# Hydrochemical Characterization And Quality Appraisal Of Groundwater Suitability For Irrigation Purpose In Semi-Arid Region Of Balatira Watershed, Sangli District, Maharashtra.

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## Abstract

*Seasonal study on the groundwater quality was carried out in Balatira watershed of Sangli district during pre-monsoon and post-monsoon seasons of 2014. Increased population and intensive agricultural activity make it imperative to assess the quality of the groundwater system to ensure long-term sustainability of the resources. Thirty five groundwater samples were collected from dugwells of various location and analyzed for pH, EC, TDS, TH, Ca, Mg, Na, K, Cl, $HCO_3$, $SO_4$ and $NO_3$. Based on the physicochemical analyses, irrigation quality parameters like Sodium Absorption Ratio (SAR), Residual Sodium Carbonate (RSC), Soluble Sodium Percentage (Na%), Kelly Ratio (KR), Permeability Index (PI), Magnesium Hazard (MH) and Chloro Alkaline Index (CAI) were calculated. The result of Wilcox diagram shows that samples fall in the field of excellent to unsuitable in pre-monsoon and excellent to doubtful in post-monsoon 2014, U.S. Salinity diagram indicate that water are of C3S1 and C4S1 types in pre-monsoon 2014 and C2S1, C3S1 and C4S1 type in post-monsoon that is low to high salinity and low sodium which is suitable for plants having good salt tolerance and also limit the suitability for irrigation. The values of Sodium Adsorption Ratio indicate that the groundwater of the area falls under the category of low sodium hazard. Some samples have high sodium percentage and high SAR indicating its unsuitability for irrigation that suggests need of adequate drainage in the area.*

***Keywords:*** *Sodium Adsorption Ratio, Permeability Index, Magnesium Hazard, Balatira watershed*

## Introduction

The water scenario facing India by the end of its 50th year of Independence is grim. Current per capita water availability in India is about 1050 $m^3$, placing India in the category of water stress countries. Obviously, this is expected to fall to as low as 700 $m^3$ by 2050 implying acute water scarcity. Even if the total available water is taken into account, per capita water availability was estimated to be about 1700 $m^3$ in 2007, 1544 $m^3$ in 2011and projected to be 700 $m^3$ by 2050. There by implying that India would continue to be water stressed even if all existing natural flows are utilized. Groundwater depletion and contamination are attaining acute crisis in Western and Peninsular India. Maharashtra is a relatively better off state in the country in terms of rainfall, but it may soon become a state facing increasing water crisis with perennial water shortages, if urgent measures are not undertaken to address quantity and the quality issues related to groundwater.

Maharashtra is mainly an agriculture state with around 82% of rural population relying farming. Out of the total area under irrigation, 28.75 lakh hectares (71%) of the agricultural land is irrigated by groundwater while 11.83 lakh hectares (29%) by flow or canal irrigation. Out of the total groundwater consumed, 85% is for irrigation, 10% for industries and only 5% is for domestic consumption. Drinking water needs of around 80% of the total rural population are met from groundwater. As per the "Report on Dynamic Groundwater Resources of Maharashtra" as on 2011-12, around 93% of the total abstracted groundwater is used for irrigation withdrawal, around 5% used for drinking and 2 to 3% for industries and if groundwater is limited then the share in irrigation use needs to be reduced to attain sustainability.

The quality of groundwater is resultant of all the processes and reaction that act on the water from the moment it condenses in atmosphere to the time it is discharged by a well. Therefore, determination of groundwater quality is important to observe the suitability of water for a particular use. The groundwater quality data gives important clues to the geologic history of rocks and indications of groundwater recharge, movement and storage (Walton, 1970). Groundwater quality depends on number of factors, such as general geology, degree of chemical weathering of prevailing lithology, quality of recharge water and inputs from sources other than water-rock interaction (Domenico, 1972 and Freeze and Cherry, 1979). The present study is aimed at determining groundwater quality of Balatira watershed for irrigation purpose.

