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Assessment of Groundwater Pollution Due to Ballarpur Industries Ltd. (BILT), Ballarpur, Dist. Chandrapur, Maharashtra, India

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Abstract
An assessment of impact of Industrial effluent on groundwater quality was carried out in around Ballapur industrial area underlain by Archean metamorphic rocks, Vindhyan Limestone, Gondwana and Deccan Trap formation. Total twenty one groundwater and surface water samples were collected during pre and post monsoon season in the year 2015. The quality of groundwater were asses for drinking purpose on the basis of physico-chemical parameters like pH, EC,TDS,TH, Cl, Ca, Mg ,TA, Na, K, SO_4 & F, etc. The concentration of these elements co-related with BIS (2012) [3], guideline for drinking purpose in both seasons. It shows that, the concentration of EC, TDS, TH, Cl, Ca, Mg, Na, K, & SO_4 are higher than MPL limit of BIS guideline. Overall it is shows that, the groundwater quality in the study area, for drinking purpose is affected. The sources of groundwater pollution are investigated with the help of concentration ionic ratio of Cl/HCO_3 and Ca/Mg and Na/Ca, indicating the amount of industrial effluent generated in the area has affected the groundwater quality. The Ballarpur area consists of many working small and large scale Industries. Among these, Ballarpur Industries Ltd. (BILT) is the largest paper Industry in Asia is established here.

Keywords: Physico-chemical parameters, Industrial effluent, Groundwater pollution, Ballarpur Industries Ltd. (BILT).

Introduction

Water is the most precious resources in the world, because all life depends on it. Groundwater is the most important source for domestic, industrial and agricultural water supply in the world. On the basis of groundwater quality, soil type, rock formation and pollution source such as mining, agriculture, acid precipitation, domestic and Industrial waste can be determined. (Appello and Postma, 1993; Zhang *et al*. 2011) [20].

The physical, chemical and biological composition of water is influenced to a great extent by different factors including climate, geomorphology and geology. The physical variable like temperature and turbidity; chemical variables includes non-toxic variables such as pH, total dissolved salts, salinity, conductivity, ions, nutrients, organic matter, dissolved gases and toxic variables like biocides and trace metals (Rajdeep P. Fulzele *et al*. 2017).

Study Area

Ballarpur Industrial area is situated on the bank of Wardha River. Ballarpur is a City and Municipal Concil in Chandrapur, district Chandrapur, Maharashtra State, India. The study area is spread between 79^0 19'30'' to 79^0 22'0'' E Longitude and 19^0 49' 00'' to 19^0 53' 00'' N Latitude of Survey of India, Toposheet No. 56M/5 and situated 20 km. away from Chandrapur (Fig. 1). Ballarpur has a nine coal mines, nearly owned by public sector company, Western Coalfield Ltd., Avantha group established their flagship paper factory BILT in Ballarpur. BILT is the largest manufacture of writing and printing paper in India. Many cement factories are located in this region. Due to large number of coal mines present around the Chandrapur City it is also known as Black Gold City. The population of Chandrapur district is 375000 as per census (District census 2011).

The population growth rate over the decade 2001-2011 was 5.95%. The Chandrapur has sex ratio of 959 females for every 1000 males and literacy rate of 81.35%. The temperature start decreasing from month of October, December is the coldest month. The mean temperature during December is 28.2^0 C and minimum is 11.6^0 C. The average annual rainfall is about 1420 mm. The average number of rainy days is 60 to 65, throughout the district.

Ballarpur has many probems regarding the drinking water. The study of groundwater and its quality for drinking purpose is very essential. Keeping this view in mind it is decided to investigate, the Impact of Industrial effluent on groundwater quality, around Ballarpur Industries Ltd. (BILT), Ballarpur, Chandrapur, Maharashtra., India.

