

# GLOBAL JOURNAL

OF SCIENCE FRONTIER RESEARCH: B

## Chemistry



Kinetic Study of Ni

Spatial Variation of Water

### Highlights

Water Quality Index

Water Partition Coefficients

Discovering Thoughts, Inventing Future

VOLUME 15

ISSUE 6

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CHEMISTRY

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# 1-Octanol/Water Partition Coefficients of Dialkylated Methylimidazolium Halide Salts

By Marissa K. Gard, Elliot G. Ennis & John H. Summerfield

*Missouri Southern State University, United States*

**Abstract-** Dialkylated methylimidazolium halide salts are a current research topic. The 1-octanol/water partition coefficient for these salts has come to signify the tendency of a charged organic molecule to cross a biological membrane, be sequestered in soil, and indicate the lethal dose of the chemical. The purpose of this work is to add to existing data for the 1-octanol/water partition coefficient for these salts. The novelty of this work is that dialkylated methylimidazolium salts are investigated.

**Keywords:** ionic liquids, partition functions.

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# 1-Octanol/Water Partition Coefficients of Dialkylated Methylimidazolium Halide Salts

Marissa K. Gard <sup>α</sup>, Elliot G. Ennis <sup>σ</sup> & John H. Summerfield <sup>ρ</sup>

**Abstract-** Dialkylated methylimidazolium halide salts are a current research topic. The 1-octanol/water partition coefficient for these salts has come to signify the tendency of a charged organic molecule to cross a biological membrane, be sequestered in soil, and indicate the lethal dose of the chemical. The purpose of this work is to add to existing data for the 1-octanol/water partition coefficient for these salts. The novelty of this work is that dialkylated methylimidazolium salts are investigated.

**Keywords:** ionic liquids, partition functions.

## I. INTRODUCTION

Green chemistry is founded on guidelines that are designed to prevent and reduce the waste associated with the production of chemicals. Any modifications to existing processes as well as the creation of new processes that lead to more efficient and recyclable solvents, safer reactions, and renewable feedstocks are successes.[1]

Ionic liquids or molten salts are molecules composed wholly of ions and occur in the liquid state. An inorganic salts such as NaCl is an ionic liquid above its melting point. Due to their high melting point many inorganic salts are of little use in daily life. Instead, chemists have turned to imidazolium-based ionic liquids. These organic salts are current candidates for

green solvents. They can be highly soluble, can have high ionic conductivity, are generally inflammable, have high thermal and chemical stability, and relatively low vapor pressures compared to cyclohexane, benzene, and acetone. Typically the imidazolium salts under investigation are alkylmethylimidazolium compounds. The novelty of this work is that dialkylated methylimidazolium salts are investigated.[2]

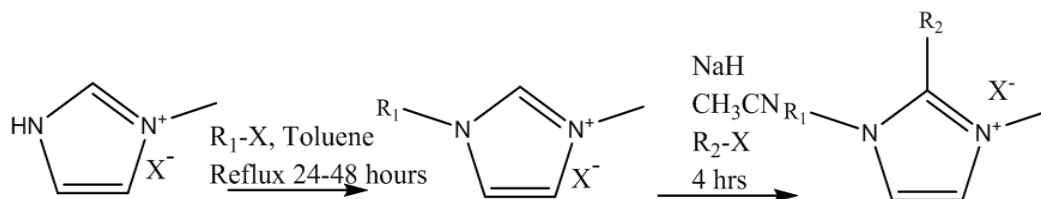
Trisubstituted imidazolium salts are a current research topic. They have been investigated as a solvent, an electrolyte solution additive, a reaction initiator, a product precursor, a molecular aggregator, and a composite material.[3]

The 1-octanol/water partition coefficient ( $K_{ow}$ ) for these salts has come to signify the tendency of a charged organic molecule to cross a biological membrane,[4] and as an estimate to the salt's environmental impact before widespread use. The purpose of this work is to add to existing data for the 1-octanol/water partition coefficient for these salts.[5, 6]

## II. MATERIALS AND METHODS

### a) Synthesis

The synthesis is shown below (Scheme 1). It is outlined in the literature.[7]



**Scheme 1 :** Two R groups are added to the 3-methyl-1H-imidazol-3-ium ion

The chemicals used in the syntheses, the CAS numbers, sources and grades are below. The proton NMR was performed on a Bruker AV-III 300 MHz spectrometer. The solvent was DMSO and the standard was  $\text{Si}(\text{CH}_3)_4$ . The peak assignments are below.

### 1-methyl-3-octyl-1H-imidazol-3-ium bromide

3-methyl-1H-imidazol-3-ium (1-methylimidazole 616-47-7, Aldrich, 99%, 25.00 mL), 1-bromooctane (111-

83-1, Aldrich, 99%, 71.00 mL), and toluene (108-88-3, Aldrich, 99.8%, 40.00 mL) were mixed. The solution was refluxed for two days. The resulting mixture was frozen and the excess toluene was decanted. The product was thawed and washed with ethyl acetate (141-78-6, Aldrich, 99.8%). The solution was evaporated to dryness. The product was frozen and the excess reagents were decanted.  $\delta\text{H}$ (300 MHz; DMSO;  $\text{Si}(\text{CH}_3)_4$ ) 8.90 (1 H, s, 2-H), 7.91 (1 H, d, 5-H), 7.78 (1 H, d, 4-H), 5.00 (2 H, t NH), 3.75 (3 H, s,  $\text{NCH}_3$ ), 2.00 (2 H, qt,  $\text{CH}_2$ ), 1.30 (10 H, s,  $\text{CH}_2$ ) 0.91 (3 H, br,  $\text{CH}_3$ ) The x-ray photoelectric spectroscopy, FTIR, and  $^1\text{H}$  NMR markers are also in the literature.[8, 9].

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*1,2-dimethyl-3-octyl-1H-imidazol-3-ium iodide*

To a stirred solution of 1-methyl-3-octyl-1H-imidazol-3-ium bromide (10.00 g) in acetonitrile (75-05-8, Aldrich, 99.8%, 175.00 mL) was added NaH (7646-69-7, Aldrich, 60% in mineral oil, 2.00 g). After allowing the mixture to stir four hours, iodomethane (74-88-4, Aldrich, 99%, 6.90 mL) was added and the reaction was stirred for 12 hours. The solution was filtered to remove any precipitated NaI. The resulting oil as washed with ethyl acetate (141-78-6, Aldrich, 99.8%, 3x75.00 mL) and the residual volatiles were then removed under vacuum. The residual nonvolatiles were removed by freezing and decantation.  $\delta$ H(300 MHz; DMSO; Si(CH<sub>3</sub>)<sub>4</sub>) 7.91 (1 H, d, 5-H), 7.78 (1 H, d, 4-H), 5.00 (2 H, t NH), 3.75 (3 H, s, NCH<sub>3</sub>), 2.85 (3 H, s, 2-CH<sub>3</sub>) 2.00 (2 H, qt, CH<sub>2</sub>), 1.30 (10 H, s, CH<sub>2</sub>) 0.91 (3 H, br, CH<sub>3</sub>) The <sup>1</sup>H NMR markers are in the literature.[10, 11]

Workers find the IUPAC nomenclature wearisome. This paper will represent the 1-methylimidazolium fragment as mim. The molecule 1-methyl-3-octyl-1H-imidazol-3-ium bromide is shortened to [omim]Br. Similarly, 1,2-dimethyl-3-octyl-1H-imidazol-3-ium iodide becomes [momim]I. The two letters hx will refer to the hexyl group.

*[bomim]Cl*

2-butyl-1-methyl-3-octyl-1H-imidazol-3-ium chloride was prepared in the same manner as [momim]I with the exception that 1-chlorobutane (109-69-3, Aldrich, 99.5%, 11.6 mL) was used instead of iodomethane.  $\delta$ H(300 MHz; DMSO; Si(CH<sub>3</sub>)<sub>4</sub>) 7.91 (1 H, d, 5-H), 7.78 (1 H, d, 4-H), 5.00 (2 H, t NH), 3.75 (3 H, s, NCH<sub>3</sub>), 2.50 (2 H, t, CH<sub>2</sub>), 2.00 (2 H, qt, CH<sub>2</sub>), 1.61 (2 H, qt, CH<sub>2</sub>) 1.30 (12 H, s, CH<sub>2</sub>) 0.91 (6 H, br, CH<sub>3</sub>)

*[pomim]Cl*

1-methyl-3-octyl-2-pentyl-1H-imidazol-3-ium chloride was prepared in the same manner as [momim]I with the exception that 1-chloropentane (543-59-5, Aldrich, 99%, 13.4 mL) was used instead of iodomethane.  $\delta$ H(300 MHz; DMSO; Si(CH<sub>3</sub>)<sub>4</sub>) 7.91 (1 H, d, 5-H), 7.78 (1 H, d, 4-H), 5.00 (2 H, t NH), 3.75 (3 H, s, NCH<sub>3</sub>), 2.50 (2 H, t, CH<sub>2</sub>), 2.00 (2 H, qt, CH<sub>2</sub>), 1.61 (2 H, qt, CH<sub>2</sub>) 1.30 (14 H, s, CH<sub>2</sub>) 0.91 (6 H, br, CH<sub>3</sub>)

*[oomim]Cl*

1-methyl-2, 3-dioctyl-1H-imidazol-3-ium chloride was prepared in the same manner as [momim]I with the exception that chlorooctane (111-85-3, Aldrich, 99%, 18.9 mL) was used instead of iodomethane.  $\delta$ H(300 MHz; DMSO; Si(CH<sub>3</sub>)<sub>4</sub>) 7.91 (1 H, d, 5-H), 7.78 (1 H, d, 4-H), 5.00 (2 H, t NH), 3.75 (3 H, s, NCH<sub>3</sub>), 2.50 (2 H, t, CH<sub>2</sub>), 2.00 (2 H, qt, CH<sub>2</sub>), 1.61 (2 H, qt, CH<sub>2</sub>) 1.30 (20 H, s, CH<sub>2</sub>) 0.91 (6 H, br, CH<sub>3</sub>)

*[domim]Cl*

2-decyl-3-methyl-2-octyl-1H-imidazol-3-ium chloride was prepared in the same manner as [momim]I with the

with the exception that chlorodecane (1002-69-3, Aldrich, 98%, 22.6 mL) was used instead of iodomethane.  $\delta$ H(300 MHz; DMSO; Si(CH<sub>3</sub>)<sub>4</sub>) 7.91 (1 H, d, 5-H), 7.78 (1 H, d, 4-H), 5.00 (2 H, t NH), 3.75 (3 H, s, NCH<sub>3</sub>), 2.50 (2 H, t, CH<sub>2</sub>), 2.00 (2 H, qt, CH<sub>2</sub>), 1.61 (2 H, qt, CH<sub>2</sub>) 1.30 (22 H, s, CH<sub>2</sub>) 0.91 (6 H, br, CH<sub>3</sub>)

*[bbmim]Cl*

3-methyl-1H-imidazol-3-ium (1-methylimidazole 616-47-7, Aldrich, 99%, 25.00 mL), 1-chlorobutane (109-69-3 Aldrich, 99.5%, 43.00 mL), and toluene (108-88-3, Aldrich, 99.8%, 40.00 mL) were mixed. The solution was refluxed for two days. The resulting mixture was frozen and the excess toluene was decanted. The product was thawed and washed with ethyl acetate (141-78-6, Aldrich, 99.8%). The solution was evaporated to dryness. The product was frozen and the excess reagents were decanted. To a stirred solution of 1-methyl-3-octyl-1H-imidazol-3-ium bromide (10.00 g) in acetonitrile (75-05-8, Aldrich, 99.8%, 150.00 mL) was added NaH (7646-69-7, Aldrich, 60% in mineral oil, 2.67 g) After allowing the mixture to stir four hours, 1-chlorobutane (109-69-3 Aldrich, 99.5%, 17.8 mL) was added and the reaction was stirred for 12 hours. The solution was filtered to remove any precipitated NaCl. The resulting oil as washed with ethyl acetate (141-78-6, Aldrich, 99.8%, 3x75.00 mL) and the residual volatiles were then removed under vacuum. The residual nonvolatiles were removed by freezing and decantation.  $\delta$ H(300 MHz; DMSO; Si(CH<sub>3</sub>)<sub>4</sub>) 7.91 (1 H, d, 5-H), 7.78 (1 H, d, 4-H), 5.00 (2 H, t NH), 3.75 (3 H, s, NCH<sub>3</sub>), 2.50 (2 H, t, CH<sub>2</sub>), 2.00 (2 H, qt, CH<sub>2</sub>), 1.61 (2 H, qt, CH<sub>2</sub>) 1.30 (4 H, sx, CH<sub>2</sub>) 0.91 (6 H, t, CH<sub>3</sub>)

*[pbmim]Cl*

2-butyl-1-methyl-3-pentyl-1H-imidazol-3-ium chloride was prepared in the same manner as [bbmim]Cl with the exception that 1-chloropentane (543-59-9, Aldrich, 99%, 20.7 mL) was used instead of 1-chlorobutane.  $\delta$ H(300 MHz; DMSO; Si(CH<sub>3</sub>)<sub>4</sub>) 7.91 (1 H, d, 5-H), 7.78 (1 H, d, 4-H), 5.00 (2 H, t NH), 3.75 (3 H, s, NCH<sub>3</sub>), 2.50 (2 H, t, CH<sub>2</sub>), 2.00 (2 H, qt, CH<sub>2</sub>), 1.61 (2 H, qt, CH<sub>2</sub>) 1.30 (6 H, sx, CH<sub>2</sub>) 0.91 (6 H, t, CH<sub>3</sub>)

*[hxbmim]Cl*

2-butyl-3-hexyl-1-methyl-1H-imidazol-3-ium chloride was prepared in the same manner as [bbmim]Cl with the exception that 1-chlorohexane (544-10-5, Aldrich, 99%, 23.5 mL) was used instead of 1-chlorobutane.  $\delta$ H(300 MHz; DMSO; Si(CH<sub>3</sub>)<sub>4</sub>) 7.91 (1 H, d, 5-H), 7.78 (1 H, d, 4-H), 5.00 (2 H, t NH), 3.75 (3 H, s, NCH<sub>3</sub>), 2.50 (2 H, t, CH<sub>2</sub>), 2.00 (2 H, qt, CH<sub>2</sub>), 1.61 (2 H, qt, CH<sub>2</sub>) 1.30 (8 H, br, CH<sub>2</sub>) 0.91 (6 H, t, CH<sub>3</sub>)

*[dbmim]Cl*

2-butyl-3-decyl-1-methyl-1H-imidazol-3-ium chloride was prepared in the same manner as [bbmim]Cl with the exception that 1-chlorodecane (1002-69-3,

Aldrich, 98%, 34.8 mL) was used instead of 1-chlorobutane.  $\delta$ H(300 MHz; DMSO; Si(CH<sub>3</sub>)<sub>4</sub>) 7.91 (1 H, d, 5-H), 7.78 (1 H, d, 4-H), 5.00 (2 H, t NH), 3.75 (3 H, s, NCH<sub>3</sub>), 2.50 (2 H, t, CH<sub>2</sub>), 2.00 (2 H, qt, CH<sub>2</sub>), 1.61 (2 H, qt, CH<sub>2</sub>) 1.30 (16 H, br, CH<sub>2</sub>) 0.91 (6 H, t, CH<sub>3</sub>)

The UV/Vis spectra were produced on a Beckman DU-640B UV/Vis spectrophotometer. The salt, its phase, the  $\lambda_{\max}$ , and the corresponding absorbance are shown in the Results and Discussion section. The maximum absorbance is in the neighborhood of 265.0 nm, which indicates the imidazolium ring.[12]

The compound [oomim]Cl was excluded. The spectrum was simply noise. This may indicate a very similar blank and sample. The difference between the two---the UV/Vis spectrum---is noise.[13]

The compound [momim]I shows negative absorbance. Negative absorbance has no physical meaning except that the blank absorbs more light than the [momim]I.

This work finds the 1-octanol/water partition coefficient by the slow-stirring method.[14–18] The salt was added to a solution of 1-octanol saturated with water. Each solution was stirred for 45 days at 21°C. This was done slowly to prevent emulsification.

For this work initially 5.0  $\mu$ g of the organic salt was added to 5.0 mL of a saturated 1-octanol/water solution. When an emulsion formed, the solution was stirred for six hours and left to rest overnight. This removed the emulsion. Serial dilutions were done to keep the absorption values between –0.150 and 1.000. The aqueous layer was drawn off and compared to a saturated solution of 1-octanol. One extraction was done for each compound. The  $K_{OW}$  value was then calculated using

$$K_{OW} = \frac{(A_i \square df_i - A_f \square df_f) \square V_{water}}{A_f \square df_f \square V_{octanol}} \quad (1)$$

where  $A_i$  and  $A_f$  are the absorbances of the aqueous layer before and after extraction.  $V_{water}$  and  $V_{octanol}$  are the volumes of the water and 1-octanol phases. The symbols  $df_i$  and  $df_f$  are the dilution factors used to find  $A_i$  and  $A_f$ . [19,20]

### III. RESULTS AND DISCUSSION

The UV/Vis data, the experimental log  $K_{OW}$  values, the calculated log  $K_{OW}$  values, and the absolute difference between them are shown below in Table 1.

| Compound in water phase | $\lambda_{\max}$ in nm | Absorbance at $\lambda_{\max}$ | Exp. Log $K_{OW}$ | Calc. Log $K_{OW}$ | $ \Delta \log K_{OW} $ |
|-------------------------|------------------------|--------------------------------|-------------------|--------------------|------------------------|
| [momim]I                | 248.0                  | –0.1459                        | –0.62             | –.8850             | 0.27                   |
| [bomim]Cl               | 269.0                  | 0.4209                         | 1.1               | 0.5020             | 0.6                    |
| [pomim]Cl               | 265.0                  | 0.21450                        | 0.98              | 1.031              | 0.051                  |
| [domim]Cl               | 263.0                  | 0.1249                         | 5.1               | 3.676              | 1.4                    |
| [bbmim]Cl               | 264.0                  | 0.6850                         | –1.3              | –1.614             | 0.31                   |
| [pbmim]Cl               | 264.0                  | 0.6413                         | –0.93             | –1.085             | 0.16                   |
| [hxbmim]Cl              | 259.0                  | 0.1866                         | –0.31             | –0.5560            | 0.25                   |
| [dbmim]Cl               | 232.0                  | 0.2346                         | 1.9               | 1.560              | 0.3                    |

Table 1: UV/Vis data, experimental log  $K_{OW}$  values, calculated log  $K_{OW}$  values, and the absolute difference between them. The calculated values were determined by the group contribution method rather than the linear free energy relation scheme.[5, 21]

Using the cLog P program[22] the calculated log  $K_{OW}$  values in Table 1 were found. The expectation is 85% of the calculated log  $K_{OW}$  values will be in error by less than 0.5, 10% by 0.5 to 1.0, and 5% by more than 1.0.[23] For this work, the values are 75%, 13%, and 13% respectively. The clog P program is best suited for molecules with typical fragments.[24] The charged five-membered ring and the long hydrocarbon chains may be misrepresented in this group additive method or the small sample size may explain the discrepancies.

