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Impacts of Mining Activities on Water and Soil

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Seven coal mines are situated in Wardha River Valley. These mines are located at Wani (Dist. Yavatmal of Maharashtra). Out of these, 5 open cast coal mines are run by Western Coal Field Ltd. India. The present study has been undertaken to assess the impacts of mining activities in the adjacent areas. Total 25 samples of water and 19 samples of soil from Nilapur, Bramhani, Kolera, Gowari, Pimpari and Aheri were analyzed for pH, TDS, hardness, alkalinity, fluoride, chloride, nitrite, nitrate, phosphate, sulfate, cadmium, lead, zinc, copper, nickel, arsenic, manganese, sodium and potassium, and the results were compared with the limits of Indian Standards : 10500.

Key words : *Impact of mining activity, water pollution, impact of WCL, mining impacts*

Introduction

Water pollution has now reached a crisis point. Almost every water body is polluted to an alarming level. Thus, estimation of quality of water is extremely important for proper assessment of the associated hazards. The extensive mining activities also adversely affect the environment. Due to lack of proper planning and negligence of regulations, an appreciable amount of environmental degradation and ecological damage to water, air and soil occurs[1]. The problems associated with mining activities are land degradation, disposal of over burden (OB), deforestation, washing rejects, subsidence, water pollution due to wash off, discharge of mine water, acid mine drainage, coal washing operation, air pollution due to release of gases and dust, noise pollution, mine fires, damage to forest flora and fauna, occupational health hazards etc. In order to assess the impact of mining on aquifers water quality, a study has been carried out on 26 aquifers in mining area[2].

Wardha Valley Coalfield is known to be the oldest coalfield in Maharashtra state and is ideally situated in the centre of India. In 1973, at the time of nationalization of coal mines in India, there were 6 underground mines and no opencast mine. Geological exploration started after nationalization and extensive coal reserves were found spread over vast areas in Yavatmal district. This covers about 70 km. The nearest railway station is Chandrapur, 35 km away. By road it is 150 km away from Nagpur, the 2nd capital of Maharashtra. Topographically the area is situated in plain, flat having an altitude between 170 to 220 meters above mean sea level. The drainage of the area is controlled by Wardha river with the help of tributaries like Nirguda and Penganga rivers. The temperature ranges from 10°C to 48°C. Annual rainfall varies from 1000 to 1500 mm between June to September. Highest rainfall was 2725 mm in the year 1994. Coal is found in Barakar formations which are overlapped by Kamthi series sandstone. There is a single composite coal seam varying in thickness between 15 – 20 meters. The coal seam does not affect crop any where in the area as it is concealed under thick black cotton soil.

The studies have already been carried out to assess the water quality of Kolar river, which has connection with Koradi thermal power station, situated in Nagpur district[3]. The water quality was tested for its use for irrigation and interpreted in terms of salinity, sodium absorption ratio, sodium % and Mg hazard. The tolerance limits for some parameters recommended by Indian Standards[4] and as given by Wilcox[5] are given below :

Classification of water for irrigation use based on TDS, SAR and Na %

Classification	TDS (ppm)	SAR	Na %
Excellent	< 200	< 10	< 20
Good	200 – 500	10 – 18	20 – 40
Fair	500 - 1500	18 – 26	40 – 60
Unsuitable	> 1500	> 26	> 60

The characteristics of water, which have been accepted as sufficient[6] to determine its suitability for irrigation, are : (a) TDS (salinity) expressed as mg/L or the specific conductance in mmho/cm at 25 °C, (b) The sodium percentage describing the sodium hazard given by

$$Na\ \% = 100 \times Na^{+} / (Na^{+} + Ca^{2+} + Mg^{2+} + K^{+})$$

and (c) boron, chloride and sulfate concentration. Owing to many variable factors, no rigid limits of salinity can be set for irrigation waters. According to western Australia, water with

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salinity 1000 mg/L is suitable for growing all types of plants, provided that drainage is good. Calcium and magnesium in the proper proportions maintain soil in good condition of tilth and structure. It has been widely recommended that the percentage of sodium in irrigation water should not exceed 50 – 60 in order to avoid the deleterious effects on soil.

The sodium hazard gets increased, if the water contains a high concentration of bicarbonate ions, because if the soil solution becomes more concentrated then there is a tendency for calcium and magnesium to precipitate as carbonates and for the relative proportion of sodium to be increased as a consequence. The bicarbonate values are conveniently expressed in terms of 'Residual Sodium Carbonate' (RSC) given by the following equation.[6]

$$RSC = (CO_3^{2-} + HCO_3^{-}) - (Ca^{2+} + Mg^{2+})$$

Waters containing less than 1.25 of RSC are probably safe, those containing 1.25 to 2.5 meq/l are marginal and those with more than 2.5 meq/l are not suitable.

Sodium Absorption Ratio (SAR) can be calculated to determine the alkali hazard due to use of irrigation water rather than its soluble sodium %. SAR is defined by the following equation[3,7]

$$SAR = Na^{+} \Big/ \sqrt{(Ca^{2+} + Mg^{2+}) / 2}$$

As magnesium has an important role, magnesium hazard ratio[3] is given as :

$$Mg\ Hazard = 100 \times Mg^{2+} \Big/ (Ca^{2+} + Mg^{2+})$$

where concentrations are expressed in milli equivalents per liter (meq/l) in all the above equations.

The present work is a part of systematic study undertaken to analyze the impact of mining activity for a period of 2 years during summer and winter seasons of 2004 – 05.

Materials and methods

All the chemicals used were of GR/AR grade. Standard methods[8] of American Public Health Association (APHA 18th edition) were used for the analysis of samples. Estimation of cations were carried out on Atomic Absorption Spectrometer (Make – GBC Australia, Model GBC 932) at RSIC, Nagpur University Nagpur.

Results and discussion

Results obtained for water samples for parameters pH, COD, alkalinity, total hardness, TDS, chloride, fluoride, nitrite, nitrate, phosphate, sulphate, calcium, magnesium, sodium, potassium, arsenic, cobalt, iron, lead, nickel, cadmium, copper, zinc and manganese are tabulated in **Tables 1-6** for Nilapur, Bramhani, Kolera, Gowari, Pimpari and Aheri villages. As per the IS : 10500 standards[10], desirable and maximum permissible limits, if alternative source is not available for drinking water, are also included in these tables. Similar results for soil samples are also included.

a) Water quality in Nilapur village : The pH, hardness, fluoride, nitrite, nitrate, sulfate, calcium, magnesium, arsenic, iron, lead, nickel, cadmium, copper, zinc and manganese content in all the tube well and dug well water samples (NW1 - NW5) found well within the desirable limit. Chloride at NW1, NW2 and NW4 was also within the desirable limit. TDS and alkalinity of all samples and chloride at NW3 and NW5 were found higher but did not exceed the maximum permissible limit.

