Groundwater Pollution Assessment and Mitigation Options in Baddi Industrial Complex of Himachal Pradesh

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KEYWORDS

Groundwater, Pollution, Assessment, Mitigation, Heavy metals

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ABSTRACT: (9 pt)

The Baddi Industrial Complex covers about 50 km^2 and is located around the towns of Baddi and Barotiwala in Solan District of Himachal Pradesh. The proposed study area is a fast developing industrial hub with polluting and non-polluting industries, along with development of domestic and commercial infrastructures to support the industry. In this industrial complex, it is proposed to have more than 10,000 industrial units out of which 2500 are pharmaceutical and food processing units and 5000 small and big units , some of them are textile units. The area has well developed drainage displaying dendritic pattern. All the tributaries (khads) of Sirsa river flow from ENE directions, almost parallel to each other, join the South east to Northwest flowing Sirsa River. Geologically the area is underlain with valley fill deposits of Pleistocene period and comprise of boulders, cobbles and pebbles with clay layers of variable thickness. On the whole the area represents one unified aquifer system which is being exploited to meet the entire demand of the industries and the infrastructure, there being no surface water source or surface water supply for this industrial hub. It is observed that in the pre-monsoon period the water table has declined almost 11m in the last 10years. The discharge from the industries are polluting the ground water, the only source of water supply, therefore the preset study pertains to comprehensive geochemical investigation to know the present status of groundwater pollution . The geochemical study has covered all the significant water quality parameters including heavy metals causing potential health hazards due to the ongoing industrial pollution. Due to unlined sewerage system of the industries, seepage from surface water from the unlined channels is affecting the groundwater quality. Also some of the industries are discharging the treated/untreated effluents directly to the groundwater through an open well or shallow tube well so as to adhere to the direction of “zero discharge”. For the preset study, 45 groundwater samples have been collected from hand pump, borewells and dugwells to spatially cover all the possible point sources of pollution. The value of TDS, Chloride, magnesium, calcium, and sulphate is higher than the permissible limits at many locations. Higher concentration of Sodium and Chloride indicates leaching of secondary salts and anthropogenic impact by industry and salt water intrusion. Spatial distribution of EC indicates anthropogenic impact in the downstream side of the basin. It indicates that the aquifer zone of the region is at its verge of being polluted to irreparable extent. In spite of the very high rate of dispersion of pollution streams due to favorable aquifer characteristics and dilution of the pollutants during the monsoon, trace metals are exceeding the safe limits. A few of the groundwater samples in the study area were found to be unsuitable for domestic and drinking purposes. Further, statistical and spatial analytical tools have been utilized for understanding the intensity of the groundwater problems in the area, and to suggest remedial measures for mitigation.

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1. INTRODUCTION

The Baddi industrial complex covering an area of about 40 km^2, is located at the foot hills of the Himalayas, forms a part of the Nalagarh Valley in the Solan district of Himachal Pradesh. The area is reckon as a fast developing industrial hub having more than 10,000 industrial units out of which 2500 are the Pharmaceutical and food processing units and 5000 small and big units, some of them are textile units. The industrial units, are both polluting and non-polluting, along with the development of domestic and commercial infrastructure depend entirely on the development of the groundwater resources. The groundwater is being exploited through construction of tubewells mostly drilled upto 150m depth as the information on aquifers below this depth has not been ascertained.

2. GEOLOGY AND HYDROGEOLOGY

Geologically, the area is underlained with quaternary alluvial sediments which are present on the western side of the Solan District (Figure 1). The Sediments consists of mixed of gravel, boulders, cobbles with intervening clay layers of variable thickness. These valley fill deposits overlie the Shiwalik rocks. The sub-surface lithological section are given in Figure 2.

