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PHYSICOCHEMICAL AND CHEMICAL QUALITY OF MAILSI CITY GROUNDWATER

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Quality of groundwater samples in Mailsi city of district Vehari was assessed using physico-chemical and chemical parameters. Twenty seven (27) groundwater samples were collected for physico-chemical and major ion analysis. Absence of carbonate ions (CO_3^{-2}) in all groundwater samples indicates presence of limestone dissolution giving rise to bicarbonate. Piper diagram reveals dominance with Ca-Mg-type of water in the studied area. pH of all samples were within WHO guidelines. The mean value of Total Dissolved Solids (TDS) for Mailsi groundwater is 755.1 mg/L having a range of 272 to 1667mg/L. The TDS for majority of samples lies above the guideline values as defined by the WHO. Twenty two (22) percent samples exhibit high nitrate levels; consumption of water samples with high nitrate content may produce harmful effects in children.

Keyword: Groundwater, pH, Electrical Conductivity, Total Dissolved Solids, Anions, Cation, WHO guidelines.

1. Introduction

Water is an imperative necessity of human life; it has multifold usage including drinking, bathing, washing thus numerous others. Earth is a watery place but only one-third of fresh water is accessible for human utilization [1]. About 80 countries, constituting 40 per cent of the world's population, were suffering from serious water shortages by the mid-1990s [2] and it is estimated that in less than 25 years two-third of the world's people will be living in water-stressed countries [3]. Safe water is a precondition for health and development and a basic human right, yet it is still denied to hundreds of millions of people throughout the developing world [4]. The groundwater is very important for human utilization, and any change in its quality can have serious results. In last 50 years expanding populace densities and horticultural exercises has increased excessive utilization of groundwater, which is the main cause of degradation of quality and quantity of groundwater. Usage of groundwater is alarmingly increasing and surface water reserves are getting rare. In Pakistan, water misuse and predominating water less conditions are the major reasons for extinction of water reserves and insufficient groundwater aquifers [5].

In Pakistan, water remains a basic need for managed prosperity of its nationals. The water deficiencies and its multifold usage has violently influenced the water quality, hence, water contamination has turned into a genuine issue in Pakistan. Contaminated water is directly or indirectly affecting the health issues [6]. About 60% population in Pakistan does not have access to safe drinking water [7]. For every capita water accessibility in Pakistan has diminished from 5,000 in 1951 to 1100 cubic meter per annum [8].

Mailsi city is located in Indus Valley of district Vehari, Punjab, Pakistan. The city has the most extreme weather in the country with hot summers and cold winters. Mailsi is situated along river Sutlej, however, this river is dry in most part of the year that's why this area is facing shortage of good quality drinking water. Groundwater is the most important source of drinking water in this area. Unfortunately due to injudicious and unplanned urbanization for the past few decades, the resource is either being depleted or degraded in quality. Main factors which are affecting water quality of Mailsi are sewerage system, Drainage system, solid waste management and land fill/ dumping sites. Scarcity of fresh water in Mailsi is due to the inappropriate sewerage system because of poor sewerage system the sewerage water is mixing with ground water.

Analysis of Water quality is a very essential part of groundwater studies. The hydro chemical study uncovers nature of water which is good for drinking, horticulture and mechanical purposes. Further, it is easy to comprehend the change in water quality because of host rock [9,10] anthropogenic impacts and finding out the chemical budgets for terrestrial or aquatic systems [11,12]. Chemical classifications of groundwater play a critical part in classification and evaluating water quality [13]. Chemical classification also gives the hints about predominant cations concentration, anions and their inter-relationships [14].