COD values of all the samples were low indicating little contamination of carbon dust. Its marginally higher values in dug wells indicated contamination of water by coal dust. More value of COD in the dug well NW5 is a definite indication of coal dust accumulation, as it is situated very close to road (at a distance of 5m), which is extensively used for coal transportation. However, the dug well NW4 is located relatively away from the road and showed less COD than NW5, which explains the contamination of open water due to coal dust.

Higher values of alkalinity and TDS of all the samples are indicative of the contribution of washery situated at about 2 km away from this village. Surface minerals of the coal get percolated during washing and probably find way through the strata towards these sources. With respect to other parameters, the water sources in this village are not toxic for drinking and domestic use.

b) Water quality in Bramhani village : pH, fluoride, nitrite, arsenic, iron, lead, nickel, cadmium, zinc, copper and manganese content of all the samples (BW1–BW3) and the quantity of magnesium in the sample BW1 found within the desirable limits. TDS, alkalinity, chloride, nitrate, sulfate and calcium of all the samples and hardness of BW1 and BW2, and magnesium of BW2 and BW3 were found higher, but did not exceed the maximum permissible limits. Hardness of BW3 was marginally higher than the maximum limit.

A lake is located near Bramhani village. In monsoon the coal dust from catchments area gets collected in this lake. BW2 and BW3 are relatively closer to this lake. Higher alkalinity, hardness, TDS, chloride, nitrate, calcium and magnesium may thus be attributed to the percolation of minerals from the lake. Low COD values of all the samples indicate the negligible contamination of coal dust in these samples. Thus, with respect to the parameters studied, the sources are safe for drinking and domestic use.

c) Water quality in Kolera village : pH, fluoride, nitrite, arsenic, iron, lead, nickel, cadmium, copper, zinc and manganese of all the samples in this village and hardness, nitrate, sulfate, calcium and magnesium of KW1, KW3 and KW4, and chloride of KW4 were found within the desirable limits. TDS and alkalinity of all the 4 samples and chloride in KW1 and KW3 were found higher

Table 1 : Water and soil quality at Nilapur village

Village –Nilapur		Tube well samples			Dug well samples		IS : 10500 Limits		Soil samples		
SNo.	**Parameter**	**NW1**	**NW2**	**NW3**	**NW4**	**NW5**	**Desirable**	**Maximum**	**NS1**	**NS2**	**NS3**
1	pH	7.68	7.67	7.39	7.50	7.60	6.5 – 8.5	6.5 – 8.5	7.26	7.46	7.50
2	COD	0.21	0.85	0.69	1.60	2.03			- -	- -	- -
3	Total Alkalinity as $CaCO_3$	560	510	430	450	490	200	600	550	413	465
4	Total Hardness as $CaCO_3$	139	129.6	262.42	123.6	277.5	300	600	391.8	413.5	372.2
5	TDS	1232.2	1168.4	1835.4	573.1	1821.2	500	2000	1190	1030	1006
6	Chloride	215.6	193.1	545.9	65.1	602.7	250	1000	162.3	97.1	43.7
7	Fluoride	1.28	1.08	0.97	1.20	1.16	0.5 - 1.5	0.5 - 1.5	4.35	5.80	5.85
8	Nitrite*	0.01	0.02	0.01	0.01	0.01	0.02	0.02	1.85	0.31	1.57
9	Nitrate	9.7	8.6	36.6	22.6	20.4	45	100	109.0	115.2	112.9
10	Phosphate	4.0	4.7	4.2	1.9	9.2			4.2	29.4	60.2
11	Sulphate	191.9	176.0	261.0	28.6	198.8	200	400	172.1	142.9	113.1
12	Calcium	24.03	27.0	56.8	27.6	62.0	75	200	121.4	142.4	125.2
13	Magnesium	19.0	14.9	28.9	13.1	29.4	30	100	21.2	13.8	14.2
14	Sodium	301.1	261.6	472.5	114.5	486.7			156.3	92.42	96.6
15	Potassium	2.8	3.6	5.0	1.3	2.3			25.0	7.2	15.2
16	Arsenic (ppb)*	0.54	0.24	0.74	0.55	1.54	50	50	0.01	0.01	0.01
17	Cobalt	0.09	0.10	0.08	0.06	0.09			0.06	< 0.05	< 0.05
18	Iron	0.11	0.12	0.10	0.13	0.15	0.3	1.0	1.4	0.08	0.10
19	Lead	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	0.05	0.05	< 0.1	< 0.1	< 0.1
20	Nickel	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.02	0.020	0.45	0.20	0.45
21	Cadmium	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	0.01	0.01	< 0.15	< 0.15	< 0.15
22	Copper	< 0.01	< 0.01	0.01	< 0.01	< 0.01	0.05	1.5	< 0.05	< 0.05	< 0.05
23	Zinc	< 0.01	0.02	0.18	< 0.01	< 0.01	5.0	15.0	< 0.05	< 0.05	< 0.05
24	Manganese	< 0.01	< 0.01	0.01	< 0.01	0.04	0.1	0.3	< 0.05	< 0.05	< 0.05

*** All parameters in ppm except arsenic**

NW1 – NW3 – Water samples from tube wells of Nilapur NW4 and NW5 – Water samples from dug wells of Nilapur

NS1 – NS3 – Soil samples from farms around Nilapur

but did not exceed the maximum permissible limits. Relatively, KW2 had higher values of hardness, chloride, fluoride, nitrate, sulfate, phosphate, calcium, magnesium and COD. The Kolera open cast mine is located very close to this village. After mining of coal, some patches may act as underground reservoirs, which collect water from the surrounding area, resulting in the higher values of many parameters.

