Supplementary material for

Assessment of groundwater contamination by heavy metals for a managed aquifer recharge project in Indus River Basin in Pakistan

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Table S1: Details of samples collected from field from different sources

Sample Code	Date of sampling	Tube Well Type	Source of energy	Lat	Long	Depth (m)
HM1	27/05/2021	Turbine	Electric	29.865359	72.296017	85
HM2	27/05/2021	Turbine	Electric	29.927919	72.218076	94
HM3	27/05/2021	Tubewell	Electric	29.881449	72.331247	95
HM4	28/05/2021	Turbine	Electric	29.923879	72.337716	110
HM5	27/05/2021	Tubewell	Electric	30.030974	72.245258	70
HM6	26/05/2021	Turbine	Electric	30.033492	72.356333	95
HM7	28/05/2021	Turbine	Electric	29.993998	72.394419	108
HM8	28/05/2021	Turbine	Electric	29.960032	72.428099	115

HM9	26/05/2021	Tubewell	Electric	29.871523	72.545842	70
HM10	27/05/2021	Turbine	Electric	29.896457	72.502013	140
HM11	27/05/2021	Tubewell	Electric	29.896943	72.483115	78
HM12	26/05/2021	Tubewell	Electric	30.049621	72.396629	108
HM13	26/05/2021	Tubewell	Electric	30.046657	72.474392	75
HM14	26/05/2021	Turbine	Electric	29.984891	72.521888	94
HM15	26/05/2021	Turbine	Electric	29.939639	72.542453	95
HM16	27/05/2021	Tubewell	Electric	29.927672	72.662382	70
*HM17	28/05/2021	Turbine	Electric	29.971414	72.605120	125
HM18	28/05/2021	Turbine	Electric	30.022755	72.588136	95
HM19	26/05/2021	Turbine	Electric	30.104320	72.606532	110
HM20	25/05/2021	Tubewell	Electric	30.117675	72.527476	80
HM21	28/05/2021	Sukh Beas Drain	-	30.13853	72.62458	-
HM22	28/05/2021	PI Link canal	-	30.12675	72.65466	-
HM23	27/05/2021	Sutlej River	-	29.828652	72.54947	-

Table S2: Maximum permissible/standard limits of heavy metals for drinking and irrigation purposes

Heavy Metals	WHO/FAO/EPA-Maximum Permissible limits for **drinking** (ppb)		WHO/FAO/EU Maximum permissible limits for **irrigation** water (ppb)	
Aluminum (Al)	200	(WHO, 2017)	5000	(Jeong et al., 2016)
Arsenic (As)	10 50	**(GoP_EPA, 2008)** (WHO, 2017)	100	(Jeong et al., 2016) (FAO, 2013)
Barium (Ba)	1300	(WHO, 2017)	-	
Cadmium (Cd)	3	-do-	10	(Jeong et al., 2016)
Cobalt	50	-do-	50	(Jeong et al., 2016), **(GoP_EPA, 2008)**
Chromium (Cr)	50	-do-	100	-do-
Copper (Cu)	2000	-do-	200	-do-
Manganese (Mn)	50	(Khwaja & Aslam, 2018)	200	(Jeong et al., 2016)
Molybdenum (Mo)	10	WHO 2017	10	(Jeong et al., 2016)
Nickel (Ni)	70	-do-	200	-do-
Lead (Pb)	10	-do-	65	
Selenium (Se)	10	(Khwaja & Aslam, 2018)	20	**(GoP_EPA, 2008)**
Zinc (Zn)	20	-do-	2000	**(GoP_EPA, 2008)**