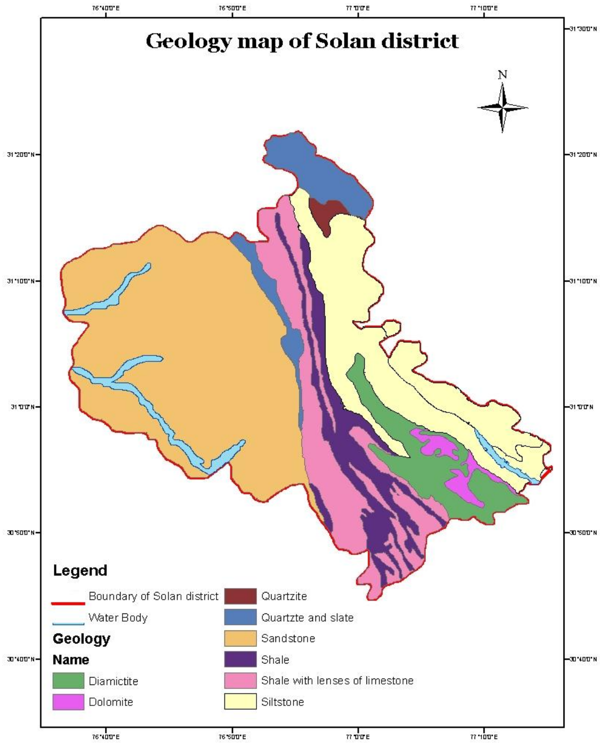

Fig.1: Geological Map of study area

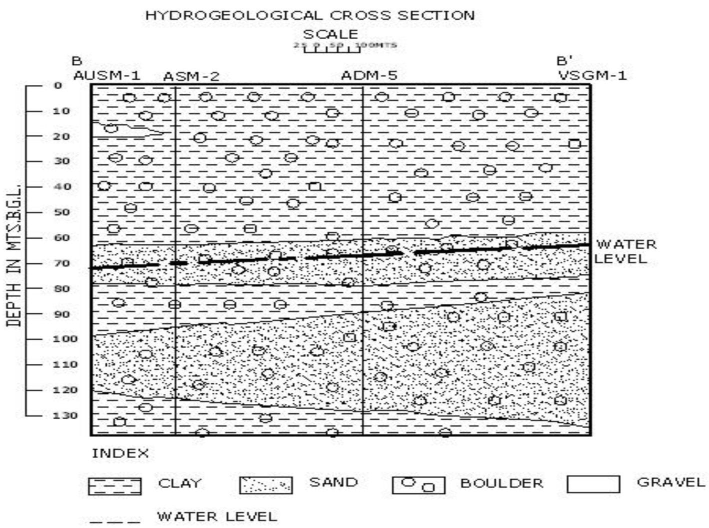

Fig. 2: Sub-surface lithological Section showing the presence of thick boulder and gravel sediments

Groundwater occurs in the unconfined condition in the shallow aquifers but the deep aquifers show semi-confined conditions. Inventories of the groundwater structures show the depth to water table vary from 5m-70m bgl. Based on this data, water table contour map (Figure 3) has been prepared to mark the groundwater flow direction which helps in understanding the movement of the pollutants.