**Study Area**: In Maharashtra, the Sangli district is a semi-arid and drought prone area. The Balatira watershed is designated as BM113 by GSDA and is a tributary of Man river. The study area lies between latitudes $17^o18'$ and $17^o28'$ North and longitudes $74^o42'$ and $75^o0'$ East covering an area of about 278 $Km^2$ as shown in figure 1. The area comprise of volcanic rock of Deccan trap with alternating layers of compact massive basalt and vesicular amygdaloidal basalts formed during the Cretaceous – Eocene age. 'Aa' and 'pahaehoe' lava flows of varying thickness constitute the lithology of the area.

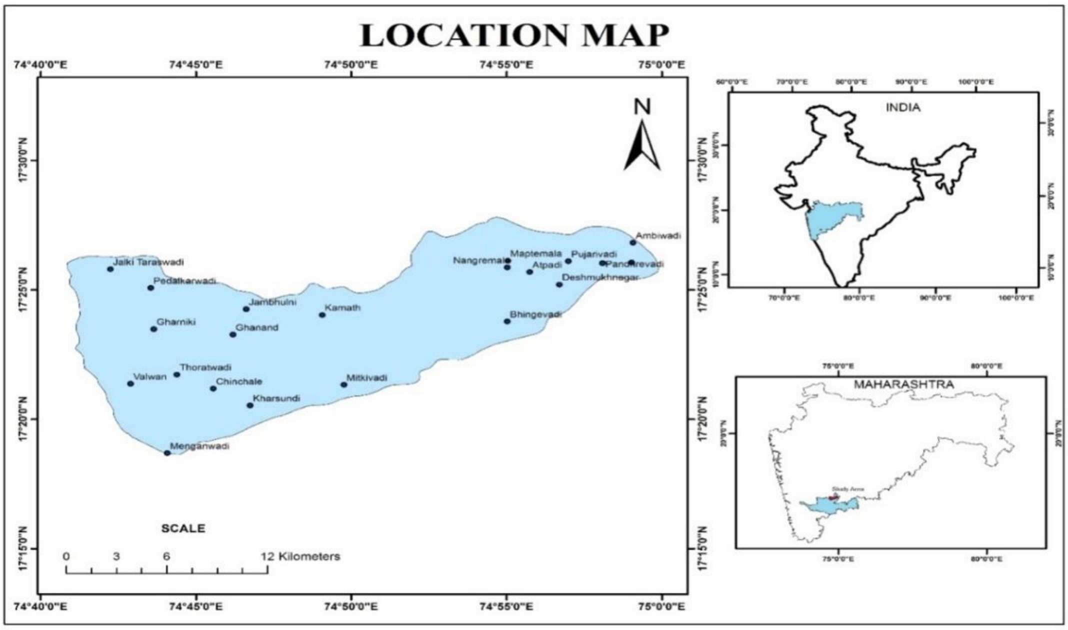


**Figure 1: Location map of study area.**

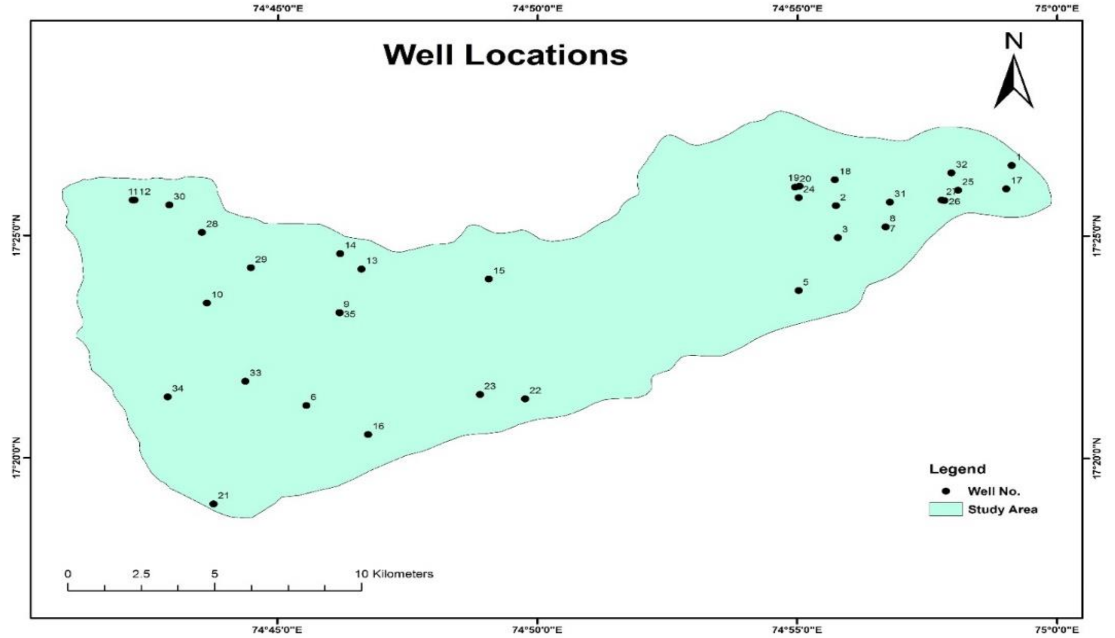


**Figure 2: Illustrates location of observation wells sampled in Balatira watershed.**

**Material and Methodology:** Groundwater samples were collected from all 35 location wells in the field in both pre-monsoon and post-monsoon period of 2014. The water samples were collected in pre-cleaned polythene bottles of 1000 ml and the locations are marked on the study area map by using GPS (figure 2). The groundwater samples are analysed as described by American Public Health Association (APHA, 1995) procedure and suggested precautions are taken to avoid contamination. The spatial distribution for groundwater quality parameters were done with the help of spatial analyst module in Arc GIS 10.0 software.

**Results and Discussion:** The analytical results, computed values and the statistical parameters like minimum, maximum, mean and the standard deviation values of water samples are given in Tables 1. The parameters such as Sodium Adsorption Ratio (SAR), Soluble Sodium Percentage (SSP), Residual Sodium Carbonate (RSC), Magnesium Adsorption Ratio (MAR), Total Hardness (TH) , Kelly Ratio (KR), Chloro Alkali Index (CAI) and Permeability Index (PI) were calculated to evaluate the suitability of the water quality for agriculture purposes and are shown in Table 2. Further the results of the analyses were interpreted using different graphical representations.