Geology and Hydrogeology

The area consist of Archean metamorphic rocks, Vindhyan Limestone, Gondawana and Deccan Traps formations. In Archean formation consisting granite and granitic gneiss occur in most of the eastern part of the district of extending north-south from Nagbhid to Gondpipri. The rocks are generally devoid of primary porosity but weathering, jointing, fracturing, shearing etc. create secondary porosity within which the groundwater occur in phreatic condition, however deeper confined aquifer are also common (CGWB 2005, 2009) [4].

The Vindhyan Limestone is water bearing formation while sandstone due to their hard and compact nature has poor groundwater potential. Vindhyan sediments mainly occur in north

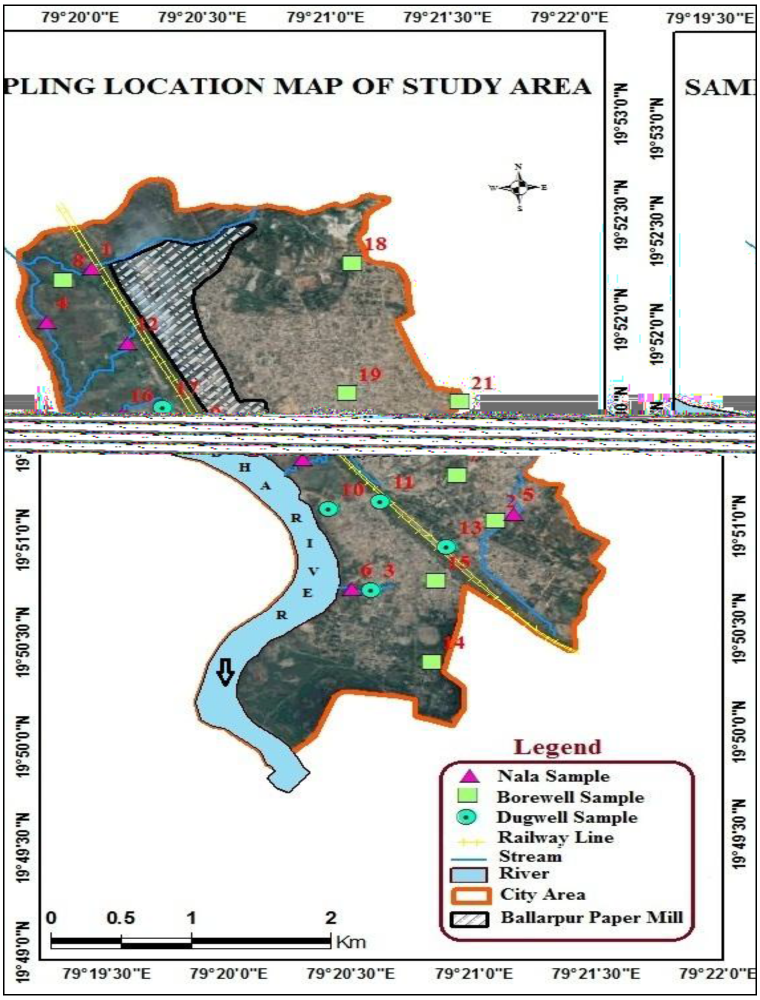

Fig 1: Location map of the study area, Ballarpur.

central part of the district around Tadoba and Nagbhid in part of Chimur, Sindewadi, Bhandravati and Nagbhid taluka and in south eastern part of the district in part of Chandrapur and Rajura Talukas. Deccan Trap basalt is observed in small areas in the north-eastern and south-eastern peripheral part of the distract and does not form promising aquifer in the district. Weathered, jointed, fracture, massive and vesicular basalt forms an aquifer in the area. In Gondwana formation comprising of Kamathi and Barakar sandstone; Maleri and Talchir shale occupy north-south, extending elongated stretch in central and southern part of the district in part of Warora, Bhandara, Chandrapur, Ballarpur, Rajura and Gondpipri taluka (Table. 1).