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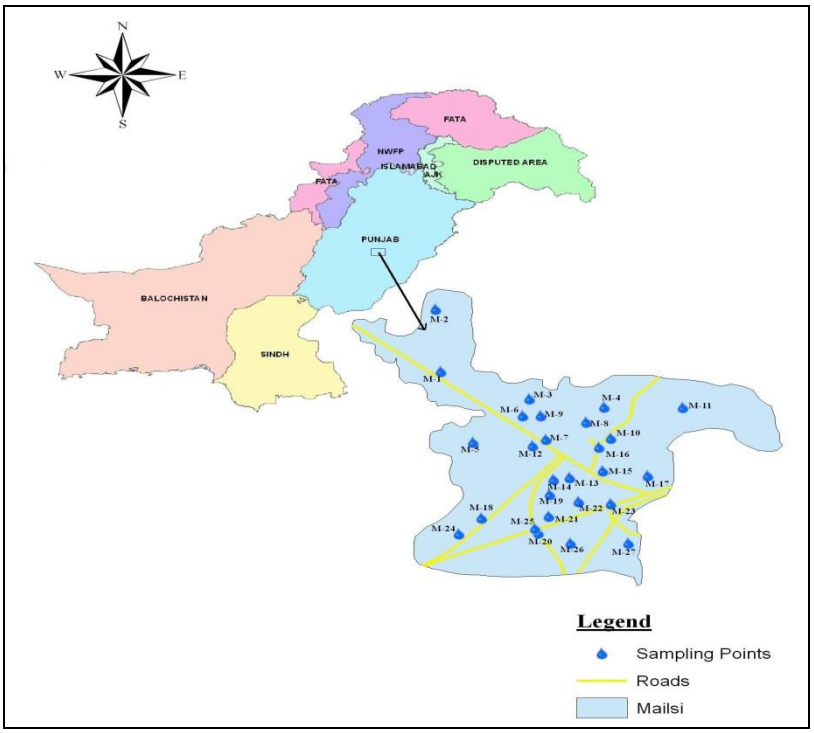

Figure 1. Location map of the study area, sampling points are shown.

The objective of this study is to characterize drinking water of Mailsi ,a city in District Vehari, with respect to physical parameters (pH, EC, TDS and DO) and chemical parameters (Nitrate, SO_4^{-2}, Cl^{-1}, Mg^{+2}, Ca^{+2}, Na^{+}, CO_3^{-2}, HCO_3^{-1}) for evaluating groundwater quality of Mailsi city.

2. Material and Methods

2.1 Study Area

Mailsi is a city situated in Vehari District, Punjab, Pakistan (Figure 1). It is located at 29°48'1N 72°10'33E at an altitude of 126 m (416 ft). Total Area covered by Tehsil Municipal Administration (TMA) Mailsi is 1,639 square kilometers with a population of 704,878 (as per DCR 1998). It is incorporated by 31 union councils. The whole city is placed on the right bank of river Sutlej. District Vehari comprises three tehsils and Mailsi is one of them. The other two are Vehari and Burewala. In 1952 Mailsi was raised to the status of Municipal Committee but presently it attained the status of TMA after the implementation of Punjab Local Government Ordinance 2001 [15].

2.2 Geography and Climate

Mailsi is situated in the Indus Valley. The area of this city is considered as flat alluvial plain, which are perfect for horticulture. Irrigation system depends upon the canals system across the tehsil. The water rights were given to India during the Indus Water Treaty; decreased water in the river has severe impacts on the flora and fauna of the city. The Mailsi Siphon was assembled to control the water stream in the Sidhnai Link Canal and Sutlej River under this same Indus Water Treaty. Mailsi has extreme weather with hot summers and cold winters. In summers the highest temperature recorded is 54 °C (129 °F), and the least recorded temperature in winter is −1°C (30.2 °F). 127 millimeters (5.0 in) is the average record of rain fall followed by dust storms [15].

2.3 Field Sampling

Twenty seven (27) groundwater samples (Figure 1) were collected from different areas of city Mailsi. Groundwater samples were taken from hand-pumps and boreholes /mini pumping wells not greater than 150 feet. Table 1 shows sample inventory with sample locations.

Physiochemical parameters i.e., pH, electrical conductivity, Total Dissolved Solids (TDS), dissolved oxygen, were analyzed in situ during sampling. For chemical analysis water samples were collected in leak proof plastic bottles and preserved, as per standard practices. The pH was determined using the Adwa AD1030 pH/mv and temperature meter. Meter was first calibrated for pH with the help of buffer solution of pH 4.01, pH 7 and pH 9.21 respectively. Electrical conductivity and Total Dissolved Solids of water

Table 1. Samples inventory.