The toxicity of organic solvents in animal tissue, in soil, and in water is an ongoing concern. In this work

we examine three toxicity indicators that are linked to the 1-octanol/ water partition coefficients. Positive value log  $K_{OW}$  values indicate the octanol phase is favored. These compounds are candidates for tissue storage. That is, candidates for the calculated of a bioconcentration factor (BCF). The soil sorption coefficient ( $K_{OC}$ ) is the ratio of the mass of a chemical absorbed per weight of carbon in a soil to the concentration of the chemical in water. The lethal concentration of a chemical is defined as the lethal dose for half the population ( $LC_{50}$ ). [25]

Two BCF models are shown in Figure 1. The lower dashed line is  $\log(\text{BCF}) = 0.85 \log(K_{OW}) - 0.70$ . The upper dashed line is  $\log(\text{BCF}) = 0.79 \log(K_{OW}) - 0.40$ . [25] The log(BCF) for benzene from these models is 1.3 and 1.1, respectively.[2]

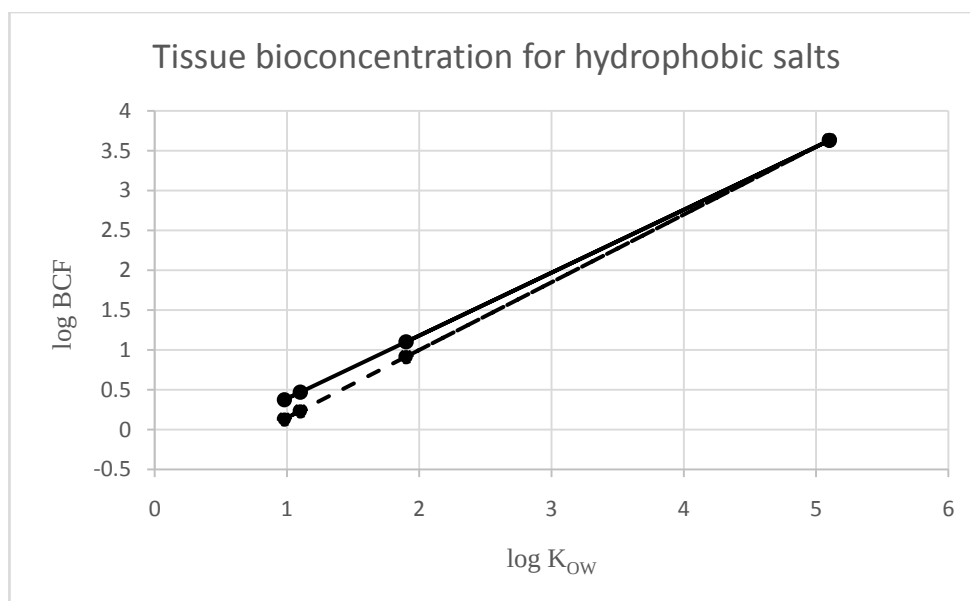


**Figure 1 :** Log of the tissue bio concentration for the positive  $\log(K_{OW})$  salts. The lower dashed line is  $\log(BCF) = 0.85 \log(K_{OW}) - 0.70$ . The upper dashed line is  $\log(BCF) = 0.79 \log(K_{OW}) - 0.40$ .

Three  $K_{OC}$  models are shown below in Figure 2. The lower solid line is  $\log(K_{OC}) = 0.989 \log(K_{OW}) - 0.364$ . The middle line is  $\log(K_{OC}) = 679 \log(K_{OW}) + 0.663$ . The

top dashed line is  $\log(K_{OC}) = 0.544 \log(K_{OW}) + 1.377$ . [25] The  $\log(K_{OC})$  for benzene for these three models are 1.7, 2.1, and 2.5, respectively. [2]

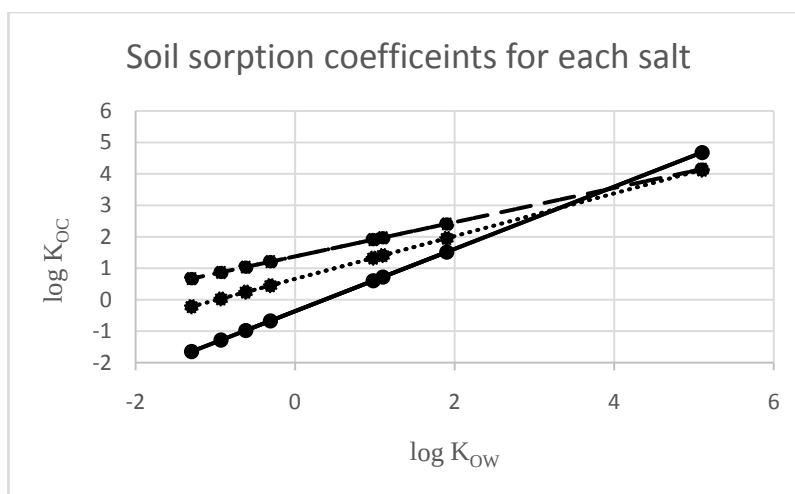


**Figure 2 :** Log of soil sorption coefficients for all the salts. The lower solid line is  $\log(K_{OC}) = 0.989 \log(K_{OW}) - 0.364$ . The middle line is  $\log(K_{OC}) = 679 \log(K_{OW}) + 0.663$ . The top dashed line is  $\log(K_{OC}) = 0.544 \log(K_{OW}) + 1.377$

Figure 3 shows the log of the inverse lethal concentrations ( $1/LC_{50}$ ) for each salt. The top line is  $\log(1/LC_{50}) = 0.629 \log(K_{OW}) - 0.489$ . The middle dotted line is  $\log(1/LC_{50}) = 0.854 \log(K_{OW}) - 1.74$ . The solid line is  $\log(1/LC_{50}) = 0.89 \log(K_{OW}) - 1.75$ . [25] The  $\log(1/LC_{50})$  for benzene from these models are 0.85, 0.079, 0.15, respectively. [2]

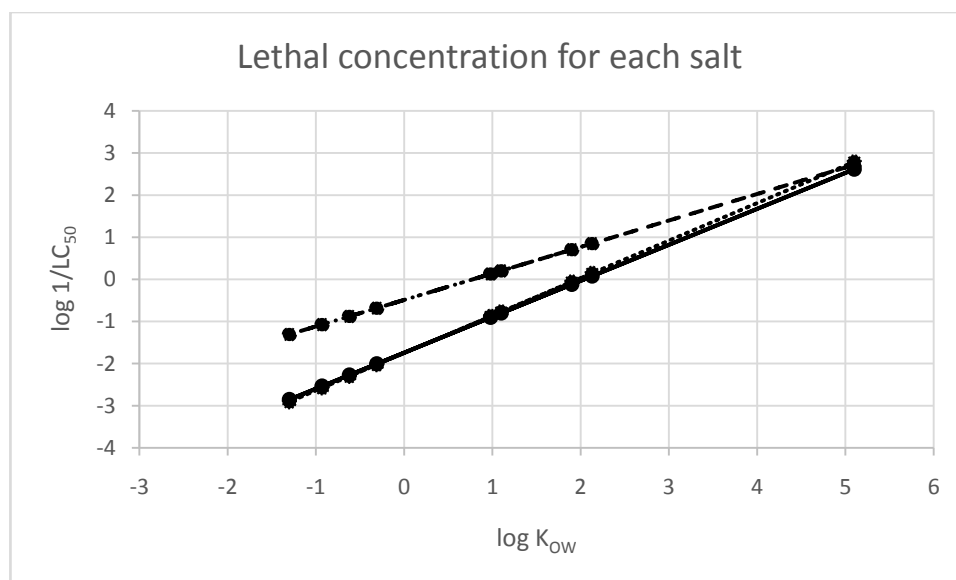


**Figure 3 :** The log of the inverse lethal concentrations ( $1/LC_{50}$ ) for each salt. The top line is  $\log(1/LC_{50}) = 0.629 \log(K_{ow}) - 0.489$ . The middle dotted line is  $\log(1/LC_{50}) = 0.854 \log(K_{ow}) - 1.74$ . The solid line is  $\log(1/LC_{50}) = 0.89 \log(K_{ow}) - 1.75$

#### IV. CONCLUSIONS

Green chemistry has taken a winding road in its search for benign solvents. Some, such as  $CO_2$ , have become firmly established.[26] Others, such as imidazolium salts, continue to be under investigation.[27–32] A physical quantity that continues to be of interest is the 1-octanol/water partition coefficients. One reason is their direct link to the environmental impact of the salts.[33, 34]

Dialkylated methylimidazolium salts have low vapor pressure compared to typical solvents such as benzene. This work shows they can be synthesized to be water soluble or lipophilic. This work also shows that every imidazolium salt is not “green”. The salts with octyl and/or decyl substituents have comparable toxicity to benzene. It has recently been shown that cholinium alkanoates may provide a set of molecules that are more ecologically friendly.[35]

#### Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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## Seasonal and Spatial Variation of Water Quality Index of Bassi Tehsil of District Jaipur, Rajasthan, India

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**Abstract-** The present study was intended to calculate the water quality index (WQI) of Bassi Tehsil of district Jaipur, Rajasthan, India in order to assess its suitability for drinking purpose. For this ground water samples from 71 sampling sites of 50 villages of study area were collected from tube wells and hand pumps of varying depths in pre and post monsoon seasons and analyzed for ten physico-chemical parameters namely pH, Total Alkalinity, Total Hardness, Calcium, Magnesium, Chloride, Nitrate, Fluoride, Total Dissolved Solid and Electrical Conductivity. Analysis of results showed that almost all parameters were exceeding the permissible limits prescribed by BIS, ICMR and WHO. Assessment of water quality index (WQI) showed remarkable variation of water quality as WQI values ranged from 13.53 to 1052.2 in pre-monsoon and 25.72 to 1024.6 in post monsoon season. The study also revealed that drinking water of Bassi tehsil is not potable and there is an instant need to take ameliorative steps in this region to prevent the population from adverse health effects as 61.97% and 63.38% ground water samples were classified under “unsuitable for drinking” category in accordance with their WQI values in pre and post monsoon seasons, respectively.

**Keywords:** groundwater quality, physico-chemical parameters, water quality index, bassi tehsil and rajasthan.

**GJSFR-B Classification :** FOR Code: 090508



*Strictly as per the compliance and regulations of :*



# Seasonal and Spatial Variation of Water Quality Index of Bassi Tehsil of District Jaipur, Rajasthan, India

Swati Saxena <sup>α</sup>, Umesh Saxena <sup>σ</sup> & A. K. Sinha <sup>ρ</sup>

**Abstract-** The present study was intended to calculate the water quality index (WQI) of Bassi Tehsil of district Jaipur, Rajasthan, India in order to assess its suitability for drinking purpose. For this ground water samples from 71 sampling sites of 50 villages of study area were collected from tube wells and hand pumps of varying depths in pre and post monsoon seasons and analyzed for ten physico-chemical parameters namely pH, Total Alkalinity, Total Hardness, Calcium, Magnesium, Chloride, Nitrate, Fluoride, Total Dissolved Solid and Electrical Conductivity. Analysis of results showed that almost all parameters were exceeding the permissible limits prescribed by BIS, ICMR and WHO. Assessment of water quality index (WQI) showed remarkable variation of water quality as WQI values ranged from 13.53 to 1052.2 in pre-monsoon and 25.72 to 1024.6 in post monsoon season. The study also revealed that drinking water of Bassi tehsil is not potable and there is an instant need to take ameliorative steps in this region to prevent the population from adverse health effects as 61.97% and 63.38% ground water samples were classified under "unsuitable for drinking" category in accordance with their WQI values in pre and post monsoon seasons, respectively.

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## I. INTRODUCTION

“Jalam Jeevamrutham” Water is one of the five elements described in “shastra” to life. It is also one of the most important commodities which Man has exploited than any other resource for sustenance of his life. Potable safe water is absolutely essential and is the basic need of all human beings on the earth. Due to modern civilization, rapid urbanization, and industrialization, subsequent contamination of surface and ground water sources, water conservation and water quality management has now a day's assumed a very complex shape. Attention on contamination and its management has become a need of the hour, because of its far reaching impact on human health.

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In India so many factors contribute to pollution of ground water such as; scarcity of water resources, uncontrolled population, urbanization, poverty, lack of education, lack of political commitment etc. Groundwater quality is highly dependent on the nature of the aquifers and on the surrounding climatic conditions (Chand, 2013; Dhok et al., 2011).

Assessment of the groundwater quality has always been important in the field of environmental quality management. One of the most effective tools for the assessment and management of the water quality is Water quality index; it offers a simple, stable, reproducible unit of measure and communicates information of water quality to the concerned citizens and policy makers (Chauhan and Singh, 2010). The water quality is difficult to evaluate from a large number of samples, each containing concentrations of many parameters. WQI is a mathematical instrument used to transform large quantities of water quality data into a single number which represents the water quality level while eliminating the subjective assessments of water quality and biases of individual water quality experts (Yogendra and Puttaiah, 2008; Chowdhury et al., 2012; Khwakaram et al., 2012; Hussain et al., 2014).

## II. STUDY AREA

Rajasthan is known as “the land of king” and it is the largest state of the republic of India in terms of geographical spread. It is situated in the North- Western part of India having total area is around 3,42,239 Sq. Km. Which represents 10.41 % of total area of the country and population of 6.86 Crores spread over in 44,672 villages, which is 5.67 % of nations population but being just available 1% of the total water resources of the country. The state has extreme climatic and geographical condition and it suffers both the problems of quantity and quality of water (Bhalla and Bhalla, 2013; Yadav et al., 2010).

Jaipur, the capital of Rajasthan, has a total area of 11,117 sq. Km covering the 3.23% of the total area of the state, administered by 13 tehsils or sub-divisions. Our focused area of study is Bassi tehsil, out of the 13 tehsils of Jaipur district. The area of tehsil is 654.69 sq.km, located at 26°96' N latitude and 75°62'E longitude. In Bassi Tehsil there are 210 villages (famous for their

leather footwear and Embroidery beading). In the study area there are no major surface water sources however; main sources of drinking water are open wells, hand pumps and bore wells (Singh et al., 2012; CGWB, 2007; JDA, 2012).

In Bassi Tehsil 84 villages are reported having fluoride concentration more than 1.5 ppm, 78 villages are exhibiting nitrate concentration more than 45 ppm and 30 villages are having Electrical conductivity more than 3000 micromhos/cm (CGWB, 2007; Mathur, 2007).

Review of literature reveals that no studies have been made to scientifically investigate the ground water contamination of the study area. The present study aims to calculate the Water Quality Index (WQI) in most rural habitations of Bassi Tehsil of Jaipur, Rajasthan, India in order to assess the suitability of ground water for human uses and it also deals with the necessity of restoring the water quality.

### III. MATERIALS AND METHODS

#### a) Sample Collection

Ground water samples from a total of 71 sampling sites of 50 villages of Bassi Tehsil were

**Table 1 :** Parameters and methods employed in the physicochemical examination of water samples

| S.No. | Parameters                                 | Unit     | Method Employed                                           |
|-------|--------------------------------------------|----------|-----------------------------------------------------------|
| 1.    | pH                                         | -        | Digital pH-meter                                          |
| 2.    | Total Alkalinity                           | Mg/L     | Titrimetric method (With H <sub>2</sub> SO <sub>4</sub> ) |
| 3.    | Total Hardness (as CaCO <sub>3</sub> )     | Mg/L     | Titrimetric method (with EDTA)                            |
| 4.    | Calcium Hardness (as CaCO <sub>3</sub> )   | Mg/L     | Titrimetric method                                        |
| 5.    | Magnesium Hardness (as CaCO <sub>3</sub> ) | Mg/L     | Titrimetric method                                        |
| 6.    | Chloride (as Cl <sup>-</sup> )             | Mg/L     | Titrimetric method (With AgNO <sub>3</sub> )              |
| 7.    | Nitrate (as NO <sub>3</sub> <sup>-</sup> ) | Mg/L     | Spectrophotometric method                                 |
| 8.    | Fluoride (as F <sup>-</sup> )              | Mg/L     | Ion Selective Electrode                                   |
| 9.    | Total Dissolved Solids                     | Mg/L     | Digital TDS-meter                                         |
| 10.   | Electrical Conductivity                    | μmhos/cm | Digital Conductivity-meter                                |

#### c) Water Quality Index (WQI) Calculation

The calculation of WQI was made using weighed arithmetic index method (Brown et al., 1972) in the following steps-

**Step I- Calculation of sub index of quality rating (qn)-** Let there be n water quality parameters where the quality rating or sub index (qn) corresponding to the nth parameter is a number reflecting the relative value of this parameter in the polluted water with respect to its standard permissible value. The value of qn is calculated using the following expression.

$$qn = 100[(V_n - V_{io}) / (S_n - V_{io})]$$

where,

qn = quality rating for the nth water quality parameter.

Vn = estimated value of the nth parameter at a given sampling station.

Sn = standard permissible value of nth parameter

Vio = ideal value of nth parameter in pure water.

collected in pre-cleaned and rinsed polyethene bottles of two litre capacity with necessary precautions (Brown et al. 1974). The total water collection in the year of 2013 is divided in to two seasons, one is pre monsoon and another one is post monsoon. The sampling is carried out, during April 2013 for pre monsoon season and in September-October 2013 for post monsoon season from manually operated tube wells and hand pumps of varying depth.

