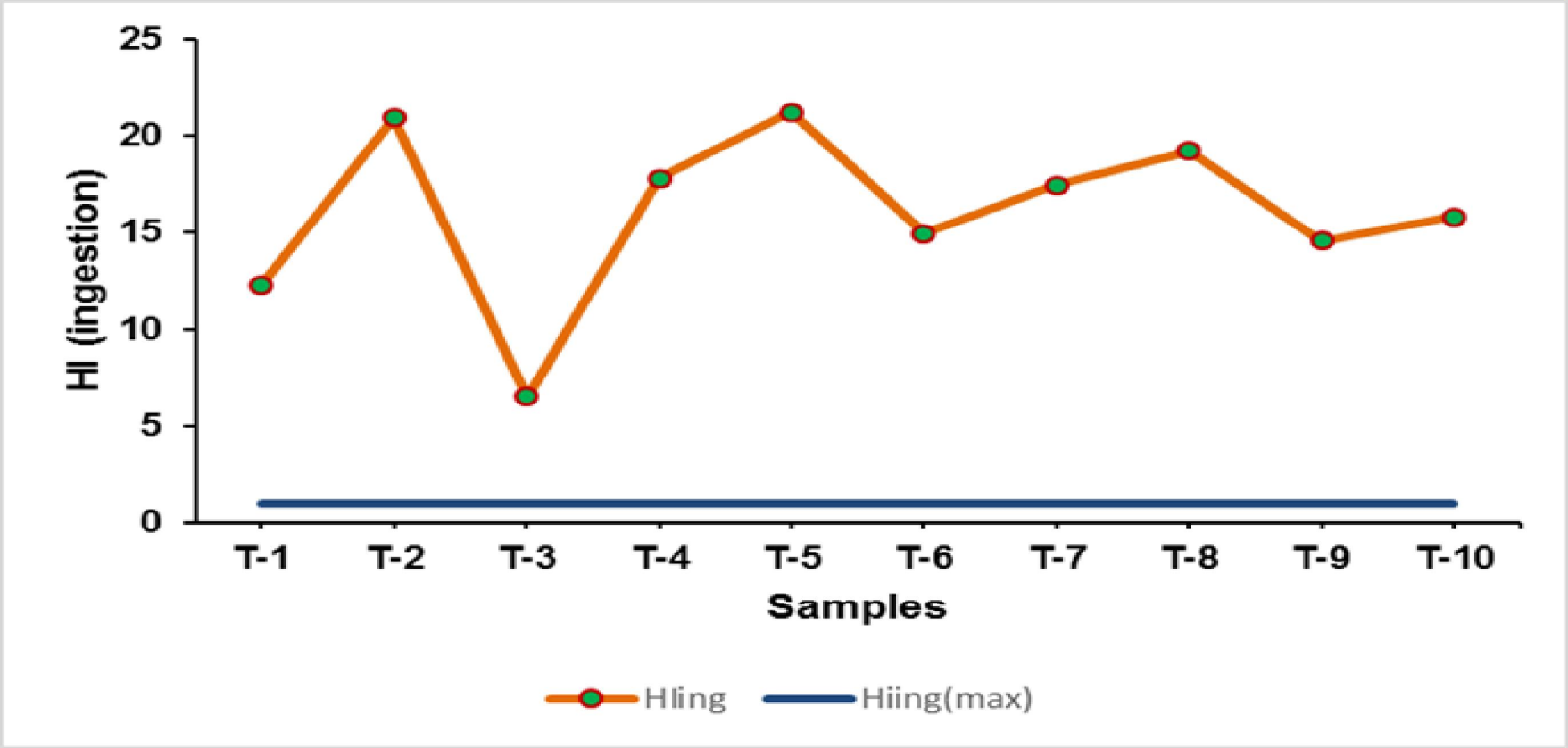


Fig 8: Hazard Index in different samples for oral intake

Hazard Index (HI)