S. No	Code	Locations	Latitude	Longitude
1	M-1	Doreta	29° 49′ 4.08″	72° 9′ 23.56 ″
2	M-2	Ahmad Raza Colony	29°49′45.58″	72° 9′ 4.89 ″
3	M-3	Din Pura	29° 48′ 48.90″	72° 10′ 4.44 ″
4	M-4	R.C.A Colony	29° 48′ 45.84″	72° 10′ 45.72 ″
5	M-5	Grid Station	29° 48′ 21.02″	72° 9′ 36.48″
6	M-6	Riaza Baad	29° 48′ 38.44″	72° 10′ 1.76″
7	M-7	Rasul Pura	29° 48′ 20.49″	72° 10′ 15.28″
8	M-8	Islam Pura	29° 48′ 35.75″	72° 10′ 36.42″
9	M-9	Iqbal Oil Mill	29° 48′ 38.92″	72° 10′ 11.33″
10	M-10	DSP Chowk	29° 48′ 22.16″	72° 10′ 43.03″
11	M-11	Basti Hasaan Abaad	29° 48′ 46.74″	72° 11′ 28.42″
12	M-12	Rasool Pura	29° 48′ 20.44″	72° 10′ 8.44″
13	M-13	Stadium	29° 48′ 0.85″	72° 10′ 21.47″
14	M-14	Lal-Jahania Chowk	29° 48′ 2.29″	72° 10′ 29.48″
15	M-15	Tillo Pura	29° 48′ 7.39″	72° 10′ 46.50″
16	M-16	Civil Hospital	29° 48′ 13.47″	72° 10′ 44.17″
17	M-17	Model Town	29° 48′ 5.27″	72° 11′ 10.41″
18	M-18	Shakhu Pura Basti	29° 47′ 38.43″	72° 9′ 45.82″
19	M-19	Madina Town	29° 47′ 52.31″	72° 10′ 19.19″
20	M-20	Colony Chowk	29° 47′ 33.01″	72° 10′ 13.74″
21	M-21	Dharam Pura	29° 47′ 40.61″	72° 10′ 20.37″
22	M-22	Allah Rkha Colony	29° 47′ 49.30″	72° 10′ 35.02″
23	M-23	Fadda Chowk	29° 47′ 47.83″	72° 10′ 51.67″
24	M-24	Basti Rasheedabaad	29° 47′ 29.29″	72° 9′ 35.12″
25	M-25	Garrison Cenima	29° 47′ 32.52″	72° 10′ 16.28″
26	M-26	Mailsi Garrison	29° 47′ 25.86″	72° 10′ 32.42″
27	M-27	Fadda Town	29° 47′ 27.45″	72° 11′ 1.74″

samples were measured by LF95 (wtw) Conductivity meter. HACH Sension 6 meter was used for evaluation of DO values in samples. Prior to analysis, the instrument was calibrated according to the standard procedure with the help of NaOH solution and water.

2.4 Laboratory Analysis

The nitrate was determined by Ion Selective Electrode (ISE) Ion meter. Cl^{-1}, HCO_3^{-1}, CO_3^{-2} were measured by titration, and sulfate concentration was determined by spectrophotometric method by UV Spectrometer. Major cations namely; (Ca^{+2}, Mg^{+2}, Na^{+1} and K^{+1}) were analyzed by Atomic Absorption Spectrometry [5].

3. Results and Discussions

3.1 Physiochemical Analysis

Table 2 elaborates the range of studied physiochemical parameters. The values of pH in Mailsi groundwater lie in the range of 7.30 to 8.12 with the mean value of 7.7. Majority of samples lie within the range of 7.5 to 7.8. pH of all the samples was within the permissible limits of WHO guideline [16].

Electrical conductivity of groundwater samples varies from 526 to 2410µS/cm with the mean value of 1148.5µS/cm. Majority of samples were within 800-1500 µS/cm range. EC of three samples were in the range of 1500- 2000 while one sample bears EC more than 2000 µS/cm. This sampling point is located near the small industrial unit of cotton factory and oil mill. High salt content in groundwater may due to effluent seepage into groundwater.

The mean value of TDS for Mailsi groundwater is 755.1 mg/L having a range of 272 to 1667mg/L. The measure of TDS is a good indicator of the mineralized character of the water. Groundwater having less than 500 mg/L of total dissolved solids is generally satisfactory for domestic and industrial use while groundwater having greater than 1000 mg/L of total dissolved solids is generally unsatisfactory for these uses. TDS has a direct relation with EC and thus as expected TDS was also higher in the groundwater samples exhibiting high EC. High total dissolved solids are often indicative of other characteristics such as hardness. The values of TDS for majority of samples lie above the guideline values (500 mg/L) as defined by the WHO [16]. Seven samples have TDS less than 500 mg/L which is permissible limit of drinking water [16] while five samples have TDS value more than 1000 mg/L which is harmful for drinking purpose. However, the percentage of total dissolved solids in groundwater of Mailsi was 81.5% above permissible limit. There is no local groundwater runoff, nearby canal is dry except during the monsoon period. There may be a regional outflow of groundwater from the area, but this must be small. When the water is used for irrigation under such conditions this leads to a recirculation of the groundwater. Accumulated salts leave the area only with the runoff during the rainy periods, when the uppermost layers of the soil are washed.