Slightly higher COD value of KW2, compared to the other water samples, indicated contribution of coal dust. COD values of dug wells in this village were found more than the COD values of the tube well samples, which is indicative of contribution of coal dust through open air, as mine is very close to this village.

d) Water quality in Gowari village : It is a small village located very close to open cast mine and has 2 tube wells. pH, fluoride, nitrate, nitrite, magnesium, arsenic, iron, lead, nickel, cadmium, copper, zinc and manganese of both the samples, and hardness and calcium of GW1 were found within desirable limits. TDS, alkalinity, chloride and sulfate of both the samples and calcium of GW2 were higher but did not exceed the maximum permissible limits. Higher values of some parameters may be attributed to the proximity of the mine from this village. In context to the parameters studied, the water sources in this village are safe for domestic use. However, due to proximity of the mine, characteristics of the underground water table are likely to be affected in future.

e) Water quality in Pimpari village : At this village, 3 water samples from tube wells (PW1–PW3), 1 water sample from river (PW4) before discharge of mine water to the river, another water sample from the same river (PW5) after discharge of mine water and one water sample from nala after discharge (PW6), were collected and analyzed to study effects of mine water on the river water.

pH, chloride, fluoride, nitrite, nitrate, magnesium, arsenic, iron, lead, nickel, zinc, cadmium, copper, and manganese of all the samples, hardness of PW3–PW6, sulfate of PW1–PW4 and calcium of PW1, PW3, PW4 and PW5 were found within the desirable limits. TDS and alkalinity of all the samples, hardness of PW1 and PW2, sulfate of PW5 and PW6, calcium of PW2 and PW6 were found higher but did not exceed the maximum permissible limits.

Table 2 : Water and soil quality at Bramhani village

Village –Bramhani		Tube well samples			IS 10500 Limits		Soil samples		
Sl.No.	**Parameter**	**BW1**	**BW2**	**BW3**	**Desirable**	**Maximum**	**BS1**	**BS2**	**BS3**
1	pH	7.41	7.40	7.55	6.5 – 8.5	6.5 – 8.5	6.9	7.19	7.63
2	COD	0.31	0.19	0.12					
3	Total Alkalinity as $CaCO_3$	284	280	370	200	600	210	375	525
4	Total Hardness as $CaCO_3$	303.4	569	620.6	300	600	520.1	559.4	531.1
5	TDS	1598.2	1624.6	1561.3	500	2000	844	1010	990
6	Chloride	344.3	453.8	476.1	250	1000	134.1	123.8	99.6
7	Fluoride	1.01	1.01	0.93	0.5 - 1.5	0.5 - 1.5	3.55	3.25	4.00
8	Nitrite	0.01	0.01	0.02	0.02	0.02	1.345	1.345	1.195
9	Nitrate	47.3	72.0	53.3	45	100	145.2	166.7	69.9
10	Phosphate	4.5	4.4	3.4			74.2	29.4	19.6
11	Sulphate	393.6	348.1	240.5	200	400	47.6	95.2	113.1
12	Calcium	75.7	162.6	162.4	75	200	183.2	202.1	184.1
13	Magnesium	27.4	39.0	51.5	30	100	14.9	13.0	17.0
14	Sodium	333.2	255.5	237.4			27.4	23.1	25.1
15	Potassium	49.4	65.8	19.9			11.9	13.8	18.1
16	Arsenic (ppb)*	0.01	0.10	0.76	50	50	0.004	0.003	<0.001
17	Cobalt	0.11	0.10	0.08			< 0.05	0.07	< 0.05
18	Iron	0.11	0.14	0.13	0.3	1.0	0.14	0.15	0.12
19	Lead	0.02	<0.02	<0.02	0.05	0.05	<0.1	<0.1	<0.1
20	Nickel	<0.01	<0.01	<0.01	0.02	0.020	<0.05	0.15	0.30
21	Cadmium	< 0.03	< 0.03	< 0.03	0.01	0.01	< 0.15	< 0.15	< 0.15
22	Copper	< 0.01	< 0.01	< 0.01	0.05	1.5	< 0.05	< 0.05	< 0.05
23	Zinc	< 0.01	< 0.01	0.45	5.0	15.0	0.20	0.25	<0.10
24	Manganese	< 0.01	< 0.01	0.04	0.1	0.3	0.08	0.07	0.09

*** All parameters in ppm except arsenic**

BW1 — BW3 – Water samples from tube wells of Bramhani

BS1 – BS3 – Soil samples from farms around Bramhani

Table 3 : Water and soil quality at Kolera village

Village –Kolera		Tube well samples			Dug well samples	IS : 10500 Limits		Soil samples		
SNo.	**Parameter**	**KW1**	**KW2**	**KW3**	**KW4**	**Desirable**	**Maximum**	**KS1**	**KS2**	**KS3**
1	pH	7.69	7.58	8.05	8.10	6.5 – 8.5	6.5 – 8.5	7.85	7.45	7.46
2	COD	0.69	0.95	0.43	2.31					
3	Total Alkalinity as $CaCO_3$	390	268	510	570	200	600	610	588	613
4	Total Hardness as $CaCO_3$	211.6	539.1	211.7	278.5	300	600	95.1	329.5	352.8
5	TDS	1253.3	1316.3	996.7	837.7	500	2000	920	1020	910
6	Chloride	288.5	383.2	261.5	125.4	250	1000	82.6	62.8	34.0
7	Fluoride	0.99	1.16	1.15	1.22	0.5 - 1.5	0.5 - 1.5	3.25	4.15	3.2
8	Nitrite	0.01	0.01	0.02	0.01	0.02	0.02	0.56	0.67	1.57
9	Nitrate	37.6	77.4	33.3	17.2	45	100	77.5	80.6	102.2
10	Phosphate	4.9	9.4	2.6	5.3			14.0	21.0	23.8
11	Sulphate	188.1	206.0	63.1	64.3	200	400	58.3	118.3	77.4
12	Calcium	45.3	135.3	53.0	65.4	75	200	35.7	119.8	125.3
13	Magnesium	23.6	48.2	19.0	27.6	30	100	1.4	7.2	9.5
14	Sodium	254.1	184.0	226.9	115.7			197.6	115.4	91.9
15	Potassium	53.6	26.1	11.1	10.2			36.2	23.4	5.1
16	Arsenic (ppb)*	< 0.01	0.16	0.32	0.30	50	50	< 0.01	< 0.01	< 0.01
17	Cobalt	0.10	0.11	0.11	0.09			0.08	< 0.05	< 0.05
18	Iron	0.15	0.12	0.15	0.11	0.3	1.0	1.6	0.25	0.35
19	Lead	< 0.02	0.05	< 0.02	< 0.02	0.05	0.05	< 0.01	< 0.01	< 0.01
20	Nickel	< 0.01	< 0.01	< 0.01	< 0.01	0.02	0.02	< 0.05	< 0.05	< 0.05
21	Cadmium	< 0.03	< 0.03	< 0.03	< 0.03	0.01	0.01	2.45	4.05	5.3
22	Copper	< 0.01	< 0.01	0.01	< 0.01	0.05	1.5	< 0.05	< 0.05	< 0.05
23	Zinc	< 0.01	< 0.01	0.04	< 0.01	5.0	15.0	< 0.05	0.10	< 0.05
24	Manganese	< 0.01	< 0.01	< 0.01	0.02	0.1	0.3	0.08	0.11	0.09