**Electrical Conductivity (EC):** Electrical Conductivity of the groundwater samples was measured and is produced in table 2. EC data indicates that in pre-monsoon the water lies between permissible to doubtful and in post-monsoon the water lies between good to doubtful.

**Sodium Adsorption Ratio (SAR):** The relative activity of sodium ion exchange reaction with soil is expressed by a ratio known as Sodium Adsorption Ratio (SAR). It is the proportion of sodium to calcium and magnesium, which affect the crops ( Singh et al., 2007). Salinity hazard is based on EC measurements. If water used for irrigation is high in $Na^{+}$ and low in $Ca^{2+}$ the ion exchange complex may become saturated with $Na^{+}$ which reduce the soil structure, due to the dispersion of clay particles (Todd, 1980) and reduces the plant growth. Excess salinity reduces the osmotic activity of plants. This will also result in a decreasing infiltration and permeability of the soil leading to problems with crop production. The Sodium Absorption Ratio gives a clear idea about the absorption of sodium by soil and therefore considered to be an important parameter for determining the suitability of groundwater for irrigation purpose and it can be estimated by the standard formula. The classification of groundwater samples based on SAR values (Hem, 1991) is shown in table 2. The SAR values of all the samples are found to be in the range of excellent during pre-monsoon and excellent to good during post-monsoon 2014.

On the basis of SAR irrigation water is classified into four categories C1, C2, C3 and C4. The Sodium Hazard is classified into four groups S1, S2, S3 and S4. The obtained values are plotted in the US Salinity laboratory diagram (1954) to find out suitability of irrigation water (figure 3). In the present area, pre-monsoon groundwater samples fall in the field of C3S1 and C4S1 by 37% and 63%, respectively. In post-monsoon the percentage samples falling in the field of C2S1, C3S1 and C4S1 are as 20%, 57% and 23%, respectively. The samples indicating water of high to very high salinity and low sodium which is suitable for plants having good salt tolerance and it also restricts suitability for irrigation, especially in soils with restricted drainage.