Table S3: Heavy metals concentrations in the water samples in the study area

Samples	Al (ppb)	As (ppb)	Ba (ppb)	Cd (ppb)	Co (ppb)	Cr (ppb)	Cu (ppb)	Mn (ppb)	Mo (ppb)	Ni (ppb)	Pb (ppb)	Se (ppb)	Zn (ppb)
Drinking limit	**200**	**50**	**1300**	**3**	**50**	**50**	**2000**	**50**	**10**	**70**	**10**	**10**	**20**
Irrigation Limit	**5000**	**100**	**-**	**10**	**50**	**100**	**200**	**200**	**10**	**200**	**65**	**20**	**2000**
HM1	153.76	27.03	74.1	BDL	0.52	1.52	0.89	81.9	7.71	1.13	0.25	9.95	115.1
HM2	26.55	97.23	137.06	BDL	0.61	1.19	0.78	261.68	3.65	0.88	0.25	10.17	145.39
HM3	39.82	25.8	66.62	BDL	0.91	1.5	25.88	128.94	4.21	1.68	0.25	11.81	1.97
HM4	21.8	**133.71**	50.66	BDL	0.97	0.7	0.93	74.25	2.64	0.76	0.25	BDL	205.48
HM5	14.43	62.43	33.79	BDL	0.81	1.24	0.05	76.92	26.92	0.58	0.79	BDL	0.03
HM6	76.63	57.64	72.17	BDL	0.94	1.25	1.59	29.64	5.37	1.39	1.41	BDL	1.31
HM7	30.25	166.84	107.03	BDL	0.53	1.68	2.38	69.83	3	1.52	1.5	BDL	6.6
HM8	1982.52	39.47	202.69	BDL	0.9	5.47	11.93	153.4	2.7	6.21	4.25	BDL	11.22
HM9	271.66	18.11	42.82	BDL	1.04	1.75	1.27	202.98	6.23	2.21	1.58	BDL	6.15
HM10	233.88	25.35	110.32	BDL	1.27	1.75	2.81	54.84	6.63	2.19	5.36	BDL	172.55
HM11	2463.75	21.15	159.28	BDL	0.75	6.17	4.53	157.22	1.92	7.61	4.81	BDL	79.63
HM12	17.6	96.46	35.61	BDL	0.77	1.46	1.05	93.81	6.86	1.77	2.59	BDL	9.96
HM13	52.04	112.34	43.44	BDL	0.51	1.88	0.82	148.12	3.29	1.47	0.25	BDL	5.5
HM14	563.59	36.58	117.97	BDL	0.39	2.81	13.22	141.68	3.74	2.59	3.21	BDL	28.22
HM15	5.76	14.62	76.99	BDL	1.42	1.49	0.56	15.1	8.86	1.22	0.25	BDL	0.03
HM16	567.33	33.1	52.71	BDL	1.35	2.92	1.54	66.36	3.49	3.3	0.25	BDL	14.29
HM17	17.48	20.45	105.8	BDL	1.77	1.25	0.64	21.27	12.39	0.58	0.25	BDL	0.03
HM18	20.69	21.17	58.96	BDL	1.11	1.7	2.2	33.67	4.75	1.16	0.25	BDL	7.12
HM19	125.79	63.72	41.38	BDL	0.76	2.15	1.29	35.51	14.57	0.92	0.25	BDL	26.19
HM20	11.36	43.55	102.66	BDL	0.79	1.49	0.43	35.98	6.99	1.58	2.97	BDL	69.16
HM21 (Drain)	6.68	9.52	47.68	BDL	0.96	0.46	1.8	0.4	4.15	1.23	0.25	13.88	0.03
HM22 (Canal)	22.03	31.38	71.05	BDL	2.07	0.96	1.09	137.95	2.33	2.31	0.25	BDL	0.03
HM23 (River)	213.57	9.36	52.57	BDL	0.44	2.05	3.13	16.83	2.87	2.08	0.25	9.1	9.49