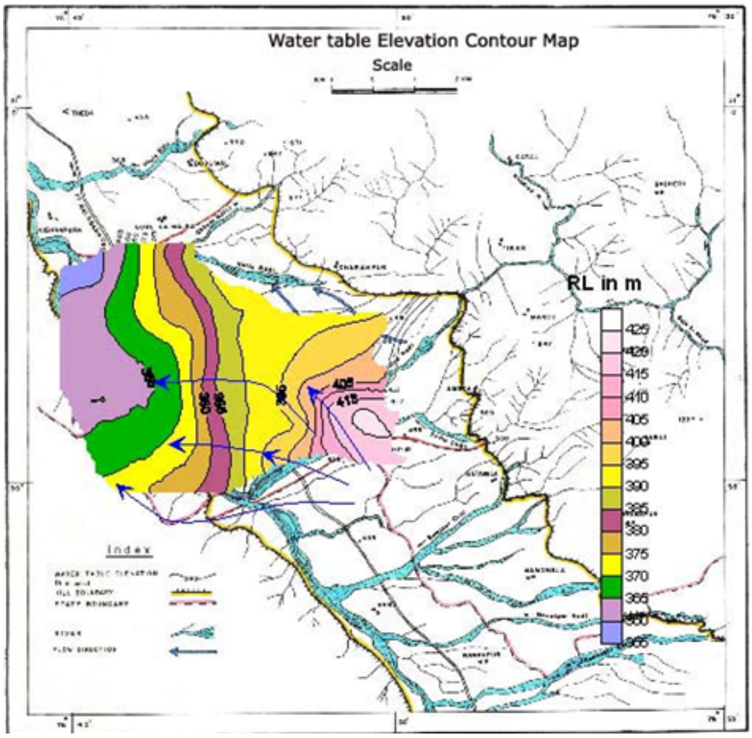

Fig.3: Water Table contour map with groundwater flow direction

It is important to estimate the dynamic and in storage potential for planning the groundwater development on long term basis. An assessment of the groundwater resources of the Nalagarh valley within which Baddi industrial complex is located, show an estimated recharge of 7753 ham against which the total draft from industry, domestic and irrigation is estimated as 4000ham, thus indicating the stage of groundwater development is only 51%. In addition to this dynamic resource, the in storage potential is estimated as 158167 ham. Since in the Baddi Industrial Complex groundwater development is more than the rest of the Nalagarh Valley, therefore further development of groundwater in Baddi area needs caution.

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3. GROUNDWATER QUALITY AND POLLUTION

The major industries are the pharmaceuticals, soap and detergents, food and beverages which generate large quantities of effluents discharging into the different drains of the area which join the Sirsa River. It is gathered that in order to achieve zero discharge from the industries, as per direction of CPCB, some of the industries are discharging effluents (treated/untreated) directly into the groundwater by constructing an open well/ shallow tube well. This is resulting into increase in pollution each day to the groundwater in spite of the fact that the aquifer system is highly permeable.

In order to assess the groundwater quality and the status of groundwater pollution, 45 samples have been collected from groundwater structures and analyzed for the major elements. The results of the analyses for the major elements are given in Table 1.

Loc.No	pH	EC	TDS	Ca	Mg	Na	K	Cl	HCO_3	So_4	No_3	F	Fe	BOD mg/L	COD mg/L
S1	6.8	830	530	119	16	30	2.7	79	285	7	15	0.08	0.01	0	0
S2	6.81	980	640	106	19	82	3.5	94	325	33	18	0.17	0.03	0	0
S3	6.66	1180	770	123	24	80	4.5	120	345	26	58	0	0.04	0	0
S4	6.93	1070	700	150	21	51	2.6	113	395	26	16	0.16	0.02	0	71
S5	7.11	800	530	123	12	24	1.6	49	285	38	46	0.09	0.12	2	53
S6	6.96	1050	680	163	17	27	2.1	101	325	16	56	0.05	0.01	0	0
S7	7.12	900	590	132	21	20	2	113	270	5.7	26	0.03	0.02	0	0
S8	7.27	820	530	104	13	45	2.3	90	250	28	24	0.07	0.02	0	0
S9	7.14	880	570	99	20	46	2.5	98	265	8.9	43	0.14	0.03	0	71
S10	7.12	2650	1750	278	29	210	2.8	691	260	12	28	0.08	0.05	2	53
S11	7.06	1450	950	229	21	29	2.5	248	280	7.7	77	0.05	0.07	0	0
S12	7.19	780	500	93	24	35	2.6	56	290	39	17	0.12	0.53	0	0
S13	6.92	1055	654	122	11	66	1.7	172	232	22	18	0	0.24	0	0
S14	6.77	2135	1324	240	22	111	2.4	399	295	72	23	0	0.26	0	0
S15	6.92	1941	1204	220	21	88	2.2	389	283	44	19	0	0.21	0	0
S16	7.01	839	520	122	11	23	1.7	96	232	34	21	0	0.3	0	0
S17	6.85	2581	1600	319	23	105	3	585	237	72	21	0	0.29	0	0
S18	7.1	661	410	109	6	52	2.1	37	237	24	40	0.15	0.45	0	0
S19	6.8	629	390	94	8.5	32	3.9	31	273	20	11	0.38	0.31	20	53
S20	6.8	806	500	115	11	40	1.8	62	300	11	24	0.08	0.25	0	9.6
S21	7.02	581	360	91	4.9	28	2	31	252	8	6.8	0.12	0.11	0	0
S22	6.95	742	460	111	9.7	34	1.8	49	0	11	21	0.12	0.09	0	0
S23	6.8	2419	1500	297	24	130	2.6	531	278	43	45	0.15	0.21	0	0
S24	7.3	919	570	136	7.3	31	2.2	133	236	15	15	0.1	0.08	0	0
S25	7.48	500	310	72	12	20	1.8	10	242	7	8	0.15	0.45	0	0
S26	7.24	661	410	106	15	18	1.8	52	237	34	24	0.11	0.22	0	0
S27	7.06	710	440	54	50	20	1.8	49	263	35	43	0.2	0.33	0	0
S28	6.55	2161	1340	345	19	60	3	517	257	47	31	0.03	0.35	0	0
S29	7.05	310	210	67	8.4	21	1.6	24	194	20	11	0.35	1.16	0	0
S30	6.95	330	210	71	11	20	3	38	194	16	14	0	0.25	0	0
S31	7.2	240	150	47	8.4	17	1.6	21	133	31	4	0.06	0.28	0	0
S32	6.75	1780	1200	126	119	258	4	52	327	944	23	0.15	0.5	0	71
S33	7	3430	2310	314	23	610	12	1269	236	218	50	0	0.26	2	53
S34	6.9	710	470	137	23	25	2	117	266	12	53	0.06	0.73	0	0
S35	6.9	920	620	145	17	97	3	168	351	35	29	0.17	0.24	0	0
S36	7.1	660	440	120	20	53	3	100	315	37	24	0	0.39	0	0
S37	7.25	370	240	63	18	19	2	17	242	9	10	0.26	0.16	0	0
S38	6.7	590	390	94	7.2	25	2	31	247	12	14	0.11	0.05	0	0
S39	6.53	1220	820	172	22	50	3	158	314	44	51	0.11	0.63	0	0