The shale and sandstone of the meso proterozoic age belonging to Penganga Group from the basement along with the underlying by the Archean metamorphic (Table 1). These rocks are uncomfortable overlain by the sediments of Gondwana Super Group of permo-carboniferous to Jurassic age. Geologically the area is dominated by Talchir shale and attained almost 80 to 100 mts., thickness as noticed from borehole data (DGM, 2000). The Talchir formation mainly comprises light green shale and sandstone. Talchir formation exhibit conformable relationship with the succeeding Barakar formation. The rocks of formation are feldspathic sandstone and shale are overlain by sandstone of Kamthi formation (Table. 1). In Deccan Trap basaltic flows cover the area and local alluvial patches can be noted from Wardha and Irai River which forms the southern and eastern boundary by the district.

Methodology

The preliminary surveys of the study area were carried out for locating the geology of the area. The plan includes the selection of groundwater sampling sites; collection of groundwater and effluent samples is to be carried out in pre and post monsoon seasons in 2015. The physic-chemical parameters like pH, EC, TDS, TH, Cl, Ca, Mg, TA, Na, K, SO_4 & F are analyzed in the field and Laboratory.

The pre-monsoon season samples collected in the month of May 2015 and post-monsoon season in the month of December, 2015. Total twenty one water samples were collected from bore wells, dug wells and Nala (Fig.2). The temperature and pH of water samples are measured by digital thermometer and digital pH meter in the field. The EC of the water samples were measured by using digital conductivity meter. TDS of the water samples measured by gravimetric method and Chlorides (Cl), Ca, Magnesium (Mg), Total alkalinity (TA) were determined by standard methods by APHA (1998) and Trivedy *et al*. (1998). The Na & K were determined by Flame photometer and Fluorides (F) were determined with UV-Spectro- photometer.

Table 1: Geological succession of the study area (after DGM, 2000)

Age	Formations	Rock types
Recent to sub- recent	Alluvium and soils	Sandy clay, salty soil and gravel.
Lower Eocene to Upper Cretaceous	Deccan Traps Unconformity	Basalt, weathered vecicular and massive basalt.
Lower Triassic to upper Carboniferous	Kamthi Unconformity	Reddish brown sandstone and clay.
	Barakar	Light grey to white feldspathic sandstone, carboniferous shale's, coal seam and clay.
	Talchirs Unconformity	Greenish to dark, olive green colored shale's and coarse grained sandstone.
Mesoproterozoic	Vindhyan	Sandstone, shale's, flaggy and massive limestones and variegated colors.
Archean	Crystalline and other metamorphic	Weathered and fractured granite, granite gneisses, quartzite schist with acid and basic intrusive.

Fig 2: Collection of Industrial effluent from Ballarpur Industries Ltd. (BILT), Ballarpur.

Results and Discussion

The impact of Industrial effluent on groundwater quality for domestic purpose were carried out on the basis of certain physic-chemical parameters, it includes pH, EC, TDS, TH, Cl, Ca, Mg, TA, Na, K, SO_4 & F. The determine concentration of these major elements correlate with recommended permissible limit for certain parameters describe in BIS (2012) [3] (Table 2). Twenty one water samples collected from dug wells and nala (effluent sample) during pre and post-monsoon season in 2015. The analytical results of surface and groundwater samples were correlated with the BIS (2012) [3]. pH is a measure of the balance between the concentration of hydrogen ions and hydroxyl ions in water. The pH of water provides vital information in many types of geochemical equilibrium or solubility concentration (Hem J.D. 1985) [6]. Even though pH has no direct effect on human health, its higher range accelerates the scale formation in water heating apparatus (Narsimha A.*et al*. 2013) [13]. In study area, the average of pH 7.0, in pre- monsoon season and 7.5 in post-monsoon season in bore well. In dug wells, in pre-monsoon season, the average pH value is 7.5 and post-monsoon season is 8.0. In nala in pre-monsoon season it is 7.6 and in post-monsoon season it is 8.2 (Table 2).

Table 2: Minimum, Maximum and average values of all parameters.