#### b) Physico-chemical Analysis

All the samples were analyzed for the following Physico-chemical parameters; pH, Total Alkalinity (TA), Total Hardness (TH), Calcium hardness (Ca H), Magnesium hardness (Mg H), Chloride, Nitrate, Fluoride, Total Dissolved Solid (TDS) and Electrical Conductivity (EC). The analysis of water samples were out carried in accordance to standard analytical methods (APHA, 2005). All the chemicals used were of AR grade and double distilled water used for preparation of solutions. Details of the analysis methods are summarized in Table 1.

All the ideal values (Vio) are taken as zero for drinking water except for pH=7.0 and dissolved oxygen=14.6mg/L.

#### Calculation of quality rating for pH

For pH the ideal value is 7.0 (for natural water) and a permissible value is 8.5 (for polluted water). Therefore, the quality rating for pH is calculated from the following relation:

$$qpH = 100 [(V_{pH} - 7.0)/(8.5 - 7.0)]$$

where

VpH = observed value of pH during the study period.

#### Calculation of quality rating for dissolved oxygen

The ideal value (VDO) for dissolved oxygen is 14.6 mg/L and standard permitted value for drinking water is 5 mg/L. Therefore, quality rating is calculated from following relation:

$$qDO = 100 [(VDO - 14.6)/(5 - 14.6)]$$

Where,

VDO = measured value of dissolved oxygen

#### Step II- Calculation of unit weight ( $W_n$ )

Calculation of unit weight ( $W_n$ ) for various water quality parameters are inversely proportional to the recommended standards for the corresponding parameters.

$$W_n = K/S_n$$

Where,

$W_n$  = unit weight for nth parameters

$S_n$  = standard value for nth parameters

$K$  = constant for proportionality

The value of 'K' can be determined by-

$$K = \frac{1}{\frac{1}{S_1} + \frac{1}{S_2} + \dots + \frac{1}{S_n}} = \frac{1}{\sum S_n}$$

#### Step III- Calculation of WQI

WQI is calculated from the following equation-

$$WQI = \sum q_n W_n / \sum W_n$$

**Table 2 :** Water Quality Index (WQI) range and Quality Status of Water

| Water Quality Index | Description             |
|---------------------|-------------------------|
| 0-25                | Excellent Water Quality |
| 26-50               | Good                    |
| 51-75               | Poor                    |
| 76-100              | Very poor               |
| >100                | Unsuitable for drinking |

(Brown et al., 1972; Hariharan, 2007; Yogendra and Puttaiah, 2008; Chowdhury et al., 2012; Eugene et al., 2014; Sisodia and Moundiotiya, 2006; Rao et al., 2010)

## IV. RESULT AND DISCUSSION

### a) Physico-chemical Parameters

The respective values of all observed water quality parameters of groundwater samples in pre and post monsoon seasons are illustrated in Table 3 and 5 respectively. Statistical Parameters of groundwater samples of study area in both seasons are summarized in Table 4 and 6.

### b) Quality Assessment using WQI

Water quality parameters mentioned in Table 3 and 5 are considered for calculating the WQI values using the above mentioned method. The water quality weightings used in the formula are mentioned in Table 7.

#### i. Seasonal Variation of WQI

Lower WQI values indicate that water is free from impurities at the sampling site, while WQI values more than 100 represents the polluted nature of water and its unsuitability for drinking purpose. Water Quality Index values for pre and post monsoon seasons are calculated and presented in Table 8. Developed Pie-diagrams (Figure 1 and 3) states the percentage variations of different qualities of waters in pre and post monsoon seasons, while Figure 2 and 4 represents the number of sampling sites classified on the basis of WQI values. From the results, it is seen that the WQI values in pre and post monsoon seasons are in the range of 13.53 to 1052.2 and 25.72 to 1024.6 respectively. The graphical representation of WQI values of ground water samples in Pre and Post monsoon seasons depicts that there is not any significant change in WQI values with respect to water quality.

Table 3 : Physico Chemical Characteristics of Groundwater Samples- Pre Monsoon Season

| S.No. | Village       | Source | Sample No. | Colour | Odour | pH  | Alkalinity | TH  | CaH | Ca <sup>2+</sup> ions | MgH | Mg <sup>2+</sup> ions | Cl <sup>-</sup> | NO <sub>3</sub> <sup>-</sup> | F <sup>-</sup> | TDS  | EC   |
|-------|---------------|--------|------------|--------|-------|-----|------------|-----|-----|-----------------------|-----|-----------------------|-----------------|------------------------------|----------------|------|------|
| 1     | Akhepura      | HP     | S1         | UO     | UO    | 7.9 | 411        | 529 | 237 | 94.8                  | 292 | 70.95                 | 400             | 56                           | 0.71           | 2216 | 3165 |
|       |               | TW     | S2         | UO     | UO    | 8.4 | 305        | 115 | 43  | 17.2                  | 72  | 17.49                 | 31              | 15                           | 1.44           | 778  | 1111 |
| 2     | Anantpura     | HP     | S3         | UO     | UO    | 7.9 | 748        | 360 | 151 | 60.4                  | 209 | 50.78                 | 278             | 22                           | 0.37           | 2100 | 3000 |
|       |               | TW     | S4         | UO     | UO    | 8.3 | 462        | 161 | 67  | 26.8                  | 94  | 22.84                 | 176             | 18                           | 1.8            | 1470 | 2100 |
| 3     | Banskho       | HP     | S5         | UO     | UO    | 7.5 | 651        | 516 | 172 | 68.8                  | 344 | 83.59                 | 137             | 28                           | 2.12           | 1696 | 2422 |
|       |               | TW     | S6         | UO     | UO    | 8.4 | 396        | 105 | 40  | 16                    | 65  | 15.79                 | 123             | 12                           | 1.99           | 1298 | 1855 |
| 4     | Barala        | HP     | S7         | UO     | UO    | 7.5 | 586        | 192 | 78  | 31.2                  | 114 | 27.7                  | 333             | 78                           | 2.05           | 2146 | 3065 |
| 5     | Bassi         | HP     | S8         | UO     | UO    | 8.4 | 258        | 158 | 64  | 25.6                  | 94  | 22.84                 | 202             | 86                           | 1.14           | 1590 | 2271 |
|       |               | TW     | S9         | UO     | UO    | 7.8 | 333        | 156 | 67  | 26.8                  | 89  | 21.62                 | 163             | 44                           | 0.79           | 1191 | 1701 |
| 6     | Benada        | HP     | S10        | UO     | UO    | 7.6 | 435        | 732 | 336 | 134.4                 | 396 | 96.22                 | 315             | 131                          | 0.93           | 1740 | 2486 |
| 7     | Bharampur     | HP     | S11        | UO     | UO    | 7.7 | 368        | 188 | 78  | 31.2                  | 110 | 26.73                 | 176             | 20                           | 0.42           | 920  | 1314 |
| 8     | Chainpuriya   | HP     | S12        | UO     | UO    | 7.7 | 562        | 115 | 46  | 18.4                  | 69  | 16.76                 | 80              | 12                           | 1.3            | 1034 | 1477 |
| 9     | Chapariya     | HP     | S13        | UO     | UO    | 7.7 | 426        | 163 | 70  | 28                    | 93  | 22.59                 | 60              | 70                           | 1.13           | 760  | 1085 |
| 10    | Charangarh    | HP     | S14        | UO     | UO    | 7.4 | 243        | 264 | 121 | 48.4                  | 143 | 34.74                 | 33              | 29                           | 0.71           | 792  | 1131 |
| 11    | Chatarpura    | HP     | S15        | UO     | UO    | 7.6 | 707        | 112 | 45  | 18                    | 67  | 16.28                 | 65              | 19                           | 4.67           | 1200 | 1714 |
| 12    | Danau Kalan   | HP     | S16        | UO     | UO    | 8.2 | 582        | 46  | 22  | 8.8                   | 24  | 5.83                  | 20              | 22                           | 1.4            | 1055 | 1507 |
| 13    | Danau Khurd   | HP     | S17        | UO     | UO    | 7.7 | 409        | 568 | 206 | 82.4                  | 362 | 87.96                 | 484             | 8                            | 0.9            | 2644 | 3777 |
|       |               | TW     | S18        | UO     | UO    | 8.2 | 458        | 284 | 121 | 48.4                  | 163 | 39.6                  | 140             | 22                           | 2.9            | 1680 | 2400 |
| 14    | Garh          | HP     | S19        | UO     | UO    | 8.1 | 651        | 108 | 44  | 17.6                  | 64  | 15.55                 | 361             | 118                          | 1              | 1962 | 2803 |
| 15    | Ghasipura     | HP     | S20        | UO     | UO    | 8.4 | 344        | 88  | 32  | 12.8                  | 56  | 13.6                  | 20              | 38                           | 0.03           | 847  | 1210 |
|       |               | TW     | S21        | UO     | UO    | 8.3 | 766        | 74  | 33  | 13.2                  | 41  | 9.96                  | 51              | 26                           | 11.4           | 1613 | 2304 |
| 16    | Ghata         | HP     | S22        | UO     | UO    | 7.1 | 402        | 437 | 198 | 79.2                  | 239 | 58.07                 | 601             | 11                           | 0.86           | 2593 | 3704 |
|       |               | TW     | S23        | UO     | UO    | 7.3 | 467        | 632 | 297 | 118.8                 | 335 | 81.4                  | 468             | 14                           | 0.7            | 2171 | 3101 |
| 17    | Gudha Meena   | HP     | S24        | UO     | UO    | 7.8 | 423        | 160 | 66  | 26.4                  | 94  | 22.84                 | 23              | 18                           | 0.27           | 980  | 1400 |
| 18    | Gumanpura     | HP     | S25        | UO     | UO    | 7.8 | 460        | 317 | 128 | 51.2                  | 189 | 45.92                 | 380             | 16                           | 0.88           | 2310 | 3300 |
|       |               | TW     | S26        | UO     | UO    | 7.9 | 595        | 528 | 238 | 95.2                  | 290 | 70.47                 | 259             | 72                           | 1.4            | 1764 | 2520 |
| 19    | Gwalini       | HP     | S27        | UO     | UO    | 7.9 | 520        | 374 | 171 | 68.4                  | 203 | 49.32                 | 22              | 8                            | 1.8            | 1333 | 1904 |
| 20    | Hans Mahal    | HP     | S28        | UO     | UO    | 7.6 | 157        | 424 | 187 | 74.8                  | 237 | 57.59                 | 220             | 7                            | 0.32           | 1182 | 1688 |
| 21    | Hanumanpura   | HP     | S29        | UO     | UO    | 7.7 | 552        | 123 | 51  | 20.4                  | 72  | 17.49                 | 83              | 27                           | 0.8            | 967  | 1381 |
|       |               | TW     | S30        | UO     | UO    | 8.2 | 784        | 67  | 23  | 9.2                   | 44  | 10.69                 | 95              | 24                           | 12.5           | 1473 | 2104 |
| 22    | Jhajhwar      | HP     | S31        | UO     | UO    | 7.4 | 523        | 668 | 283 | 113.2                 | 385 | 93.55                 | 1430            | 58                           | 0.41           | 4235 | 6050 |
|       |               | TW     | S32        | UO     | UO    | 8.4 | 254        | 109 | 45  | 18                    | 64  | 15.55                 | 107             | 45                           | 0.8            | 980  | 1400 |
| 23    | Jhar          | HP     | S33        | UO     | UO    | 7.9 | 412        | 233 | 102 | 40.8                  | 131 | 31.83                 | 44              | 37                           | 0.65           | 960  | 1371 |
| 24    | Kalyanpura    | HP     | S34        | UO     | UO    | 8.5 | 527        | 89  | 36  | 14.4                  | 53  | 12.87                 | 28              | 34                           | 1.3            | 1122 | 1603 |
|       |               | TW     | S35        | UO     | UO    | 8.2 | 530        | 65  | 22  | 8.8                   | 43  | 10.44                 | 41              | 16                           | 1.8            | 1190 | 1700 |
| 25    | Kaneta        | HP     | S36        | UO     | UO    | 7.8 | 286        | 364 | 144 | 57.6                  | 220 | 53.46                 | 1424            | 6                            | 0.11           | 4762 | 6802 |
|       |               | TW     | S37        | UO     | UO    | 8.4 | 564        | 77  | 34  | 13.6                  | 43  | 10.44                 | 40              | 14                           | 0.7            | 1050 | 1500 |
| 26    | Kaneti        | HP     | S38        | UO     | UO    | 7.5 | 586        | 867 | 322 | 128.8                 | 545 | 132.43                | 1075            | 236                          | 1.06           | 4890 | 6985 |
| 27    | Kanota        | HP     | S39        | UO     | UO    | 8.3 | 409        | 203 | 90  | 36                    | 113 | 27.45                 | 296             | 33                           | 0.62           | 1835 | 2621 |
|       |               | TW     | S40        | UO     | UO    | 8.4 | 741        | 91  | 36  | 14.4                  | 55  | 13.36                 | 225             | 8                            | 1.7            | 1983 | 2833 |
| 28    | Kashipura     | HP     | S41        | UO     | UO    | 7.5 | 695        | 105 | 40  | 16                    | 65  | 15.79                 | 90              | 21                           | 3.2            | 1305 | 1864 |
| 29    | Keshopura     | HP     | S42        | UO     | UO    | 7.6 | 555        | 350 | 140 | 56                    | 210 | 51.03                 | 644             | 5                            | 0.75           | 2520 | 3600 |
| 30    | Kuthada Kalan | HP     | S43        | UO     | UO    | 7.1 | 233        | 66  | 25  | 10                    | 41  | 9.96                  | 20              | 22                           | 0.77           | 709  | 1013 |
| 31    | Lalgarh       | HP     | S44        | UO     | UO    | 7.6 | 510        | 284 | 122 | 48.8                  | 162 | 39.36                 | 230             | 15                           | 1.42           | 1240 | 1771 |
| 32    | Mundali       | HP     | S45        | UO     | UO    | 7.7 | 482        | 117 | 46  | 18.4                  | 71  | 17.25                 | 55              | 12                           | 4.2            | 1321 | 1887 |
|       |               | TW     | S46        | UO     | UO    | 8.2 | 734        | 90  | 34  | 13.6                  | 56  | 13.6                  | 152             | 26                           | 3.38           | 1682 | 2404 |
| 33    | Nagal Karna   | HP     | S47        | UO     | UO    | 7.4 | 371        | 154 | 57  | 22.8                  | 97  | 23.57                 | 60              | 11                           | 4.35           | 1295 | 1850 |
|       |               | TW     | S48        | UO     | UO    | 8.1 | 795        | 73  | 32  | 12.8                  | 41  | 9.96                  | 80              | 26                           | 5.9            | 1610 | 2300 |
| 34    | Parasoli      | HP     | S49        | UO     | UO    | 7.7 | 412        | 774 | 397 | 158.8                 | 377 | 91.61                 | 320             | 2                            | 1.17           | 2146 | 3065 |
|       |               | TW     | S50        | UO     | UO    | 8.4 | 464        | 78  | 35  | 14                    | 43  | 10.44                 | 60              | 23                           | 2.2            | 1050 | 1500 |
| 35    | Parempura     | HP     | S51        | UO     | UO    | 7.8 | 431        | 641 | 283 | 113.2                 | 358 | 86.99                 | 444             | 18                           | 1.15           | 3474 | 4963 |
| 36    | Patan         | HP     | S52        | UO     | UO    | 7.1 | 655        | 622 | 264 | 105.6                 | 358 | 86.99                 | 885             | 10                           | 0.52           | 3535 | 5050 |
| 37    | Peepalabai    | HP     | S53        | UO     | UO    | 7.2 | 160        | 374 | 209 | 83.6                  | 165 | 40.09                 | 266             | 82                           | 1.84           | 1680 | 2400 |
|       |               | TW     | S54        | UO     | UO    | 8.2 | 435        | 400 | 185 | 74                    | 215 | 52.24                 | 65              | 26                           | 8.95           | 1505 | 2150 |
| 38    | Peipura       | HP     | S55        | UO     | UO    | 7.8 | 532        | 267 | 118 | 47.2                  | 149 | 36.2                  | 250             | 11                           | 1.35           | 1750 | 2500 |
|       |               | TW     | S56        | UO     | UO    | 8.4 | 435        | 110 | 40  | 16                    | 70  | 17.01                 | 35              | 28                           | 1.5            | 875  | 1250 |
| 39    | Rajwas        | HP     | S57        | UO     | UO    | 7.6 | 648        | 463 | 205 | 82                    | 258 | 62.69                 | 551             | 52                           | 1.33           | 2306 | 3295 |
| 40    | Ramser        | HP     | S58        | UO     | UO    | 7.3 | 520        | 254 | 103 | 41.2                  | 151 | 36.69                 | 60              | 18                           | 3.8            | 1050 | 1500 |
|       |               | TW     | S59        | UO     | UO    | 8.4 | 464        | 118 | 44  | 17.6                  | 74  | 17.98                 | 50              | 25                           | 2              | 1053 | 1504 |
| 41    | Ratanpura     | HP     | S60        | UO     | UO    | 7.9 | 532        | 299 | 135 | 54                    | 164 | 39.85                 | 80              | 32                           | 1.02           | 1435 | 2050 |

| S.No. | Village      | Source | Sample No. | Colour | Odour | pH  | Alkalinity | TH  | CaH | Ca <sup>+2</sup> ions | MgH | Mg <sup>+2</sup> ions | Cl <sup>-</sup> | NO <sub>3</sub> <sup>-</sup> | F <sup>-</sup> | TDS  | EC   |
|-------|--------------|--------|------------|--------|-------|-----|------------|-----|-----|-----------------------|-----|-----------------------|-----------------|------------------------------|----------------|------|------|
|       |              | TW     | S61        | UO     | UO    | 8.4 | 552        | 88  | 35  | 14                    | 53  | 12.87                 | 60              | 19                           | 1.07           | 1129 | 1613 |
| 42    | Roopura      | HP     | S62        | UO     | UO    | 7.5 | 263        | 107 | 42  | 16.8                  | 65  | 15.79                 | 130             | 24                           | 1.44           | 1113 | 1590 |
|       |              | TW     | S63        | UO     | UO    | 8.1 | 415        | 430 | 200 | 80                    | 230 | 55.89                 | 81              | 25                           | 8.75           | 1610 | 2300 |
| 43    | Sambhariya   | HP     | S64        | UO     | UO    | 7.4 | 314        | 232 | 96  | 38.4                  | 136 | 33.04                 | 58              | 14                           | 0.07           | 356  | 508  |
| 44    | Shankarpura  | HP     | S65        | UO     | UO    | 7.6 | 588        | 134 | 53  | 21.2                  | 81  | 19.68                 | 58              | 6                            | 4.2            | 1028 | 1469 |
| 45    | Siya Ka Bas  | HP     | S66        | UO     | UO    | 7.7 | 235        | 234 | 98  | 39.2                  | 136 | 33.04                 | 62              | 91                           | 0.85           | 1225 | 1750 |
| 46    | Tehda        | HP     | S67        | UO     | UO    | 8.2 | 276        | 145 | 62  | 24.8                  | 83  | 20.16                 | 221             | 20                           | 1.4            | 1478 | 2111 |
| 47    | Tekchandpura | HP     | S68        | UO     | UO    | 7.8 | 328        | 306 | 133 | 53.2                  | 173 | 42.03                 | 40              | 14                           | 0.2            | 563  | 804  |
| 48    | Tilpatti     | HP     | S69        | UO     | UO    | 7.8 | 642        | 194 | 81  | 32.4                  | 113 | 27.45                 | 80              | 14                           | 0.9            | 1280 | 1828 |
| 49    | Todabhata    | HP     | S70        | UO     | UO    | 8.5 | 328        | 65  | 22  | 8.8                   | 43  | 10.44                 | 52              | 24                           | 2              | 984  | 1405 |
| 50    | Tunga        | HP     | S71        | UO     | UO    | 7.6 | 36         | 38  | 16  | 6.4                   | 22  | 5.34                  | 15              | 10                           | 0.1            | 63   | 86   |

Where- TA = Total Alkalinity, TH = Total Hardness, CaH = Calcium Hardness, MgH = Magnesium Hardness, Cl<sup>-</sup> = Chloride, NO<sub>3</sub><sup>-</sup> = Nitrate, F<sup>-</sup> = Fluoride, TDS = Total Dissolved Solids, EC = Electrical Conductivity.