S40	6.7	970	650	145	11	43	2	113	295	37	32	0.14	0.33	0	0
S41	7	660	440	106	12	22	2	55	241	16	22	0.17	0.43	0	0
S42	6.75	860	580	126	16	31	3	138	223	26	19	0.15	0.28	0	0
S43	7.05	520	350	79	11	23	2	21	247	14	10	0.21	0.32	0	0
S44	6.8	4320	2920	420	12	505	4	1286	241	95	22	0.24	0.24	0	0
S45	7.3	1380	930	155	7.1	104	2	292	211	24	17	0.17	1.97	0	0

4. DISCUSSION OF THE RESULTS:

4.1 Major Elements: The reduction in pH value and higher values of electrical conductivity show that these are because of the continuous pollution of groundwater. The graph of major elements is given in figure 4.

4.1.1 TDS: The value of TDS varies between 150 and 2920. High value 2920 mg/l is observed from the groundwater samples collected from near the Vardhman Mill 2310 mg/l in dugwell of Dakhumajra village of Baddi and 1200 mg/l in the borewell near the Sansui Industry.

4.1.2 Chloride:. The chloride values are varying from 17 mg/l to 1286 mg/l. High values are observed from the groundwater samples collected from near the Vardhman Industry (1286 mg/l) and in the dugwell near Dhakumajra, Baddi (1269 mg/l) with shows increase in salinity as a result of pollution from industry.

*4.1.3 Sulphate: T*he high value of sulphate goes upto 944 mg/l near the Sangsui industry against the permissible limits ranges from 200 to 400 mg/l max for drinking water according to BIS. The increase in value may be because of percolation from the effluents discharge from the industries.

4.1.4 Calcium: The calcium values are between 47 and 420 mg/L. The value 420 mg/L is obtained near vardhaman bore well and 314 mg/L in the borewell near the Su Kam industry.

4.1.5 Magnesium: The value of magnesium are varying from 7.1 mg/L to 119 mg/L. High value of magnesium 119 mg/L is observed in the borewell located at Katha village, Baddi near the Suekem Industry.