 # All parameters in ppm except arsenic

KW1, KW2 and KW3 – Water samples from tube wells of Kolera

KW4 – Water samples from dug well of Kolera

KS1 – KS3 – Soil samples from farms around Kolera

Table 4 : Water and soil quality at Gowari village

Village –Gowari		Tube well samples		IS : 10500 Limits		Soil samples		
SNo.	**Parameter**	**GW1**	**GW2**	**Desirable**	**Maximum**	**GS1**	**GS2**	**GS3**
1	pH	7.97	7.91	6.5 – 8.5	6.5 – 8.5	7.46	7.72	7.51
2	COD	0.25	0.69					
3	Total Alkalinity as $CaCO_3$	370	380	200	600	425	525	460
4	Total Hardness as $CaCO_3$	261.3	318	300	600	384.6	318.6	358.6
5	TDS	1360.2	1494.1	500	2000	730	804	840
6	Chloride	372.3	355.6	250	1000	51.0	51.9	70.4
7	Fluoride	1.12	1.11	0.5 - 1.5	0.5 - 1.5	4.50	4.60	4.25
8	Nitrite	0.01	0.01	0.02	0.02	0.11	1.35	1.40
9	Nitrate	22.6	18.3	45	100	84.4	102.2	134.4
10	Phosphate	15.3	4.4			11.2	18.2	11.2
11	Sulphate	246.2	301.2	200	400	56.5	29.5	65.5
12	Calcium	64.2	80.8	75	200	136.5	113.1	128.6
13	Magnesium	24.2	27.8	30	100	10.4	8.6	8.9
14	Sodium	341.7	326.4			15.4	66.4	72.3
15	Potassium	1.5	1.4			8.4	6.0	10.0
16	Arsenic (ppb)*	0.67	0.73	50	50	0.01	< 0.01	< 0.01
17	Cobalt	0.09	0.08			0.09	0.07	< 0.05
18	Iron	0.16	0.11	0.3	1.0	0.15	0.80	0.17
19	Lead	< 0.02	< 0.02	0.05	0.05	< 0.1	< 0.1	< 0.1
20	Nickel	< 0.01	< 0.01	0.02	0.02	< 0.05	< 0.05	< 0.05
21	Cadmium	< 0.03	< 0.03	0.01	0.01	6.3	2.55	3.5
22	Copper	0.01	<0.01	0.05	1.5	<0.05	<0.05	<0.05
23	Zinc	0.03	<0.01	5.0	15.0	0.25	<0.05	<0.05
24	Manganese	0.03	0.03	0.1	0.3	0.11	0.06	0.07

*** All parameters in ppm except arsenic**

GW1 – GW2 – Water samples from tube wells of Gowari GS1 – GS3 – Soil samples from farms around Gowari

Table 5 : Water and soil quality at Pimpari village

Village –Pimpari		Tube well samples			River		Nala	IS : 10500 Limits		Soil samples			
					Before discharge	After discharge	After discharge						
Sl.No.	**Parameter**	**PW1**	**PW2**	**PW3**	**PW4**	**PW5**	**PW6**	**Desirable**	**Maximum**	**PS1**	**PS2**	**PS3**	**PS4**
1	pH	7.58	7.68	7.64	7.66	7.36	7.24	6.5 – 8.5	6.5 – 8.5	7.39	7.41	7.64	2.12
2	COD	0.34	0.43	0.23	2.93	4.32	9.50						
3	Total Alkalinity as $CaCO_3$	510	580	570	540	380	394	200	600	528	560	488	-
4	Total Hardness as $CaCO_3$	310	355	247.5	213.5	266.5	293.8	300	600	409.5	464.3	445.6	987.7
5	TDS	970.2	828.8	760.7	664.2	940	954	500	2000	860	890	830	9690
6	Chloride	168.9	119.3	111.6	51.1	101.5	128.2	250	1000	75.9	49.6	34.0	2212.4
7	Fluoride	1.18	1.12	1.15	0.90	1.08	1.14	0.5 - 1.5	0.5 - 1.5	4.80	3.50	5.55	2.40
8	Nitrite	0.02	0.02	0.01	0..02	0.02	0.02	0.02	0.02	1.07	1.52	1.46	3.03
9	Nitrate	15.1	24.7	22.6	26.9	32.9	37.6	45	100	134.4	123.6	112.9	295.7
10	Phosphate	4.0	11.2	5.3	4.1	2.2	2.9			8.4	37.8	64.4	11.2
11	Sulphate	83.3	64.3	19.0	39.3	259.5	207.1	200	400	6.0	11.9	6.0	3590
12	Calcium	72.9	91.6	61.5	51.9	61.6	78.7	75	200	145.8	164.7	161.9	164.4
13	Magnesium	30.6	30.3	22.5	20.1	27.0	23.3	30	100	10.8	12.6	9.8	138.4
14	Sodium	132.8	97.4	112.3	86.5	167.2	155.2			36.4	26.2	10.6	478
15	Potassium	2.0	1.2	0.6	6.2	4.1	3.4			11.2	14.7	21.5	0.7
16	Arsenic (ppb)*	0.26	0.52	0.26	0.13	0.40	0.20	50	50	< 0.01	< 0.01	< 0.01	0.03
17	Cobalt	0.21	0.06	0.07	0.10	0.11	0.12			0.08	< 0.05	< 0.05	0.07
18	Iron	0.11	0.17	0.14	0.16	0.15	0.15	0.3	1.0	0.25	0.28	0.21	1224
19	Lead	0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	0.05	0.05	< 0.1	< 0.1	< 0.1	< 0.1
20	Nickel	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.02	0.02	0.55	< 0.05	< 0.05	2.4
21	Cadmium	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	0.01	0.01	< 0.15	< 0.15	< 0.15	< 0.15
22	Copper	< 0.01	< 0.01	< 0.01	< 0.01	0.01	< 0.01	0.05	1.5	< 0.05	< 0.05	< 0.05	1.99
23	Zinc	< 0.01	< 0.01	0.07	< 0.01	< 0.01	< 0.01	5.0	15.0	< 0.05	< 0.05	< 0.05	5.85
24	Manganese	< 0.01	0.03	0.02	< 0.01	< 0.01	< 0.01	0.1	0.3	0.11	0.10	0.09	2.16