**Residual Sodium Carbonate (RSC):** The Residual Sodium Carbonate is calculated to determine the hazardous effect of carbonate and bicarbonate on the quality of water used for agriculture activities (Srinivasamoorthy et al., 2011). When the sum of carbonates and bicarbonates is in excess of calcium and magnesium, there may be possibility of complete precipitation of $Ca^{2+}$ and $Mg^{2+}$ ( Raghunath, 1987). RSC values of the groundwater samples have been calculated by using the formula and is shown in table 2.

A negative RSC value indicates sufficient calcium and magnesium are in excess and would be precipitated as carbonates. Whereas a positive RSC values indicates that sodium build up in the soil is possible. It is observed that in the present area most of the groundwater samples are within safe zone during the pre-monsoon and post-monsoon 2014. However, 3% samples in post-monsoon are in moderate zone.

**Soluble Sodium Percentage (SSP):** Sodium is an important ion used for the classification of irrigation water due to its reaction with soil, which reduces its permeability. Sodium is usually expressed in terms of percent sodium. The percent sodium (Na%) values are obtained by using the standard equation proposed by Wilcox (1955)**.**

According to Wilcox classification of the groundwater for irrigation purposes, the sodium percent is plotted against electrical conductivity. The classification of groundwater samples with respect to percent sodium and EC illustrates that 3%, 33%, 50% , 11% and 3% of the groundwater samples fall in the field of excellent, good, permissible ,doubtful and unsuitable, respectively during pre-monsoon 2014. But in post-monsoon 2014, 14%, 54%, 6% and 26% of the groundwater samples fall in the field of excellent, good, permissible and doubtful respectively in the area of study. Thus the groundwater samples fall mostly in the range of good to permissible for irrigation purpose.

**Kelly's Ratio (KR):** Kelly's ratio (1963) is defined as the excess amount of sodium over calcium and magnesium. A Kelly's ratio of more than one indicates an excess of sodium in waters. Water with less than one is suitable for irrigation. The KR is calculated by using the standard formula. Kelly's ratio in the groundwater samples in the study area indicates that most of the samples are suitable for irrigation in pre-monsoon and post-monsoon season of 2014.

**Magnesium Hazard (MH):** It is described as the excess amount of magnesium over calcium and magnesium amount where otherwise generally calcium and magnesium will be in a equilibrium . During equilibrium more magnesium in groundwater will adversely affect the soil quality rendering it alkaline effecting decrease in crop yield. Paliwal (1972) developed an index for calculating the magnesium hazard where calcium and magnesium ratios are taken into consideration, as mostly calcium and magnesium maintain equilibrium in water. Magnesium hazard for irrigation water has been calculated by using the standard formula.

Irrigation water with MH above 50 is usually not suitable and has an adverse affect on the crop yield as the soil becomes more alkaline. In the study area the samples indicating less than 50 of MH are 67% and 57% during pre monsoon and post monsoon, respectively. Rest of the samples having MH values above the permissible limit of 50mg/l indicate the unfavourable effect on crop yield and increase the soil alkalinity.

**Permeability Index (PI):** The soil permeability is affected by long-term use of irrigation water and is influenced by $Na^+$, $Ca^{2+}$, $Mg^{2+}$ and $HCO_3^-$ contents of the soil. Permeability index is given by Doneen (1964). According to PI values, the groundwater samples falling in class I ( PI < 25%) and class II ( PI ranged between 25 to 75%) indicate that the water is excellent to good for irrigation purposes. Waters falling under class III (PI > 75%) are not suitable for irrigation. In the study area 92% and 94% of the groundwater samples fall in excellent to good category in pre-monsoon and post-monsoon, respectively. Thus it is imperative to say that the overall quality of groundwater is suitable for irrigation purposes.