BDL= Below detection limits [cd: 0.03 ppb, Se : 0.1 ppb,

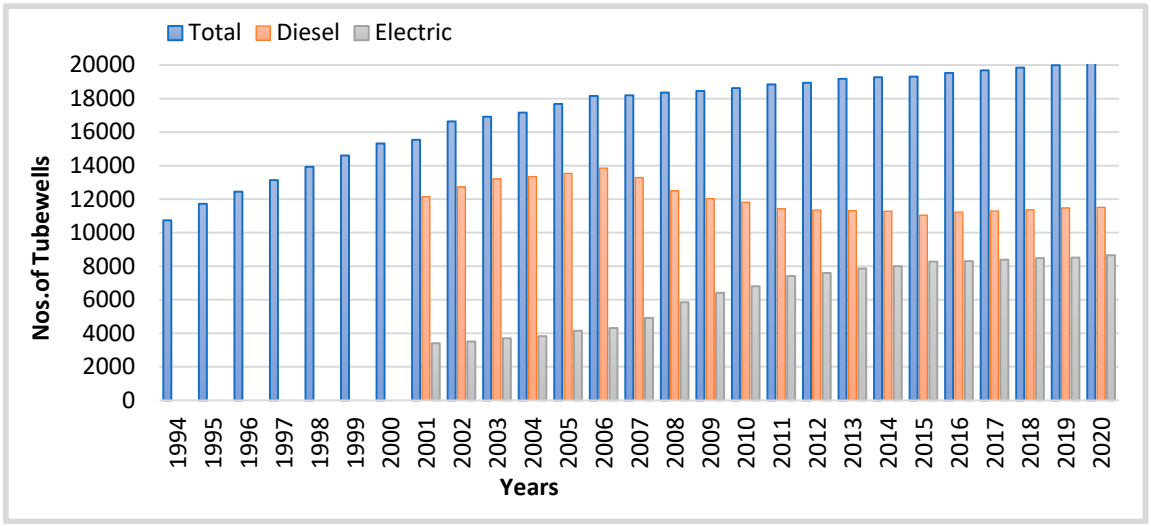


Figure S1: Grwoth of tubewells in study area

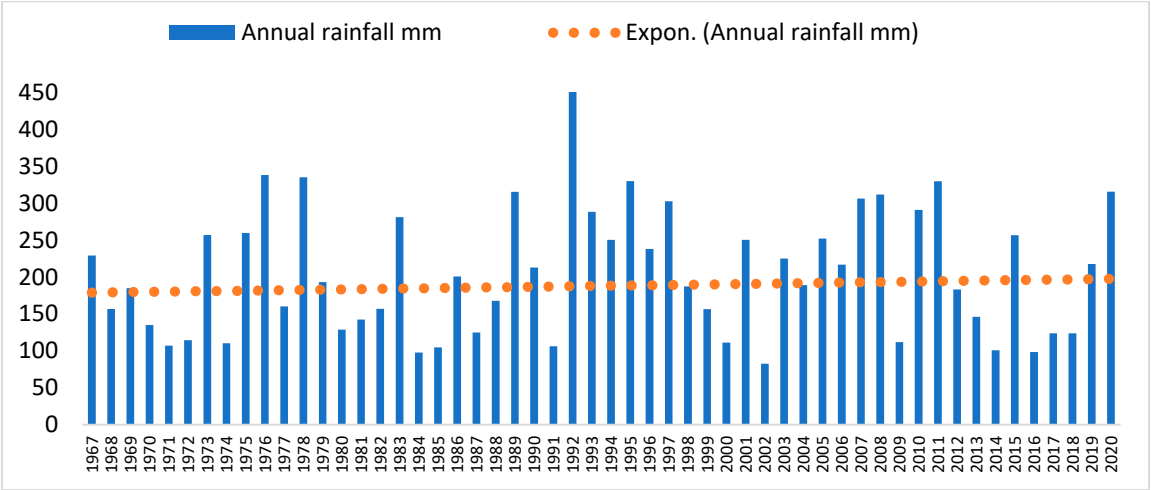


Figure S2: Annual Rainfall in the Study Area for the Period 1967–2020