All parameters are expressed in mg/L except pH and EC. EC is expressed in  $\mu$ mhos/cm.

Ca<sup>+2</sup> = Ca mg/L (as CaCO<sub>3</sub>), Mg<sup>+2</sup> = Mg mg/L (as CaCO<sub>3</sub>).

UO = Unobjectionable, HP = Hand Pump, TW = Tube Well.

**Table 4 :** Minimum, Maximum and Average Characteristics of Groundwater Sampling Stations – Pre Monsoon Season

| S.No. | Parameter                    | Minimum | Maximum | Average | Standard Deviation |
|-------|------------------------------|---------|---------|---------|--------------------|
| 1.    | pH                           | 7.1     | 8.5     | 7.86    | 0.39               |
| 2.    | Total Alkalinity (mg/L)      | 36      | 795     | 469.47  | 162.55             |
| 3.    | Total Harness (mg/L)         | 38      | 867     | 260.19  | 201.90             |
| 4.    | Calcium Hardness (mg/L)      | 16      | 397     | 111.23  | 90.30              |
| 5.    | Ca <sup>+2</sup> Ions (mg/L) | 6.4     | 158.8   | 44.49   | 36.12              |
| 6.    | Magnesium Hardness (mg/L)    | 22      | 545     | 148.95  | 113.86             |
| 7.    | Mg <sup>+2</sup> Ions (mg/L) | 5.34    | 132.43  | 36.19   | 27.66              |
| 8.    | Chloride (mg/L)              | 15      | 1430    | 222.01  | 290.48             |
| 9.    | Nitrate (mg/L)               | 2       | 236     | 32.16   | 35.64              |
| 10.   | Fluoride (mg/L)              | 0.03    | 12.5    | 1.96    | 2.41               |
| 11.   | TDS (mg/L)                   | 63      | 4890    | 1589.88 | 899.48             |
| 12.   | EC ( $\mu$ mhos/cm)          | 86      | 6985    | 2271.05 | 1285.04            |

**Table 5 :** Physico-Chemical Characteristics of Groundwater Samples – Post Monsoon Season

| S. No. | Village     | Source | Sample No. | Colour | Odour | pH  | Alkalinity | TH  | CaH | Ca <sup>+2</sup> ions | MgH | Mg <sup>+2</sup> ions | Cl <sup>-</sup> | NO <sub>3</sub> <sup>-</sup> | F <sup>-</sup> | TDS  | EC   |
|--------|-------------|--------|------------|--------|-------|-----|------------|-----|-----|-----------------------|-----|-----------------------|-----------------|------------------------------|----------------|------|------|
| 1      | Akhepura    | HP     | S1         | UO     | UO    | 8.1 | 410        | 406 | 180 | 72                    | 226 | 54.91                 | 306             | 102                          | 1.36           | 1581 | 2259 |
|        |             | TW     | S2         | UO     | UO    | 8.6 | 294        | 82  | 32  | 12.8                  | 50  | 12.15                 | 22              | 21                           | 1.94           | 616  | 880  |
| 2      | Anantpura   | HP     | S3         | UO     | UO    | 7.7 | 607        | 284 | 122 | 48.8                  | 162 | 39.36                 | 194             | 15                           | 0.85           | 1493 | 2132 |
|        |             | TW     | S4         | UO     | UO    | 7.7 | 517        | 540 | 245 | 98                    | 295 | 71.68                 | 417             | 29                           | 0.73           | 2074 | 2962 |
| 3      | Banskho     | HP     | S5         | UO     | UO    | 7.8 | 580        | 478 | 173 | 69.2                  | 305 | 74.11                 | 193             | 31                           | 0.92           | 1630 | 2328 |
|        |             | TW     | S6         | UO     | UO    | 8.5 | 363        | 98  | 41  | 16.4                  | 57  | 13.85                 | 98              | 14                           | 1.54           | 1207 | 1724 |
| 4      | Barala      | HP     | S7         | UO     | UO    | 7.7 | 484        | 110 | 45  | 18                    | 65  | 15.79                 | 118             | 7                            | 1.8            | 668  | 954  |
| 5      | Bassi       | HP     | S8         | UO     | UO    | 7.6 | 459        | 161 | 68  | 27.2                  | 93  | 22.59                 | 171             | 94                           | 0.81           | 1274 | 1820 |
|        |             | TW     | S9         | UO     | UO    | 7.4 | 255        | 187 | 80  | 32                    | 107 | 26                    | 113             | 56                           | 0.51           | 1356 | 1937 |
| 6      | Benada      | HP     | S10        | UO     | UO    | 8.5 | 838        | 254 | 111 | 44.4                  | 143 | 34.74                 | 107             | 59                           | 0.98           | 1612 | 2303 |
| 7      | Bharampur   | HP     | S11        | UO     | UO    | 7.8 | 482        | 364 | 163 | 65.2                  | 201 | 48.84                 | 146             | 21                           | 0.6            | 1044 | 1491 |
| 8      | Chainpuriya | HP     | S12        | UO     | UO    | 7.7 | 703        | 261 | 113 | 45.2                  | 148 | 35.96                 | 118             | 11                           | 1              | 1206 | 1723 |
| 9      | Chapariya   | HP     | S13        | UO     | UO    | 7.7 | 282        | 211 | 88  | 35.2                  | 123 | 29.88                 | 28              | 27                           | 0.9            | 424  | 605  |
| 10     | Charangarh  | HP     | S14        | UO     | UO    | 7.7 | 168        | 220 | 92  | 36.8                  | 128 | 31.1                  | 40              | 27                           | 0.32           | 432  | 617  |
| 11     | Chatarpura  | HP     | S15        | UO     | UO    | 7.6 | 698        | 147 | 63  | 25.2                  | 84  | 20.41                 | 60              | 18                           | 2.6            | 956  | 1365 |
| 12     | Danau Kalan | HP     | S16        | UO     | UO    | 7.6 | 454        | 159 | 66  | 26.4                  | 93  | 22.59                 | 34              | 24                           | 1.17           | 712  | 1018 |

| S. No. | Village       | Source | Sample No. | Colour | Odour | pH  | Alkalinity | TH   | CaH | Ca <sup>+2</sup> ions | MgH | Mg <sup>+2</sup> ions | Cl <sup>-</sup> | NO <sub>3</sub> <sup>-</sup> | F <sup>-</sup> | TDS  | EC   |
|--------|---------------|--------|------------|--------|-------|-----|------------|------|-----|-----------------------|-----|-----------------------|-----------------|------------------------------|----------------|------|------|
| 13     | Danau Khurd   | HP     | S17        | UO     | UO    | 7.2 | 312        | 660  | 237 | 94.8                  | 423 | 102.8                 | 103             | 106                          | 0.45           | 910  | 1300 |
|        |               | TW     | S18        | UO     | UO    | 7.8 | 382        | 337  | 151 | 60.4                  | 186 | 45.19                 | 84              | 29                           | 2.6            | 1478 | 2111 |
| 14     | Garh          | HP     | S19        | UO     | UO    | 7.8 | 422        | 777  | 392 | 156.8                 | 385 | 93.55                 | 355             | 94                           | 1.02           | 1685 | 2407 |
| 15     | Ghasipura     | HP     | S20        | UO     | UO    | 7.7 | 365        | 127  | 51  | 20.4                  | 76  | 18.46                 | 21              | 13                           | 0.55           | 640  | 914  |
|        |               | TW     | S21        | UO     | UO    | 7.9 | 817        | 92   | 37  | 14.8                  | 55  | 13.36                 | 54              | 19                           | 11.9           | 1271 | 1816 |
| 16     | Ghata         | HP     | S22        | UO     | UO    | 7.9 | 443        | 313  | 140 | 56                    | 173 | 42.03                 | 246             | 14                           | 1.43           | 1414 | 2020 |
|        |               | TW     | S23        | UO     | UO    | 7.7 | 514        | 501  | 217 | 86.8                  | 284 | 69.01                 | 367             | 17                           | 0.96           | 1669 | 2384 |
| 17     | Gudha Meena   | HP     | S24        | UO     | UO    | 7.6 | 403        | 199  | 88  | 35.2                  | 111 | 26.97                 | 20              | 19                           | 0.4            | 642  | 917  |
| 18     | Gumanpura     | HP     | S25        | UO     | UO    | 7.7 | 384        | 208  | 89  | 35.6                  | 119 | 28.91                 | 103             | 8                            | 2              | 808  | 1154 |
|        |               | TW     | S26        | UO     | UO    | 7.8 | 509        | 404  | 181 | 72.4                  | 223 | 54.18                 | 183             | 53                           | 2.5            | 1205 | 1721 |
| 19     | Gwalini       | HP     | S27        | UO     | UO    | 7.7 | 510        | 270  | 125 | 50                    | 145 | 35.23                 | 80              | 6                            | 1.4            | 891  | 1273 |
| 20     | Hans Mahal    | HP     | S28        | UO     | UO    | 7.6 | 476        | 1100 | 423 | 169.2                 | 677 | 164.5                 | 1455            | 20                           | 2.08           | 5434 | 7763 |
| 21     | Hanumanpura   | HP     | S29        | UO     | UO    | 7.1 | 560        | 316  | 144 | 57.6                  | 172 | 41.79                 | 507             | 95                           | 1.6            | 2196 | 3137 |
|        |               | TW     | S30        | UO     | UO    | 7.5 | 812        | 92   | 33  | 13.2                  | 59  | 14.33                 | 148             | 37                           | 12.2           | 1837 | 2624 |
| 22     | Jhajhwar      | HP     | S31        | UO     | UO    | 7.9 | 575        | 440  | 190 | 76                    | 250 | 60.75                 | 436             | 41                           | 1.1            | 2204 | 3149 |
|        |               | TW     | S32        | UO     | UO    | 8.6 | 278        | 76   | 31  | 12.4                  | 45  | 10.93                 | 154             | 38                           | 1.08           | 647  | 924  |
| 23     | Jhar          | HP     | S33        | UO     | UO    | 7.8 | 488        | 271  | 118 | 47.2                  | 153 | 37.17                 | 63              | 32                           | 0.41           | 926  | 1322 |
| 24     | Kalyanpura    | HP     | S34        | UO     | UO    | 7.8 | 256        | 307  | 134 | 53.6                  | 173 | 42.03                 | 30              | 18                           | 0.8            | 487  | 696  |
|        |               | TW     | S35        | UO     | UO    | 7.8 | 318        | 83   | 29  | 11.6                  | 54  | 13.12                 | 52              | 13                           | 1.2            | 607  | 867  |
| 25     | Kaneta        | HP     | S36        | UO     | UO    | 7.7 | 223        | 268  | 105 | 42                    | 163 | 39.6                  | 57              | 14                           | 0.5            | 804  | 1148 |
|        |               | TW     | S37        | UO     | UO    | 8.2 | 459        | 56   | 26  | 10.4                  | 30  | 7.29                  | 34              | 21                           | 0.39           | 651  | 930  |
| 26     | Kaneti        | HP     | S38        | UO     | UO    | 7.4 | 674        | 347  | 129 | 51.6                  | 218 | 52.97                 | 80              | 2                            | 0.14           | 918  | 1312 |
| 27     | Kanota        | HP     | S39        | UO     | UO    | 7.5 | 415        | 361  | 148 | 59.2                  | 213 | 51.75                 | 342             | 40                           | 1.3            | 1436 | 2051 |
|        |               | TW     | S40        | UO     | UO    | 7.8 | 689        | 134  | 61  | 24.4                  | 73  | 17.73                 | 266             | 11                           | 2.3            | 1606 | 2294 |
| 28     | Kashipura     | HP     | S41        | UO     | UO    | 7.6 | 411        | 161  | 64  | 25.6                  | 97  | 23.57                 | 86              | 19                           | 1.35           | 910  | 1301 |
| 29     | Keshopura     | HP     | S42        | UO     | UO    | 7.6 | 330        | 227  | 92  | 36.8                  | 135 | 32.8                  | 80              | 26                           | 0.49           | 1333 | 1904 |
| 30     | Kuthada Kalan | HP     | S43        | UO     | UO    | 7.6 | 785        | 262  | 110 | 44                    | 152 | 36.93                 | 42              | 21                           | 0.5            | 800  | 1142 |
| 31     | Lalgarh       | HP     | S44        | UO     | UO    | 7.7 | 505        | 185  | 80  | 32                    | 105 | 25.51                 | 105             | 49                           | 0.9            | 1042 | 1488 |
| 32     | Mundali       | HP     | S45        | UO     | UO    | 7.8 | 600        | 106  | 42  | 16.8                  | 64  | 15.55                 | 92              | 21                           | 5.6            | 1131 | 1616 |
|        |               | TW     | S46        | UO     | UO    | 8.3 | 822        | 77   | 31  | 12.4                  | 46  | 11.17                 | 206             | 32                           | 4.02           | 1951 | 2787 |
| 33     | Nagal Karna   | HP     | S47        | UO     | UO    | 7.7 | 389        | 119  | 43  | 17.2                  | 76  | 18.46                 | 148             | 2                            | 1.9            | 608  | 869  |
|        |               | TW     | S48        | UO     | UO    | 8.5 | 859        | 53   | 21  | 8.4                   | 32  | 7.77                  | 112             | 19                           | 3.25           | 822  | 1174 |
| 34     | Parasoli      | HP     | S49        | UO     | UO    | 7.8 | 440        | 553  | 280 | 112                   | 273 | 66.33                 | 326             | 15                           | 1.43           | 1322 | 1889 |
|        |               | TW     | S50        | UO     | UO    | 8.5 | 516        | 48   | 22  | 8.8                   | 26  | 6.31                  | 56              | 34                           | 1.8            | 693  | 990  |
| 35     | Parempura     | HP     | S51        | UO     | UO    | 7.8 | 403        | 520  | 200 | 80                    | 320 | 77.76                 | 475             | 13                           | 0.8            | 2880 | 4114 |
| 36     | Patan         | HP     | S52        | UO     | UO    | 7.7 | 535        | 479  | 199 | 79.6                  | 280 | 68.04                 | 652             | 18                           | 1.22           | 2468 | 3526 |
| 37     | Peepalabai    | HP     | S53        | UO     | UO    | 7.8 | 206        | 228  | 123 | 49.2                  | 105 | 25.51                 | 58              | 25                           | 0.5            | 408  | 583  |
|        |               | TW     | S54        | UO     | UO    | 7.7 | 513        | 248  | 99  | 39.6                  | 149 | 36.2                  | 38              | 16                           | 5.3            | 723  | 1033 |
| 38     | Peipura       | HP     | S55        | UO     | UO    | 7.7 | 700        | 242  | 106 | 42.4                  | 136 | 33.04                 | 446             | 24                           | 1.23           | 1946 | 2780 |
|        |               | TW     | S56        | UO     | UO    | 8.2 | 504        | 97   | 34  | 13.6                  | 63  | 15.3                  | 47              | 41                           | 1.3            | 1016 | 1451 |
| 39     | Rajwas        | HP     | S57        | UO     | UO    | 7.6 | 704        | 428  | 183 | 73.2                  | 245 | 59.53                 | 320             | 27                           | 1.3            | 2883 | 4118 |
| 40     | Ramser        | HP     | S58        | UO     | UO    | 7.3 | 540        | 210  | 85  | 34                    | 125 | 30.37                 | 100             | 13                           | 1.3            | 1040 | 1485 |
|        |               | TW     | S59        | UO     | UO    | 8.3 | 483        | 89   | 27  | 10.8                  | 62  | 15.06                 | 66              | 21                           | 1.06           | 924  | 1320 |
| 41     | Ratanpura     | HP     | S60        | UO     | UO    | 7.8 | 860        | 260  | 113 | 45.2                  | 147 | 35.72                 | 193             | 8                            | 1.13           | 1600 | 2286 |
|        |               | TW     | S61        | UO     | UO    | 7.9 | 871        | 190  | 75  | 30                    | 115 | 27.94                 | 130             | 19                           | 2.65           | 1440 | 2057 |
| 42     | Roopura       | HP     | S62        | UO     | UO    | 7.8 | 353        | 243  | 110 | 44                    | 133 | 32.31                 | 60              | 30                           | 1.4            | 722  | 1031 |
|        |               | TW     | S63        | UO     | UO    | 8.4 | 511        | 627  | 283 | 113.2                 | 344 | 83.59                 | 58              | 28                           | 8.49           | 1159 | 1656 |
| 43     | Sambhariya    | HP     | S64        | UO     | UO    | 7.6 | 425        | 145  | 60  | 24                    | 85  | 20.65                 | 30              | 30                           | 2.25           | 920  | 1314 |
| 44     | Shankarpura   | HP     | S65        | UO     | UO    | 7.8 | 540        | 197  | 85  | 34                    | 112 | 27.21                 | 80              | 2                            | 3.6            | 1125 | 1607 |
| 45     | Siya Ka Bas   | HP     | S66        | UO     | UO    | 7.6 | 313        | 179  | 73  | 29.2                  | 106 | 25.75                 | 56              | 71                           | 1.13           | 773  | 1104 |
| 46     | Tehda         | HP     | S67        | UO     | UO    | 7.7 | 425        | 174  | 72  | 28.8                  | 102 | 24.78                 | 172             | 24                           | 1.55           | 1140 | 1629 |
| 47     | Tekchandpura  | HP     | S68        | UO     | UO    | 7.8 | 254        | 292  | 130 | 52                    | 162 | 39.36                 | 40              | 12                           | 0.25           | 529  | 756  |
| 48     | Tilpatti      | HP     | S69        | UO     | UO    | 7.8 | 633        | 366  | 153 | 61.2                  | 213 | 51.75                 | 114             | 22                           | 0.76           | 1306 | 1867 |

| S. No. | Village   | Source | Sample No. | Colour | Odour | pH  | Alkalinity | TH  | CaH | Ca <sup>+2</sup> ions | MgH | Mg <sup>+2</sup> ions | Cl <sup>-</sup> | NO <sub>3</sub> <sup>-</sup> | F <sup>-</sup> | TDS  | EC   |
|--------|-----------|--------|------------|--------|-------|-----|------------|-----|-----|-----------------------|-----|-----------------------|-----------------|------------------------------|----------------|------|------|
| 49     | Todabhata | HP     | S70        | UO     | UO    | 7.8 | 550        | 129 | 54  | 21.6                  | 75  | 18.22                 | 63              | 20                           | 1.8            | 1043 | 1490 |
| 50     | Tunga     | HP     | S71        | UO     | UO    | 7.8 | 290        | 780 | 395 | 158                   | 385 | 93.55                 | 288             | 309                          | 0.65           | 1604 | 2291 |