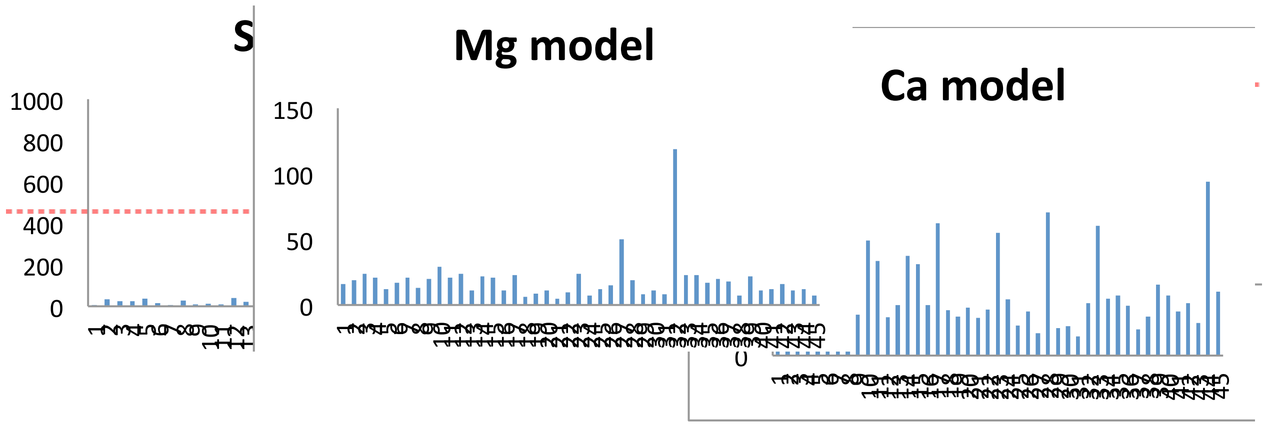


Fig.4. Major Elements model for 45 samples

4.2 Inter-ionic relationship: The aquifer system as such show very good quality of groundwater which is indicative from the water sample collected away from the polluting industries. The inter-ionic relationship are explained below and given in Figure 5.

4.2.1 Calcium-Bicarbonate: There is general predominance of bicarbonate ions over calcium in ground water but here at some places calcium is predominant over bicarbonates in the study area. The 1:1 line of Ca-HCO_3 plot at most of the places is away from the line. It implies that calcium is also being contributed by other source i.e. from Industrial pollution, other than natural source of Ca-HCO_3

*4.2.2 Sodium-Chloride***:** there is marked predominance of sodium over chloride ions in the ground water at some places and 1:1 line of Na-Cl plot at most of the places is away from the line. It indicates that apart from the common source of Na-Cl, there is additional source of sodium and chloride ions. Such sources are likely to be industrial pollution.

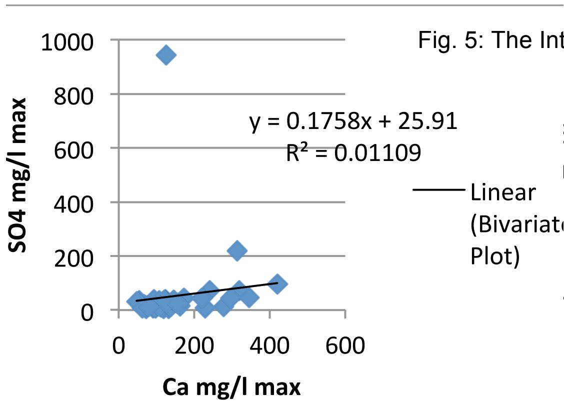
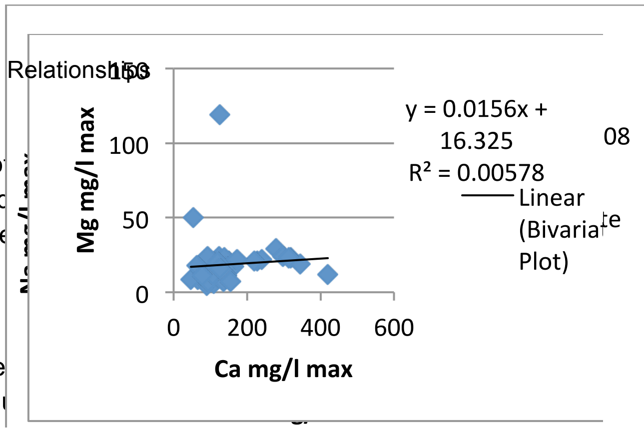


Fig. 5: The Inter-Ionic Relationship



Based on the analysis, pollution model have been developed (Figure 6)