Parameters	Pre-monsoon-2015				Post-monsoon-2015		
	Source	Min.	Max.	Average	Min.	Max.	Average
Temp. ^{0}C	Bore well	27.0	29.0	27.6	23.0	24.0	23.5
	Dug well	27.00	28.5	27.8	24.0	24.5	24.3
	Nala	26.0	29.5	27.9	24.0	26.0	25.2
pH	Bore well	6.0	7.4	7.0	7.3	7.9	7.5
	Dug well	7.4	7.8	7.5	7.9	8.2	8.0
	Nala	7.1	8.3	7.9	7.6	8.6	8.2
EC (µS/cm)	Bore well	830.0	1910.0	1249.0	910.0	1970.0	1310.0
	Dug well	850.0	1610.0	1247.0	900.0	1695.0	1329.0
	Nala	1580.0	2450.0	2108.0	1630.0	2530.0	2182.0
TDS (mg/l)	Bore well	498.0	1490.0	1032.0	850.0	1540.0	1136.0
	Dug well	580.0	1420.0	1012.0	630.0	1450.0	1045.0
	Nala	860.0	3090.0	2408.0	1050.0	3140.0	2423.0
Cl (mg/l)	Bore well	144.3	310.8	234.6	158.3	328.8	255.3

	Dug well	78.6	334.6	207.6	98.6	354.6	222.1
	Nala	169.0	910.0	622.0	289.0	944.0	684.0
TH (mg/l)	Bore well	340.0	1138.0	770.0	355.0	1152.0	693.0
	Dug well	344.0	627.0	429.6	354.0	580.0	424.0
	Nala	1267.0	1560.0	1449.0	1280.0	1585.0	1461.0
Ca (mg/l)	Bore well	62.3	430.4	248.0	60.2	338.2	160.9
	Dug well	52.4	238.2	156.7	69.1	873.2	265.5
	Nala	530.2	652.0	592.7	71.2	667.0	459.5
Mg (mg/l)	Bore well	110.8	380.1	163.3	130.7	148.2	138.1
	Dug well	78.2	198.3	118.5	96.4	147.3	121.0
	Nala	213.4	374.1	299.7	227.2	328.7	280.6
TA (mg/l)	Bore well	118.0	291.0	219.7	105.0	265.0	149.5
	Dug well	103.0	192.0	123.3	103.0	116.5	109.6
	Nala	298.0	410.0	349.8	318.0	434.0	371.0
Na (ppm.)	Bore well	186.6	480.0	268.9	116.0	498.0	253.3
	Dug well	170.6	280.0	201.7	172.0	296.0	214.5
	Nala	246.0	620.0	477.0	256.0	645.0	497.4
K (ppm)	Bore well	23.0	114.0	59.6	46.0	138.0	94.9
	Dug well	35.0	78.5	55.4	70.0	118.5	91.2
	Nala	64.0	210.0	124.0	81.2	253.0	152.5
SO_4 (ppm)	Bore well	163.4	421.2	314.6	187.2	444.7	336.1
	Dug well	157.3	410.3	274.2	214.2	431.3	344.8
	Nala	412.2	810.6	651.0	430.3	834.1	657.1
F (ppm)	Bore well	0.2	0.7	0.5	0.5	1.0	0.7
	Dug well	0.3	0.8	0.4	0.6	1.2	0.8
	Nala	0.3	1.3	0.8	0.6	1.6	1.1

Electrical conductivity (EC) is a measure of water capacity to convey electric current. The electrical conductivity may be an approximate index of the total content of dissolved substance in water. The EC concentration in water may be depends upon temperature; concentration and type of ions present (Him J.D. 1985). Concentration of EC is a good measure of the relative difference in water quality between different aquifers (Roscoe M.1990) [17].