**Chloro Alkaline Indices (CAI):** The chemical reactions in which ion exchange between the groundwater and aquifer environment occurs during the periods of residence and movement may be understood through Chloro Alkaline Indices 1 and 2 proposed by Schoeller (1967). The chloro alkaline indices is calculated by standard equation.

When there is an exchange between calcium or magnesium in the groundwater with sodium and potassium in the aquifer material, both the above indices are negative, and if there is a reverse ion exchange, then both these indices will be positive (Schoeller 1977). The values indicating most of the samples show negative and some wells show positive in the study area (Table 2). This observation indicates that the normal ion exchange is the dominant process in the groundwater, whereas reverse ion exchange is observed in a few wells.

## Conclusion

In the present study, the quality of groundwater for irrigation purposes has been evaluated on the basis of various guidelines. The SAR values of all the samples are found to be within the range of excellent to good during pre-monsoon and post-monsoon 2014. The analytical data plotted on the US salinity diagram illustrates that in pre-monsoon groundwater samples fall in the field of C3S1 and C4S1by 37% and 63%, respectively. In post-monsoon the samples falling in the field of C2S1, C3S1 and C4S1 are as 20%, 57% and 23%, respectively. The samples indicating water of high to very high salinity and low sodium which is suitable for plants having good salt tolerance and it also restricts suitability for irrigation. Base on the classification of irrigation water according to the RSC values, all of groundwater samples belongs to the good category. The Permeability Index values for the groundwater of in the study area can be designated as class I (<25%) and class II (25–75%) that shows that the groundwater in study area is suitable for irrigation purposes in both the seasons. Kelly's ratio in the groundwater samples in the study area indicates that most of the samples are suitable for irrigation in both seasons. Majority of pre-monsoon (67%) and post-monsoon (57%) samples have MH value less than 50, thereby representing favourability for irrigation. However, rest of the samples having MH values above the permissible limit of 50mg/l indicate the unfavourable effect on crop yield and increase the soil alkalinity.

To avoid further deterioration of the environment and to ensure sustainable development, the following measures are to be adopted:

1. Practice of drip water irrigation should be encouraged as it helps in retarding / procrastinating soil akalinity.
2. Installation of distillation plant and adaptation of rain harvesting farm ponds can be used to overcome salinity problems for irrigation purposes and
3. Soils require gypsum treatment to improve permeability of soils and yields of the crops.

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**Table 1: Physico-chemical parameters of groundwater samples of Balatira watershed.**

| Sr. No. | Parameters | Pre-monsoon 2014 | | | Post-monsoon 2014 | | |
|---|---|---|---|---|---|---|---|
| | | Minimum | Maximum | Average | Minimum | Maximum | Average |
| 1 | pH | 6.4 | 7.9 | 7.5 | 7.8 | 8.5 | 8.23 |
| 2 | Ec | 1056 | 7200 | 3061.4 | 520 | 4100 | 1450.6 |
| 3 | TDS | 700 | 5400 | 2243 | 120 | 2740 | 1074.5 |
| 4 | Alk | 90.5 | 485.3 | 242.8 | 376 | 1311 | 768.8 |
| 5 | TH | 122.3 | 2348.2 | 848.2 | 175.1 | 525.3 | 349.5 |
| 6 | Ca | 16 | 609 | 169.1 | 20 | 355 | 152.8 |
| 7 | Mg | 20 | 256.8 | 103.4 | 3.9 | 304.8 | 94 |
| 8 | Na | 86.3 | 644 | 303.9 | 57 | 1295.6 | 335.7 |
| 9 | K | 0.36 | 6.2 | 11.3 | 0.39 | 7.02 | 1.92 |
| 10 | Cl | 80 | 980 | 325.3 | 161 | 542.5 | 302.3 |
| 11 | $CO_3$ | 10 | 60 | 26.8 | 30 | 60 | 30.9 |
| 12 | $HCO_3$ | 60 | 518.5 | 241.5 | 152.5 | 579.5 | 363.4 |
| 13 | $SO_4$ | 182.4 | 1466.8 | 601.7 | 67.2 | 1749.6 | 462.3 |
| 14 | $NO_3$ | 37.2 | 750.2 | 253.9 | 43 | 1469 | 376.4 |