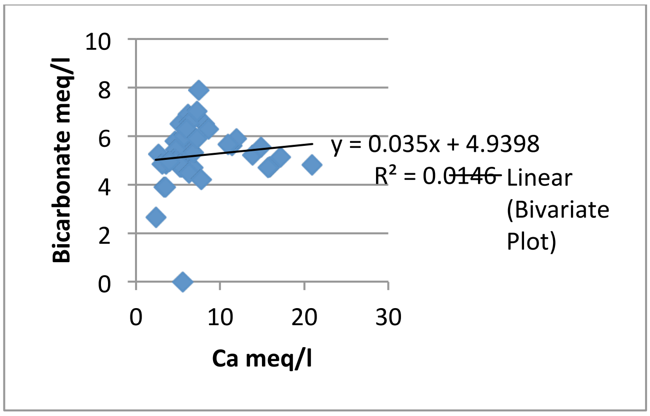
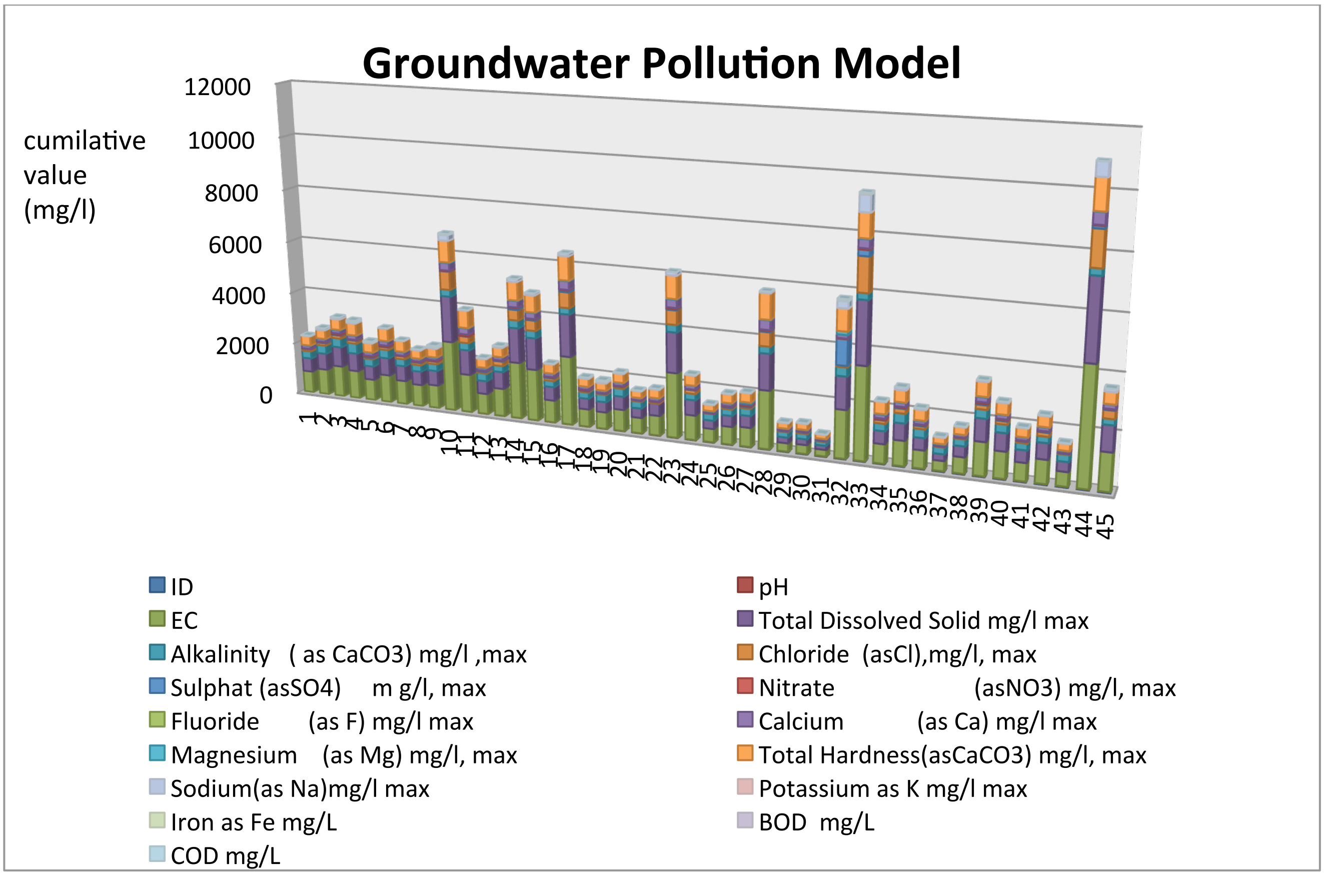