The most desirable limit of EC in drinking water is prescribed as 1500 µS/cm. (WHO 2004). The EC of the groundwater in pre-monsoon season of bore wells varies from 830 t0 1910 µS/cm. with an average 1249 µS/cm. In dug well, the EC varies from 850 to 1610 µS/cm. with an average varies of 1247 µS/cm. Nala, EC varies from 1630 to 2530 µS/cm. with an average of 2182 µS/cm. (Table 2). In pre-monsoon season, the nala water samples were cross the desirable limit of EC in the study area in both the seasons, indicate the enrichment of salts in the groundwater (Narsimha *et al*. 2023) (Table 2).

A total dissolved solid (TDS) generally reflect the amount of minerals content that dissolved in the water, and this controls its suitability for use. High concentrations of total dissolved solid may cause gastrointestinal irritation to the human being but longer time use of water with high TDS can cause kidney stone and heart disease (Das, 2013) [5]. In pre-monsoon season, in bore wells, the TDS values range from 498 to 1490 with 1032 mg/l in average; in dug well 580 to 1420 with average 1012 mg/l, and in Nala 860 to 3090 with 2408 mg/ l. In post-monsoon season in bore wells 850 to 1540 with 1136 mg/l; in dug well 630 to 1450 with 1045 mg/l and in Nala 1050 to 3140 with 2423 mg/l.

Significantly, the Nala water samples in both seasons are above the desirable limit (Table 2) because of discharge of industrial influent in the Nala. The high concentration of TDS in dug wells and bore wells in the study area may be due to human activity, waste disposal and enrichment of industrial influent through Nala water.

Chloride (Cl) in groundwater can be caused by industrial or domestic waste. The chloride concentration serves as an indicator of pollution by sewage. Soil porosity and permeability also has a key role in building up the chloride concentration (Davina V Gonsalves and Jeo D Souza, 1999). High chloride content in water bodies, harms agricultural crops, metallic pipes and injurious to people suffering due to heart and kidney diseases. According to BIS (2012) [3], the desirable limit of chloride is 250 mg/l and maximum permissible limit is 1000 mg/l.

In the study area, the chloride concentration is in pre-monsoon and post-monsoon seasons, for twenty groundwater samples from dug wells and bore wells are within the permissible limit, but in Nala, the chloride values in post-monsoon are varies from 169-910 mg/l with 622 mg./l and in pre-monsoon season 289-944 with 684 mg/l (Table 2). It is observed that, the high concentration of chloride in Nala in pre and post- monsoon seasons due to sewage water, high organic pollution as well as eutrophication of water or discharge of domestic sewage and industrial effluent near sampling sites (Das, 2013) [5].

The total hardness (TH) of water is an aesthetic quality of water and is caused by carbonates, sulphate and chlorides of calcium and magnesium. It prevents the lather formation with soap and increases the boiling points of water. The desirable limit of total hardness is 200 mg/l and the permissible limit is 600 mg/l (BIS 2012) [3]. Water having hardness more than 600 mg/l may cause heart and kidney problems.

In study area (TH), in pre-monsoon season it varies from 340-1138 with average 770 mg/l in bore wells. In dug wells it varies from 344-627 mg/l with average 429.6 mg/l. In Nala it varies from 530-652 with average 592.7 mg/l. In post monsoon season, in bore wells it varies from 355-1152 with an average 693 mg/l; in dug wells 354-589 with average 424 mg/l; in Nala 1280-1585 with average 1461 mg/l (Table 2). The total hardness of ground water is increase due to the leaching effect of Nala surface water. The Nala water having excess total hardness because of sewage water. The sewage water carries excessive soap water which is release from houses, laundries, textile and paper mill industries (Pratiksha Tambekar *et al*. 2012) [14].

The feldspars, calcite, and clay minerals are the probable source of calcium from sedimentary rocks. The limestone and industrial waste are rich sources of calcium from where it is leached in the groundwater. Calcium plays an important role in for proper bone growth (Das, 2013) [5]. The desirable limit of calcium is 75 mg/l and maximum permissible limit is 200 mg/l (BIS, 2012) [3].