**Table 2: Classification of groundwater quality for irrigation purpose.**

| Parameters | Classes | Water suitability for irrigation | Percentage of samples | |
|---|---|---|---|---|
| | | | Pre-monsoon 2014 | Post-monsoon 2014 |
| EC | <250 | Excellent | - | - |
| | 250 – 750 | Good | - | 20 |
| | 750 – 2000 | Permissible | 23 | 57 |
| | 2000 - 3000 | Doubtful | 77 | 23 |
| SAR | <10 | Suitable for all types of soils except for those crops which are highly sensitive to sodium. | 100 | 78 |
| | 10-18 | Suitable for coarse textured or organic soil with good permeability. Relatively unsuitable in fine textured soil. | - | 22 |
| | 18-26 | Harmful for almost all types of soils. Requires good drainage, high leaching and gypsum addition. | - | - |
| | >26 | Unsuitable for irrigation | - | - |
| RSC | <1.25 | Safe | 100 | 97 |
| | 1.25-2.5 | Moderate | - | 3 |
| | >2.5 | Unsuitable | - | - |
| SSP | <20 | Excellent | 3 | 14 |
| | 20-40 | Good | 33 | 54 |
| | 40-60 | Permissible | 50 | 6 |

| | | | | |
|---|---|---|---|---|
| | 60-80 | Doubtful | 11 | 26 |
| | >80 | Unsuitable | 3 | - |
| KR | <1 | Excellent | 66 | 71 |
| | 1-3 | Good | 31 | 23 |
| | >3 | Unsuitable | 3 | 6 |
| MH | <50 | Suitable | 67 | 57 |
| | >50 | Unsuitable | 33 | 43 |
| PI | <25 | Excellent | 3 | 3 |
| | 25-75 | Good | 89 | 91 |
| | >75 | Unsuitable | 8 | 6 |
| CAI-I / CAI-II | -ve | Discharge | 89 | 31 |
| | +ve | Recharge | 11 | 69 |
| USSL Diagram | C2S1 | Good | - | 20 |
| | C3S1 | Moderate | 37 | 57 |
| | C4S1 | Poor | 63 | 23 |