Fig. 6: The Groundwater Pollution model of the study area



4.3 **Trace Elements**: In order to have first approximation of the presence of heavy metals in groundwater, 11 samples were analyzed,the result are presented in Table 2. It is observed that the concentration of lead, copper, zinc wherever observed in groundwater is still within the permissible limit. However, the concentration of Iron is observed to be very higher i.e. 1.07 and 0.36 indicating the increasing pollution load in groundwater.

Table 2: Result of the chemical analysis of Heavy metals.

S.no.	Parameter	Permissible Limit	1	2	3	4	5	6	7	8	9	10	11
1	Lead mg/l	0.01 mg/l	0.008	BDL	BDL	BDL	BDL	0.021	BDL	BDL	BDL	BDL	BDL
2	Copper mg/l	1.5 mg/l	BDL	BDL	BDL	BDL	BDL	0.011	BDL	0.008	BDL	BDL	BDL
3	Zinc mg/l	15 mg/l	0.672	0.064	0.231	0.052	0.236	7.685	0.093	1.360	0.013	0.112	0.200
4	Iron mg/l	0.3 mg/l	0.090	0.201	0.100	0.034	**1.070**	0.295	0.047	0.223	BDL	0.208	**0.361**
5	Chromium mg/l	0.05 mg/l	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL

BDL- Below detection limit

The above results indicate that the deep aquifers have now the threat of becoming polluted. However, pollution to shallow aquifers and surface water of Sirsa River has become colored because of the mixing of the effluents discharged from the industries. The pollution to the deep aquifers is not so pronounced because the aquifer system is highly permeable and the pollution load get washed away during post monsoon period.

5. MITIGATION MEASURES:

The Baddi Industrial complex with more than 10,000 industrial units, most of them being generating effluents of different chemical characteristics, therefore multiple mitigation approach need to be adopted to contain the increasing pollution to groundwater. The mitigation measures can be classified into three categories: A. Implementation of environmental guidelines, B. Legal clauses/action C. Adaptation measures

A. The environmental guidelines are provided to all the industries while sanctioning the project. All the measures contained in the environmental act should be strictly followed and regular monitoring at least once in six months should be undertaken by state pollution control board and quality monitoring by the third party should also be made mandatory.

B. The legal clauses should be provoked to put penalty on the polluting industries, this is important as at the later stage the aquifer cleaning and its rehabilitation will not be possible.

C. The area has a good potential of non-utilized monsoon run-off therefore a master plan should be prepared and implemented. If required rainwater harvesting cess from industry may also be collected. The design of the recharge structure followed by different industries should be evaluated for their effectiveness. In order to generate awareness and strengthen the capability, Capacity Building and training program should be regularly organized involving gram panchayat including local community. The grievances of the local community as a result of pollution to drinking water sources, a legal provision may be made for registering the grievances and filing of FIR against the polluting industries. In order to contain the pollution, it has been proposed to install 25MLD CEPT for treating the effluents.

6. CONCLUSION:

The quality of groundwater is always excellent in such type of valley fill deposits as the aquifer system is very thick with high permeable strata. The change in water quality can be attributed to the discharge of effluents from different industries. The Baddi industrial complex with more than 10,000 units, most of them being discharging treated/untreated effluents, the groundwater resources is at great risk and vulnerable to non-recoverable pollution leading to contamination of groundwater. The pollution load at present may not be very significant but the way the environmental guidelines are being over looked by some of the industries, the quality of groundwater will became a health hazard. It is in the interest of the industries to adopt measures to protect groundwater resources from getting polluted by adapting adequate measures to treat the effluent being discharged from the industries.

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