In pre-monsoon season, the calcium concentration ranges from 63.3 to 430.4 mg/l with an average 248 mg/l in bore wells. In dug wells 52.4 to 238.2 mg/l with average 156.7 mg/l. in Nala 530.2 to 652 mg/l with an average 592.7 mg/l. During post- monsoon season the calcium concentration ranges from 60.2 to 338.2 with an average of 160.9 mg/l in bore wells. In dug wells 69.1- 873.2 mg/l with an average 265.5 mg/l and in Nala 71.2- 667 mg/l with an average 459.5 mg/l (Table 2). The high concentration of calcium in the groundwater of the study area is due to industrialization and urbanization specially Ballarpur Paper Mill and Pottery Industries (Murkute and Solanki, 2014) [10,11].

Magnesium is directly related to hardness, the principal source of Mg in the natural water is the magnesium bearing minerals present in the rocks. The chief sources of magnesium in natural water are the magnesium bearing minerals like pyroxene, olivine and amphiboles (Marghade *et al*., 2010) [9]. According to BIS (2012) [3], the desirable limit of magnesium is 30 mg/l and maximum possible limit is 100 mg/l.

In post and pre-monsoon season, all the bore wells, dug wells and the entire Nala water samples are above permissible limit (Table 2).

Total alkalinity (TA) of water is the measure of ability to neutralize a strong acid. The base like carbonates, bicarbonates, hydroxides, phosphates, nitrate, silicates, are responsible for alkalinity of water (Subramanian, 1980) [19]. Alkalinity provides an idea of natural salt present in water. Alkalinity is a parameter which is not harmful to human beings.

The alkalinity values in pre-monsoon season were recorded from 118 to 291 with an average 219.7 in bore wells; in dug wells 103 to 192 mg/l with an average 123.3 mg/l. In Nala 298 to 410 mg/l with an average 349.8 mg/l. In post-monsoon season, in bore wells it ranges from 105 to 265 mg/l, in dug wells 103 to 116.5 mg/l, with an average 109.6 mg/l, in Nala it ranges from 318 to 434 mg/l with an average is 371 mg/ (Table 2). According to BIS (2012) [3] for total alkalinity, the acceptable limit is 200 mg/l and the permissible is 600 mg/l. The total alkalinities of groundwater and Nala water samples are within permissible limit.

Sodium (Na) ion in drinking water may cause heart problems and high sodium ion in irrigation water may cause salinity problem. The sodium concentrations in water during pre-monsoon season were found in between 186.6 to 480 ppm. With an average 268.9 ppm. In dug wells 170.6 to 280 ppm with an average 201.7. In Nala 246 to 620 ppm with an average is 477 ppm, where as in post-monsoon season, the Na content ranged from 116 to 498 ppm with an average is 235.3 ppm in bore wells. In dug wells 172 to 296 ppm with an average 214.5 ppm. In Nala 256 to 645 ppm with an average is 497.4 (Table 2). The sodium in groundwater is released from rock-forming minerals like sodium plagioclase, potash plagioclase etc. Anthropogenic sources like domestic and animal waste have pointed out increased sodium content (Marghade *et al*. 2010) [9], (Handa 1975) [7], (Jacks *et al*. 2005), (Murkute, 2014) [10,11].

The major sources of potassium (K) in natural fresh water is weathering of rocks but the quantities increased in the polluted water due to disposal of waste (Khare S.L. *et al* 2007) [21]. Potassium content in pre-monsoon season in bore wells water samples varies from 23 to 114 ppm. with an average is 59.6 ppm. In dug wells 35 to 78.5 with an average is 55.4 ppm. In Nala water samples the concentration of potassium are 46 to 138 ppm with an average is 94.9 ppm. in dug wells 70 to 118.5 ppm with an average 91.2 ppm. In Nala 81.2 to 235 ppm with an average 152.5 ppm (Table 2).

Sulphate occurs naturally in water as a result of leaching from gypsum and other common minerals. According to BIS (2012) [3], the desirable limit for sulphate is 200 ppm and maximum permissible limit is 600 ppm. A high concentration of sulphate also causes laxative effect on cattle and human.