*** All parameters in ppm except arsenic**

PW1– PW3 – Water samples from tube wells of Pimpari PW6– Water sample where mine water is discharged to nala of Pimpari

PW4 & PW5 – Water samples from river before and after discharge of mine water respectively PS1 – PS4 – Soil samples from farms around Pimpari

Table 6 : Water and soil quality at Aheri village

Village –Aheri		Water samples					IS : 10500 Limits		Soil samples		
		Tube wells			Dug well	Discharge to Nala					
Sl.No.	Parameter	AW1	AW2	AW3	AW4	AW5	Desirable	Maximum	AS1	AS2	AS3
1	pH	8.10	7.79	7.97	7.38	7.16	6.5 – 8.5	6.5 – 8.5	7.81	7.42	7.68
2	COD	0.86	0.69	0.77	2.34	8.38					
3	Total Alkalinity as $CaCO_3$	436	430	510	420	230	200	600	650	610	613
4	Total Hardness as $CaCO_3$	289.58	262.4	286	265.1	328.8	300	600	282.6	451.0	455.2
5	TDS	792.4	836	884	894.2	1340	500	2000	1108	1450	1140
6	Chloride	155.4	145.9	153.4	126.2	375.1	250	1000	82.6	142.7	148.6
7	Fluoride	0.71	0.97	0.75	0.92	1.07	0.5 - 1.5	0.5 - 1.5	3.75	4.9	3.75
8	Nitrite	0.02	0.01	0.02	0.02	0.02	0.02	0.02	0.06	1.30	4.48
9	Nitrate	57.0	36.6	47.3	33.3	42.1	45	100	129.0	139.8	150.5
10	Phosphate	1.9	4.1	4.7	5.1	15.1			18.2	22.4	7.0
11	Sulphate	27.4	101.0	34.5	148.1	275.0	200	400	71.9	291.7	74.9
12	Calcium	78.0	56.8	68.4	73.2	88.7	75	200	98.7	137.4	159.4
13	Magnesium	22.7	28.9	27.5	19.7	25.7	30	100	8.6	25.8	13.6
14	Sodium	102.6	135.5	122.8	135.5	291.9			164.2	232.4	118.9
15	Potassium	1.5	5.0	2.0	13.5	18.9			9.4	17.5	17.7
16	Arsenic (ppb)*	0.32	0.74	0.55	0.45	0.58	50	50	0.004	0.013	0.001
17	Cobalt	0.12	0.08	0.06	0.08	0.08			0.08	0.07	< 0.05
18	Iron	0.11	0.14	0.13	0.17	0.16	0.3	1.0	0.15	0.19	0.17
19	Lead	0.02	0.03	< 0.02	< 0.02	< 0.02	0.05	0.05	< 0.1	< 0.1	< 0.1
20	Nickel	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.02	0.02	0.20	0.40	< 0.05
21	Cadmium	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	0.01	0.01	< 0.15	< 0.15	< 0.15
22	Copper	< 0.01	0.01	< 0.01	< 0.01	< 0.01	0.05	1.5	< 0.05	< 0.05	< 0.05
23	Zinc	< 0.01	0.18	< 0.01	< 0.01	< 0.01	5.0	15.0	< 0.05	0.40	< 0.05
24	Manganese	< 0.01	0.01	< 0.01	0.08	< 0.01	0.1	0.3	0.11	0.09	0.10

*** All parameters in ppm except arsenic**

AW1 – AW3 – Water samples from tube wells of Aheri

AW4 – Water sample from dug well of Aheri

AW5 – Water sample where mine water is discharged to nala of Aheri

AS1 – AS3 – Soil samples from farms around Aheri

This village has no dug well and it is also very close to mine and coal loading station. Therefore, mine water seepage is also expected. Higher alkalinity, hardness and TDS of all the tube well samples may therefore be attributed to the proximity of the mine and coal dumping station from this village. With respect to the parameters studied, the water sources available in this village are fit for domestic use. However, due to proximity of the mine and coal dumping station, characteristics of the underground water table are likely to be affected in future.

On receiving mine water, a slight decrease in pH of the river water (from 7.66 to 7.36) was observed. Still lower value of pH (7.24) was observed for water sample from nala, where mine water is discharged. This decreasing trend of pH corroborates satisfactorily with the decreasing alkalinity of these samples. COD values of the river water was also found to increase, after receiving mine water. The water of nala had still higher COD. This clearly indicated that the mine water is contaminated with coal dust and when it is discharged into river and nala, the COD value increases considerably. Also, the mine water increases the alkalinity, hardness, TDS, chloride, fluoride, nitrate, sulfate, calcium, magnesium and sodium of the water body (river and nala), to which it is discharged. This clearly indicates that the mine water contains more minerals and considerable amount of fine carbon dust.

f) Water quality in Aheri village : Water samples from 3 tube wells, 1 dug well and 1 nala (after receiving mine water discharge) were collected and analyzed. The pH, hardness, chloride, fluoride, nitrite, nitrate, sulfate, calcium, magnesium, arsenic, cobalt, iron, lead, nickel, zinc, copper, cadmium, and manganese content of all the samples (AW1–AW4) were found within the desirable limits, except nitrate of two tube wells AW1 and AW2 having marginally higher values. TDS and alkalinity of all the samples were found higher, but below the maximum permissible limits.

The water sample from nala, after receiving the mine water discharge, was found to have lower pH and alkalinity than other samples. Similar effects were also observed after discharging mine water to the river and nala in Pimpari. The water sample from nala was also found to have relatively higher concentration of COD, hardness, TDS, chloride, nitrate, phosphate, sulfate, calcium, sodium and potassium. This clearly indicates that the mine water is contaminated with coal dust and minerals, and hence after discharge, it enhances the mineral contents and COD of the water body.

The statistical analysis of 25 water samples for all 24 parameters studied is indicated in **Table 7**. Minimum values of all the parameters are well within the desired limits, except TDS, which is marginally higher than the desired limit. Mean values of all the parameters are also within the desired limit, except alkalinity, TDS and chloride. Mean chloride is marginally higher than the desired limit, however, mean alkalinity and mean TDS values are mid-way of the desired and maximum permissible limits. This is because of the discharge of mine water to the water body. Otherwise, all the water sources in the study area are fit for domestic use. In this area, fluoride concentration was found in the range of 0.7–1.3 with mean value of 1.1 ppm. Thus, fluoride is not a problem.