**Table 6 :** Minimum, Maximum and Average Characteristics of Groundwater Sampling Stations – Post Monsoon Season

| S.No. | Parameter                    | Minimum | Maximum | Average | Standard Deviation |
|-------|------------------------------|---------|---------|---------|--------------------|
| 1.    | pH                           | 7.1     | 8.6     | 7.80    | 0.31               |
| 2.    | Total Alkalinity (mg/L)      | 168     | 871     | 495.04  | 174.15             |
| 3.    | Total Hardness (mg/L)        | 48      | 1100    | 276.26  | 195.79             |
| 4.    | Calcium Hardness (mg/L)      | 21      | 423     | 118.38  | 87.05              |
| 5.    | Ca <sup>+2</sup> Ions (mg/L) | 8.4     | 169.2   | 47.35   | 34.82              |
| 6.    | Magnesium Hardness (mg/L)    | 26      | 677     | 157.88  | 111.31             |
| 7.    | Mg <sup>+2</sup> Ions (mg/L) | 6.31    | 164.51  | 38.36   | 27.05              |
| 8.    | Chloride (mg/L)              | 20      | 1455    | 171.04  | 206.72             |
| 9.    | Nitrate (mg/L)               | 2       | 309     | 32.77   | 40.60              |
| 10.   | Fluoride (mg/L)              | 0.14    | 12.2    | 1.82    | 2.20               |
| 11.   | TDS (mg/L)                   | 408     | 5434    | 1252.28 | 746.36             |
| 12.   | EC (μmhos/cm)                | 583     | 7763    | 1788.87 | 1066.23            |

**Table 7 :** Unit Weightage of parameters for Drinking Water based on standard values

| S.No. | Parameter               | Standard Value (Sn) | Recommending Agency | Ideal Value (V <sub>id</sub> ) | Unit Weight (W <sub>n</sub> = K/Sn) |
|-------|-------------------------|---------------------|---------------------|--------------------------------|-------------------------------------|
| 1.    | pH                      | 8.5                 | BIS/ICMR/WHO        | 7.0                            | 0.097427                            |
| 2.    | Total Alkalinity        | 120                 | ICMR/WHO            | 0                              | 0.006901                            |
| 3.    | Total Hardness          | 300                 | BIS/ICMR            | 0                              | 0.002760                            |
| 4.    | Calcium                 | 75                  | BIS/ICMR/WHO        | 0                              | 0.011042                            |
| 5.    | Magnesium               | 30                  | BIS/ICMR/WHO        | 0                              | 0.027604                            |
| 6.    | Chloride                | 250                 | BIS/ICMR            | 0                              | 0.003313                            |
| 7.    | Nitrate                 | 45                  | BIS/ICMR/WHO        | 0                              | 0.018403                            |
| 8.    | Fluoride                | 1.0                 | BIS/ICMR/WHO        | 0                              | 0.828133                            |
| 9.    | Total Dissolved Solids  | 500                 | BIS/ICMR/WHO        | 0                              | 0.001656                            |
| 10.   | Electrical Conductivity | 300                 | ICMR/WHO            | 0                              | 0.002760                            |

(All values are in mg/l except pH and EC)

**Table 8 :** Calculated WQI values and quality rating of water in the study area in Pre and Post Monsoon Seasons

| S. No. | Village   | Source | Sample No. | Pre- Monsoon |                | Post- Monsoon |                |
|--------|-----------|--------|------------|--------------|----------------|---------------|----------------|
|        |           |        |            | WQI Value    | Quality Rating | WQI Value     | Quality Rating |
| 1      | Akhepura  | HP     | S1         | 81.883       | VP             | 135.79        | Unsuitable     |
|        |           | TW     | S2         | 134.0011     | Unsuitable     | 176.02        | Unsuitable     |
| 2      | Anantpura | HP     | S3         | 51.405       | Poor           | 86.357        | VP             |
|        |           | TW     | S4         | 166.1971     | Unsuitable     | 81.65         | VP             |
| 3      | Banskho   | HP     | S5         | 195.8513     | Unsuitable     | 97.203        | VP             |
|        |           | TW     | S6         | 180.74       | Unsuitable     | 143.66        | Unsuitable     |
| 4      | Barala    | HP     | S7         | 186.73       | Unsuitable     | 159.75        | Unsuitable     |
| 5      | Bassi     | HP     | S8         | 114.01       | Unsuitable     | 82.41         | VP             |
|        |           | TW     | S9         | 79.036       | VP             | 54.006        | Poor           |
| 6      | Benada    | HP     | S10        | 103.56       | Unsuitable     | 105.01        | Unsuitable     |
| 7      | Bharampur | HP     | S11        | 47.101       | Good           | 66.214        | Poor           |

| S. No. | Village       | Source | Sample No. | Pre- Monsoon |                | Post- Monsoon |                |
|--------|---------------|--------|------------|--------------|----------------|---------------|----------------|
|        |               |        |            | WQI Value    | Quality Rating | WQI Value     | Quality Rating |
| 8      | Chainpuriya   | HP     | S12        | 119.65       | Unsuitable     | 98.208        | VP             |
| 9      | Chapariya     | HP     | S13        | 107.41       | Unsuitable     | 86            | Poor           |
| 10     | Charangarh    | HP     | S14        | 69.478       | Poor           | 37.48         | Good           |
| 11     | Chatarpura    | HP     | S15        | 399.4        | Unsuitable     | 228           | Unsuitable     |
| 12     | Danau Kalan   | HP     | S16        | 130.45       | Unsuitable     | 108.21        | Unsuitable     |
| 13     | Danau Khurd   | HP     | S17        | 96.57        | VP             | 57.788        | Poor           |
|        |               | TW     | S18        | 259.05       | Unsuitable     | 231.79        | Unsuitable     |
| 14     | Garh          | HP     | S19        | 104.02       | Unsuitable     | 110.81        | Unsuitable     |
| 15     | Ghasipura     | HP     | S20        | 18.051       | Ex             | 55.921        | Poor           |
|        |               | TW     | S21        | 961.89       | Unsuitable     | 1000.5        | Unsuitable     |
| 16     | Ghata         | HP     | S22        | 86.605       | VP             | 135.02        | Unsuitable     |
|        |               | TW     | S23        | 77.189       | VP             | 99.02         | VP             |
| 17     | Gudha Meena   | HP     | S24        | 35.005       | Good           | 44.383        | Good           |
| 18     | Gumanpura     | HP     | S25        | 90.947       | VP             | 177.55        | Unsuitable     |
|        |               | TW     | S26        | 139.77       | Unsuitable     | 225.97        | Unsuitable     |
| 19     | Gwalini       | HP     | S27        | 166.34       | Unsuitable     | 129.46        | Unsuitable     |
| 20     | Hans Mahal    | HP     | S28        | 40.613       | Good           | 209.21        | Unsuitable     |
| 21     | Hanumanpura   | HP     | S29        | 78.8         | VP             | 149.53        | Unsuitable     |
|        |               | TW     | S30        | 1052.2       | Unsuitable     | 1024.6        | Unsuitable     |
| 22     | Jhajhwar      | HP     | S31        | 61.684       | Poor           | 113.24        | Unsuitable     |
|        |               | TW     | S32        | 82.195       | VP             | 105.51        | Unsuitable     |
| 23     | Jhar          | HP     | S33        | 68.938       | Poor           | 49.235        | Good           |
| 24     | Kalyanpura    | HP     | S34        | 125.18       | Unsuitable     | 79.435        | VP             |
|        |               | TW     | S35        | 163.72       | Unsuitable     | 109.45        | Unsuitable     |
| 25     | Kaneta        | HP     | S36        | 32.02        | Good           | 53.715        | Poor           |
|        |               | TW     | S37        | 73.891       | Poor           | 45.58         | Good           |
| 26     | Kaneti        | HP     | S38        | 128.4        | Unsuitable     | 25.72         | Good           |
| 27     | Kanota        | HP     | S39        | 70.143       | Poor           | 123.71        | Unsuitable     |
|        |               | TW     | S40        | 159.55       | Unsuitable     | 205.19        | Unsuitable     |
| 28     | Kashipura     | HP     | S41        | 277.16       | Unsuitable     | 123.14        | Unsuitable     |
| 29     | Keshopura     | HP     | S42        | 80.245       | VP             | 53.505        | Poor           |
| 30     | Kuthada Kalan | HP     | S43        | 68.973       | Poor           | 56.335        | Poor           |
| 31     | Lalgarh       | HP     | S44        | 131.98       | Unsuitable     | 88.828        | VP             |
| 32     | Mundali       | HP     | S45        | 359.84       | Unsuitable     | 477.01        | Unsuitable     |
|        |               | TW     | S46        | 297.49       | Unsuitable     | 352.15        | Unsuitable     |
| 33     | Nagal Karna   | HP     | S47        | 370.28       | Unsuitable     | 167.46        | Unsuitable     |
|        |               | TW     | S48        | 505.31       | Unsuitable     | 286.99        | Unsuitable     |
| 34     | Parasoli      | HP     | S49        | 119.32       | Unsuitable     | 137.63        | Unsuitable     |
|        |               | TW     | S50        | 197.94       | Unsuitable     | 165.13        | Unsuitable     |
| 35     | Parempura     | HP     | S51        | 120.21       | Unsuitable     | 88.47         | VP             |
| 36     | Patan         | HP     | S52        | 65.009       | Poor           | 122.19        | Unsuitable     |
| 37     | Peepalabai    | HP     | S53        | 166.33       | Unsuitable     | 52.83         | Poor           |
|        |               | TW     | S54        | 761.36       | Unsuitable     | 452.44        | Unsuitable     |
| 38     | Peipura       | HP     | S55        | 127.99       | Unsuitable     | 119.09        | Unsuitable     |
|        |               | TW     | S56        | 140.35       | Unsuitable     | 123.45        | Unsuitable     |
| 39     | Rajwas        | HP     | S57        | 131.82       | Unsuitable     | 128.82        | Unsuitable     |
| 40     | Ramser        | HP     | S58        | 326.39       | Unsuitable     | 118.57        | Unsuitable     |
|        |               | TW     | S59        | 182.23       | Unsuitable     | 103.09        | Unsuitable     |
| 41     | Ratanpura     | HP     | S60        | 101.89       | Unsuitable     | 111.12        | Unsuitable     |
|        |               | TW     | S61        | 105.06       | Unsuitable     | 236.81        | Unsuitable     |
| 42     | Roopura       | HP     | S62        | 128.8        | Unsuitable     | 129.5         | Unsuitable     |
|        |               | TW     | S63        | 744.64       | Unsuitable     | 728.18        | Unsuitable     |
| 43     | Sambhariya    | HP     | S64        | 15.25        | Ex             | 197.83        | Unsuitable     |
| 44     | Shankarpura   | HP     | S65        | 359.35       | Unsuitable     | 311.65        | Unsuitable     |
| 45     | Siya Ka Bas   | HP     | S66        | 85.941       | VP             | 106.48        | Unsuitable     |
| 46     | Tehda         | HP     | S67        | 131.22       | Unsuitable     | 141.3         | Unsuitable     |
| 47     | Tekchandpura  | HP     | S68        | 30.129       | Good           | 33.43         | Good           |

| S. No. | Village   | Source | Sample No. | Pre- Monsoon |                | Post- Monsoon |                |
|--------|-----------|--------|------------|--------------|----------------|---------------|----------------|
|        |           |        |            | WQI Value    | Quality Rating | WQI Value     | Quality Rating |
| 48     | Tilpatti  | HP     | S69        | 89.386       | VP             | 80.97         | VP             |
| 49     | Todabhata | HP     | S70        | 181.07       | Unsuitable     | 162.15        | Unsuitable     |
| 50     | Tunga     | HP     | S71        | 13.535       | Ex             | 88.001        | VP             |

Where- VP = Very Poor, Ex = Excellent

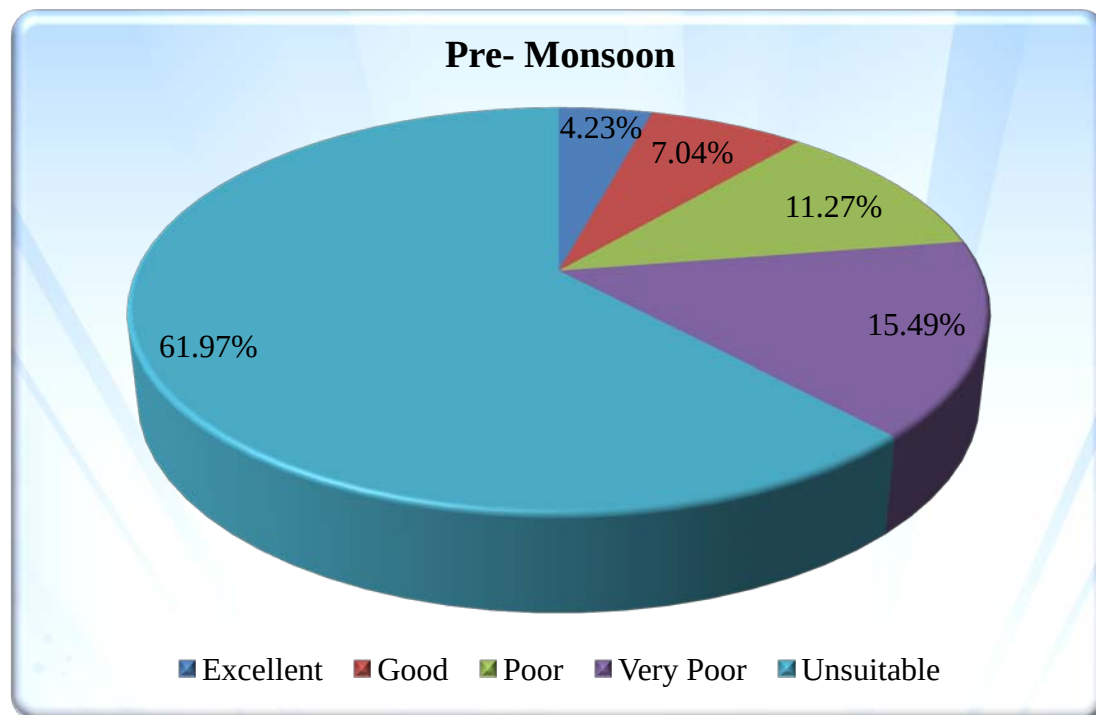


Figure 1 : Percentage representation of WQI classification in Pre monsoon season

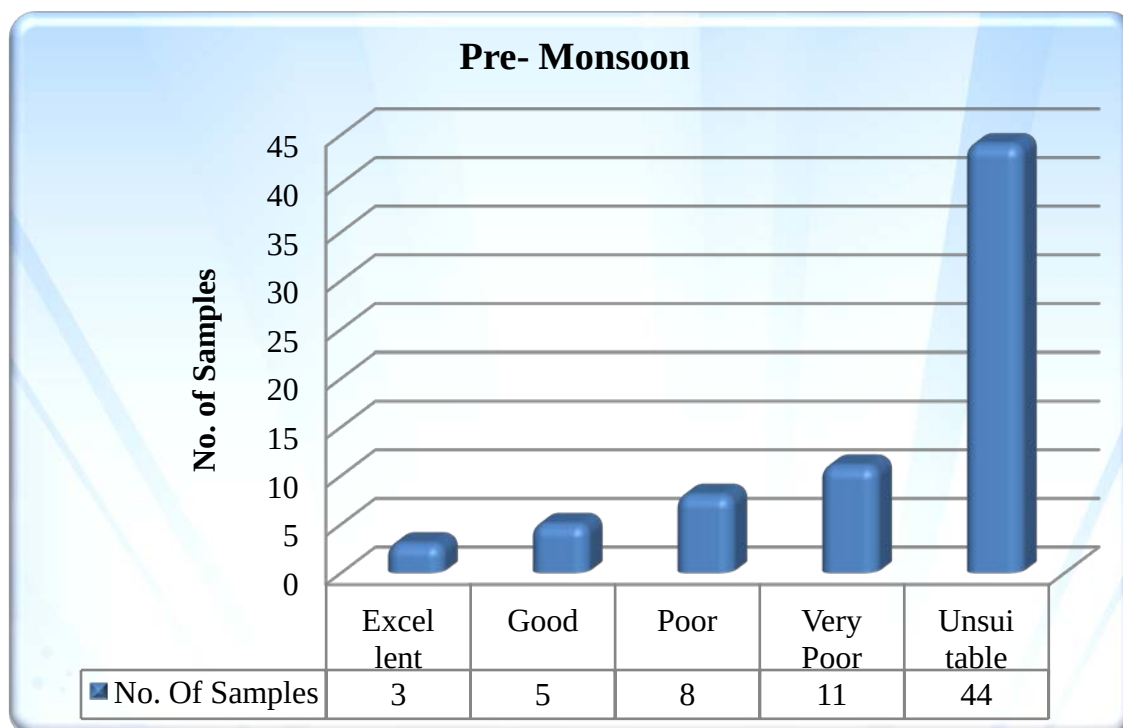


Figure 2 : Number of Villages classified on the basis of WQI values in Pre monsoon season