The sulphate concentration in water samples during pre-monsoon in bore wells is between 163.4 to 421.2 with 314.6 ppm. In dug wells it contains 157.3 to 410.3 with 274.2 ppm and in Nala 412.2 to 810.6 with 651.0 ppm. In post-monsoon season it varies from 187.2 to 444.7 with 336.1 ppm in bore wells, in dug well it varies from 214.2 to 431.3 with 344.8 ppm. In Nala water it content 430.3 to 834.1 ppm with an average 657.1 ppm.

The concentration of sulphate in groundwater in bore wells, dug wells and Nala water crosses the maximum permissible limit, recommended by BIS (2012) [3]. The concentration of sulphate increase in certain wells and Nala water because of leaching effect of Gondawana formation minerals like pyrite (FeS_2) which is very common secondary minerals in the Gondawana formation and associated sediment (Murkute Y.A. and Solanki V.V. 2014) [10,11]. Sulphate is used for manufacturing of paper and hence the sulphate is mixed with an effluent for polluting the certain wells and Nala water. The high concentration of sulphate in Nala wateris due to discharge of Industrial water and domestic sewage mixing with surface and groundwater (Table 2).

The fluoride (F) content during pre-monsoon season ranges between 0.2 to 0.7 ppm with an average 0.5 ppm in bore wells in bore wells. In dug wells 0.3 to 0.8 ppm with an average is 0.4 ppm.

In Nala water it's contain 0.3 to 1.3 with an average is 0.8 ppm. In post-monsoon season, in bore wells 0.5 to 1.0 ppm. In dug wells contain 0.6 to 1.2 with an average 0.8 ppm. In Nala 0.6 to 1.6 ppm with an average is 1,1 ppm (Table 2).The source of fluoride in groundwater is due to fluoride bearing minerals such as fluorspar, fluorite, cryolite, fluorapatite and hydroxylapatite besides, the source of fluoride is also expected to be the amphibole's and biotite (Madhnure and Malpe 2007). The high value of fluoride in the study area are due to high concentration of ionic constituent present in water bodies and reflect the concentration mainly from Industrial effluents.

Effluent as a Source of Pollution

The effluent as a source of pollution can be investigated with the help of ion concentration ratio of Cl/HCO_3 and Ca /Mg and Na/Ca (Pawar, *et al*., 1998; R.D. Kaplay *et al*., 2004). For the determination of source of pollution, the study area is divided in two groups (1) Polluted zone and Non-Polluted zone. The percentage of pollution in pre and post-monsoon season 2005 is given in Table 3 & 4 and Fig. 3 & 4. The average values of ionic ratios of post and pre-monsoon season, 2015 is shown in Table 5 & 6.

Table 3: Percentage of polluted wells in pre-monsoon season 2015

Source	TDS	TH	Ca+2	Mg+2	SO_4
Bore wells	0.0	75.00	62.50	100.0	0.00
Dug wells	0.0	16.66	49.98	49.98	0.00
Nala	71.40	100.0	100.0	100.0	71.40

Table 4: Percentage of polluted wells in post-monsoon season 2015

Source	TDS	TH	Ca+2	Mg+2	SO_4
Bore wells	0.0	50.00	37.5	100.0	0.00
Dug wells	0.0	0.0	49.98	83.3	0.00
Nala	71.40	100.0	71.4	100.0	71.40