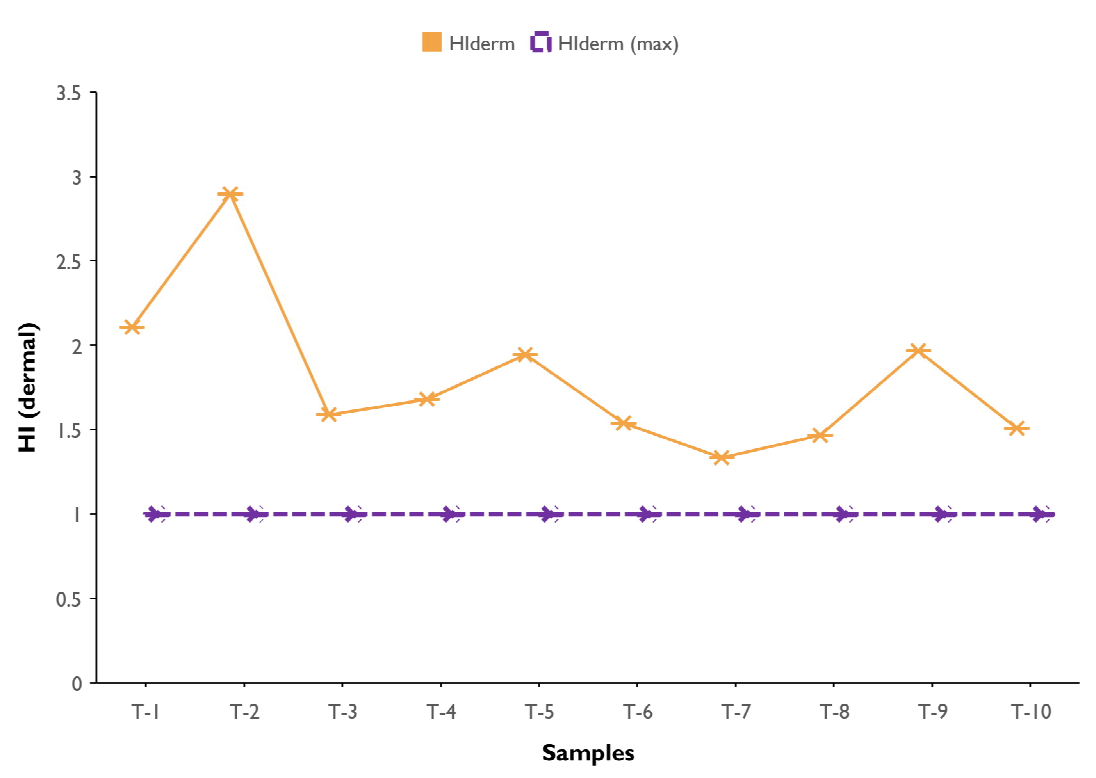


Fig 9: Hazard Index in different samples for dermal exposure

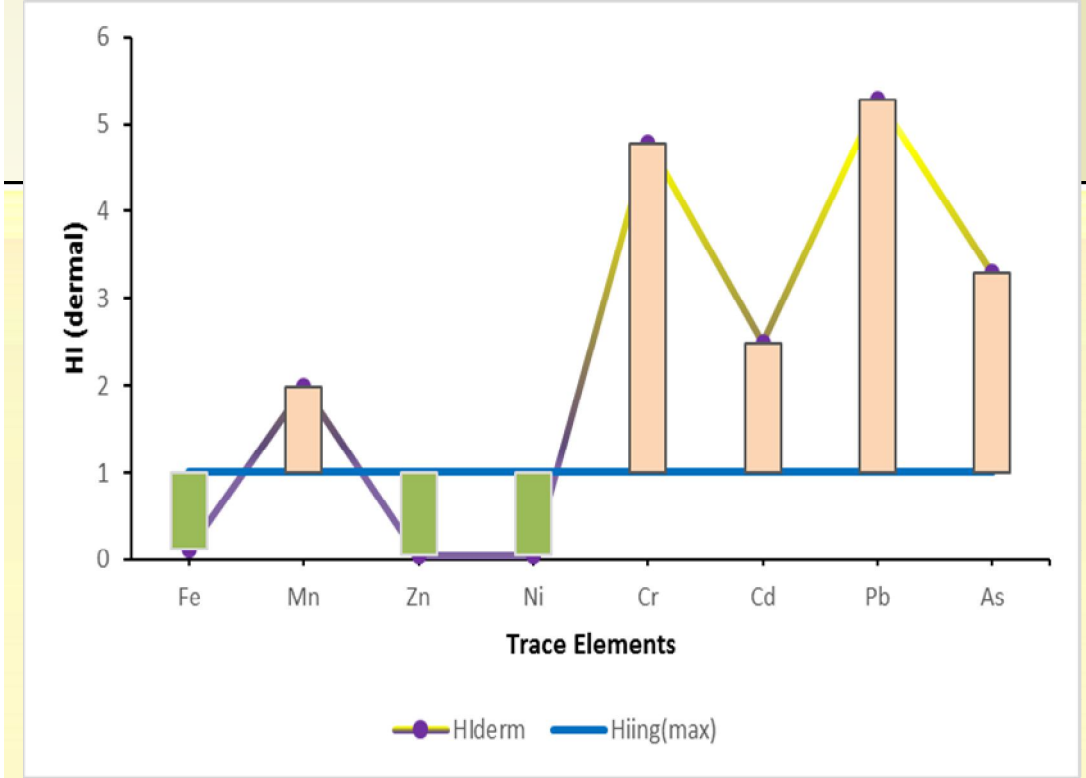


Fig 10: Hazard Index of different elements in collected samples for dermal exposure

Carcinogenic Risk

Carcinogenic health risks are expressed by their cancer slope factor (CSF) which converts the estimated exposure through inhalation or ingestion via intake of metals into incremental risk of an individual developing cancer over time. The range of carcinogenic risks (CR_{ing}) acceptable or tolerable is 1.0E-06 to 1.0E-04. The equation is as follows:

$$CR_{ing} = \frac{C_{water} \times IR \times EF \times ED}{AT \times BW} \times CSF$$

**Cancer Slope Factor (CSF) for Pb, Cd, As and Cr is 0.0085, 6,3, 1.5 and 0.5 mg/kg/day respectively

Exposure Factors	Unit	Values