The large variation in electrical conductivity and total dissolved solids in water of Mailsi is attributed to the fact that some of the wells located near the Sutlej bed have low electrical conductivity and total dissolved solids values, whereas some of samples away from Sutlej River bed are not recharged from river water and have more salts contents which rises the EC and TDS values of the samples in addition weathering of rocks can be another reasons for increased salts in Mailsi groundwater [17].

Dissolved oxygen in groundwater sample varied from 1.74- 3.23 and averaged 2.6. The majority of samples have DO in the range of 2.5-3.5 mg/L. Low values of DO indicate high rate of oxygen consumption by oxidisable mater, which in turn indicates high concentration of organic matter. DO concentration in groundwater has a relative significance since they control the valence state of trace metals and constrain the bacterial metabolism of organic matter [18]. It also hints at the rate of inorganic ferrous silicate oxidation rates, which is a significant low temperature weathering mechanism.

Low dissolved oxygen (DO) primarily results from excessive algae growth caused by phosphorus. Nitrogen is another nutrient that can contribute to algae growth. As the algae die and decompose, the process consumes dissolved oxygen. This can result in insufficient amounts of dissolved oxygen available for fish and other aquatic life. Die-off and decomposition of submerged plants also contributes to low dissolved oxygen [19].

Table 2. Range of Physiochemical parameters of Mailsi groundwater samples.

Parameters	Ranges
pH	7.30 to 8.12
Electrical Conductivity (µS/cm)	526 to 2410
Total Dissolved Solids (mg/L)	272 to 1667
Dissolved oxygen (mg/L)	1.74 to3.23

3.2 Anions Analysis

Chlorides are not removed in typical sewage treatment processes and they entirely pass into surface waters deteriorating their quality. Chloride contents of Mailsi groundwater ranges from 19.3 to 287.12 ppm with a mean value of 96.6 ppm (Figure 2). Only one sample has chloride contents more than 250 ppm which is above WHO permissible limit [16].

Nitrate in Mailsi groundwater lies from 1.0 to 114.57 mg/L with a mean value of 32.1 mg/L. Twenty one (21) samples lie within permissible limit but remaining six samples have nitrates value above guidelines values. The nitrate concentration is very high in six samples which are over the WHO-recommendation of 50 mg/L, for drinking water. With such water there is a risk of small children developing methemoglobinaemia. It seems as the soil conditions are very favorable for nitrobacters, and hence the conversion of organically bound nitrogen to nitrate. Oxidizing, neutral conditions favor this microbial conversion. The use of fertilizers is very common in adjacent fields which may percolate in groundwater.