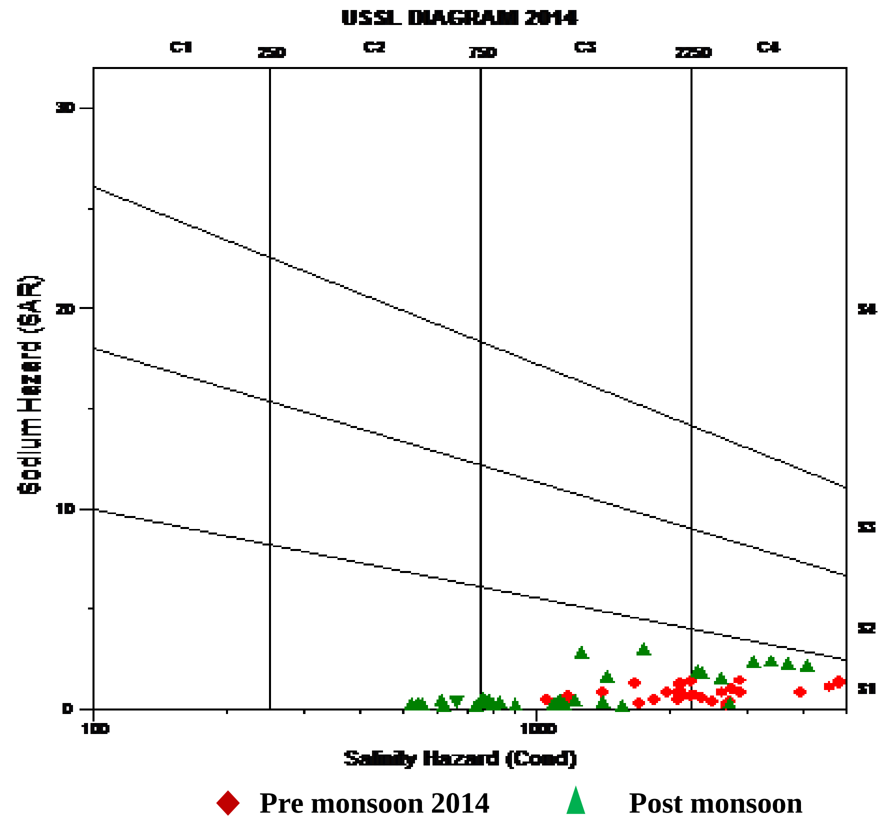
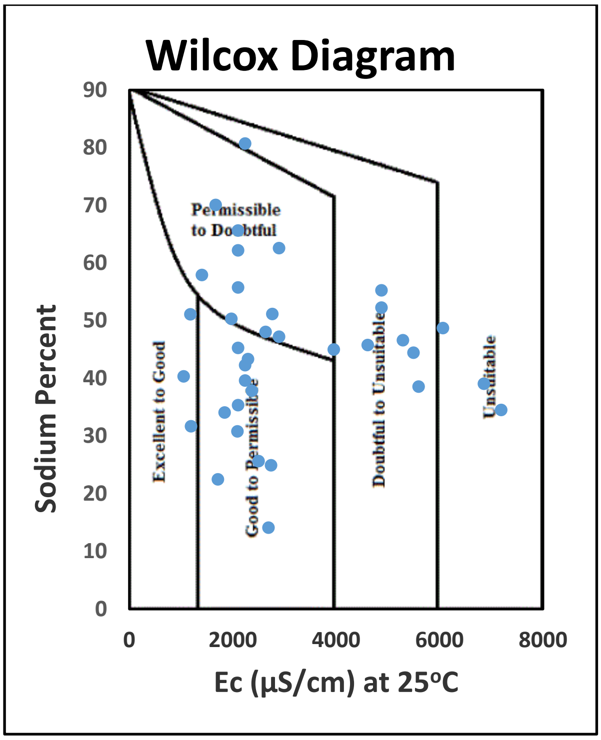
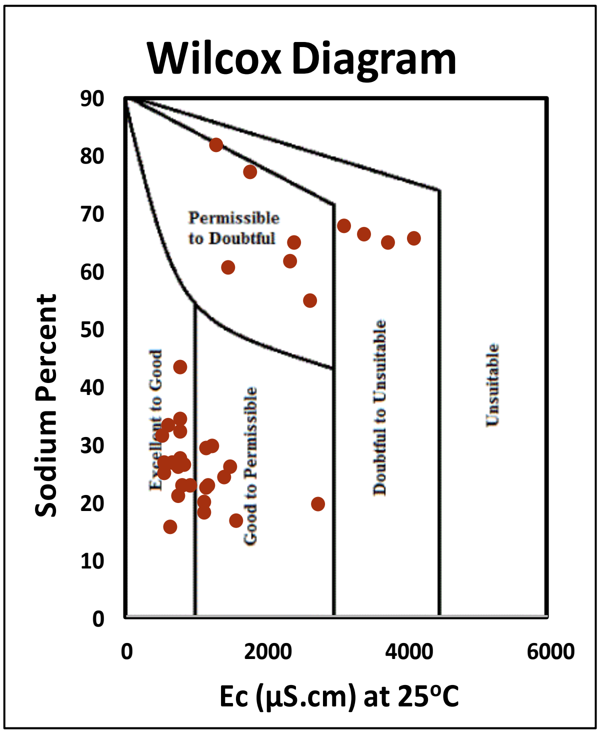



**Figure 3: Classification of groundwater samples of Balatira watershed USSL diagram for Pre and Post -monsoon 2014.**




Pre monsoon 2014




Post – monsoon 2014

**Figure 4: Wilcox diagram of groundwater samples chemistry of Pre and post-monsoon 2014 of Balatira watershed**