C_{water} (Metal concentration in water)	mg/L	-----
IR (Ingestion Rate)	L/day	2.2
EF (Exposure Frequency)	Day/year	365
ED (Exposure Duration)	Year	70
AT (Average Time)	Days	25,550
BW (Average Body Weight)	Kg	70
CSF (Cancer Slope Factor)	mg/kg/d	**

Carcinogenic Risk

Sample ID	Cr(CR_{ing})	Cd(CR_{ing})	Pb(CR_{ing})	As(CR_{ing})
T-1	**0.00074**	**0.00455**	1.6296E-05	**0.00377**
T-2	**0.00058**	**0.00673**	2.8584E-05	**0.00707**
T-3	**0.00121**	**0.00257**	5.6100E-06	**0.00189**
T-4	**0.00050**	**0.00178**	5.8771E-06	**0.00660**
T-5	**0.00071**	**0.00277**	6.4114E-06	**0.00801**
T-6	**0.00066**	---	7.4800E-06	**0.00566**
T-7	**0.00031**	**0.00337**	4.0071E-06	**0.00660**
T-8	**0.00042**	**0.00317**	2.4043E-06	**0.00754**
T-9	**0.00039**	---	2.3509E-05	**0.00519**
T-10	**0.00063**	**0.00198**	7.7471E-06	**0.00613**
Acceptable range of CR	**1.0E-06 – 1.0E-04**			