3 soil samples of different farms from each village, viz. Nilapur (NS1–NS3), Bramhani (BS1 –BS3), Kolera (KS1–KS3), Gowari (GS1–GS3), Pimpari (PS1–PS3), Aheri (AS1 to AS3) and one sample of overburden (PS4) were selected. All these sampling locations are often contaminated due to various mining activities, like coal washery, heavy transportation of coal by trucks, coal dumping and loading station and formation of dust due to blasting. After analysis of the soil samples, an inconsistency has been found in the values of TDS, chloride, alkalinity, nitrate, sodium, phosphate and sulfate, etc. This variation may be due to the various mining activities. The wash out minerals, due to transportation of coal trucks, are being accumulated in the nearby lands. Probably, different dosing of fertilizers and manures used during farming and different crop patterns, may also be contributing to this inconsistency. Mineral concentrations and pH at some locations appear to be more or less, which indicate contamination of soil due to mining activities.

Over burden sample (PS4) had high acidity (pH = 2.12) and exceptionally very high TDS, hardness, chloride, nitrate, sulphate, magnesium, iron, sodium, copper, manganese and zinc. In monsoon, washout of overburden contributes extensively to the contamination of surface water.

Minimum, maximum and mean values of 23 parameters for 18 soil samples are given in **Table 7**. All the soil samples have slightly alkaline pH, except at Bramhani, which is almost neutral. TDS ranged from 730–1450 ppm. Soil samples also showed large difference in the minimum and maximum values of many parameters indicating contamination due to mining activities in uneven manner. Overall variations in parameters at all the villages are shown in the **Fig 1–3** for 25 water samples and **Fig 4-5** for 18 soil samples.

Some parameters of irrigation concern are shown in **Table 8** for the following water samples : (1) River before mine water discharge (PW4), (2) River after mine water discharge (PW5), (3) mine water discharge to nala at Pimpari (PW6) and (4) mine water discharged to nala at Aheri (AW5). The values of Sodium Absorption Ratio of PW4–PW6 were not found affected much and can be classified as good water for irrigation. However, that of nala at Aheri after mine water discharge showed higher value, probably due to no dilution of flow; still this water is also good for irrigation (SAR < 10). After dilution in to the river the effect becomes negligible. Sodium percent values and TDS of PW4–PW6 were found less than 60 and 1000 respectively, where as AW5 had a slightly higher value for both the parameters. Thus as stated[11], PW4–PW6 are safe water sources. But AW5 after dilution in river showed improvement.

Values of Mg hazard ratio for all the samples ranged from 32 to 42. Out of the dissolved ions HCO_3^-, Cl^-, SO_4^{2-} and Na^+ taken together constitute the major components. These parameters together constitute about 76 – 81% of the TDS. TDS of all four samples ranged from 664 to 1340 mg/L and were found well within the tolerable limits[9] for Indian conditions accepted for irrigation water. Bicarbonates for all the samples were found on lower side and Mg/Ca ratio was also on lower side ranging from 0.48 to 0.72. For all these four samples, COD:N:P ratios are calculated and shown in **Table 8**.

Study[2] on environmental impact of limestone mining on aquifers reveals that parameters like hardness, Ca, Mg, Na, TSS and TDS have higher values for water samples in affected area than the similar sources away from mining activity. It was found that the water quality of aquifers in Sangrah Bhootmani area has high mineral contents in terms of hardness : 172–385 ppm (Spring value 247 ppm), Ca : 38–97 ppm (Spring value 55 ppm), Mg : 18–38 ppm (Spring value 26 ppm), alkalinity : 33–46 ppm (Spring value 39 ppm), turbidity: 0.7–3.9 NTU (Spring value 0.87 NTU), pH : 8.02–8.17 (Spring value 7.90), TDS : 299–2736 ppm (Spring value 351 ppm), TSS : 6–19 ppm (Spring value 1 ppm) and Iron : 0.06–0.29 ppm (Spring value 0.01 ppm)[2].

A case study[12] on environment impact assessment in open cast mining area at Neyveli, Tamilnadu reveals that the surface water in the Neyveli has neutral pH in general and it ranges from 4.5 to 8.12 with an average value of about 7.3. TDS ranges from 160 to 1721 ppm with an average value of 505 ppm. In monsoon season, generally TDS is high in fly ash ponds. Among the dissolved ions, HCO_3^-, Cl^- and SO_4^{2-} were found abundant than other ions. Due to mixing of mine water and effluents from thermal power station and other nearby industries, TDS showed higher values. Dissolution was higher in the monsoon. Chloride and sulphate were higher in monsoon

and became lower during summer/pre-monsoon periods. HCO_3^- did not exceed 600 ppm and in most of the cases it was around 100 ppm suggesting the existence of reverse weathering process, which ultimately decreases the alkalinity. HCO_3^- was higher than Na and other cations. Mg/Ca ratio was very low indicating the high salinity and low flushing activity resulting in their enrichment in water. HCO_3^-, Cl^-, SO_4^{2-} and Na^+ constitute 90% of the TDS indicating the active secondary geochemical process controlling the surface water chemistry. Cl^- and SO_4^{2-} were in excess than HCO_3^- in summer and pre-monsoon period suggesting[13] the leaching of salt precipitate coating in sandstone and clays in summer. Sulphate concentration might have increased by the leaching and oxidation of FeS_2 (marcasite) in the study area[12]. Sodium concentration was higher in monsoon showing the leaching of precipitated salts in the soil/ sediment. Phosphate was high in certain locations due to the impact of agricultural effluents, which leads to eutrophication of ponds and streams. Nitrate was higher in specific locations and exceeded over the prescribed limit of 45 ppm. Excess of phosphate might be derived from the agricultural inputs.

According to Ayers and Branson[14], chloride also deserves attention in addition to TDS, SAR and Na%. When chloride in irrigation water is more than 10 epm (354.5 ppm), it is likely to pose severe problems and affects crop production adversely. It has been concluded[3] that the Kolar river water is mostly of medium salinity, medium SAR and medium Na % and also their chloride is much below 50 epm, hence the water is fit for irrigation purposes.

Concentration of fluoride in surface soils in Vallioor Union of Tirunelveli district of Tamilnadu was studied[15]. Fluoride[16,17] causes a serious dental and skeletal fluorosis, if present in higher concentration exceeding 1.5 ppm in water and 1 ppm and 5 ppm in soil respectively. Fluoride[15-17] in the surface soil was found in the range of 2.88 – 9.82 ppm, which affects the growth of crops. It also causes dental and traces of skeletal fluorosis in inhabitants consuming these crops. In the present study, the fluoride concentration in water and soil ranged from 0.7–1.3 and 3.2–5.9 ppm respectively. Thus, the present investigation shows that the fluoride levels in the area studied are within the desirable limits.