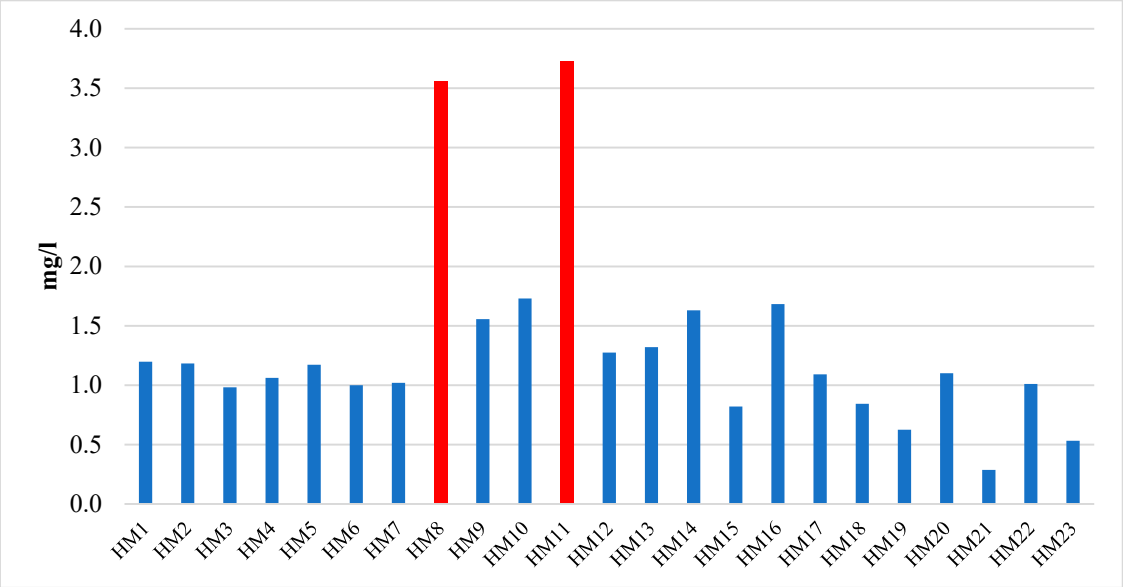


Figure S3: Total load of heavy metal (mg/l) in surface and groundwater

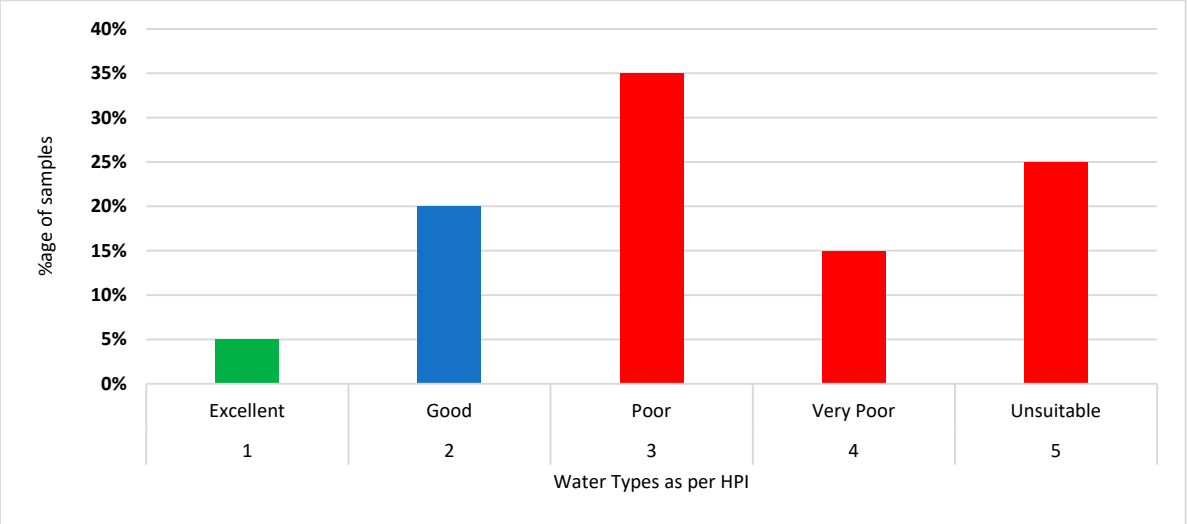


Figure S4. Results of Heavy Metal Assessment in groundwater samples of study area.

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