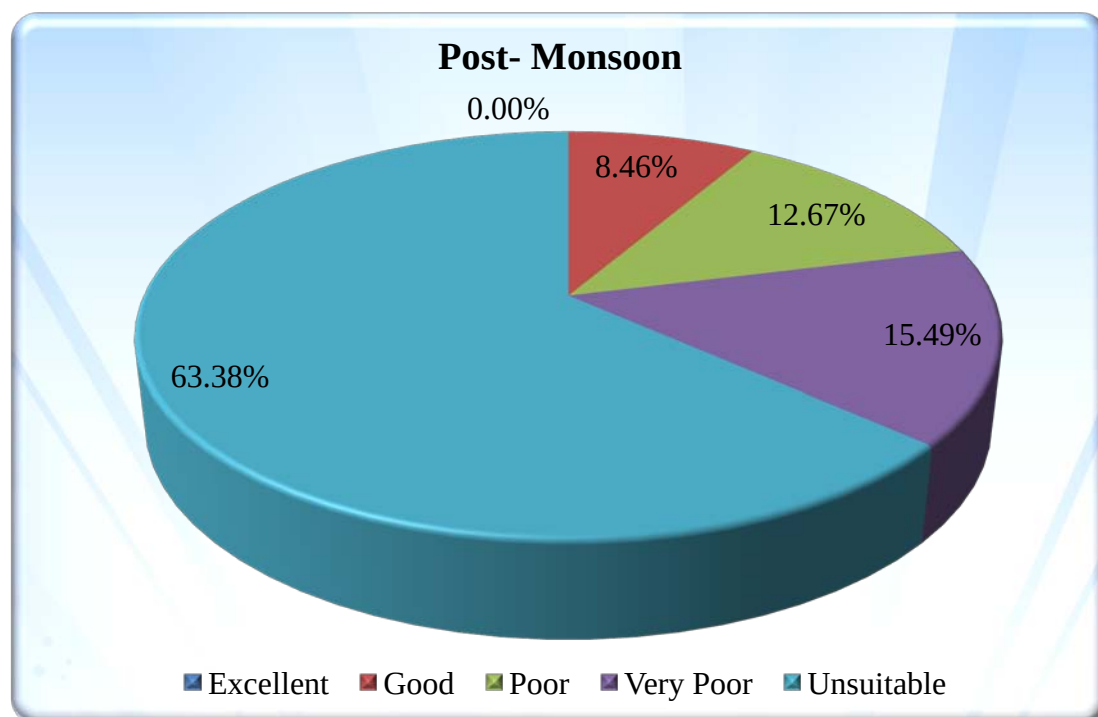


Figure 3 : Percentage representation of WQI classification in Post monsoon season

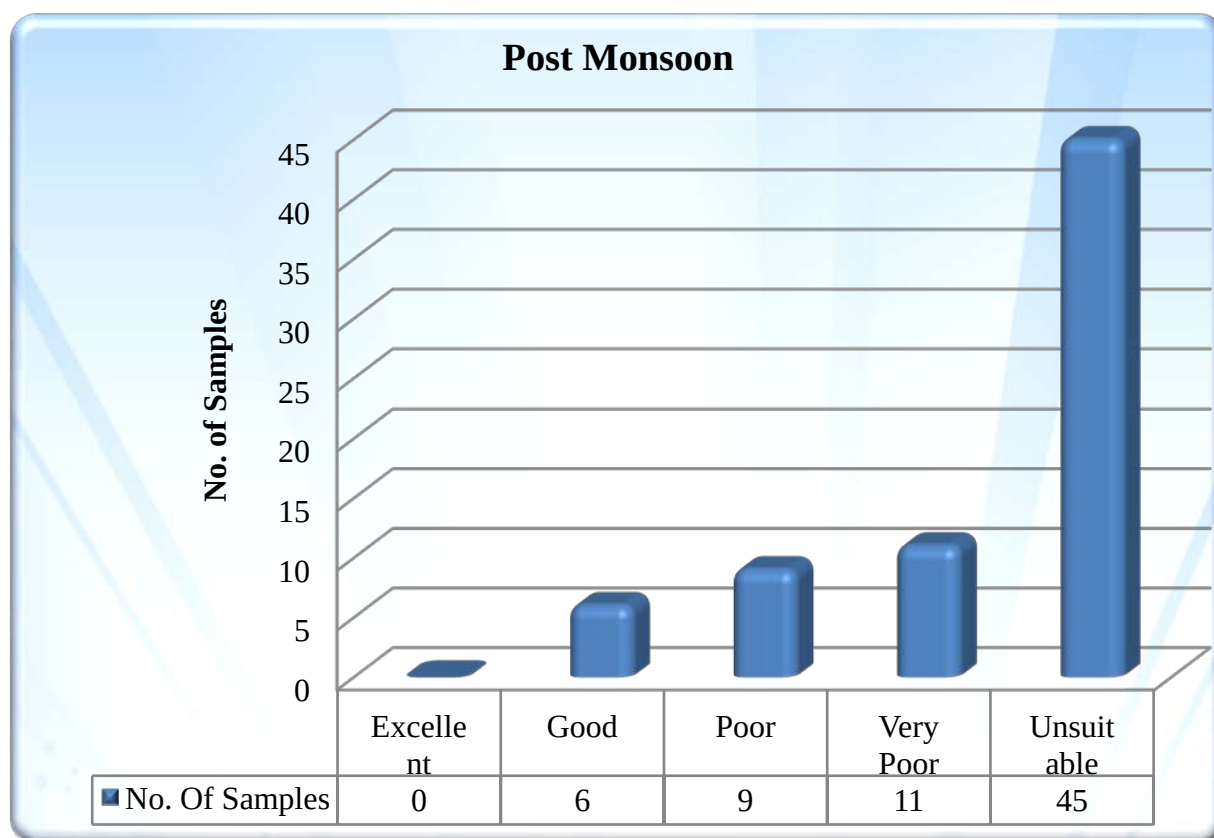


Figure 4 : Number of Villages classified on the basis of WQI values in Post monsoon season

## ii. Spatial Variation of WQI

According to the results, it is revealed that in pre-monsoon season only three sampling sites namely *Ghasipura* (HP), *Sambhariya* and *Tunga* exhibit excellent groundwater quality for drinking, and five sampling sites namely *Bharamपुरi*, *Gudha Meena*, *Hans Mahal*, *Kaneta* (HP) and *Tekchandpura* indicate good ground water quality for drinking. The remaining 63 sampling sites are not directly suitable for potability because they are classified as poor, very poor and unfit categories as per the WQI ranges.

In post monsoon season there is not even a single sampling site under the excellent category and only six sampling sites namely *Charangarh*, *Gudha Meena*, *Jhar*, *Kaneta* (TW), *Kaneti*, and *Tekchandpura* fall in the category good for drinking. The rest 65 sampling sites are not suitable for potability as according to their WQI ranges they are classified as poor, very poor and unfit for drinking purposes. Graph (Figure 5) depicts the spatial variation of the WQI in the study area for the pre and post monsoon seasons both.

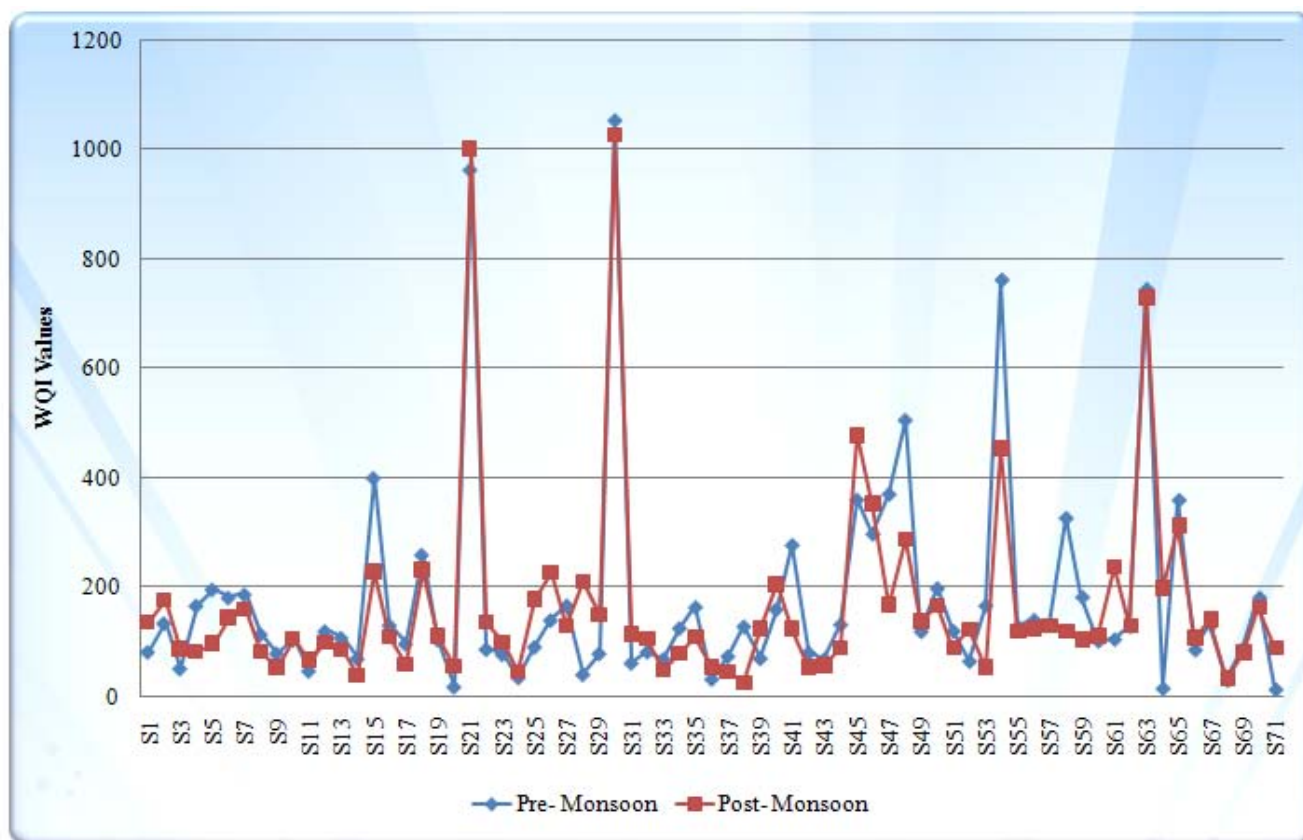


Figure 5 : Comparative graphical representation of WQI of groundwater at different Locations in the study area in pre and post monsoon seasons

Most of the stations are having groundwater of very poor and unsuitable categories with water quality ranging from 75 to 100 and >100 respectively. Table 9 and 10 contains the information about the various sampling sites in the study area with varying values of WQI in pre and post monsoon season respectively. These tables provide the appropriate information to take necessary steps in treatment of groundwater in the study area.

Table 9 : Classifications of groundwater in the Study area with respect to WQI in Pre Monsoon Season

| Name of the Sampling Site                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | No. of Samples | WQI Range | Quality Category        |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------|-----------|-------------------------|
| Ghasipura (HP), Sambhariya, Tunga.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 03             | 0-25      | Excellent               |
| Bharamपुरi, Gudha Meena, Hans Mahal, Kaneta (HP), Tekchandpura.                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 05             | 26-50     | Good                    |
| Anantpura (HP), Charangarh, Jhahjwar (HP), Jhar, Kaneta (TW), Kanota (HP), Kuthada Kalan, Patan.                                                                                                                                                                                                                                                                                                                                                                                                                       | 08             | 51-75     | Poor                    |
| Akhepura (HP), Bassi (TW), Danau Khurd (HP), Ghata (both), Gumanpura (HP), Hanumanpura (HP), Jhahjwar (TW), Keshopura, Siya Ka Bas, Tilpatti.                                                                                                                                                                                                                                                                                                                                                                          | 11             | 76-100    | Very Poor               |
| Akhepura (TW), Anantpura (TW), Banskho (HP and TW), Barala, Bassi (HP), Benada, Chainpuriya, Chapariya, Chatarpura, Danau Kalan, Danau Khurd (TW), Garh, Ghasipura (TW), Gumanpura (TW), Gwalini, Hanumanpura (TW), Kalyanpura (HP and TW), Kaneti, Kanota (TW), Kashipura, Lalgah, Mundali (HP and TW), Nagal Karna (HP and TW), Parasoli (HP and TW), Parempura, Peepalabai (HP and TW), Peipura (HP and TW), Rajwas, Ramser (HP and TW), Ratanpura (HP and TW), Roopura (HP and TW), Shankarpura, Tehda, Todabhata. | 44             | Above 100 | Unsuitable for Drinking |

Table 10 : Classifications of groundwater in the Study area with respect to WQI in Post Monsoon Season

| Name of the Sampling Site                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | No. of Samples | WQI Range | Quality Category        |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------|-----------|-------------------------|
| Nil                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 00             | 0-25      | Excellent               |
| Charangarh, Gudha Meena, Jhar, Kaneta (TW), Kaneti, Tekchandpura.                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 06             | 26-50     | Good                    |
| Bassi (TW), Bharamपुरi, Chapariya, Danau Khurd (HP), Ghasipura (HP), Kaneta (HP), Keshopura, Kuthada Kalan, Peepalabai (HP).                                                                                                                                                                                                                                                                                                                                                                                                 | 09             | 51-75     | Poor                    |
| Anantpura (HP and TW), Banskho (HP), Bassi (HP), Chainpuriya, Ghata (TW), Kalyanpura (HP), Lalgah, Parempura, Tilpatti, Tunga.                                                                                                                                                                                                                                                                                                                                                                                               | 11             | 76-100    | Very Poor               |
| Akhepura (HP and TW), Banskho (TW), Barala, Benada, Chatarpura, Danau Kalan, Danau Khurd (TW), Garh, Ghasipura (TW), Ghata (HP), Gumanpura (HP and TW), Gwalini, Hans Mahal, Hanumanpura (HP and TW), Jhahjwar (HP and TW), Kalyanpura (TW), Kanota (HP and TW), Kashipura, Mundali (HP and TW), Nagal Karna (HP and TW), Parasoli (HP and TW), Patan, Peepalabai (TW), Peipura (HP and TW), Rajwas, Ramser (HP and TW), Ratanpura (HP and TW), Roopura (HP and TW), Sambhariya, Shankarpura, Siya Ka Bas, Tehda, Todabhata. | 45             | Above 100 | Unsuitable for Drinking |

## V. CONCLSIONS

WQI values of groundwater samples analyzed for pre and post monsoon seasons depict that there exists an uncertain and narrow change in the WQI values which is not very significant with reference to potability and groundwater quality.

The results of current study revealed that ground water, used by the people residing in villages of Bassi Tehsil, is not suitable for drinking purpose. So, there is a need of continuous monitoring of water quality and proper environment management plan must be adopted to control drinking water pollution immediately. Based on these results and analysis of water samples, it is also recommended to use water only after boiling and filtering or by Reverse Osmosis treatment for drinking purpose by the individuals to prevent adverse health effects.

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## Adsorption and Kinetic Study of Ni(II) Ions from Aqueous Solution using Natural Syrian Zeolite

By Dr. Ibrahim Raheb

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**GJSFR-B Classification :** FOR Code: 030703



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# Adsorption and Kinetic Study of Ni(II) Ions from Aqueous Solution using Natural Syrian Zeolite

Dr. Ibrahim Raheb

**Abstract-** Adsorption of Ni(II) ions from aqueous solution using natural Syrian zeolite has been studied. Batch shaking adsorption experiments were performed in order to determined the effects of contact time, pH and initial concentration on removal process. The experimental equilibrium data were tested for the Langmuir and Freundlich isotherms. It was determined that removal of Ni(II) ions was well fitted by pseudo-first order kinetic model. The adsorption involves a film diffusion, an intra-particle diffusion and a chemical ion-exchange between  $\text{Na}^+$  ions of adsorbent and the  $\text{Ni}^{2+}$  ions. The adsorption is endothermic and spontaneous process under studied conditions.

**Keywords:** adsorption, zeolite, Ni(II) ions.

## I. INTRODUCTION

Environmental preservation is nowadays matter of deep concern. Heavy metals release in wastewaters is one of most worrying pollution causes, as its effects on life may be particularly serious, either referring to plants and animals, or to man, reached indirectly by the toxic through food chain. Heavy metals are well-known toxic substances and therefore their removal from wastewater is required prior to discharge into receiving water [1,2].

Ions of heavy metals like copper, nickel, zinc, cadmium, lead, chromium and mercury as a significant impact on the environment since they are often detected in industrial wastewaters. Many techniques are using to removal of heavy ions. Conventional methods involve the use of processes such as coagulation, precipitation, ion-exchange, electrochemical methods, membrane processes, extraction biosorption, adsorption, etc [3-6].

Adsorption and ion-exchange methods are widely using for removal of the heavy ions from aqueous solutions because of simple and low cost of these methods.