The parameters studied in the surface water, dug well, bore well, etc. found within the desirable limits of IS: 10500. Only hardness exceeded the prescribed maximum limit by 3.3%. The water contamination is therefore still in non - hazardous range. However, care should be taken in future so that the desirable concentrations of contaminants are maintained well below the hazardous level.

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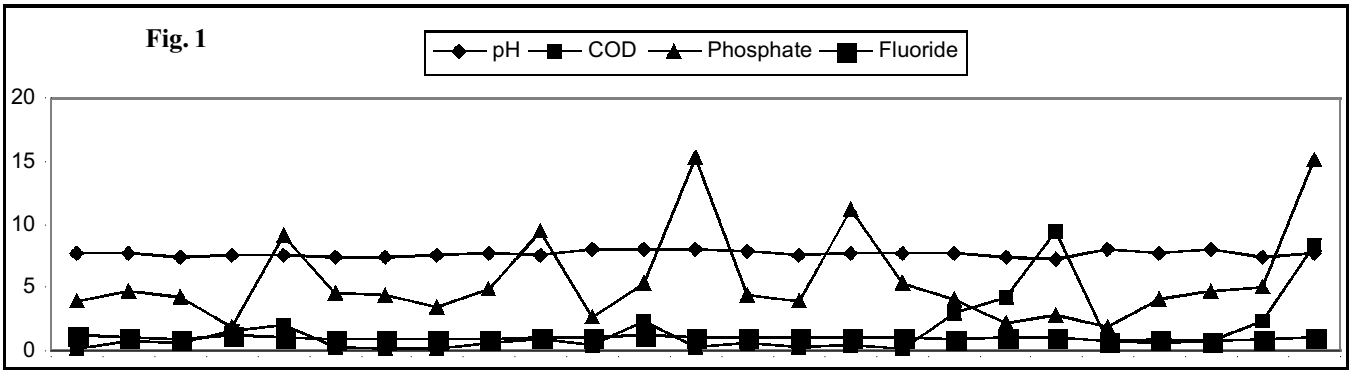
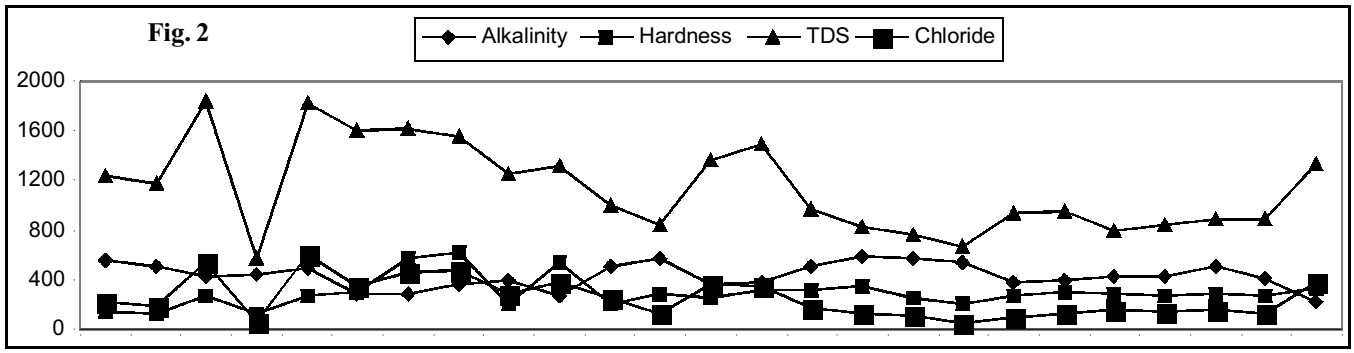
Table 7 : Statistical analysis of water and soil samples for all villages

Sr.No.	Parameter	Water samples			Soil samples		
		Minimum	Maximum	Mean	Minimum	Maximum	Mean
1	pH	7.16	8.10	7.64	6.90	7.85	7.49
2	COD	0.12	9.50	1.68			
3	Total Alkalinity as $CaCO_3$	230.0	580.0	434.5	210.0	650.0	511.6
4	Total Hardness as $CaCO_3$	123.6	620.6	294.5	95.1	559.4	396.4
5	TDS	573.1	1835.4	1141.5	730.0	1450.0	976.2
6	Chloride	51.1	602.7	252.8	34.0	162.3	85.9
7	Fluoride	0.7	1.3	1.1	3.2	5.9	4.3
8	Nitrite	0.01	0.02	0.01	0.06	4.48	1.29
9	Nitrate	8.6	77.4	34.1	69.9	166.7	116.1
10	Phosphate	1.9	15.3	5.6	4.2	74.2	26.4
11	Sulphate	19.0	393.6	166.6	6.0	291.7	86.2
12	Calcium	24.0	162.6	73.0	35.7	202.1	138.1
13	Magnesium	13.1	51.5	26.9	1.4	25.8	12.3
14	Sodium	86.5	486.7	218.0	10.6	232.4	87.1
15	Potassium	0.6	65.8	12.5	5.1	36.2	15.1
16	Arsenic (ppb)*	0.01	1.54	0.46	0.001	0.013	0.007
17	Cobalt	0.06	0.21	0.10	0.06	0.09	0.08
18	Iron	0.10	0.17	0.14	0.08	1.60	0.36
19	Lead	0.02	0.05	0.03	<0.1	<0.1	<0.1
20	Nickel	< 0.01	< 0.01	<0.01	0.15	0.55	0.34
21	Cadmium	0.06	0.06	0.06	2.45	6.30	4.03
22	Copper	0.01	0.01	0.01	< 0.05	1.99	1.02
23	Zinc	0.02	0.45	0.14	0.10	0.40	0.24
24	Manganese	0.01	0.08	0.03	0.06	0.11	0.09