Table-7: Carcinogenic risk assessment of different samples of Tangail Sadar

Carcinogenic Risk

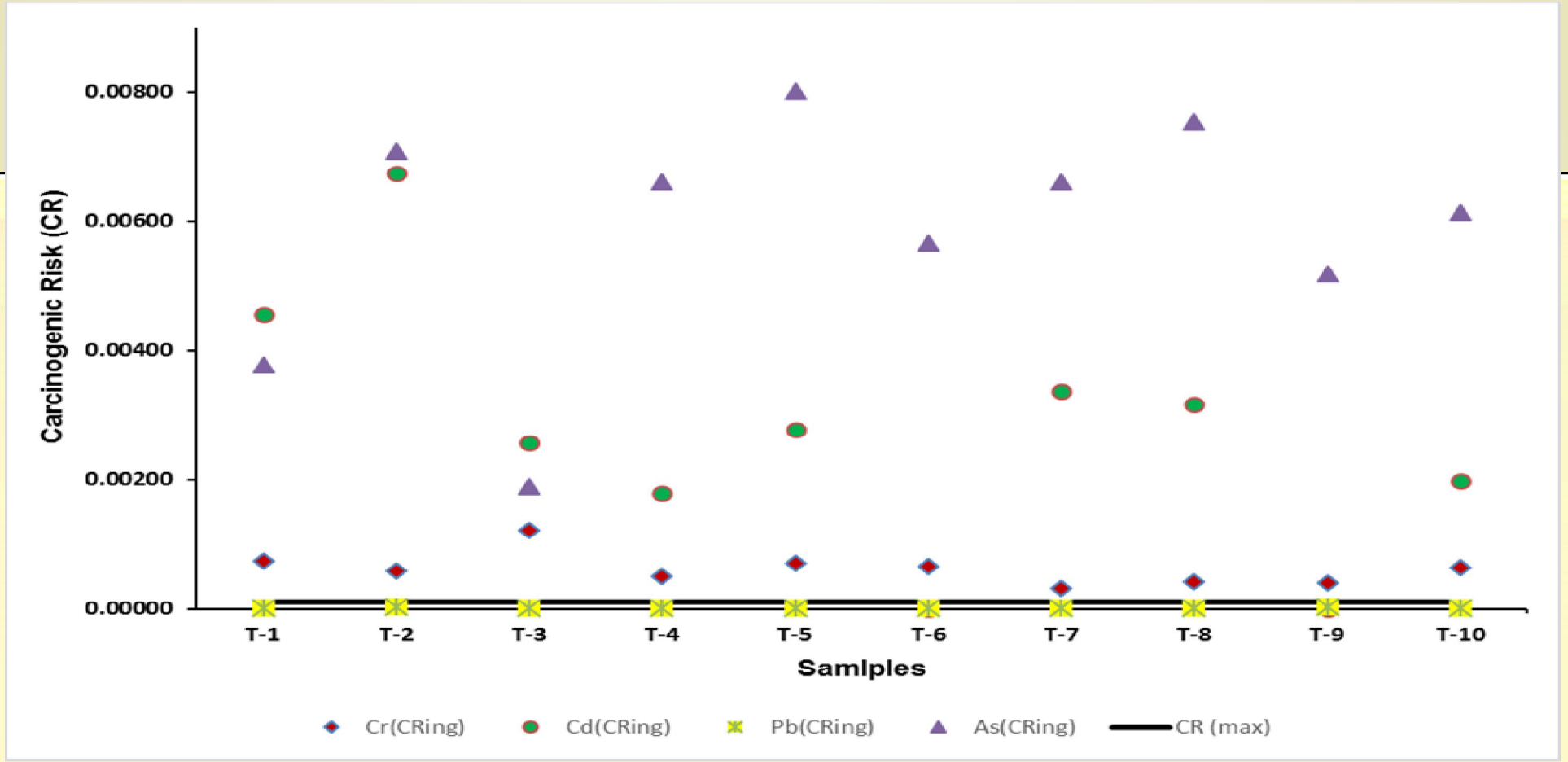


Fig 11: Graphical representation of Carcinogenic Risks of elements in collected samples

Conclusion

- Several trace elements has been analysed and the concentration of Fe and As in all samples were above the WHO standard and the concentration of Mn, Ni, Pb and Cd exceeded the standard limit in few samples.

- Acceptable Daily Intake of Fe, Mn, Zn, Cd, Cr, Ni, Pb and As were calculated and for most of the samples **Fe**, **Mn** and **Zn** crossed the maximum ADI limit of WHO.

- **Hazard Quotient** and **Hazard Index** for both Oral and Dermal exposure has been calculated and for most of the samples both the results were above 1 which can be alarming for daily use. The non-carcinogenic effect decreased for oral ingestion in order of As>Pb>Cd>Mn>Cr>Fe>Ni>Zn and for dermal exposure Pb>Cr>As>Cd>Mn>Fe>Zn>Ni.

Conclusion (contd….)

- The carcinogenic risk factor was also calculated for Cr, Pb, As and Cd and it was found within the standard limit (1×10^{-6} to 1×10^{-4}) only for Pb but for **Cd, Cr and As** most of the samples exceeded the highest risk factor which can lead to cancer risk for long term usage.

- Possibility of contamination from corrosive effect of pipes.

Thank You All