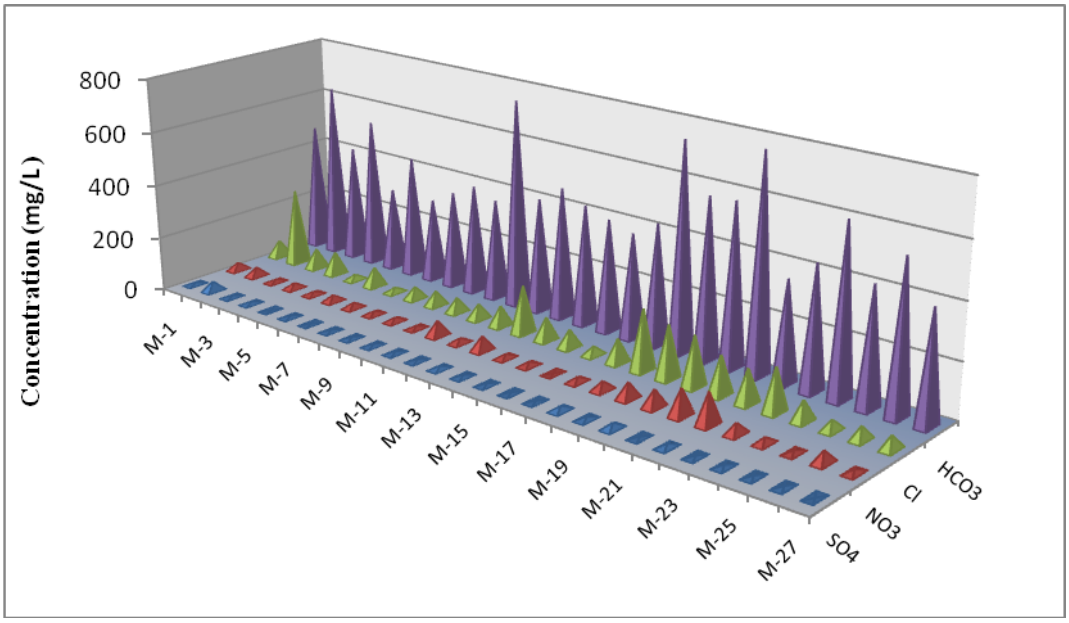

Figure 2. Anions concentrations in Mailsi groundwater samples.

The concentration of sulfate in groundwater of Mailsi was within the range from 0.2 to 37.13 mg/L. The concentration of bicarbonates in the groundwater ranges from 304.39 to 778.36 mg/L and mean value is 485.1 mg/L. There are no guidelines defined by WHO, Pak-EPA and EU for carbonates and bicarbonates in drinking water. Most of water samples were within the range of 300-600 mg/L. Only three samples have bicarbonates in the range of 750-800 mg/L.

Cations measured in Mailsi groundwater is shown in Figure 3. The concentration of sodium in groundwater of Mailsi varies from 24.1- 266.14 mg/L with an average of 94.3 mg/L. World Health Organization and EU recommends concentration of sodium in drinking water for 200mg/L [16]. Sodium values of all groundwater samples were within permissible limit except three samples. High sodium level in groundwater may be because of infiltration of surface water contaminated by soil salt or irrigation and precipitation leaching through soils high in sodium. Groundwater pollution by sewage effluent can also cause high level sodium. The percentage of sodium in groundwater of Mailsi was 11.1% above permissible limit.

The concentration of potassium in groundwater of studied area ranges from 4.5-29.1 mg/L with an average of 8.5 mg/L. World Health Organization recommends concentration of potassium in drinking water for 200 mg/L [16]. Most of the groundwater samples have potassium concentration within the range of 10-30 mg/L.

The concentration of calcium in groundwater ranges from 36.4-112.11 mg/L and averages at 72.2 mg/L. World Health Organization recommends concentration of calcium in drinking water from 75 to 200 mg/L [16]. However, all the samples lie within the range of 30-150 mg/L which are standard values recommended by WHO [16]. In groundwater of Mailsi the range of magnesium is from 10-72.62 mg/L with the average of 31.7 mg/L. Twenty five samples lie in the permissible limits recommended by WHO. Remaining two samples bear magnesium concentration higher than 50 mg/L. However, the percentage of magnesium in groundwater of Mailsi was 7.41% above permissible limit. Infiltration of leachate from landfills or industrial sites may the reason for this high concentration. World Health Organization recommends 50mg/L concentration of magnesium in drinking water [16].

Ionic concentrations were plotted in a Piper diagram [20] to evaluate the geochemical characteristics of the sampled groundwater (Figure 4). The diagrams reveal the analogies, dissimilarities and different types of waters in the study area. The concentrations of major ions in the groundwater were notably higher. The general chemical composition of water supply was pertinently characterized as HCO_3 type and less impact of sulfate and chloride. The solute constituents in the groundwater were chemically unique and almost all the data fell into the category of HCO_3 type. Groundwater is significantly dominated by alkaline–earth cations (Ca^{2+} and Mg^{2+}) over alkali (Na^{+} and K^{+}) [21].