* All parameters in ppm except arsenic





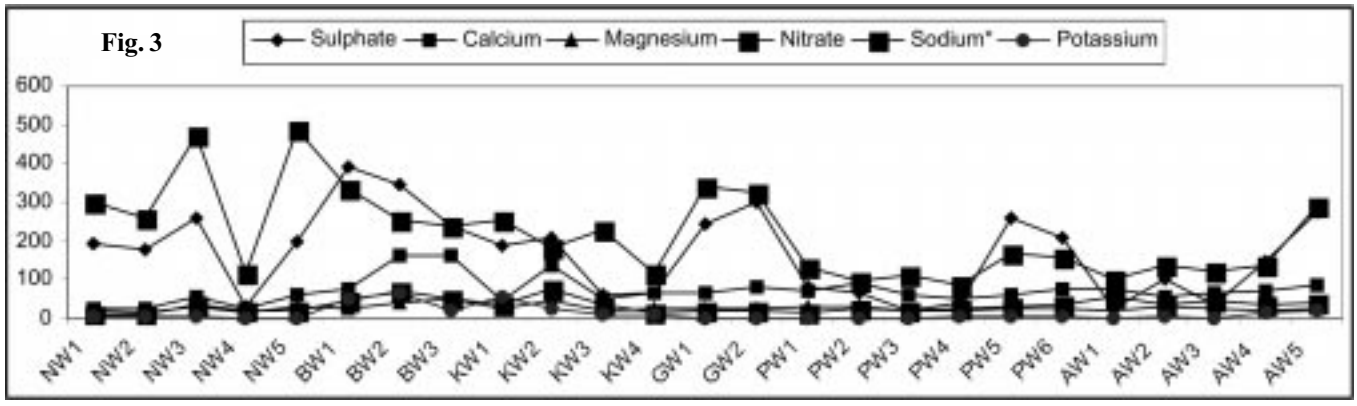
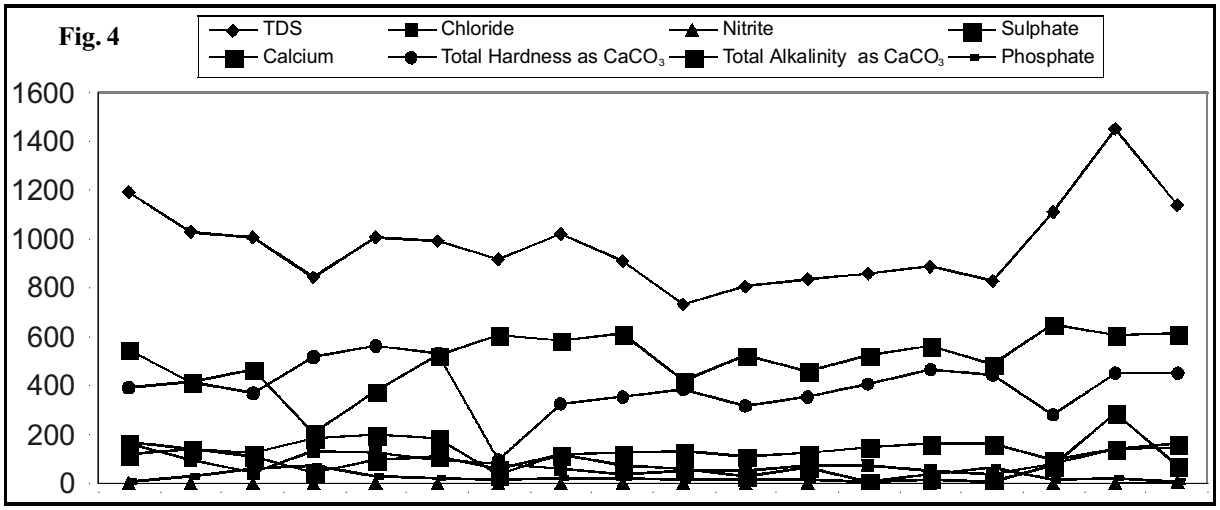


Fig. 1-3 : Variations in the values of various parameters studied to assess the water quality at various locations



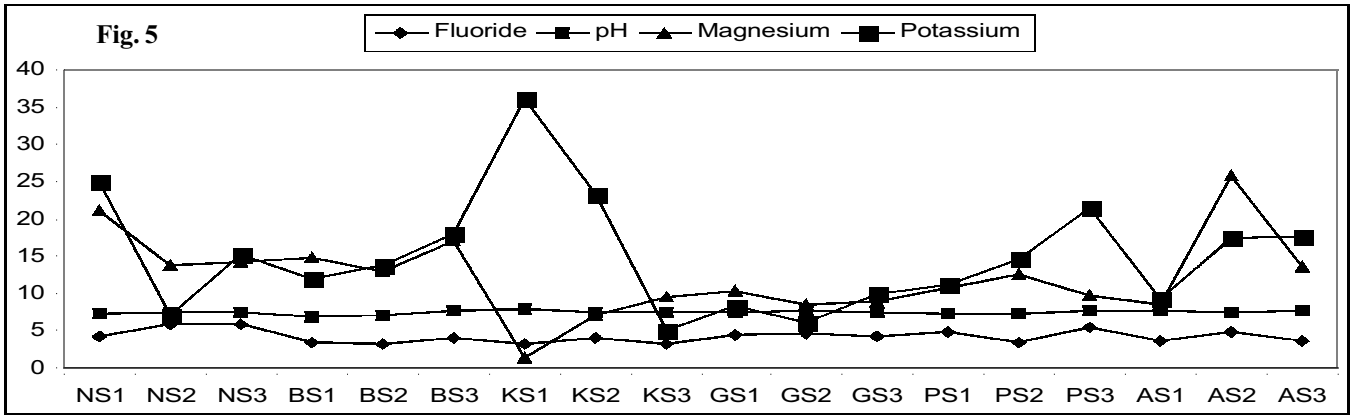


Fig. 4-5 : Variations in the values of various parameters studied to assess the soil quality at various locations

Table 8 : Surface water analysis

Sr. No.	Parameters	PW4	PW5	PW6	AW5	Tolerable limits[9]
1	SAR	2.58	4.47	3.95	7.02	< 10
2	Na%	46.1	57.4	53.23	64.4	60
3	Mg Hazards	39	41.9	32.8	32.3	
4	$HCO_3^-+Cl^-+SO_4^{2-}+Na^+$	506	760	730.8	1082	
5	TDS	664	940	954	1340	2000 mg/L
6	Bicarbonate	329	232	240.3	140	
7	Mg / Ca Ratio	0.64	0.72	0.488	0.48	
8	Sulfate	39.3	259.5	207.1	275.0	480 mg/L
9	Chloride	51.1	101.5	128.2	375.1	355 mg/L
10	Iron	0.16	0.15	0.15	0.16	1 mg/L
11	COD:N:P ratio	1:2.1:0.5	1:1.7:0.2	1:1.5:0.2	1:1.3:0.7	

PW4 — Water sample from river before mine water discharge at Pimpri
PW5— Water sample from river after mine water discharge at Pimpri
PW6 — Water sample where mine water is discharged to nala of Pimpri
AW5– Water sample where mine water is discharged to nala of Aheri

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