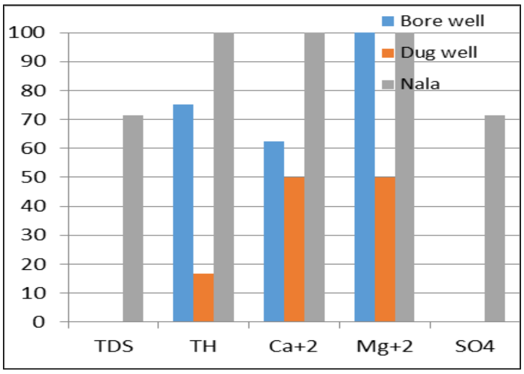

Fig 3: Percentage of polluted well in Pre- Monsoon season 2015

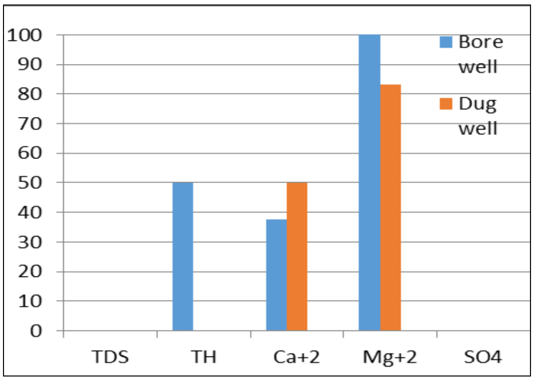

Fig 4: Percentage of polluted well in Post-Monsoon season 2015

Table 5: Average of ionic ratios for the well group and effluent

	Post-monsoon			Pre-monsoon		
Sources	Cl/HCO_3	Ca /Mg	Na/Ca	Cl/HCO_3	Ca /Mg	Na/Ca
Effluent	4.81	1.39	0.84	4.01	1.06	0.80
Bore wells	3.33	0.70	2.38	1.85	0.92	1.31
Dug wells	3.62	1.42	1.52	3.08	0.85	1.58
Nala	3.14	0.98	1.69	3.05	1.28	0.67

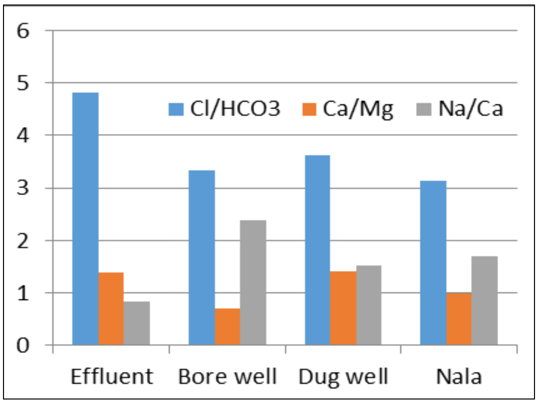

Fig 5: Average of ionic ratios for the well groups and effluent (Pos-Monsoon)

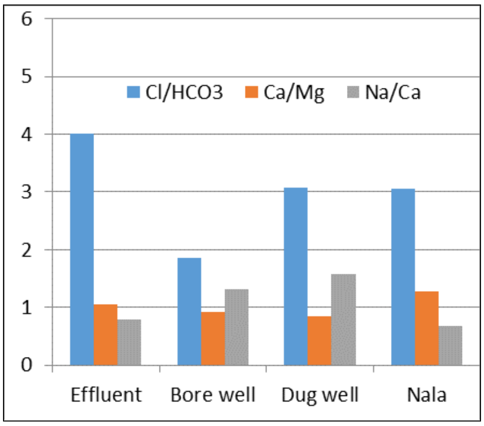

Fig 6: Average of ionic ratios for the well groups and effluent (Pre-Monsoon)

It is observed that in post and pre-monsoon season, the average ionic ratios of Cl/HCO_3 and Ca /Mg ratio for the effluent samples is higher than bore well, dug well and Nala water. It suggests that, the most of the groundwater from wells and Nala receiving ions in solution from effluent. Higher values of Na/Ca of bore wells, dug wells and Nala as compare to effluent samples, it is observed that precipitation of calcium carbonate in groundwater (Pawar, 1993) [16]. The average ionic ratios for well groups and effluents suggest that the effluent is polluting the ground water of the area. It is proved that, the groundwater quality of Ballarpur study area is polluted by Ballarpur Industries Ltd. (BILT), Ballarpur and other small scale Industries.

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