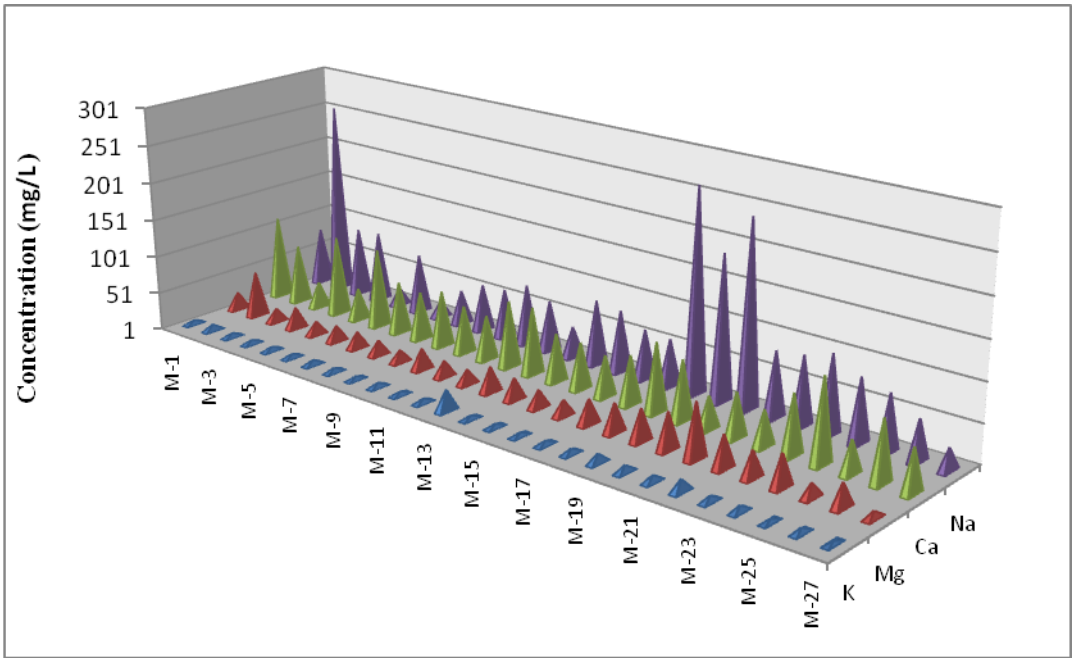

Figure 3. Cations concentrations in Mailsi groundwater samples.

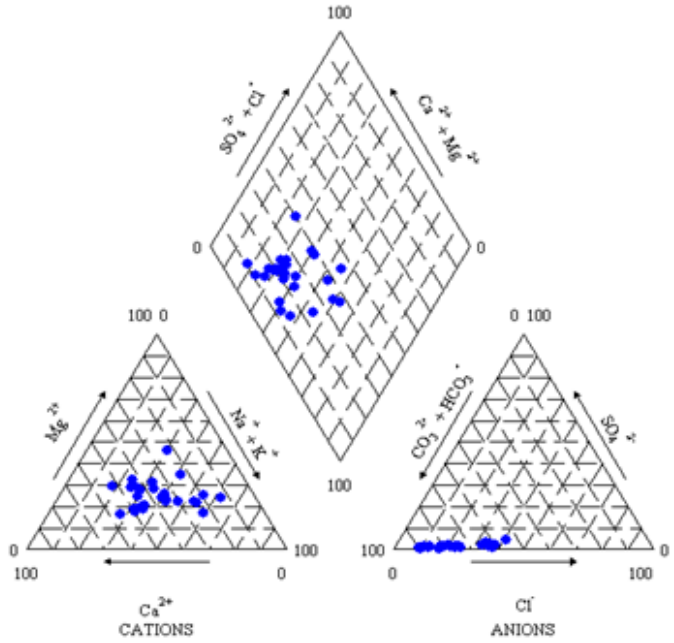

Figure 4. Piper diagram of collected water samples showing water type present in the study area.

Piper diagram also shows that the nature and concentration of ions originating from the groundwater of Mailsi is high. Mailsi groundwater is characterized as HCO_3 type, and the cation concentration was non-dominant type. But some samples have higher sodium and calcium values [22]. High sodium level in groundwater may be because of weathering of rocks or Irrigation and precipitation leaching through soils high in sodium [17, 23].

4. Conclusions

- The analysis results of the main ion hydro chemical for groundwater samples taken from wells in the study area showed that major abundant cations are sodium (Na^+) with average value of 32.1 ppm and calcium, average of 72.2 mg/L. The abundant anion is chloride ions (Cl^-) with average of 96.6 ppm and bicarbonate ions (HCO_3^-) with the average of 485.1ppm.
- The percentage of total dissolved solids in ground water of Mailsi was 81.5% above permissible limit. 22.2% samples exhibit nitrate higher than permissible limits.
- Eight samples M-2, M-11, M-13, M-18, M-19, M-20, M-21 and M-22 have anions and cations values higher than permissible limit and water of these samples can be harmful for drinking purposes resulting in kidney and gastrointestinal diseases. The hydro chemical data also reveals that the remaining 19 samples have chemical values within permissible limit.
- The general chemical composition of groundwater as determined by piper diagram is characterized as HCO_3^- type water.

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