Natural zeolite is generally regarded as the suitable material for using as a adsorbent and exchanger for wastewater treatment. Zeolites are widely used in ion-exchange applications, where they exchange cations from their structure with dissolved ones. The most important property of zeolite is the ion-exchange capacity expressing the ability of the material to take up cations. It is also important that Zeolites are environmentally friendly materials [3,7,8].

The present study discusses the possibility of the Syrian natural zeolite for removing nickel ions from aqueous solution. Also, the effect of different parameters on ion-exchange process were investigated. Some kinetic parameters were calculated for determination of adsorption mechanism. It is thought that results of this study can be useful for treatment processes of sectors containing heavy metal in their wastewaters.

## II. EXPERIMENTAL

### a) Materials

All chemicals used in this study were analytical grade reagents. The natural zeolite ore using in this work collected from Omm'Ozen region in Syria. It was crushed and then sieved to different fractions, of which  $100\text{--}200\mu$ , was used in this study. This adsorbent is containing different zeolite phases (analcim, phillipsite and shabazite) [9]. A certain amount of natural zeolite washed with distilled water three times to avoid any effects from dissolved salts in the equilibrium solution. The adsorbent was then dried at  $120^\circ\text{C}$  for 24h and named Z. Modified zeolite with Na ions was prepared as following: 20g of Z sample was added to 500ml of NaCl(1M) solution, agitated at room temperature for 24h filtrated and washed by distilled water and then dried at  $120^\circ\text{C}$  for 24h and named Z-Na sample. The stock solution of Ni(II) (1000mg/l) was prepared by dissolving a weighed quantity of  $\text{NiCl}_2 \cdot 6\text{H}_2\text{O}$  salt in bi-distilled water. The stock solution was used to prepare different solutions with Ni(II) concentration ranging (100, 200, 400, 700, 1000mg/l). Before adding the adsorbent, the pH of each solution adjusted to the required value by adding (0.1 M NaOH or 0.1 M  $\text{HNO}_3$ ).

### b) Equilibrium Studies

The batch ion-exchange experiments performed in a wide variety of conditions including contact time, pH, temperature and initial concentration. Effects of each factor were determined keeping other variables constant. In the experiments 0.3g of adsorbent was added to 50ml of Ni(II) solutions. Solutions were shaken for predetermined period. At the end of the experiment, solution filtered and the metal contents in solution determined by Atomic Absorption Spectroscopy method. In these experiments, the averages of three tested samples reported.

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### c) Isotherm Studies

The adsorption capacity was calculated using following formula:

$$q_e = (C_0 - C_e) \cdot \frac{V}{m} \quad (1)$$

Where  $q_e$ (mg/g) is the equilibrium adsorption capacity,  $C_0$  and  $C_e$  are the initial and equilibrium concentration(mg/L), respectively,  $V$ (L) is the volume and  $m$ (g) is the amount of the adsorbent.

The nickel removal percentage was calculated using the formula:

$$\text{Removal}(\%) = \frac{C_0 - C_e}{C_0} \cdot 100 \quad (2)$$

The data obtained were applied to Langmuir isotherm using the following liner expression of this model [10]:

$$\frac{1}{q_e} = \frac{1}{q_{\max}} + \frac{1}{q_{\max} \cdot K_L} \cdot \frac{1}{C_e} \quad (3)$$

Where  $q_{\max}$ (mg/g) and  $K_L$ (L/mg) the Langmuir constants related to the ion-exchange capacity and energy of ion-exchange, respectively. Another isotherm, the Freundlich isotherm also used, which expressed as follows [10]:

$$\text{Log } q_e = \text{Log } K_f + \frac{1}{n} \text{Log } C_e \quad (4)$$

Where  $K_f$  and  $n$  are the Freundlich constants.

### d) Kinetic and Thermodynamic studies

Kinetic experiments were performed by using 50ml of nickel solution of various concentrations (100, 200, 400mg/L). To these solutions, we added 0.3g of modified zeolite Z-Na and shacked. Samples were taken at different time intervals (0-480 min) and different temperatures (298,313, 333 K) and remaining metal concentrations were determined. The rate constants were calculated using tow reaction-based kinetic models, the pseudo-first rate equation whose integrated form is given by formula [11].

$$\log(q_e - q_t) = \log q_e - \frac{k_1}{2.303} t \quad (5)$$

Where  $q_e$  and  $q_t$  are the amount of Ni(II) adsorbed(mg/g) at equilibrium and at the time  $t$ , respectively, and  $k_1$ (min<sup>-1</sup>) is the rate constant. The integrated form of the pseudo-second order rate reaction also was used [11].

$$\frac{t}{q_t} = \frac{1}{k_2 \cdot q_e^2} + \frac{1}{q_e} t \quad (6)$$

Where  $k_2$ (g.mg<sup>-1</sup>.min<sup>-1</sup>) is the rate constant of the pseudo-second order adsorption.

The effect of the temperature on the removal of Ni(II) by Z-Na adsorbent was studied and the activated energy was calculated using Arrhenius equation:

$$\text{Ln } k = \text{Ln } A - \frac{E_a}{R} \cdot \frac{1}{T} \quad (7)$$

Thermodynamic parameters such as enthalpy  $\Delta H^0$ , entropy change  $\Delta S^0$  and Gibbs free energy  $\Delta G^0$  for the adsorption of Ni(II) were calculated using the equations[12]:

$$\text{Ln } K_d = \frac{\Delta S^0}{R} - \frac{\Delta H^0}{RT} \quad (8)$$

$$\Delta G^0 = -RT \text{Ln } K_d \quad (9)$$

Where  $R$  is the general gas constant, 8.314 J/mol.K and  $T$  is the adsorption absolute temperature,  $K_d$ (ml/g) is the distribution coefficient which is obtained by the following equation:

$$K_d = \frac{q_e}{C_e} = \frac{C_0 - C_e}{C_e} \cdot \frac{V}{m} \quad (10)$$

## III. RESULTS AND DISCUSSION

### a) Effect of contact time

Due to equilibrium nature of the removal process of Ni(II) by the modified zeolite Z-Na, it seen that the contact time affect the removal efficiency of the used adsorbent. Hence, the effect of contact time on the removal of Ni(II) by the Z-Na was studied in the batch experiment. The corresponding results are given in Fig.1. It can be seen that the removal of Ni(II) ions from aqueous solution using The Z-Na increased during time and reached to nearly constant amount at equilibrium conditions after 360min. This obtained time was selected for the next adsorption experiments. The variation in the time of adsorption may also be due to the fact that initially all sites on the surface of Z-Na were vacant and the Ni(II) ion concentration gradient was relatively high. After 360min the adsorbent surface becomes saturated with respective metal and the removal efficiency becomes almost constant.

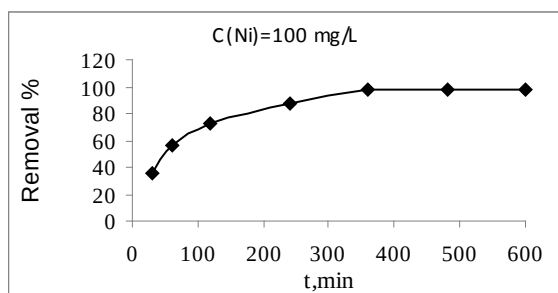


Fig.1 : Effect of contact time on Ni(II) removal by Z-Na

$C_{Ni(II)} = 100 \text{ mg/L}$ ,  $V = 50 \text{ mL}$ ,  $m = 0.3 \text{ g}$ ,  $T = 298 \text{ K}$ ,  $\text{pH} = 6$

b) Effect of pH solution

The effect of pH on the ion-exchange of Ni(II) by the Z-Na is presented in Fig.2. The pH of aqueous

solution was an important parameter that controlled the ion-exchange process.

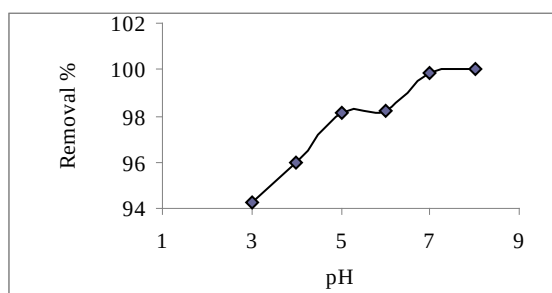


Fig.2 : Effect of pH on the removal of Ni(II)

$C_{Ni(II)} = 100 \text{ mg/L}$ ,  $V = 50 \text{ mL}$ ,  $m = 0.3 \text{ g}$ ,  $T = 298 \text{ K}$ ,  $t = 360 \text{ min}$

Adsorption of Ni(II) increased with increasing pH to a pH in range 5-6, then increased up to pH 7-8 where beginning the precipitation process. Under acidic conditions the Z-Na surface will be completely covered with  $\text{H}^+$  ions and the Ni(II) ions cannot compete with them. However, with increasing pH, the competition from the  $\text{H}^+$  ions decreases and the positively charged Ni(II) ions can be exchanged and be also adsorbed at the negatively charged sites on the Z-Na. At pH higher 8 the precipitation process  $\text{Ni}(\text{OH})_2$  will accure[13]. Based on these results, Z-Na exhibited a good capacity for removing Ni(II) from solution at a range of pH values

from 5-8. The maximum removal about 98% was at  $\text{pH} = 5$ .

c) Adsorption isotherm

Adsorption equilibrium measurements were used to determine the maximum adsorption capacity and the obtained data were formulated into the most commonly models include Langmuir and Freundlich isotherms[14].

The adsorption capacity was calculated using formula (1). Fig.3 shows the adsorption isotherm for Ni(II) on adsorbent Z and Z-Na zeolite.

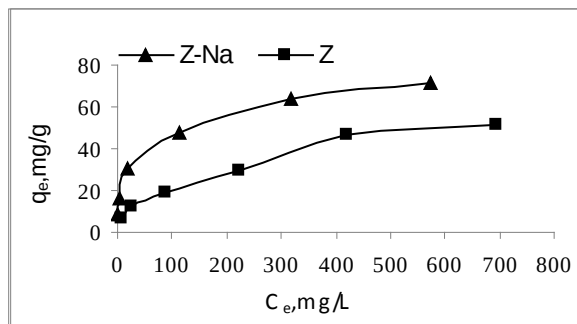


Fig.3 : The adsorption isotherm for Ni(II) on Z and Z-Na zeolite

$V = 50 \text{ mL}$ ,  $m = 0.3 \text{ g}$ ,  $T = 298 \text{ K}$ ,  $t = 360 \text{ min}$

It is seen from Fig.3 that the adsorption capacity of both Z and Z-Na zeolite increases with the Ni(II)

solution concentration. The equilibrium data from Fig.3 have been analyzed according to equation (3) and (4).

The Langmuir isotherm is a commonly applied model for adsorption on a completely homogeneous surface. The model assumes uniform adsorption energies onto the surface. The Freundlich model is shown to be consistent with exponential distribution of

active sites, characteristic of heterogeneous surfaces. The values of the Langmuir constants  $K_L$  and  $q_{\max}$  and Freundlich constants  $K_f$  and  $n$  were determined from the slope, intercept in Fig.4(a) and Fig.4(b) respectively and the results presented in table (1).

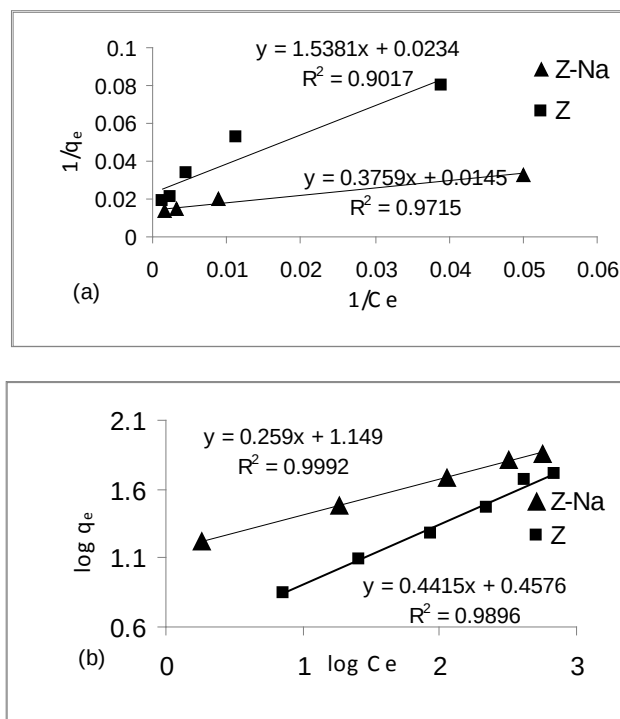


Fig.4 : Langmuir (a) and Freundlich (b) adsorption isotherms of Ni(II)

Table(1) : Isotherm Parameters Calculated for Ni(II) Removal on Adsorbent Z and Z-Na

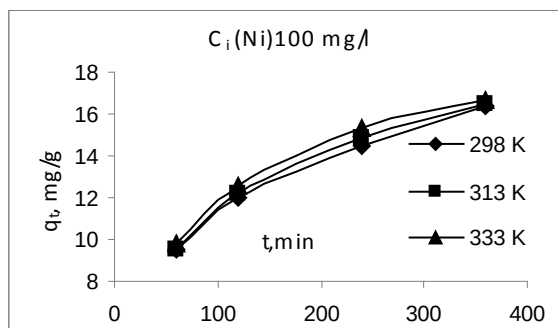
|      | Langmuir model |        |       | Freundlich model |      |       |
|------|----------------|--------|-------|------------------|------|-------|
|      | $q_{\max}$     | $K_L$  | $R^2$ | $K_f$            | $n$  | $R^2$ |
| Z    | 43.48          | 0.0149 | 0.901 | 2.86             | 2.27 | 0.989 |
| Z-Na | 71.43          | 0.0373 | 0.971 | 14.1             | 3.86 | 0.999 |

Comparing of  $R^2$  values of tow isotherm models, confirms that the Freundlich model is the best to describe the adsorption data. On the other hand, a competitive adsorption of Ni(II) accurse on the surface because the value of  $n > 1$ . From the Langmuir isotherm, the maximum ion-exchange capacity  $q_{\max}$  was 43.48 and 71.43 mg/g for Z and Z-Na adsorbents, respectively. It

was seen the important of the modification process of zeolite for the removal of heavy metals ions from the aqueous solutions.

#### d) kinetic studies

In order to determined the ion-exchange kinetics of Ni(II) on the modified Z-Na, the pseudo-first order and pseudo-second order kinetics models were examined. On the other hand some of the thermodynamic parameters were determined. The Ni(II) adsorption dependence on time was studied at 298, 313, 333K for solutions with  $C_0 = 100, 200$  and  $400 \text{ mg/L}$ . The uptake values for removal of Ni(II) from solution are shown in Fig.5.



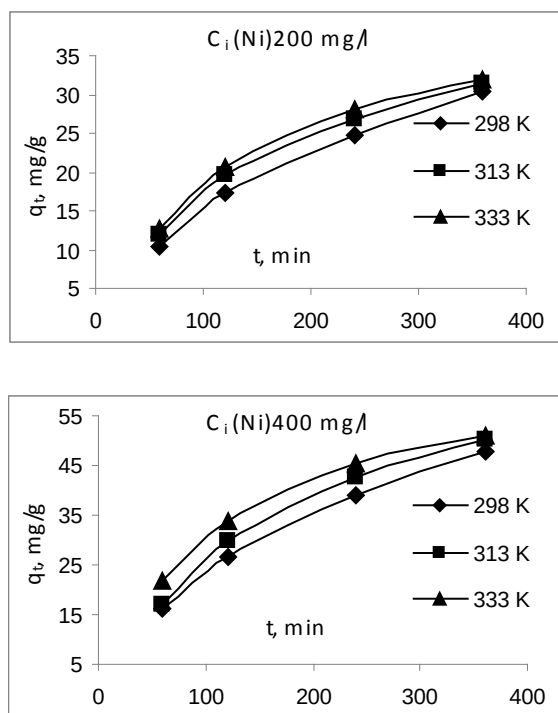
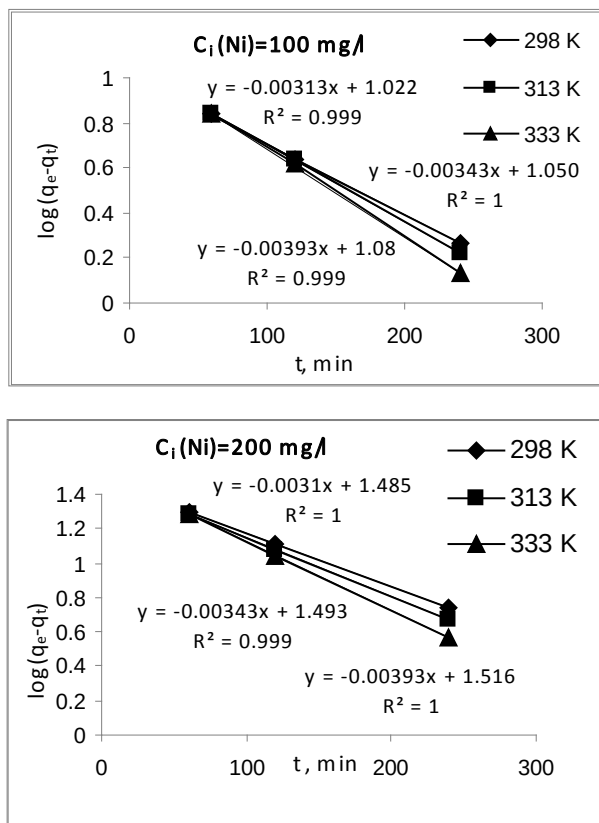


Fig. 5 : Adsorption kinetics for Ni(II) on Z-Na for different initial Ni(II) concentrations

It is seen from the Fig.5 that the adsorption takes place in tow steps. The first step accurse at the beginning stages(i.e. apporx. in the first 50-250 min), when the Ni(II) uptake increases. After these periods adsorption process exhibit slower rate and reach

equilibrium after 360min. Similar behavior was found in other systems[15]. The data from Fig.5 were analyzed using (5,6) equations and presented in Fig. 6 and 7. Calculated rate constants  $k_1$ ,  $k_2$  and correlation coefficients  $R^2$  were summarized in table 2.



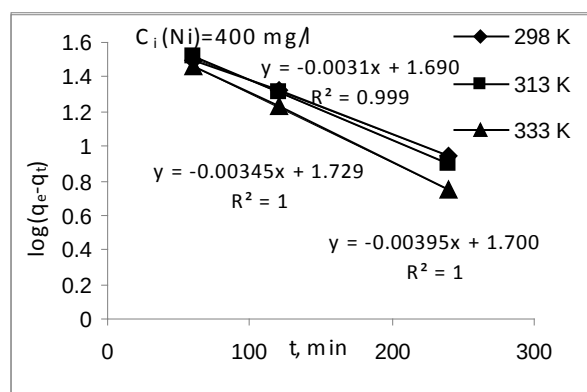


Fig.6 : Pseudo-first order reaction kinetics for the adsorption of Ni(II) onto Z-Na

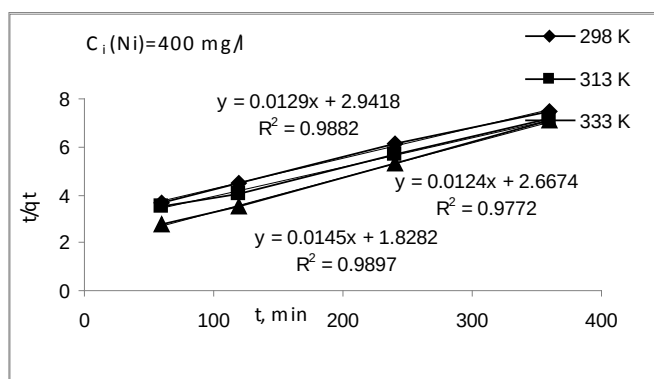
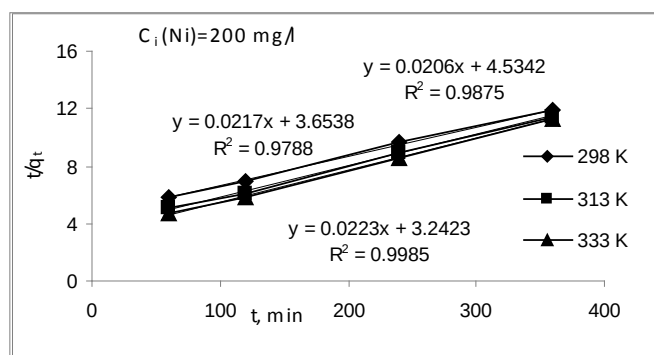
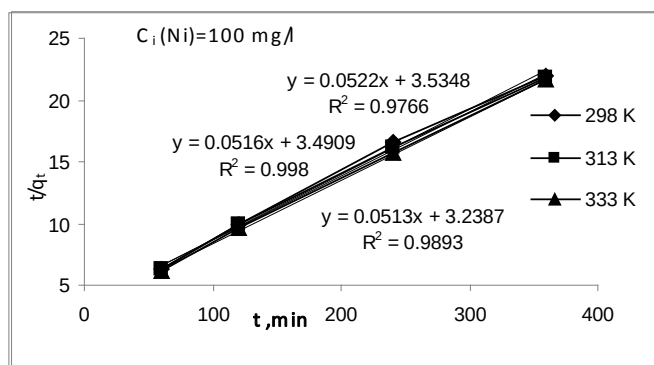


Fig.7 : Pseudo-second order reaction kinetics for the adsorption of Ni(II) onto Z-Na

**Table 2 :** Rate constants and  $R^2$  values for the pseudo first-and second order reaction kinetics and activation energy of the removal of Ni(II) onto Z-Na

| $C_0, \text{mg/L}$ | T, K | $k_1 \cdot 10^3 \text{ min}^{-1}$ | $R^2$ | $k_2 \cdot 10^3 \text{ g/mg/min}$ | $R^2$ | $E_a \text{ kJ/mol}$ |
|--------------------|------|-----------------------------------|-------|-----------------------------------|-------|----------------------|
| 100                | 298  | 7.2                               | 0.999 | 0.765                             | 0.976 | 5.32                 |
|                    | 313  | 7.8                               | 1     | 0.745                             | 0.998 |                      |
|                    | 333  | 9                                 | 0.999 | 0.803                             | 0.989 |                      |
| 200                | 298  | 7.1                               | 1     | 0.088                             | 0.987 | 5.64                 |
|                    | 313  | 7.8                               | 0.999 | 0.120                             | 0.978 |                      |
|                    | 333  | 9                                 | 1     | 0.149                             | 0.998 |                      |
| 400                | 298  | 7.1                               | 0.999 | 0.049                             | 0.988 | 5.62                 |
|                    | 313  | 7.9                               | 1     | 0.054                             | 0.977 |                      |
|                    | 333  | 9                                 | 1     | 0.107                             | 0.989 |                      |

As seen from table 3 the values of correlation coefficients for pseudo-first order are higher than  $R^2$  for pseudo-second order and the  $k_1$  rate constant increases quite slightly with temperature. The  $k_2$  rate constant variables when initial concentration is increasing. The studied adsorption is better described by the pseudo-first order model. From the results in table 3 we can say,

that the process accurse according to the film diffusion and interaction particles diffusion mechanisms[16].

The variation of  $k_1$  with temperature in the 298-333K region was used for the calculation of the activation energy( $E_a$ ) of the adsorption. The activation energy was calculated using Arrhenius equation(7) as shown in Fig.8.

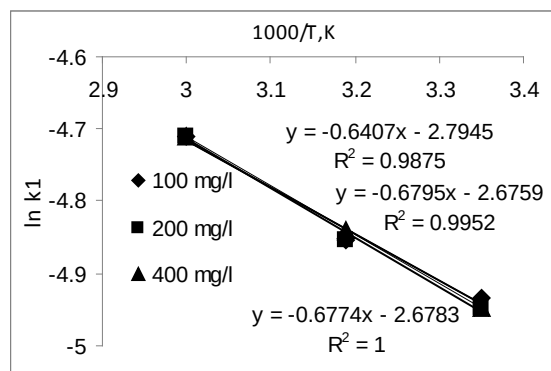


**Fig. 8 :** The Arrhenius plot using rate constant values from table 3 for the pseudo-first order

The values of the activation energy in table 2 are quite small and change only slightly for different initial concentrations. In general a low  $E_a$  value means that the adsorption involved is physisorption[17].

The data obtained from the adsorption experiments at 298, 313 and 333K and the initial Ni(II) concentrations of 100, 200 and 400 mg/L, were used for

the calculation of thermodynamic properties using (8-10) equations. The plot of  $\ln K_d$  vs.  $1/T$  in Fig.9. gave a strait line, and the values of  $\Delta H^0$  and  $\Delta S^0$  can obtained from the intercept and slope, respectively. The thermodynamic parameters are presented in table 3.

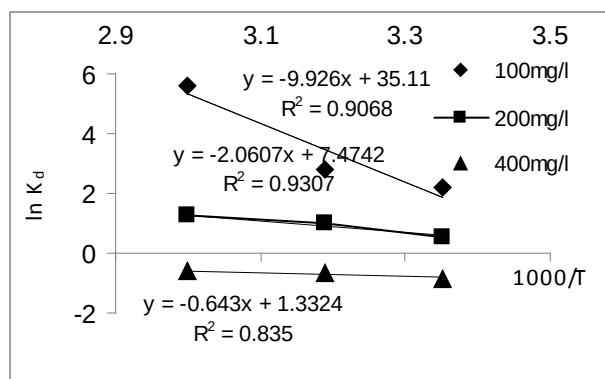


**Fig. 9 :** The plot of  $\ln K_d$  vs  $1/T$  for different initial Ni(II) concentrations

Table 3 : Thermodynamic parameters for the Ni(II) adsorption on Z-Na

| C <sub>0</sub><br>mg/L | T,K | LnK <sub>d</sub> | $\Delta G^0$<br>kJ / mol | $\Delta H^0$<br>kJ / mol | $\Delta S^0$<br>J / K.mol | R <sup>2</sup> |
|------------------------|-----|------------------|--------------------------|--------------------------|---------------------------|----------------|
| 100                    | 298 | 2.207            | -5.48                    | 82.4                     | 291.4                     | 0.906          |
|                        | 313 | 2.803            | -7.29                    |                          |                           |                |
|                        | 333 | 5.626            | -15.50                   |                          |                           |                |
| 200                    | 298 | 0.509            | -1.26                    | 17.12                    | 62.14                     | 0.930          |
|                        | 313 | 1.014            | -2.64                    |                          |                           |                |
|                        | 333 | 1.240            | -3.43                    |                          |                           |                |
| 400                    | 298 | -0.853           | 2.11                     | 5.34                     | 11.07                     | 0.835          |
|                        | 313 | -0.661           | 1.72                     |                          |                           |                |
|                        | 333 | -0.623           | 1.72                     |                          |                           |                |

The  $\Delta G^0$  values in table 4 show that, the adsorption of Ni(II) on Z-Na occurs spontaneously in the 298-333K temperature range and the spontaneity slightly decreases with temperature. The Ni(II) adsorption is endothermic ( $\Delta H^0 > 0$ ). It is also evident that the spontaneity as well as the  $\Delta H^0$  and  $\Delta S^0$  values all decrease as the initial Ni(II) concentration increases. The similar behavior has also been reported for some other adsorbents [18]. The positive  $\Delta S^0$  values reflect the fact that the adsorption involves the liberation of two Na<sup>+</sup> when one Ni<sup>2+</sup> ion is bound to the adsorbent.

#### IV. CONCLUSION

The Syrian natural zeolite is effective in removing the nickel(II) ions from aqueous solutions by adsorption.

The Ni(II) ions distributed inside the Z-Na adsorbent indicating that the removal process from water solutions is mainly an ion-exchange. The adsorption kinetics is described by the pseudo-first order model. The activation energy ~ 5kJ/mol. The adsorption involves a combination of the film and interaction particle diffusions, and chemical cation-exchange between Na<sup>+</sup> ions of zeolite and the Ni<sup>2+</sup> ions. The process is endothermic and spontaneous in the 298-333K temperature range.

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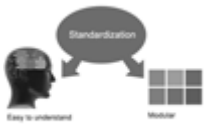
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Metric SI units are supposed to generally be used excluding where they conflict with current practice or are confusing. For illustration, 1.4 l rather than  $1.4 \times 10^{-3} \text{ m}^3$ , or 4 mm somewhat than  $4 \times 10^{-3} \text{ m}$ . Chemical formula and solutions must identify the form used, e.g. anhydrous or hydrated, and the concentration must be in clearly defined units. Common species names should be followed by underlines at the first mention. For following use the generic name should be constricted to a single letter, if it is clear.

## Structure

All manuscripts submitted to Global Journals Inc. (US), ought to include:

**Title:** The title page must carry an instructive title that reflects the content, a running title (less than 45 characters together with spaces), names of the authors and co-authors, and the place(s) wherever the work was carried out. The full postal address in addition with the e-mail address of related author must be given. Up to eleven keywords or very brief phrases have to be given to help data retrieval, mining and indexing.

*Abstract, used in Original Papers and Reviews:*

### Optimizing Abstract for Search Engines

Many researchers searching for information online will use search engines such as Google, Yahoo or similar. By optimizing your paper for search engines, you will amplify the chance of someone finding it. This in turn will make it more likely to be viewed and/or cited in a further work. Global Journals Inc. (US) have compiled these guidelines to facilitate you to maximize the web-friendliness of the most public part of your paper.

### Key Words

A major linchpin in research work for the writing research paper is the keyword search, which one will employ to find both library and Internet resources.

One must be persistent and creative in using keywords. An effective keyword search requires a strategy and planning a list of possible keywords and phrases to try.

Search engines for most searches, use Boolean searching, which is somewhat different from Internet searches. The Boolean search uses "operators," words (and, or, not, and near) that enable you to expand or narrow your affords. Tips for research paper while preparing research paper are very helpful guideline of research paper.

Choice of key words is first tool of tips to write research paper. Research paper writing is an art. A few tips for deciding as strategically as possible about keyword search:



- One should start brainstorming lists of possible keywords before even begin searching. Think about the most important concepts related to research work. Ask, "What words would a source have to include to be truly valuable in research paper?" Then consider synonyms for the important words.
- It may take the discovery of only one relevant paper to let steer in the right keyword direction because in most databases, the keywords under which a research paper is abstracted are listed with the paper.
- One should avoid outdated words.

Keywords are the key that opens a door to research work sources. Keyword searching is an art in which researcher's skills are bound to improve with experience and time.

Numerical Methods: Numerical methods used should be clear and, where appropriate, supported by references.

*Acknowledgements: Please make these as concise as possible.*

## References

References follow the Harvard scheme of referencing. References in the text should cite the authors' names followed by the time of their publication, unless there are three or more authors when simply the first author's name is quoted followed by et al. unpublished work has to only be cited where necessary, and only in the text. Copies of references in press in other journals have to be supplied with submitted typescripts. It is necessary that all citations and references be carefully checked before submission, as mistakes or omissions will cause delays.

References to information on the World Wide Web can be given, but only if the information is available without charge to readers on an official site. Wikipedia and Similar websites are not allowed where anyone can change the information. Authors will be asked to make available electronic copies of the cited information for inclusion on the Global Journals Inc. (US) homepage at the judgment of the Editorial Board.

The Editorial Board and Global Journals Inc. (US) recommend that, citation of online-published papers and other material should be done via a DOI (digital object identifier). If an author cites anything, which does not have a DOI, they run the risk of the cited material not being noticeable.

The Editorial Board and Global Journals Inc. (US) recommend the use of a tool such as Reference Manager for reference management and formatting.

## Tables, Figures and Figure Legends

*Tables: Tables should be few in number, cautiously designed, uncrowned, and include only essential data. Each must have an Arabic number, e.g. Table 4, a self-explanatory caption and be on a separate sheet. Vertical lines should not be used.*

*Figures: Figures are supposed to be submitted as separate files. Always take in a citation in the text for each figure using Arabic numbers, e.g. Fig. 4. Artwork must be submitted online in electronic form by e-mailing them.*

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Even though low quality images are sufficient for review purposes, print publication requires high quality images to prevent the final product being blurred or fuzzy. Submit (or e-mail) EPS (line art) or TIFF (halftone/photographs) files only. MS PowerPoint and Word Graphics are unsuitable for printed pictures. Do not use pixel-oriented software. Scans (TIFF only) should have a resolution of at least 350 dpi (halftone) or 700 to 1100 dpi (line drawings) in relation to the imitation size. Please give the data for figures in black and white or submit a Color Work Agreement Form. EPS files must be saved with fonts embedded (and with a TIFF preview, if possible).

For scanned images, the scanning resolution (at final image size) ought to be as follows to ensure good reproduction: line art: >650 dpi; halftones (including gel photographs) : >350 dpi; figures containing both halftone and line images: >650 dpi.



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#### TECHNIQUES FOR WRITING A GOOD QUALITY RESEARCH PAPER:

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**26. Go for seminars:** Attend seminars if the topic is relevant to your research area. Utilize all your resources.



**27. Refresh your mind after intervals:** Try to give rest to your mind by listening to soft music or by sleeping in intervals. This will also improve your memory.

**28. Make colleagues:** Always try to make colleagues. No matter how sharper or intelligent you are, if you make colleagues you can have several ideas, which will be helpful for your research.

**29. Think technically:** Always think technically. If anything happens, then search its reasons, its benefits, and demerits.

**30. Think and then print:** When you will go to print your paper, notice that tables are not be split, headings are not detached from their descriptions, and page sequence is maintained.

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**33. Report concluded results:** Use concluded results. From raw data, filter the results and then conclude your studies based on measurements and observations taken. Significant figures and appropriate number of decimal places should be used. Parenthetical remarks are prohibitive. Proofread carefully at final stage. In the end give outline to your arguments. Spot out perspectives of further study of this subject. Justify your conclusion by at the bottom of them with sufficient justifications and examples.

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### Key points to remember:

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- Write your paper in the form, which is presented in the guidelines using the template.
- Please note the criterion for grading the final paper by peer-reviewers.

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A purpose of organizing a research paper is to let people to interpret your effort selectively. The journal requires the following sections, submitted in the order listed, each section to start on a new page.

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Mistakes to evade

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In every sections of your document

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The summary should be two hundred words or less. It should briefly and clearly explain the key findings reported in the manuscript-- must have precise statistics. It should not have abnormal acronyms or abbreviations. It should be logical in itself. Shun citing references at this point.

An abstract is a brief distinct paragraph summary of finished work or work in development. In a minute or less a reviewer can be taught the foundation behind the study, common approach to the problem, relevant results, and significant conclusions or new questions.

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- Fundamental goal
- To the point depiction of the research
- Consequences, including definite statistics - if the consequences are quantitative in nature, account quantitative data; results of any numerical analysis should be reported
- Significant conclusions or questions that track from the research(es)

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- Center on shortening results - bound background information to a verdict or two, if completely necessary
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### Approach:

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## Content

- Sum up your conclusion in text and demonstrate them, if suitable, with figures and tables.
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- Never confuse figures with tables - there is a difference.

### Approach

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- Give details all of your remarks as much as possible, focus on mechanisms.
- Make a decision if the tentative design sufficiently addressed the theory, and whether or not it was correctly restricted.
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- Recommendations for detailed papers will offer supplementary suggestions.

### Approach:

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|                               | A-B                                                                                                                                                                                    | C-D                                                                                                 | E-F                                                                |
| <b>Abstract</b>               | Clear and concise with appropriate content, Correct format. 200 words or below                                                                                                         | Unclear summary and no specific data, Incorrect form<br><br>Above 200 words                         | No specific data with ambiguous information<br><br>Above 250 words |
| <b>Introduction</b>           | Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited | Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter | Out of place depth and content, hazy format                        |
| <b>Methods and Procedures</b> | Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads                                                              | Difficult to comprehend with embarrassed text, too much explanation but completed                   | Incorrect and unorganized structure with hazy meaning              |
| <b>Result</b>                 | Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake                                         | Complete and embarrassed text, difficult to comprehend                                              | Irregular format with wrong facts and figures                      |
| <b>Discussion</b>             | Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited                                               | Wordy, unclear conclusion, spurious                                                                 | Conclusion is not cited, unorganized, difficult to comprehend      |
| <b>References</b>             | Complete and correct format, well organized                                                                                                                                            | Beside the point, Incomplete                                                                        | Wrong format and structuring                                       |



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